ISSN 0972-5741 Volume 113 July 2017

IGC Newsletter

IN THIS ISSUE

INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH

newsletter

No. 1
June 1986

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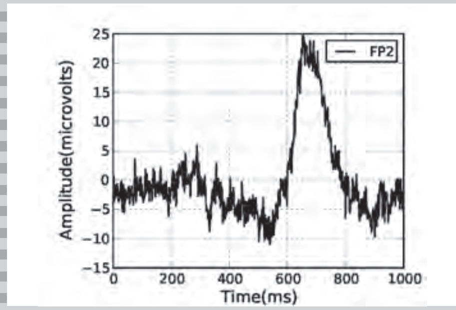
C. V. SUNDARAM, *Director IGC*

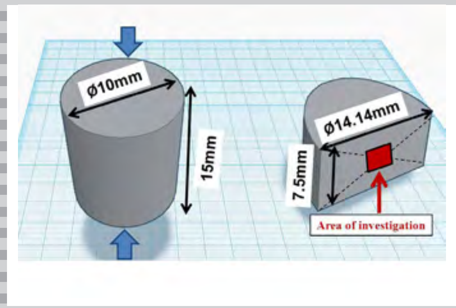
FAST BREEDER TEST REACTOR

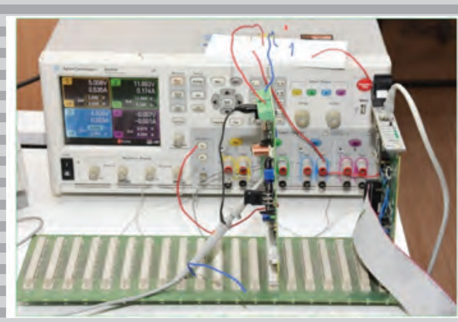
First Phase of Experiments

The Fast Breeder Test Reactor (FBTR) achieved criticality on 18th October 1985 when a self-sustaining fission chain reaction was started in an initial core loading of 22 sub-assemblies with the six control rods raised to near the top of the core. FBTR is a 40 MWt/13 MWe, liquid sodium cooled, mixed plutonium-uranium carbide fuelled, loop type fast reactor. The purpose of constructing FBTR is to use it as an irradiation facility for the development of the

neutrons from the fuel sub-assemblies has been established. The main physics measurements related to control rod worths, peripheral fuel sub-assembly worth and temperature coefficient of feedback reactivity. For the temperature coefficient measurement, the primary sodium temperature was increased in progressive stages to 350°C. Achievement of azimuthal uniformity of the temperature of the reactor vessel at the argon cover gas level initially posed a problem but was subsequently obtained by appropriate 'feed and bleed' of helium and argon gases at different levels.







INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH
http://www.igcar.gov.in/lis/nl113/igc113.pdf

From the Editor

Dear Reader

It is my pleasant privilege to forward a copy of the latest issue of IGC Newsletter (Volume 113, July 2017, issue)

In the first technical article, we have tried elucidating the Genesis of Newsletter, tracing back into history.

In the second technical article Shri Rajesh Patel and colleagues have described their work on the development of a novel technique for suppressing ocular artifacts in single channel electroencephalography data by hybridizing ensemble empirical mode decomposition with principal component analysis.

This issue's young officer's forum features an article by Shri Aashranth on analytical tool to assess dynamic recrystallization and grain growth during hot deformation, namely flow softening index and stabilization stress.

Ms. S. Sravanthi has shared her experience in designing a novel online diagnostic method for detecting relay contact in weld condition.

We are happy to share with you the awards, honors and distinctions earned by our colleagues.

This would be the last issue coming with me as the Chairman of the Editorial committee and I look back with satisfaction for having got an opportunity to be associated with bringing out the newsletter. It has been a learning experience and enhanced my editorial skills. I take this opportunity to thank all the fellow members of the editorial committee for their excellent cooperation. Also thank several of the readers for their suggestions, observations and encouragement.

We look forward to your comments, continued guidance and support.

With my best wishes and personal regards,

Yours sincerely,

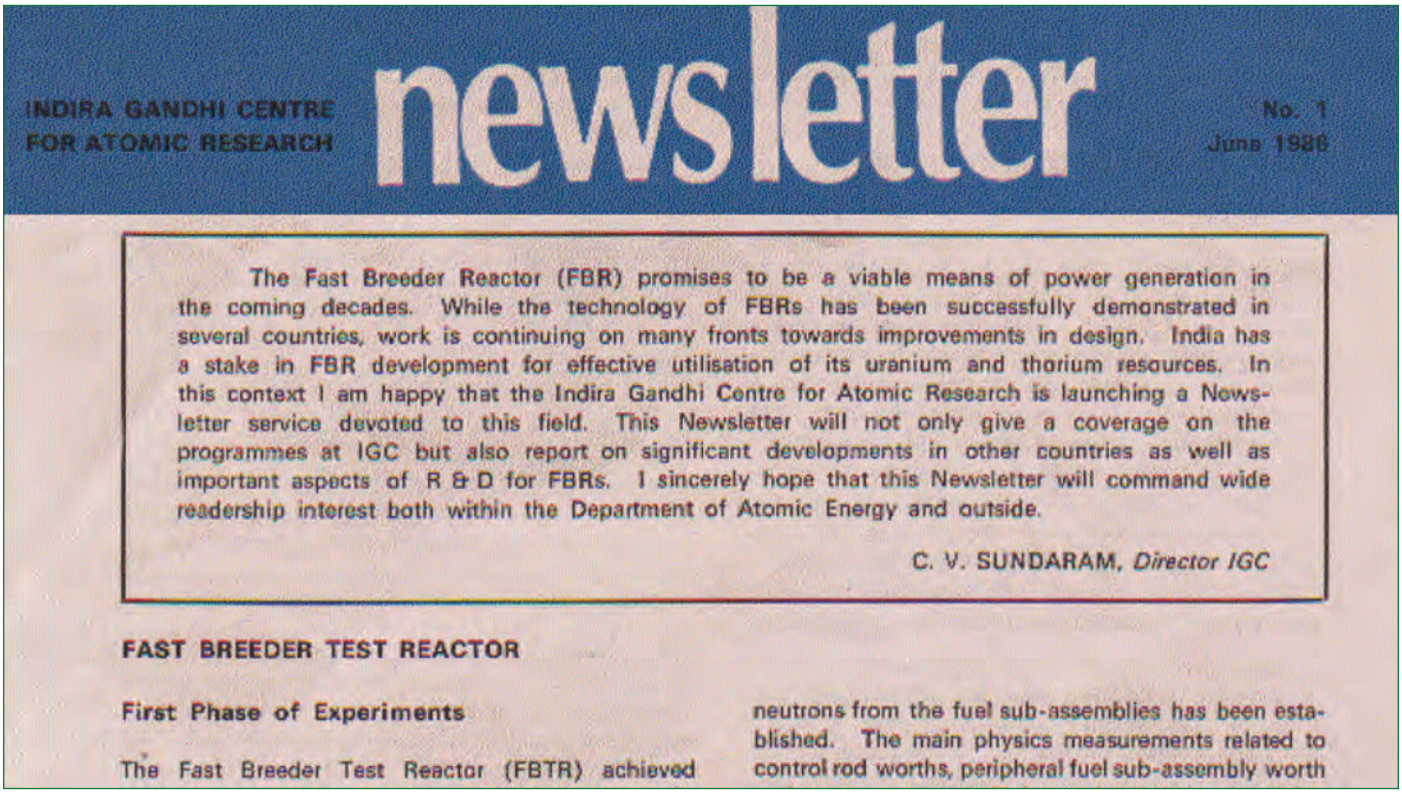
(M. Sai Baba)

Chairman, Editorial Committee, IGC Newsletter

&

Director, Resources Management Group

The Genesis of Newsletter



INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH

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Newsletter first issue

Communicating with the members of the organisation about the developments and progress being made in a formal way, is an important endeavour for motivating the colleagues to continue and enhance their contributions towards achieving the goals of the organisation. Newsletter is one such medium to achieve the objective and create a bond with the organization which one is part of. With research and development activities gearing and gaining the required momentum at our Centre, Late Shri C. V. Sundaram, the then Director of IGCAR initiated the publishing of newsletter way back in the year 1986. He launched the newsletter, with the aim to highlight the R&D programmes at our Centre and also included reports on significant and important developments in other countries on R&D of FBRs. The first issue of the newsletter had reports on core status, structural, coolant and safety of FBTR. Announcements on forthcoming seminars/conferences and highlights of the symposia/seminars which were held at the Centre formed a part of the Newsletter. The editorial team consisted of Dr. Baldev Raj, Dr. P. R. Vasudeva Rao and Dr. S. M. Lee and the first issue was published with four pages. The first fourteen issues (up to Volume 14, September 1989) were published quarterly (March, June, September and December).

