Issue 23 *November 2020*

SFA Newsletter

Seasons Greetings!

About SFA

Objectives

Local centers

Welcome you all to join as members of SFA! Please find the membership form inside; kindly fill in and contact Secretary of SFA through email.

Experts and experiences:

G K Sharma and Anish Kumar, IGCAR, Kalpakkam

Message from our President

Dear readers,

Warm season's greetings! I am happy to find the 23rd issue of SFA Newsletter getting launched coinciding the Diwali festival which the Indian Nation celebrates with much ado!

The global situation regarding COVID-19 is evolving in a rapid manner. While our nation is continuously appealing to take as many precautionary measures as possible in order to reduce transmission of this deadly virus and protect ourselves and associates, I appeal to all of you to remain safe, vigilant and remain resilient and committed to the cause.

This kind of quick adaption is essential and we shall work while balancing our commitment to family, friends, colleagues and society at large. On the industrial front, production and manufacturing activities are slowly catching up and attaining the pre-COVID levels. At This juncture, it is important that proper preventive maintenance of all critical equipment is ensured before re-starting the production activities after confirming to the unlock guidelines.

What we have currently at hand is the time which provides us for "thought-work," which further allows flexible hours, routines and locations more familiar.

While this pandemic has forced us into a challenging new reality, we will continue to publish important research in the area of failure analysis and share what we have learnt. Therefore, I appeal to all members to provide articles for the forthcoming newsletters. We wish to hear our experts through their articles, comments and what not! Together we will get through this and continue to create a sustainable world.

Dr. B P C Rao
President, SFA

Best wishes to all the readers!

B P C Rao
PRESIDENT, SFA

From the Desk of Editors

Dear Readers:

Season's Greetings! You are glancing through the 23rd issue of the Newsletter of Society for Failure Analysis (SFA).

It is essential that we should consciously rejuvenate our SFA activities since the COVID -19 pandemic has brought our regular life to standstill with several restrictions. We have circumvented this in our professional life through video conferencing mode for our interactions.

Meanwhile, for the present issue of our Newsletter, we solicited articles from experts of our country who had worked on many case histories and domain areas of relevance to employ advanced methods to understand the materials in its finer dimensions.

In this respect, Dr. Govind Kumar Sharma and Dr Anish Kumar have contributed an article bringing out the methodology of employing the capability of ultrasonics to measure the grain size in non-equiaxed polygonal metals, dual phase alloys which is an excellent contribution towards development of the Ultrasonic Metallography.

We thank the authors for their contribution which you would find quite interesting to read.

We take this opportunity to appeal to the Indian industry to use SFA as a forum to share their experiences on trouble shooting. A great way to add content to this newsletter is to include a calendar of upcoming events. The details of important forthcoming international and national events are included; so also the books recently published on the topics of the subject.

We value your comments, which really boost our enthusiasm to perform better. Therefore, as always, your views and comments, mailed to param@igcar.gov.in are welcome. We wish you all success free of failures and a joyful life!

You may visit our web site for your comments/suggestions or any queries: www.sfaindia.org

Kalpakkam

10-11-2020 (P.Parameswaran
Swati Biswas)
Editors

*We encourage you to join the society, Kindly fill up the application form (enclosed at the end of the newsletter) and contact secretary:param@igcar.gov.in; alternatively, post your application with draft to Sri.B Jana, Treasurer, **RCMA,** CEMILAC, Kanchanbagh, Hyderabad, 500 058*

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Aims and Objectives of Society for Failure Analysis

The aims and objectives of the Society shall be:

To serve as National Society to promote, encourage and develop the growth of "Art and Science of Failure Analysis" and to stimulate interest in compilation of a database, for effective identification of root causes of failures and their prevention thereof.

To serve as a common forum for individuals, institutions, organizations and Industries interested in the above.

To disseminate information concerning developments both in India and abroad in the related fields.

To organize lectures, discussions, conferences, seminars, colloquia, courses related to failure analysis and to provide a valuable feed back on failure analysis covering design, materials, maintenance and manufacturing deficiencies / limitations.

To train personnel in investigation on failures of engineering components and their mitigation.

To identify and recommend areas for research and development work in the Country relating to failure analysis.

