



BARC

NEWSLETTER



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- Friction Stir Welding of Aluminium Alloys
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- Behaviour of Single Piles in Liquefied Soils during Earthquake
- Composite Polyamide Reverse Osmosis (RO) Membranes – Recent Developments and Future Directions
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Director, Chemistry Group

Vice Chairman

Dr. N. Ramamoorthy
Senior Advisor to Director, BARC

Edited by

Dr. K. Bhanumurthy
Head, SIRD

Associate Editors for this issue

Mr. Avaneesh Sharma, RED
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From the Editor's Desk

We are happy to inform you all, that the Editorial Committee of the BARC Newsletter has a New Chairman, Dr. Tulsi Mukherjee, Director, Chemistry Group and a Vice Chairman, Dr. N. Ramamoorthy, Senior Advisor to Director, BARC. Both these Senior Officers with their vast and varied expertise and experience, will provide valuable inputs, which will further enhance the quality of the BARC Newsletter.

Dr. V. Venugopal, Director, Radiochemistry and Isotope Group, was the First Chairman of our Committee, who retired in June this year. We would like to place on record, our heartfelt thanks and sincere appreciation for all his efforts.

We would like to thank you all, for your overwhelming response to the Founder's Day Special Issue of the BARC Newsletter. For the first time, all the papers were uploaded directly by the BARC Scientists and Engineers, through a special web link created on the BTS, thus saving time and effort.

This issue carries seven different articles, ranging from Electronics & Instrumentation, Metallurgy and Material Science to Earthquake, Chemical and Nano Engineering, Food processing and Mass Spectrometry.

We hope that you would all continue to give your R&D contributions to the BARC Newsletter.



Dr. K. Bhanumurthy
On behalf of the Editorial Committee

स्वतंत्रता दिवस की 64वीं वर्षगांठ सोमवार, दिनांक 15 अगस्त 2011

डॉ. आर.के. सिन्हा, निदेशक, भापअ केंद्र का संबोधन

“प्रिय साथियो,

सबसे पहले मैं आप सभी को अपने देश के स्वतंत्रता दिवस की 64वीं वर्षगांठ के अवसर पर बधाई देता हूँ। आज की सुबह, हम सब यहां न केवल अपने राष्ट्रध्वज के गौरव और सम्मान की रक्षा करने की शपथ लेने के लिए उपस्थित हुए हैं बल्कि उन सभी शहीदों को अपनी श्रद्धांजलि अर्पित करने हेतु भी एकत्रित हुए हैं जिन्होंने देश की स्वतंत्रता के लिए सर्वोपरि बलिदान किया है। इस अवसर पर, हम अपने सैन्य बलों के सदस्यों का भी अभिवादन करते हैं जो हमारे देश की सुरक्षा करते हैं।

इस अवसर पर हम अपने कार्यों का पुनरावलोकन करते हुए विगत समय में प्राप्त उपलब्धियों का अध्ययन करते हैं। जैसा कि आप जानते हैं, हमारे केंद्र के कार्यक्रमों में नाभिकीय ऊर्जा, नाभिकीय ईंधन चक्र, रेडियो आइसोटोप के उत्पादन एवं आइसोटोपों के अनुप्रयोगों सहित अनुसंधान रिएक्टरों से संबंधित विभिन्न प्रगत प्रौद्योगिकियां, मौलिक विज्ञान तथा अनुप्रयुक्त अनुसंधान एवं महत्वपूर्ण गतिविधियां शामिल हैं। मैं यहां केन्द्र द्वारा हाल ही में किए गए कुछ उल्लेखनीय विकासात्मक कार्य और प्राप्त उपलब्धियों का वर्णन करूंगा।

अनुसंधान रिएक्टर

अनुसंधान रिएक्टर ध्रुवा रेडियो आइसोटोप के उत्पादन हेतु मुख्य सुविधा और न्यूट्रॉन बीम अनुसंधान हेतु राष्ट्रीय सुविधा के रूप में लगातार कार्यरत रहा है। 25 वर्ष पुराने इस रिएक्टर के सुसज्जीकरण कार्यक्रम के अंतर्गत अनेक महत्वपूर्ण उपस्करों का प्रतिस्थापन पूरा कर लिया गया है। इसमें मुख्य मोटर प्रत्यावर्तित सैट और स्विच गियर, चैनल फ्लो मॉनीटरिंग गेज और मुख्य नियंत्रण कक्ष के आई एण्ड सी पैनेल शामिल हैं। सायरस के क्रोड को पूर्णतः ईंधनरहित कर दिया गया है। इसकी प्रक्रम प्रणालियां परिरक्षण विधि के अंतर्गत सुरक्षित रखी गई हैं।

उन्नत अप्सरा रिएक्टर की विभिन्न रिएक्टर प्रणालियों की विस्तृत इंजीनियरी प्रगति पर है। उन्नत रिएक्टर द्वारा बीम ट्यूब अनुसंधान, रेडियो समस्थानिक का उत्पादन, न्यूट्रॉन संसूचकों के अंशांकन एवं परीक्षण, पथर्य परीक्षण तथा बृहत् परिरक्षण प्रयोगों के लिए विस्तृत सुविधाएं उपलब्ध करायी जाएंगी।

उच्च फ्लक्स अनुसंधान रिएक्टर (एचएफआरआर) का संकल्पनात्मक अभिकल्पन पूरा किया जा चुका है। इस नवीन अनुसंधान रिएक्टर का अभिकल्पन मुख्यतया उच्च विशिष्ट सक्रियता रेडियो आइसोटोपों की बृहत् आवश्यकताओं को पूर्ण करने और विज्ञान के अग्रणी क्षेत्रों में मूलभूत अनुसंधान एवं विकास संबंधी अनुप्रयुक्त अनुसंधान हेतु विस्तृत सुविधाएं उपलब्ध कराने और नाभिकीय ईंधन एवं रिएक्टर पथर्य का परीक्षण करने के लिए किया गया है।

नाभिकीय विद्युत संबंधी अनुसंधान एवं विकास

फुकुशीमा रिएक्टर दुर्घटना के बहुत पहले से ही, हमारे रिएक्टर संरक्षा अनुसंधान कार्यक्रमों में संभाव्य आंतरिक तथा बाह्य घटनाओं पर विचार किया गया है। तारापुर में विस्तृत यंत्रोकरण के 540 मेगावाट पीएचडब्ल्यूआर (बारकाम) का 1:4 संरोधन परीक्षण मॉडल का निर्माण एवं कमीशनन किया गया। इस मॉडल का हाल ही में अभिकल्पन थब के 1.77 गुना पर अति थब परीक्षण किया गया जो पहली महत्वपूर्ण उपलब्धि रही यथा, चफस्ट एपियरेंस ऑफ क्रैकल प्राप्त किया गया। चार भारतीय एवं सात विदेशों से ग्यारह विदेशी प्रतिभागी संघटनों के साथ अंतर्राष्ट्रीय राऊंड रॉबिन अभ्यास के रूप में परीक्षण डाटा का विश्लेषण किया जा रहा है।

भवनों की संबंधित भूकंपीय भार परिस्थितियों के अधीन उत्पन्न स्थितियों (गतिविधियों) को समझना संयंत्र संरक्षा का महत्वपूर्ण पहलू है। थे बृहत् प्रवालित कंक्रीट संरचनाओं पर किए गए महत्वपूर्ण प्रयोग द्वारा यह पाया गया है कि भूकंपीय परिस्थितियों

के अंतर्गत संरचनाओं की समग्र गतिविधियों का अनुकरण एक सरल पुश-ओवर पद्धति से किया जा सकता है। इस जानकारी से भूकंपीय रोक के लिए महंगी शेक-टेबल परीक्षण या विस्तृत आरेखीय गतिक विश्लेषण की आवश्यकता कम होगी।

कार्यवाही के अंतर्गत, विस्तृत पीएचडब्ल्यूआर के लिए स्टेशन ब्लैक आउट (एसबीओ) के परिणामों को दूर करने के लिए गंभीर दुर्घटना प्रबंधन दिशानिर्देश (एसएएमजी) कार्रवाई के अधीन भाग में वॉटर इन्जेक्शन के प्रभाव का मूल्यांकन किया गया।

पिछले तीन वर्षों से सभी तटीय क्षेत्रों के लिए सुनामी मूल्यांकन अभ्यास चल रहे थे और इस कार्यक्रम के अंतर्गत एक राष्ट्रीय राउंड रॉबिन अभ्यास किया गया। स्थानीय बाढ़ मानचित्रण एवं तारापुर स्थल के लिए विश्लेषण हेतु तैयार की गई एक विस्तृत विश्लेषण क्रियाविधि पूर्ण की गई है।

प्रगत भारी पानी रिएक्टर (एचडब्ल्यूआर)

एचडब्ल्यूआर परियोजना को शीघ्र प्रारंभ करने की दिशा में एचडब्ल्यूआर की पारंपरिक इंजीनियरी प्रणालियों के विस्तृत इंजीनियरी परामर्श पद्धति से कार्य प्रारंभ किया गया है।

एचडब्ल्यूआर के संबंध में कुछ विपरीत घटनाएं घटित न हो इसलिए दुर्घटना प्रबंधन का विश्लेषण किया गया जिसमें शीतलक एसी थ्रुटना जिसकी क्षतिपूर्ति न हो सके। इस के साथ-साथ मंथक ऊष्मा सिंक भी शामिल है। आपातकालीन कोर शीतलन प्रणाली की अनुपलब्धता सहित थोरियम आधारित ईंधन के लिए प्रयुक्त भौतिकी अभिकल्पन प्राचलों एवं परिकलनात्मक प्रतिरूपों के वैधता के अंतर्गत एचडब्ल्यूआर क्रांतिक सुविधा (ThO_2 -1%wt % PuO_2) में थोरिया एवं प्राकृतिक यूरेनियम युक्त क्लस्टर गुच्च एवं मिश्रित गुच्च के साथ समाकलन प्रयोग किए गए जिससे एचडब्ल्यूआर के वध् अभिकल्पन के लिए महत्वपूर्ण आंकड़े प्राप्त हो सके। तत्पश्चात ईंधन गुच्च को ध्रुवा की नियमित ईंधन स्थिति में लोड किया गया ताकि थोरिया आधारित एचडब्ल्यूआर ईंधन को किरणित व्यवहार का अध्ययन किया जा सके।

अनेक नई सुविधाओं का स्थापना तथा विद्यमान सुविधाओं में प्रयोग करने के साथ-साथ एचडब्ल्यूआर हेतु डिजाइन मार्जिन के मूल्यांकन की दिशा में प्रयोगात्मक कार्यक्रम जारी रहे। इस परिघटना के संसूचन के लिए नए प्रयोगात्मक सेटअप में क्रांतिक ऊष्मा फ्लक्स का संसूचन करने के लिए अभिनव प्रयोग किए गए।

प्रगत नाभिकीय ईंधन दाबित तीव्र अभिजनक रिएक्टर (पीएफबीआर) ईंधन संविरचन

तारापुर स्थित भापअ केंद्र की प्रगत ईंधन संविरचन सुविधा में पीएफबीआर के प्रथम कोर हेतु मिश्रित ऑक्साइड ईंधन पिन का संविरचन कार्य प्रगति पर है। प्रक्रम फ्लोशीट चित्र में इन पिनो के लेसर विसदूषण का समाकलन किया गया है। लेसर विसदूषण प्रणाली के प्रयोग से प्रचालन कर्मियों के उद्भासन को कम किया है।

एचडब्ल्यूआर हेतु एलईयू ईंधन के विकास के एक भाग के रूप में, 8 से 22.5% तक UO_2 वाले विभिन्न मिश्रणों का ThO_2 - UO_2 पेलेटों (300 नग) को विभिन्न वातावरणों जैसे, Ar, Ar-8% H_2 एवं N_2 में संहत एवं निसादित किया गया। इन ईंधन संहतों के प्रसार के गुणांक को निरूपित किया गया है। इन ईंधनों के ताप-भौतिक गुणधर्मों का इससे अधिक मूल्यांकन प्रगति पर है।

U-धातु उत्पादन इकाई में उचित परिवर्तन पुनःचक्रण परिवर्तन (सीआरसी) तकनीकों का प्रयोग करते हुए, फ्लूओराइड बहिःस्राव का शून्य डिस्चार्ज प्राप्त किया गया।

तीव्र रिएक्टरों हेतु प्रगत ईंधनों का विकास वाइब्रो पैक ईंधन

भापअ केंद्र तीव्र रिएक्टरों के लिए प्रगत ईंधनों के विकास के क्षेत्र में कार्यरत रहा है। इस गतिविधि के अंतर्गत विश्व में सर्वप्रथम भापअ केंद्र में सोल-जैल प्रक्रिया का प्रयोग करते हुए आंतरिक जेलेशन पद्धति द्वारा लगभग 780 माइक्रोन व्यास वाले फ्लूटोनियम समृद्ध मिश्रित ऑक्साइड सूक्ष्म गोले तैयार किए गए। ये सूक्ष्मगोले, आईजीकार में तैयार किए गए

छोटे आकार के (लगभग 100 माइक्रॉन) UO_2 सूक्ष्म गोलों के साथ अब आईजीकार स्थित एफबीटीआर में किरणन हेतु जाच पिन के ईंधन पदार्थ के रूप में प्रयुक्त किए जाएंगे।

धात्विक ईंधन

क्वार्ट्ज नली साँचे में यूरेनियम/U-मिश्रधातु के इंजेक्शन कास्टिंग, कास्ट दड़ों के डीमोलिंडिंग, दड़ों के दोर के अपरूपण एवं स्वचालित निरीक्षण प्रणाली युक्त एक ग्लव बॉक्स सुविधा स्थापित की गई। आवश्यक विनिर्देशों को पूरा करने वाले प्राकृतिक U-6wt% Zr मिश्रधातु धात्विक ईंधन के आवश्यक संख्या में संविरचन के लिए इस सुविधा का सफलतापूर्वक प्रयोग किया गया। यूरेनियम का लगातार कास्टिंग सफलता पूर्वक की गई। इससे एफबीआर हेतु धात्विक ईंधन के संविरचन के थैरान अल्फा अपशिष्ट को घटाने में सहायता मिलेगी।

तीव्र रिएक्टरों के लिए यांत्रिक आबंध धात्विक ईंधन के विकास के अंतर्गत, U-15%Pu स्लग का संविरचन अभिलक्षणन के लिए किया गया। उपर्युक्त मिश्रधातु का उसके अनेक संबंधित गुणधर्मों के लिए परीक्षण किया गया।

सीईआरएमईटी ईंधन

तीव्र रिएक्टरों हेतु ईंधन विकास के अंतर्गत, U धातु चूर्ण में परिक्षेपित UO_2 के आयतन द्वारा 15% एवं 30% सीईआरएमईटी ईंधन संहत किए गए और इन्हें Ar एवं निर्वात में 1090 °C पर सिंटरित किया गया। डायलेटोमीटर का प्रयोग करते हुए उपर्युक्त समेट ईंधन के संकुचन आचरण का मूल्यांकन किया गया। यह देखा गया है कि Ar वातावरण में सिंटरण उच्चकोटि का था।

पुनर्संसाधन

ट्रॉबे स्थित प्लूटोनियम संयंत्र सुरक्षित रूप से प्रचालनरत रहा और ध्रुवा/सायरस से प्राप्त किरणित ईंधन गुच्चों का पुनर्संसाधन किया गया। इसके अतिरिक्त, थोरिया रैफिनेट से थोरियम की पुनःप्राप्ति हेतु यूरेनियम थोरियम पृथकरण सुविधा (यूटीएसएफ) प्रचलित की गई।

कलपाक्कम स्थित पुनर्संसाधन संयंत्र को संतोषजनक एवं संरक्षित रूप से प्रचालित किया गया। नाभिकीय पुनश्चक्रण बोर्ड के अधीन, प्रिफ्री-2 तारापुर संयंत्र में उत्पादन आरंभ हो चुका है। अतिरिक्त अपशिष्ट टंकी फार्म भी प्रचालनरत है।

भावी बृहत स्तरीय पुनर्संसाधन संयंत्रों के अभिकल्पन समावेश प्रवाह प्राप्त करने के लिए, एक पूर्ण आकार के प्रोटोटाइप सतत धूर्णी विलयनित्र का संविरचन एवं स्थापन किया गया। इस इकाई का प्रचालन अनुकारित परिस्थितियों (यूरेनियम नाइट्रेट के साथ) के अंतर्गत किया जाएगा ताकि उपयुक्त डाटा प्राप्त किया जा सके और निर्माण पदार्थ, सुदूर हस्तन, हल आदि से पदार्थ की पुनःप्राप्ति जैसे विभिन्न पहलुओं पर फीडबैक उपलब्ध हो सके।

देश में पहली बार हाइड्रोक्सिल एमीन नाइट्रेट (एचएएन) के संश्लेषण हेतु प्रक्रिया विकसित की गई ताकि भुक्तशेष ईंधन पुनर्संसाधन में वैकल्पिक विलेयक के रूप में इसका प्रयोग किया जा सके। इस पदार्थ को लीटर पैमाने तक स्वदेशी रूप से उत्पन्न किया गया।

^{90}Sr , ^{90}Y एवं ^{241}Am जैसे उपयोगी आइसोटोपों के सक्रिय अपशिष्ट से पुनःप्राप्ति जारी रही और प्रयोक्ताओं को आपूर्ति होती रही।

नाभिकीय अपशिष्ट प्रबंधन

हॉट सेल के अंदर जूल गालक के सुदूर विघटन एवं विकमीशनन हेतु प्रौद्योगिकी विकसित की गई और जूल गालक प्रणाली का अतिरिक्त मैन-रेम व्यय के साथ विकमीशनन और प्रगत काचीकरण सुविधा, तारापुर में ठोस अपशिष्ट निर्माण कार्य समापन के निकट है।

कलपाक्कम स्थित अपशिष्ट निश्चलन संयंत्र में, अनुकारित उच्च स्तरीय अपशिष्ट (एचएलडब्ल्यू) का प्रयोग करते हुए दूसरा जूल तप्त सिरैमिक गालक का निष्क्रिय कमीशनन किया गया। बहिर्गैस तापीय कूप, तापयुग्म एवं तल प्राचलन जैसे घटकों का पुनःस्थापन किया गया।

अतप्त क्रूसिबल प्रेरण गालक (सीसीआईएम) का प्रयोग करते हुए काचीकरण प्रौद्योगिकी अनुकारित अपशिष्ट भरण प्रयोगों के सफलतापूर्वक संपन्न होना इस दिशा में एक और महत्वपूर्ण उपलब्धि रही।

कलपाक्कम के केन्द्रीकृत अपशिष्ट प्रबंधन सुविधा में मद्रास परमाणु बिजलीघर के सामूहिक शीतलक चैनल प्रतिस्थापन से थब-नलिकाओं के पुनः प्रापण, आयतन को कम करने और इनके निपटान के लिए परमाणु ऊर्जा विभाग में पहली बार एक अभियान शुरू किया गया है।

सीजियम-आपेक्षिक क्राउन ईथर के संश्लेषण और किलोग्राम पैमाने तक पदार्थ के स्वदेशी उत्पादन के लिए एक प्रक्रम विकसित किया गया है। निम्न और मध्यवर्ती स्तर के द्रव अपशिष्टों से ^{106}Ru , ^{99}Tc , ^{144}Ce जैसे विशिष्ट आइसोटोपों के निष्कासन के लिए मनके (बीड) के रूप में अकार्बनिक आयन-एक्सचेंजर मीडिया विकसित किया गया है।

पर्यावरण मॉनीटरन और विकिरण संरक्षा

फुकुशिमा नाभिकीय दूधटना के कारण विभिन्न रेडियोन्यूक्लाइडों के वायुमंडल में और प्रशान्त महासागर में निस्सरण की दरों के प्राथमिक आकलन, स्वदेश में विकसित पर्यावरणीय मॉडलों का प्रयोग करके निकाले गए। विभिन्न एजेंसियों द्वारा रिपोर्ट किए गए अनुमानों के साथ आकलित निस्सरण दरों का युक्तिसंगत सुमेलन देखा गया। देश के सभी पर्यावरणीय सर्वेक्षण प्रयोगशालाओं ने पर्यावरणीय आव्यूहों में रेडियोसक्रियता के अत्यंत निम्न स्तर के मॉनीटरन के लिए एक विशेष अभियान चलाया। आंकड़ों को विभागीय वेबसाइटों में नियमित रूप से अद्यतन (अपडेट) किया गया है और अन्तर्राष्ट्रीय परमाणु ऊर्जा एजेंसी को सूचित किया गया है। हम इस बात की पुष्टि कर पाए कि इस घटना ने भारत पर कोई उल्लेखनीय प्रभाव नहीं डाला है।

मोबाईल नेटवर्किंग (जीएसएम), स्थानीय क्षेत्र नेटवर्क (लैन) तथा प्रकाशिक तंतु आधारित संचार चैनलों के लिए भूमंडलीय प्रणाली के लघु संदेश सेवा (एसएमएस) का उपयोग करके विवृत क्षेत्र प्रस्थापन के लिए सौर ऊर्जायुक्त पर्यावरणीय विकिरण मॉनीटर (ईआरएम) को आंकड़ा संचार सुविधा के साथ प्रचालित

किया गया। पर्यावरण में गामा विकिरण स्तर में वृद्धि के कारण उत्पन्न नाभिकीय आपातकाल की स्थिति में, ये स्टैंड-अलोन स्वछालित प्रणालियां, मुंबई स्थित किसी सेंट्रल स्टेशन को पार्श्व पर्यावरणीय विकिरण आंकड़े भेजते हैं और इस तरह से ये एक पूर्व चेतावनी प्रणाली के रूप में कार्य करते हैं। ईसीआईएल के साथ एक समझौता ज्ञापन के तहत इन इकाइयों का औद्योगिक श्रेणी उत्पादन शुरू किया गया है।

रेडॉन के कारण संचित डोज के प्रत्यक्ष मॉनीटरन के लिए अंतःश्वसन डोजीमापी बैजों का विकास किया गया है। इन बैजों को देश के भीतर लगभग 2000 स्थानों में और विभिन्न विदेशी संस्थानों के अनुरोध पर यूरोप में लगभग 1000 स्थानों में भी नियोजित किया गया है।

सार्वजनिक क्षेत्र होकर रेडियोसक्रिय पदार्थों के परिवहन के समय संरक्षा में वृद्धि करने के लिए अनुसंधान एवं विकास प्रयासों के परिणामस्वरूप पॉली यूरीथेन फोम (पीयूएफ) का सफलतापूर्वक विकास हुआ, जिसे परिवहन पैकेजों में तापीय परिरक्षण और संघट्ट सीमक (इंपैक्ट लिमिटर) के रूप में इसके उपयोग के लिए और अधिक विशिष्ट बनाया जा रहा है। सायरस में एक समर्पित (डेडिकेटेड) किरणपुंज सुविधा का उपयोग करके न्यूट्रॉन रेडियोग्राफी को अपनाते हुए पहली बार वास्तविक काल में सीसा गलने का प्रतिछित्रण किया गया। यह प्रायोगिक आंकड़ा आग में निमग्न किए जा रहे किसी भुक्तशेष ईंधन ट्रांसपोर्ट कास्क की परिकल्पित दूधटना के दौरान सीसा की मॉडलिंग के लिए प्रयुक्त कम्प्यूटर कोडों का मान्यकरण आसान बनाएगा।

आईपीआर, गांधीनगर और आरएमपी, मैसूर में विकिरण मानीटरन प्रणाली और प्रशिक्षित आपातकाल अनुक्रिया दलों (ERTs) के साथ थे आपातकाल अनुक्रिया केंद्रों (ERCs) की स्थापना की गई है। इससे देश में नाभिकीय एवं विकिरण आपातकाल स्थिति की तैयारी एवं अनुक्रिया के लिए कुल ईआरसी की संख्या 20 हो गई है।

नाभिकीय आपथ से निपटने की तैयारी और अनुक्रिया पर दिशानिर्देश तैयार करने के लिए राष्ट्रीय आपथ प्रबंधन प्राधिकरण (एनडीएमए) को तकनीकी सहयोग प्रदान किया गया।

भौतिक विज्ञान

इंडस में किरणपुंज रेखा विकास गतिविधि के एक भाग के रूप में खगोल भौतिकी और पर्यावरण विज्ञान से संबंधित अणुओं के स्पेक्ट्रमिकी अध्ययन के लिए उच्चा विभेदन निर्वात पराबैंगनी किरणपुंज रेखा का कमीशनन किया गया।

इंडस में पृष्ठ, तनुफिल्मों और बहुपरतों के अभिलक्षणन के लिए प्रतिदीप्ति मापन के साथ EXAFS किरणपुंज रेखा का संवर्धन किया गया।

तूतीकोरिन स्थित भारी पानी संयंत्र में 1 एएमयू विभेदन और 150 एएमयू द्रव्यमान रेंज वाले एक चतुर्ध्रुवी द्रव्यमान स्पेक्ट्रममापी का संविरचन और स्थापना की गई।

रसायन विज्ञान

उच्च अम्लीय माध्यम में प्लूटोनियम की अल्फा गतिविधि के मॉनीटर के रूप में एक स्वगृहे विकसित नैनो-डायमंड फिल्म का संभाव्यता अध्ययन सफलतापूर्वक पूरा किया गया।

एक सरल और किफायती हाइड्रोजेल आधारित पदार्थ विकसित किया गया जिसमें साइट्रिक अम्ल भारित कपास गोज के साथ संयुक्त एगारोज जेल निस्सरित करनेवाले नाइट्रोजन आक्साइड शामिल हैं। इसमें उत्कृष्ट रोगाणु प्रतिरोधी गुणधर्म हैं और अल्सर-जनित त्वचा के संक्रमणों में ड्रेसिंग मटेरियल के रूप में इसका प्रबल उपयोग है।

मिश्रित रोगाणु कणिकाओं का उपयोग करके जैव-विनाइट्रीकरण पर अध्ययन से पता चला कि 1.5 C/N अनुपात पर एसीटेट की आपूर्ति करके 4050 मि.ग्रा. तक $\text{NO}_3\text{-N/L}$ (18,000 mg/L NO_3 के समतुल्य) का उपचार किया जा सकता है। इसे ६ लीटर आयतन के प्रयोगशाला पैमाना अनुक्रमण बैच रिएक्टरों में प्रदर्शित किया गया।

जैव विज्ञान

एक महत्वपूर्ण जांच से पता चला कि बहुत से ट्यूमर प्रतिरोधी प्राकृतिक यौगिकों के एक जनक अणु 1,4-नेथोक्विनोन (एनक्यू) ने 4 Gy गामा विकिरण की एक खुराक से चूहों के लिम्फोसाइटों

और आंत की कोशिकाओं को बचाया। चूहों में, 2m/kg NQ दिए जाने से (गिवन इन-वाइवो) विकिरण प्रेरित अस्थि-मज्जा संदमन में सुधार कर इसे पुरानी स्थिति में लाया गया। इन संभव क्रियाविधियों में रेडॉक्स ट्रांसक्रिप्शन फैक्टर Nrf-2 (नाभिकीय फैक्टर E2 संबंधित फैक्टर-2) का सक्रियण शामिल है।

खाद्य प्रौद्योगिकी

आलू के चिप्स जैसे कार्बोहाइड्रेट से भरपूर तले हुए खाद्य पदार्थ में एक न्यूरोटॉक्सिन और एक संभावित कैंसरजन एंफ्रीलेमाइड अत्यन्त उच्च स्तर पर मौजूद होना रिपोर्ट किया गया है। तलने के दौरान अमीनो अम्ल एस्प्राजीन के साथ खाद्य पथर्थ में मौजूद शर्करा की घटती हुई मात्रा ग्लूकोज की अभिक्रिया होने पर इस यौगिक की उत्पत्ति होती है। अंकुरित होने से रोकने के लिए किरणित किए गए आलुओं से तैयार छिप्स में एंफ्रीलेमाइड की मात्रा इसके संगत अकिरणित कंट्रोलों की अपेक्षा कम पाई गई है।

किरणित फलों और सब्जियों में इनके कटने के बाद भूरा रंग हो जाने में कमी आती है। पहली बार जब काटने से पहले पकाने के लिए तैयार कट्टू (ऐश गोर्ड) पर अध्ययन किया गया तो यह देखा गया कि विकिरण प्रक्रिया के थेरान अपने पुरोवर्ती (प्रीकर्सर) से मुक्त गामा रिसॉर्साइक्लिक अम्ल, कटे हुए फलों और सब्जियों का रंग भूरा बनाने में शामिल एन्जाइम पॉलीफेनॉल आक्सीडेज के प्राकृतिक अवरोधक के रूप में कार्य करता है।

नाभिकीय-कृषि

कृषि के क्षेत्र में, थे नई विकिरण प्रेरित उत्पत्तिवर्ती फसल की किस्में जारी की गईं। TAT-96-29 नाम से पहली किस्म, महाराष्ट्र में खेती के लिए जारी की गई। TG 47 नामक अन्य बड़ी बीज वाली मीठी मूंगफली की किस्म, आंध्रप्रदेश में खेती के लिए भीमा के रूम में जारी की गई।

वस्त्र, खाद्य एवं कागज उद्योगों के बहिःस्राव उपचार संयंत्रों (ईटीपी) में उत्पादित जैविक आपंक की बृहत मात्राओं के प्रक्रमण के लिए निर्सगत्रण प्रौद्योगिकी का सफलतापूर्वक विस्तार किया गया। इस तरह के चार संयंत्र स्थापित किए गए।

आइसोटोप अनुप्रयोग

केरल के तिरुवनंतपुरम के तटीय क्षेत्र में विभिन्न प्रकार के ज्वार-भाटा की स्थितियों में होनेवाले समुद्री भूमिजल निस्सरण (एसजीडी) की मात्रा जानने के लिए जांचा किए गए। प्राकृतिक ^{222}Rn (अर्ध आयु=3.8 दिन) का उपयोग ट्रेसर के रूप में किया गया। यह अध्ययन, तटीय क्षेत्र के अंदर समुद्रीजल अंतरापृष्ठ कूप का रखरखाव करके तटीय जलभृतों में भूमिजल के विवेकपूर्ण उपयोग में सहायक होगा।

ल्यूटेटियम-177 आधारित रेडियोभेषजों के विकास की ओर हमारे प्रयासों से सकारात्मक परिणाम प्राप्त हुए हैं। वर्तमान में, भारत के कुछ नाभिकीय औषधि विभाग, न्यूरोएंडोक्रिन ट्यूमरों के उपचार हेतु ^{177}Lu -DOTATATE बनाने के लिए ध्रुवा रिएक्टर में उत्पादित उच्च विशिष्ट सक्रियता ^{177}Lu का उपयोग कर रहे हैं। भारत उन सात देशों में से एक है जो कैंसर के उपचार के लिए ^{177}Lu आधारित चिकित्सा का अनुसरण कर रहे हैं।

वड़ोदरा के आपंक स्वास्थ्यकी अनुसंधान किरणक (एसएचआरआई) सुविधा को आपंक में उच्चतर ठोस मात्रा वाले नए 66 एमएलडी सीवेज उपचार संयंत्र के साथ अब जोड़ा गया है।

पदार्थ कार्यक्रम

700⁰ से 1100⁰ डिग्री सेंटीग्रेड तापमान पर कास्ट Zr-2.5 Nb पर संसाधन नक्शे बनाए गए। उत्पादित आंकड़ों के आधार पर, विनिर्माणकर्ता द्वारा Zr-2.5Nb के फुल स्केल कास्ट इन्गॉट्स पर ढलाई का काम (फॉर्जिंग) सफलतापूर्वक किया गया। यह कार्य हैदराबाद स्थित नाभिकीय ईंधन सम्मिश्र के सहयोग से किया गया।

व्युत्क्रम चुंबकीय कैलोरी प्रभाव पदर्शित करने के लिए ज्ञात Ni-Mn-Sn प्रणाली पर आधारित लौहचुंबकीय शोप मेमरी मिश्रधातु की नई श्रेणी का अध्ययन किया गया। ब्रिजमैन क्रियाविधि और मृदु सांचा (सॉफ्ट मोल्ड) तकनीक का उपयोग कर तापीय प्रत्यास्थ शोप मेमरी मिश्रधातु Cu-16Zn-16Al के एकल क्रिस्टलों को सफलतापूर्वक तैयार किया गया।

आईटीईआर परीक्षण आवरक मॉड्यूल (टीबीएम) प्रथम भित्ति के एक आदि प्ररूप (प्रोटोटाईप) का संविरचन मशीनन, बंकन और लेजर वेल्डन द्वारा किया जा रहा है। इस संबंध में, फेरिटिक मारटेंसाइटिक स्टील p91 पर लेजर वेल्डिंग अध्ययन किए गए। इसके बाद वेल्डिंग के बाद के उपचार के साथ और इसके बिना वेल्ड जोड़ों का यांत्रिक परीक्षण किया गया।

लीथियम धातु संयंत्र के फेज-I भाग के सफलतापूर्वक संवर्धन और नियामक निर्वाधन (क्लियरेंस) प्राप्त करने के बाद आईटीईआर टीबीएम कार्यक्रम के लिए आवश्यक लीथियम के वांछित ग्रेड प्राप्त करके संयंत्र की क्षमता के प्रदर्शन के लिए इसे प्रचलित किया गया।

निर्वात तप्त-थबित बेरिलियम के विशेष आकारों की बड़ी संख्या का संविरचन प्रयोक्ता विनिर्देशनों के अनुसार किया गया। इन आकारों को स्वीकारा गया और इनका उपयोग न्यूट्रॉन भौतिकी प्रयोगों के लिए किया जा रहा है।