After a brief break (for two years) the publication of the Newsletter was resumed under the guidance of Late Dr. Placid Rodriguez when he took charge as Director, in the year 1993. He brought in few changes for enhancing the newsletter for better reach. Drawings and photographs in the articles were introduced for enhancing the presentation and readability. Another unique feature that got

IGC newsletter

Vol No. 15 INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH January 1993

INSIDE THE NEWSLETTER

- MESSAGE
  New year - eve message from Dr Placid Rodriguez, Director, IGCAR to staff of IGCAR
- FAST BREEDER TEST REACTOR (FBTR)
  1992 saw many improvements in the operation of FBTR, and the reactor is now poised to generate steam.
- OUT-OF-PILE SIMULATION
  Laboratory simulation of thermal effects in fast reactor fuels during reactor opeartion
- STRESS CORROSION CRACKING
  Studies in IGCAR have led to an understanding of the incidence of this phenomenon in nuclear systems
- PARTICLE IRRADIATION FACILITY (PIF)
  PIF fully commissioned; declared open for research
- EVENTS
  National Workshop on Chemical Sensors
  Professional Societies at Kalpakkam join to form a Federation (FOPSAK); seminar on Indian Fast Reactor Programme and farewell to Shri S.R.Paranjpe.

The Editorial Committee of IGC Newsletter congratulates Dr Placid Rodriguez on his taking over as Director of IGCAR on 1.12.1992. The Centre looks forward to many achievements under his able and proven leadership. Reproduced below is a message from Dr Placid Rodriguez, which indicates the priorities of the Centre in the years to come.

Message

Dr. Placid Rodriguez, Director, IGCAR

I am writing to wish each and every one of you a very happy, professionally rewarding and meaningful NEW YEAR; a New Year, which let us hope and trust will bring much success and many achievements to our Centre.

The dawn of a New Year, just one month after the commencement of my tenure as Director, is an opportune moment to share with you my thoughts on the plans for the future and my expectations.

I am aware that expectations are very subjective. Last week in Bombay I was told that everyone at Kalpakkam and Trombay are having high expectations and that I would have a tough time living upto these expectations. I have already sensed these expectations which vary from the mundane, the trivial, and the material to those at a higher plane of bringing about an organisational transformation!

I firmly believe that success would come if we define our common expectations in terms of our Mission, Goals and a Vision

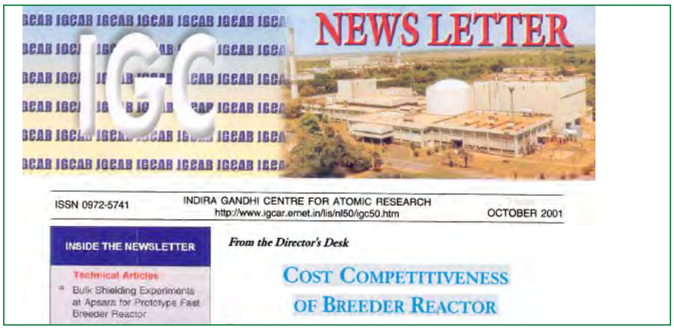
Rechristened as IGC Newsletter

introduced, is the starting of the column called "Placid Thoughts" which was used as a platform to share the ideas of the Director on a wide variety of topics ranging from need of breeder reactors to techniques of project management. In the introductory "Placid thoughts" he discussed about the immediate goals of the Centre for a five year time span i,e. to take FBTR to full power and use it as a test bed for fuels and materials for future FBRs. As a leader he wanted to extend his planning horizon for 15 years and discussed different ways on thinking about the future as "what will happen, what could happen and what we want to happen". The article was concluded by quoting from Gita: "Yoga Karmasu Kausalam" - Yoga is efficiency in action. It was also decided by the then editorial committee, led by Dr. Baldev Raj to include announcements on awards and honors earned by our colleagues. The issues continued to be published quarterly, but with a change of publishing in the month of January, April, July and October. The format and style of publishing continued till volume 46.

After Shri S. B. Bhoje took charge as Director, he renamed the column "Placid Thoughts" as "From the Director's Desk" and from then on it continued to be "From the Director's Desk". This column was used by successive Director's to convey the achievements during the previous year and also the goals set forth for the year ahead, to colleagues through New Year Message. To commemorate the publishing of fifty volumes, the fiftieth volume was assigned ISSN (International Standard Serial Number) by INSDOC (Indian National Scientific Documentation Centre).

Volumes 47-60 were published under the guidance of Shri S. B. Bhoje. In his last issue (Volume 60) "From the Director's Desk" Shri Bhoje gave on overview of fifty years of Department of Atomic Energy.

The sixty first volume (July, 2004) has "From the Director's Desk" by Dr. Baldev Raj, the then Director of IGCAR, where the


IGC NEWS LETTER

ISSN 0972-5741 INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH http://www.igcar.ernet.in/lis/nl50/igc50.htm OCTOBER 2001

INSIDE THE NEWSLETTER

Technical Articles

- Bulk Shielding Experiments at Apsara for Prototype Fast Breeder Reactor

From the Director's Desk

COST COMPETITIVENESS OF BREEDER REACTOR

Placid thoughts renamed as from the Director's desk

story of IGCAR has been documented. The editorial committee always looked for bringing in innovations in the Newsletter. With the setting up of HBNI in the year 2005, a large number of employees/ scholars enrolled for M.Tech and Ph.D. programmes. In order to reflect the changing face of our employees, a new column christened as "Young Officers Forum" was introduced. The "Young Officers Forum" serves as a platform for the young minds to showcase their research work being pursued. The "Young Officers Forum" became a part of Newsletter from the sixty third volume. The first Young officers Forum had two articles from Shri Indranil Banerjee, FRTG and Ms. Annalakshmi, Safety Group. The young officers whose article featured under this column conveyed a sense of pride in their article being part of the Newsletter.

An Editorial Committee with Dr. P.R. Vasudeva Rao as Chairman, constituted by Dr. Baldev Raj, published Volumes 66- 76 (October, 2005 -April, 2008). This committee decided to include various events under "News and Events" from the seventy first volume. Dr. Baldev Raj entrusted the responsibility of publishing the IGC Newsletter to a new committee, with me as the Convener in the year 2008 (Volume 77, July 2008). "Young Researcher's Forum"

Dr. C.N.R. Rao Interacting with Young Ofificer's at IGCAR

Newsletter volume 90 with modified cover page

was introduced giving a forum from young researchers who are pursuing their doctoral studies at IGCAR from the seventy seventh volume. The first article under Young Researcher's forum was by Ms. Judy Gopal on "Microbiology in Metallurgy: Microbiologist in Metallurgy". Delegates/eminent personalities visit our Centre for various purposes like delivering special lectures/ colloquia, reviewing collaborative research etc. The information on dignitaries visiting our Centre was also included from the seventy seventh volume.

Our Department has always paid attention on the flora and fauna in its habitat. Kalpakkam campus has been blessed with a rich heritage of flora and fauna, to reflect the heritage it was decided to highlight the ecological diversity and they became part of the Newsletter in the form of back cover form the ninetieth volume.