To establish liaison with Government, individuals, institutions and commercial bodies on failure analysis, methodologies and to advise on request.

To cooperate with other professional bodies having similar objectives.

To affiliate itself to appropriate international organization(s), for the promotion of common objectives and to represent them in India.

To organize regional chapters in different parts of the country as and when the need arises.

To do all such other acts as the Society may think necessary, incidental or conducive to the attainment of the aims and objectives of the Society.

Application of time-frequency techniques for analysis of ultrasonic signals in high scattering materials

Govind Kumar Sharma and Anish Kumar
Non Destructive Evaluation Division
Indira Gandhi Centre for Atomic Research
Kalpakkam - 603102

Abstract

Ultrasonic technique is a non-destructive testing (NDT) method commonly used for determination of thickness of materials and detection of flaws in base metal and welds. In addition, ultrasonic technique has also been extensively used for microstructural characterization of metallic materials. The changes in the microstructure of materials influence the ultrasonic velocity and attenuation of propagating ultrasonic waves, in turn becomes vital parameters for predication of changes in microstructure. Several studies have been proposed to predict grain size of stainless steel material by ultrasonic technique, which comprises of using time, frequency and time-frequency domain analysis techniques. This article discusses studies related to time-frequency analysis techniques for predication of grain size and detection of flaws in austenitic stainless steel.

1.0 Introduction

An ultrasonic wave propagating in a high scattering medium such as a coarse grain austenitic stainless steel suffers spectral distortion due to high rate of attenuation of its high frequency components. This results in a change in the spectral content of the incident wave, a clear change in the peak frequency of a signal can be observed. This information can be clearly obtained by using Fourier transform (FT) of a signal acquired from the particular specimen. However, the information available after processing will be limited only to frequency. This may limit its usefulness in the high scattering signals due to poor signal to noise ratio (SNR). The time frequency based approaches such as Short time Fourier transform (STFT) and Wavelet transform (WT) based methods have been used in analysis of signals obtained from high scattering stainless steel materials.

The STFT and WT based approaches are adopted to understand the frequency dependent attenuation in material and determination of grain sizes in type 316 LN austenitic stainless steel. In this article, basics and applications of the above mentioned TF analysis techniques is discussed.

2.0 Experimental

Various specimens of type 316 LN stainless steel were used in this study. The blocks of 316 LN were heat treated at different temperatures to generate different grain sizes. Specimens of 10 mm thickness were prepared from these blocks. Ultrasonic immersion testing was carried out using a 25 MHz frequency unfocussed broadband transducer. Typical micrographs representing very fine to coarse grain sizes are shown in Fig.1. The experimental setup used in this study is shown in Fig. 2.

3.0 Results & Discussion

Ultrasonic signals acquired in

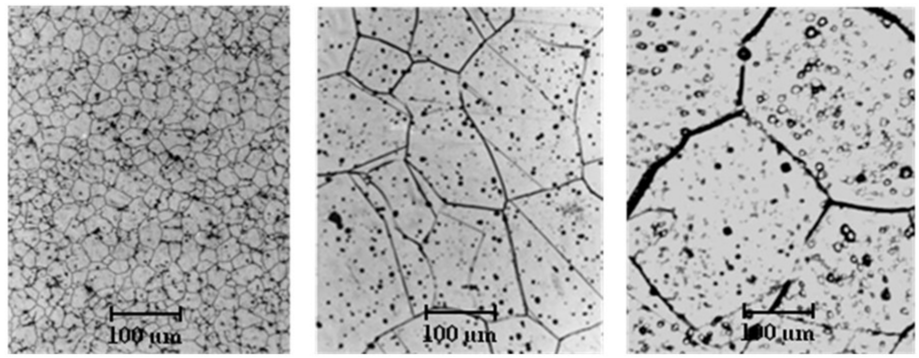


Fig.1. Typical micrographs obtained from a few specimens used in this study [1].

