Chapter - 1

INTRODUCTION
1.1 SIGNATURE IDENTIFICATION PROBLEM IN ACOUSTIC EMISSION SIGNAL ANALYSIS

Non-Destructive Testing is one of the prime fields of engineering and is extensively used in all the engineering applications for component level testing as well as system level testing. Among the various Non-Destructive Testing (NDT) methods, Acoustic Emission Technique (AET) is widely used for structural evaluation of large structures, pressure vessels, rocket motor hardware, nuclear reactors etc. Acoustic Emission technique is also widely used for materials research, on-line process monitoring and structural integrity monitoring because of its potential for detection and location of dynamic events.

Acoustic Emission (AE) is defined as the class of phenomenon where by transient elastic waves are generated by rapid release of energy from localized sources such as cracks, leaks, fretting, rubbing of fasteners, matrix crazing etc., in a material or structure [8]. The energy thus released from the packet travels as spherical wave-front and it can be picked up from the surface of materials using high sensitive transducers. The wave thus picked up by the transducer is converted into electrical signal, which on suitable processing and analysis can reveal valuable information about the source. Acoustic Emission has the capability to locate and evaluate dynamic discontinuities in the entire structure under test.
Based on the above reasons, Acoustic Emission Technique has been recommended for assessment of structural integrity of rocket motor hardware during their proof pressure testing. In Indian Space Research Organisation (ISRO), AET is being used to qualify the rocket motor hardware used in the Polar Satellite Launch Vehicles (PSLV) and Geostationary Satellite Launch vehicles (GSLV). During the proof pressure testing, the rocket motor hardware is extensively instrumented to monitor the events related to the crack growth phenomenon and abort the test to avoid any catastrophic failure of the rocket motor hardware. The AE data recorded during proof pressure test contains all the events related to crack growth phenomenon and other events related to hydraulic noise, rubbing of fasteners, fretting etc. Further, it is often found that the AE signals related to these events are influenced by various noises, viz., mechanical noise, electrical noise (i.e. electromagnetic), welding noise, and other pseudo noises. Due to the presence of these noises it has become difficult to identify the events mentioned above. To analyse the AE signal for identification of these events, it is essential to eliminate the noise.

Classical methods of noise elimination, such as Fast Fourier Transformation (FFT) technique and Windowed Fourier Transformation (WFT) technique have resulted in loss of signal information. Even the advanced acoustic emission signal analyzers, currently being used in the industry, employ artificial neural network based subsystems for classifying the acoustic emission signal claim that the influence of noise can be reduced only to certain extent. Hence, attempting to classify the noisy
acoustic emission signals using the above methods would result in reduced probability of correct classification [113].

Though standard procedures are available for Acoustic Emission monitoring of pressure vessel applications, no work has been reported for de-noising of acoustic emission signals related rocket motor hardware and signature identification of different events recorded during proof pressure testing. Hence, this research work is focussed towards de-noising of transient AE signals and event classification of the AE signals obtained during proof pressure testing of rocket motor hardware.

After detailed literature survey, it is found that the Wavelet Transformation (WT) technique is most appropriate for analysis of acoustic emission signals, particularly for de-noising and event identification [114].

1.2 SCOPE OF THE WORK

In the present research work, reference acoustic emission signatures corresponding to hydraulic noise, crack and rubbing of fasteners are recorded as reference data for event classification. A sample signature is also generated to verify the method of classification. Then the test data is recorded in the presence of heavy back ground noise. The acoustic emission signals recorded during the test, are corresponding to hydraulic noise, crack initiation in the material and rubbing of fasteners and the back ground noise.
Denoising of the Acoustic Emission signals, recorded during the proof pressure test, is carried out using Discrete Wavelet Transformation (DWT) technique. Discrete wavelet transform of the test data with different wavelets is computed. In this work, the test signals are de-noised using sym8, coif8, dg8, bio3.9 and harr wavelets, which are found to be most suitable. If more than one de-noised signal is obtained from different wavelets, then their average is considered. During the computation of discrete wavelet transformation the test signal is passed through a low pass filter and a high pass filter for every level of the signal. The output of the low pass filter is called as 'approximation' and the output of the high pass filter is called as 'detail'. To de-noise the AE signal the detail coefficients are heavily thresholded. All the detail coefficients at all the levels are made zero and the signal is reconstructed back. The effectiveness of the present method of thresholding is verified by applying the same to the reference signal and found the method used in this work is very effective.