Volumes 89-95 (July, 2011 - January 2013) were published when Shri S.C.Chetal, steered the Centre. Volumes 96-105 (April, 2013 - July 2015) were published when Dr. P.R. Vasudeva Rao steered the Centre. A new feature, the interview of an eminent person by a team of young officers formed the ninety seventh issue. We had the privilege of documenting the experience shared by eminent personalities with the young colleagues of the Centre. It gave the young colleagues of the Centre an opportunity to interact with them and the exercise has became a platform for youngsters to learn methods of formal interaction. The luminaries who were interviewed included Dr. R. Chidamabaram, Dr. Anil Kakodkar, Prof. C.N.R.Rao, Dr. Baldev Raj, Dr. Srikumar Banerjee, Dr. G.Venkataraman, Dr. R. A. Mashelkar and Shri S.C. Chetal.

Volumes 106 -108 (October, 2015 - April, 2016) were published when Dr. S.A.V. Satya Murty steered the Centre.

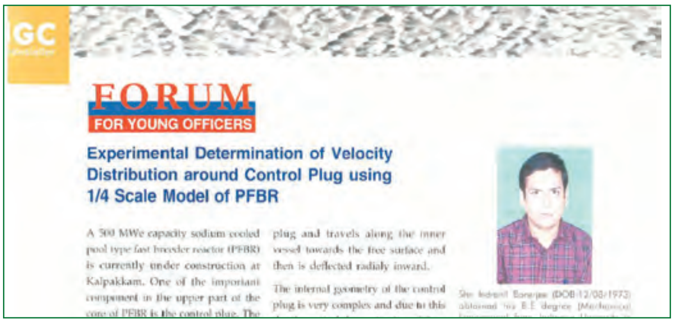
A collage of Newsletter back covers

From volume 109 onwards IGC Newsletter is being guided by Dr. Arun Kumar Bhaduri, the current Director of the Centre.

Till date 42% articles on FBR, 13% on FBTR, 17% on Materials Science programme, 15% on Metallurgy & Materials programme, 6% on Reprocessing and 7% in Chemical Sciences have been published

The Newsletter is sent to several eminent personalities both from India and abroad. Very encouraging and appreciating feedback from the readers has been a tonic to the editorial team to continue to work towards enhancing both the quality of the content and appearance. Personally it has been a very enriching experience being associated in bringing out the Newsletter. Recognizing the change the way information is being communicated, a decision was taken to bring out the newsletter in the digital form.

Reported by
M. Sai Baba and colleagues
Resources Management Group


FORUM
FOR YOUNG OFFICERS

Experimental Determination of Velocity Distribution around Control Plug using 1/4 Scale Model of PFBR

A 500 MWe capacity sodium cooled pool type fast breeder reactor (PFBR) is currently under construction at Kalpakkam. One of the important component in the upper part of the core of PFBR is the control plug. The

plug and travels along the inner vessel towards the free surface and then is deflected radially inward.

The internal geometry of the control plug is very complex and due to this

Introduction of Young Officer's Forum


IGC Newsletter

Young Researcher's FORUM

Microbiology in Metallurgy: Microbiologist in Metallurgy

Background

The official reason why a microbiologist like me had something to do in the metallurgy division of IGCAR for a good long period of five years was only because microbes had something to do with metallurgy. Besides, my interaction with IGCAR as research scholar was made possible because of the metal-microbes interactions, so a big thank you to them. To name a few of the metal-microbe interactions

Ms.Judy Gopal has obtained an interdisciplinary Ph.D. in Microbiology-Metallurgy in the year 2007. During her research work at IGCAR, she also worked on a three year collaborative project with the IISc. Bangalore. She has published 15 papers in national and international journals and has 9 best paper awards to her credit. She is presently working on materials characterization using AFM in CSTD-RPM, MMG and

Introduction of Young Researcher's Forum

Development of Advanced Signal Processing Techniques for Analysis of Biomedical Signals

The measurement of electrical potential distribution on the thoracic surface due to the activity of the cardiac cells of heart is known as electrocardiography (ECG); similarly, the electrical potential distribution on the scalp due to activity of the neurons in the brain is measured in electroencephalography (EEG). The measurement of weak magnetic fields associated with the flow of ionic current inside the human body, requires the use of very sensitive sensors called "superconducting quantum interference devices (SQUIDs)" inside a magnetically shielded facility. Measurement of magnetic signal from heart and brain offers several distinct advantages compared to ECG and EEG, since the measurements are non-contact and are relatively less sensitive to the variations of electrical conductivity of the intervening tissues leading to better source localization accuracy. The key facilities for the measurement of tiny bio-magnetic fields associated with the human heart and the brain have been established at IGCAR, called Magnetocardiogram (MCG) and Magnetoencephalogram (MEG) respectively. Several clinical studies have been conducted in the context of MCG in collaboration with hospitals, highlighting the superiority of MCG signals over ECG in a variety of cardiac dysfunctions.

EEG and MEG signals often have interference by other biological signals of non-cerebral origin such as heart, eye-blink, etc.; these parasitic signals pose a serious problem in analysing the recorded EEG/MEG activity. Signals associated with eye blinks, termed as ocular artifact, are orders of magnitude larger than electric potentials/magnetic field generated on the scalp because of cortical activity. Hence it is very important to detect and suppress this unavoidable artifact before analyzing the EEG/MEG data. In the present work, the artifact signal related to eye blink is first identified automatically and then suppressed by the proposed method, which in principle could also be extended to MEG.

Automatic detection of the EEG signal contaminated due to eye-blink based on statistical properties of the signal

Manual detection of the EEG data segments contaminated by ocular artifacts is a laborious and time-consuming task. To resolve this issue, we have proposed and used the metrics such as variance and absolute value of skewness for identification of the ocular artifact, if present, in each epoched data segment of one second duration. The eye-blinks are higher in amplitude than the EEG signals; hence, the contaminated EEG data segments are expected to show higher variance compared to the uncontaminated segments and similarly, a higher absolute value of skewness in a particular data segment is expected to indicate the presence of the eye-blinks or other artifacts such as muscle activity. Using these metrics, our detailed studies have shown that the success rate is as high as 88% for the automatic detection of ocular artifacts in the EEG recordings, consisting of the EEG data recorded on 20 different subjects.

Automatic suppression of ocular artifact using single channel EEG

A number of different techniques like regression based approach, principal component analysis (PCA), independent component analysis (ICA) and wavelet transform based methods have been suggested in the literature to eliminate the relatively common ocular artifacts from EEG. These methodologies though removes the ocular artifact, they either suppress the actual signals of interest or distort the original signals. Hence we have proposed a method based on ensemble empirical mode decomposition (EEMD).

Recently, a non-parametric technique called empirical mode decomposition (EMD) has been suggested to analyse the data, by decomposing the signal into a number of elementary amplitude and frequency modulated zero mean signals referred to as intrinsic mode functions (IMFs). Empirical mode decomposition has the distinct advantage that it relys only on a set of predefined basis functions and derives the basis functions adaptively from the data set itself. The instantaneous frequency via Hilbert Transform admits of a physical significance only for mono-component signals. This is taken into consideration in empirical mode decomposition while deriving the intrinsic mode functions. Intrinsic mode functions are required to satisfy two conditions to be mono-component, which are as follows:

i) Symmetric upper/lower envelopes, which result into zero mean.

ii) The number of zero-crossings and extrema that are either equal or differ at most by exactly one.

Intrinsic mode functions satisfying the above conditions ensure narrowband signal and convey physically meaningful information. The empirical mode decomposition algorithm applied to a given data x(t) for deriving the intrinsic mode functions is defined in the following way:

i). All the local maxima and minima are identified and they are connected by a cubic spline to form an upper and a lower envelope.

ii). The mean of the upper and lower envelope $d_1(t)$ is obtained and the difference is calculated.

$$h_1(t) = x(t) - d_1(t)$$

iii). If the difference $h_1(t)$ does not satisfy the intrinsic mode function conditions, above steps (1) and (2) are repeated until the envelopes are symmetric with respect to zero.

iv). The first intrinsic mode function $c_1(t)$ is obtained and the residue is calculated as,

$$r_1(t) = x(t) - c_1(t)$$

v). Now the residue r_1 (t) is treated as the signal and the above steps are repeated to obtain r_2 (t), r_3 (t).... $r_m(t)$.

vi). The above procedure, called the sifting process, stops when the residue $r_m(t)$ is either monotonic or a function with only one extremum.

