

RESUME

Name: Dr. RAM KUMAR SINGH

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Date of birth: May 17, 1953 **Nationality:** Indian



Interests: Computational Mechanics, Coupled Fluid-Structure-Thermal Interaction, Impact Dynamics, Wave Propagation in Solid and Fluid Media, High Strain Rate Problems, Blast & Combustion Studies, Fracture Mechanics of Quasi Brittle Materials.

Dr. Ram Kumar Singh is an active researcher with over 38 years of experience and has been involved in finite element code development for coupled fluid-structure-thermal interaction problems for nuclear reactor safety and structural integrity issues, experimental stress analysis, nuclear containment structural and thermal hydraulics safety studies, impact and high strain rate problems for soft and hard missiles and wave propagation studies in solid and fluid media. His recent focus has been on containment integrity assessment, hydrogen transport and combustion studies, passive hydrogen recombiner development and hydrogen deflagration and detonation assessment, aerosol transport and tsunami evaluation of Indian coastal nuclear facilities for reactor safety assessment and development of severe accident management guidelines for Indian nuclear power plants and facilities. As Associate Director Reactor Design and Development Group & Head Reactor Safety Division at BARC Trombay, he has supervised a team of over 90 nuclear engineers and scientists for structural mechanics, thermal hydraulics, reliability and safety evaluation of Indian nuclear reactors for design and beyond design basis accidents for external and internal extreme events, which were addressed through plan projects executed under his supervision in addition to the collaborative projects with academic and research institutes.

Dr. R K Singh has guided a large number of Ph D and M Tech students at IITs / IISc and Homi Bhabha National Institute. Dr Singh served as Chairman of International Scientific Committee for 21st International Conference on Structural Mechanics in Reactor Technology (SMiRT-21), and has been the guest editor of the Special Issue of Nuclear Engineering and Design on Selected Papers of SMiRT 21, (Vol. 269, April-2014). He has organized a large number of international and national conferences and has successfully coordinated standard problem and round robin exercises on concurrent computational mechanics / experimental studies related to reactor safety problems.

Dr Singh is a fellow of Indian National Academy of Engineering and member of Indian Nuclear Society, Indian Association for Computational Mechanics and Indian Society for Heat and Mass Transfer. He is recipient of Homi Bhabha Science and Technology Award -2011, BARCOM Group Achievement Award-2011 and Hydrogen Recombiner Development Group Achievement Award-2014 for his distinguished contributions.

Publications International Journals 90, Books 6, International Conferences 230 and National Conferences 99, BARC Reports 34, Restricted Reports 9 & FZK (KIT) Reports 9

Dr. Ram Kumar Singh, Honorary Visiting Professor, Department of Mechanical & Industrial Engineering, Indian Institute of Technology-Roorkee

Major Areas of Specialization

- ✓ nuclear reactor design & development, reactor structural & thermal hydraulics safety & reliability studies
- ✓ computational structural, thermal & fluid mechanics & experimental stress analysis
- ✓ fluid-structure-thermal interaction problems for reactor core components
- ✓ strategic studies, rock dynamics, seismic and blast wave propagation, impact and high strain rate problems, multi-body dynamics for soft and hard missiles
- ✓ hydrogen transport and combustion studies and passive autocatalytic recombiner development & prototyping, severe accident management guideline development for Indian nuclear plants
- ✓ tsunami wave modeling, national warning system and site evaluation of nuclear facilities for extreme events

Employment

Present: Honorary Visiting Professor, Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee, ROORKEE-247667, Uttarakhand, since November 2015

Formerly Employed at **Bhabha Atomic Research Centre (BARC), Trombay, Mumbai-400 085**, since August 1978

Last Post held: Distinguished Scientist, Associate Director, Reactor Design and Development Group / Head Reactor Safety Division, Bhabha Atomic Research Centre, Trombay & Senior Professor Homi Bhabha National Institute, Mumbai, India