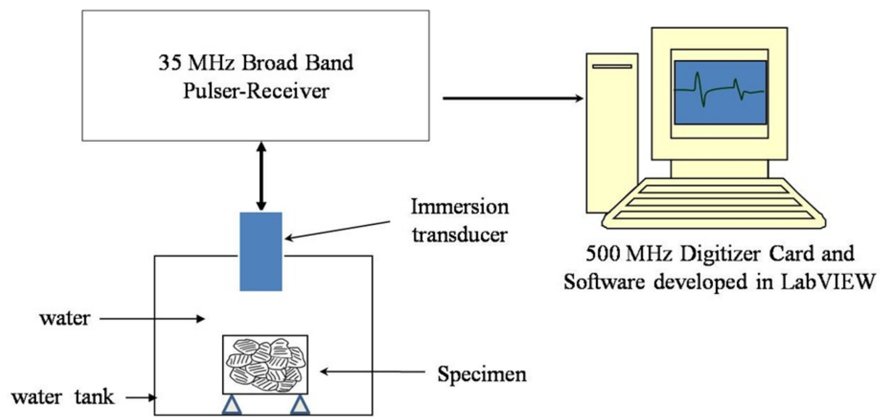


Fig.2. Experimental set up for acquisition of data [1].

immersion mode from the specimens of different grain sizes are shown in Figure 3. Systematic increase in the back-scattered signals amplitude and reduction in the back-wall echoes is observed with increase in the grain size.

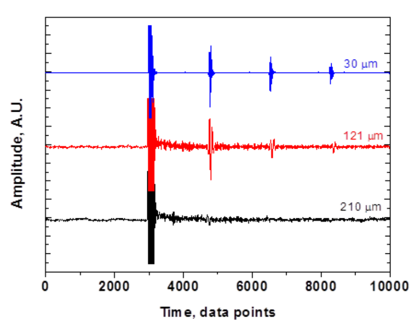


Fig.3. Influence of grain size on ultrasonic signals.

Ultrasonic signals were acquired from austenitic stainless steel (316 LN) specimens of 10 mm thickness of different grain sizes. These signals were acquired at different gain values.

3.1 <u>Time-frequency analysis techniques</u>

3.1.1 <u>Short Time Fourier Transform (STFT)</u>

The STFT is one of the most widely used algorithms in joint time frequency analysis (JTFA) based on detail Fourier transform centred at each time point. In STFT, the signal is compared with window functions that are concentrated in both time and frequency domains. The spectra at any particular time are then stacked to reflect the lateral variation of signal behaviour in both time and frequency

in JFTA.
The STFT algorithm and the window function can be mathematically represented as Eq. 1:

$$STFT[s(t)] = S(\tau,\omega) = \int_{-\infty}^{+\infty} s(t)\chi(t-\tau).e^{-j\omega t}dt \quad \text{--(1)}$$

Where, χ(t) is the window function which has a user defined time duration; and s(t) is the waveform signal in time domain. This operation (Eq. 1) differs from the Fourier transform only by the presence of the window function χ(t). As the name implies, the STFT is generated by taking the Fourier transform of smaller durations of the original waveform. Alternatively, we can interpret the STFT as the projection of the function s(t) onto a set of bases with parameters t and ω. Since the bases are no longer of infinite extent in time, it is possible to monitor how the signal frequency spectrum varies as a function of time. This is accomplished by the translation of the window as a function of time t, resulting in a 2D joint time-frequency representation STFT(t,ω) of the original time signal. The magnitude display │STFT (t,ω)│ is called the spectrogram of the signal. The result of analysis depends on the choice of the window function leading to a trade-off between time localization and frequency resolution. If the window length is too small, spectral leakage of low frequency component appear and when it is too long, the target of interest would be blurred.
Figure 4 (b) shows typical STFT spectrogram of an ultrasonic signal acquired from 121 μm grain size specimen. It can be clearly observed that the consecutive back-wall echoes show diminishing content of the frequency and the back-scatter is of high frequency. This phenomenon can be explained based on the