इलेक्ट्रानिकी एवं यंत्रिकरण

यूरेनियम अयस्कों के हवाई अन्वेषण के लिए हेलिकॉप्टर-वाहित काल प्रक्षेत्र विद्युतचुंबकीय (टीडीईएम) प्रणाली का हाल ही में सफलतापूर्वक हवाई परीक्षण किया गया। इस परीक्षण के दौरान, 22 मीटर व्यास प्रेषित्र (ट्रॉंसमीटर) सहित झूलते (अंडरस्लंग सिस्टम) को हेलिकॉप्टर से 30 मीटर नीचे और जमीन से 30 मीटर ऊपर लटकाया गया।

अवश्रव्य परास में औसत वायुमंडलीय दाब के चारों ओर माइक्रोबारों के क्रम में अति सूक्ष्म वायुमंडलीय दाब परिवर्तन को मापने हेतु विभेदी सूक्ष्म बैरोमीटर को देश में इसके बड़े पैमाने पर उत्पादन को सुविधाजनक बनाने हेतु विकसित किया गया है।

0.35m CMOS प्रौद्योगिकी वाले तथा विभिन्न संसूचक अनुप्रयोगों में उपयोग में आनेवाले तीन ASIC यथा अणुस्पर्श, अणुदृष्टि और अणुसचक का अभिकल्पन, विकास और परीक्षण सफलतापूर्वक किया गया। अणुस्पर्श, योजनाबद्ध भारतीय न्यूट्रॉनों प्रेक्षण कक्ष में उपयोग किए जाने वाले प्रतिरोधी प्लेट चेंबर संसूचकों के लिए एक अग्रभाग रीड-आउट है, अणुदृष्टि,

संहत गामा संसूचन जांचों के लिए एक अखंडित फोटोडायोड और रीडआउट इलेक्ट्रॉनिक्स है, और अणुसूचक, सिलिकॉन प्रकार का आंतरिक और प्रतीक संसूचक के लिए एक निम्न क्षमता अग्र-भाग रीडआउट है।

एक जड़त्वीय नेविगेशन प्रणाली (आईएनएस) विकसित किया गया है, जिसे भापअ केंद्र द्वारा विकसित पाइप निरीक्षण (PIG) गेज के साथ युग्मित किया जा सकता है। आईएनएस आंकड़ों का पश्च प्रकमण, पाइपलाइन के ३-डी ले आऊट का सही-सही निर्धारण कर सकता है। फरीदाबाद के आईओसीएल अनुसंधान एवं विकास केंद्र में परीक्षण पाश (लूप) में प्रणाली की परख की गई है।

त्वरक एवं उच्च शक्ति इलेक्ट्रॉनिक्स

एडीएसएस हेतु अनुसंधान एवं विकास कार्यक्रम के अंतर्गत सीसा-बिस्मट-यूटैटिक (एलबीई) द्रवधातु पर आधारित उच्च तीव्रता न्यूट्रॉन समुत्खण्डन लक्ष्यों के विकास के लिए अध्ययन प्रारंभ किए गए। अनुसंधान एवं विकास अध्ययन हेतु 30 MeV एवं 500 माइक्रो-ऐम्पियर प्रोटॉन किरणपुंज के साथ जोड़ने के लिए सुदूर विघटन सुविधा सहित गैस चालित द्रव धातु परिचालन प्रणालीयुक्त एलबीई लक्ष्य मॉड्यूल विकसित किया गया। प्रोटॉन किरणपुंज के साथ जोड़ने से पूर्व एलबीई पर सघन परीक्षणों हेतु एक लक्ष्य मॉड्यूल का संविरचन किया गया।

ईबीसी स्थित 10 MeV RF इलेक्ट्रॉन त्वरक प्रचालनरत रहा और इसका अनेक औद्योगिक प्रक्रिया विकास में प्रयोग किया जा रहा है। बीएचईएल हेतु सिलिकॉन पावर डायोड चिप्स का 0.4 kGy पर किरणन से पावर डायोडों का उत्क्रम पुनः प्राप्ति (Trr) समय 14 माइक्रो सेकन्ड से लगभग 6 माइक्रो सेकन्ड तक हो गया है।

एचपीएम उत्पादन के लिए रिफ्लेक्स ट्रायोड एवं परावर्तकों के साथ 300 kV, 12kA, 300 ns, 10 Hz पुनरावर्तन दर की रेटिंग सहित एक द्विध्रुवीय प्रकार का उच्चस्तरीय मार्क्स जनरेटर का अभिकल्पन एवं संविरचन किया गया। यह प्रचालनरत रहा और उच्च शक्ति माइक्रोवेव निर्माण के लिए इसका प्रयोग किया गया।

अन्य प्रगत प्रौद्योगिकियां कंप्यूटर

नवीनतम समानान्तर संसाधन अनुपम सुपर कंप्यूटर को 47 टेराफ्लॉप पर बेंचमार्क करके अनुपम-अध्यायट के नाम से प्रयोक्ताओं को जारी किया गया।

क्रायो प्रौद्योगिकी

क्रायोजनिक अनुप्रयोग हेतु एक प्रगत स्वदेशी हीलियम रेफ्रिजरेशन प्रणाली के विकास में विशिष्ट उपलब्धियां प्राप्त की गई। प्रचालन प्रयोगों के दौरान रेफ्रिजरेशन पावर 20k पर करीब 500 W तक प्राप्त की गई।

निर्लवणीकरण

भू-जल से यूरेनियम को हटाने के लिए पंजाब के छः जिलों में 24 गांवों के नलकूप के पानी पर भापअ केंद्र द्वारा विकसित झिल्ली आधारित जलशोधन प्रणाली का क्षेत्र परीक्षण किया गया। 685 ppb यूरेनियम युक्त जल से 6 ppb से कम यूरेनियम युक्त शुद्ध जल (जो ईआरबी की अनुमेय सीमा 30 ppb से काफी कम है) का उत्पादन किया गया। इस यूनिट को घरों में स्थापित किया जा सकता है और बहुत कम बिजली खपत पर इस उपकरण का प्रयोग किया जा सकता है।

प्लाज्मा प्रौद्योगिकियां

यूरेनियम टेट्राफ्लूओराइड (UF₆) से यूरेनियम टेट्राफ्लूओराइड (UF₄) के अपचयन के लिए शुष्क प्रक्रिया के विकास के अंतर्गत, तापीय प्लाज्मा सहयोग के साथ-साथ ज्वाला अपचयन आधारित बेंच स्केल सेट-अप का सफलतापूर्वक अभिकल्पन, निर्माण एवं प्रचालन किया गया।

स्पंद शक्ति प्रौद्योगिकियां

एचपीएम उत्पादन के लिए रिफ्लेक्स ट्रायोड एवं परावर्तकों के साथ 300 kV, 12kA, 300 ns, 10Hz पुनरावर्तन दर की रेटिंग का एक द्विध्रुवीय प्रकार का उच्चस्तरीय मार्क्स जनरेटर का अभिकल्पन एवं संविरचन किया गया। यह 225 kV पर प्रचालनरत रहा और इसका प्रयोग 1.2 GHz से 3.8 GHz तक की रेंज में उच्चशक्ति माइक्रोवेव के उत्पादन में किया गया।

रोबोटिकी

सौर विद्युत संयंत्र में प्रयुक्त 1.8 m x 3m आकार के परवलयी सौर परावर्तकों की स्वचालित सफ़ाई के लिए एक उपकरण का विकास किया गया। हाल ही में इस उपकरण को पुणे के निकट स्थित सौर विद्युत संयंत्र में क्षेत्र परीक्षण के लिए उपलब्ध करवाया गया।

भूकंप विज्ञान

भापअ केन्द्र के भूकंप डाटा केन्द्रों (SDC) में सुनामी जनिक भूकंप सहित भूकंपी घटनाओं का स्थान एवं उसकी पहचान करने के उद्देश्य से अनेक नई विश्लेषण तकनीकों का विकास किया गया और उनका तत्परता के साथ क्रियान्वयन किया गया।

एसडीसी, भापअ केंद्र से यह प्रमाणित किया गया है कि सामान्यतः किसी अन्य राष्ट्रीय एवं अंतरराष्ट्रीय भूकंपी एजेंसियों की तुलना में 2500 किमी के घेरे के भीतर स्थित स्थानीय घटनाओं की रिपोर्ट अतिशीघ्र प्राप्त हो जाती है।

सामाजिक प्रयास एवं प्रौद्योगिकी हस्तांतरण

अमरावती जिले के जल अभाव क्षेत्र निमखेड गांव में समस्थानिक जलविज्ञान तकनीक के प्रयोग द्वारा 30,000 लीटर प्रति घंटे की निस्सरण क्षमता वाले भूगर्भीय जलस्रोत की पहचान की गयी। भापअ केंद्र के आकृति कार्यक्रम के अंतर्गत इस जल स्रोत को किसानों के उपयोग के लिए स्थापित किया गया।

50,000 केले के पौधों की क्षेत्र कठोरन सुविधा के साथ एक ऊतक संवर्धन प्रयोगशाला को प्रचालनरत किया गया एवं अमरावती, महाराष्ट्र में आकृति कार्यक्रम के अंतर्गत कठोर किए गए पौधों की पहली खेप खेत में उगाई गई।

आकृति कार्यक्रम के माध्यम से दापोली के फरारे नामक तटीय ग्राम में 300 lph क्षमता वाले खारा जल प्रति परासरण (RO) संयंत्र की स्थापना की गई है। ग्रामवासियों को संयंत्र के प्रचालन एवं अनुरक्षण में प्रशिक्षित किया गया।

ग्रामीण क्षेत्र के लिए आकृति प्रौद्योगिकी पैक पांच और पार्टियों को हस्तांतरित किया गया। पहली बार दो नई प्रौद्योगिकियाँ उद्योग को हस्तांतरित की गईं।

चिकित्सा सेवाएं

हमारे वाशी औषधालय को पूर्णतया सुसज्जित किया गया और मार्च 2011 से यह पूर्णरूप से कार्यरत है। भापअ केंद्र अस्पताल के आधुनिकीकरण और लाभार्थियों को उन्नत सेवाएं प्रथन करने के लिए अनेक नए उपस्करों का प्रापण किया गया।

प्रशासन वर्ग

प्रशासन वर्ग द्वारा प्रशासन, स्थापना, मानवशक्ति नियोजन, कार्मिक डाटा प्रबंधन, वित्त एवं लेखा और सुरक्षा के क्षेत्रों में महत्वपूर्ण योगदान दिया गया।

सुरक्षा एवं प्रत्यक्ष संरक्षा

हमारे केन्द्र की सुरक्षा अत्यंत महत्वपूर्ण है। भापअ केंद्र की सुरक्षा एवं सीआईएसएफ के कार्मिकगण हमारी स्थापना को प्रत्यक्ष सुरक्षा उपलब्ध कराने में सराहनीय कार्य करते रहे हैं। मैं, भापअ केंद्र के अग्निशमन कर्मचारियों की प्रशंसा करता हूँ जिन्होंने हमारे केंद्र की विभिन्न स्थापनाओं की सुरक्षा करने में महत्वपूर्ण भूमिका निभाई है। मैं अपने केन्द्र के सभी अधिकारियों और कर्मचारियों की भी सराहना करता हूँ जो सुरक्षा कर्मियों को अपनी ड्यूटी प्रभावी तरीके से निभाने में सहयोग देते हैं। मैं अपने सभी साथियों से आग्रह करता हूँ कि वे वर्तमान परिस्थितियों में सदैव सावधान एवं सतर्क रहें।

भूदृश्य एवं बागबानी

हमारे भूदृश्य एवं स्वच्छता अनुरक्षण अनुभाग के कार्मिकों के योगदान की स्पष्ट झलक इस परिसर के सुंदर परिवेश में दिखाई देती है। मैं इस अवसर पर उनकी सेवाओं की सराहना करना चाहता हूँ।

निष्कर्ष

प्रिय साथियो,

यहाँ मैंने वर्ष के दौरान किए गए कार्यकलापों की संक्षिप्त झलक ही प्रस्तुत की है। समय की कमी के कारण बहुत सी बातों की चर्चा मैं नहीं कर पाया हूँ। इसका अर्थ यह नहीं कि वे कम महत्वपूर्ण हैं।

पिछले वर्ष मैंने इसी अवसर पर अपने भाषण में अंतर्राष्ट्रीय सहयोग के संदर्भ में वैश्विक चुनौतियों को पूरा करने के लिए अपनी श्रेष्ठता बनाए रखने पर जोर दिया था। आगामी १२ वीं पंचवर्षीय योजना के प्रस्ताव इन्हीं लक्ष्यों को ध्यान में रखकर बनाए गए हैं।

जैसा कि आप सभी जानते हैं हमारे कार्यक्रमों द्वारा प्रदत्त सेवाएं हमारी सामाजिक आवश्यकताओं के लगभग सभी क्षेत्रों को

समाहित करते हैं जिनमें खाद्य, जल, पर्यावरण, विद्युत, स्वास्थ्य सेवा, उद्योग, शिक्षा तथा राष्ट्रीय सुरक्षा शामिल है। समाज के हित के लिए अब हमें और अधिक प्रयास करने होंगे। हमने इस आवश्यकता को पूरा करने के लिए नयी पहल की है। मैं परमाणु ऊर्जा विभाग के परिवार के हमारे सभी सदस्यों से आग्रह करता हूँ कि वे समाज की आवश्यकता की पूर्ति के लिए हमारे सामाजिक कार्यक्रम में सक्रिय रूप से योगदान दें।

मित्रो, अंत में इस अत्यंत शुभ दिन के अवसर पर आइए, हम यह दृढ़ संकल्प करें कि अपने लोगों के कल्याण के लिए हम नाभिकीय विज्ञान एवं प्रौद्योगिकी के अग्रणी क्षेत्रों में उत्कृष्टता को बनाए रखने हेतु पूर्ण समर्पण की भावना से कार्य करेंगे।

- जय हिन्द -"

64th Anniversary of the Independence Day Monday, August 15, 2011

Address by Dr. R.K. Sinha, Director, BARC

"Dear colleagues,

Let me first extend my greetings to you all on the occasion of the 64th anniversary of the independence day of our country. This morning, we have assembled here not only to take a collective pledge to preserve the honour and dignity of our national flag, but also to pay our homage to those who have made supreme sacrifices for the sake of freedom of our country. We also salute the members of our armed forces, who provide security to our country.

We take this opportunity to review our work and take stock of what we have achieved in the recent past. As you know, our mandate includes nuclear energy and nuclear fuel cycle, research reactor along with radioisotope production and isotope applications, different advanced technologies associated with these programmes, basic science and applied research, and strategic activities. Let me cite a few examples to illustrate some of the notable developmental work carried out and achievements made recently in our Centre.

Research Reactors

Research reactor Dhruva continued to serve as a major facility for radioisotope production and as a national facility for neutron beam research. As a part of the refurbishment programme of this 25 year old reactor, replacement of several major equipment has been completed. These include main Motor-Alternator sets and switch gears, channel flow monitoring gauges and I&C panels in the main control room.

The core of CIRUS has been fully defueled. Its process systems are kept under preservation mode.

Detailed engineering of various reactor systems of upgraded APSARA reactor is in progress. The upgraded reactor will provide enhanced facilities for beam tube research, radio-isotope production, calibration and testing of neutron detectors, material testing and bulk shielding experiments.

The conceptual design of a High Flux Research Reactor (HFRR) has been completed. This new research reactor is designed primarily to meet the large requirements of high specific activity radio-isotopes and to provide enhanced facilities for basic research in frontier areas of science and for applied research related to development and testing of nuclear fuel and reactor materials.

Nuclear Power Related R&D

Even before the accident at Fukushima, our reactor safety research programmes covered extreme internal as well as external event scenarios. A 1:4 Containment Test-Model of the 540 MWe PHWR (BARCOM), with extensive instrumentation was constructed and commissioned at Tarapur. The model was recently subjected to an over-pressure test when at 1.77 times the design pressure, the first milestone, viz. "first appearance of crack" was reached. The test data are being analysed as an International Round Robin exercise with four Indian and eleven foreign participating organisations from seven foreign countries.

Understanding the behaviour of buildings under relevant seismic loading conditions is an important aspect of plant safety. Through a major experiment on two large reinforced concrete structures, we found that the overall behaviour of the structures under seismic conditions can be closely simulated by a simpler push-over procedure. This finding will reduce the need for expensive shake-table test or elaborate non-linear dynamic analysis for seismic qualification.

On the process side, the effectiveness of water injection into moderator side as a Severe Accident Management Guidelines (SAMG) action to mitigate the consequences of Station Black Out (SBO) was assessed for a large PHWR.

The tsunami evaluation exercise for all the coastal sites has been underway since last three years and a National Round Robin Exercise has been carried out under this programme. A detailed analysis procedure has been formulated for local inundation mapping and analysis has been completed for Tarapur site.

AHWR Programme

Towards an early launch of AHWR project, the work for detailed engineering design of conventional engineering systems of AHWR has been started in consultancy mode.

Accident Management Analyses have been carried out for AHWR for some of the extreme events, including Large Break Loss of Coolant Accident, along with non-availability of Emergency Core Cooling System, together with loss of Moderator Heat Sink.

As a part of validation of the physics design parameters and the calculational models used for thorium based fuel, integral experiments with (ThO₂- 1% wt% PuO₂) cluster and a mixed

cluster consisting of Thoria and natural uranium have been performed in AHWR critical facility yielding valuable data relevant for design validation of AHWR. The fuel cluster was later loaded in a regular fuel position of Dhruva to study the irradiation behaviour of the thoria based AHWR fuel.

The experimental programmes towards evaluation of design margins for AHWR continued with the setting up of several new facilities and conduct of experiments in the existing ones. Innovative experiments to detect occurrence of critical heat flux in a new experimental set up were conducted to detect occurrence of this phenomenon.

Advanced Nuclear Fuels

PFBR Fuel Fabrication

Fabrication of the Mixed Oxide fuel pin for the first core of PFBR is in progress in Advanced Fuel Fabrication Facility of BARC at Tarapur. Laser decontamination of these pins has been incorporated in the process flow sheet. The use of laser decontamination system has reduced the exposure to operating personnel.

AHWR Low Enriched Uranium Fuel

As a part of development of LEU fuel for AHWR, ThO₂-UO₂ pellets (300 Nos.) of different compositions having UO₂ from 8 to 22.5% were compacted and sintered in various atmospheres like, Ar, Ar-8%H₂ and N₂. The co-efficients of expansion of these fuel compacts have been determined. The evaluation of further thermo-physical properties of these fuels is in progress.

By utilising appropriate conversion-recycle-conversion (CRC) technique, a zero discharge of fluoride effluent has been achieved in U-metal production unit.

Development of advanced fuels for Fast Reactors

Vibro pack fuel

BARC has been working in the area of development of advanced fuels for fast reactors. As a part of this activity, plutonium rich mixed oxide microspheres of nearly 780 micron diameter were prepared for the first time in the world at BARC, by internal gelation method using sol-gel process. These microspheres, along with smaller size (around 100 micron) UO_2 microspheres prepared at IGCAR, will now be used as fuel material of a test pin for irradiation in FBTR at IGCAR.

Metallic Fuel

A glove box facility consisting of, injection casting of uranium/U-alloy rods in quartz tube moulds, demoulding of cast rods, end-shearing of rods and an automated inspection system, has been set up. This facility has been successfully used for fabrication of required numbers of natural U-6wt% Zr alloy metallic fuel slugs meeting required specifications. Continuous casting of uranium has been carried out successfully. This will help in reducing alpha waste during the fabrication of metallic fuel for FBR.

As a part of development of mechanically bonded metallic fuel for fast reactor, U-15%Pu slug has been fabricated for characterisation. The above alloy has been investigated for several of its relevant properties.

CERMET fuels

As a part of development of fuel for Fast Reactors, Cermet fuels comprising of 15% and 30% by volume of UO_2 dispersed in U metal powder were compacted and sintered at 1090°C in Ar and vacuum. The shrinkage behaviour of the above cermet fuels were evaluated using a dilatometer. It

was observed that sintering was superior in Ar atmosphere.

Reprocessing

Plutonium Plant at Trombay continued to operate safely and the irradiated fuel bundles received from Dhruva/CIRUS were reprocessed. In addition, Uranium Thorium Separation Facility (UTSF) was operated to recover thorium from thoria raffinate.

Reprocessing Plant at Kalpakkam was operated quite satisfactorily and safely. Under the Nuclear Recycle Board, the PREFRE-2, Tarapur Plant has started production. Additional Waste Tank Farm is also operational.

In order to realise the design through-put of future large scale reprocessing plants, a full size prototype continuous rotary dissolver has been fabricated and installed. This unit will be operated under simulated conditions (with uranium nitrate) to generate useful data and provide feedback on various aspects such as material of construction, remote handling, recovery of material from hulls, etc.

For the first time in the country, a process has been developed for synthesis of Hydroxyl Amine Nitrate (HAN) to be employed as an alternate solvent in spent fuel reprocessing. The material has been indigenously produced up to litre scale.

Recovery of useful isotopes such as ^{89}Sr , ^{90}Y & ^{241}Am from radioactive waste was continued and supply to the users was maintained.

Nuclear Waste Management

Technology for remote dismantling and decommissioning of Joule Melter inside hot cell was developed and decommissioning of Joule Melter System is nearing completion with very low man-

rem expenditure and solid waste generation at the Advanced Vitrification facility, Tarapur.

At Waste Immobilisation Plant, Kalpakkam, inactive commissioning of second Joule Heated Ceramic Melter using simulated High Level Waste (HLW) was carried out. Remote replacement of components such as off-gas jumper, thermo wells, thermocouples and level probe has been achieved.

Vitrification technology employing Cold Crucible Induction Melter (CCIM) crossed another milestone by successful completion of simulated waste feed experiments.

A first time activity in DAE to retrieve, reduce the volume and dispose of the pressure tubes from the en-masse coolant channel replacement campaign of MAPS, has been taken up at the Centralised Waste Management Facility, Kalpakkam.

A process has also been developed for the synthesis of cesium-specific crown ether and indigenous production of the material upto kilogram scale. Inorganic ion-exchanger media, in bead form have been developed for removal of specific isotopes such as ^{106}Ru , ^{99}Tc , ^{144}Ce from low and intermediate level liquid wastes.

Environmental Monitoring and Radiation Safety

Preliminary estimates of the release rates of different radio-nuclides into the atmosphere and into the Pacific Ocean due to Fukushima nuclear accident were derived using indigenously developed environmental models. Reasonable matching of the estimated release rates was observed with the values reported by different agencies. All the environmental survey laboratories in the country carried out a special campaign to monitor very low level of radioactivity in the environmental matrices. The data have been regularly updated in the

departmental websites and communicated to the IAEA. We were able to confirm that this event has not caused any noticeable impact on India.

The solar powered Environmental Radiation Monitor (ERM) for open field installation was enabled with data communication facility using Short Message Service (SMS) of Global System for Mobile Networking (GSM), Local Area Network (LAN) and Optical Fibre Based Communication channels. These stand-alone automated systems transmit background environmental radiation data to a central station at Mumbai and serve as an early warning system, in case of a nuclear emergency due to an increased gamma radiation level in the environment. Industrial grade production of these units has been initiated under an MoU with ECIL.

Inhalation dosimeter badges have been developed for directly monitoring the cumulative doses due to radon, thoron decay products using direct progeny sensors. These badges have been deployed in about 2000 places within the country and also in about 1000 locations in Europe, based on the request from several foreign institutions.

The R&D efforts to enhance safety during transportation of radioactive materials through public domain have resulted in successful development of Poly Urethane Foam (PUF), which is being further qualified for its use as thermal shielding and impact limiter in the transportation packages. Mapping of lead melting in real time was captured for the first time by adopting neutron radiography, using a dedicated beam facility at CIRUS. This experimental data will facilitate validation of computer codes used for modeling the behaviour of lead during the hypothetical accident of a spent fuel transport cask being engulfed in fire.

Two Emergency Response Centres (ERCs) have been established at IPR, Gandhinagar and RMP, Mysore with radiation monitoring systems and trained

Emergency Response Teams (ERTs). This brings the total number of ERCs for preparedness and response to nuclear and radiological emergencies to 20 in the country.

Technical support was provided to National Disaster Management Authority (NDMA) for the preparation of guidelines on Preparedness and Response to Nuclear Disaster.

Physical Sciences

As a part of beam line development activity at INDUS, High Resolution Vacuum Ultraviolet beam line has been commissioned for spectroscopic study of molecules of interest to astrophysics and environment science.

The EXAFS beam line at INDUS has been augmented with fluorescence measurement facility for characterisation of surface, thin films and multilayers.

A quadrupole mass spectrometer, which has a resolution of 1 AMU and mass range of 150 AMU, has been fabricated and installed at Heavy Water Plant, Tuticorin.

Chemical Sciences

The feasibility study of in-house developed nano-diamond film as monitor of alpha activity of plutonium, in highly acidic medium, has been successfully completed.

A simple and inexpensive hydrogel-based material has been developed, which consists of nitrogen oxides releasing agarose gel, combined with citric acid loaded cotton gauze. It has excellent antimicrobial properties and has potential as a dressing material for ulcerative skin infections.

The studies on bio-denitrification using mixed microbial granules showed that treatment of up to 4050 mg NO₃-N/L (equivalent to 18,000 mg/L NO₃) could be achieved by supplying acetate at a C/N ratio of 1.5. This was demonstrated in 6 litre volume

laboratory scale sequencing batch reactors.

Biological Sciences

In a significant finding, 1,4-Naphthoquinone (NQ), a parent molecule for many anti-tumour natural compounds, protected lymphocytes and intestinal cells from mice against a dose of 4 Gy gamma radiation. In the mice, 2 m/kg NQ given in-vivo restored radiation induced bone marrow suppression. The possible mechanisms involve activation of redox transcription factor Nrf-2 (nuclear factor E2 related factor-2).

Food Technology

Acrylamide, a neurotoxin, and a probable carcinogen, has been reported to be present at significantly higher levels in carbohydrate-rich fried foods, such as potato chips. The compound originates from the reaction of amino acid asparagine with reducing sugars like glucose present in food during frying. The acrylamide content in chips prepared from potatoes irradiated for sprout inhibition, was found to be lower than that in the corresponding non-irradiated controls.

The browning of cut fruits and vegetables is reduced in irradiated fruits and vegetables. For the first time, in a study conducted on pre-cut ready to cook ash gourd, it has been shown that gamma resorcylic acid liberated from its precursor during radiation processing acts as a natural inhibitor of polyphenol oxidase, the enzyme involved in brown discoloration of cut fruits and vegetables.

Nuclear Agriculture

In the field of agriculture, two new Trombay radiation induced mutant crop varieties have been released. The first variety, named TAT-96-29, was released for cultivation in Maharashtra. Another large seed confectionary groundnut variety, TG 47 has been released as Bheema for cultivation in Andhra Pradesh.

Nisargruna technology has been successfully extended to process large quantities of biological sludge generated in Effluent Treatment Plants (ETP) of textile, food and paper industries. Four such plants were set up.

Isotope Applications

Investigations were carried out to quantify the Submarine Groundwater Discharge (SGD) occurring under various tidal conditions in Thiruvananthapuram coast, Kerala. Natural ^{222}Rn (half life = 3.8 days) was used as a tracer. The study will help in the judicious exploitation of groundwater in coastal aquifers by maintaining the seawater interface well within the coastal zone.

Our efforts towards development of Lutetium-177 based radiopharmaceuticals have shown positive results. Currently, six nuclear medicine departments in India are using the high specific activity ^{177}Lu produced in the Dhruva reactor, for the preparation of ^{177}Lu -DOTATATE for the treatment of neuroendocrine tumors. India is among one of the seven countries which are pursuing ^{177}Lu based therapy for the treatment of cancer.

Sludge Hygienisation Research Irradiator (SHRI) facility, Vadodara has now been linked to the new 66 MLD sewage treatment plant that has higher solid content in the sludge.

Materials Programme

Processing maps have been generated on cast Zr-2.5Nb over a temperature range of 700° to 1100°C. On the basis of the data generated, forging has been carried out successfully on full scale cast ingots of Zr-2.5Nb by a manufacturer. This work was carried out in collaboration with Nuclear Fuel Complex, Hyderabad.

A new class of ferromagnetic shape memory alloys based on Ni-Mn-Sn system known to exhibit Inverse

magnetocaloric effect was studied. Single crystals of the thermoelastic shape memory alloy Cu-16Zn-16Al were successfully prepared using Bridgmann methodology and soft mould technique.

A prototype of ITER Test Blanket Module (TBM) first wall is being fabricated by machining, bending and laser welding. Laser welding studies on ferritic martensitic steel P91 were carried out in this connection, followed by mechanical testing of the weld joints with and without a post weld treatment.

After successful augmentation of Phase-I part of Lithium Metal Plant, and after obtaining the regulatory clearance, the plant was operated for demonstration of its capability by achieving desired grade of lithium, required for the ITER TBM programme.

A large number of special shapes of vacuum hot-pressed beryllium have been fabricated as per the user specifications. These shapes have been accepted and are being used for neutron physics experiments.

Electronics & Instrumentation

Helicopter-borne Time Domain Electromagnetic (TDEM) system for aerial exploration of uranium ores was successfully flight tested recently. During this test, the underslung system, including 22 m diameter transmitter, was suspended 30m below the helicopter and 30m above ground.

Differential microbarometer to measure very small atmospheric pressure variations of the order of microbars around the mean atmospheric pressure, in infrasonic range, has been developed to facilitate its large scale production in the country.

Three ASICs - ANUSPARSH, ANUDRISHTI and ANUSUCHAK in 0.35 μm CMOS technology, and to be used in different detector applications, were designed, developed and tested successfully. The ANUSPARSH is a front-end readout for Resistive Plate Chamber detectors to be used in the planned Indian

Nutrino Observatory, the ANUDRISHTI is a monolithic photodiode and readout electronics for compact gamma detection probes and the ANUSUCHAK is low power front-end readout for silicon type Intrinsic and type detectors.

An Inertial Navigation System (INS) has been developed, that can be coupled to the Pipe Inspection Gauge (PIG) developed by BARC. Post processing of the INS data can accurately determine the 3-D layout of the pipeline. Trials of the system have been made in the test loop at the IOCL R&D Centre, Faridabad.

Accelerator & High Power Electronics

As a part of R&D programme for ADSS, studies were initiated to develop high intensity neutron spallation targets based on Lead-Bismuth-Eutectic (LBE) liquid metal. An LBE target module consisting of gas driven liquid metal circulation system with remote dismantling facility has been designed to couple with 30 MeV and 500 micro-Ampere proton beam for R&D studies. A target module has been fabricated for full scale trials with LBE before coupling it to the proton beam.

The 10 MeV RF Electron Accelerator at EBC has been operational and being used for several industrial process development. Irradiation of silicon power diode chips for BHEL at 0.4 kGy improved the reverse recovery time (T_{rr}) of power diodes from 14 microseconds to about 6 microseconds.

A bipolar type six stage Marx generator of rating 300kV, 12kA, 300ns, 10Hz repetition rate with a Reflex Triode and reflectors for HPM generation was designed and fabricated. It has been operational and used for generation of high power microwaves.

Other Advanced Technologies

Computers

The latest parallel processing ANUPAM

supercomputer, benchmarked at 47 Teraflops, and called "ANUPAM-Adhya" has been released to users.

Cryo-Technology

A significant milestone was achieved in the development of an advanced indigenous helium refrigeration system for cryogenic application. During operational trials, refrigeration power of about 500 W was achieved at 20K.

Desalination

Field test of BARC developed membrane based water purification system was carried out on tube well water for 24 villages in six districts of Punjab for removal of uranium from the ground water. Purified water containing less than 6 ppb uranium (which is far below the AERB permissible limit of 30 ppb) was produced from the raw water having 685 ppb uranium, The unit can be installed in homes and can be used as a point of use device with very low electrical power consumption.

Plasma Technologies

As a part of the development of dry processes for reduction of Uranium – Hexafluoride (UF₆) to Uranium - Tetra Fluoride (UF₄), thermal plasma assisted as well as flame reduction based bench scale setups were successfully designed, constructed and operated.

Pulse Power Technologies

A bipolar type six stage Marx generator of rating 300kV, 12kA, 300ns, 10Hz repetition rate with a Reflex Triode and reflectors for HPM generation was designed and fabricated. It has been operational at 225 kV and used for generation of High Power Microwaves in the range 1.2 GHz to 3.8 GHz.

Robotics

A gadget has been developed for automated

cleaning of parabolic solar reflectors of size 1.8 m x 3 m used in the solar power plant. The gadget has recently been provided for field testing in a solar power plant near Pune.

Seismology

With the objective of promptly detecting, locating and identifying seismic events, including tsunamigenic earthquakes, several new analysis techniques have been developed and implemented at the Seismic Data Centers (SDC) of BARC. It has been demonstrated that from SDC, BARC, regional events located within a radius of 2500 km are, in general, reported much faster as compared to that by any other national and international seismological agencies.

Societal Outreach & Technology Transfer

An underground water source with a discharge capacity of 30,000 lph has been identified using Isotope Hydrology technique in a village called Nimkhed in Amravati District, a water scarce area. This water source has been established for use of farmers under BARC's AKRUTI Programme.

A tissue culture laboratory with field hardening facility of 50,000 banana plantlets has been made operational and first batch of hardened plantlets have been sown in the field in AKRUTI programme at Amravati, Maharashtra.

A brackish water Reverse Osmosis (RO) plant with 300 lph capacity has been set up in a coastal village named Farare in Dapoli, through AKRUTI programme. The villagers have been trained to operate, run and maintain the plant.

