



IIM @ 75 – MONTHLY WEBINAR SERIES (IIM PLATINUM JUBILEE YEAR CELEBRATIONS)

Webinar on

***Improved Materials & Fabrication Technologies for the
Indian Fast Breeder Reactor and
Advanced Ultra Super Critical Power Plant Programmes***



Dr. Arun Kumar Bhaduri

***Distinguished Scientist & Director
Indira Gandhi Centre for Atomic Research***

**16 April 2021 (Friday)
Time: 15:00 to 16:30 hrs**

Webex Meeting ID: 184 977 6201 | Password: iimPJY16april

<https://iimkalpakkam.webex.com/iimkalpakkam/onstage/g.php?MTID=e07c62474b95e0b725efcdf2bc8396d9b>

Organized by
Indian Institute of Metals, Kalpakkam Chapter
Indira Gandhi Centre for Atomic Research
Kalpakkam, Tamil Nadu

IIM Kalpakkam Chapter
IIM @ 75 – MONTHLY WEBINAR SERIES
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PROGRAMME

Date : 16 April 2021 (Friday)	
Venue : IGCAR, Kalpakkam over IIM-KC Webex	
Time : 15:00 to 16:30 hrs	
Inaugural Address	Dr. Shaju K. Albert <i>Outstanding Scientist & Director MMG & MSG, IGCAR</i>
Presidential Address	Professor. Amol Gokhale <i>President, IIM</i>
About IIM Platinum Jubilee Webinar Series	Dr. R. Balamuralikrishnan <i>Convener, IIM Platinum Jubilee Monthly Webinar Series</i>
Address by Chief Guest	Dr. Srikumar Banerjee <i>Chancellor, Homi Bhabha National Institute, Mumbai Homi Bhabha Chair Professor, BARC, Mumbai</i>
Introducing Speaker	Dr. Divakar R <i>Outstanding Scientist & AD, MEG Chairman, IIM Kalpakkam Chapter</i>
IIM Platinum Jubilee Webinar	Dr. Arun Kumar Bhaduri <i>Distinguished Scientist & Director Indira Gandhi Centre for Atomic Research Kalpakkam</i>
<i>Improved Materials & Fabrication Technologies for the Indian Fast Breeder Reactor and Advanced Ultra Super Critical Power Plant Programmes</i>	
Vote of thanks	Dr. V. Karthik <i>Secretary. IIM Kalpakkam Chapter</i>

Webinar Platform: CISCO Webex Events

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Dr. Arun Kumar Bhaduri
Distinguished Scientist & Director
Indira Gandhi Centre for Atomic Research
Kalpakkam

Dr. Arun Kumar Bhaduri, a graduate and Ph.D. in Metallurgical Engineering from Indian Institute of Technology, Kharagpur, joined Department of Atomic Energy in 1983. He is with Metallurgy and Materials Group at Indira Gandhi Centre for Atomic Research, Kalpakkam since 1984, where he is presently Distinguished Scientist and Director since July 2016.

Dr. Bhaduri is also a Senior Professor, Homi Bhabha National Institute (University). He received Research Fellowship from Alexander von Humboldt Foundation, Germany in 1994 for a 2-year post-doctoral research at University of Stuttgart, Germany. He pilots the design and technology development of sodium-cooled fast reactors and its associated fuel cycle for the second stage of India's nuclear power programme, and anchors the development of materials and their fabrication technologies for Indian programmes on sodium-cooled fast reactors, fusion reactors and advanced ultra supercritical thermal power. He specializes in the field of materials joining, and has to his credit more than 270 journal publications, 410 conference presentations and 2 international patents.

Dr. Bhaduri is Fellow of Indian National Academy of Engineering, Indian Institute of Metals and Indian Institute of Welding. Some of his notable recognitions include: Doctor of Science (2017), Jadavpur University, Kolkata; Distinguished Alumnus Award (2017), IIT Kharagpur; Jaeger Lecture Award (2017), International Institute of Welding; GD Birla Gold Medal (2017), Indian Institute of Metals; Carl von Bach Commemorative Medal (2016), MPA University of Stuttgart, Germany; VASVIK Award (2005), Vividhlaxi Audyogik Samshodhan Vikas Kendra, Mumbai; DAE Group Achievement Awards (2006–2016) 12 times, including 4 times as Group Leader; National Metallurgists' Day Metallurgist of the Year Award (2003), Ministry of Steel; DAE Homi Bhabha Science & Technology Award (2002). He has been an elected member of the Board of Directors of the International Institute of Welding (2016–2019), and President of The Indian Institute of Welding (2017–2019).

