रिएक्टर परियोजना वर्ग के साथ उच्च प्रभाव वाले पदार्थ का तालमेल

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High Impact Materials Synergy with Reactor Projects Group

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The Reactor Projects Group, BARC is engaged in design, development, construction and operation of pressurised water reactor based plants. Indigenisation and self-reliance have been our core philosophies and our development efforts invariably emanated from these. Our resolute partnership with Materials Group ensured excellent outcome in all these efforts.

Recently, we had completed development of technology for industrial scale production of special grade low alloy steel forgings (christened APURVA) meant for manufacturing of reactor pressure vessel (RPV) for the Indian PWR programme viz. APURVA was the result of a decade-long collective multidisciplinary collaborative R&D efforts undertaken at BARC in partnership with a domestic industrial partner. Qualification of the final forgings and evolving of the manufacturing technology were the major milestones of this task. As part of the acceptance committee of the material developed, Dr R. Tiwari's thorough review of the test results of APURVA lead to its eventual certification for pressure vessel applications. During the development of APURVA we were faced with the challenge of bringing out its performance under irradiation environment. Towards this Dr. Tewari initiated a test program involving proton irradiation of APURVA samples at VECC Kolkata followed by post irradiation examination. Results of the above studies on APURVA samples revealed its remarkable properties in comparison with a similar imported popular low alloy steel grade. Dr. Tiwari's untiring support and guidance were crucial in reinforcing confidence in APURVA as an indigenous alternative for pressure vessel steel.

Dr. Raghvendra Tewari has also been guiding the team, with members from MG, PG, RDDG and RPG, which undertook development of stainless steel–titanium alloy diffusion bonded tubular adaptors. Under his leadership, the metallurgical team successfully executed a pilot comprehensive development programme involving 50 trial joints, culminating in the establishment of optimized bonding specifications. He supervised various metallurgical evaluations including determination of high-temperature mechanical properties of the alloys through hot-compression testing, metallographic examination of the Ti–SS interface, optical micrographs for groove-filling assessment, characterization of intermetallics and diffusion zones, SEM-based estimation of intermetallic layer thickness, EDS elemental mapping, EPMA diffusion profiling, and microhardness measurements across the interface to benchmark joint quality. His technical guidance during the review process played a pivotal role in finalizing the diffusion bonding parameters. Following successful pilot development, the process was scaled-up for bulk production. Dr. Tewari continued to mentor and guide the metallurgical activities, enabling timely batch-wise microstructural evaluation and microhardness qualification to ensure consistent production quality in this phase as well.

RPG was tasked with development of nickel-based clad material (with a composition of 42%Cr, 56%Ni,1% Mo) capable of superior corrosion resistance and high residual irradiation ductility. This task was realised with the involvement of MG and Nuclear Fuels Complex Hyderabad. MG under the guidance of Dr. Tewari optimised extrusion parameters such as strain-rate and temperature through dilatometry studies and process parameters w.r.t annealing and study of micro-structure by SEM, TEM, precipitate sizes, density of precipitates, grain size etc. as well. Extensive comparison of the final micro-structure with the reference samples was carried out by MG resulting in its eventual certification for reactor use.

Titanium alloy tubes and structural materials are the invariable choice in tubular heat exchangers subjected to aggressive seawater environment. Indigenous production of these tubes was essential to facilitate expansion of the domestic PWR programme. Hence, development of titan-24 (typical composition Al 1.8-2.5%, Zr 2-3%) was progressed with RPG with MG's deep involvement in association with MIDHANI and NFC. MG was responsible for optimization alloy melting techniques to yield desired composition with tight control of impurity levels at MIDHANI. Also crucial were the evolution of pass schedules, annealing temperature range, micro-structure assessment by SEM, TEM etc. This was followed by an extensive corrosion study in autoclave to quantify oxidation kinetics and hydrogen pick-up. Comparison of the final micro-structure with the reference samples and certification of the material developed for the intended application was accomplished by colleagues at MG under Dr. Tewari's mentorship.

In order to ensure longer service life of shut-off rods of the reactor MG developed a special boron alloy capable of withstanding high temperatures and irradiation environment. Dr. Tewari established an in-house production facility for this material at MG to ensure availability of this material in line with the project schedule.

With the recent launching of indigenous small modular reactor programme by the Department, it was recognised that in-core structures including control rods guide tubes need to be designed with Zr-Sn-Nb-Fe which is capable of providing longer service life with minimum distortion in neutron irradiation environment. Development of this material was co-ordinated by NFC in association with RPG and MG. During this optimization of parameters for extrusion, beta quenching, annealing and pass schedules followed by study of micro-structure by techniques such as optical microscopy, SEM, TEM, EBSD XRF ascertain microstructure properties like composition, grain size, phase distribution, texture, hydride orientation, secondary phase properties (composition, size distribution, particle density) were scrupulously carried out MG team. This material was recently launched for industrial scale production by NFC.

Dr. Tewari leaves behind a strong legacy of scientific discipline, mentoring, and leadership that has materially resulted in the realization of several technologies for multiple projects of national importance. RPG stands deeply indebted to him.