AKRUTI Tech Pack, meant for rural sector, was transferred to five more parties. Two new technologies were transferred to the industry for the first time.

Medical Services

Our Vashi Dispensary is completely renovated and from March 2011 it is fully functional. Several new equipment have been procured for the BARC Hospital to facilitate its further modernisation and enhanced services to the beneficiaries.

Administrative Group

The administrative Group continued to provide vital supporting functions in the fields of administration, establishment, including man power planning, personnel data management, finance and accounts, and security.

Security & Physical Protection

Security of our Centre is of paramount importance. BARC security and CISF personnel have been performing a commendable task of providing the physical protection of our establishment. I take this opportunity to express appreciation of the BARC Fire Service personnel for their role in the protection of the various establishments of our Centre. I also compliment all officers and staff of our Centre for extending their cooperation to help the security personnel in discharging their duties effectively. I urge all my colleagues in our Centre to continue to remain vigilant and alert in the present environment.

Landscape and Gardening

The contributions made by the personnel of our Landscape & Cosmetics Maintenance Section is evident from the beautiful ambience of this venue. I take this opportunity to acknowledge their services.

Closing Remarks

Dear Colleagues,

I have attempted to give here only a few brief glimpses of some of our activities carried out by us during the recent past. Due to constraint of time, I could not cover many more, which are by no means less important.

In my speech last year, on the same occasion, I had highlighted the importance of continuing to maintain our excellence to meet the new challenges in the context of the emerging international co-operation. I would like to mention that our proposals for the forthcoming XII Five Year Plan, particularly address the realisation of this objective.

As you are aware, our programmes and deliveries directly address nearly all sectors of our societal

needs, including food, water, environment, energy, healthcare, industry, education and national security. We now have a need to further strengthen the visibility of these deliveries to the society at large. We have already taken new initiatives to meet this need. I urge all members of our DAE family to contribute to our outreach and public awareness programmes with greater vigour.

Friends, finally on this very special day, let us firmly resolve and rededicate ourselves to continue our pursuit of excellence in the frontier areas of nuclear sciences and technologies for the betterment of the quality of life of our people.

- Jai Hind -"

Radiation Processing of Temperate Fruits of Kashmir Valley

Peerzada R. Hussain, Raghuveer S. Meena, Mohd A. Dar and Ali M. Wani

Astrophysical Sciences Division, Nuclear Research Laboratory, BARC, Srinagar.

Abstract:

Kashmir valley is famous for its temperate horticulture. Main temperate fruits grown commercially in the valley include apple, pear, peach, plum, cherry, strawberry and apricot. These fruits being perishable and susceptible to microbial spoilage, have a short shelf-life. The short shelf-life is an impediment in their transportation and marketing and results in huge losses. Study was carried out at NRL, Srinagar to investigate the effect of gamma irradiation on the keeping quality of most of these fruits. The effect of gamma irradiation alone and in combination with other techniques like controlled low temperature storage, edible polysaccharide coating and calcium chloride treatment was studied in detail. Our results revealed that there is a great potential for the use of radiation in extending the storage life of most of the temperate fruits produced in the valley of Kashmir.

Keywords: Gamma irradiation, Temperate fruits, Quality improvement, Shelf life extension

Introduction

The valley of Kashmir is famous for its temperate horticulture. Nearly 75% of India's temperate fruits are grown in the valley of Kashmir. Main temperate fruits presently being grown include apple, pear, peach, plum, cherry, strawberry and apricot. The area under cultivation of fresh fruits is 161136 hectares and production of fresh fruits is 957861 metric tons. Among fruits, apple has a leading position both in terms of cultivation and production followed by pear. Apple occupied about 50% of the total area under its cultivation and constitutes around 90% of the total fruit produced in the state. These fruits being perishable in nature hence have short shelf-life at optimal temperatures. Short shelf life of the fruits represents a serious constraint for efficient handling, transportation and marketing chain of the produce. Inappropriate post-harvest management practices and lack of proper scientific storage and transportation facilities result in huge post-harvest losses of the order of 20-40% during handling, packaging, and transportation of the produce. Microbial contamination besides

contributing to the losses, poses potential health risks as well. Therefore, the post-harvest treatment of fruits has become necessary to provide longer life to the fruit, which at the same time establishes price for the grower during the glut season.

Gamma irradiation at present is used as the potential method of food preservation. Gamma irradiation effectively delays the ripening and senescence of climacteric fruits, sprouting of bulb and tuber crops and checks the microbial proliferation, thus extends the shelf-life of perishable foods. It is widely used as a quarantine treatment for export purposes and has emerged as a potential alternate to the use of chemical preservatives. Moreover, gamma irradiation treatment can be performed at room temperature and can be applied to bulk as well as prepackaged food, thus obviating the chances of cross contamination. Being a cold process in nature preserves the food in natural form and does not destroy heat-labile aroma and other sensitive constituents of food. Additionally, it can improve food security by cutting down food losses caused by storage insects, microorganisms and physiological

changes. Combinatory treatments have also widely been investigated as they often result in synergistic effects. Gamma irradiation in combination with other treatments (e.g., heat, washing, modified atmosphere storage, edible coating process) decreases the microbial contamination level leading thus to an improvement of shelf life

Radiation processing of most of the tropical fruits has been extensively studied at Food Technology Division, BARC, Mumbai over the decades. The commendable efforts of radiation processing studies carried out at FTD enabled the market access to Indian Mango from Deogarh to DC, Washington (Sharma, 2008; Hajare et al., 2010; Thomas and Janave, 1975; Thomas, 1986; Dharkar et al., 1970). However, little information is available in the literature on the radiation processing of temperate

fruits of Kashmir valley. At NRL, BARC Srinagar, studies have been conducted during the last five years on the effect of gamma irradiation on the Kashmir valley fruits using the PANBIT gamma irradiation facility. These studies were aimed at evaluating the effect of gamma irradiation alone and in combination with edible coating, calcium chloride dip treatment and low temperature storage for the quality improvement, shelf-life extension and as a quarantine treatment for export purposes. The fruits after harvesting at their commercial maturities followed by subsequent pre-cooling and grading were subjected to gamma irradiation alone and in combination with polysaccharide based edible coatings and calcium chloride dip and the synergistic effect on the storage quality and shelf-life extension was evaluated. Table 1 shows the fruits that have been studied so far.

Table 1. Temperate fruits that have been evaluated for feasibility of gamma irradiation for quality improvement and shelf-life extension

S.No.	Fruits tested	Variety
1	Pear (<i>Pyrus communis</i> L.)	William/Bartlett
2	Apple (<i>Malus domestica</i>)	Ambri, Golden Delicious, Royal Delicious, Red Delicious
3	Strawberry (<i>Fragaria</i> spp.)	Confitura
4	Peach (<i>Prunus Persica Bausch</i>)	Elberta
5	Dried apricot (<i>Prunus armeniaca</i> L)	Halmann
6	Plum (<i>Prunus domestica</i> L.)	Santarozza
7	Cherry (<i>Prunus avium</i> L.)	Misri, Double

The level of treatments to which the fruits were subjected and subsequent storage conditions are presented in Table 2.

Table 2. Treatments and storage conditions of the studies conducted

Fruit	Irradiation dose (kGy)	CMC con. (% w/v)	Storage condition
Pear	0.8 - 2.0	0.25-1.0	Ambient (25±2 °C, RH 70%) Refrigerated (3±1 °C, RH 90%)
Strawberry	0.5-2.0	0.5 - 1.0	do
Peach	1.0-2.0	0.5 -1.0	do
Apple	0.1-0.5	0.25 -1.0	Ambient (15±2 °C, RH 80%) Refrigerated (3±1 °C, RH 90%)
Dried apricot	1.0 – 3.0	-	Ambient (12-25±2 °C, RH 70-80%)
Plum	0.2- 1.5	-	Ambient (25±2 °C, RH 70%) Refrigerated (3±1 °C, RH 90%)
Cherry	0.3 – 1.5	-	Ambient (25±2 °C, RH 70%) Refrigerated (3±1 °C, RH 90%)
CMC = Carboxymethyl Cellulose			

Results of the studies

Following are the highlights of the results obtained for various fruits.

1. Pear (*pyrus communis* L. Cv. Bartlett/William)

Treatment	Decay percentage		Shelf-life extension (days)	
	Amb. storage	Ref. storage	Amb. storage	Ref. storage
Control	97.2% after 14 DOS	35.9% after 35 DOS	-	-
Irradiation alone 1.5 – 1.7 kGy)	ND up to 16 DOS	ND up to 45 DOS	16 days	4 days extension in shelf-life during Post- ref. storage at 25 ± 2 °C, RH 70% following 45 days of refrigeration.
CMC Coating alone (1.0% w/v)	ND up to 12 days	ND up to 35 DOS	12 days	5 days extension in shelf-life during post-ref. storage at 25 ± 2 °C, RH 70% following 30 day of refrigeration.
CMC Coating, Irradiation (1.0% w/v, 1.5 kGy)	ND up to 22 days	ND up to 60 DOS	22 days	8 days extension in shelf-life during post- ref. storage at 25 ± 2 °C, RH 70% following 60 days of refrigeration.

ND = No Decay; DOS = Days of storage; Amb. = ambient; Ref. = refrigerated

(Wani et al., 2007, 2008; Hussain et al., 2010)

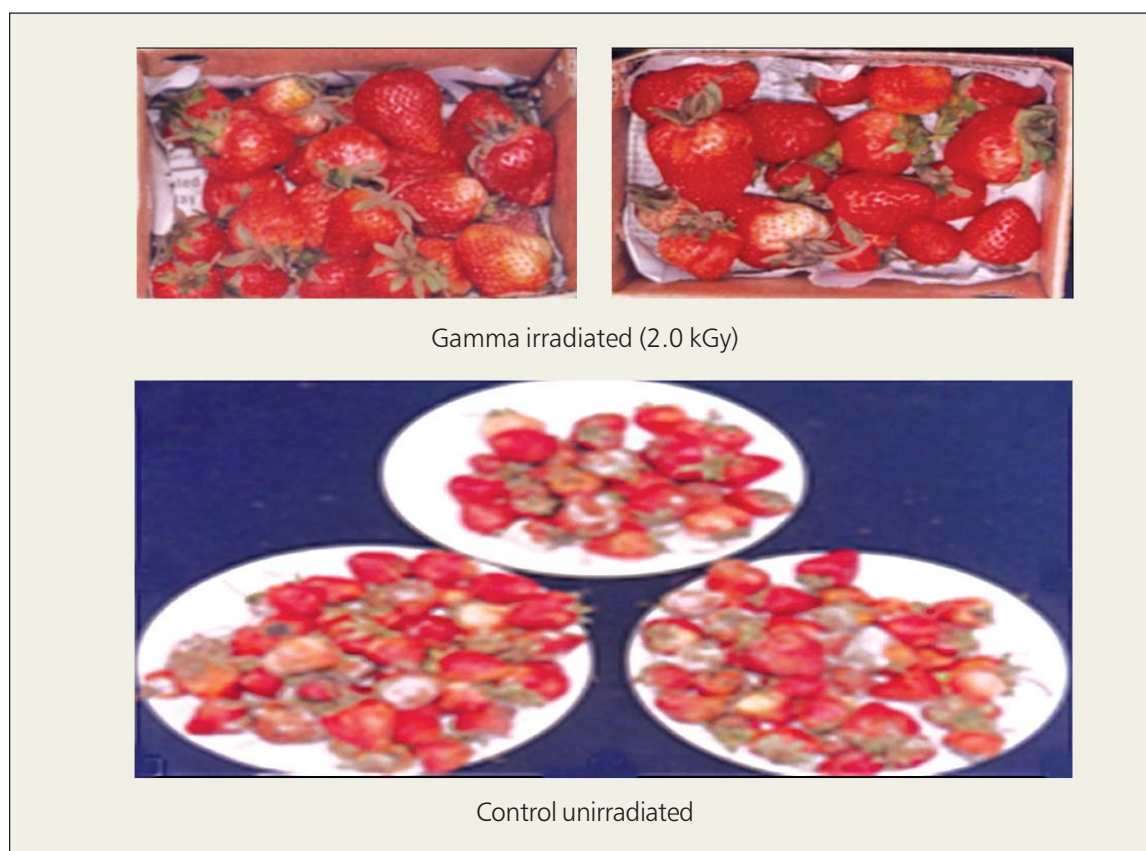


Effect of gamma irradiation treatment on delay in ripening (a) and decaying (b) of pear during storage under ambient conditions

2. Strawberry (*Fragaria spp.* Cv. Confitura)

Treatment	Appearance of mold growth		Shelf-life extension (days) under refrigerated storage
	Ambient storage	Refrigerated storage	
Control Irradiation alone (2.0 kGy)	at 1 st DOS after 2 DOS	after 3 DOS after 12 DOS	- 9 days extension
CMC Coating alone (1.0 % w/v)	at 1 st DOS	after 5 DOS	2 days extension
(CMC Coating, Irradiation) (1.0 % w/v, 2.0 kGy)	after 2 DOS	after 21 DOS	18 days extension
DOS = Days of Storage			

(Hussain et al., 2007)



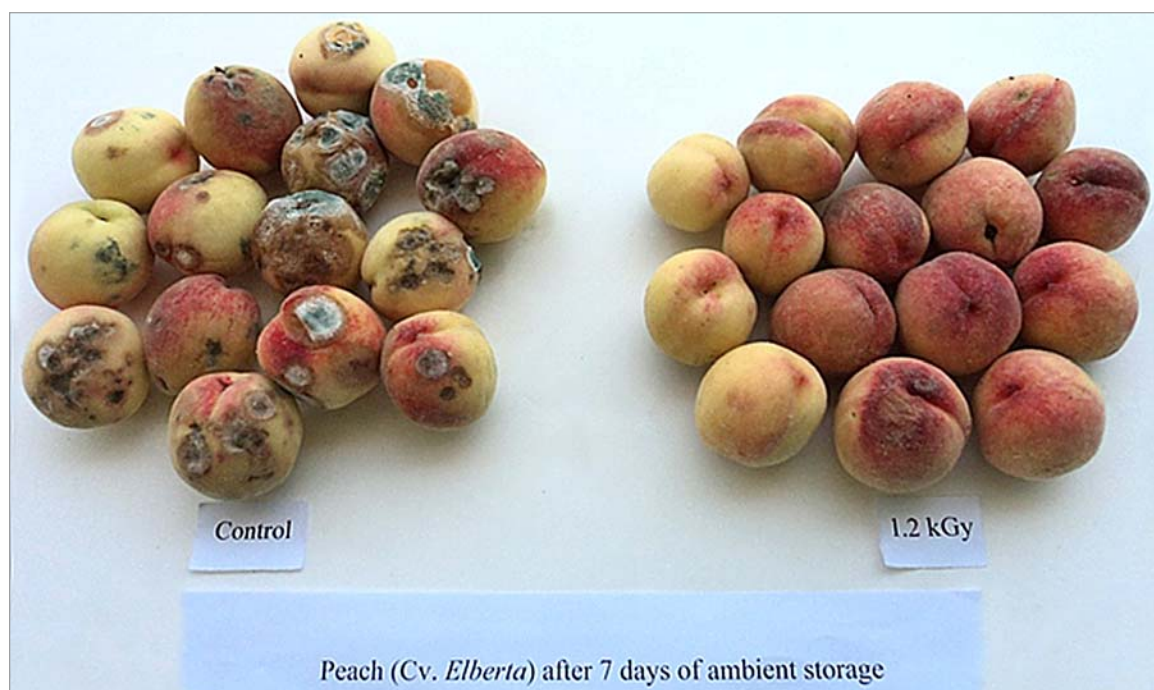
Effect of gamma irradiation on fungal growth of strawberry after 12 days of refrigerated storage

3. Peach (*Prunus persica Bausch*) Cv. Elberta

Treatment	Decay percentage		Shelf-life extension (days)	
	Amb. storage	Ref. storage	Amb. storage	Ref. storage
Control	51.1% after 6 DOS	40.0% after 20 DOS	-	-
Irradiation (1.2 – 1.4 kGy)	ND up to 7 DOS	ND up to 20 DOS	7 days	20 days
CMC coating (1.0% w/v)	ND up to 5 days	ND up to 12 DOS	5 days	12 days
CMC coating, Irradiation (1.0% w/v, 1.2 kGy)	ND up to 12 days	ND up to 30 DOS	12 days	7 days extension in shelf-life during post-refrigerated storage at 25 ± 2 °C, RH 70% following 30 days of refrigeration.

* Irradiation enhanced the Phenylalanine ammonia lyase (PAL) and antioxidant activity of peach fruit.
ND = No Decay; DOS = Days of Storage

(Hussain et al., 2010, 2008)



Effect of Radiation Treatments on inhibition of Decay in Peach Fruit

4. Apple (*Malus domestica*)

1. Response of apple varieties to irradiation treatment was cultivar dependent. Gamma irradiation doses of 0.2, 0.3 and 0.5 kGy proved beneficial in maintaining the storage quality of Ambri, Golden delicious, Royal delicious and Red delicious apples under ambient as well as refrigerated conditions.
2. Irradiation treatment proved beneficial than control in maintaining the overall quality of apple varieties by about 30 days under ambient conditions and 90 Days under refrigerated storage conditions (Hussain et al., 2008)
3. Irradiation in combination with edible coating (1.0% conc.) was helpful in maintaining the quality of apple varieties up to 100 days of ambient storage.
4. Irradiation in combination with calcium chloride dip treatment (2.0% w/v) extended the shelf-life of Red delicious apples by 20 – 25 days at 17 ± 2 °C, RH 75% following 90 days of refrigeration (Hussain et al., 2011).



Effect of gamma irradiation and edible coating treatment on storage quality of apple varieties. (After 100 days of ambient storage)

5. Cherry (*Prunus avium* L.)

Treatment	Appearance of mold growth		Shelf-life extension (days)	
	Amb. storage	Ref. storage	Amb. storage	Ref. storage
Control	after 3 DOS	after 21 DOS	-	-
Irradiation (1.2 kGy)	after 9 DOS	NMG up to 35 DOS	6 days	9 days extension in shelf- life during post-ref. storage at 25 ± 2 °C, RH 70% following 35 days of refrigeration.

NMG = No mold growth; Amb. = ambient; Ref. = refrigerated



CONTROL (Ambient)



1.2 kGy (Ambient)



CONTROL (Refrigerated)



1.2 kGy (Refrigerated)

Effect of gamma irradiation treatment on fungal growth of cherry after 9 and 35 days of storage under ambient and refrigerated conditions.

6. Plum (*Prunus domestica* L.)

Treatment	Decay percentage		Shelf-life extension (days)	
	Amb. storage	Ref. storage	Amb. storage	Ref. storage
Control	13.5% after 6 DOS	12.5% after 30 DOS	-	-
Irradiation (1.2 – 1.5 kGy)	ND up to 16 days	ND up to 30 DOS	16 days	7 days extension in shelf-life during post-refrigerated storage at 25±2 °C, RH 70% following 30 days of refrigeration.

ND = No decay; DOS = Days of storage; Amb. = ambient; Ref. = refrigerated

7. Dried apricot (*Prunus armeniaca* L)

The study revealed that medium dose radiation processing of dried apricots proved beneficial in terms of quality maintenance and quarantine control for export purposes of commercially sun dried apricots. Radiation treatment of dried apricots at dose levels of 2.5 and 3.0 kGy proved beneficial in

retention of higher levels of β -carotene, ascorbic acid and color values without impairing the taste. Irradiation at all dose levels facilitated the release of residual sulphur dioxide during storage, thereby lowering the residual sulphur dioxide of pre-sulfured dried apricots significantly below the prescribed limit for dried products. Irradiation at 3.0 kGy gave about 1 log reduction in microbial load of dried apricots.

Treatment	β -Carotene (mg/100g)	Sulphur dioxide (ppm)	Microbial load (cfu/g)
Control	8.6 ± 0.33	590.4 ± 2.3	5.4 ± 0.3
1.0 kGy	9.6 ± 0.30	545.5 ± 2.5	5.2 ± 0.2
1.5 kGy	9.6 ± 0.30	490.2 ± 2.4	5.0 ± 0.1
2.0 kGy	10.1 ± 0.32	405.6 ± 2.2	4.8 ± 0.2
2.5 kGy	10.8 ± 0.25	382.6 ± 2.3	4.6 ± 0.1
3.0 kGy	11.4 ± 0.29	350.1 ± 2.3	4.4 ± 0.2
LSD	0.34	2.2	0.13

(Hussain *et al.*, 2011)

Values are sum of means ± SD (n = 3); LSD = least significant difference (pd"0.05).

Values reported are after 18 months of ambient storage.



Effect of radiation processing on quality retention of dried apricot after 18 months of ambient storage.

Conclusion

Gamma irradiation alone and in combination with polysaccharide based edible coatings proved significantly effective in delaying the onset of decay, improving keeping quality and extending the shelf-life of tested fruits under ambient as well as refrigerated conditions. The optimized doses can be used as quarantine treatment for export purposes without any deleterious effect on physico-chemical parameters. Therefore, radiation processing technique offers huge potential for the quarantine treatment as well as shelf-life extension of temperate fruits for domestic as well as export markets.

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Friction Stir Welding of Aluminium Alloys

N.T. Kumbhar and G.K. Dey

Materials Science Division

and

K. Bhanumurthy

Scientific Information Resource Division

Abstract

Friction Stir Welding (FSW) is a solid state joining technique, widely used for welding of aluminium, magnesium, copper and titanium alloys. Being a solid state joining process, friction stir welding offers various advantages like low distortion, absence of melt-related defects, high joint strength, etc. as compared to other conventional fusion welding techniques. A brief overview of the friction stir welding process and recent developments are presented in this paper. In addition, a composite picture of the work done at BARC, relating to the microstructural developments in a friction stir welded Al 5052 alloy is presented.

Introduction

Friction stir welding is one of the new entrants to the solid state joining techniques, which have made remarkable progress in welding technology. Friction stir welding was developed in 1991 [1] and is essentially a solid state joining process, widely used for the welding of light and difficult-to-weld metals and their alloys like aluminium, magnesium, copper etc [2]. Recently, its applications have been extended to the welding of high melting point materials such as various types of steels [3], Ti alloys [4], Ni-based superalloys [5], the welding of metal matrix composites and polythene [2]. Friction stir welding is being used in various engineering applications, which require the joining of dissimilar material combinations and which are not viable using conventional fusion welding techniques. With recent developments in technology of friction stir welding, it is now possible to carry out dissimilar welding of various types of steels with alloys of aluminium, magnesium, copper, titanium and also other alloy combinations [6]. Moreover, workpieces in the form of plates, sheets and hollow pipes can be welded by this method. Over a period of time developments in friction stir welding have led to different variants

like friction stir processing, friction stir spot welding, friction stir channeling etc. [2]. Thus, it can be said that friction stir welding and its variants have brought a revolution in the field of solid state joining technology.

Friction Stir Welding : The Process

Friction Stir Welding (FSW) is a simple process in which a rotating cylindrical tool with a shoulder and a profiled pin is plunged into the abutting plates to be joined and traversed along the line of the joint. A schematic of the friction stir welding process is shown in Fig. 1.

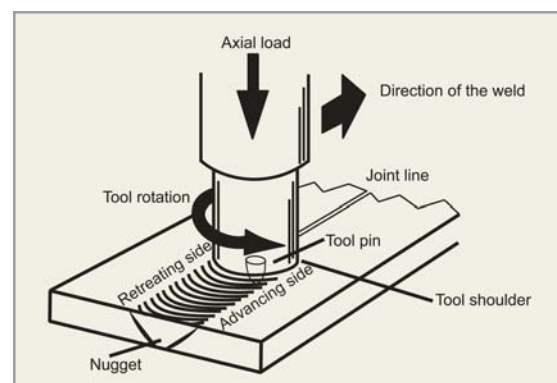


Fig. 1: Schematic of the friction stir welding process

The plates are tightly clamped on to the bed of the FSW equipment to prevent them from coming apart during welding. A cylindrical tool rotating at high speed is slowly plunged into the plate material, until the shoulder of the tool touches the upper surface of the material. A downward force is applied to maintain the contact. Frictional heat, generated between the tool and the material, causes the plasticized material to get heated and softened, without reaching the melting point. The tool is then traversed along the joint line, until it reaches the end of the weld. As the tool is moved in the direction of welding, the leading edge of the tool forces the plasticized material, on either side of the butt line, to the back of the tool. In effect, the transferred material is forged by the intimate contact of the shoulder and the pin profile. It should be noted that, in order to achieve complete through-thickness welding, the length of the pin should be slightly less than the plate thickness, since only limited amount of deformation occurs below the pin. The tool is generally tilted by 2-4°, to facilitate better consolidation of the material in the weld. Upon reaching the end of the weld, the tool is withdrawn, while it is still being rotated. As the pin is withdrawn, it leaves a keyhole at the end of the weld. This is the main disadvantage of FSW and few variants are being used to overcome this aspect.

Microstructure during FSW

During friction stir welding, a variety of interactions

occur amongst the tool, workpiece, backing plate and surrounding environment. These interactions affect the temperature distribution and material flow [7,8]. As a result of these complex interactions, the microstructure in and around the weld region is affected. This has resulted in the classification of friction stir welds, into four microstructurally distinct regions. According to Threadgill [9] the four regions are (i) Parent Material, (ii) Nugget, (iii) Heat Affected Zone (HAZ) and (iv) ThermoMechanically Affected Zone (TMAZ). All these regions are identified in Fig. 2, which shows the schematic of a typical cross-section of a friction stir weld. The *parent material* (or base material) is the region which does not undergo deformation and the microstructure in this region is not affected by the heat produced during the process. No detectable changes are seen in the microstructure of this region. The *nugget* region is formed by the intense plastic deformation induced mainly by the tool pin and consists of fine recrystallized grains. Hence this zone is also referred to as '*dynamically recrystallized zone*'. The *heat affected zone* is the region which is affected only by heat and there is no plastic deformation. In this region, the microstructure and/or properties are modified by the thermal heat. The *thermomechanically affected zone* surrounds the nugget and it experiences lower temperatures and less deformation, as compared to those in the nugget. In this region, the material is plastically deformed by the tool and is affected by the heat produced (both due to deformation and friction) during the process.

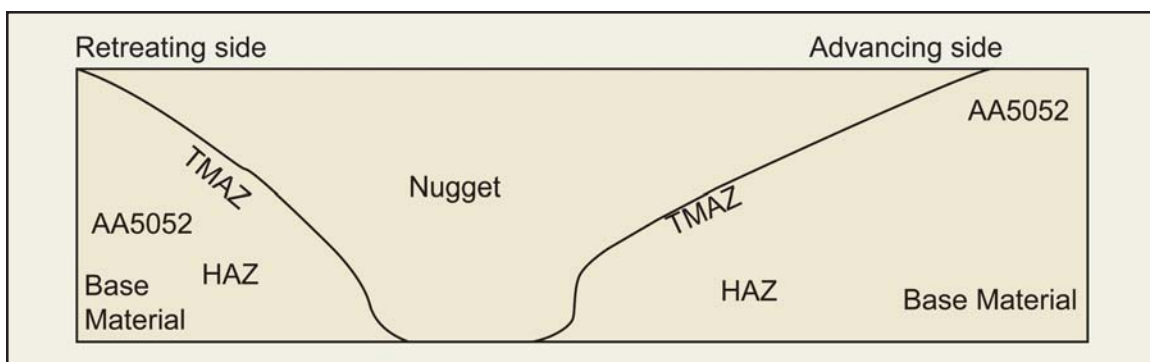


Fig. 2: Schematic of the cross-section of the friction stir weld showing the various characteristic regions

Friction stir welding is regarded as an asymmetric process mainly due to the material flow being affected by the rotation and translational motions of the tool. This asymmetry is reflected in the shape of the nugget and to some extent on temperature distribution, on either side of the nugget [7]. The side of the weld, where the local direction of the tool is the same as the traversing direction, is called the '*advancing side*'. The other side, where the directions are opposite and the local movement of the shoulder is against the traversing direction, is called the '*retreating side*' [2,7,9].

Present Status of Friction Stir Technologies

Applications

Friction Stir Welding has grown into an important industrial process that has led to many worldwide applications, predominantly in the fabrication of aluminium components and panels. FSW is being used in all transport industries including shipbuilding, automotive, rail and aerospace industries [10]. In shipbuilding industry, the FSW process is used for the production of large aluminium panels, which are made from aluminium extrusions. Large tanks for satellite launch vehicles are fabricated by FSW from high-strength aluminium alloys for the aerospace industry. Several companies (The Boeing Company, Eclipse Aviation Corporation, Airbus etc.) manufacture lightweight aluminium airframe structures, fuselage and wing applications using FSW for commercial and military aircrafts. The railway industry uses FSW for the production of large prefabricated aluminium panels, which are made from aluminium extrusions. The automotive industry uses FSW in the production of components like light alloy wheels and fuel tanks.

Design and development of tools

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and

the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough and hard wearing, at the welding temperature. Further, it should have good oxidation resistance and low thermal conductivity, to minimize heat loss and thermal damage to the machinery further up the drive train [2]. Tool steels have been widely used for welding aluminium alloys within thickness ranges of 0.5 - 50 mm, but more advanced tool materials like Carbides, Polycrystalline Cubic Boron Nitride (PCBN) and tungsten rhenium (W-Re) alloys are necessary for more demanding applications such as highly abrasive metal matrix composites or higher melting point materials like steel or titanium. Improvements in tool design have been shown to bring about substantial improvements in productivity and quality [11]. Modifications in the design of the pins (Threaded pins and fluted pins) ensured, that the plastically deformed material is fully delivered around the pin, and from the upper parts of the joint to the lower parts. This results in efficient mixing and enables the use of higher speeds and results in better quality, void free welds. Tools with scrolled shoulders eliminated weld surface undercutting and the flash that extrudes under the tool shoulder.

Process Parameters

In friction stir welding process, a number of process parameters have to be defined to get good, defect-free joints. The important process parameters are tool rotation speed, tool traverse speed, tool tilt angle, insertion depth of the tool pin, etc [2]. The quality of friction stir welds depends upon the use of an optimum combination of these process parameters. For harder alloys or alloys with thicker sections, slower traverse speeds and lower rotational speeds are used. Increasing the rotational speed or decreasing traverse speeds increases heat input and welding temperatures. However, extremely high or low travel and rotational speeds can adversely affect properties. Any inappropriate combination of the process parameters may result in incomplete welds or the formation of defects or weld flaws. The most

common defects observed during friction stir welding are : the groove and channel defects, lazy S defect, 'Kissing bond' defect, formation of voids, root flaws, joint line remnants, etc. [9].

FSW of Al alloy 5052 at BARC: Experimental work

The aim of the study is to provide a composite picture of microstructural development associated with FSW of AA5052 and correlate these with associated mechanical (mainly tensile) properties.

Friction stir welding (FSW) of partially recrystallized aluminium 5052 alloy plates with dimensions 300 mm × 50 mm × 5 mm and having the chemical composition – 2.3 Mg, 0.15 Si, 0.2 Fe, 0.1 Cr, 0.02 Cu, 0.02 Mn, 0.01 Ti, 0.01 Zn, Bal — Al (all in wt.%), was carried out using a dedicated, locally designed and fabricated friction stir welding equipment. A commercial High Speed Steel (HSS) tool, having a cylindrical geometry with 4.8 mm pin length was used for friction stir welding with a tilt of 3°. Further details of the dimensions of the plate and the tool design can be found in our earlier work [12]. FSW trials were carried out at 1120 and 1400 rpm and for various traverse speeds ranging from 60 mm/min, 80 mm/min and 100 mm/min. The qualification of Defect-free joints was done through X-ray radiography and also by dye penetration tests. The transverse cross-section of the specimen (welded at tool rotation speed of 1400 rpm and tool traverse speed of 80 mm/min), prepared using standard metallographic procedure, was used for optical as well as electron microscopy observations. The microstructural characterization using electron microscopy comprised of techniques like electron probe microanalysis, orientation imaging microscopy, transmission electron microscopy and scanning electron microscopy. A Vickers' microhardness profile was obtained in the mid-thickness region across this structure using a load of 50 g and a 10 s dwell time. Standard tensile specimen having gauge length of 25 mm and gauge

width of 5 mm were cut from the welded plates, by keeping the tensile axis perpendicular to the welding direction. The tensile specimens were tested by using screw-driven Instron machine, at a strain rate of 10^{-4} s^{-1} . The fractured surfaces were further examined using scanning electron microscopy.

Results and Discussion

Optical microstructure

The parent AA5052 material microstructure consists of pancake-shaped and elongated grains in the rolling plane, whereas, in the cross-section plane perpendicular to rolling direction, the grains are equiaxed. At the region of the joint (interface), intense plastic deformation (aided by the tool, along with the frictional heat thus generated between the tool and the plates), results in the refinement of the grain structure. This region, which is referred to as the 'nugget', assumes roughly the shape of the tool pin, depending on the process parameters and the interaction of the material with the tool pin and tool shoulder. Fig. 3 shows the optical micrograph of the cross-section of the friction stir welded specimen (welded at 1400 rpm and 80 mm/min).