Original signal can be recovered by adding up all the intrinsic mode functions, obtained from the empirical mode decomposition. This can be represented as,

$$x(t) = \sum_{i=1}^{m-1} c_1(t) + r_m(t)$$

where, $c_i(t)$ is the i^{th} order intrinsic mode functions and $r_m(t)$ is the residue or the last intrinsic mode functions.

In the ensemble empirical mode decomposition approach the finite amplitude of normally distributed white noise is added to the signal in each trial before empirical mode decomposition is performed and the ensemble average is taken. The noise is reduced when sufficient number of trials is averaged, since the noise introduced in each trial is uncorrelated and thus the ensemble mean represents the true signal.

We have developed a novel technique for the suppression of ocular artifacts in single channel EEG data by hybriding ensemble empirical mode decomposition with principal component analysis. In this technique, only those principal components are retained automatically which extract the features corresponding to the ocular artifacts after performing principal component analysis on the intrinsic mode functions obtained by applying ensemble empirical mode decomposition on a single channel signal contaminated by the eye-blinks.

The goal of artifact suppression algorithm is to eliminate the artifact without affecting the brain signals. To quantitatively evaluate the performance of the proposed artifact suppression algorithm with that of the wavelet based approach, the extracted eye-blink peak and the root mean square error are compared. Root mean square error is calculated between the contaminated EEG segment and the cleaned EEG segment after extracting ocular artifact in the time interval where effect of eye-blink is expected to be nearly negligible. Figure 1 shows a section of the time trace from the electrooculography electrode and the corresponding section of the time trace of EEG (contaminated with eye-blink), viz. from the frontal FP2 electrode, which was used for the analysis. The proposed methodology is implemented using freely available and user-friendly Python, which allows more researchers to explore the new and superior methodologies in brain-imaging research by sharing ideas and codes.

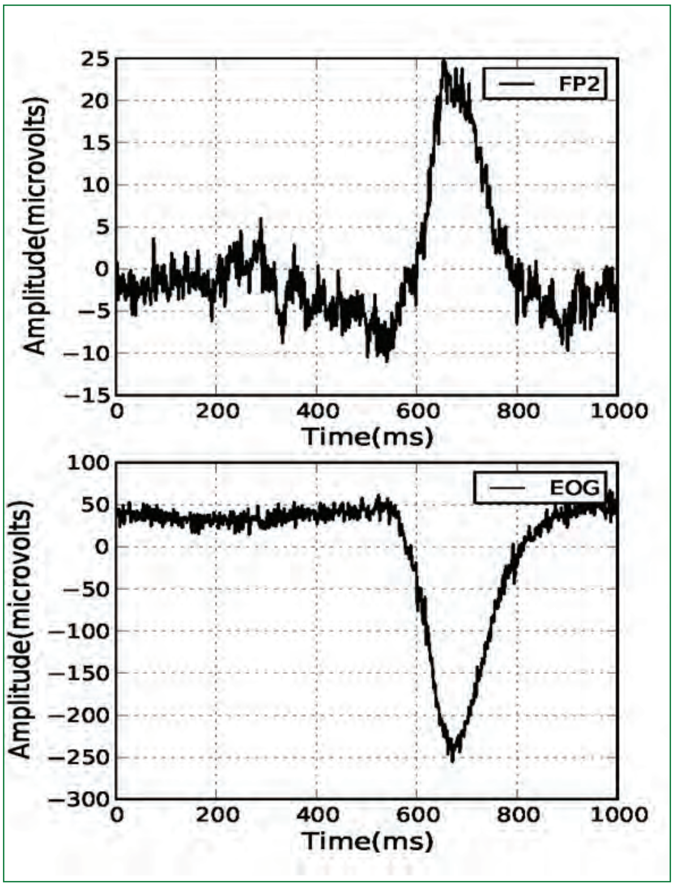


Figure 1: Section of recording from the reference electrooculography (bottom panel) and the corresponding section of the electroencephalography (contaminated with EOG) from the FP2 electrode (top panel).

The applied methodology is summarized in the following steps:

i) After capturing an artifact completely, ensemble empirical mode decomposition was performed on each section of the contaminated EEG signal (FP2) as shown in Figures 2a and 2b to get the intrinsic mode functions. We have determined the principal components and arranged them in decreasing order of their respective variation after performing principal component analysis on the intrinsic mode functions. We reconstructed the signal by progressively increasing the number of principal components retained and calculated root mean square error after adding one more principal component in each step. Parameters of the algorithm (optimum number of principal components to extract ocular artifact features) were systematically varied to investigate the artifact elimination performance in each case. We have compared the root mean square error and the peak amplitude of the extracted eye-blink

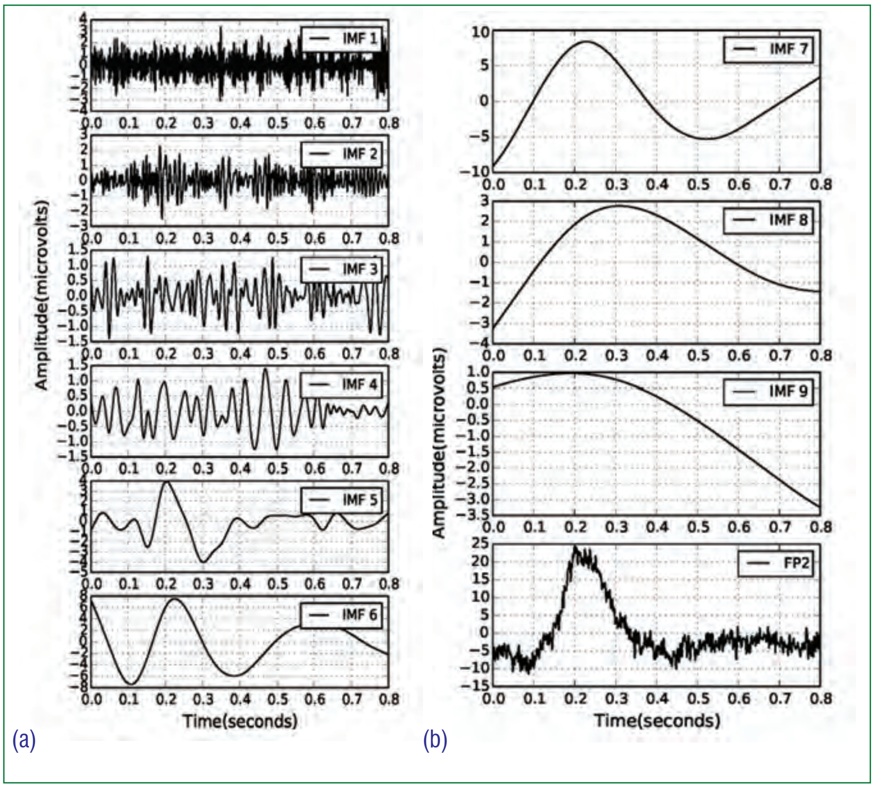


Figure 2: (a) Intrinsic mode functions (1-6) after applying ensemble empirical mode decomposition on the contaminated electroencephalography segment and (b) contaminated electroencephalography segment (bottom trace: FP2) and their intrinsic mode functions (7-9) after applying ensemble empirical mode decomposition

