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Technical note on Acoustic emission testing – An effective NDT tool for the structural Integrity evaluation of pressure vessels

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Abstract: Aerospace vehicle systems necessitate light weight, high strength pressurized tanks to store propellant, nitrogen, oxygen and other medium. Health monitoring of such vessels are indispensable preceding to its installation and in its operation. Acoustic emission technique is one of the powerful NDT tools capable of detecting a few atomic movements in a structure/material. AE testing is the only active NDT technique which can observe the growth of discontinuities and their severity while functioning. Consequently the incorporation of structural integrity evaluation with acoustic emission technique is critical in the aerospace and petrochemical industries. The structural integrity of a pressure vessel is generally assessed by proof testing. While proof testing the pressure vessel, the pressurisation of the vessel may lead the catastrophic failure without any significant deformation and prior indication. Such a bursting is frequently originated from the weldments of pressure vessel. This may cause remarkable damages in the aerospace industry. Hence the role of acoustic emission test is predominant to accomplish safe and controlled proof testing of pressure vessels and pipe lines. This study summarizes how the acoustic emission technique was handled effectively while proof testing towards the structural integrity assessment. Also it gives a good insight to the prior prediction of failure of the pressure vessels.

Key words: pressure vessel, proof testing, acoustic emission, structural integrity assessment, AA2219, NDT

1. INTRODUCTION

Acoustic emission is the transient elastic stress waves generated by the energy released during the micro structural changes occur in a material [1]. The stress waves can be generated by loading the material. The load can be mechanical, thermal and chemical. The emission is originated by sudden release of energy within the material due to crack initiation, crack propagation, phase transformation and even due to elastic/plastic deformation. If the atomic bonds break while testing a material, energy will be released and will propagate through the material based on the law of acoustics.

The stress waves originated from the source will propagate and reach the surface. When the stress waves reach the surface, it will cause a small vibration on the surface and the magnitude of the vibration is measurable. High sensitive transducers have the capability of detecting such surface displacement even in the order of several picometers. Among various transducers, piezoelectric transducers are the most useful and widely acceptable transducers. The transducers are placed on the surface of the material and the vibrations are transferred into the transducers and it is converted into electrical signals by the transducers for the further analysis [figure1].

The pressure vessel has been used widely in various fields of aerospace industry. Aircrafts are in need of high pressure stored gas for emergency oxygen supply, landing gear activation and engine pressurized air starting system. Hence the outflow or damage in the pressure vessel results in severe malfunctioning of the vehicle systems. In usual practice the pressure vessels are made with tungsten inert gas [TIG] welding process or with diffusion bonding process [2]. The vessels made such processes do have minor snags, pores, undercut, etc. in the weldments. These defects are not critical generally. But once the crack has originated, the propagation rate will be very high [3]. So the weldments of the pressure vessels should be given priority in testing to avoid running defects. This demand increases the attention towards the protection and reliability assurance of metallic pressure vessel before put into use and also during its running.

Aluminium alloys are preferred in the aerospace industry due to its low weight and high strength at high temperature as well as cryogenic temperature. AA2219 aluminium alloys are preferred for the manufacturing of propellant tanks of launch vehicles [4]. Alloy elements of the AA2219 are given in the table 1[Aerospace specification metals INC]. AA 2219 has 5.8 to 6.8 % of copper as the main alloying element. Due to the presence of copper the weldability of the metal increases significantly

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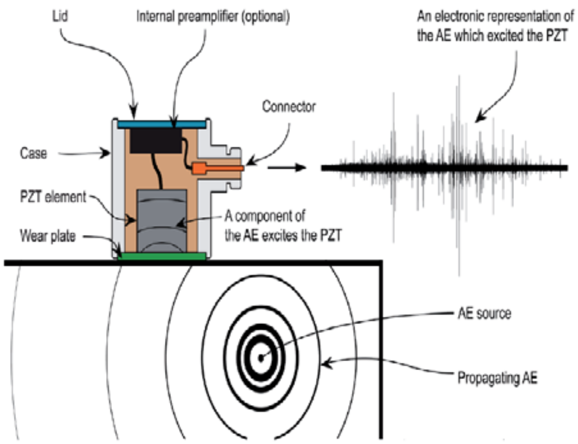