Worked as guest scientist at **Institute for Nuclear and Energy Technologies (IKET), Research Centre (Forschungszentrum) - Karlsruhe, GERMANY** during sabbatical period April 2003-March 2004 on Hydrogen Economy Program for Safety Evaluation of Hydrogen Test Cell Structure, BWR Tube Failure Investigation for Hydrogen Detonation Loads and ITER Project Hydrogen Safety Studies

Educational Qualifications:

| Degree | Discipline | Institute/University | Year |
|----------------------|--------------------------------|--------------------------------|-----------|
| B. Sc. (Engineering) | Mechanical Engineering | BIT Sindri (Ranchi University) | 1977 |
| Post Graduate Course | Nuclear/Mechanical Engineering | BARC Trombay Training School | 1977-1978 |
| Ph.D. | Structural Engineering | IIT-Bombay | 1990 |

Ph. D. Thesis Title: “Development of Efficient C⁰ Elements for Two and Three Dimensional Fluid-Structure Interaction Problems”. Finite element program ‘FLUSHEL’ developed during the course of this study cited in database ‘MAKEBASE’ developed by Prof J Mackerle of Linkoping Institute of Technology, Sweden and published in ‘A Handbook of Finite Element Software’.

Fellowships / Awards: Fellow Indian National Academy of Engineering (FNAE), Life Member Indian Association for Computational Mechanics, Indian Nuclear Society and Indian Society for Heat & Mass Transfer. Recipient of Homi Bhabha Science and Technology Award-2011, BARCOM Group Achievement Award-2011 & Hydrogen Recombiner Development Group Achievement Award-2014.

Biography published in “2001 Outstanding Scientists of the 21st Century” by International Biographical Centre Cambridge, England, “Who's Who in the World (18th ed.-2001 & 19th ed.)” and “Who's Who in Science and Engineering (6th ed.-2002-2003)” by Marquis Who's Who Publishers, New Providence, NJ07974 (USA).

Present Activities at IIT-Roorkee (Since Dec 2015)

Lecture Series for M Tech/ Ph D Student for projects / Dissertations on computational mechanics on concurrent relevant topics

Assistance to Faculty Members on Research Projects

Recent Activities (Dec 2012 - Oct 2015):

(i) Coordination of safety and security studies through in-house research projects / plan projects, collaboration with academic, research institutes and technical organizations for Indian Pressurized Heavy Water Reactors of 220/540/700 MWe, VVER – 1000 MWe, forthcoming Pressurized Water Reactor, Advanced Heavy Water Reactor, Compact High Temperature Reactor, operating Research Reactors and other nuclear facilities as per the applicable national / international safety codes and guides to ensure the compliance for the requisite short / long term safety goals. With in-depth knowledge of design code requirements for the qualification of structures, systems and components of nuclear power plants and research reactors expertise services for resolution of critical issues related to its compliance has been provided in the advisory role to Indian regulatory bodies such as Atomic Energy Regulatory Board and BARC Safety Council.

(ii) Preparation of inputs for national response to Convention on Nuclear Safety (CNS), contributions to International Atomic Energy Agency (IAEA) meetings on extreme events namely earthquake, tsunami, external events such as aircraft impact and malevolent acts. Providing expertise services to IAEA conventions, Extra Budgetary Projects, Coordinated Research Projects and standard problem exercises with participation of experts and trained manpower from Reactor Design & Development Group / Reactor Safety Division on various issues. Development of guidelines for Indian plants based on IAEA actions & plans on nuclear safety (Fukushima event related), Fukushima related technical strengthening framework of safety for Indian plants, active role in peer reviews and periodic safety review with different agencies.

(iii) Safety review of Indian reactors in the role of Technical Support Organization (TSO) to Atomic Energy Regulatory Board the requisite support has been provided for generic

reactor safety reviews through trained manpower with expertise in structural, thermal hydraulics and reliability studies for nuclear plants and other nuclear facilities. As Member of various Committees of BARC Safety Council for the review of research reactors and other nuclear facilities, critical issues have been settled to meet the safety compliance with regard to its continued safe operation.