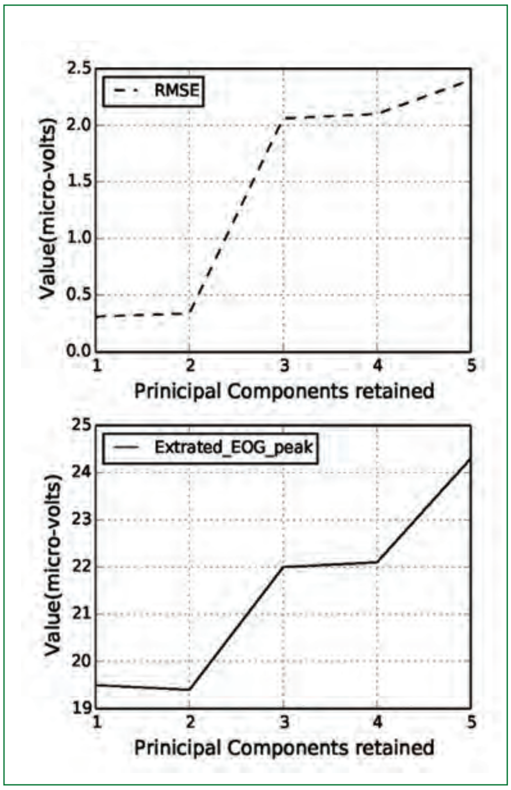


Figure 3: Variation of root mean square error and extracted EOG peak amplitude as a function of number of principal components retained

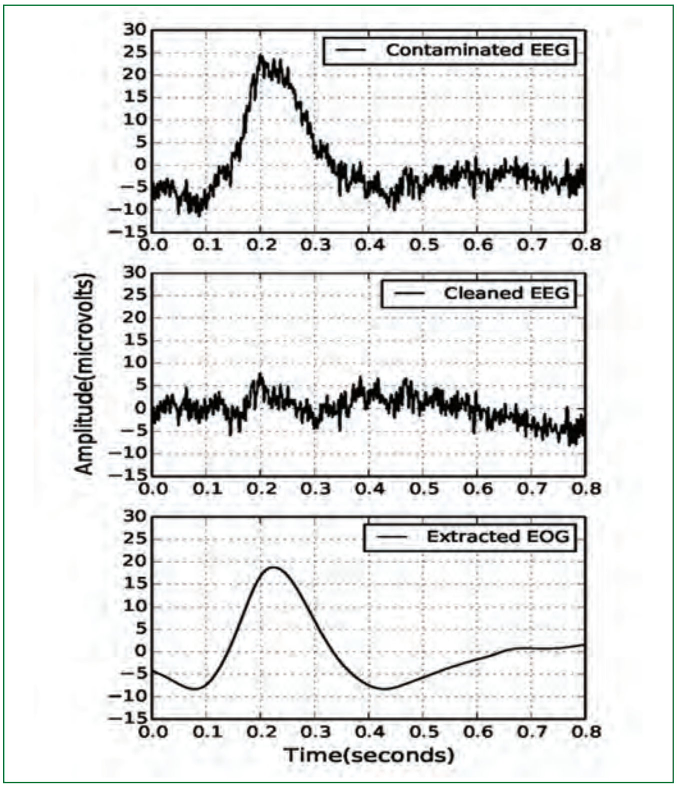


Figure 4: Top: EEG signal contaminated by EOG (FP2), Middle: Cleaned EEG data after elimination of EOG using the proposed method; root mean square error: 0.31, Bottom: EOG artifact extracted from the corresponding contaminated EEG signal.

when the number of principal components retained was varied from 1 to 5 as shown in Figure 3.

ii) Lowest value of the root mean square error was adopted as the criteria for retaining the optimum number of principal components. This was done with a view to extract the features of the eye-blink alone in the retained principal components with little distortion of the brain signal. Figure 4 shows the cleaned and extracted eye-blink using the proposed method from a contaminated EEG segment.

We found that only two or three principal components were sufficient to extract eye-blink features from the entire EEG data of a subject which is contaminated by the eye-blinks. We have presented a new approach for the elimination of the eye-blink artifacts by using the principal component analysis with the ensemble empirical mode decomposition, capable of eliminating the eye-blink artifacts from the measured EEG without using an auxiliary reference eye-blink electrode, while causing significantly lower distortion in the EEG data compared to the conventional methods.

Reported by
Rajesh Patel and colleagues
Materials Science Group

Young Officer's FORUM

Analytical Tools to Assess Dynamic Recrystallization and Grain Growth during Hot Deformation

Shri B. Aashranth completed his B.Tech. in Metallurgical and Materials Engineering from NITK Surathkal in 2013. He is from 57th batch OCES, BARC Training School, Mumbai. Presently he is working as Scientific Officer in Metallurgy and Materials Group. He completed his M. Tech. in Metallurgy from Homi Bhabha National Institute in 2015 and is working in the areas of hot deformation, dynamic recrystallization and microstructural evolution.

The vast majority of metallic objects used by us, whether in the domestic or engineering domain, have undergone hot deformation at some stage. Therefore, hot deformation, i.e. deformation at high temperatures where metallic materials 'dynamically' soften by recrystallization, is all-pervasive. The process assumes special importance when large engineering components are involved. In the context of the second stage of the Indian nuclear programme extensive studies on hot deformation are carried out on various structural alloys to be used in different reactor components.

These studies show that optimization of hot deformation is inherently a multi-scale problem; external process parameters such as temperature, strain level and strain rate simultaneously influence macro-scale properties (stress-strain curves and deformed specimen geometry) and micro-scale features (grain size and morphology). To address these different effects, it is necessary to first understand the underlying microstructural phenomena such as work hardening (WH), dynamic recrystallization (DRX) and grain growth, and then relate the same to flow behavior. For such relations to be of practical value, they must be robust, simple and easy to apply outside the laboratory.

These guidelines are used to develop two analytical tools for assessing the important processes of dynamic recrystallization and grain growth during hot deformation. Though these tools are developed primarily for the potential future cladding and wrapper material IFAC-1 SS, the same concepts can be applied to other materials. Some efforts in this direction are described in the latter part of this article.

In these studies, cylindrical specimens of IFAC-1 SS are isothermally deformed to nominal strain of 50% in uniaxial compression. Deformation is carried out at temperatures 1173–1473 K in steps of 50 K, at deformation rates(true strain rates) in the range 0.01-100 s^{-1}. Post-deformation, specimens are water-quenched to retain the high temperature microstructure. The deformation load-stroke data is converted to true stress-true strain curves for understanding the flow behavior. The deformed specimens are cut into sections, as schematically shown in Figure 1, and prepared for optical and electron microscopy.

At the micro-scale, the average grain size (D_{avg}) is widely used to study hot working. D_{avg} is primarily determined by the occurrence and kinetics of dynamic recrystallization. To accurately estimate D_{avg} values, 800-1000 individual grains are measured in each microstructure. Analysis reveals that D_{avg} is a strong, non-linear

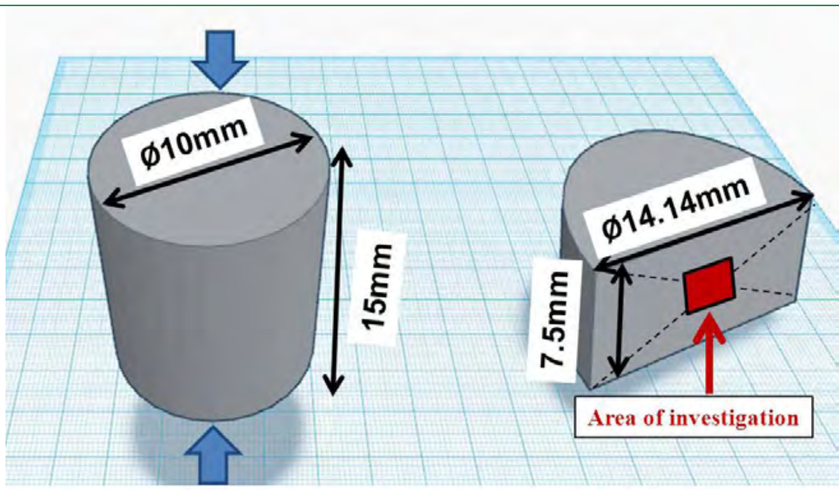


Figure 1: Schematic diagram of specimen geometry and area of metallographic investigation (a) undeformed specimen and (b) deformed cut section

function of deformation temperature (T), but shows erratic variation with strain rate.