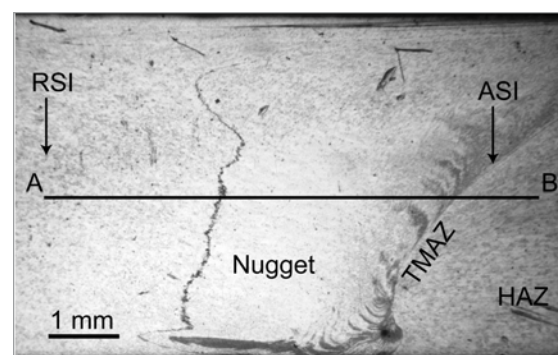


Fig. 3: Optical micrograph of the transverse cross section of the friction stir welded AA 5052 specimen

EBSD and TEM

Fig. 4a shows the inverse pole figure map of a section from the Base Material (BM) region. The grain structure in the base material in the cross-

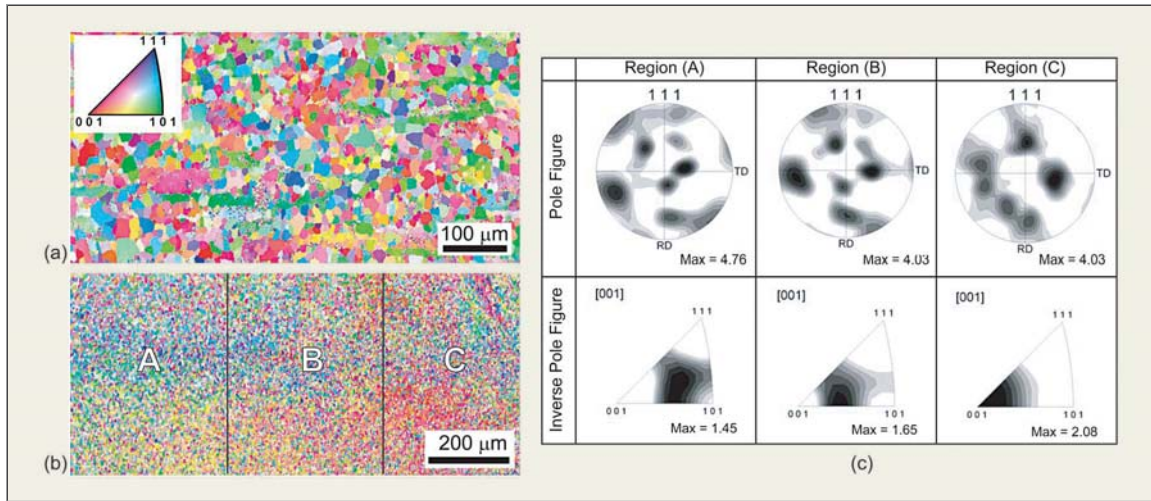


Fig. 4: Inverse pole figure map of (a) base material and (b) nugget region of the friction stir welded AA5052. (c) Chart depicting the {111} pole figures and [001] inverse pole figures corresponding to each of the regions A to C of the nugget shown in (c)

section is equiaxed similar to the parent material in the transverse cross-section plane. From the grain boundary distribution it is observed, that most of the BM region is covered with high angle grain boundaries with clean grain interiors suggesting that the parent material was partially recrystallized. The BM region shows a typical rolling deformation texture as expected for a rolled aluminium plate [12].

The nugget consists of fine equiaxed grains which are formed due to the breakup of the original grain structure, because of the severe plastic deformation and the frictional heat input. Fig. 4b shows the inverse pole figure map of a section in the nugget region and the appropriate colour coding, corresponding to the orientation of the grains. Apart from the fine grain distribution, a section of the onion rings can be identified (in the middle-lower part of the figure). Alternating rings of near $\langle 101 \rangle$ and $\langle 111 \rangle$ orientation can be seen in the lower right portion of the figure. The {111} pole figures and [001] inverse pole figures, corresponding to each of the regions A to C, identified in Fig. 4a, are represented in a chart

given in Fig. 4c. It was found that the misorientation (GAM and KAM) values were higher in the nugget than those for the base material (BM). This combination indicates possible involvement of both plastic deformation and softening, in the formation of the nugget.

To further explore the microstructural developments in the nugget, TEM specimens were examined. As shown in Fig. 5, the equiaxed nugget grains had clear signatures of plastic deformation – signatures

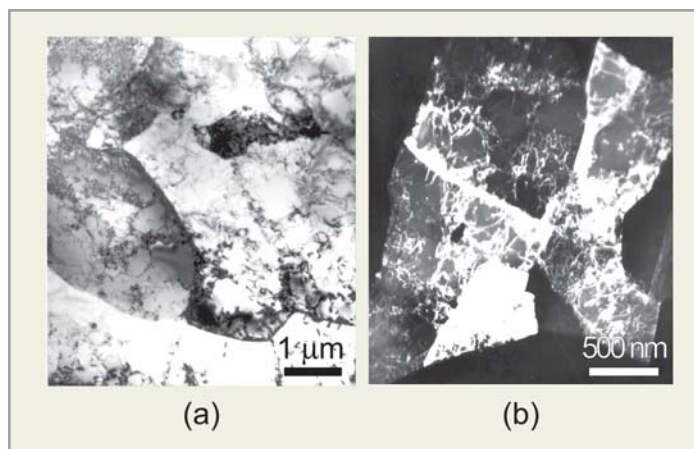


Fig. 5: TEM images of the nugget region. (a) Bright field image showing grains with dislocation substructure inside. (b) Dark field image indicating misorientation developments and outlining dislocation substructure in further details

both in terms of dislocation substructure and also in misorientation build-up. To explain the observed patterns of microstructural developments, it is important to discuss/hypothesize about the two apparent causes – plastic deformation and thermal activation through localized heating/friction. In the FSW, plastic deformation evidently has an important role. The strain path is expected to be complex and large strains with strong shear and possible solid-state stirring are often hypothesized [13].

Indirect evidence of thermal activation is identifiable from clear softening of the partially recrystallized base material near the FSW interfaces. Direct evidences of thermal activation vs. plastic deformation are difficult to distinguish or demarcate – their effects on the respective microstructural parameters (GAM, grain interior dislocation structure, grain refinement, etc.), often being cumulative and/or subtractive. For example, both severity of plastic deformation and higher working temperature may aid geometric dynamic recrystallization and corresponding grain refinement, while developments in GAM are expected to be aided by low working temperature and by higher plastic strains. A temperature profile on a FSW is expected to show a decrease in temperature from the center of the weld (or nugget region) towards the respective interfaces. Such a temperature profile, experimental or simulated, is typically reported to be nearly symmetric. Plastic deformation, on the other hand, was asymmetric. For example, evidence of strong shear (and of grain fragmentation) was observed on the advancing side (AS), while the retreating side (RS) had captured clear indications of the initial stages of geometric dynamic recrystallization [12,14]. The final microstructure appears to be a result of asymmetric and heterogeneous plastic deformation, aided by differential thermal activation (arising from the temperature profile).

Mechanical properties

The microhardness profiles were taken at the

mid-thickness region on the transverse cross-section, across the weld nugget, along the line AB as shown in Fig. 3. It was found that there was a marginal increase in microhardness in the nugget, as compared to the base material. The microhardness near advancing side interface (ASI) region was higher than that at any other region of the weld. The regions near the HAZ and base material (BM) on the retreating side, exhibited marginally higher microhardness than their counterparts at the advancing side.

Tensile properties of all the welded specimens for various combinations of tool rotation speeds and tool traverse speeds are shown in Fig. 6. It was observed that the Ultimate Tensile Stress (UTS) values for the specimens welded with various traverse speeds (60, 80 and 100 mm/min) at 1120 rpm are in the range 260–265 MPa, which is higher than for those welded at 1400 rpm (UTS values being just above 200 MPa). The % elongation of the

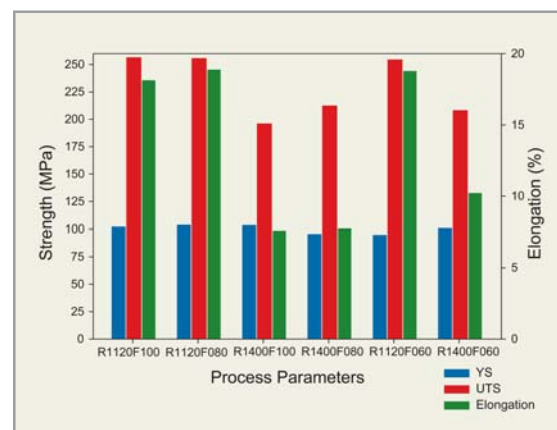


Fig. 6: Comparison of the ultimate tensile strength, yield strength and ductility of the friction stir welds at various combinations of tool rotation speeds and tool traverse speeds

specimens welded with tool rotation speeds of 1400 rpm was significantly lower (10% approx.) compared to those for welded with speeds of 1120 rpm. In fact, the ductility for these specimens was around 18%, which is significantly more compared to that of their counterparts welded at 1400 rpm. It is also seen, that the yield strength (Ys) values for

all the specimens remained more or less constant and in the range 93–103 MPa. Most of the specimens fractured on the retreating side, except the specimen welded at the process parameters of 1400 rpm and 100 mm/min, which fractured in the nugget. From the fractography analysis, it was found that the mode of failure is basically ductile in nature [15]. The voids, typical 10–30 μm in size, formed due to coalescence of microvoids could be noticed. For, the specimen which failed in the nugget, did not reveal any presence of voids. It is quite clear from these, that the process parameters substantially influence the nature of fracture in these specimens.

Conclusions

Friction Stir Welding has evolved as a mature and efficient solid state joining method, for the joining of aluminium alloys. However, there is a need to develop special materials/tool design for the joining of steels, zirconium and titanium alloys.

The present study on Al 5052 alloy provides an in-depth study for characterizing the microstructure, microchemistry, microtexture and mechanical properties. In addition, the study convincingly shows that under optimized condition, the welded specimens show superior mechanical properties. In general, the specimens showed ductile mode of fracture.

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Matrix Assisted Laser Desorption Ionization Mass Spectrometry (MALDI-MS)

T. Jayasekharan and N. K. Sahoo

Applied Spectroscopy Division

Abstract

A state of the art Matrix Assisted Laser Desorption Ionization (MALDI) technique in combination with linear and reflectron Time of Flight Mass Spectrometer (TOFMS) facility has been developed for the detection, identification and characterization of peptides, proteins, DNA, other molecular complexes and clusters. The performance of the indigenously developed MALDI-TOF mass spectrometer has been tested extensively by recording the mass spectra of many different molecules (inorganic, organic, and biomolecules) in the molecular weight range up to 50,000 Da. The mass spectra are calibrated and the mass to charge (m/z) ratio of these molecules are measured more accurately. The detection sensitivity of the spectrometer is very high and is capable of detecting peptide and proteins in the sub picomole range. Recently this spectrometer has been utilized to characterize the silver ion complexes of two peptides namely human *Angiotensin* and *Substance P*.

Introduction

Mass spectrometers are analytical instruments that convert neutral molecules into gas phase ions and separate these ions according to their mass-to-charge ratios (m/z), and are the most powerful method to probe the structure and composition of matter. For many years the mass spectrometers were restricted to the analysis of volatile compounds by electron impact or other ionization methods. The application of mass spectrometers for the analysis of biomolecules posed a greater challenge due to the poor volatility, polar and charged nature of these molecules. In late 1980s two new soft ionization techniques viz., Matrix Assisted Laser Desorption Ionization (MALDI) and Electrospray Ionization (ESI) translated the biomolecules into gas phase ions without fragmentation, and revolutionized the structural analysis of biomolecules.

MALDI is a laser based technique which produces intact protonated/deprotonated molecular ions such as $[M + nH]^{n+}$ and $[M - nH]^{n-}$ of non volatile,

thermally fragile, and massive bio molecules in gas phase [1]. In this technique analyte macro molecules are embedded in UV/VIS/IR radiation absorbing low molecular weight organic molecules (matrix) and are deposited on a solid target and air dried. A low power UV/VIS/IR laser beam of short pulse duration (nanoseconds) is used to desorb and ionize the analyte macromolecules from condensed phase to gas phase. Following absorption of laser radiation by matrix, a plasma plume is generated that ejects neutrals and ions of the matrix and analyte molecules in gas phase. MALDI source is preferentially coupled with linear and/or reflectron TOF-mass analyzers [2, 3]. Different type of mass analyzers is used depending on the properties of molecules to be analyzed. For example, a simple linear TOF analyzer is preferred for analyzing the intact high mass ions of peptides, proteins, and oligonucleotides while reflectron analyzer is used for analyzing the fragment ions and small molecules with higher resolving power and mass accuracy. The schematic of a typical MALDI-TOFMS is depicted in Fig. 1. The matrices usually contain OH and/or NH_2

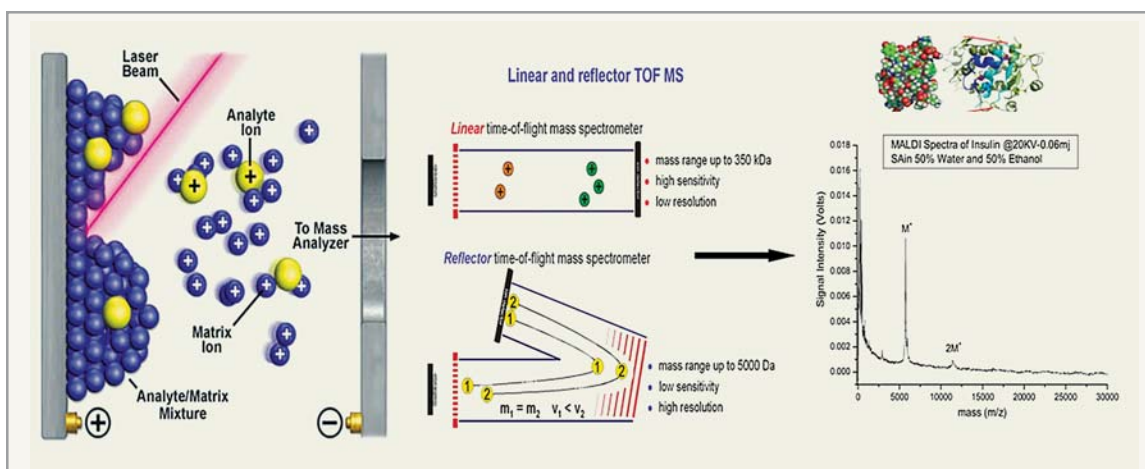


Fig. 1: Schematic of the MALDI technique and its coupling with linear and reflectron time of flight mass spectrometers

functional groups that act as protonating agents and the protons are believed to be transferred from these groups during desorption/ionization process. MALDI processes involve large number of physical and chemical process occurring at different time scales, the exact mechanism of the process has been the subject of extended discussion [4]. This technique has found immense application in proteomic research, disease diagnostics, drug analysis, polymer analysis and other chemical/biological research areas. In recent years MALDI-MS become the method of choice for rapidly identifying proteins and determining the primary structures by bottom-up and top-down approaches [5, 6].

MALDI-Mass Spectrometry

Briefly the home built MALDI-TOFMS consists of three circular stainless steel (SS) electrodes, a pair of deflector plates, a three meter long hollow flight tube, and a Microchannel Plate detector (MCP). The circular discs acts as acceleration and extraction grids. A pair of deflector plates are used to steer the direction of the ions, hollow flight tube provides field free region for the ions. The entrance and the exit of the flight tube are coupled with the TOF assembly and a detector respectively. A reflectron grid assembly is placed near the first detector to reflect the ions back to the second detector. The

entire assembly is pumped by two turbo molecular pumps through gate valves for better vacuum (1×10^{-7} mbar). The samples (analyte + matrix) are deposited on a flat polished SS sample probe and are inserted into the TOFMS through a vacuum interlock, and is in flush with the acceleration grid. A stepper motor is attached with the sample probe for positioning the samples and is controlled through a Personnel Computer. Laser radiation of wavelength $\lambda = 266$ or 355 nm, harmonics produced by a Q-switched Nd:YAG is allowed to impinge on the sample surface through a quartz lens of focal length 20 cm. Typically $10\text{-}50 \mu\text{J/pulse}$ energy is focused on the sample spot size of $\sim 100 \mu\text{m}$.

The molecular ions are generated by MALDI or LDI processes, and the generated ions are promptly extracted and accelerated by different combination of static electric field of 1-30 kV on different grids (depending on the mass of the ions) and detected by MCP detector in a linear TOFMS. In reflectron these ions are further reflected back by series of grids/voids and are detected by another MCP. Depending on the mass of the ion typically 1-10 kV DC is used in the reflectron to compensate the initial distribution kinetic energy of the ions, as well as to increase the flight path of the ions for better resolution. Data acquisition is performed using a Tektronix digital storage oscilloscope

(200MHz, 2GS/s) triggered by a photodiode pulse produced by the laser radiation. The oscilloscope is interfaced with a PC for data transfer and further analysis. Each laser shot produces complete mass spectra of the sample. The photograph of the home built MALDI-TOFMS is shown in Fig. 2. Table I lists important specifications of the indigenously developed MALDI mass spectrometer in the Applied Spectroscopy Division of BARC.

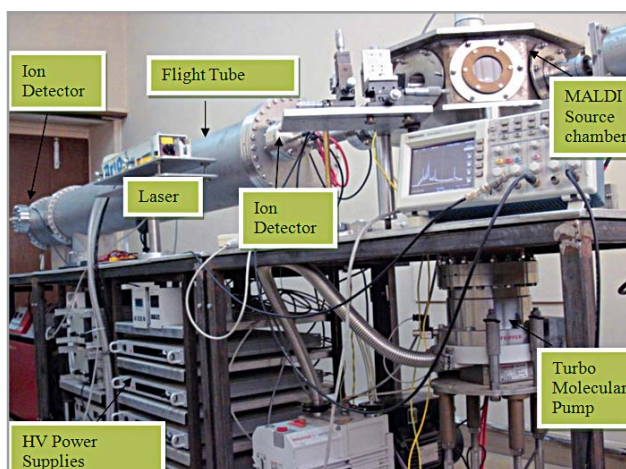


Fig. 2: Photograph of home built MALDI-TOF Mass Spectrometer

Typical MALDI mass spectra obtained for insulin molecule and the fragmented

Table 1: Features of the home built MALDI-TOFMS

Component/Feature	Important Specifications	Remarks
Laser Q- Switched Nd:YAG (3 rd & 4 th harmonics)	$\lambda = 266, 355 \text{ nm}$, Energy/pulse = 0.5 mJ, Rep.Rate= 1-20 Hz Pulse width = 5 ns Average power = 2.4-2.6 W @20Hz	For desorption and ionization
Linear Time-of-flight Mass Spectrometer Reflectron	Total Length = 3 m, X-Y deflection, Ion gates Length of reflectron = 12 cm, Total flight length of MALDI-RTOFMS = 5 m	For Mass Dispersion
Ion Detector	Gain = 10^6 , Area = 18mm ² (MCP)	Micro Channel Plate
Vacuum	1×10^{-7} mbar	TMP 500l/sec
DC Power supplies	0-30 kV, 10mA, 300 W	For extraction and acceleration
Sample holder	Stepper motor controlled by PC/micro controller for analysis of 10 samples at one load.	To change the position of the samples
Mass range	1 – 50,000 Da	Tested with various inorganic, organic, peptide, protein molecules
Mass calibration/precision	$\pm 0.01\%$ (< 1000 Da) $\pm 0.02\%$ (1-10 K Da) $\pm 0.05 - 0.2\%$ (10-50 K Da)	Tested with inorganic, organic molecules, C ₆₀ , phthalocyanin, Porphyrins, peptides and proteins
Sensitivity	Sub pico moles	For peptides and proteins
Organic Matrices used	α -Cyano hydroxy cinnamic acid, 2,5 dihydroxy benzoic acid, Sinapinic acid, Nicotinic acid, Ferrulic acid, Caffeic acid etc.	Mass spectra also show the photo dissociated products.
Peptides/Proteins studied	Substance-P, Angiotensin, Insulin, Cytochrome-C, Lysozyme, Trypsin, Carbonic Anhydrase, Thermolysin.	Tested at different concentrations, and in different matrices.

product ions of substance P using this spectrometer are shown in Figs. 3 and 4.

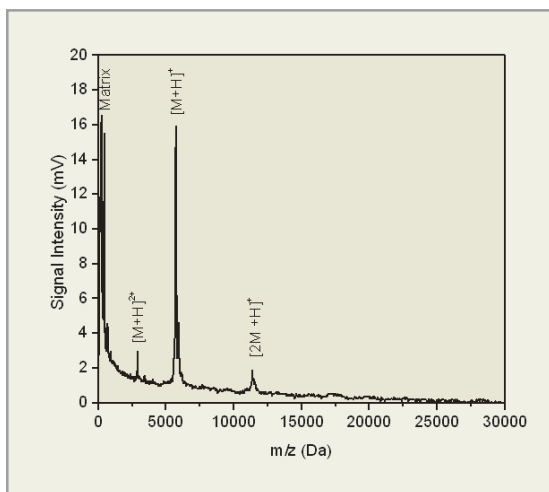


Fig. 3: MALDI mass spectra of insulin molecule

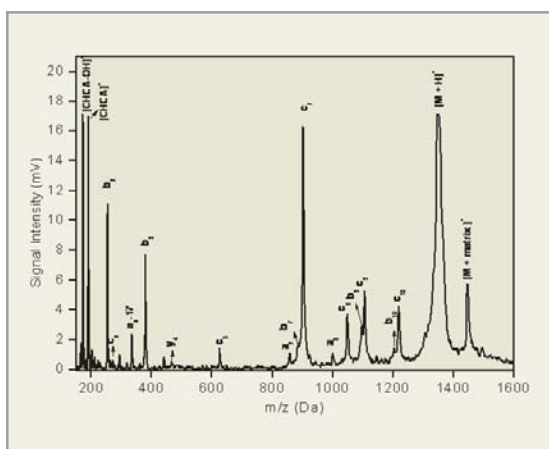


Fig. 4: In source decay (ISD) product ion spectra of substance –P

Characterization of Peptide - Metal ion complexes

Metal ions interact with the peptides and form metal ion-peptide complexes and these complexes play broad role and functions in biology. Investigation of the intact metal ion complexes of peptides/proteins and their fragmented ions in gas phase using mass spectrometry provides valuable insight about the primary structure of the peptides, location of the metal ion binding sites, possible dissociation sites, and the nature of bonds exist between them.

The bioinorganic chemistry of Ag⁺ is diverse and interesting since it is considered as soft cation and it prefers to bind ligands that are relatively polarizable. Silver ion also forms strong s - p bonds by back donation of the electrons from the d orbitals of the metal to the p orbitals of the ligand. Human Angiotensin I (Mr = 1296.5 Da) is a 10 amino acid residue peptide and is a vasoconstrictor precursor under physiological conditions whose primary sequence is Asp-Arg-Val-Tyr-Ile-His-Pro-Phe-His-Leu. Substance P is also an oligopeptide and is a neurotransmitter found in central and peripheral nerves which contains 11 amino acid residues, its primary sequence is Arg-Pro-Lys-Pro-Gln-Gln-Phe-Phe-Gly-Leu-Met-NH₂ (M_r = 1346.7 Da). Ag⁺ has been used to label peptides and proteins that have

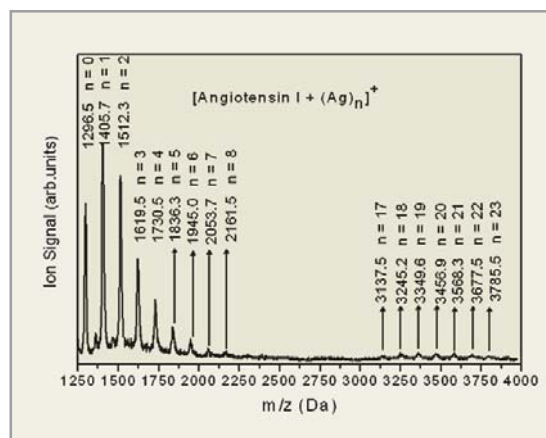


Fig. 5: MALDI mass spectra of silver ion complexes human angiotensin I

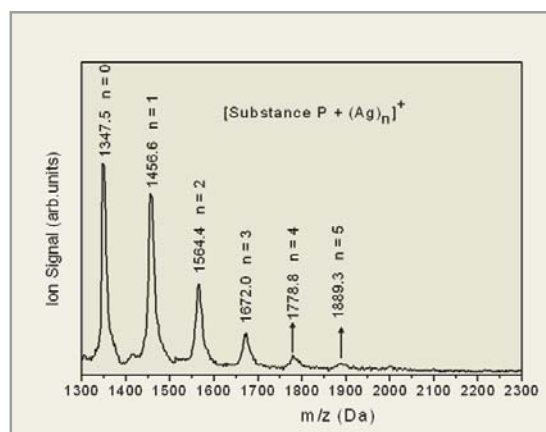


Fig. 6: MALDI mass spectra of silver ion complexes Substance P

sulfur containing residue, it is therefore of interest to probe the specific binding of silver ion to these residues which are analytically useful. We have detected, identified, and characterized silver ion complexes of peptides $[M + (Ag)_n]^+$, $M =$ Angiotensin I and Substance P where $n = 1-8$ & $17-23$ for Angiotensin I and $n = 1-5$ for Substance P using this mass spectrometer [7]. The MALDI mass spectra of hybrid silver ion-peptides complexes obtained using this spectrometer are shown in Figs. 5 and 6.

Conclusion

A state-of-the-art matrix assisted laser desorption ionization time-of-flight mass spectrometer with linear as well as reflectron modes of operation has been developed for the analysis of macromolecules up to the mass range 50 k Da. The performance of the spectrometer has been tested extensively by recording the mass spectra of inorganic, organic, biomolecules and clusters. The mass spectra are calibrated using known molecular species and the molecular mass of unknown molecule is measured precisely. Further, the spectrometer has been used to characterize the silver ion complexes of *Angiotensin and Substance P* for their silver ion binding ability.

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Building Web based Surveillance, Personnel Tracking and Secure Software Solutions

D.K. Dixit, Renuka Ghate, Bhagwan Bathe, Gurmeet Singh, Abhishek Bajpai, Mahesh Date, Chetna Rastogi, Umesh C. Lad, S.K. Parulkar, A.G. Apte, G.P. Srivastava
 Computer Divn., Electronics & Instrumentation Group

Introduction

BARC is involved in number of important projects where a variety of digital information is processed, stored and communicated. In order to develop an electronic system with low vulnerability, several applications and components are developed, using various technologies like encryption, RFID, biometrics, mobile communication and public key infrastructure. In this article, some representative applications in the following areas are described:

1. Personnel tracking & Time attendance systems
2. Public Key Infrastructure (PKI)
3. Web based Surveillance Systems
4. Security Gadgets & Secure Software Applications

This will give a flavour of the width and depth of the domain of secure digital applications. The development is done across multiple platforms on desktops, mobile phones, handheld devices and embedded systems. An RFID card based access control and personnel tracking system (Chitragupt), and an enhanced state of the art web based surveillance system for the security personnel is implemented.

Identity Verification, Personal Tracking & Attendance System (Chitragupt)

BARC is a secure campus, where entry of only identified, verified and authorized personnel is permitted. The identity management is generally based on one or more of the three factors of authentication, 'what you are', 'what you know'

and 'what you have'. The biometric information verification is the 'what you are', Password/Passphrase is an example of 'what you know' and Identity cards fall under the 'what you have' category.

Chitragupt is an identity-card issuance, verification and validation system. In this system, RFID based identity cards are issued to the personnel, the authenticated photos of every individual are displayed at manned entry-gates and optionally, PIN of the ID-card holder is also verified thus incorporating all the three factors of authentication to a large extent. It provides a secure, authentic, accountable and scalable access control and personnel tracking solution. Fig. 1 shows the architecture of the system and it's interaction with

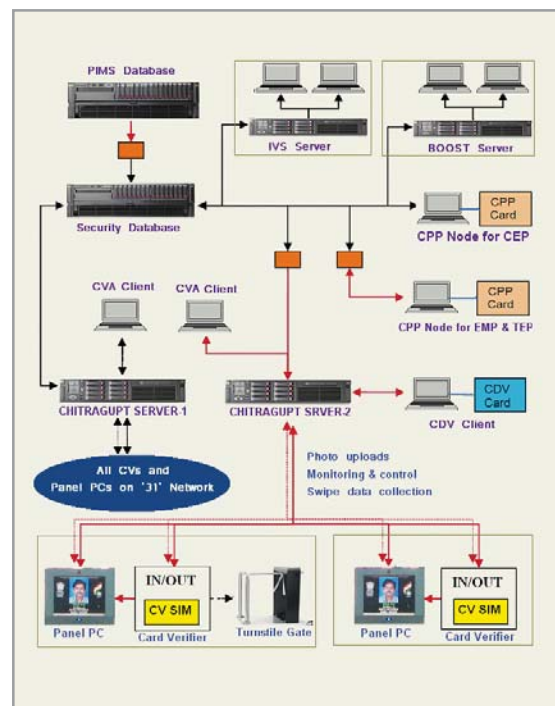


Fig. 1: Chitragupt Architecture

other sub-systems. The whole system may be broadly classified into three major subsystems:

- 1.1 Identity card issuance
- 1.2 Identity card verification
- 1.3 Logging and reporting for different types of users Section
- 1.4 describes the key features of this system.

Identity-card Issuance

Employees & Temporary Entry Permit (TEP) cards

The issuance of identity cards to employees and long term visitors (TEP) is carried out in two phases. In the first phase a few authorized personnel are identified and issued specialized authority cards. As this process is very crucial, these cards are prepared on an isolated secure node in the presence of multiple authorities. There are five types of such authorities to perform different roles, so that no single person can misuse the system. The second phase involves issuing Identity cards to employees and TEP personnel by the authorized persons.

Full accountability of each issued card is ensured and the application for printing and personalization is designed and tested for high throughput. Fig. 2

shows a snap shot of ID card issuing application for employees.

Casual Entry Permit card (CEP)

All the short duration visitors are issued CEP cards for which the forms are applied and approved through an online application provided on BOOST



Fig. 3: CEP Issuing Application

(BARC Online Operations of Secure Transactions) web site. Fig. 3 show a snapshot of CEP card issuing application.

An RFID based Casual Entry Permit (CEP) issuance system is deployed at entry gates. It downloads approved forms, verifies digital signature of the approving authority and issues a pre-printed RFID card to the visitor with one day validity. Photos of the visitors are captured and uploaded at all designated manned security nodes instantaneously. It is a robust and secure application which is operational 24X7.

Identity Card Verification

The identity cards are verified with two types of devices:

- 1. Fixed RFID readers
- 2. Handheld RFID readers



Fig. 2: Card Issuing Application



Fig. 4 : Entry/Exit Lanes

Fixed RFID readers are installed at the entry gates and all the building entrances of BARC. These are SIM (Subscriber Identification Module) enabled which authenticate the personnel cards by verifying the Digital signature of the card data at the time of swipe. A snapshot of exit wing is shown in Fig. 4.

Handheld identity card readers are provided for authentication and verification of vehicle commuters at entry points. These handheld devices operate in 'Fail safe' mode, thereby closing safely when battery power is low. The handheld just needs to be placed



Fig. 5 : Handheld identity card reader

on the cradle for up loading the data. Fig. 5 shows a snapshot of hand-held reader.

Similar RFID cards are fixed in all the staff vehicles so that the same handheld readers are used additionally to monitor them. This will facilitate BARC Emergency Preparedness. Fig. 6 shows line diagram of hand-held reader uses for personnel as well as vehicles.

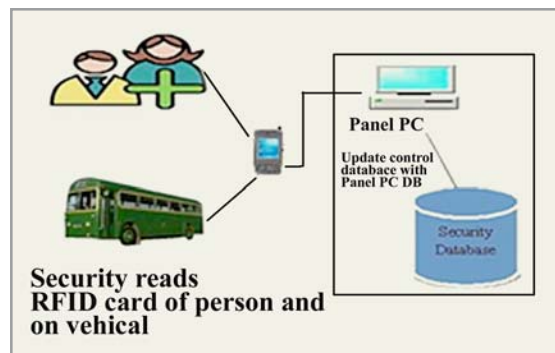


Fig. 6 : Data upload from handheld reader

In-house developed hand-held device

There was a need of in-house development of a reliable, modular and compact RFID card reader based on mifare technology with enhanced features like local image display, remote video monitoring, access control, secure communication protocol, remote configuration and management.

In order to fulfill these requirements an RFID

hardware module is designed, developed and integrated with open source hardware and indigenous software.

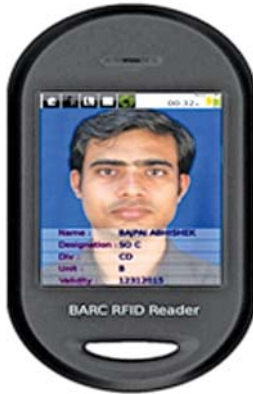


Fig. 7: Indigenous handheld Reader

Fig. 7 shows a snapshot of this hand-held device.

Key features:

- Power Efficient Design.
- Based on open source Linux.
- Higher resolution color graphics LCD display.
- Wireless communication via Blue-tooth.
- Touch screen.

Logging and Reporting for different types of users

Online reports of personnel and vehicle tracking systems are accessible on Identity Validation System (IVS) web site. Reports are available for three classes of users - security, administration and individuals.

The administrative users can view attendance related reports of persons under their administrative control. Location based head count and vehicle monitoring reports are provided for the emergency and security usage.

A graphical representation of daily and monthly population and vehicle traffic is available for efficient manning at the entry points.

Key features of Chitragupt system

- All the authority cards and reader SIMs are prepared on an isolated secure node in the

presence of multiple authorities.

- All keys are encapsulated into the cards at the time of preparation and never get exposed outside the cards.
- A unique key is used for each issued card to prevent single point failure.
- Employee data at central database is digitally signed by the authorized persons.
- Data inside the issued cards is digitally signed by authorized person and verified at the readers at entry gates on each swipe.
- Swipe records are digitally signed from the readers itself before sending to the server.
- Authenticated photos are displayed at manned security nodes at each swipe.
- System is designed keeping future scalability across DAE units in simplified manner.