The signals after de-noising are classified using Continuous Wavelet Transformation (CWT) technique. The continuous wavelet transformation is used to convert the time domain signal into two dimensional data with time scale as coefficients. The results are represented in a two dimensional plot of scale and shift parameters with pseudo colouring representing wavelet coefficients. To classify the de-noised signal as one among the set of reference signatures continuous wavelet transform of the de-noised and the reconstructed wave is obtained. Both the reference signal and the denoised signal are compared and found to have a good match between them.
During proof pressure testing of rocket motor hardware, it was observed that some of the sensors have picked up the acoustic emission signals corresponding to leakage of hydraulic oil. The reference signals mentioned above and their wavelets are not matching with the signature of this leak. Hence, a new wavelet is developed to meet the requirements of leak detection application. Although some of the wavelets like daubechies wavelets have been considered as the best wavelet for decomposition but they are found to be unsuitable for this application. Hence, the new wavelet named as 'SVBSLET' has been developed based on cosine function. For this wavelet a set of scaling functions are defined in terms of integer translates of the basic scaling function. The cosine function of the wavelet is associated with a constant which is used for normalization and for better recovery of the signals. The scaling coefficients and wavelet coefficients are calculated from orthogonal scaling functions. The limits for the wavelet function are defined so that the wavelet matches with the reference signal. The developed wavelet ‘SVBSLET’ is tested with different leak signals and found meeting the requirement of hydraulic oil leak detection for rocket motor hardware.

A detailed literature review on the Acoustic Emission signal processing techniques is carried out. Chapter-2 gives the summary work carried out by different authors on the application of wavelet transformation technique for acoustic emission signal analysis. Literature related to detection of crack growth in structures and during condition monitoring of processes using wavelet transformation technique is reviewed and presented.
An overview on Acoustic Emission is given in Chapter-3. The phenomenon of Acoustic Emission and sources of this phenomenon is briefly mentioned. Then the acoustic emission signal characteristics are detailed. Types of noises encountered in acoustic emission signal analysis are explained. Further, Acoustic Emission data acquisition, processing and analysis of these signals are given in brief. The trends in signal analysis viz, Fourier transform, multi-resolution analysis are explained in this chapter.

In Chapter-4 the test set up, details of reference data and the acoustic emission data acquired during the test are discussed. Methodology adopted for de-noising the data using Discrete Wavelet Transformation technique is described in detail. Further, the method adopted for signature identification of Acoustic Emission signals using continuous wavelet transformation technique is detailed in this chapter. In addition, the concepts of Coherence Estimation Function and Continuous Wavelet Transformation for pattern classification application are also described in detail. The results related to signature identification are presented in this chapter.

Chapter-5 gives the details of the newly developed wavelet called 'SVBSLET'. This wavelet is developed for leak detection applications related to rocket motor hardware as the existing wavelets are not suitable. This wavelet is developed based on the cosine function as the signal characteristics are close to the leak signal.
The conclusions of this research work are given in Chapter-6. It is observed that the wavelet transform is best suitable method and gives superior results in de-noising acoustic emission signals related to rocket motor hardware when compared to any other signal analysis methods. Event classification based on continuous wavelet transform of the acoustic emission signal is found to be more accurate and reliable. The newly developed wavelet 'SVBSLET' found to have a good match with leakage applications.

The developed method of wavelet analysis has been successfully used in real time applications during proof pressure testing of rocket motor hardware. It is found that there are no false alarms and aborting of the test due to the influence of various noises on the AE data. The method clearly identified the events related to hydraulic noise, cracks and rubbing of the fasteners during proof pressure testing of the rocket motor hardware. It is concluded that wavelet transformation technique is the best suitable signal processing technique for signature identification of Acoustic Emission signals during proof pressure testing of rocket motor hardware. Future work is proposed in the areas of radar signal processing, satellite image processing, power quality monitoring and health care systems. As signatures in these applications are well defined, the method adopted in this work can be taken as basis for further research.