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Monitoring Crack Initiation in Metallic Components through Acoustic Emission

M.MAHESH KUMAR, M.S.RAWAT
Bharat Heavy Electricals Limited
Hyderabad, India

Acoustic Emission is a proven NDT technique to measure structural integrity under operating condition and is highly beneficial for monitoring of ageing infrastructure. Over the last decade attempts have been made to simplify the practice of Acoustic Emission monitoring in order to make it user friendly. In this paper we have discussed the approach followed for evaluating AE signals which will go a long way in developing the remnant life estimation of engineering materials.

Abstract

Acoustic Emission has been finding increasing application for monitoring of aging infrastructures. The materials undergo degradation mechanism during long service exposure. High stresses result in microscopic movement of grains generating voids. These voids further grow under dynamic conditions resulting in cavity formation accompanied by release of strain energy. This energy is picked up by A.E. sensors for analysis. Experiments have been carried out on different steel grades normally used in thermal power plant boilers. Pre-notched samples have been subjected to gradual loading. The material initially undergoes elastic deformation with the movement of dislocation upto certain level and thereafter turns to plastic range. A sudden burst of energy is released which the sensors signifying the crack initiation process pick up. The release of energy continues with the load in parabolic fashion. The samples with varying notch sizes were studied. An interesting conclusion is drawn based on the experiments carried out. The initial energy release is found to be same irrespective of the initial notch size or the loading pattern. The experiments were repeated with different materials and the results were found to be the same. This would lead to believe that the initial energy release is a material property. Since the energy release pattern is fixed for a material for crack initiation process, this could lead to monitoring the healthiness of components through on line A.E. monitoring.

Key words: Acoustic Emission, strain energy crack initiation, dislocation movement, A.E. sensors.

Introduction

During manufacturing process of metal every care is taken to have sound metallurgical microstructure. When components are put in service they are subjected to high temperature and mechanical stresses resulting in microscopic movement of dislocations within the grains. The movement when reaches upto certain critical value leads to generation of voids and stresses at some regions. The voids grow in size to form a cavity and gives rise to energy release. These are the stress wave, which propagate over the whole body. The sensors will pick the stress waves after amplification. The detection of signals is sensitive to sensor frequency and a variety of sensors are available out of which frequency above 100 Khz for structural system are helpful to detect extremely fine details of plastic deformation, crack development, initiation of voids etc. These signals can easily be picked up and classified using Noises software available with the system.

Experimental Work

Experiment carried out on variety of steels namely rotor steel, mild E_n 31 steel, E_n 08, E_n 0 austenitic stainless and ferrite stainless steels. The specimens were suitably prepared and all the samples were properly ground and machined to avoid spurious signals during the experiment. The test was performed on loading device as shown in Fig. 1. The set up consists of fixture for bending the specimen. The samples were prepared with different V-notch depths varying from 5mm to 15mm on the samples. The sample was loaded on the loading devices and two sensors were fixed at both the ends of the sample and load cell was attached to the loading system.

Fig.1 Loading set-up

These load cells were connected to the load indicator system so that continuous monitoring of load applied is undertaken. The PAC system with Mistras software is used for the purpose of test. The suitable file was prepared with maximum available band pass filter frequency and a sampling rate of 10Mhz was selected. The two sensors were placed in the linear location by setting longitudinal wave velocity up to 6000 m/s and placing at a distance of 60mm from the notch. The load was applied in the opposite direction of the notch as shown in Fig.2. A number of experiments have been carried out on each material in order to ensure the repeatability of test results.

The first test was carried out with 5mm notch on E_n 08 sample. The parameter found to be of interest were energy, counts and RMS values for crack initiation and propagation. The frequency range which was found to be best suited for the present case was 50 Khz – 500Khz. The wide range of frequency was selected to account for the noise levels as external surrounding factors which otherwise influence the interpretation of test results.