The system is spread across BARC Trombay campus, and at RRCAT Indore, VECC Kolkata and BARC hospital. It is further extended to BARC staff buses.

Public key infrastructure

A Public Key Infrastructure (PKI) is setup to facilitate digital signature based applications as digital signatures are well accepted by the Indian law under the IT Act 2000.

Issuance of Digital Certificate

Computer division functions as Registration Authority (RA) under the Certifying Authority (CA) of National Informatics Centre (NIC), New Delhi for issuance of digital certificates to authorities within BARC. Tamper proof USB tokens are provided to the authorities for this purpose.

A PKI server is developed to store user's certificates in the local repository to provide the public key certificates over the local network for verifying digital signatures. Fig. 8 shows all the steps of issuing digital signature certificates from NIC CA and its uses thereafter.

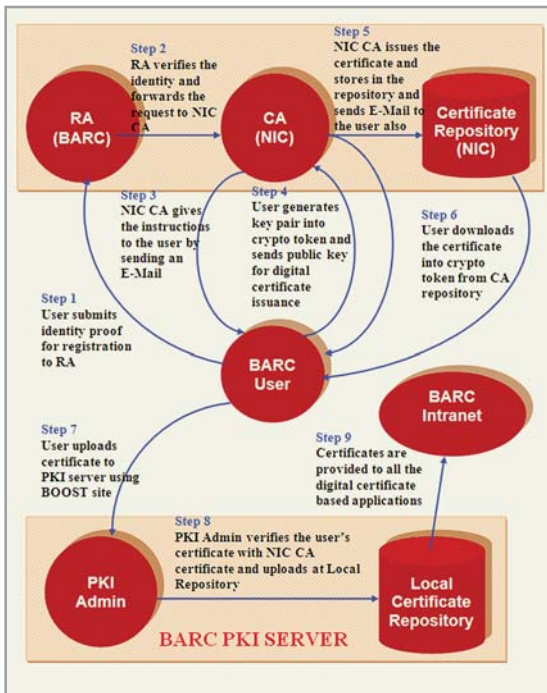


Fig. 8: Process of acquiring Digital Certificate in BARC

Boost

BOOST (BARC Online Operations of Secure Transactions) site is developed for processing online applications with digital signatures. Presently Casual Entry Permit (CEP), Casual Leave, Out-Duty, C-Off applications are supported and many new

applications are being added to BOOST. Fig. 9 shows a snapshot of online CEP application on BOOST and Fig. 10 show high level architecture of BOOST.

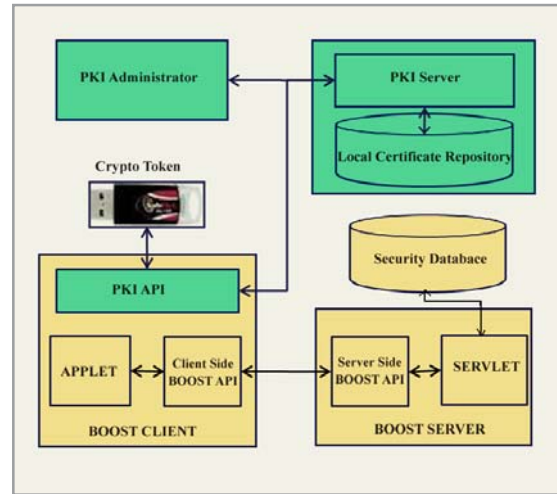


Fig.10: BOOST Architecture

Crypto Token Library

The USB crypto tokens issued can as well be used with other applications supporting Digital Signatures and encryption / Decryption. For this purpose a special plug-in library is developed for performing all security related tasks. The verification of digital signatures is done by fetching public key certificates from PKI server available on the intranet.

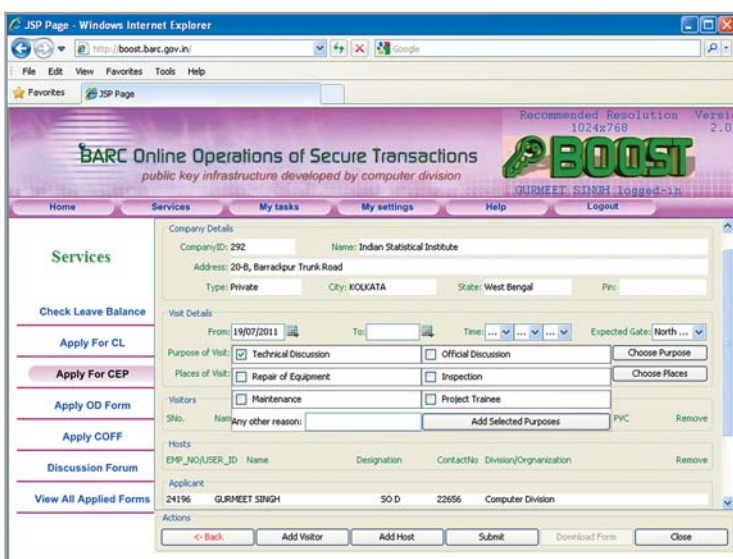


Fig. 9: A Snapshot of BOOST

A third party software is developed using this library. A secure document exchange application, DocShield, is also developed using the same library.

Surveillance Systems

BARC is spread across a few kilometers along the sea and to ensure effective surveillance by the security personnel is a huge task. A state of the art, web based surveillance system is established that enhances the security measures at the entry gates, improves security

guard on the sea face especially at night, and helps carrying out security drills.

Web Based Surveillance System

The system includes static network cameras, Pan/Tilt/Zoom Dome Cameras and static CCTV cameras installed at various key locations in BARC campus.

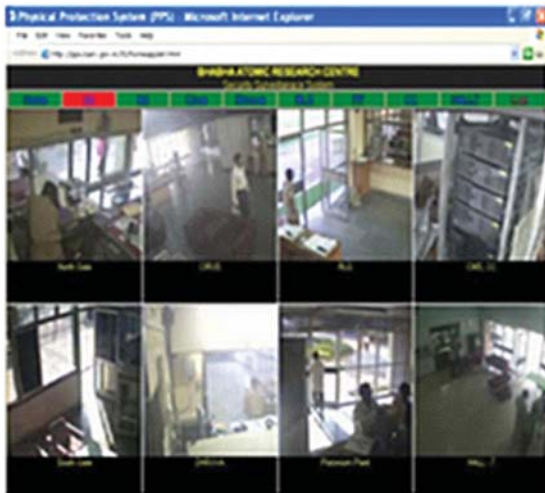


Fig. 11: Snapshot of Surveillance website

An integrated view of all these cameras is available on a web interface. Fig. 11 show view of CCTV cameras on website.

Key Features:

- Distress alarm management for automated communication of distress condition among the various key security posts.
- Centralized- continuous or event based recording RAID server.
- Role based integral view of all cameras on a single web interface.
- Online secure voice communication among important security posts.

Central Monitoring Station (CMS)

With the increasing load of monitoring multiple cameras, it was difficult for security personal to view all the surveillance sites simultaneously at a central location. A cost effective high resolution video wall of approximate size of 20 feet width and 5 feet

height is established using tiled displays for an integral and clear view. The tiled display is made from commercially available LCD display of 19" and 42" size.

All the displays are mounted on an in-house developed special mounting structure that enables rotation for all the three degrees of freedom so that displays can be arranged with proper viewing angle and monitored from a single location. All these displays are driven from central servers located elsewhere. The seamless control of all these displays is available to security from a single control desk.

Web Based Remote Monitoring System

A Web Based Remote Monitoring System (WBRMS) is developed for the surveillance of various geographically spread unmanned stations that does smoke and motion detection and monitors several environmental parameters like temperature,

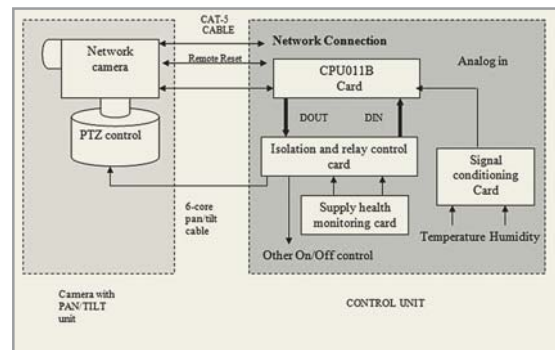


Fig. 12: Architecture of WBRMS

humidity. Fig. 12 show a typical architecture of the system and Fig. 13 show a snapshot of WBRMS website.

The setup includes a specialized network camera with Real Time Operating System (RTOS). A specialized embedded card is used for measuring the analog input from temperature, humidity sensor after signal conditioning, reading the digital contacts from fire alarm and controlling the PTZ (pan, tilt,

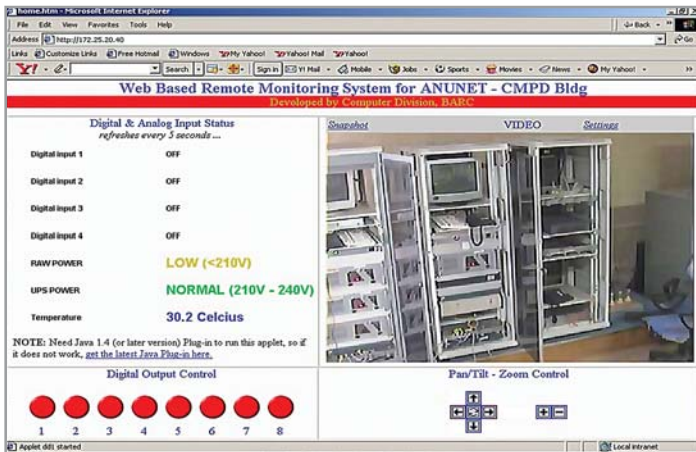


Fig.-13 WBRMS Website - A Snapshot

zoom) of camera and other contacts such as air-conditioner. In case of any emergency a system generated intimation is sent by audio/video/ e-mail.

Security Gadgets & Secure Software Applications

Apart from the above systems for personnel tracking and surveillance, several security gadgets and secure software applications are developed on desktops and mobiles phones, as per the requirements from the users and technology updates from time to time.



Fig. 14: Secure Network Adapter

Secure Network Adapter (SNA)

It is a Virtual Private Network (VPN) adapter, with support for proprietary encryption algorithm and key management protocols, used to provide data communication security over a public network and restrict access from private network to public network.

A Secure Network Adapter is developed based on a proprietary protocol. It supports speed ranging from 2 Mbps to 100 Mbps and multiple interfaces like Ethernet, E1 etc. Fig. 14 shows a snapshot of SNA.



Fig. 15: Multiport Secure Network Adapter

This can be used as a fully functional router and VPN tunnel for secure data transfer applications. This is designed on, open source kernel and tested with an open source router and operating system. It is a reliable, low cost and small form factor embedded system. Fig. 15 shows a snapshot of Multiport SNA.

Multi Encryption Line Interface Card (MELIC)

MELIC system (Secure Telephone Apparatus) is developed in collaboration with Ms. ECIL for secure Voice, Data and Fax Communication on PSTN line suitable for a close user group applications.



Fig. 16: MELIC Telephone Instrument

A central setup for key generation and distribution is created. Fig.16 shows a snapshot of MELIC Telephone Instrument.

Hardware Encryption Module

It is a standalone crypto accelerator developed using FPGA technology suitable for high throughput of the order of 3.312 Gbps. The major challenge is to develop number of mathematical models for the transformations, required in the encryption algorithm, based on Galois field, pipe-lining, and finding out the most optimum model considering delay and resource (CLB) constraints.

Secure Applications on Mobile Phones

Mobile phones enable the authorities to carry out their work even when not at their desk. With the increased mobile computing power and features, it becomes feasible to have all communication and document storage on mobile phones. Having limited resources in terms of processing power and memory as compared to general purpose PCs, a major challenge was the selection of appropriate encryption algorithms and key exchange protocols. A few applications for secure mobile communication are developed.

Secure SMS and MMS

This application facilitates users to communicate with each other through encrypted SMS. A secure voice MMS application is developed with the purpose of sending encrypted messages by voice

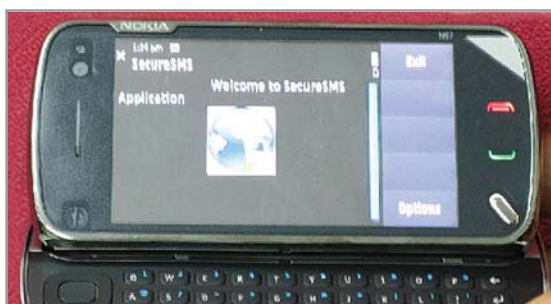


Fig. 17: Secure SMS application on mobile

recording, instead of using the cumbersome keypad. Fig.-17 shows a snapshot of SMS application on mobile phone.

Key features:

- The authentication is done with unique username, password and passphrase.
- Confidentiality is achieved using 128 bit encryption algorithm.
- Integrity check is implemented using Message Digest.
- Digital signatures are used prevent sender Non-Repudiation.
- Time-stamps are added to prevent replay attack.

Mobile Alert System

A system is developed, that will send alert messages from a central server to the registered mobile phones. Different tones can be conFig.d for different types



Fig. 18: Mobile Alert System

of alerts messages. The message can also be encrypted if desired. Fig.-18 shows the flow diagram of the alert system.

Secure Video Conferencing System

This is an indigenously developed desktop- based conferencing application with encryption support using Java Media Framework. Server-Client architecture is used where the server manages the connection between the clients, generates and distributes session key for every session to encrypt audio/video streams and controls the quality of service. Fig. 19 shows a Snapshot of Secure Video Conferencing.

The video and audio streams are first compressed and then encrypted and later sent over the network

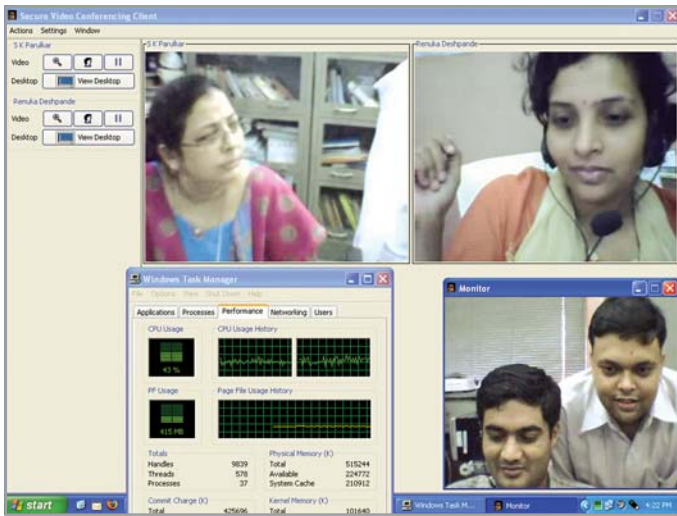


Fig.-19 A Snapshot of Secure Video Conferencing

decompression and encryption/decryption are done using software codec only.

Secure Mail Client

E-mail sent over the Internet is more like paper mail on a postcard, than mail in a sealed envelope. It can easily be read, or even altered, by anyone with privileged access to any of the computers (including mail servers) along the route followed by the mail. Hackers can read and/or forge e-mails.

using RTP over UDP. The video streams are compressed in H.263 format and the audio streams are compressed using G.723 format.

Public key algorithm is used for authentication and key establishment and users are issued USB crypto token using which they can participate in a secure video conference. All the compression/

Fig. 20 shows how the secure mails are composed before sending. This application enables the users to compose, send and read secure E-Mails. It allows the users to send video mails also using webcam and mike. For encrypting and digitally signing the E-Mails it follows a scheme which is very similar to PGP. GUI is very similar to Outlook Express. All the users are issued USB based crypto token using which

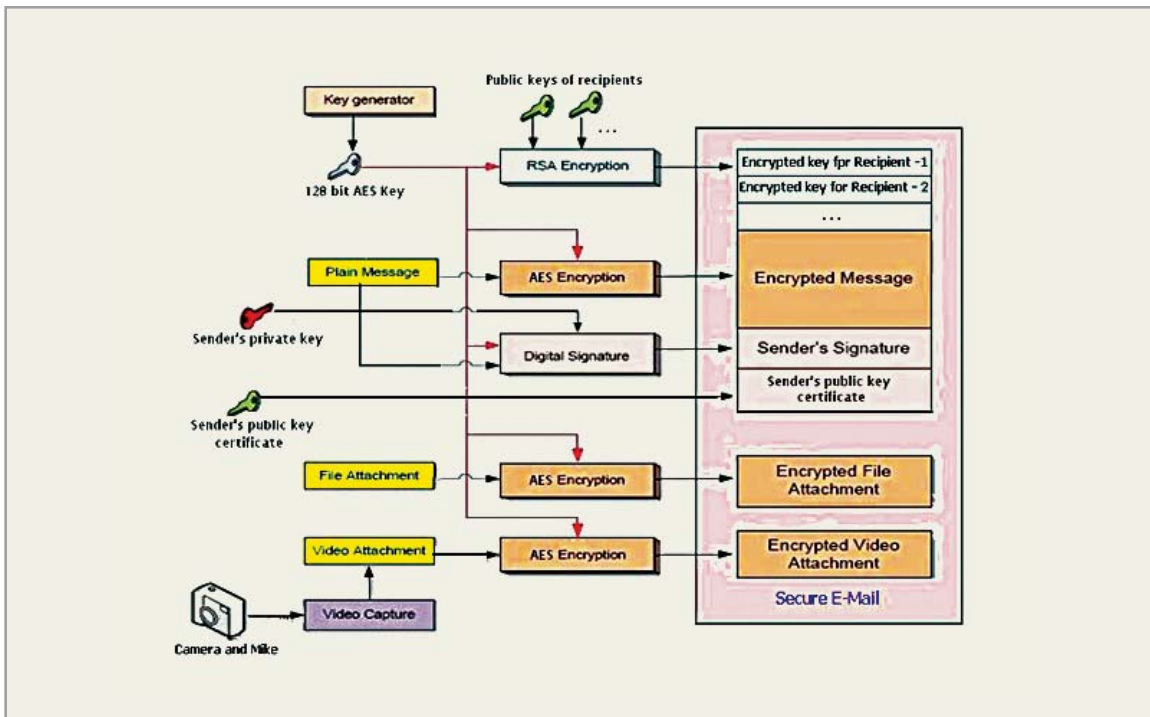


Fig. 20: Secure Email Client Architecture

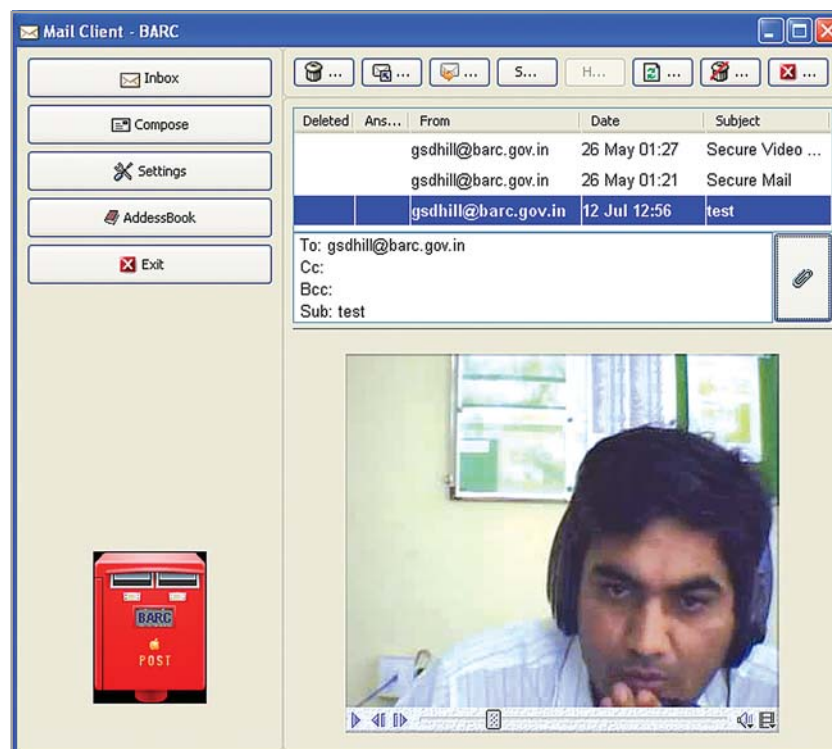


Fig. 21: A Snapshot of Secure Mail Client

they can send/receive secure e-mails. Fig. 21 shows a snapshot of secure mail client application.

Users need a simple desktop PC, web-cam and headphone. It can be used for any mail server which provides IMAP/POP3 and SMTP access to the users.

Future Plans

The secure digital application projects undertaken, completed and deployed are designed for scalability and enhancement using the upcoming technologies. The process of developing new applications and enhancing the existing one is crucial for their sustainability.

A comprehensive indigenously designed identity card verifier is being developed which will have features like camera, video streaming, storing of photo, barred cards list and network connectivity. It is planned to replace existing Identity cards with Java cards to provide end to end security without altering the present infrastructure. The access control

system with biometric support that addresses the 'what we are' category is being studied for its reliability and occasions where they can be used.

Several digital signature based applications are under production to have an authentic online system and a local Certification Authority (CA) will be setup to issue digital certificates on a large scale to enable more persons in BARC to sign digitally.

As handheld devices and mobile phones are equipped with features available on desktops/laptops, applications are being developed so they can be used in a secure manner for communication and as a laptop alternative.

Development of Secure Network Adapter with more enhanced security features like location based encryption scheme, Security analysis and 1 Gbps network throughput is under process.

Behaviour of Single Piles in Liquefied Soils during Earthquake

V.S. Phanikanth and K. Srinivas

Architecture & Civil Engineering Division

and

Deepankar Choudhury

Associate Professor, Indian Institute of Technology, Bombay

and

G.R. Reddy

Reactor Safety Division

Abstract

Analysis of pile foundations for earthquake loads, requires the consideration of inertial loads due to soil-pile-super structure interaction and also need the evaluation of kinematic interactions due to the movement of the surrounding soil and the pile. Also such soil-pile interaction analysis, must consider the stiffness degradation due to earthquake loading in liquefying soils. In the present study, pile-soil interaction analysis is attempted by considering stiffness degradation effects for a range of earthquakes with different amplitudes [Maximum horizontal acceleration, (MHA)], frequency contents, and different durations. The pile response is observed for both rigid piles and flexible piles under earthquake loading. Effects of both kinematic and inertial interactions are considered by using seismic deformation method. Results of ground response analysis obtained from separate study were used for soil-pile interaction analysis. Pile response for kinematic interactions is validated with the available solutions in the literature. Parametric studies have been carried out to understand the effect of depth of embedment, depth of liquefying layer etc. and their results are presented. It is observed that the effect of depth of liquefying layer has significant influence on the pile bending response. Also it is observed that the peak bending moment occurs at the interface of liquefying and non-liquefying layer.

Introduction

Pile foundations supporting super structure shall be designed for lateral loads arising due to wind loads, seismic loads, wave forces etc. in addition to the vertical loads. During earthquake loading the pile will be subjected to lateral loading due to kinematic and inertial interactions. For piles in liquefying soils the presence of liquefying layer makes the pile vulnerable to buckling due to significant stiffness degradation. Also this involves the consideration of bending-buckling interaction phenomenon [Dash et al. 2010].

For soil-pile response analysis several approaches have been proposed including sophisticated mathematical or numerical analyses and simplified methods. The finite difference technique is most commonly adopted due to its simplicity. However, finite element techniques have more flexibility to perform seismic analysis of soil pile interaction in both frequency and time domain. In the present study a pseudo static analysis is carried out using seismic deformation method and the behavior of liquefying soils under earthquake loads is studied and their results are presented.

Design Approaches

The current design methods are based on pile design against bending failure due to lateral loads such as inertia load and loads due to lateral spreading. The most commonly used methods [Bhattacharya 2007, Liyanapathirana and Poulos 2005] are discussed below:

- i) **Force based method or limit equilibrium method:** In this method, lateral pressure acting on the pile is estimated and response of the pile is evaluated. Pile yielding and allowable deflection are checked in this method.
- ii) **Displacement based method or p - y method or seismic deformation method:** In this method, free field ground displacement is evaluated and the displacement profile is applied on the pile and pile response is evaluated.

For the seismic analysis of piles in liquefying soils Liyanapathirana and Poulos 2005, proposed pseudo-static method which is simple and practicable and yet gives reasonably accurate results. The method mainly involves two solution stages. In the first stage a free field ground response analysis is carried out to obtain maximum ground displacement along the depth of the pile and ground surface acceleration. In the second stage a pseudo-static analysis is carried out for the pile, subjected to the maximum ground displacements along the depth, and the pseudo-static loading at the pile head is computed by multiplying the cap mass with the maximum ground acceleration. In the present study the above approach is adopted and the ground response analysis results obtained in stage I, using different earthquake loadings are used to obtain the pile response in the second stage.

Limit Equilibrium Method

Dobry et al. 2003, presented a simplified limit

equilibrium method for computing maximum bending moment in a pile and is given as:

$$M_{max} = (0.5A_p H_p + A_c H_c) p_L \quad (1)$$

where A_p = Area of pile exposed to lateral liquefied soil pressure and H_p = length of pile exposed to lateral liquefied soil pressure,

and A_c = Area of pile cap exposed to lateral liquefied soil pressure and H_c = Height of force F_c above the bottom of liquefied sand layer; F_c = Lateral equivalent force on the pile cap and p_L is the limiting liquefied soil pressure.

Seismic Deformation Method or p - y Method

The most commonly used model for predicting the non-linear behavior of soil is using p - y curves (API, 2003). The basic differential equation of laterally loaded pile is as given below:

$$EI \frac{d^4 y}{dz^4} + E_s y = F \quad (2)$$

Where,

y = lateral deflection of pile

z = distance along the pile from the top

EI = flexural rigidity of pile

E_s = soil modulus

F = applied force per unit length of the pile

In earthquake engineering the equation (2) is modified as given below [AIJ, 2001]:

$$EI \frac{d^4 y}{dz^4} = -k_h D (y - y_g) \quad (3)$$

y_g = ground displacement; D = diameter of pile; k_h = subgrade modulus.

p - y curves are usually employed for obtaining the pile response (Matlock 1970, Reese et al. 1974)

Using the above equation, pile response due to kinematic interactions may be evaluated. Also by adding inertia loads on right side of equation (3) and using principle of superposition the combined pile response due to kinematic and inertial loading may be obtained.

In case of liquefying soils, the subgrade modulus is degraded and the degradation of k_{hn} with increasing displacement is expressed as [Tokimatsu et al. 1998, Tokimatsu 1999]:

$$k_h = k_{hn} S_f \tag{4}$$

where S_f is the scaling factor for the liquefied soil.

Variation of horizontal subgrade modulus, k_{hn} (for non-liquefied soils) with depth in the soil deposits is correlated with the Standard Penetration Test (SPT) N values. The modulus of subgrade reaction for non-liquefied soils k_{hn} proposed by AIJ (2001), JRA (1996) is given as:

$$k_{hn} = 80 E_o B_o^{-0.75} \tag{5}$$

$$E_o = 0.7N \tag{6}$$

Where k_{hn} is the modulus of subgrade reaction in MN/m^3 , and E_o is the modulus of deformation in MN/m^2 , N is the SPT value, and B_o is the diameter of the pile in cm .

As soil liquefies, the stiffness of soil degrades. It can be found from the case studies that the modulus of subgrade reaction for the laterally spreading soils can be reduced by a scaling factor, termed as stiffness degradation parameter, S_f varying from 0.001 to 0.01 (Ishihara and Cubrinovski, 1998) as compared to normal soil condition where there is no liquefaction. The degree of stiffness degradation in the laterally flowing deposits is related to the displacement of the pile relative to the surrounding soil.

Validation of Pile response for Laterally spreading grounds

Based on the Equation (3) a computer program is developed for single piles in liquefied soil by using MATLAB (2004). The pile top (node '1', Fig. 2) is assumed to be free headed and pile tip (node 'n+1') as floating tip in the present study.

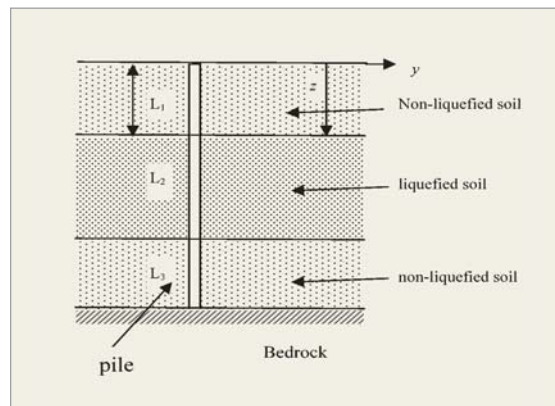


Fig.1: Pile passing through liquefied layer

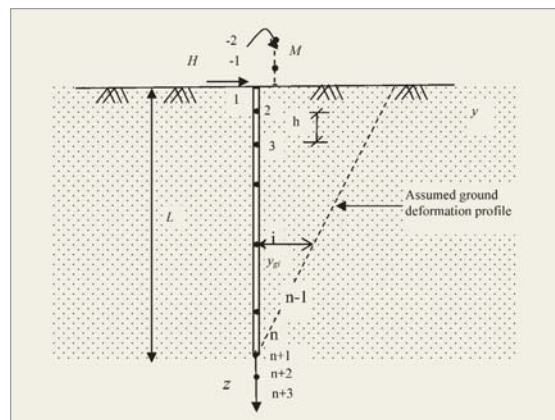


Fig. 2: Soil-pile analysis considering ground deformations using finite difference technique

By applying central difference method at point 'i' (Fig. 2):

$$EI \frac{y_{i+2} - 4y_{i+1} + 6y_i - 4y_{i-1} + y_{i-2}}{(h)^4} + k_i D(y_i - y_{gi}) = 0 \tag{7}$$

n = number of elements along the pile. h = segment length = L/n and k_i is modulus of subgrade reaction

k_n at i. Equation 7 may be used for points '2' to 'n' to give n-1 equations. The remaining unknowns may be obtained by using appropriate boundary conditions and equilibrium equations.

In the present study kinematic and inertial loads are imposed separately and the combined response is algebraically added. The kinematic interaction response is obtained by considering the ground deformations y_{gi} alone. In the second stage inertial loads (H) alone are applied at the pile top as equivalent static loads and the pile bending response is obtained. In order to estimate the peak bending moment due to combined inertial and kinematic loads, Tokimastu et al. (2005), Tokimastu and Suzuki (2005) suggested that when T_b (natural period of structure) > T_g (ground natural period), the peak pile bending moment in the pile can be estimated by the SRSS (square root of sum of squares) of the individual moments due to the inertial and kinematic loads. When $T_b < T_g$, the peak bending moment in the pile can be computed by the algebraic addition of inertia and kinematic components. In the present study the bending moments in the pile considering kinematic and inertial interactions are algebraically added at various nodes along the pile length.

The computer program developed is initially validated by using available solutions in literature (Meera and Basudhar 2008) for kinematic interactions. The validation on flexural behavior of pile is

performed for free headed pile with floating tip at the base. The notations used are: non-liquefied depth factor $r (= L_f/L)$, liquefied depth factor $s (= L_f/L)$, embedded depth factor $t (= L_f/L)$, pile flexibility factor $R [= E_p I_p / (E_s L^4)]$, ratio of young's modulus of the pile to the soil modulus $K (= E_p/E_s)$, the pile length to pile diameter ratio L/D (slenderness ratio), soil modulus to soil strength ratio $Q (= E_s/s_u)$, vertical load factor $V (= 4P/\pi D^2 E_s)$, horizontal load factor $H (= H_f/s_u D^3)$, moment factor $M (= M_f/s_u D^3)$, ratio of distance of location of pile from the waterfront to the affected distance of lateral spreading, i.e., location factor $L_x (= x/L_s)$, scale factor for liquefied soil (S), and gradient of surface topography (s). The pile deflections and moments also depend on the gradient of the surface topography and hence are evaluated by considering various slopes. The results are given in terms of non-dimensional coefficients. The non-dimensional deflection coefficient, is $Y^* = y/D$, where y is pile deflection, D is diameter of pile and non-dimensional bending moment coefficient is, $M^* = M/(s_u D^3)$, where M is the bending moment developed at the pile soil interface, s_u is the shear strength of soil. The various input parameters considered for obtaining the effect of lateral spreading are: $L/D=25$; $r = 0.20$; $s = 0.60$; $K = 500$; $R = 1.0 \times 10^{-4}$; $Q = 200$; $s_f = 0.01$; $L_x = 0$; $V = 0$; $H = 0$; $M = 0$.

The soil pile interaction is performed with the above input parameters and the results of the present study

Table 1: Variations of non-dimensional deflection coefficient Y^* and non-dimensional moment coefficient M^* with slope – Present study vs. those obtained by Meera and Basudhar (2008).

Slope	Present study		Meera and Basudhar (2008)		% diff.(absolute)	
	Y^*	M^*	Y^*	M^*	Y^*	M^*
10	2.214	217.11	2.232	214.70	0.8	1.2
20	2.783	272.90	2.805	269.88	0.8	1.1
30	3.181	311.98	3.207	308.52	0.8	1.1
40	3.498	343.05	3.526	339.25	0.8	1.1

are compared with results obtained by Meera and Basudhar 2008, and are given in Table 1. Clearly it can be seen that the results are in good agreement with that of available solutions in the literature. Also the variation of pile deflections and bending moments are plotted in Fig. 3A and Fig. 3B respectively by considering various ground surface topographies (slopes). It is observed that the ground surface slope has significant influence on the pile response and it is found that the amplification factor is about 1.60 for non-dimensional deflection and bending moment coefficients when the ground surface slope is increased from 10% to 40% and hence pile design must consider the slope effects in laterally spreading grounds. Also it can be seen that the maximum bending moments are observed at the interface of liquefying soil layer to non-liquefied layer.