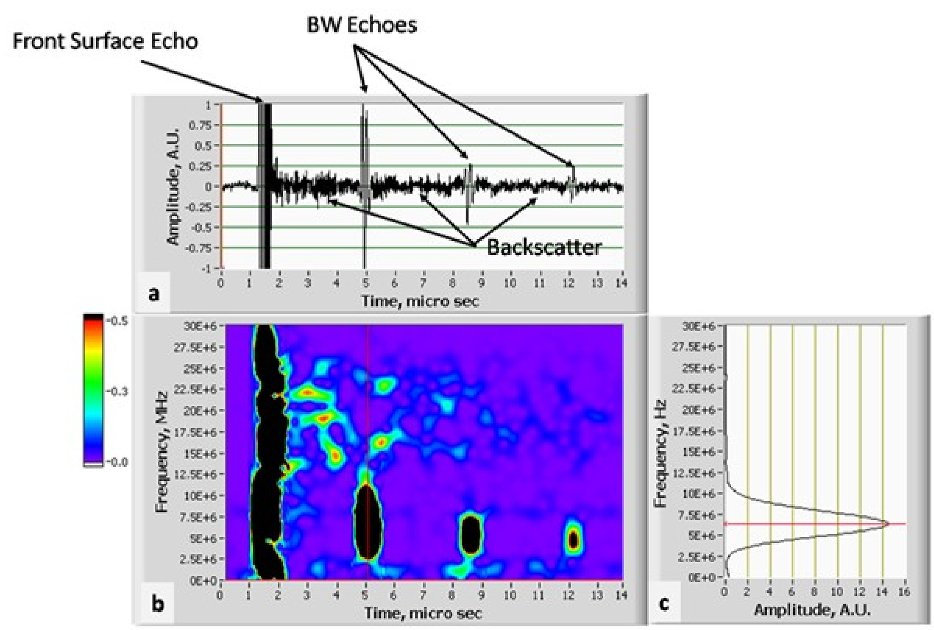


Fig.4(a-c). Ultrasonic signal, STFT spectrogram and frequency content at the location of cursor is shown, respectively [1].

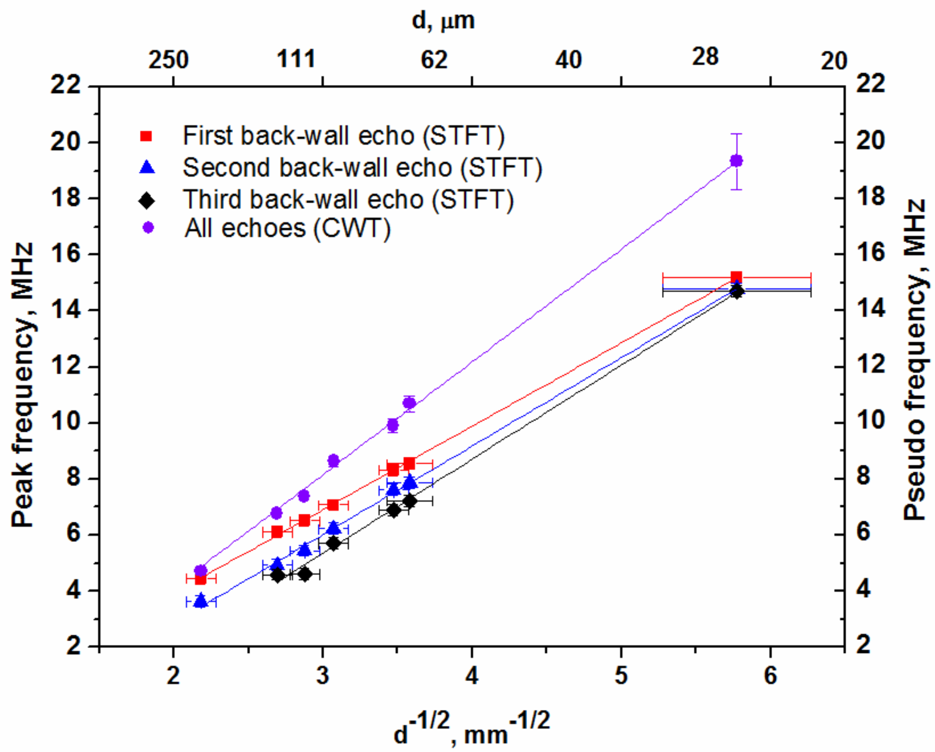
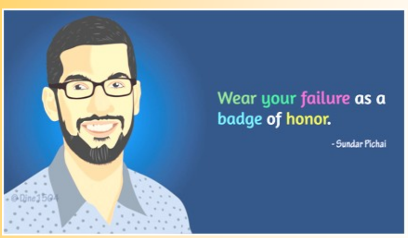


Fig. 5 Correlation between peak frequency and grain size (STFT approach) and pseudo peak frequency and grain size (CWT approach) [2].



scattering theory.