(iv) Coordination of International collaboration in reactor safety and security related studies with OECD-NEA, US-NRC, IRSN, CNS / Organization of international standard problem exercises & round robins for containment integrity, tsunami, seismic PSA, extreme events, reactor core safety, evaluation and review of Severe Accident Management Guideline (SAMG) for Indian Reactors for internal reviews and providing inputs for Convention on Nuclear Safety.

(v) Expertise services for Indian Lead Lithium Cooled Ceramic breeder (LLCB) Test Blanket Module (TBM) design and safety assessment as per design codes such as ASME, RCCMR, ITER-SDC & PED-ESPN. Coordination for the preparation of Preliminary Safety Analysis Report / Conceptual Design Report for Indian Test Blanket Module (TBM) for International Thermonuclear Experimental Reactor (ITER) and response to ITER on the quarries.

(vi) Coordination of theme meetings, workshops and specific project oriented discussion meetings for HRD development to hone the skills of team members of Reactor Safety Division BARC Trombay for the relevant safety and security related studies.

Employment History

Sep 2008 - Nov 2012

Employer: Bhabha Atomic Research Centre Trombay, Mumbai

Description of activities: (i) For the research and development program of containment structural safety evaluation, BARC Containment (BARCOM) Test Model was constructed, commissioned and experiments were conducted under my guidance and supervision for its ultimate load capacity evaluation as a plan project activity. An International Round Robin Analysis for BARCOM with fifteen participants from Austria (1), Brazil (1), Czech Republic (1), Finland (1), France (2), South Korea (2), United Kingdom (3) and India (4) was coordinated for studying its failure modes and to benchmark the inelastic computer codes. A number of pre/post-test meetings / workshops were coordinated with registered participants and other experts. This research project is very relevant for the growth of nuclear power program in the aftermath of Chernobyl and recent Fukushima severe accident events. The developed expertise on the nuclear containment integrity assessment has been internationally recognized and recently Electric de France (EDF) has sought collaborations with our team for the forthcoming French containment ultimate load capacity test program. I initiated air craft impact load and structural reliability evaluation of PHWR/AHWR containment structures and have developed nonlinear static and transient finite element codes for the damage evaluation of the Indian containment structures, which have been benchmarked with experimental results of the international standard problems of Sandia National Laboratory PWR containment model test and Nuclear Energy Agency sponsored impact benchmark tests IRIS-2010/2012.

(ii) For the first time, India hosted Structural Mechanics in Reactor Technology (SMiRT-21) Conference at New Delhi and as Chairman of International Scientific Committee (ISC); I shared the major responsibilities of this prestigious conference very efficiently. I coordinated planning meeting, to review around 700 papers under ten divisions of SMiRT-21 with support from around 40 members of ISC. The five days Conference with 7 keynote & 8 plenary invited lectures from renowned experts and 10 parallel sessions was successfully conducted at New Delhi in Nov 2011 with 650 international participants. In addition, 11 special workshops in SMiRT-21 Conference with contributions from different countries on Fukushima event, Tsunami, Code harmonization, NEA OECD IRIS-2010 benchmark and BARC Containment (BARCOM) Test Model were organized. In view of the relevance of reactor safety issues, Special Workshops specific to extreme events and Fukushima event were additionally included within a short period just before the Conference with intensive coordination with experts from IAEA, OECD-NEA, NRC, IRSN, EDF, CNSC, HSE, other national regulatory organizations from various countries and nuclear companies even though the planning meeting of the Conference was already concluded just a week before the Fukushima event.

(iii) Actively participated in Extra Budgetary Project on tsunami and represented my institute in various IAEA meetings and contributed with my expertise on tsunami assessment of Indian nuclear power plants.

(iv) Execution of plan projects with regard to containment structural and thermal hydraulics safety evaluation, environmental dispersion assessment, fire safety and generic reactor safety assessment which includes collaboration with research, academic and technical organizations.

(v) The preliminary safety report submission to ITER for the safety clearance of Indian Lead Lithium Cooled Ceramic Breeder (LLCB) concept based Test Blanket Module (TBM) design was made.