On the other hand, stress-strain curves are the most fundamental manifestation of hot working at the macro-scale. The trend observed is that flow stress (σ) at a given strain decreases with increasing temperature (T), as shown in Figure 2, and increases with increasing strain rate. At each deformation condition, the flow stress peaks at an intermediate strain, followed by a gradual reduction and ultimate saturation. This type of stress-strain curve is associated with dynamic recrystallization and grain refinement. Since dynamic recrystallization - a softening process- is common across the two length scales, an index which represents softening of the material during deformation is sought after.

To construct this index, the σ–T characteristics at different strain rates are examined. To make the index non-dimensional and facilitate comparison of different materials at different deformation conditions, σ is normalized with adiabatic bulk modulus (G) and T is normalised with melting point (T_m).

It is found that the softening characteristic is best described by $(\sigma/G)^{\bar{m}}$-T/T_m relations, where $\bar{m}$ is an experimental constants. The equivalent softening index, named the 'Flow Softening Index' (FSI) is given by the slope of this relation, i.e.:

$$\text{FSI} = -(\sigma/G)^{(\bar{m}-1)}[\partial(\sigma/G)/\partial(T/T_m)]_{\varepsilon,\dot{\varepsilon},T}$$

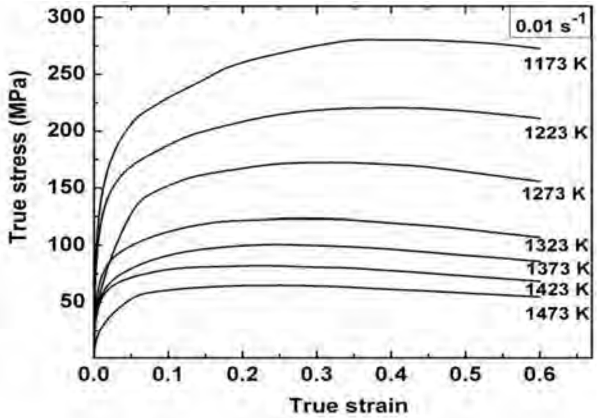


Figure 2: True stress – true strain curves of IFAC-1 SS at different temperatures with $\dot{\varepsilon} = 0.01$s^{-1}

For IFAC-1 SS, the flow softening index is found to range from 4.7 to 0.6; higher values indicate high work hardening (WH), intermediate values indicate dynamic recrystallization and low values indicate grain growth.

The flow softening index initially decreases with an increase in temperature and strain rate. Work-hardening of the alloy reduces and low angle grain boundaries (LAGB) are replaced by high angle grain boundaries (HAGB), eventually leading to dynamic recrystallization. With a decrease in strain rate, the fine grains of dynamic recrystallization grow by the grain growth process.

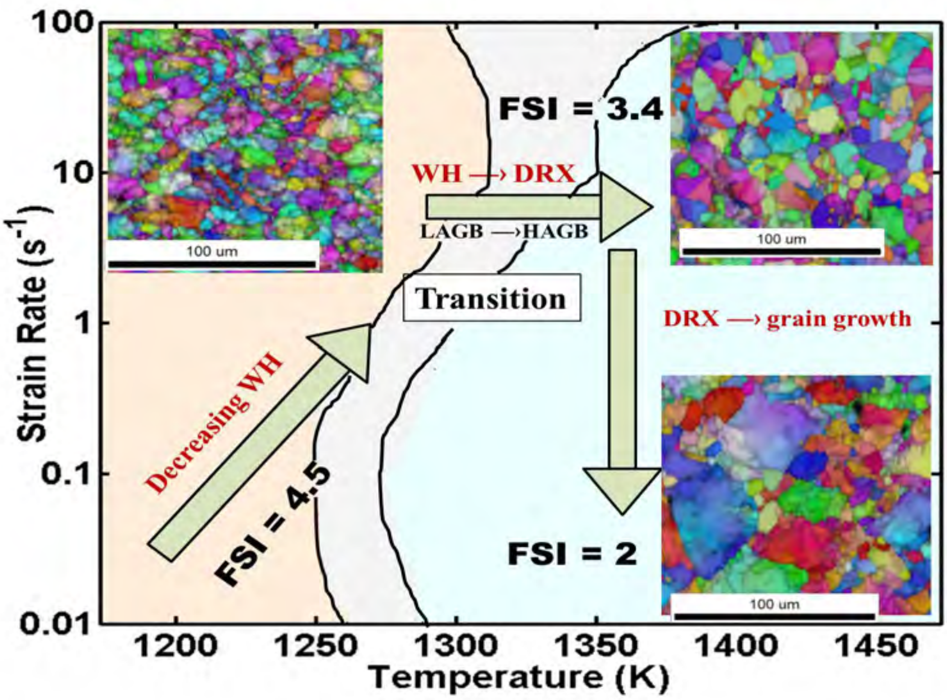


Figure 3: Flow softening index with corresponding microstructural phenomena

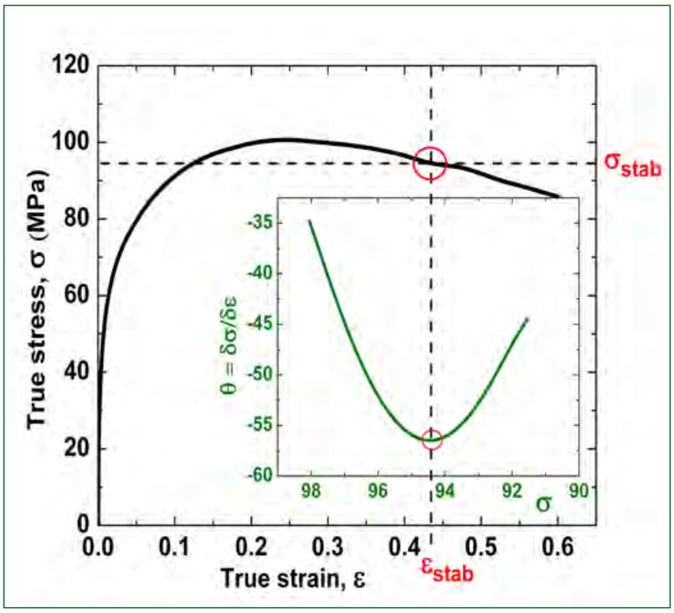


Figure 4: Determination of stabilisation stress (σ_{stab})

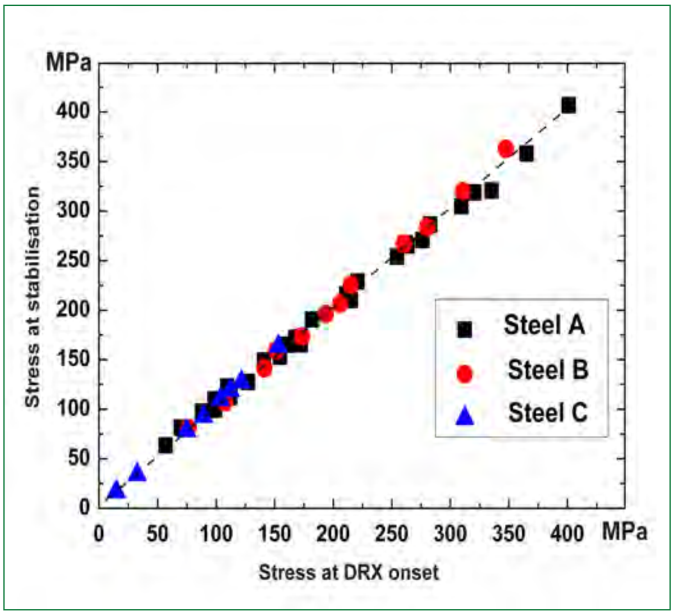


Figure 5: Relation between dynamic recrystallization onset and stabilization stress ($R^2 = 0.996$)

These changes are illustrated by the map and electron back scatter diffraction (EBSD) images shown in Figure 3. Each value of flow softening index is quantitatively associated with a particular D_{avg} value and grain size distribution. Since a given flow softening index can be achieved using different temperature-strain rate combinations, the hot working process can be tailored to attain a desired microstructure. Further, the inherent simplicity of flow softening index and its validity across a wide range of hot deformation conditions make it a suitable analytical tool to assess microstructural evolution.