The most important usage of STFT is to obtain simultaneous time and frequency information. The peak frequency information at each back-wall echo location was extracted and correlated with metallographically obtained grain sizes of different specimens, as shown in Fig. 5. *The peak frequencies obtained at the three back-wall echo positions using STFT also showed the linear relationship with $d^{-1/2}$ for a range of grain sizes* as follows:

$PF_{FBW} = -2.0 + 2.89\, d^{-1/2}$ (R=0.97)----(2)

$PF_{SBW} = -3.7 + 3.14\, d^{-1/2}$ (R=0.97) ---- (3)

$PF_{TBW}=-5.3+ 3.39d^{-1/2}$ (R=0.96) ----(4)

It can be observed that the slope of the fitted curve increases with back-wall echo locations and this is attributed to increase in the signal interaction length in the medium leading to enhanced sensitivity for the determination of grain size.

3.1.2 <u>Continuous wavelet transform</u>

The continuous wavelet transform is an alternative approach to the STFT to overcome the constant resolution problem. In the wavelet analysis, the signal is multiplied with a function called wavelet, similar to the window function in the STFT, and the transform is computed separately for different segments of the time-domain signal. The width of the window is changed as the transform is computed for every single spectral component, which is the most significant characteristic of the wavelet transform.

The continuous wavelet transform is defined as follows:

$$CWT_x^{\psi}(\tau, s) = \psi_x^{\psi}(\tau, s) = \frac{1}{\sqrt{s}} \int x(t)\psi^*\left(\frac{t-\tau}{s}\right) dt$$

------(5)

As can be observed in equation (5), the transformed signal is a function of two variables, τ (translation) and s (scale) parameters. The ψ(t) is the transforming function, and it is called the mother wavelet. According to equation (5), for every (τ, s), we have a wavelet coefficient, representing how much the scaled wavelet is similar to the function at location t=(τ/s). The term "wavelet" means a small wave. The "smallness" refers to the condition that this (window) function is of finite length (compactly supported). The "wave" refers to the condition that this function is oscillatory. The term "mother" implies that the functions with different region of support that are used in the transformation process are derived from one main function, or the mother wavelet. Hence, the "mother wavelet" is a prototype for generating the other window functions.

The term "translation" is used in the same sense as it is used in the STFT. It is related to the location of the window, as the window is shifted through the signal. This term, corresponds to time information in the transform domain. However, in the wavelet analysis, frequency parameter is not used, as it is assigned for STFT analysis. Instead, a scale parameter is used. The inverse of the scale can be correlated with pseudo frequency.

The wavelet transform is a widely used time-frequency analysis method, which can be well adapted for extracting the information content of the signals. The general recommendation of the choice of wavelets users is a similarity criterion between the shapes of the wavelet and the signal. In this paper, 'Morlet' has been used as the mother wavelet, due to its shape similarity and enhancement of SNR for the signals used in the study.

Figure 6 shows a comparative analysis between STFT and wavelet processing of a signal obtained from a 10 mm thickness and 210 µm grain size specimen. From comparative analysis, it can be inferred that only first back-wall echo frequency information is viable from the STFT spectrogram however, even up to the third back-wall echo information can be obtained from the wavelet transform.

It was observed that the signal to noise ratio improves with increase in the wavelet scale, this is due to filtering of high frequency content. Systematic improvement in the SNR takes place with scales and peaks for a particular scale depending on the grain size of the specimen. The pseudo peak frequency was calculated corresponding to the scale pertaining to best SNR, and correlated with grain size of the specimens. *A linear correlation between pseudo peak frequencies and grain size was found.* The slope of the correlation was found higher for wavelet compared to STFT approach (Fig. 5). This can be attributed to flexible window approach of wavelets.