Improved Materials & Fabrication Technologies for the Indian Fast Breeder Reactor and Advanced Ultra Super Critical Power Plant Programmes

Dr. Arun Kumar Bhaduri

Director, Indira Gandhi Centre for Atomic Research, Kalpakkam

Abstract

As India is making best efforts to reduce carbon emission from power plants, there is a focussed interest in adopting Fast Breeder Reactor (FBR) technology for nuclear and Advanced Ultra Super Critical (AUSC) technology for fossil power plants for production of power. This has necessitated indigenous development of improved materials and associated joining technologies for fabrication of components for FBRs and AUSC plants. IGCAR is responsible for development of these materials and welding technologies for Indian FBR programme and is closely working with BHEL and NTPC as partners in AUSC consortium set up by Government of India for India's AUSC mission project to build an 800MW AUSC power plant. In the FBR programme, the efforts are to improve the structural materials already chosen for Prototype Fast Breeder Reactor (PFBR) to further enhance the fuel efficiency and the design life of reactor components. In the AUSC mission programme, the focus is on indigenous development of India-specific materials that can operate at service temperatures up to 700°C and 300 bar steam pressure.

For PFBR, 15Cr-15Ni-2Mo-Ti austenitic stainless steel (SS), Alloy D9 is chosen as the material for fuel clad tube, 316L(N) SS (maximum nitrogen content of 0.08 wt.%) for most of the reactor structures and Grade 91 ferritic steel for steam generators. For the future FBRs, it is proposed to use Alloy D9I (a modified version of Alloy D9 with controlled addition of silicon and phosphorus) in place of Alloy D9 to improve the radiation swelling resistance, 316L(N) SS with enhanced nitrogen content of 0.12 wt.% in place of 316L(N) SS to improve high temperature mechanical properties of structural materials; and modified 9Cr-1Mo steel with controlled addition of boron and nitrogen, in place of Grade 91 steel to improve resistance to Type IV cracking of the steam generator structural material. The chemical compositions of Alloy D9I and the high-nitrogen containing 316L(N) SS make them more susceptible to hot cracking than Alloy D9 and 316L(N) SS, respectively, and hence there was a need to study weldability of these steels and develop procedure for welding components made out of them. There was also a need to develop consumables for welding of high-nitrogen 316L(N) SS. All these studies and development activities have been successfully completed leading to the development of procedures for welding of end plug of Alloy D9I clad tube for fuel pin fabrication using both TIG and laser welding processes, as also the procedure for shielded metal arc welding of high-nitrogen containing 316L(N) SS plates and pipes using indigenously developed welding electrodes.

For welding of boron-containing modified 9Cr-1Mo steel, the challenge was to optimize the boron and nitrogen content in the steel to improve the resistance of the steel to Type IV cracking, resulting from the poor creep resistance of the heat affected zone (HAZ). Based on the HAZ simulation followed by creep tests for different heats of this steel with varying boron and nitrogen contents, it has been shown that best resistance for Type IV cracking (i.e. minimum reduction in creep strength of the HAZ of weld joints) is obtained for modified 9Cr-1Mo steel with ~100 ppm of nitrogen and ~100 ppm of boron. Welding consumables containing boron has also been developed to weld this class of steel. Further, Activated Tungsten Inert Gas (A-TIG) welding process, along with activated flux developed in-house, has been successfully implemented on various FBR-related components.

To reduce carbon footprint substantially, India has initiated a national mission programme of design, development and establishment of 800 MWe Advanced Ultra Supercritical (AUSC) power plant having steam parameters of 710°C / 720°C / 310 bar. Materials and fabrication technologies play decisive roles in the success of such mission project. For this purpose, two important India-specific high-temperature tube materials, 304HCu austenitic stainless steel (304HCu SS) and modified Alloy 617M, as also large cylindrical forgings of Alloy 617M of up to 800 mm diameter for turbine rotors have been indigenously developed. For the indigenously developed Alloy 617M and 304HCu SS boiler tubes and procedures for manual welding these tubes (including dissimilar joints between the tubes of these two materials) have been finalized. Welding procedures for automated orbital welding have also been developed. One of the major technology developments for the AUSC project has been the development of procedures for dissimilar welding of turbine rotor. The manufacturer of turbine rotors (BHEL) has never produced welded rotor in the past and even international experience available on welding of turbine rotor is largely confined to welding of rotors made from two different ferritic steels. However, for AUSC power plant rotors, welding of ferritic steel and Alloy 617M rotor is required. IGCAR has established a hot-wire Narrow-Gap TIG (NG-TIG) welding facility for rotor welding and demonstrated successful welding of 200 mm and 400 mm diameter rotors. Based on this experience, a procedure for welding of actual turbine rotor has been finalized and now BHEL has successfully carried out dissimilar rotor welding of 800 mm diameter rotors using an independent rotor welding facility established for manufacture of welded rotors for AUSC power plant project. As per the AUSC turbine design, rotors are solid bars with no provision for providing root purging during welding. A novel procedure for protecting the root of the weld while welding is in progress has been developed by IGCAR and this procedure has been employed successfully while making the full-size rotor welding by BHEL. In addition to developing these technologies for AUSC power plant, IGCAR, in collaboration with MIDHANI Hyderabad, has indigenously developed filler wires for Alloy 617M, 304HCu SS and Alloy 625M (used for turbine casing welding) in spool form so that they can be used for automatic welding.

The details of these developments carried out by IGCAR for both the Indian FBR and AUSC power plant programmes would be discussed.



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