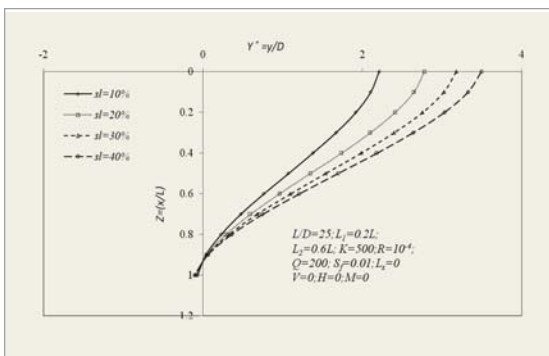


Fig. 3a: Non-dimensional pile deflections in liquefied soils along the depth of soil deposit for various ground surface slopes (Free headed pile with floating tip)

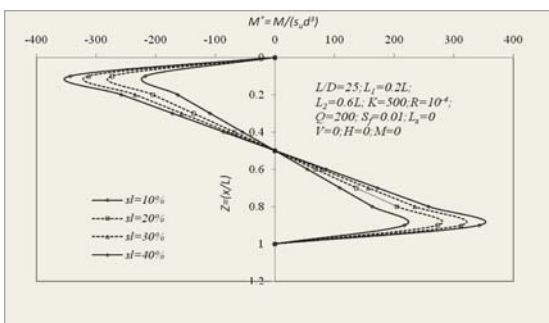


Fig. 3b: Non-dimensional pile bending moments in liquefied soils along the depth of soil deposit for various ground surface slopes (Free headed pile with floating tip)

Behavior of Piles under Seismic Loads

Having validated the pile response to kinematic loading in liquefying soils, the pile behavior is studied for both non-liquefying and liquefying conditions for selected ground motions. The boundary conditions are considered as free headed top and floating tip base. In the present study four typical strong motion earthquake events corresponding to Bhuj (2001) earthquake, Loma Prieta (1989) earthquake, Loma Gilroy (1989) motion and Kobe (1995) earthquake are considered for soil pile interaction analysis. These earthquakes represent wide range of amplitudes [maximum horizontal accelerations (MHA) of 0.106g for Bhuj (2001), 0.278g for Loma Prieta (1989), 0.442g for Loma Gilroy (1989) and 0.834g for Kobe (1989) motion respectively], frequency contents and durations. Time history of Kobe (1995), Loma Prieta (1989) and Loma Gilroy (1989) are available in DEEPSOIL v5.0 library [Hashash et al. 2008].

Response of laterally loaded pile in liquefying soils

Having validated the pile response under kinematic loading, the pile response is studied for liquefying soils due to earthquake loads. The pile length is considered as 10.0m and pile radius is considered as 0.25m in the present study. Young’s modulus of the pile is assumed as 2.74×10^7 kN/m². The various input parameters considered for seismic soil pile interaction for both liquefying and non-liquefying conditions are presented in Table 2 representing SPT, modulus of deformation, degraded subgrade modulus etc., at various depths. The relative stiffness factor (L/T) for the pile soil system varies from approximately 2.8 to 3.4 (for liquefied case) and hence the pile behavior is expected to be rigid/semi-rigid. For non-liquefying soils it can be seen that L/T varies from 7.0 to 8.5 and hence pile behavior is expected to be flexible. Results of

equivalent linear ground response analysis performed from a separate study for this soil deposit are used in the present analysis. The results obtained from ground response analysis of local soil sites are approximated as linearly varying along the depth of soil deposit. The peak ground accelerations at ground surface obtained from ground response analysis [Phanikanth et al. 2010] are 0.251g for Bhuj (2001) motion, 0.641g for Loma Prieta (1989) motion, 1.136g for Loma Gilroy (1989) motion, and 0.917g for Kobe (1995) motion respectively. It was assumed that the entire soil deposit is liquefying and hence stiffness degradation is considered as $s_f=0.01$ for evaluating the pile response.

The kinematic interactions are considered based on the results obtained from the ground response analysis and the inertial interactions are considered by multiplying the cap mass and peak surface acceleration. In the present study the ultimate pile capacity is estimated as 90.0t and the inertial loads (H) are applied at the pile top obtained by multiplying cap mass with peak ground acceleration at the ground surface. Thus the inertial loads for Bhuj (2001) input motion, Loma Prieta (1989) motion, Loma Gilroy (1989) motion and Kobe

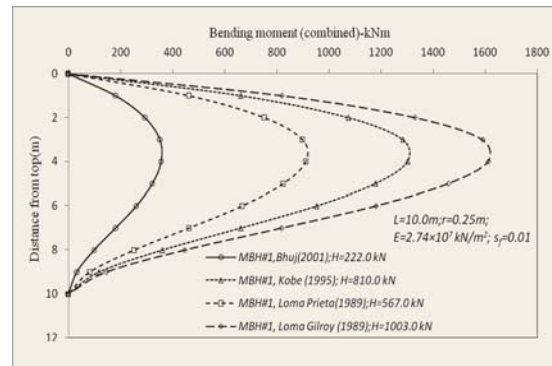


Fig. 4a: Pile bending moments (combined) in liquefied soils considering various ground motions -Free headed pile with floating tip

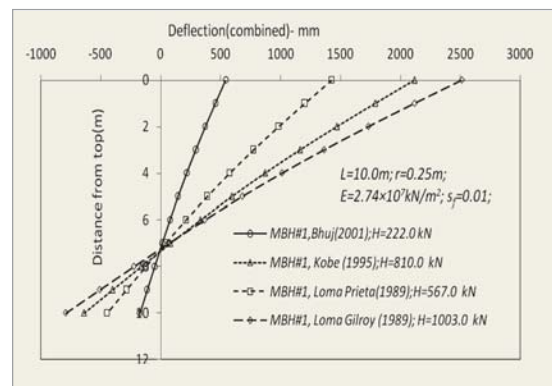


Fig. 4b: Pile deflections (combined) in liquefied soils considering various ground motions -Free headed pile with floating tip

Table 2: Input parameters for soil-pile interaction, liquefied soils

Layer No.	Stratum	Layer thickness (m)	Depth below GL (m)	SPT value (N)	E_o (MPa)	$B=D=$ pile dia. (cm)	k_{hn} (MN/m^3)	S_f	$k_h = k_{hn} S_f$ (kN/m^3)
1	Filled up soil	1.5	1.5	10	7	50	29.78	0.01	297.83
2	Yellowish loose sand	1.5	3	12	8.4	50	35.74	0.01	357.39
		1.5	4.5	13	9.1	50	38.72	0.01	387.17
		1.5	6	16	11.2	50	47.65	0.01	476.52
3	Black clayey soil	2	8	20	14	50	59.57	0.01	595.65
4	Yellowish clayey soil	1.8	9.8	25	17.5	50	74.46	0.01	744.56
5	Greyish hard rock	-	> 9.8	-	-	-	-	-	-

(1995) motion are estimated as 222.0 kN, 567.0 kN, 1003.0 kN and 810.0 kN respectively. The soil pile response in liquefying soils considering subgrade modulus evaluated with $s_f = 0.01$ ($=1/100$) is obtained considering both inertial and kinematic interactions together is shown in Fig. 4a with inertial response and kinematic response added algebraically. It was observed that the pile response is significantly affected in the presence of liquefiable layer and also it is observed that the amplification factor is approximately about 2.50 in peak bending moments. The pile deflections are presented for liquefying soils in Fig. 4b for kinematic and inertial interactions and in Fig. 4c for inertial interactions only. It can be seen that, the pile deflections due to inertial loads are significant and also from the load

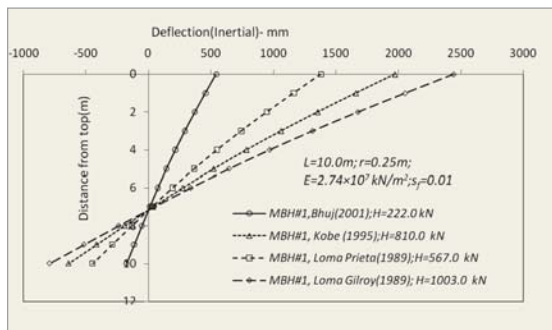


Fig. 4c: Pile deflections (inertial) in liquefied soils considering various ground motions -Free headed pile with floating tip

deflection curve the pile behavior was observed to be rigid. Also it was observed that the relative movement between the soil and the pile is significant.

Comparison of responses of fully liquefying and non-liquefying soils

The pile response is evaluated with and without stiffness degradation effects and for different ground motions. The variation of pile bending moment for kinematic and inertial interactions along depth of the pile for fully liquefying and non-liquefying soils for Bhuj (2001) motion is plotted in Fig. 5a. Clearly it can be seen that for the piles in liquefying condition the bending moments are amplified

significantly and the amplification is found to be approximately 2.50. Kagawa (1992) reported that the amplification in peak bending moments for liquefying soils is as high as 6.0 compared to non-liquefying soils and many failures observed during earthquake are due to inability of pile to sustain such large bending moments. The bending moment along depth is also plotted for Loma Prieta (1989), Loma Gilroy (1989) and Kobe (1995) input motions, based on ground response results obtained and considering inertial and kinematic interaction added algebraically and are also shown in Fig. 5a.

Also to understand the kinematic response of the pile with respect to the ground response under earthquake event, the pile deflections under kinematic loading are compared with ground displacements for both liquefying and non-liquefying soils. It can be seen that the pile is flexible under non-liquefied condition (L/T varies from 7.0 to 8.5) where as pile tends to be rigid when soil is liquefying (L/T varies from 2.8 to 3.4). The ground displacements obtained from ground response analysis results for Kobe (1995) and Loma Gilroy (1989) motion are approximated as parabolically varying to obtain the pile deflections under kinematic loading and the results are shown in Fig. 5B. It is found that when the pile is flexible the pile displacements (kinematic) nearly match with the ground displacement where as when the pile is rigid there is relative displacement between the soil and the pile.

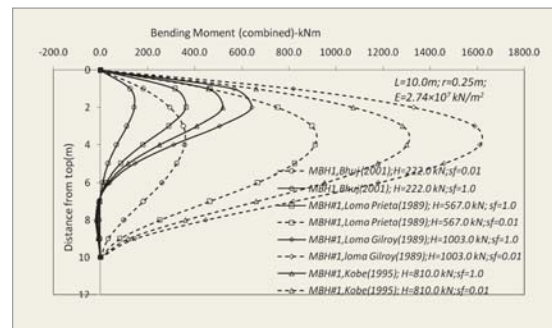


Fig. 5a: Pile bending moments (combined) in fully liquefying and non-liquefying soils for various ground motions-Free headed pile with floating tip

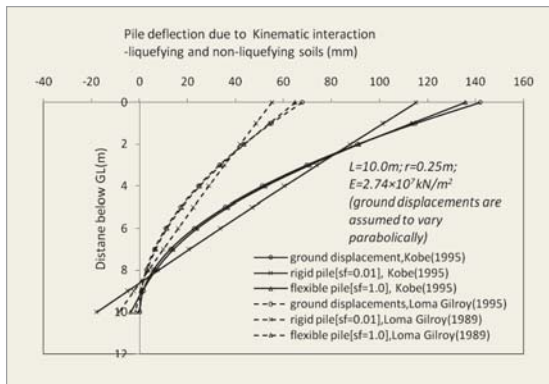


Fig. 5b: Pile deflection (mm) due to kinematic interaction-liquefying and non-liquefying soils-Free headed pile with floating tip

Effect of depth of liquefying layer

In general, loose saturated cohesion less soils are vulnerable to liquefaction hazards and the presence of such layers reduces the stiffness of the surrounding soil resulting in excessive bending moments ultimately leading to pile failure. In the present study the effect of depth of liquefying layer on the pile-soil response is also studied. The overall length of the pile is assumed as 10.0m. As can be seen from Fig. 1 parameter ' L_2 ' denotes the depth of the liquefied layer and L is the overall length of the pile. The depth of the liquefied layer is varied in terms of L_2/L from 0.20 to 1.0 (L_2 is considered as 0.0). The pile response is observed for various liquefied depth ratios and the results are presented in Fig. 6a showing pile deflections considering kinematic and inertial interactions. The deflection at any given depth is found to increase with the increase in depth of liquefied layer and is maximum, when the entire soil deposit is liquefying. Also the combined pile bending response are plotted in Fig.6b. It can be seen that the maximum bending moment occurs at the interface between the liquefied layer and non-liquefied layer. Also it is observed that the bending moments are maximum when the thickness of the liquefied layer is approximately 60% of the total layer thickness. If the thickness of the liquefying layer is higher, the pile bending moments are reduced. This may possibly due to the soil failure

preceding the pile failure (soil stresses exceeding the soil strength or passive pressure developed are beyond the shear strength of the soil).

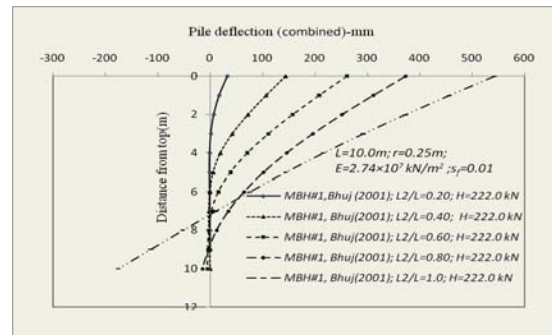


Fig. 6a: Effect of depth of liquefying layer on the pile deflections (combined) along depth for Bhuj (2001) earthquake - Free headed pile with floating tip

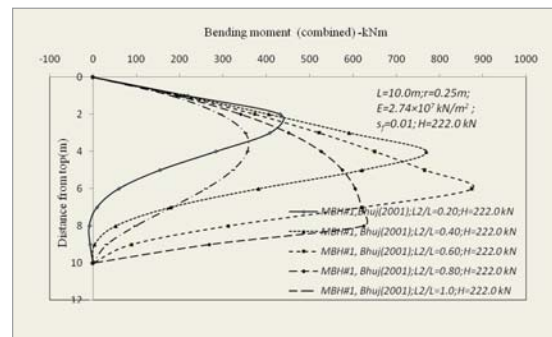


Fig. 6b: Effect of depth of liquefying layer on the pile bending moments (combined) along depth for Bhuj (2001) earthquake - Free headed pile with floating tip

Conclusions

- 1) The ground surface slope has significant influence on the pile response and it is observed that the amplification factor is about 1.60 for non-dimensional deflection and bending moment coefficients when the ground surface slope is increased from 10% to 40% and hence pile design must consider the slope effects in laterally spreading grounds. Also Pile response under kinematic loads is validated with available solutions in the literature and the results are in good agreement with the available solutions.

- 2) Flexible piles tend to deform along with the ground with little relative displacements and hence in the presence of high inertial loads the total pile bending response is mainly due to inertial interactions. Rigid piles being stiff, deform with higher relative displacements between ground and pile, resulting in high passive resistance from the soil. The pile bending response due to kinematic loads is also significant.
- 3) The pile response in liquefied soils is significantly amplified compared to that in non-liquefying soil and the amplification in peak pile bending moment is found as high as 2.50. The effect of depth of liquefied layer has significant influence on the soil pile response. Maximum pile bending moments occurs at the interface of the liquefying and non-liquefying layer. Maximum pile bending moments are developed when the thickness of liquefying soil layer is approximately 60% of the total thickness of the soil layer.

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Composite Polyamide Reverse Osmosis (RO) Membranes – Recent Developments and Future Directions

A.K. Ghosh, R.C. Bindal, S. Prabhakar and P.K.Tewari

Desalination Division

Abstract

Thin Film Composite – Polyamide (TFC-PA) are commonly used reverse osmosis (RO) membranes in water desalination and waste water applications. Their poor chlorine tolerance and fouling characteristics constrain the life and performance leading to stringent chemical pretreatment requirements. In this context, development of fouling resistant and chlorine tolerant RO membranes would be relevant to reduce the cost of pretreatment in aqueous based separations. In this article, we briefly review the commercially available polymeric RO membranes and then discuss our views on current proposals for fouling resistant RO membranes mostly based on nano-composite material chemistry. In addition, development of similar RO membranes in Desalination Division, BARC is also discussed.

Keywords: Polyamide, composite membrane, reverse osmosis, fouling resistant, chlorine resistant

Introduction

Reverse Osmosis (RO) membrane technology is one of the mature separation technology tools used in various industries for separation either as unit separation process or as combination with other processes. The productive RO membrane should offer simultaneously high solute rejection, water permeability, chemical stability and good chlorine resistance particularly for aqueous separations. Cellulose acetate and aromatic polyamide group of polymers are known as two best polymer materials for reverse osmosis (RO) applications till date [1]. Cellulose acetate (CA), cellulose triacetate (CTA) and cellulose acetate-cellulose triacetate blend (CAB) membranes are prepared generally in asymmetric form and hence give relatively lower flux compared to the new generation thin-film composite (TFC) membranes. In addition, CA based membranes are susceptible to microbiological attack, undergo compaction at higher pressures, and limited

chemically stability. On the other hand, polyamide membranes exhibit more flux at a given applied pressure, less microorganism susceptible and are more stable over a wider range of pH values than CA membranes. Thus, polyamide TFC membranes are currently the most widely used desalination membranes. TFC-RO membranes comprise of ultra-thin polyamide film formed *in situ* by polycondensation reaction of polyfunctional amine and acid chloride monomers over a porous polysulfone support membrane [2]. However, their poor chlorine tolerance (chlorine is inexpensive and effective biocide widely used in water pretreatment) constrains their life and performance characteristics leading to stringent pretreatment requirements. High feed pressures applied for RO applications damage polymeric membranes internally due to physical compaction of the porous support membrane and hence irreversible, internal fouling remains a serious concern for RO membranes till date. Apart from the internal fouling, surface fouling due to

scaling and deposition of organic materials, bioorganisms etc. also is a serious problem limiting the life of RO membranes. Hence development of fouling and chlorine resistant RO membrane with better water flux is a thrust area of membrane research. In this article, we discuss the present status of composite polyamide RO membranes and future direction of research towards development of more fouling resistant and chlorine resistant RO membranes keeping salt rejection and water permeability intact or better than the present membranes.

Strategies for synthesis of high flux fouling resistant and chlorine resistant polyamide membrane

More than 30 years, water flux and solute rejection of polyamide TFC membranes have continually improved but still these membranes are not fouling resistant. Internal fouling due to compaction can be managed to certain extent if macrovoids in support membrane can be lesser number and/or by using higher molecular weight polymer. Similarly, organic and biofouling resistant membrane needs to be such that the foulants should not attach to the surface of the membrane easily. In most of the studies so far, only one type of fouling can be solved at a time. For example, if higher molecular weight polymer is used, internal fouling due to compaction can be solved by certain extent but it does not give surface fouling resistant membranes. On the other hand, in surface functionalization by chemical modification of polymer to get surface fouling resistant membrane, chain breakage or degradation of polymer results in low compaction resistant membranes. Similarly, blending of functional polymer with base polymer can also be used for preparation of organic and biofouling resistant membranes but very few polymers are compatible with commonly used membrane polymers. However, concept of a mixed-matrix membrane (a small filler material is dispersed throughout a larger

polymeric matrix) has brought new degrees of freedom to the development of advanced membrane materials with improved mechanical, chemical, and thermal stability, as well as enhanced separation capacity [3]. And flux can also be increased by using porous nanomaterials in mixed-matrix membrane which opens a preferential flow path for pure water to flow from the feed side to the permeate side of the membrane.

For preparation of chlorine resistant polyamide composite membrane, correlation between the chemical structure of polyamides and membrane chlorine interaction need to be known. In case of polyamides synthesized from aromatic primary diamines compounds, N-chlorination followed by chlorination of aromatic ring by Orton Rearrangement is responsible for changing chemical property of polyamide [4]. The Orton rearrangement takes place only when amide linkage is directly connected with benzene ring (especially from amine side). Aliphatic polyamides, on reaction with chlorine yield N-chlorinated amide which can be regenerated to the initial amide by treatment with reducing agent [4]. Tertiary polyamides are inactive towards oxidative chlorine. So, the strategies for better chlorine resistance are: (a) by protecting active sites on aromatic rings, (b) by synthesizing polymers with tertiary amide groups, (c) by incorporating aliphatic secondary and tertiary amide linkage not directly connected with aromatic rings. Other than polyamides, polysulfone has much better chlorine resistance as it has chemically strong bonds between carbon, sulfur, and oxygen. But polysulfone is hydrophobic and hence RO types of membrane cannot be prepared unless chemical structure of polysulfone is altered by introduction of controlled levels of hydrophilicity while retaining its physical properties. Sulfonated polysulfone has been reported for making nanofiltration (NF) and loose RO membranes that are found highly tolerant to aqueous chlorine solution [5]. However, these are asymmetric membranes and hence flux is expected to be less

than that of TFC membranes. Some of the nanomaterials like carbon nanotube (CNT) can have certain extent of chlorine tolerance and hence can be embedded onto the membrane surface to make it chlorine resistant.

Discussions

Present status in developments of thin film composite (TFC) RO membranes

The present RO membrane market is dominated by thin film composite (TFC) polyamide membranes consisting of three layers: a polyester nonwoven fabric act as structural support (~100µm thick), a microporous interlayer support of polymer like polysulfone (~ 40-50 µm thick), and an ultra-thin polyamide barrier layer on the top surface (~0.2-0.25µm thick). However, some of the other polymeric materials other than polyamide also work as very good TFC RO membranes. Table 1 shows details of some of the commercially available TFC RO membranes and similar membranes developed in our division in terms of polymer used as thin film as well as membrane performance in RO testing condition [2, 6]. The membrane preparation machines used for TFC RO membrane making in

two steps are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes

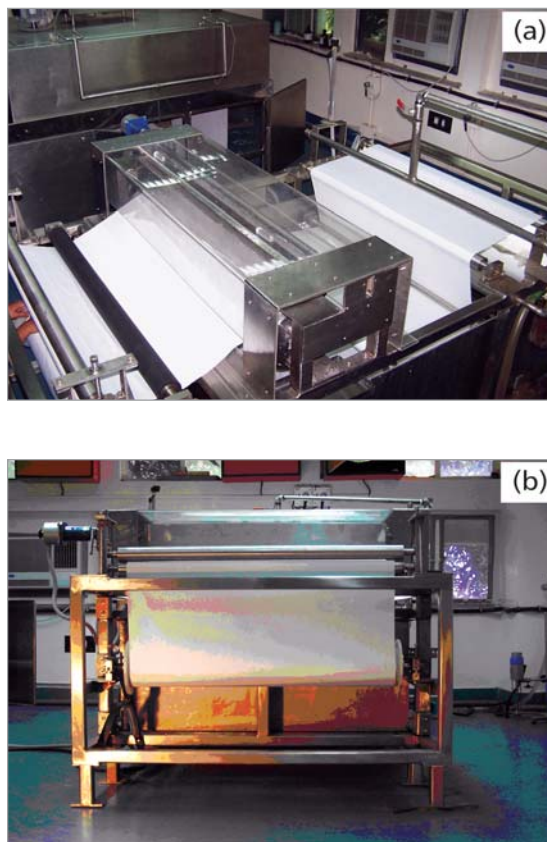


Fig. 1: Pictures of (a) support membrane casting machine and (b) thin-film polyamide coating machine

Table 1: Details of the some of the commercially available TFC RO membranes

RO membrane	Material	Testing condition (Pressure, Feed solution)	Permeate flux (m ³ . m ² . day ⁻¹)	Salt rejection (%)
NS-200	Sulfonated polyfuran	> 100 bar, 3.5% NaCl	0.8	99.8
PES-1000	Polyether-polyfuran	> 69 bar, 3.5% NaCl	0.5	99.9
CP	Sulfonated polysulfone	> 69 bar, 3.5% NaCl	0.06	98
NS-100	Polyamide (aliphatic-aromatic)	> 100 bar, 3.5% NaCl	0.7	99
PA-300/RC-100	Polyamide (via polyepiamine)	> 69 bar, 3.5% NaCl	1	99.4
NS-300	Polypiperazine-amide	> 100 bar, 3.5% NaCl	3.3	68
FT-30	Fully aromatic polyamide	> 15 bar, 0.2% NaCl	1	99
UTC series	Fully aromatic polyamide	> 15 bar, 0.5% NaCl	0.8	98.5
BARC-TFC1	Polyamide (aliphatic-aromatic)	10 bar, 0.2% NaCl	0.45	92.0
BARC-TFC2	Fully aromatic polyamide	10 bar, 0.2% NaCl	0.55	97.0

are still proprietary. A recent study substantially revealed the physicochemical properties of some of the commercially successful RO membranes [7]. The membrane samples studied included two high pressure seawater RO membranes (SWC4 and SW30HR) and six brackish water RO membranes (LFC1, LFC3, ESPA3, LE, XLE, and BW30). Membranes SW30HR, BW30, LE, and XLE are Dow FilmTec (Minneapolis, MN, USA) membrane and SWC4, LFC1, LFC3, and ESPA3 are Hydranautics (Oceanside, CA, USA) membrane. It was found that the uncoated fully aromatic RO membranes had surface elemental compositions very close to the predicted values for polyamide based on the classical interfacial polymerization chemistry of meta-phenylenediamine and trimesoyl chloride but the coated membranes had higher oxygen and lower nitrogen content. The presence of -OH groups in coating layer was further confirmed by high resolution XPS scans. Streaming potential measurements showed the zeta potential of coated membranes was significantly less negative than that of uncoated ones, consistent with ATR-FTIR and XPS results. The uncoated membranes are ESPA3, SWC4, LE, XLE and probably the polyvinyl alcohol (PVA) coated membranes are LFC1, LFC3, BW30, and SW30HR. So far the best commercially successful TFC polyamide RO membrane has the ultra-thin barrier layer made of cross-linked aromatic polyamide

prepared via interfacial polymerization of meta-phenylenediamine and trimesoyl chloride (as given in Fig. 2). From Table-1, it can be seen that BARC-TFC1 and BARC-TFC2 are typically brackish water RO membranes. BARC-TFC2 membrane that is prepared using meta-phenylenediamine - trimesoyl chloride system gives better flux membranes with higher salt rejection than that of prepared using polyethylene imine (PEI) – isophthaloyl chloride (IPC) system (BARC-TFC1). However, the application areas where upto 92% solute rejection with moderate product permeation is acceptable, BARC-TFC1 is more preferable than BARC-TFC2 membrane because stability of raw materials used in former membrane is better than that used in later membrane. Polyethylene imine (PEI) is a very stable chemical and it gives more stable aqueous solution (does not oxidize or change color in presence of air and light) than meta-phenylenediamine. Hence, PEI aqueous solution is used repeatedly and it gives obvious economic advantage. In addition, isophthaloyl chloride (IPC) is easy to purify by simple recrystallization from hexane unlike trimesoyl chloride. But for application where high salt rejection is desired, BARC-TFC2 type membranes need to be used. So, both the reagents (meta-phenylenediamine and trimesoyl chloride) either need to be prepared fresh or need purification just before use to make high salt rejecting TFC RO membranes.

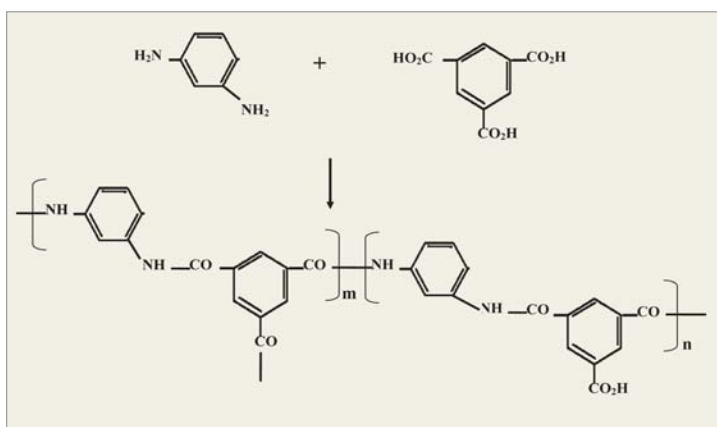


Fig. 2: Fully aromatic polyamide prepared via interfacial polymerization of meta-phenylenediamine and trimesoyl chloride.

Novel composite polyamide RO membranes

Commercially available TFC polyamide membranes are not fully fouling resistant though they show excellent permeability and selectivity. By membrane surface hydrophilization in post-treatment, different researchers attempted to increase further the permeability and organic fouling resistance upto a certain extent but problem of physical

compaction, biofouling and chlorine tolerance was still not satisfactory. In this section, we limited our discussions only on development of fouling resistant TFC polyamide membranes using nanocomposite materials chemistry and of chlorine resistant TFC polyamide membranes using polycondensation reaction of easily synthesized new reactants.

Thin film nanocomposite (TFN) RO membranes with enhanced permeability and fouling resistance

It is known that the rejection of monovalent ion in a mixed ion solution is lower than that for a pure solution of monovalent salt. So, the filtration mechanism is not only dependent on size exclusion, but also on Donnan exclusion due to the charged double layer induced by adsorbed ions on the pore or the intercrystalline walls. But ions can be completely excluded by membranes with pore sizes smaller than the size of the hydrated ions in feed solution. Nanoparticles like LTA-type zeolite nanoparticle exhibits 0.4nm pores and MFI-type has 0.56 nm pores which are lower than the size of the common ions presents in contaminated water but bigger than the size of a water molecule (0.278nm). So, LTA-type zeolite particles in the size range of 50–150nm with a Si/Al ratio of 1.5 are taken to make inorganic-organic thin film nanocomposite (TFN) membranes with assumption that nanoparticles will create a straight path for flowing of pure water only retaining salt ions from salt water. Moreover, these particles are very hydrophilic (contact angle $< 5^\circ$), with negative charge which are highly repulsive to anions. The zeolite nanoparticles are dispersed in hexane solution of trimesoyl chloride before the interfacial polycondensation reaction takes place. TFN RO membranes are prepared with various zeolite loadings, size and consequent changes in membrane characteristics have been reported [8, 9].

TFN membranes are smoother, more hydrophilic and

more negatively charged than normal TFC membranes prepared under identical condition. Hence TFN membranes have less fouling tendency than the TFC membrane. Also TFN membrane exhibits two times more flux and a slight improvement in salt rejection relative to the hand cast TFC membrane without zeolite nano-particles. Fig. 3 gives conceptual illustration of TFC and TFN membrane structures. Fig. 4 illustrates the membrane separation performance as a result of variation in zeolite nanoparticle loading.

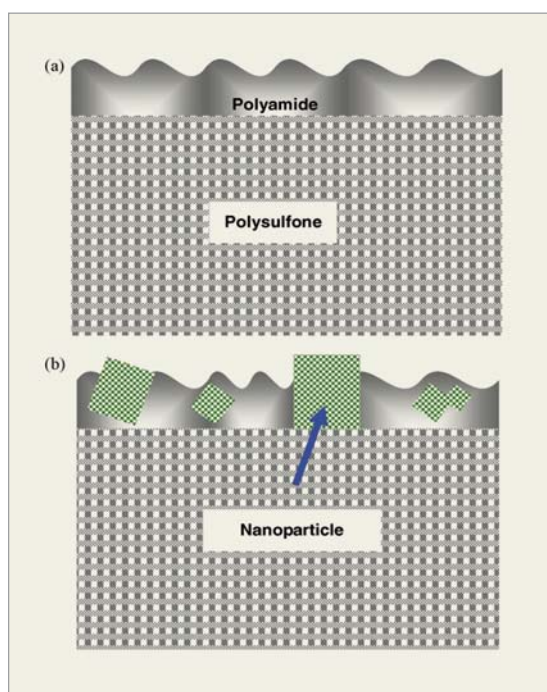


Fig.3: Conceptual illustration of (a) TFC and (b) TFN membrane structures.

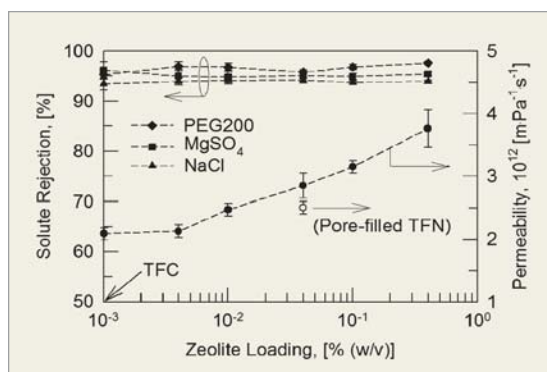


Fig. 4: TFN membrane separation performance as a function of zeolite nanoparticle

In another study, the compaction behavior of hand-cast polysulfone-nanocomposite supported polyamide composite membranes relative to pure polysulfone supported polyamide composite membranes are evaluated to control irreversible, internal fouling of RO membranes by physical compaction [10]. Nanocomposite support membranes are prepared using silica particles in the size range of approximately 34 to 130 nm and zeolite particles with size range of approximately 250 to 300nm. Cross-sectional SEM images of uncompact (as-cast) and compacted at two different pressures namely, 1724 kPa and 3448 kPa are shown in Fig.5. The figure suggests that membranes containing nanoparticles underwent less compaction, while the pure polymer based

membrane experienced a drastic change in thickness and support structure.