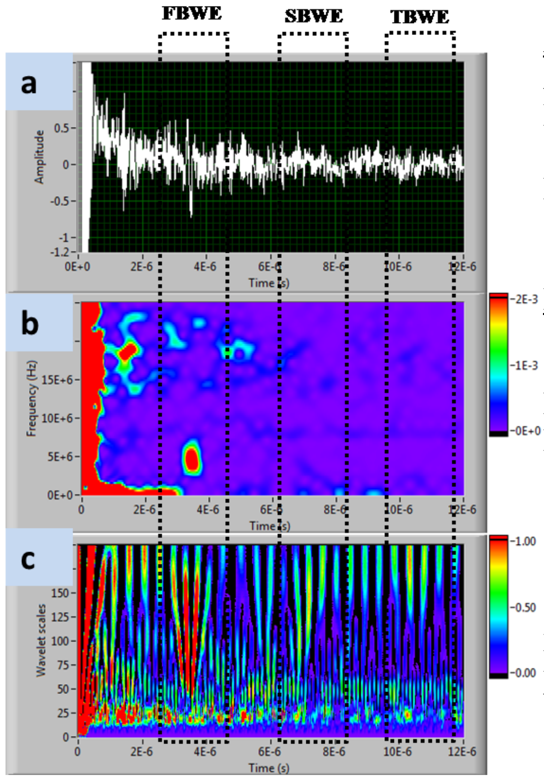


Fig. 6 (a-c) Ultrasonic signal obtained from a 10 mm thick (210 µm) grain size specimen, corresponding STFT spectrogram and CWT scalogram, respectively [2].

4.0 <u>Conclusions</u>

Comparative studies using STFT and CWT time frequency analysis methods have been performed to understand frequency dependent attenuation and evaluation of grain size in coarse grain austenitic stainless steels. The studies demonstrate the usefulness of time-frequency analysis for effectively bringing out the echoes submerged in back-scatter noise. The time-frequency approaches have led to a better understanding of the distribution of spectral content in an ultrasonic signal obtained from high scattering austenitic stainless steel. The limitation of fixed resolution in STFT has been addressed using flexible CWT analysis.

<u>Acknowledgement</u>

Authors wish to thank Dr. B. P. C. Rao, Project Director FRFCF, Kalpakkam and Dr. T. Jayakumar, Former Director, MMG, IGCAR for their encouragement and support in the work.

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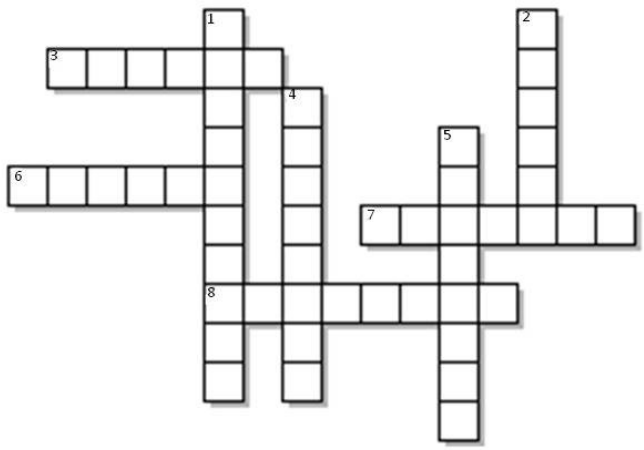
Cross word puzzle



Across	Down
3) White metal used as bearing alloy [6]	1) It can spread anything in north and south [10]
6) Used gel loses elasticity and formed into a mass [6]	2) Seer added silver to get lubricating material [6]
7) Marks evenly spaced on bearing due to denting or scale of hardness [7]	4) Sol in place can be disturbed by boiling [8]
8) Stay ripe, but surface roughness remains [8]	5) The force generated if 100 ton load work on the surface [8]

See page 15 for answers:

Society for Failure Analysis

Application Form

Society for Failure Analysis
C/O Centre for Military Airworthiness & certification, RCMA (Materials)
Hyderabad550 058

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Fax : 040-24341827
E-mail: rdrcma.mat@cemilac.drdo.in

Please √ applicable **member** ☐ **Life Member** ☐

1. **Name in Block Letters**

First Middle Last

2. **Date of birth:** **Gender:** Male / Female
3. **Father's Name/ Husband's Name**