Figure 1. Illustration of typical resonant piezoelectric AE transducer and electric representation

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Component	Weight %	Component	Weight %
Al	91.5 – 93.8	V	0.05 – 0.15
Cu	5.8- 6.8	Zn	< 0.1
Fe	< 0.3	Zr	0.1 – 0.25
Mg	< 0.02	Si	< 0.2
Mn	0.2 – 0.4	Ti	.02 -0.1

Table 1: Components of AA 2219

Aluminium pressure vessels are normally proof tested with pneumatic medium in place of hydraulic medium to avoid contamination. While pressurizing the vessel with pneumatic medium, noise signals will be generated due to pressurization jet. Noise signals will also have alike parameters as that of AE signals. This noise signals will be a major obstacle for the appropriate interpretation of genuine AE signals [3].

2. EXPERIMENTAL PROCEDURE

2.1. Instrumentation

Pressure vessels used in launch vehicles are normally proof tested with a factor of safety of 1.1 to 1.5. Hence high sensitive acoustic emission testing is the appropriate technique for acceptance testing of pressure vessels. High sensitive piezoelectric transducers are employed in the signal acquisition system. The sensors are arranged in an array mode in order to cover all of the critical weldments. The physical distance between two sensors is finalized based on the attenuation calibration carried out by Hsu-Neilson pencil lead break calibration.

While proof testing aluminium pressure vessels normally 150 KHz resonant AE sensors were used. To couple the sensors with the surface of the vessel, high viscous ultrasonic couplant was employed. The sensor sensitivity is also calibrated by Hsu-Neilson pencil lead break calibration.

2.2. Pressurization

Aluminium pressure vessels are normally tested with pneumatic medium. Since the pressurization jet will affect the reliability of testing by producing spurious noise signals, one of the basic possible ways to get genuine acoustic emission signal is hold pressure and repeat test. The storage tank made by Aluminium is filled with pneumatic medium. For better results the hold pressure data alone is considered for interpretation. The basic parameters of AE like amplitude, Duration, Energy, count were utilized for the precise analysis and assessment.

3. DISCUSSION

Acoustic Emission testing is one of the effective NDT tools which can inspect the pressure vessel during its running condition. The results of proof testing will have noise signals along with genuine flaw related signals. Figure 2 Shows typical result obtained during the pneumatic proof testing of pressure vessel. The impact of pressurization jet can be understood by comparing the data acquired from hydrostatic pressurization [Figure 3].

The role of noise signals in the data is crucial during pressurization. According to Kaiser Effect, no measurable signals will be emitted by the material until the stress go beyond the previously applied stress level. Hence the hold phase acceptance criteria will be the effective and reliable technique for the structural integrity assessment. During the hold phase the AE will be emitted only when dislocations/deformations occur in the material.