A conceptual difference exists between the initiation of dynamic recrystallization and initiation of grain growth during hot working; dynamic recrystallization requires the attainment of a critical stress, or the microstructural accumulation of a certain amount of energy. Once this energy is accumulated, the dynamic recrystallization process rapidly modifies the microstructure so as to reduce energy. On the other hand, grain growth is less effective in reducing stored energy. Therefore, grain growth can predominate only when the dynamic recrystallization process and the flow stress falls to a particular level.

In view of this difference, theoretical considerations and experimental observations have been combined to formulate an expression for the stress at which grain growth starts dominating the hot deformation process. This stress is termed the 'stabilisation' stress (σ_{stab}) to distinguish it from the 'critical' stress where dynamic recrystallization initiates. It is emphasized that the determination of σ_{stab}, i.e. the delineation of dynamic recrystallization and grain growth, is done simply on the basis of the stress-strain curve, as shown in Figure 4, and is thus a practical option for metal forming optimization.

These stresses corresponding to initiation of dynamic recrystallization and stabilisation are shown to bear a fixed, linear, material independent relation. This relation is shown for three PFBR materials in Figure 5. The Steel A is an austenitic stainless steel to be used in the future clad and wrapper material (IFAC-1 SS), Steel B is a ferritic-martensitic steel used as steam generator structural material (P91) and Steel C is the carbon steel chosen for PFBR roof slab (A48P2 steel).

These three materials represent significant metallurgical diversity, but can still be examined using the tool of stabilization stress. This can lead to better hot deformation process design for obtaining desirable microstructures.

As an example, ongoing studies indicate that process modifications based on stabilisation stress can be used to control grain size in hot deformed IFAC-1 by as much as 50%at the same deformation temperature.

In conclusion, the two analytical tools described in this article, namely flow softening index and stabilisation stress, serve to facilitate the study of hot deformation. In effect, these serve as links between mechanical response to deformation and microstructural evolution. Both tools are robust, simple and can be used for different materials/deformation systems with minor modifications.

Reported by
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Young Researcher's FORUM

A Relay Output Card with Diagnostics for Weld Detection and Reliability Modeling

Ms. S. Sravanthi did her B. Tech from Jawaharlal Nehru Technological University, Anantapur. She joined IGCAR as a Junior Research Fellow in Engineering Sciences in August 2012 and carried out her doctoral work in the Electronics and Instrumentation Group. Her doctoral thesis is on "An investigation into the fail safeness of safety critical Instrumentation & Control in a sodium cooled Fast Reactor"

In a nuclear power plant, electromagnetic (EM) relays are often used to communicate trip signal to voting logic. Relays are kept energized during normal operation and de-energized upon a shutdown demand to achieve a fail-safe behavior. Electromagnetic relays are preferred over solid-state relays since they predominantly fail to close. However, contact welding in electromagnetic relays cannot be ruled out.

Safety criteria for nuclear power plant demand online testing of protection systems from sensor to final control elements. Currently to detect relay failure, periodic opening of electromagnetic relay in one of the channels in a triple redundant architecture (operating in two out of three mode) is done and contact status is checked using an auxiliary contact.

Most of the methods are offline and use contact side measurement (healthiness is verified by opening the relay contact) for diagnostics of contact weld failure. Hence, it is desirable to develop a new method to detect electromagnetic relay contact weld failure online.

Based on detailed investigation of electromagnetic relay, a novel online diagnostic method is proposed in this study by interpreting coil current decay curve. It detects relay contact in weld condition without disturbing the load attached to the contact. This method is online, continuous, automatic and facilitates simultaneous testing of redundant channels.

During de-energization of a healthy electromagnetic relay, the coil current decay curve takes a characteristic shape as shown in Figure 1(a). It is observed that when contacts get welded, the coil current decay curve follows a distinctly different shape as depicted in Figure 1(b). Coil current decay waveforms are captured across the series resistor in freewheeling diode path.

When de-energization is triggered at t_0, coil current follows as shown in Figure 1. In case of a healthy relay, at time instant t_1, the decay curve starts taking a different locus. This change in decay curve is due to inductance change which in turn is indicative of start of armature detachment. Actual opening process of the relay contact starts after a few ms from t_1 (~1.6 milli second) as depicted in Figure 1(a) with the indication of t_2 in load current.

In case of a welded contact referred in Figure 1(b), there is no change in decay curve. This is because there is no change in L since the armature never detach. Hence, "Absence of a second minimum"

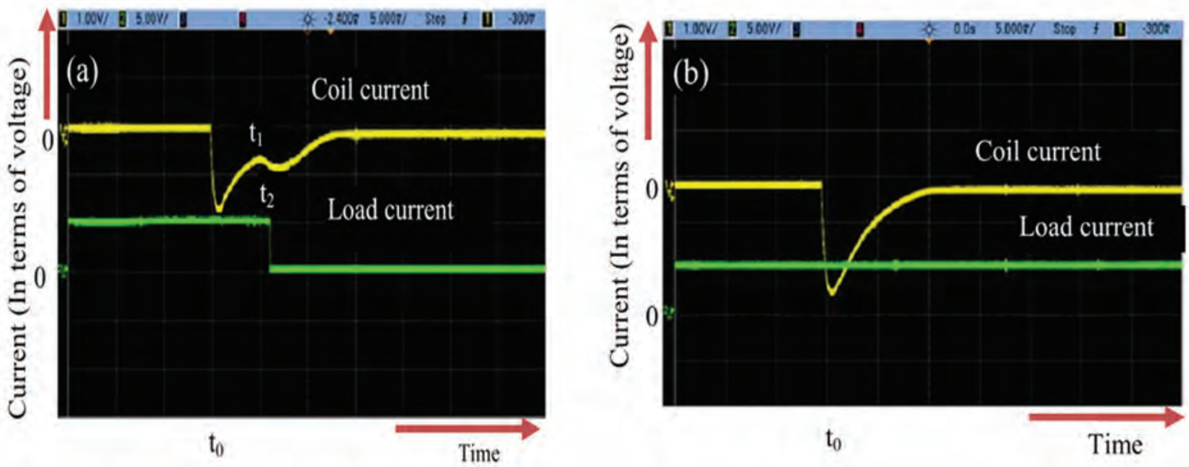


Figure 1: Coil de-energization current decay curve (a) during healthy opening, (b) under welded contacts