A recent study suggests that membranes comprising sub-nanometer diameter CNT can desalt water when used as RO membranes [11]. The narrow pores reject ions extremely well, but conduct water at 5-1000 times (depending on the loading of nanotubes) the rate of commercially available TFC RO membranes. The primary causes of salt rejection and water transport in these studies is the narrow, smooth, nonpolar nature of the CNTs; hence, separation performance may not be specific to chirality of concentric walls. To get photocatalytic reactivity and antibiofouling properties in TFC membrane, anatase TiO_2 nano-particles (<10 nm) are dip-coated onto

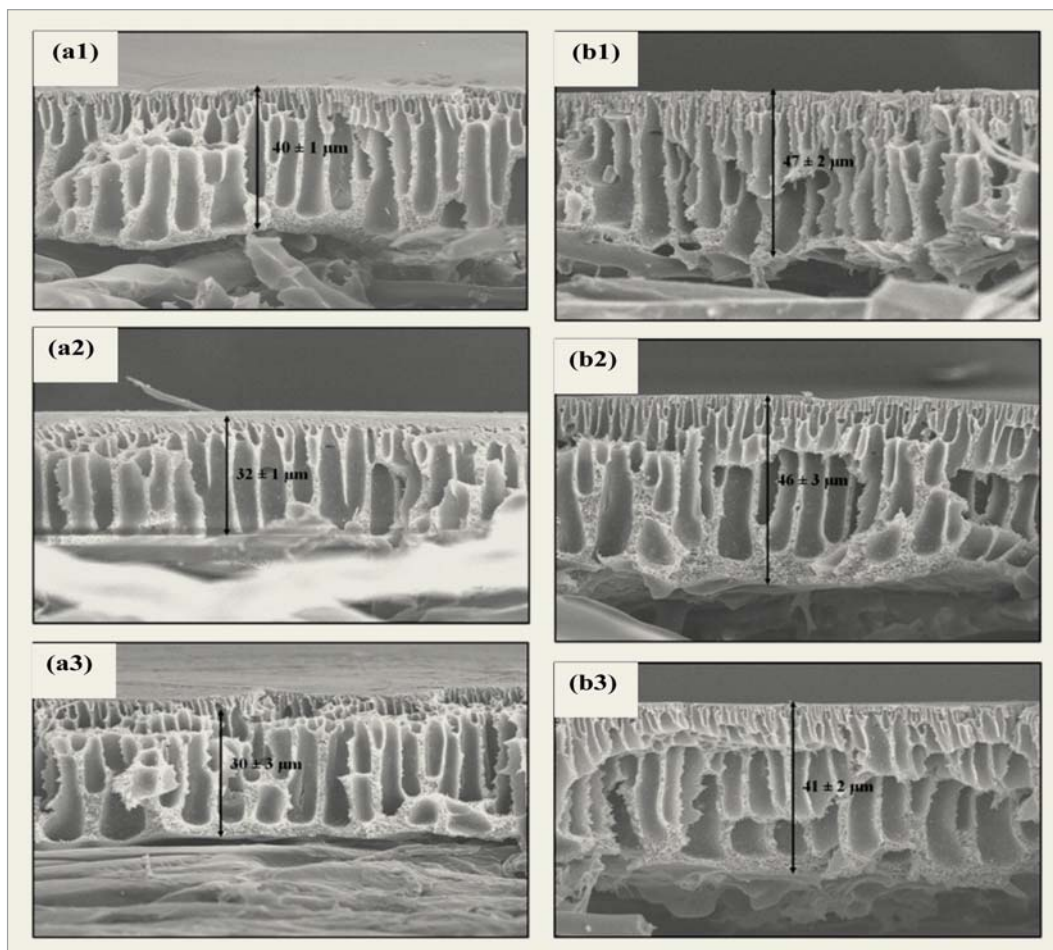


Fig. 5: SEM cross-section images of TFC (a1-uncompact, a2-compacted at 1724kPa, a3-compacted at 3448 kPa) and ST50 silica-TFC (b1-uncompact, b2-compacted at 1724kPa, b3-compacted at 3448 kPa) membranes

an interfacially polymerized TFC polyamide membrane with a surface layer functionalized with carboxylate groups [12]. These membranes have been tested with E. coli-containing feed water and confirmed superior anti-biofouling confirmed superior anti-biofouling properties in particular with the aid of UV excitation, without compromising the flux and salt rejection of the original membrane.

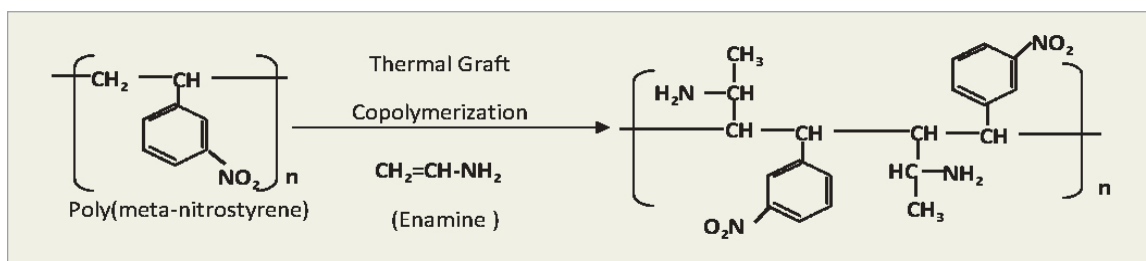
Chlorine tolerant TFC and TFN membranes

The chlorine resistant polyamide membranes reported so far are either prepared from aliphatic polypiperazineamides or from some complicated polymeric systems where water flux is less. Moreover, aliphatic polypiperazineamides can not be used at higher pressure due to compaction problem. In order to get high flux chlorine resistant polyamide membrane, the membrane polymer should have benzene ring to give structural rigidity

and mechanical strength, secondary aliphatic amide groups not directly connected with benzene ring for chlorine resistivity and substituted hydrophilic group in benzene ring for higher hydrophilicity. To get the polymers with above characteristics, the following system can be tried.

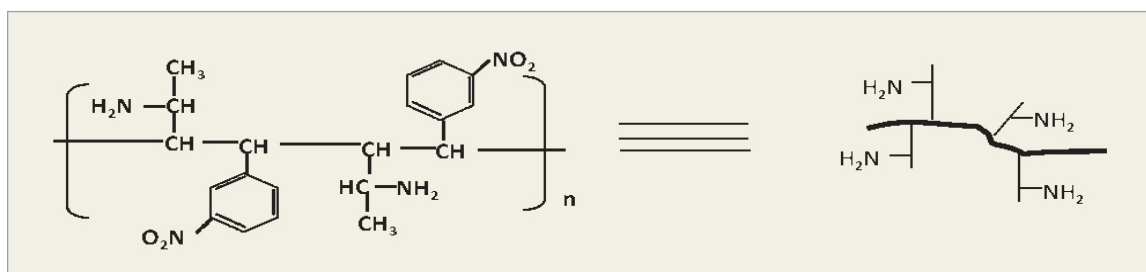
For TFC polyamide membrane preparation, amine part can be poly (enamine)-graft-poly (m- nitro styrene) and acid part can be oxalic acid. So, poly (enamine)-graft-poly (m- nitro styrene) need to be synthesized first from graft copolymerization of enamine over poly (m-nitro styrene) polymer. Reaction of this graft copolymer with oxalic acid over support membrane gives cross linked polyamide TFC membrane. In this TFC membrane, both amide group and aromatic rings are present but amide linkage is not connected directly with aromatic ring.

1st Step: Synthesis of crosslinked copolymer of Poly(enamine)-grafted-poly(nitrostyrene)

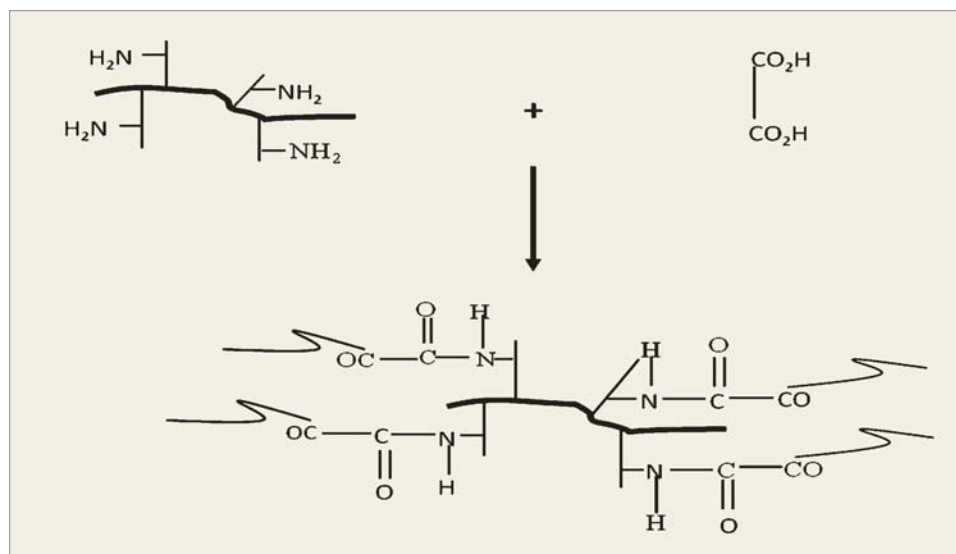


Graft copolymerization of poly (meta-nitrostyrene) with enamine could be followed procedure similar to graft copolymerization of polyvinylidene difluoride (PVDF) with N-isopropylacrylamide as reported in literature [13].

For sake of simplicity in writing the chemical equation, the following notation is used in the second step of the reaction.



2nd Step: In situ polycondensation of Poly (enamine)-grafted-poly (nitrostyrene) with oxalic acid.



(Thin film membrane material of TFC membrane)

In this case, oxalic acid is water soluble but difficulties may arise if poly(enamine)-graft-poly (m-nitrostyrene) copolymer is not soluble in a water immiscible organic solvent. In case suitable water immiscible organic solvent is not found, then the target polymer can be synthesized by solution polymerization technique and the synthesized polyamide polymer can be used for making asymmetric membranes.

Recently, it was reported that nanocomposite TFC RO membranes containing multi-walled

carbon nanotube (MWCNT) has enhanced chlorine tolerance than normal TFC membranes [14]. In the MWCNT loading range of 0.1–1% (w/v), chlorine resistance of organic/inorganic nanocomposite RO membranes was improved as the amount of MWCNT increased.

In BARC, we have already perfected silver and silver-copper based nanocomposite biofouling resistant ultrafiltration (UF) membranes [15]. Nanocomposite UF membranes are generally more compaction resistant than corresponding pure polymer

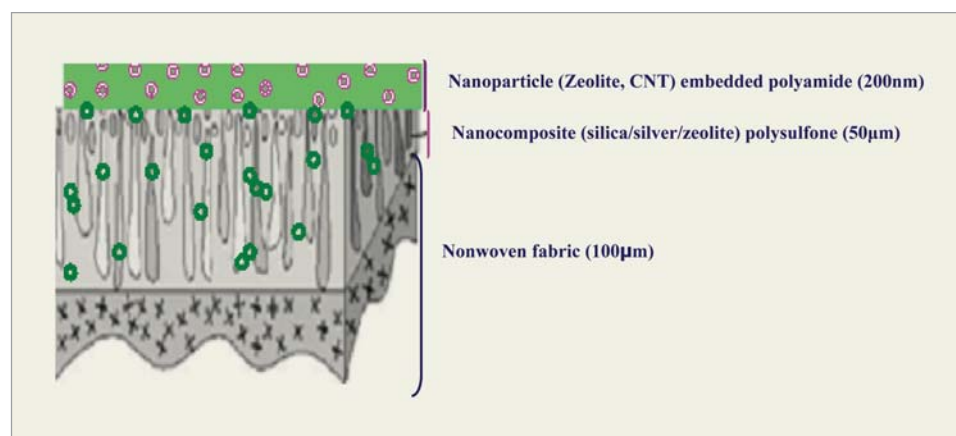


Fig. 6: Conceptual picture of probable next generation nanocomposite RO membrane

membrane. So, using these compaction and biofouling resistant support membranes (silver and silver-copper based polysulfone nanocomposite), preparations of CNT and porous silica based thin film nanocomposite (TFN) membranes are on progress to get high flux, fouling resistant and chlorine tolerant membranes. A conceptual picture of a probable fouling resistant nanocomposite membrane is given in Fig.6.

Conclusions

More resistance to physical compaction, chemical, biological and chlorine attack is most desirable to make significant reductions in both capital investment and operating costs of desalination by RO. Incorporation of nano-technology in membrane preparation could offer an attractive alternative to prepare real fouling resistant membranes and hence many scientists believe that nanotechnology would bring revolutionary advancements to the desalination industry. Among others, zeolite, silica based thin film nano-composite membranes and carbon nano-tube membranes are two most likely novel materials for enhanced RO desalination performance in the future but still a number of challenges remain with regard to their practical implementation. The major practical challenges are (a) high cost of nanomaterials, (b) the extra energy required to effectively disperse the nano-particles into the barrier layer, (c) health and safety issues for use of nanomaterials in the domestic water industry as sometime these are toxic and (d) the difficulty in scaling up nano composite membrane manufacturing processes for commercial use. However, zeolite and silica based thin film nano-composite membranes appear to be more readily adaptable to commercial use due to their similarity to current commercial RO membranes than carbon nano-tube based membranes where alignment of CNT into the polymer matrix is still a challenge. However, for nanocomposite chlorine tolerant membrane, low concentration of CNTs can be used

in which at least few CNTs remain aligned and others give chlorine tolerances.

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Precision-Micro-Nano Engineering

Suri V.K., Balasubramanium R., Kallol B. Dewangan T., Shivam M, Srinkhla G., Prabhat R, Kori B.G., Ashwin R.

Introduction

In the beginning the classical precision engineering practices were followed to craft components and products by the state-of-the-art techniques with 2s acceptance level. Probabilistic, skill oriented machining techniques were explored and developed. To prove the phenomenon and to run pilot scale studies this was the only approach available indigenously. Stringent time schedules were setting the pace. Multi pronged approach of learning, acquiring knowledge and developing the skill base, be it in-house or by out-reach was adopted. The focus was on learning various machining processes, more so, their capabilities and limitations and availability of the experts and skill sets across the country. Over a period of time, Precision Engineering has expanded significantly, several technologies and associated metrology have been developed for improving the performance of these components products & systems. Recently, the domain of Precision Engineering has expanded further by utilizing the experience of precision machining and engineering to develop MEMS-based Silicon micro-sensors and novel Opto-mechanical sensors that can be deployed for harsh operating conditions. This article presents an overview of the technologies and components developed for DAE programs in mission mode and presents a holistic view of an integrated Micro-Nano Engineering program aimed at DAE applications for the future.

Ultra-Precision Metrology

In the first phase of product development, vendors were involved in the manufacturing of critical components having intricate micro-patterns. However, metrology tools that were required to

characterize and measure these components were missing at the vendor’s end, primarily because the measuring machines were very costly and they required very stringent environmental conditions to be maintained for reliable measurement and metrology. To overcome this problem, an Ultra-Precision Metrology Lab (UPML) was established with suitable measuring machines and systems. The UPML was a precision-environment controlled, class-10,000 cleanroom metrology lab housing High Precision Universal Measuring Machine (UMM) with sub-micron measurement accuracy with 95% confidence level. It also housed a three dimensional surface-topography measuring machine with nanometer resolution, an advance signature analysis tool for manufacturing engineers. To bridge the gap between three-dimensional measurements by Universal Measuring Machine (UMM) and two-dimensional topography by surface texture a Multi-Sensing and Measuring Machine was added to view and measure 2D and 3D surface features which could not be measured with the other two machines. The UPML is shown in Fig. 1a, and typical



Universal Measuring Machine

Multi Sensing Machine

3D surface topography System

Fig. 1a: Ultra-Precision Measurement Laboratory

measurements with some of the instruments are shown in Fig 1b.

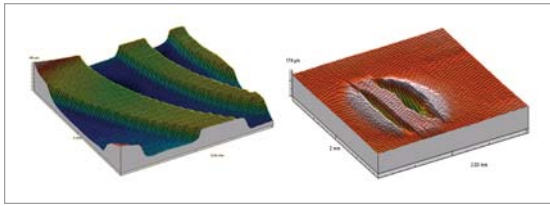


Fig. 1b: Three dimensional surface-topography of a Micro-grooved channels and measurement of H₂ Blister on Zircalloy Tube

The sight was now set on achieving sub-micron accuracies on the size as well as geometry of the precision machined components having nanometer level of surface finishes. Vendors were induced to develop process capabilities, Central Machine Tool Institute (CMTI) Bangalore was commissioned to develop ultra-precision lathe popularly known as Diamond Turning Machine (DTM).

Diamond Turn Machining

Diamond Turn Machining (DTM) is a deterministic nano regime machining wherein the size tolerance and shape can be controlled within few hundreds of nano-meters and the surface finish with- in few tens of nanometers by employing an ultra-precision machine and an extremely sharp single crystal diamond tool. The technology is developed for the machining of the wide range of engineering materials i.e. ferrous as well as non-ferrous materials. The salient features of DTM process are a) Atomic Cluster Machining, b) Extremely high loop stiffness



Fig. 2 : Solid circular and square honeycomb Al-alloy mirrors machined by DTM

between tool and work piece, c) Ability to apply and maintain very small depth of cuts and feed rates as low as few nanometer, d) Low thermal and low sub surface damage.

Some of the components machined by DTM technology are shown in Fig.2. The comparison of CNC surface and DTM machined surface are shown in Fig 3. The measurement was carried out on a high-resolution surface profilometer. The R_a value is 0.16 micron for CNC machined and lapped surface, while it is 10 nm for DTM machined surface.

Features	Precision Lapping	Diamond Turn Machining
Surface Finish	0.16 microns Ra Value	Better than 10 nanometer Ra
Surface Signature	 2D signature analysis	 2D signature analysis
	 3D Surface Topography	 3D Surface Topography

Fig 3: Comparison of Ultra Precision Lapping and DTM Surface

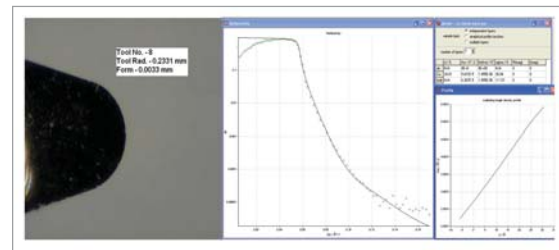


Fig. 4: Indigenously Developed Single-Crystal Diamond Tool & X-Ray Reflectivity pattern (measurement done at RRCAT Indore)

Single crystal diamond tool with ultra sharp cutting edges to the tune of 200nm, as compared to 5µm for very fine conventional tool, is an essential part of DTM process. These tools are very expensive and are presently being imported. An initiative has been taken to develop these tools indigenously. Fig(4) shows a precision diamond tool developed indigenously. The X-ray reflectivity pattern of the machined surface by indigenously developed tool as shown is 26°A. Presently single crystal diamond

tools are being developed through Focused Ion Beam Machining in collaboration with Central Machine Tool Institute (CMTI).

Non-Conventional Machining Processes

Classical machining processes use either a hard wedge shaped tool or abrasive grits to remove material on selective basis. These material removal processes are popularly known as Conventional machining processes viz turning, drilling, milling as well as grinding, lapping and honing processes. There are needs to remove materials in exotic shapes, sizes or materials, which cannot be accomplished by classical or conventional machining process. The alternative processes called Non-conventional Machining processes deploy thermal, abrasive or chemical means to remove the materials and are basically Electro-Discharge-Machining (EDM), Photo-Chemical Machining (PCM), Laser Beam Machining (LBM), Electron Beam Machining (EBM), Abrasive Jet Machining (AJM), Focused Ion Beam Machining (FIB) and Deep-Reactive Ion Etching(DRIE) to name a few ranging from Micro-machining to nano-machining processes. Some of these processes viz EDM, LBM, PCM and AJM are used by advance manufacturing shops while others are still at lab-scale phase. To meet the requirement of nuclear engineering, aerospace, telecommunication and medical diagnostics and body implants these Non-Conventional Machining processes are developed depending upon specific requirements.

Heavy Water plants, using ammonia and hydrogen need Molecular Sieve Trays. These sieve trays have more than one Lakh micro-holes with pore size of 200 micrometer and pore density about 250 per square centimeter. The task was taken up and double-sided photochemical machining (PCM) process was developed. BEL, TATA Press, IDEMI and host of vendors inclusive of Mr. Mitter Bedi, the

ace industrial photographer participated in the development process. Sieve trays are shown in Fig 5.

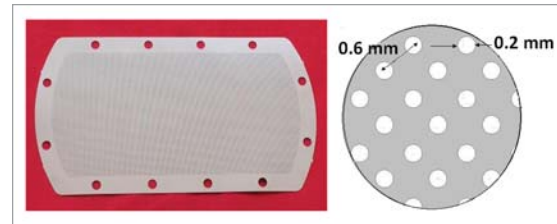


Fig. 5: Heavy Water Molecular Sieve Tray

In another application an Array of Micro Convergent-divergent supersonic nozzles were needed for some critical applications. The mask making facilities at BEL and precision photo-chemical Machining techniques were developed. Fig 6 shows the details of some critical section of the micro-supersonic nozzle.



Fig. 6: Micro-Nozzle on Cu-Beryllium Substrate

Three-dimensional Laser Lithography:

Conventional photochemical machining (PCM) is used to transfer the two-dimensional image on the 2D substrate; but this process cannot be used for generating intricate structures on the 3D substrate. Therefore a unique technique of 3D laser lithography was conceived, developed and is presently being used for the generation of high-speed fluidic devices. The custom built facility and fluidic devices are shown in Fig 7 a & b.

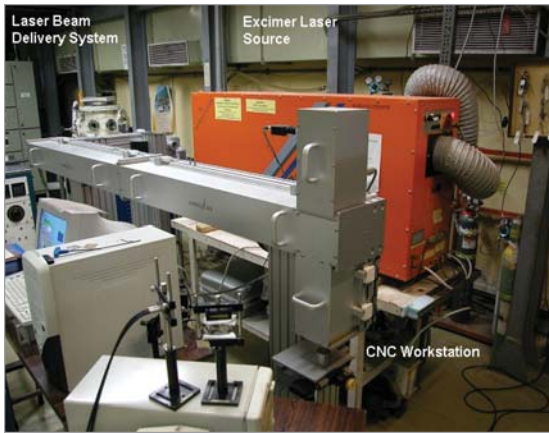


Fig.7: (a) Excimer laser lithography facility



Fig7: (b) Recurring fluidic channel on 3D surfaces

Micromachining and Related Technology Development

DAE took a pragmatic decision with an eye not only on future but also to tap the benefit of Miniature Micro and Nano-regime exploration and constituted a Steering Group by merging various disciplines of Science & Engineering viz Nanotechnology, MEMS, Sensors and Detectors and High Precision Engineering. The steering group identified the following thrust areas

- Micro-Nano Systems and Technology
- Sensors and Detectors Development
- Silicon and Nanotechnology Initiative

The developments pertaining to Micro-Nano Systems and Technology are described here. This program was further subdivided into

- Micro-machining and Nano-finishing Capacity Generation

- Micro-systems Development
- MEMS & Micro Sensor Development program

Micro-machining

A Micro-Nano Engineering Lab was established housing state-of-the art unique machines in micro domain machining for the first time in the country. These machines are now being used extensively in BARC for development and product research in micro- & nano-domain, Fig. 8 shows these. Table-1 lists the products developed using the available facilities.

	<p>Multi Purpose Micro Machining Center</p> <ul style="list-style-type: none"> • μ-Turning :Shaft dia. of 50 μm • μ-Milling :50 μm slot • μ-Drilling :50 μm • μ-EDM :20 μm slot • μ-WEDM :35 μm wire for generation of features • μ-WEDG :50 μm shaft • Cutting force measurement:
	<p>Deep hole drilling and scan milling micro EDM</p> <ul style="list-style-type: none"> • Deep hole drilling - 0.1 to 0.5mm dia • High Aspect ratio drilling • Micro-EDM milling capability
	<p>Single spark micro EDM</p> <ul style="list-style-type: none"> • Single spark generation using RC & Transistors • Micro EDM with multi sparking • Micro EDM Milling

Fig8: State of the art facilities at Micro-Nano Engineering Lab

Nano Finishing Technology

Nano-finishing is a process, used to minimize the irregularities of the surface till nanometric scale. Nano-finishing process is used to arrange cluster of

atoms on the surface of material with saturated and stable atoms on the free surface. Therefore, nano-finished components show better mechanical and chemical properties. Since, this process has very small material removal rate, it does not disturb the form of surface.

Table 1: Micro-Nano Engineering Products

 <ul style="list-style-type: none"> • Micro Crack Test Specimen for PFBR • Helical Notch on Zirconium Alloy • Width: 30 μm • Depth: 45 μm • Process: m-Milling & m-EDM 	 <ul style="list-style-type: none"> • Pin Hole Matrix for Synchrotron Beam line calibration • Process : m-EDM • Material : Copper beryllium • Total no. of holes : 70 (in matrix) + 3 • Size: 50mm x 50mm x 0.1 mm • Tool : Tungsten • User : RRCAT
 <ul style="list-style-type: none"> • Micro EDM tool and Thrust bearing with micro grooves • Rotate at 4Lakhs rpm 	 <ul style="list-style-type: none"> • Nano delivery Pin (17-4 PH (Steel)) • Process : m-Wire-EDM • Slot Size : Taper size from 40 to 80 mm • Tool : Tungsten wire diameter 30 mm
 <ul style="list-style-type: none"> • Micro Needle Array & Micro Pin Array of 5 X 5 matrix • Dia. of needles at bottom : 120 micron • Height of pins : 400 micron • Pitch : 400 micron 	 <ul style="list-style-type: none"> • Prototype Micro Chemical Reactor • ID 0.5mm & Length 10mm
 <ul style="list-style-type: none"> • Atomic Cluster Removal of Material 	 <p>Micro Drilling on 100 micron human hair of 50 micron diameter</p>

Chemo Mechanical Magneto Rheological Finishing

Magneto-rheological finishing (MRF) process is hybridized with Chemo Mechanical Polishing (CMP) and a novel finishing technology has been developed, Chemo-mechanical magneto-rheological finishing (CMMRF). The process is capable to carry out sub nano finishing. The process has been demonstrated on single crystal silicon substrate, and 0.5nm surface finish is achieved. The process can be developed for 3D sculptured surfaces.

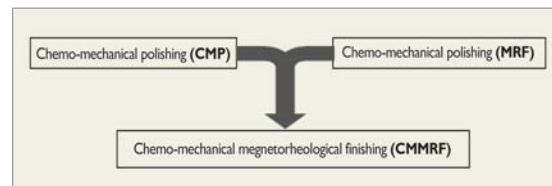


Fig 9: Hybrid Process of CMMRF

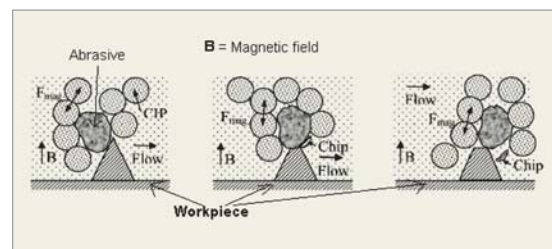


Fig. 10: Material Removal of chemically passivated layer by using magnetically assisted mechanical action

The process has the ability to finish brittle, hard and soft 3-D shaped materials. Surface roughness value of the finished surface is less than 0.5 nm (Fig 11).

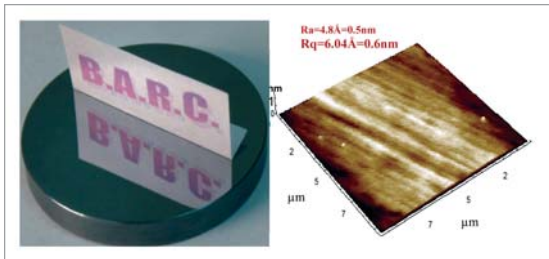


Fig. 11: CMMRF finished products showing the mirror image and AFM result of CMMRF finished product

Electrolytic In-process Dress Grinding (ELID)

Electrolytic In-process Dressing (ELID) is a simple and efficient technique that utilizes electrolysis for dressing metal-bonded grinding wheels. During the ELID, the metal bond is slowly corroded and the corrosion product is then mechanically removed by abrasion during the grinding process. The grinding wheels that can produce such a protective layer during electrolysis are more suitable for in process dressing. The process has the capability to grind any material viz. metals, non-metals, semi-conductor and ceramics to obtain surface finish values of up to 10nm. Fig12 shows the ELID machine and a Si substrate finished with the process having R_a value 10nm.

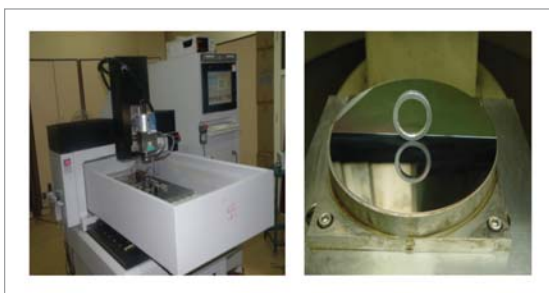


Fig. 12: ELID machine & ELID finished Si Substrate of $R_a = 10nm$ with mirror image

Sensor Development Programme

MEMS Pressure Sensors

Micro Electro Mechanical Systems (MEMS) based

sensors and actuators are finding applications in the fields of space, communications, defense, automobiles, biomedical etc. BARC has recently initiated a MEMS development programme and focused on Pressure Sensor development. These MEMS based pressure sensors are based on Piezoresistive effect in silicon, wherein resistivity changes with stress. The four Piezo-resistors are deposited in the substrate in such a way that two resistors would have longitudinal stress while other two would have transverse stress and Si substrate is bulk micro-machined to fabricate the sensing diaphragm of desired size. These resistors are connected in the form of Wheatstone bridge and the differential output voltage changes proportionally with applied pressure. Fig 13 shows a typical pressure sensor at various development stages.



Fig.13: Process Route from sensing diaphragm to packaged pressure sensor

The packaging of sensing chip plays a pivotal role in the development of MEMS sensors. The packaging is required to isolate the chip from the process media. The packaging design (fig 14) & development is basically mechanical engineering in micro & precision domain. Fig 15 shows the MEMS pressure transmitters developed for NPCIL applications. The following critical steps are involved:

- Anodic Bonding to bond the Si chip to glass substrate
- Ultra sonic wire bonding from chip to leads for external electrical connections
- Silicone Oil filling under vacuum to protect the chip from corrosive environment and for pressure transmission

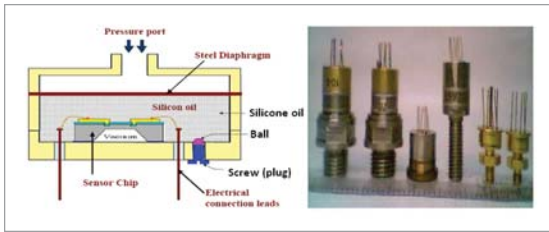


Fig. 14 Package design of MEMS based oil filled absolute pressure sensor and variety of developed pressure sensors

The critical micro-engineering challenges of packaging are:

- Design and fabrication of miniature housing for pressure sensor chip
- Media isolation by using a stainless-steel diaphragm. The diaphragm has to be sensitive on one hand and be of sufficient strength to be able to isolate the chip from mechanical loads.
- Design and manufacture of miniature glass-to-metal seal.



Fig.15: MEMS Pressure Transmitter developed for NPCIL

Specification

- 0-10 bar gauge pressure
- 1/2" NPT(F) pressure port
- SS 316L package
- 4-20 mA current output
- 2-wire electrical connection
- 24-28 V dc power supply

Opto-Mechanical Sensors

The Opto-mechanical sensor is based on the principle of a Fabry-Perot Interferometer (FPI). A FPI classically consists of two plane parallel mirrors, and acts as an optical filter in the sense that it transmits selected wavelengths and reflects others depending on the separation between the two mirrors of it as shown in fig 16. In the development process of this sensor, first a micro machined, nano finished metallic mirror is designed & manufactured. This mirror is assembled at the cleaved end of the fiber in order to constitute a Fabry-Perot interferometer at the optical fiber end. This metallic mirror acts as a one of the mirrors of FPI as well as a deflecting element (diaphragm) of the sensor. As this FPI is pressurized, the diaphragm deflects, FPI gap reduces and reflected optical signal changes. The reflected optical signal is calibrated with pressure. Fig 17 shows the setup including opto-mechanical sensor, light source and analyzer. It also shows two different optical signal patterns for two different FPI gap lengths.

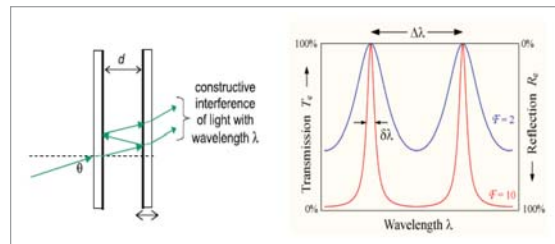


Fig. 16: A fabry-Perot interferometer and its spectral response

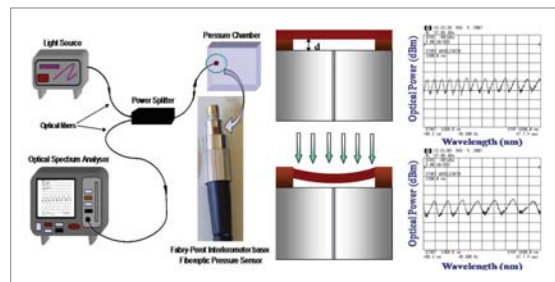


Fig. 17: Optical Setup & Principle of Opto-Mechanical Pressure Sensor

Development of Opto-mechanical Pressure Sensors has been carried out indigenously with the expertise

and capabilities available in BARC viz micromachining, nanofinishing, fiber optics, opto-electronics and instrumentation. These sensors have distinct advantage of immunity to radiation, EMI/RFI and are suitable for high temperature (450°C) while being small in size and lightweight. Fig 18 shows the prototype pressure sensors developed.