Apr 2004 - Aug 2008

Employer: Bhabha Atomic Research Centre Trombay, Mumbai

Description of activities: (i) I actively participated in the design and safety evaluation of Indian Test Blanket Module (TBM) for ITER in association with IPR, Gandhinagar and BARC team. The Indian proposal to test the concept of liquid lead-lithium cooled ceramic breeder (LLCB) in ITER port was examined by the team to address the neutronics, thermal hydraulics and mechanical design and safety issues. I was part of the team for obtaining the port allocation for testing the Indian LLCB from ITER Organization and subsequent follow up with ITER in various meetings.

(ii) Significant contributions were made for the simulation of tsunami events with the indigenous finite element code TSUSOL, which was presented in many IAEA meetings, workshops and EBP on tsunami and United States Nuclear Regulatory Commission-Atomic Energy Regulatory Board (USNRC-AERB) bilateral meetings. The tsunami evaluation and coordination with national agencies was carried out to obtain bathymetric and land morphology data and source term evaluation was made for accurate inundation and wave run-up modeling, which were confirmed with on-site observations at Kalpakkam, Tarapur and Vizag. nuclear plant sites in a National Round Robin Analysis coordinated with participants from academic, research and technical organizations. The

tsunami run-up and inundation data generated for the present and future prospective nuclear coastal facilities has been extremely useful for the site evaluation and for evolving and implementing site specific up-gradation measures, besides the development of National Warning System for tsunami.

(iii) Active participation and contributions in USNRC-AERB, OECD-NEA, IRSN-BARC bilateral meetings on generic reactor safety issues, standard problem exercises on containment safety due to its over-pressurization, aircraft impact, fire, thermal hydraulics, regulatory and licensing requirements.

(iv) Coordination in the task force for 540 MWe PHWR containment proof testing and commissioning and containment structural and thermal hydraulic safety evaluation, engineering, commissioning and execution of experiments in the "Containment Studies Facility" for blowdown, helium/hydrogen and aerosol distribution studies.

Apr 2003 - Mar 2004

Employer: IKET- FORSCHUNGSZENTRUM, Karlsruhe (Now KIT) Germany

Description of activities: Hydrogen Combustion and Safety Assessment for Nuclear Reactors, Test Cell, DN-15 Tube for BWR, ITER Vacuum Vessel & other applications (i) Coordination with the institute members, external experts for hydrogen deflagration / detonation experiments. (ii) Transient dynamic analysis / numerical modeling of test cell for hydrogen combustion load and experiments for hydrogen related safety issues and guidance to post-graduate student for hydrogen combustion simulation. (iii) BWR typical tube failure investigation for hydrogen detonation load - analysis and experiments (iv) ITER Vacuum Vessel assessment for hydrogen detonation load.

Aug 2001 - Mar 2003

Employer: Bhabha Atomic Research Centre Trombay, Mumbai

Description of activities:(i) Safety and Security related studies for nuclear containment due to aircraft impact, development of finite element codes for containment ultimate load capacity evaluation, multi-barrier impact assessment, coupled fluid-structure interaction problems. Transient dynamic analysis of nuclear double containment for aircraft impact – it involved force time history generation for various aircrafts and outer & inner containment response evaluation to address major safety and security issues.

(ii) Participation in USNRC-Sandia Lab sponsored round robin on Pre-Stressed Concrete Containment Pressure Vessel (PCCV) Ultimate Load Capacity Assessment– Our results were among the best three predictions and in excellent agreement with experimental results during the pre-test / post-test phases.

(iii) Indian participant for NUPEC, Japan sponsored seismic shear wall round robin – Our results were in excellent agreement and consistent with the experimental test data.

(iv) Significant contributions to the Indian Atomic Energy Regulatory Board (AERB) in role of member from Technical Support Organization (TSO) for review committees, task forces and working groups for Indian nuclear plants on (a) ultimate load capacity assessment of containments of various units, (b) structural and mechanical design of reactor structures, systems and components and (c) specialized courses for human resource development for Indian regulatory body.

(v) Stress analysis of nuclear structures, systems and components & seismic reevaluation.