4 **Present Occupation /Designation and office address:**	**Phone:** **Mobile:** **Fax:** **Email:**

5 **Academic & Professional Qualifications**:

6 **Home address:**	**Phone:** **Mobile:** **Fax:** **E-mail**

6. **Address for correspondence:** **office** ☐ **Home** ☐

7. **Professional Experience**:
8. **Endorsement by SFA Member**

Name	Membership No.	Signature

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Design & Failures ☐	**Quality control** ☐	**Petrochemical** ☐	**Consultancy / services** ☐	**Materials and manufacturing**	**Education** ☐

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(Please refer to Chapters' list)
11. **Subscription details:**

Payment should be made by cheque / DD favoring **"Society for Failure Analysis",** payable at Hyderabad. Outstation cheques not accepted. Payment can also be made by online NEFT transfer to the account of "Society for Failure Analysis", Account Number : 20495800082, Bank Name: Allahabad Bank, IFSC : ALLA0211473

Amount [Rs.] Cheque / D.D. No [ ] Dated [ ]

Bank Name [ ] Branch [ ]

Category	Amount Payable		
	Admission Fee (One time)	Yearly Subscription	Total on joining
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12 **Declaration by the applicant**

If elected, I agree to accept to pay the prescribed yearly subscription, to abide by the Articles of Association of the Society and to promote its aims and objects.

Signature of the Applicant

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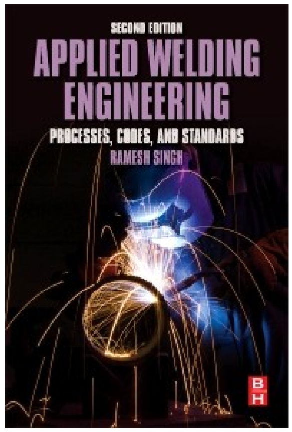
	Amount Paid (Rs)		Receipt No. / Date			

Books

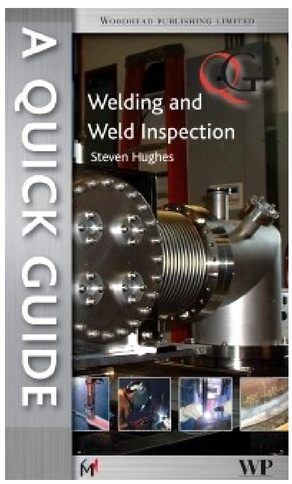


A practical and in-depth guide to materials selection, welding techniques, and procedures, *Applied Welding Engineering: Processes, Codes and Standards*, provides expert advice for complying with international codes as well as working them into "day to day" design, construction and inspection activities.

New content in this edition covers the standards and codes of the Canadian Welding Society, and the DNV standards in addition to updates to existing coverage of the American Welding Society, American Society of Mechanical Engineers, The Welding Institute (UK).

The book's four part treatment starts with a clear and rigorous exposition of the science of metallurgy including but not limited to: Alloys, Physical Metallurgy, Structure of Materials, Non-Ferrous Materials, Mechanical Properties and Testing of Metals and Heal Treatment of Steels. This is followed by applications: Welding Metallurgy & Welding Processes, Nondestructive Testing, and Codes and Standards.

Case studies are included in the book to provide a bridge between theory and the real world of welding engineering. Other topics addressed include: Mechanical Properties and Testing of Metals, Heat Treatment of Steels, Effect of Heat on Material During Welding, Stresses, Shrinkage and Distortion in Welding, Welding, Corrosion Resistant Alloys-Stainless Steel, Welding Defects and Inspection, Codes, Specifications and Standards.