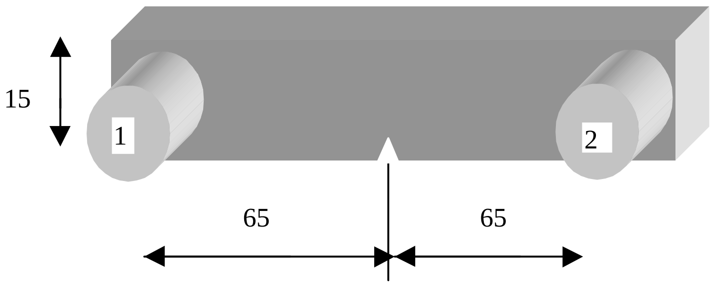

Fig.2 Pre-notched sample for test

Results and Discussion: In the recent past the study of Acoustic Emission was primarily aimed only in the cumulative counts, but now the study is based on Acoustic Emission hits as well as count data. Figure 3 shows the cumulative count data with reference to time duration. With the passage of time the cumulative count data increases consistently while the event is progressing.

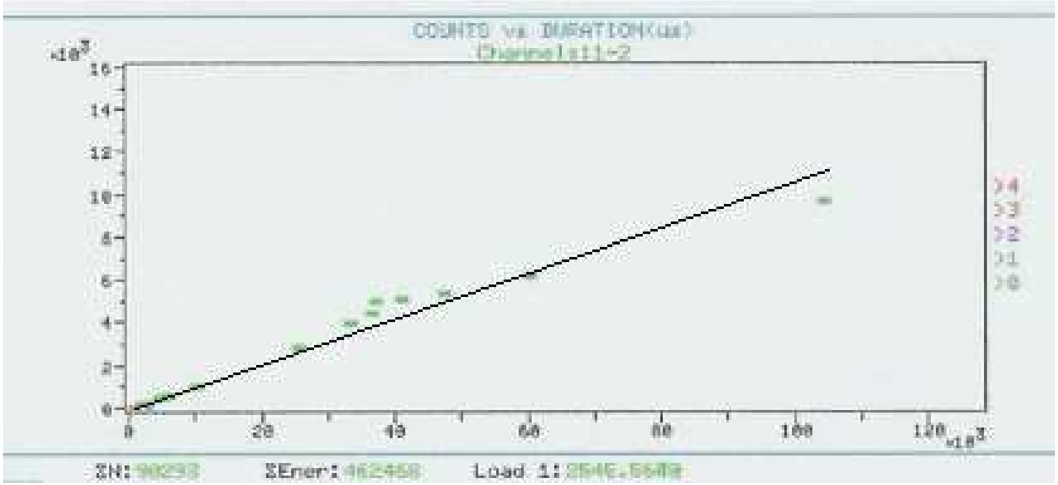

Fig.3 Counts Vs Duration

Figure 4 shows the burst event indicating crack initiation phase. In the normal course otherwise we would have received a simple sinusoidal wave pattern. These data have been scrutinized and compiled with respect to hit & count, rms and the average signal value. Figure.5 shows the amplitude of the counts as the loading progresses. The resultant data is given in Fig. 6, which clearly provides categorization of signals into initial deformation, Noise levels, plastic deformation, crack initiation and its movement. The initial phase of the graph shows plastic deformation (till the curve is almost parallel to X-axis).