Aug 1996 - July 2001

Employer: Bhabha Atomic Research Centre Trombay, Mumbai

Description of activities: (i) Simulation of HDR-PWR v.32 test problem for blowdown induced acoustic wave propagation and coupled fluid-structure interaction analysis of TAPS-Boiling Water Reactor core shroud for postulated recirculation pipeline break induced acoustic load.

(ii) Re-engineering, rehabilitation, design and proof testing of Kaiga Nuclear Plant Containment Structure

(iii) Fluid-structure interaction analysis for Combined Calandria Tube / Pressure Tube Failure and evaluation of in-core components for 540 MWe PHWR

(iv) Seismic reevaluation of structures, systems and components, sloshing studies for reactor vessel and internals

(v) Numerical analysis, design and instrumented experimental qualification of nuclear piping and pressure vessel components for 220 MWe PHWR / 540 MWe PHWR during construction, commissioning and operation.

Aug 1978 - July 1996

Employer: Bhabha Atomic Research Centre Trombay, Mumbai

Description of activities: I worked at Bhabha Atomic Research Centre (BARC) Trombay, Mumbai during 1978-1996 in various positions with basic responsibilities for novel finite element code development for structural, thermal and fluid applications, carrying out finite element stress / thermal analyses, experimental stress analysis for the pressure vessel and piping components of nuclear plants / research reactors during its design, commissioning / qualification tests, computer code development for flow and thermal problems with regard to reactor safety evaluation, reactor rehabilitation and its continued safe operation, component failure investigation and root cause analysis, containment design and commissioning after completing my post-graduation in Nuclear-Mechanical Engineering in 1978 from BARC Training School in the following capacities.

Scientific Officer Grade F - Aug 1991 - July 1996

Scientific Officer Grade E - Aug 1986 - July 1991

Scientific Officer Grade D - Aug 1982 - July 1986

Scientific Officer Grade C - Aug 1978 - July 1982

Human Resource Development

1. Delivered courses on computational mathematics, finite element method, plate and shell theory, engineering design, ASME pressure vessel code (section III and Section VIII) design and computational heat transfer and fluid dynamics for mechanical, civil and chemical engineering graduate and postgraduate engineers at B.A.R.C. training school (period 1979-2003). Coordinated courses on Finite Element

Method, Computational Mathematics and Heat Transfer in BARC Training School and industrial courses sponsored by Indian Nuclear Society.

2. Guided Ph. D. / M Tech students at IIT-Bombay, IISc Bangalore and Homi Bhabha National Institute (HBNI) and supervised B Tech and M Tech projects in BARC Training School, IIT-Bombay, Mumbai University. Served as external examiner for M Tech and Ph D theses of IITs and Mumbai University and other National Universities. Senior Professor and recognized guide for Master and Ph D programs in Mechanical/Nuclear Engineering at the Homi Bhabha National Institute, Mumbai and active in the research student mentoring program of the institute.

Industrial Experience

1. Dynamic strain measurement on a synthesis gas compressor casing, fatigue and fracture analysis of the component with recorded strain data. This was a study for a fertilizer industry to investigate the cause of recurring failures of the compressor casing.
2. Strain gauge instrumented burst test of Naphtha storage tank for a petrochemical industry and stress analysis of the tank. The test was conducted on a full size tank as part of an investigation for accident analysis.
3. Static and dynamic strain measurement of a PHWR core internal (inlet manifold) in simulated flow condition. This test was conducted on a model to predict its fatigue behavior in service conditions.
4. Strain gauge instrumented tests of nuclear power plant equipment, piping and supports during installation, initial commissioning and hot conditioning for design qualification.
5. Residual stress evaluation on PHWR pressure tube, calandria tube, pressure vessel, piping, support and mechanical equipment for failure investigation and root cause analysis for evolution of remedial measures.
6. Finite element stress and thermal analysis of nuclear components as per requirements of ASME pressure vessel code. This includes components such as pressure vessels, shell nozzle junction, composite tube sheets and support structures. These studies have been useful during initial design and reengineering of components for nuclear plants.