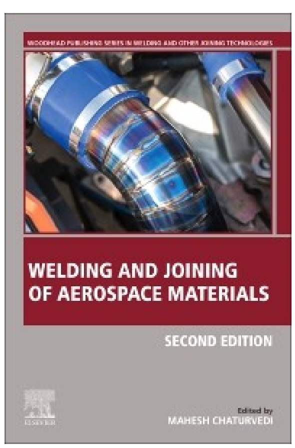


A Quick Guide to Welding and Weld Inspection

1st Edition

Editor: S E Hughes,

Woodhead Publishing



Welding and Joining of Aerospace Materials

2nd Edition

Editors: Mahesh Chaturvedi

Imprint: Woodhead Publishing
Published Date: 1st July 2020

Page Count: 560

View all volumes in this series:

Woodhead Publishing

Events in the pipeline

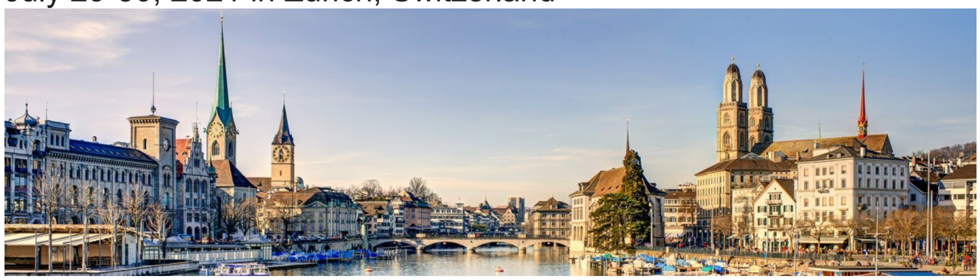
8th International Conference on Creep, Fatigue & Creep-Fatigue Interaction: 2021, Hotel Radisson Blu Resort Temple Bay, Mamallapuram, Tamil Nadu

Scope of the Conference
The challenges involved in addressing the growing global energy demands with reduced greenhouse emissions have to be met by advanced fission and fusion nuclear reactor systems and fossil-fired ultra supercritical power plants, all of which involve complex technologies and operating environments that raise new challenges for materials development and understanding of their mechanical behaviour. Performance of materials under creep, fatigue and combined creep-fatigue loadings is of utmost concern in the design, operation and reliability of high temperature components.. CF-8 aims to bring together experts working in the areas of creep, fatigue and creep-fatigue interaction, development of high temperature creep and fatigue resistant materials and life assessment so as to facilitate mutual interaction and exchange of knowledge and experience

https://www.meetingsint.com/conferences/materials-technology/abstract-submission

ICEMPTA 2021: 15. International Conference on Engineering Materials, Processes, Technologies and Applications

July 29-30, 2021 in Zurich, Switzerland



New dates announced: Ninth International Conference on Engineering Failure Analysis has been postponed to 11-14 July 2021

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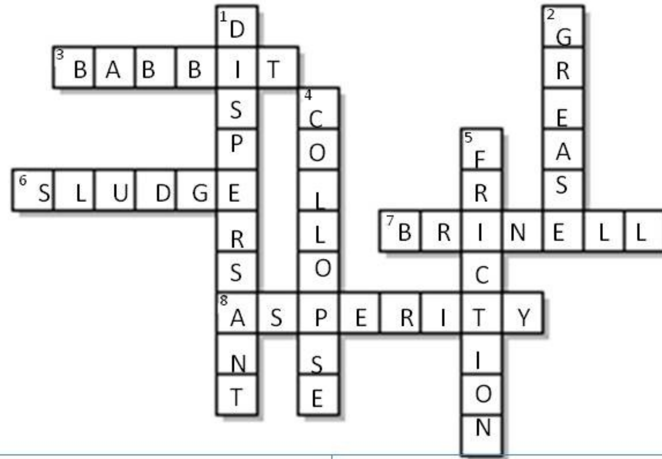
8th International Conference on Engineering Failure Analysis
7th International Conference on Engineering Failure Analysis
6th International Conference on Engineering Failure Analysis

International Conference on Engineering Failure Analysis ICEFA on August 09-10, 2022 in New York, United States

https://waset.org/engineering-failure-analysis-conference-in-august-2022-in-new-york



Across

3) White metal used as bearing alloy [6]

6) Used gel loses elasticity and formed into a mass [6]

7) Marks evenly spaced on bearing due to denting or scale of hardness [7]

8) Stay ripe, but surface roughness remains [8]

Down

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2) Seer added silver to get lubricating material [6]

4) Sol in place can be disturbed by boiling [8]

5) The force generated if 100 ton load work on the surface [8]

To

From
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C/O Centre for Military Airworthiness &
Certification, RCMA (Materials),
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Hyderabad-550058