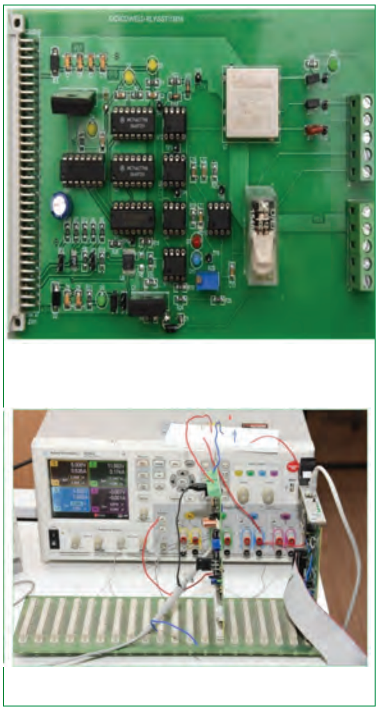


Figure 2: Experimental setup of re-emerging circuit

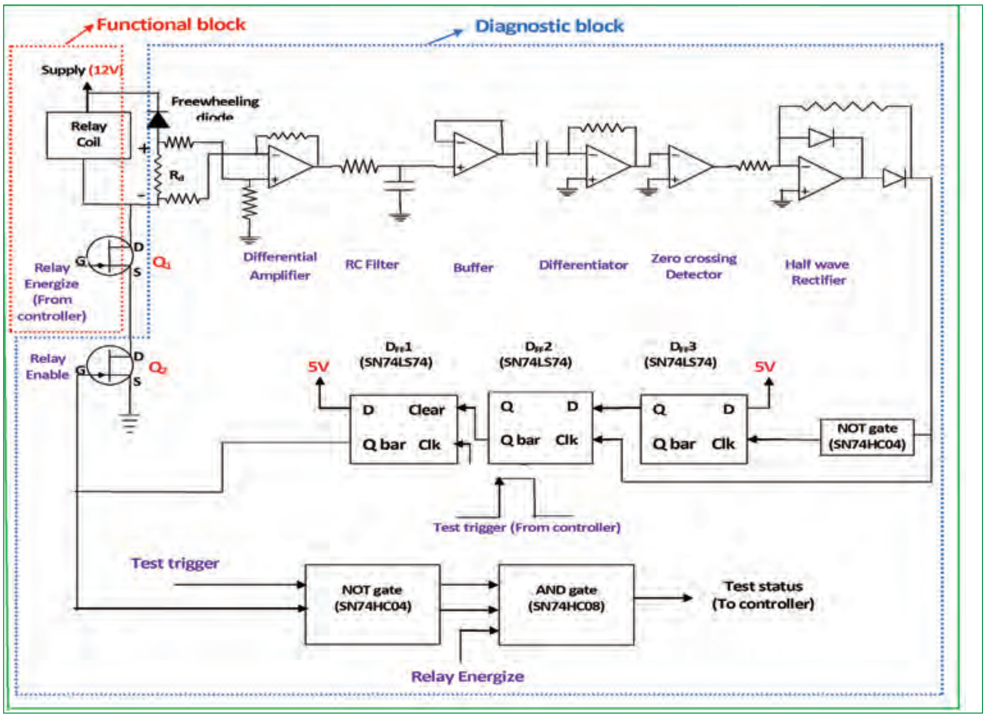


Figure 3: Schematic of relay diagnostic circuitry in ROC

can be used to detect a welded contact. The time between t_1 and t_2 ($\sim$2 ms) can be utilized for re-energizing the coil before the contact starts moving.

A re-energizing circuit is designed for re-energizing a de-energized relay before the contact starts opening. This method is practically demonstrated by using a relay output card (ROC) as shown in Figure 2. Figure 3 shows the simplified schematic of relay weld detection circuit in ROC.

A test signal (TS) is fed to CLK of D-Flip Flop-1 (D_{FF}-1). This triggers $\bar{Q}$ to go low, thus initiating de-energization of the relay shown at t_0. The current decay curve is captured using a differential amplifier. The information embedded in the waveform is extracted using a differentiator followed by a zero crossing detector. Thus, the two local minima express themselves as two short rectangular

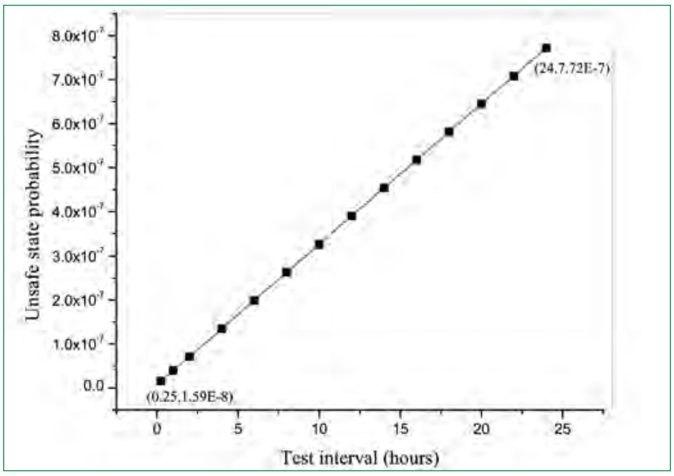


Figure 4: Unsafe state probability variation with test interval

pulses. The second pulse is used to trigger re-energization of the coil by passing through D_{FF}-3 and D_{FF}-2. By this process, the diagnostic information is extracted without any change in load current. Diagnostic circuit will verify whether re-energization of coil has taken place or not. LED will give the indication if test (re-energization) fails.

By deploying this method for online diagnostics; test interval can be drastically reduced. This is because load is not disturbed during the test. Moreover, simultaneous testing of multiple redundant channels is possible. Therefore, by reducing test interval, failure probability can be decreased, which leads to reliability improvement of relay. Markov state space model is established with ISOGRAPH to study reliability improvement.

In general, as part of periodic testing, a relay will be tested every shift (8 hours). This is because relay contacts open during the test, and the load is disturbed. Since, the proposed method of weld detection can be online (without opening the contacts), the test interval can be reduced from hours to minutes. Figure 4 shows the comparison of unsafe state probability (steady state) between 24 hours and 15 minutes. This shows that the proposed diagnostic method will significantly reduce the unsafe state probability of system. From the reliability analysis it is also noticed that diagnostic circuit failures have very less significance on the unsafe state probability of the system. It is possible to fix the test interval and proof test interval based on the target unsafe state probability requirement.

Reported by
S. Sravanthi
Electronics and Instrumentation Group

News and Events

Orientation Programme

27 June – 7 July, 2017

Dr. G. Amarendra, Director, Materials Science Group and Metallurgy & Materials Group addressing the participants during the inauguration

Orientation Programme for the directly recruited young officers and officers from Training Schools, who have joined our Department in the recent past, was organized during 27 June – 7 July, 2017. Dr. G. Amarendra, Director, Materials Science Group and Metallurgy & Materials Group inaugurated the programme. This two week programme, was designed to give an overview of the R&D activities of our Centre to the young officers. Each day a senior colleague from the DAE facilities delivered a lecture on the research activities of their Group which was followed by a visit to the respective facility. The officers were also informed about the activities of other DAE units located at Kalpakkam by senior colleagues of the respective Units. Visits were arranged to MAPS, BHAVINI and BARC-Facilities located at Kalpakkam. Interactive sessions were also organized for bringing awareness about Administration, Accounts, Purchase procedures, Rules in Contributory Health Service Scheme, Industrial Safety Practices, Security Procedures and Housing Rules. Officers from BARC Training School, IGCAR joined in the recent past were also invited to participate in this interactive session. The orientation programme concluded with a feedback session from the participants and with a address by Dr. A.K. Bhaduri, Director, IGCAR as a part of the valedictory function.

Reported by M. Sai Baba

Dr. A.K. Bhaduri, Director, IGCAR with the participants during the valedictory function

Best Paper Award

Signal Digitization using Voltage to Frequency Conversion for Wireless Sensor Node

Ms. Donia Maria Denny, Ms. K. Indumathi, Dr. S.Radha, Shri T.S. Shri Krishnan, Ms. Jemimah Ebenezer, Shri R.Jehadeesan

International conference on Recent Trends in Computing Technology (ICRTCT17) held at Bharath University, Selaiyur on 21 April, 2017

Best Paper Award

Creep behaviour of boron added modified 9Cr-1Mo steel weld joint

Shri T. Sakthivel and Dr. K. Laha

National Welding Meet - 2017, Indian Institute of Welding, Bengaluru, 12 - 13 May, 2017

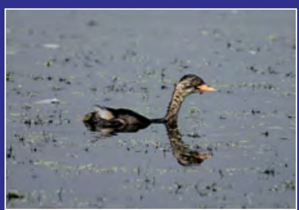
Best Paper Award

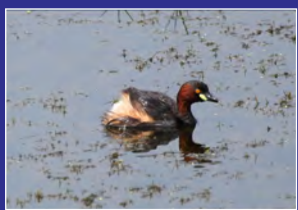
Few of our colleagues participated in the "International Conference on Fast Reactors and Related Fuel Cycle: Next Generation Nuclear Systems for Sustainable Development (FR17)" held at Yekaterinburg, Russian Federation during 26-29 June, 2017.

The following two participants have won the "Young Innovator Challenge Award"

Shri S. Aravindan from RDG for "Development of Reverse Flow Blockage Device for Primary Sodium Pumps of Fast Breeder Reactor"

Shri Balija Sreenivasulu from MC&MFCG for "Development of Tri-iso-Amyl Phosphate (TiAP) based Solvent Extraction Process as an Alternate Method for the Processing of Metallic Alloy Fuels (U-Pu-Zr and UZr)"





Lesser Whistling-duck

Published by Resource Management Group, IGCAR, Kalpakkam-603102