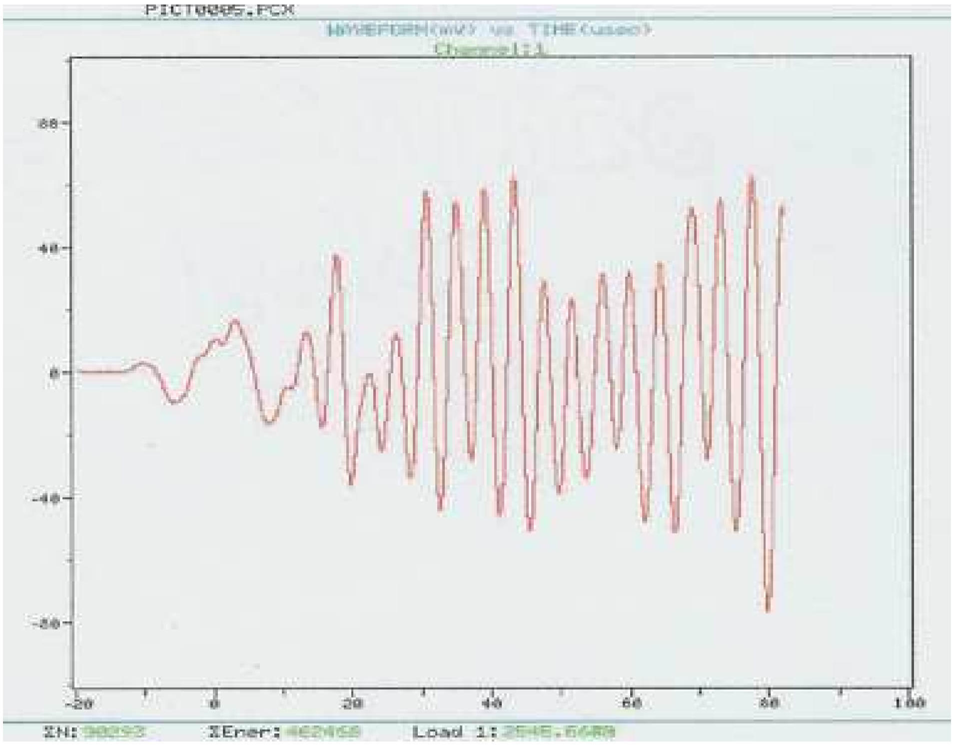

Fig.4 Wave pattern for Crack formation

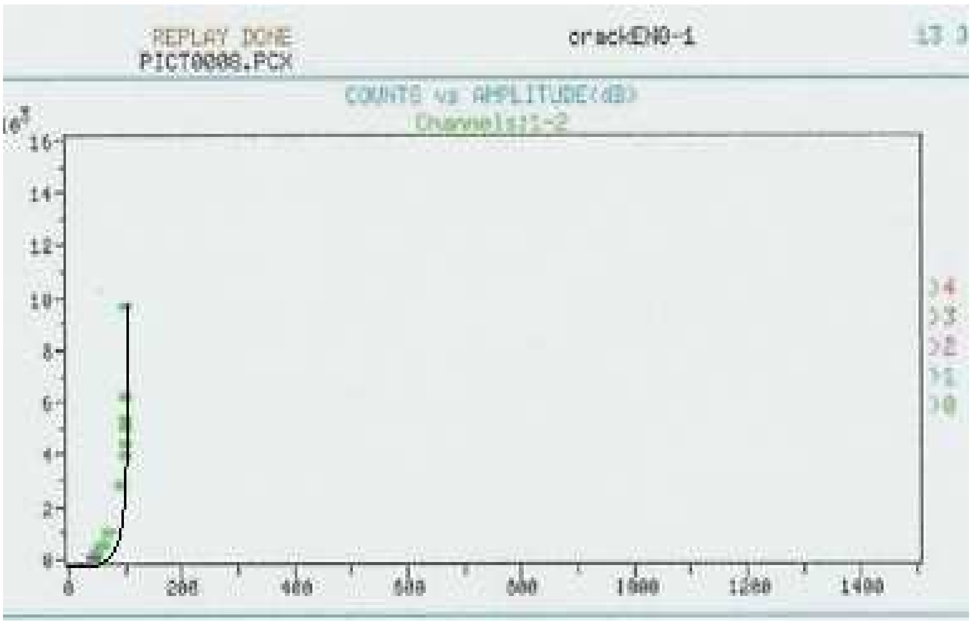

Fig.5 Counts Vs Amplitude

This phase is followed by crack initiation zone wherein the graph takes a curved shape followed by final fracture. The crack initiation and propagation zone has occupied major portion of the graph indicating that this phase takes a very long time. Thus we see that there is sufficient time gap between crack initiation and final failure.