Future Scope

Due to fast changing international scenario and to meet the needs of ambitious nuclear power generation and in allied areas there are two major relevant areas of research & development which must be pursued. These are

- Micro-Nano-Engineering
- Intelligent Manufacturing



Fig. 18. Prototypes Pressure Sensors developed for 0-10 Bar (G)

Nanotechnology is at nascent stage of development. Nano science is taking a ‘Bottom-Up’ approach where scientists manipulate atoms and molecules to create nanomaterials and nanostructures. In the ‘Top Down Approach’ Micro-Systems & MEMS are developed to create a platform for nano scale fabrication. Effectively microtechnology is the launch pad for nanotechnology deployment. Presently the National Programme on Nano-technology is heavily tilted towards scientific exploration and development & characterization of nano materials & structures. Micro-Nano-Engineering is relatively a neglected area. Conception, design, manufacture, assembly, testing and characterization of micro and nano systems is at rudimentary state. There is a need to create a suitable Micro-Nano-Engineering Center by DAE and deploy scientists, researchers and engineers

of multiple disciplines under one roof. Fig 19 shows the various aspects of engineering that need to be addressed in this Center.

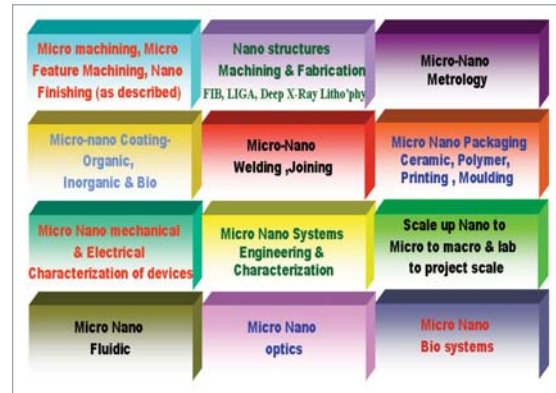


Fig. 19 : Micro-Nano Engineering Centre

Intelligent Manufacturing (IM) is another thrust area for DAE requirements:

- Intelligent-Manufacturing module consisting of flexible machining cell based on intelligent machines with real time- in situ- measurement and feed back.
- Intelligent-Quality Assurance module, measurement and calibration including on-line data transmission and quality auditing rather than batch process (Fig. 20).

IM will ensure very high quality & productivity with minimum human interaction meeting the needs of the department.

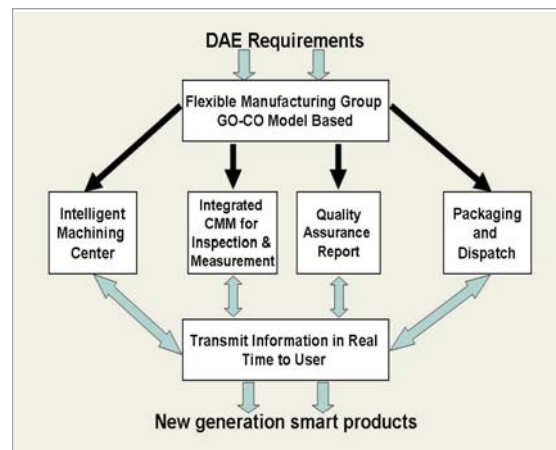


Fig. 20: Intelligent Manufacturing Module

Several collaborative projects have been taken up in consultation with leading academic institutes and research laboratories in the country for the development of custom built High Precision Miniature components. Few of the collaborative projects are listed in Fig 21.

Micro Machining	: IIT B
Sub-Nano Finishing for Si Mirror	: IITK
Crystal Polishing for Futuristic Bearing	: IITB
LIGA for Micro structures	: IITB
Micro Fluidic	: IITD
Micro Nano Products	: BATU, Lonere
Diamond Turning Technology	: CSIO, Chandigarh
MEMS Sensors	: BEL, Bangalore
Nano Finishing of Sculptured surface	: IITK
Bio Medical Implants	: IITB

Fig. 21 : Collaborative research in Precision Engineering

Conclusion

The role of precision-micro-nano engineering and non conventional machining is very critical in nuclear, aerospace, telecom and biomedical fields. With the advent of Nanotechnology, one has to be prepared to accept and adopt the intelligent, integrated and advanced technologies. Development in Microtechnology is the first step in this direction which will be the carrier of Nanotechnology. Robust Micro-engineering capabilities need to be established for future Nano-engineered components and systems deployment in a gainful manner in the department.

ISMAS International Discussion Meet on Elemental Mass Spectrometry in Health and Environmental Sciences (ISMAS / DM / HEAL 2011): Highlights

As a part of International Year of Chemistry Celebrations Discussion Meet on "Elemental Mass Spectrometry in Health and Environmental Sciences" (ISMASDMHEAL2011) was organized jointly by the Indian Society for Mass Spectrometry (ISMAS), Mumbai and Inter University Accelerator Centre (IUAC), New Delhi. The Discussion Meet was held at New Delhi during April 14 & 15, 2011.

The Discussion Meet was inaugurated by Prof. S. Kailas, Director, Physics Group, BARC on April 14, 2011. Dr. Amit Roy, Director, IUAC, New Delhi presided over the function and delivered the Presidential address. Dr. Sundeep Chopra, Co-Convenor from IUAC delivered the welcome address and gave an overview of the activities at IUAC. Prof. S.K. Aggarwal, President, ISMAS and Chairman of the Organizing Committee, briefed on the activities of ISMAS and highlighted the scope of ISMASDMHEAL2011. Mr. P.G. Jaison, Convener, Organizing Committee, proposed the vote of thanks. During the inauguration function, the Bound Volume of the Proceedings of the ISMASDMHEAL2011 was released by Prof. S. Kailas. A special ISMAS Souvenir-cum-Bulletin brought out to commemorate the occasion, was released by Dr. Amit Roy.

There were 70 participants in the ISMASDMHEAL2011. The Discussion Meet provided a forum for Research Scholars and Scientists from Industry and Research Institutes, to discuss their experiences and share new developments in the field of Elemental Mass Spectrometry with special reference to Health and Environmental Sciences. The scientific programme of the Discussion Meet was covered in 7 technical sessions.



Prof. S. Kailas, Director, Physics Group, BARC, Mumbai, delivering the inaugural address during ISMAS / DM / HEAL 2011.



Dr. Amit Roy, Director, IUAC, New Delhi, delivering the Presidential address during the inauguration of ISMAS / DM / HEAL 2011.

There were 17 Invited Talks by distinguished mass spectroscopists from within the country (11) and from overseas (6). Invited Talks covered various applications of Elemental Mass Spectrometry and Accelerator Mass Spectrometry for Biomedical applications, drug development, Forensic Science, Environmental Science and Geological Science.



Bound volume of the Proceedings of the ISMAS / DM / HEAL 2011 being released by Prof. S. Kailas, Director, Physics Group, BARC, Mumbai. On the dais from left to right: Mr. P.G. Jaison, Convener, Organising Committee, Dr. Amit Roy, Director, IUAC, Prof. S. Kailas, Director, Physics Group, BARC, Prof. S.K. Aggarwal, President, ISMAS and Chairman of the Organizing Committee, Dr. Sundeep Chopra, IUAC.

Invited speakers from overseas included Dr. Korschinek Gunther (Germany), Dr. Tim Ulrich Schulze-König (Switzerland), Dr. John Cattle (Nu Instruments, UK), Dr. R.J. Watling (Australia), Dr. Dirk Schaumloffel (France) and Dr. Bela Kovacs (Hungary).

The speakers from India included Dr. P.V. Bhagwat (BARC, Mumbai), Dr. Ravi Prasad (IOP, Bhubaneswar), Dr. Sundeep Chopra (IUAC, Delhi), Dr. B.R. Chakraborty (NPL, Delhi), Dr. V. Balamam (NGRI, Hyderabad), Dr. M.V. Balarama Krishnan (CCCM, Hyderabad), Dr. K. Chandrasekaran (CCCM, Hyderabad), Dr. J.K. Pattanaik (IISER, Kolkata), Dr.

and Dr. Susanta Lahiri were the panelists for the discussion.

ISMAS DMHEAL2011 concluded with a Valedictory Function on April 15, 2011. During this function, the delegates expressed their satisfaction over the technical content and scientific discussions held during the Discussion Meet. A need was felt to have a dedicated "Accelerator based Mass Spectrometry (AMS)" facility and "Electromagnetic Isotope Separator" in the country, in view of their increasing requirements and applications in life-sciences for societal benefit.

M.S. Seshshayee (NCBS, Bengaluru), Dr. Vinai K. Rai (PRL, Ahmadabad) and Prof. S.K. Aggarwal (BARC, Mumbai).

There were 9 Contributed Papers presented as posters in two Poster Sessions. During the Discussion Meet, a panel discussion was also held on the topic "Future of AMS in India". Prof. S. Kailas, Dr. Amit Roy, Prof. S.K. Aggarwal, Dr. Ravi Prasad, Dr. R.K. Choudhary



Group photograph of the delegates of ISMAS / DM / HEAL 2011

BARC Transfers Technologies

Quadrupole mass Spectrometer

Dr. R. K. Sinha, Director, BARC and Director, Knowledge Management Group, BARC has executed the agreement for transfer of know how of "Quadrupole Mass Spectrometer" technology developed by the Technical Physics Division, BARC to M/s Mechvac Fabricators (I) Pvt. Ltd., Navi Mumbai on 17th March, 2011.

The Quadrupole Mass Spectrometer is a versatile analytical instrument capable of compositional analysis of gases and volatile liquids. It consists of an Electron Impact ion source, quadrupole mass analyzer and a detector. QMS is a compact, reliable and low cost analytical tool. It can analyse a mass range of 1-300 amu with a resolution of 1 amu, which is adjustable.

Its applications include Gas compositional analysis from chemical and physical processes, residual gas

analysis in Ultra High Vacuum systems, molecular weight and structural identifications in many organic compounds. It can also be coupled to Gas Chromatograph or a liquid Chromatograph for varied analytical problems.

Dip n Drink Membrane Pouch

The technology of "Dip N Drink Membrane Pouch" developed by the Desalination Division, BARC has been transferred to M/s Superklean Environmental Engineers Pvt. Ltd., Mumbai on 6th May, 2011.

The Dip N Drink Membrane Pouch technology is based on the principle of osmosis, which is a natural phenomenon and is deployed for the preparation of membrane pouch for getting sterile drinkable solution from contaminated water using membranes. A low molecular weight, water soluble, non-toxic substance having a high osmotic pressure are filled inside the Membrane Pouch. Based on



Photograph taken during the occasion of signing the agreement with M/s Mechvac Fabricators (I) Pvt. Ltd., Navi Mumbai. Seen sitting Dr. R. K. Sinha, Director, BARC (centre); Mr. R. K. Chodankar (fourth from left), Chairman & MD, M/s Mechvac Fabricators (I) Pvt. Ltd. and other dignitaries seen sitting from left of Dr. R. K. Sinha, Director, BARC are : Dr. S. Kailas, Director, PG; Dr. S. K. Gupta, Head, TPD; Mr. A.M. Patankar, Head, TT&CD; Mr. V.Nataraju, SO/G and from right of Mr. R. K. Chodankar, Chairman & MD, M/s Mechvac are: Mr. Prashant Deshmukh, Director & Technical Head, M/s Mechvac; Mr. Bharat Yelkar, Vice President, Technical, M/s Mechvac ; Smt. S. Mule, SO/G, TT&CD.

Standing 1st row from R-L: Mr. T.K.Saha, SO/G, Head, DCS; Mr. M. Gopalakrishna, SO/G, Head, VIS; Mr. K.A. Jadhav, SO/D; Mr. Milind M Gulhane, SO/F; Mr. A.M. Kasbekar, SO/F; Smt Manjiri M Pande, SO/G, Head, RFSS; Mr. J. K. Misra, SO/D; Smt. Nivedita Ved, SO/F all from TPD & Mr. T. H. Salunke, SA/E, TT&CD. Second row from R-L: Mr. Ravisankar, SO/F, Mr. S.S.Misra, SO/D; Mr. Prakash Abichandani, SO/F all from TPD.



Photograph taken during the occasion of signing the agreement with M/s Superklean Environmental Engineers Pvt. Ltd.(SEEPL), Mumbai. Seen Dr. S.K. Ghosh, Director, ChEG, BARC(fourth from right); Shri Kishor Gandhi, Managing Director, SEEPL(fifth from right) and other dignitaries seen from R – L are: Shri A.M. Patankar, Head, TT&CD; Shri Amit Gandhi, Director,(SEEPL); Dr. P.K. Tewari, Head, DD, BARC and from L – R are: Smt. S.Mule, SO/G, TT&CD, BARC; Shri N.T. Kamber, T/F, DD, BARC; ; Shri G.R.Ursal, SO/E; TT&CD, BARC; Shri Vijay Shah, Technical Director, SEEPL; Dr. A.K.Ghosh, SO/F, DD, BARC and Shri V. S. Somarajan, So/D, DD, BARC.

the osmosis process, only pure water permeates through the semi permeable membrane and dissolves the nutrient salts filled in the pouches.

Its application is especially useful during disaster management/emergency conditions like floods, Tsunami, earthquakes etc. It can also be used at remote locations where natural water sources are contaminated.

The Technology Transfer and Collaboration Division coordinated all activities related to the transfer of these technologies, such as preparation of Technical documents including brochure, leaflet, Technology Transfer Document, Advertisement of the technology, Evaluation of party, Technology Transfer Agreement preparation and the signing of Agreement.

National Fire Service Week: a report

Every year, 14th April is observed as National Fire Service Day. On this day in the year 1944, fire service personnel displayed exemplary courage and devotion to duty as they fought the huge fire that had erupted, following an explosion on a Ship S.S. Fort Sticken berthed at the docks of Mumbai Port Trust. Many fire fighters lost their lives, leaving behind their names etched in the minds of mumbaites forever.

Several programmes were organized by the Fire Service Section, BARC during the Fire Service Week April 14 - April 20, 2011 to create fire safety awareness among employees in BARC Trombay and Anushaktinagar.

On behalf of BARC Mr. A.K. Tandle, Chief Fire Officer placed a wreath on 14.4.2011 at the memorials erected on the grounds of Mumbai Port Trust and at the headquarters of Mumbai Fire Brigade, Byculla.

On 15th April, 2011, Mr. N.D. Sharma, Controller, BARC was offered pin flag to inaugurate fire service week fund raising campaign. Pin flag was also offered to Mr. S.K. Ghosh, Director, Chem. Engg. Group and Mr. Hanmanth Rao, Head, ChED. On 16th April, 2011, two crews from BARC Fire Service Section participated in the Tactical Medley Drill Competition organized by the Govt. of Maharashtra at Cross Maidan, Dhobi Talao, Mumbai. 21 teams belonging to various organization viz. Mumbai Fire Brigade, BPCIL, Mumbai Port Trust, State Fire Training Centre participated in competition. Team 'B' of FSS, BARC was awarded the 4th prize and in individual ladder drill 3rd and 7th prizes. On the 17th April, a live Fire Fighting and Rescue Demonstration was organized at the Takshshila Ground for the benefit of Anushaktinagar residents. Around 350 residents witnessed the programme. On 18th April, 2011, Director, BARC Dr. R.K. Sinha was offered a pin flag on occasion of fire service week observance and



Mr. A.K. Tandle, CFO BARC welcoming Dr. R.K. Sinha, Director, BARC on the occasion of fund raising campaign " in BARC

fund raising campaign. Director in his message spoke about improvement in communication which was essential between the caller and the responder involving Anushaktinagar residential colony too. He said it was the need of the hour that information regarding operation of different types of fire extinguishers, mode of fire fighting, fire emergency telephone numbers of contact persons during emergency be available on BARC Web Site, along with Standing Fire order and do's and don'ts in case of emergency. On 18th April, 2011, an event on Fire Fighting Equipment Exhibition with fire fighting and rescue demonstration was organized at Hall-2.

On the 19th April, arrangements were made to screen a film on "Preventing Accident at the Home" through cable network at Anushaktinagar. A prize distribution function was also arranged on the 19th, at the Fire

Station, BARC, for winners of various competitions conducted among BARC fire service personnel. Mr. S.K. Ghosh, Director, ChEG & Mr. Hanmanth Rao, Head, ChED distributed the prizes to the winners of the various competitions.

This year Rs. 21,407/-only were collected through cash donations during Fire Service Week observance 2011.

On 20th April 2011, the Fire Service Week celebrations culminated with a ceremonial parade at Cross Maidan, Dhobi Talao, in which the contingent from BARC's Fire Service personnel also participated along with Emergency Rescue Tender & Equipment. Hon'ble His Excellency, Mr. K. Shankarnarayan the Governor of Maharashtra was the Chief Guest.

4th ISEAC International Discussion Meet on Electrochemistry and its Applications (DM-ISEAC-2011): a report

As part of the celebration of the International Year of Chemistry (IYC) declared by IUPAC, the Indian Society for ElectroAnalytical Chemistry (ISEAC) organized the 4th ISEAC International Discussion Meet on Electrochemistry and its Applications (DM-ISEAC-2011) at Mascot Hotel, Thiruvananthapuram, Kerala, India, during February 7-10, 2011. The Discussion Meet was aimed at updating the scientists with the latest developments in the field of electrochemistry and exposing the participants to new developments in electroanalytical techniques and innumerable applications of electrochemistry in different areas.

The Meet was inaugurated on February 7, 2011 by Prof. V. Venugopal, Director, Radiochemistry and Isotope Group, BARC. He spoke about the

contributions of Electrochemistry in the nuclear power program of our country and also formally released the Bound Volume containing manuscripts of invited talks and contributed papers. He lauded the focused activities of ISEAC in promoting the potential applications of electrochemistry. Prof. Tushi Mukherjee, Director, Chemistry Group, BARC gave the presidential address highlighting the importance of electrochemistry and its applications in different areas like nuclear science and technology, material science, biological and health sciences, environmental science etc. He formally released the first issue of the Bulletin of ISEAC acronymed "HEAT". Prof. S.K. Aggarwal, President, ISEAC, Chairman, Organising Committee, welcomed the delegates and briefed about the activities of ISEAC, since its inception in October 2003. Mr. Saurav K.



Dr. V. Venugopal, Director, Radiochemistry & Isotope Group, BARC delivering the inaugural address. Others on the dias (from left to right) are Ms. Ruma Gupta (Secretary, Organizing committee), Dr. S.K. Aggarwal (Chairman, Organizing committee), Dr. T. Mukherjee (Director, Chemistry Group) and Mr. Saurav K. Guin (Convener, Organizing Committee).

Guin, Convener, Organising Committee, from Fuel Chemistry Division, BARC gave a summary about the various topics of both fundamental and applied Electrochemistry, to be discussed during the Meet. Ms. Ruma Gupta, Secretary, Organising Committee, proposed a vote of thanks.

About 90 participants including 6 overseas speakers participated in the Discussion meet. There were 19 Invited talks, 3 Short lectures, 23 Contributed papers and 10 Research Scholars' papers presented during the Discussion Meet. All the contributions were spread over 11 Technical Sessions. Invited speakers from overseas included Prof. Christopher M.A. Brett (Portugal), Prof. (Ms) A.M. Oliveira-Brett (Portugal), Prof. John T. Luong (Canada), Prof. Serge Cosnier (France), Prof. Craig E. Banks (UK) and Prof. Emilia Kirowa-Eisner (Israel). The speakers from India included Prof. Sampath (IISc, Bangalore), Prof. J.B. Fernandes (Goa), Prof. K. Girish Kumar (Kochi), Prof. Sushil K. Mittal (Patiala), Prof. P.P. Patil (Jalgaon), Dr. T. Prasada Rao (Trivandrum), Dr. B.P. Reddy (IGCAR, Kalpakkam), Dr. M. V. Sangaranarayanan (IIT Madras), Dr. Ida Tiwari (BHU, Varanasi). Three short lectures were delivered by Dr. T. Ramakrishnappa (UK), Mr. Jonathan P. Metters (UK) and Binh T.T. Nguyen (Singapore). The scientific

topics included the Role of electrochemistry in bio-sensors, Room temperature ionic liquids, screen printed electrodes, electrochemical synthesis of nano-particles and carbon nanotubes, graphene as potential electrode material, carbon paste electrodes, micro-electrodes, conducting polymers, pyrochemical reprocessing of metallic fuels, spectroelectrochemistry, and impedance spectroscopy. Besides, there were tutorial lectures on bioelectrochemistry and development of electrochemical biosensors and electrocatalysis.

There was a panel discussion on the recent focus and challenges in Electrochemistry and allied topics. A special session on practical demonstrations of different electroanalytical techniques by M/s Sinsil International, Mumbai was conducted on the first day of the Discussion Meet.

Merit certificates and cash awards were given to the authors of the best poster presentations. Dr. S.K. Aggarwal, Chairman, DM-ISEAC-2011, thanked all the delegates from India and Overseas, as well as sponsors, for their keen interest during the deliberations of the Discussion Meet. In particular, he thanked BRNS (DAE), CSIR and DRDO, ISE for co-sponsoring the Discussion Meet.



Experts on the dais for Panel Discussion in DM-ISEAC-2011. From left to right : Dr. S.K. Aggarwal (India), Prof. A.M. Oliveira-Brett (Portugal), Prof. Christopher M.A. Brett (Portugal), Prof. Craig E. Banks (UK), Prof. P.P. Patil (India), Dr. T. Prasada Rao (India).

Theme Meeting on Very High Energy Gamma Ray Astronomy: a report

A Theme Meeting on Very High Energy Gamma Ray Astronomy was organized by the Astrophysical Sciences Division, during March 28-30, 2011 at the Mt. Abu based Gamma-Ray Observatory. The meeting comprised 15 invited talks highlighting various aspects of progress in the field during the last decade and 17 contributed presentations on various technical issues. Recently detected galactic and extragalactic gamma-ray sources were also discussed in detail. 41 scientists from Tata Institute of Fundamental Research, Physical Research

Laboratory, Indian Institute of Astrophysics, Saha Institute of Nuclear Physics and Bhabha Atomic Research Centre, participated in the theme meeting. Discussion during the meeting led to a consensus on strengthening collaboration among various institutes in the country with interest in high energy astrophysics. Need for participation through international collaboration in the setting up of the Cherenkov Telescope Array was also discussed in detail. The meeting was fully funded by the Board of Research in Nuclear Sciences.



Group photograph of the participants of the Theme Meeting

Theme Meeting on “Thermo-mechanical Deformation of Pressure Tube under Accident Condition”: a report

A one-day Theme Meeting on “Thermo-mechanical Deformation of Pressure Tube (PT) under Accident Condition”, was organised by the Reactor Safety Division, BARC on 3rd June 2011 and was held at the Multipurpose Hall, BARC Guest House, Anushaktinagar. The meeting was sponsored by BRNS.

The Thermo-mechanical Deformation prediction of PT is an important aspect of Design Basis Events analysis like Loss of Coolant Accident with unavailability of Emergency Core Cooling System for Pressurised Heavy Water Reactor (PHWR). Pressure tube deforms plastically due to internal pressure and fuel weight during a postulated event scenario. Both ballooning and sagging of PT can lead to pressure tube and calandria tube contact. Further rise in the PT temperature can get arrested as moderator will act as a large heat sink. It is required to predict Pressure Tube (PT) deformation, as it controls the heat flow to moderator. A series of experiments have been carried out, to study the sagging and ballooning behaviour of PT of Indian PHWR, under simulated accident scenario.

The Theme meeting was inaugurated by Shri K. K. Vaze, Associate Director, Reactor Design & Development Group. About 50 participants from BARC, NPCIL, AERB, NFC, IIT Roorkee and Guwahati attended the meeting. There was an invited talk by Shri N. Saibaba, DCE (ZAF & S), NFC on “Manufacturing process of Indian Pressure Tube”. In this meeting, there were talks by experts on

experimental and analytical aspects of thermo-mechanical deformation of PT, followed by a discussion on round robin exercise problem for PT ballooning. Dr. Ravi Kumar, Professor IIT, Roorkee gave a talk on “PT Sagging and ballooning experiments conducted at IIT, Roorkee. Dr. P. S. Robi, Professor, IIT, Guwahati gave a talk on PT creep correlations being developed at IIT, Guwahati. There were presentations by experts from NPCIL, BARC and AERB on theoretical simulations of PT deformation using in-house codes. There were also presentations by experts from BARC on Tensile Properties of Zr-2.5wt% Nb Pressure Tube alloy at elevated Temperature and on Post Test Microstructure and Chemical analysis study of Pressure Tube.

In the end, Problem definition of Round robin exercise on PT ballooning was presented. In round robin exercise, participants will be required to predict PT ballooning for experiments conducted at 20, 40 and 60 bar pressure using given experimental data (Pressure and temperature along with required properties of Zr-2.5 wt% Nb). The analysis results submitted by the participants will be evaluated with regard to the measured PT deflection. These analyses will be useful to benchmark the numerical codes and analysis procedures, to predict severe accident scenario for PHWR. It is proposed to hold round robin exercise meeting in the month of December 2011. Concluding remarks on the day's proceedings were given by Shri H. S. Kushwaha, former Group Director, HSE&G and Fellow, Raja Ramanna Chair.

Authors' Workshop: a report

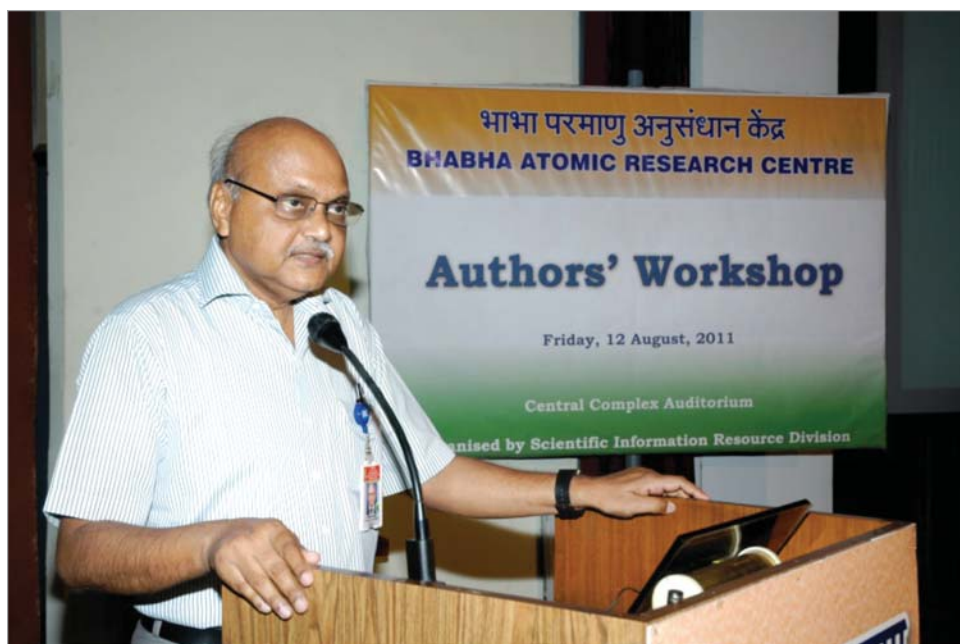
The Scientific Information Resource Division, Bhabha Atomic Research Centre, Mumbai, conducted 'Authors' Workshop' for BARC Scientists and Engineers on 12th August 2011, at the Central Complex Auditorium. There was an overwhelming response as more than 700 scientists and engineers participated in the workshop.

Dr. K. Bhanumurthy, Head, Scientific Information Resource Division, BARC, welcomed the dignitaries and gave a brief introduction about the workshop.

Dr. R. K. Sinha, Director, BARC inaugurated the workshop. Dr. R. K. Sinha in his inaugural address mentioned that this 'Authors' workshop' was very special and different from other workshops conducted by BARC. He called upon the scientists and engineers of BARC, to publish more in high impact journals.

Dr. David Clark, Sr. Vice President, Elsevier, The Netherlands, the Guest Speaker, spoke on various issues involved in scientific publishing in the electronic era. He gave a detailed step-by-step methodology of publishing in scholarly journals. He explained very succinctly, how one could find out the competencies of individual scientists, institutions and countries, through co-citation analysis. He also highlighted the importance of a scientific publication and citations and the indicators like impact factor and H-index. He touched upon various ethical issues involved in scientific publication such as plagiarism and plagiarism detection tools. Both the talk and the question-answer session were well received.

The function concluded with a vote of thanks by Dr. B. S. Kademani, SIRD.



Inaugural Address by Dr. R. K. Sinha, Director, BARC

Nuclear Energy Awareness & Applications (NEAA-2010) Symposium: a report

A two-day symposium on Nuclear Energy Awareness & Applications was held at BARC Colony, Tarapur during 9-10, October 2010. This was organized by the Bhabha Atomic Research Centre Officer's Association, Tarapur (BARCOAT), in association with the Board of Research in Nuclear Sciences (BRNS). The aim of the symposium was to increase awareness among the general public about the usefulness of nuclear energy. The symposium was attended by more than 400 participants inclusive of local village pramukhs and academicians from schools and colleges in and around Boisar.

The inaugural program began with a welcome address by Shri P. K. Jain, President BARCOAT who said that a symposium of this nature, has been arranged for the first time in the BARC colony at Tarapur premises. The convener of the symposium Dr. Amrit Prakash remarked that the main aim of the symposium was to make the public aware about the usefulness and applications of Nuclear energy. The program was inaugurated by Shri H. S. Kamath, Director, Nuclear Fuels Group. In his inaugural speech, Shri Kamath stressed the need for organizing such symposia. Shri S. Basu, Chief Executive, Nuclear Recycle Board said that it was heartening to see the large number of local public like village pramukhs, principals and teachers of local schools and colleges participating in this symposium, along with the other employees of DAE. Dr. Jose Panakkal, Director, General Services Organization and Head, AFFF stressed the role of BARC Management in organizing such a symposium at Tarapur. Shri R. K. Gargye, Site Director, TMS released the souvenir of the symposium. Shri N. L. Sonar, Shri P. M. Bhave and Shri Parth Sarthi were the other office bearers present on the dais.

The two day symposium was divided into six sessions. The first session gave an overall view of Nuclear energy. Shri S. K. Malhotra, Head, Public Awareness Division acquainted the audience with the public perceptions about nuclear energy.

Dr. Sharad Kale from BARC Mumbai narrated the dreams of Dr. Homi J Bhabha and his speech in Marathi was highly appreciated by everybody. Dr. I.V. Saradhi from EAD, BARC, Mumbai explained about the study carried out for India's electricity demand, carbon emission and the role of nuclear power.

The second session was focused on the use of radiation. Dr. S.F. D'souza, from BARC, Mumbai discussed the contribution of DAE in research and development activities in production of agricultural commodities and their preservation. Dr. A. K. Sharma from BARC, Mumbai narrated the radiation processing of food and allied products. Shri N. L. Sonar from BARC, Tarapur gave a glimpse of Nuclear energy, radiation and his speech was in Marathi. The next session was on the application of nuclear energy for power production. Eminent speakers from NPCIL gave detail description of reactors for the benefit of participants. Shri S. Maske described Boiling Water reactors and Shri D.D. Akre explained about the power production at TAPS 3&4. The second day started with a lecture of Dr. S. K. Jain, CMD, NPCIL, who described the medical applications of Nuclear energy. Dr. Meera Venkatesh, Head, RPhD, gave a very detailed lecture on Radioactivity as a powerful tool in health care. Dr. Amit Abhyankar from RMC, Mumbai acquainted the audience with the basics of nuclear medicine. The next session dealt with different aspects of nuclear energy such as radiation exposure, its limits etc. Shri G. Ganesh from BARC, Tarapur described the risks associated with radiation exposure. Shri A. Ramu from NPCIL, Tarapur explained the quality assurance aspect in nuclear power plants. Dr. Amrit Prakash talked in Hindi about the awareness and application of nuclear energy. There were two contributory papers from Shri U. V. Deokar about online remote radiological monitoring during operation of Advance Vitrification System and Shri R. K. Sah on Nuclear energy and their agricultural applications.

BARC Scientists Honoured

Name of the Scientists : Saurav K. Guin, Jisha S. Pillai, Rohan Phatak and Suresh K. Aggarwal
Fuel Chemistry Division, RC&IG, BARC

Title of the Paper : Effect of Stabilizing Agent on electrocrystallization of Silver :
 A Mechanistic Study

Award : Best Poster Award

Presented at : 4th ISEAC International Discussion Meet on Electrochemistry and its
 Applications (DM-ISEAC-2011) held at Thiruvananthapuram, Kerala,
 India, during February 7-10, 2011.

Name of the Scientists : Ruma Gupta, Saurav K. Guin and Suresh K. Aggarwal
Fuel Chemistry Division, RC&IG, BARC

Title of the Paper : A Systematic Study on the Electrocatalysis Mechanism of Fe(III)/Fe(II)
 Redox Reaction Mediated by Polyaniline Coated Platinum Electrode

Award : Best Oral Presentation Award

Presented at : 4th ISEAC International Discussion Meet on Electrochemistry and its
 Applications (DM-ISEAC-2011) held at Thiruvananthapuram, Kerala,
 India, during February 7-10, 2011.

Name of the Scientist : Dr. S. K. Sikka
DAE Homi Bhabha Chair Professor

Award : Prof. Meghnad Saha Memorial Lecture Award (2011)

Awarded by : National Academy of Sciences, India



Ashoka Tree

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