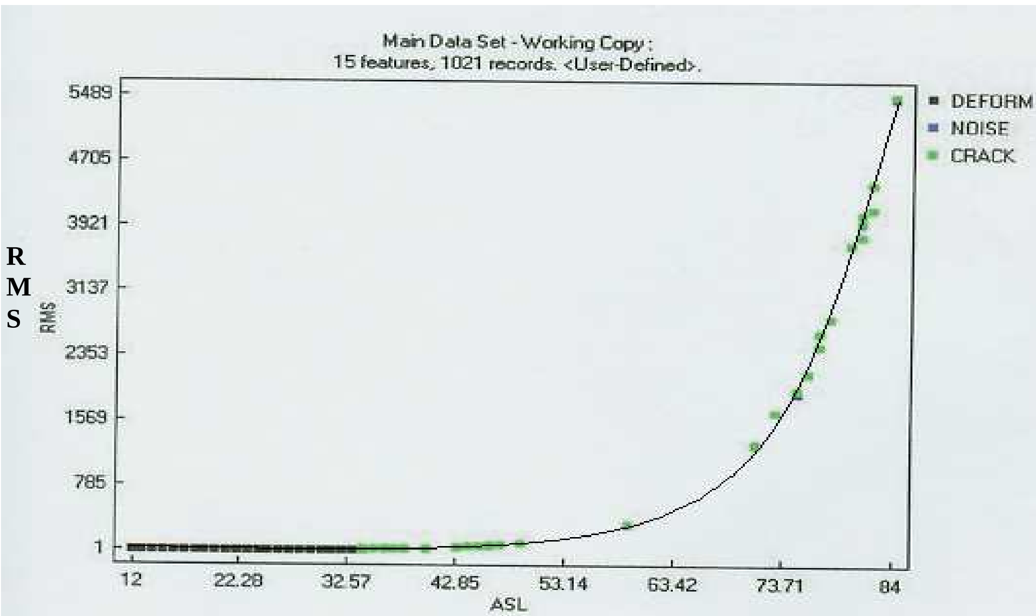

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FIG.6 AE signals for complete test.

In Acoustic Emission dislocation movements creates sudden turbulent waves, which are picked by sensors. On analysing various events we find that during crack initiation energy release is more and slowly diminishes even when load applied is much higher. This is due to the reason that when the material is loaded, the material will oppose the load applied initially.

Upon slowly increasing the load the atoms will not be in position to hold on to their position for long and voids/cavities would be created. When these voids open up with the release of energy, AE parameters such as value of energy hits, counts and rms values are compared for all the materials under consideration. The experimental data obtained also contains many spurious signals, which are basically of surrounding noise and need to be eliminated while processing the signals. The Noises software is the post processing software wherein different values extracted from the raw data are tabulated and plotted against rms value and ASL value after completion of the test. The value obtained gives us a parabolic pattern showing various phases of crack initiation, propagation and final failure quite distinctly as already outlined. Also the amount of energy released is found to be same for a material irrespective of initial notch size on the sample. This suggests that the initial energy release could be a material property.

This is a very useful technique as we will be able to get the information about damage accumulation much before the actual crack initiation and would help in planning preventive measures. Also once we are able to standardize with respect to the time frame we can even estimate the remaining life of inservice components.

CONCLUSIONS

1. The experimental results showed distinct categorization of AE signals into plastic deformation, crack propagation and final failure zones.
2. AE parameters that best suits for studying crack propagation studies are counts, hits, energy and rms values.
3. Initial energy release is found to be material property.
4. The experimental results can serve a tool for carrying out residual life assessment studies of inservice components.

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