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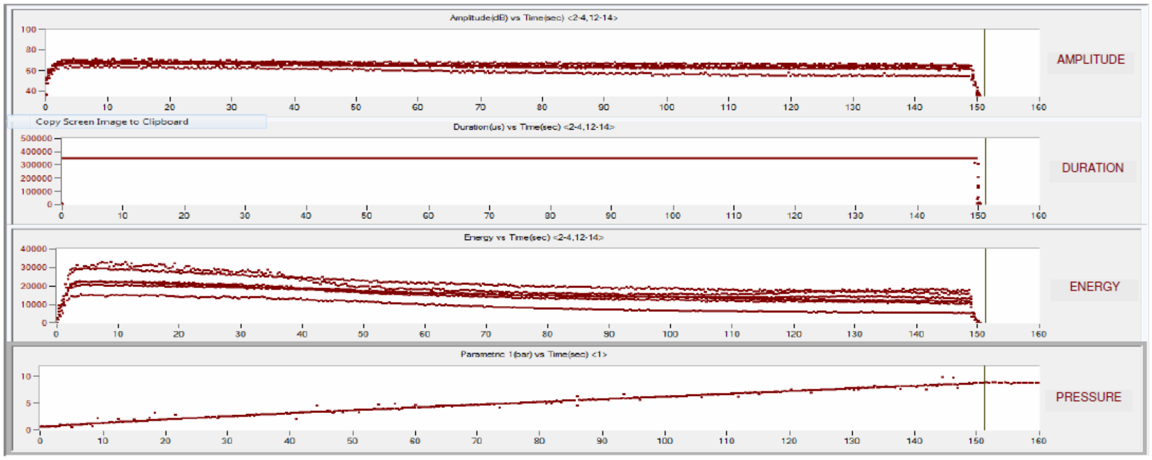

Figure 2. AE data of a component with pneumatic pressurization

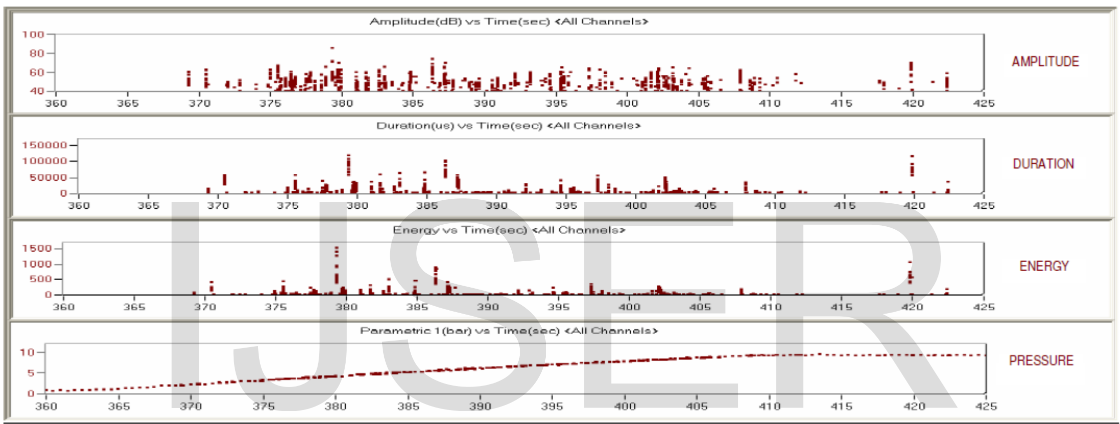

Figure 3. AE data of a component with Hydrostatic pressurization

Interpretation of proof testing results will be on the basis of basic acoustic emission parameters. There are three major criteria for test evaluation. The criteria are originated by American Society for Testing Materials [ASTM] based on the sources [5].

i. Active – Not Intensive: The number of events of Acoustic emission increases with increase in load. Energy, count number and peak amplitude are not significant in these criteria.

ii. Active – Intensive: The source is significantly more intensive hence other destructive testing methods are to be employed in order to assure the quality of the material

.iii. Critically Active – Critically Intensive: The growth of the number of acoustic events accelerates with increase in load. Energy, count number and amplitude are significant and the source may be a dangerous flaw. [5]

Typical acoustic emission testing results of two pressure vessels are shown in figure 4 and figure 5. Both the results show no hits until the load is crossing the previous preliminary test load limit. As the material is stressed above this load the hits also increases in the first result [figure 4]. Even during the hold phase AE signals were observed but the quantity in not significant. It falls under the first criteria Active – Not Intensive

Second result shows [figure 5] an increase mode of AE signals even at holding pressure and a drastic increase in the hits was observed just before the failure[period 4].This event falls on the third criteria critically Active – critically Intensive.

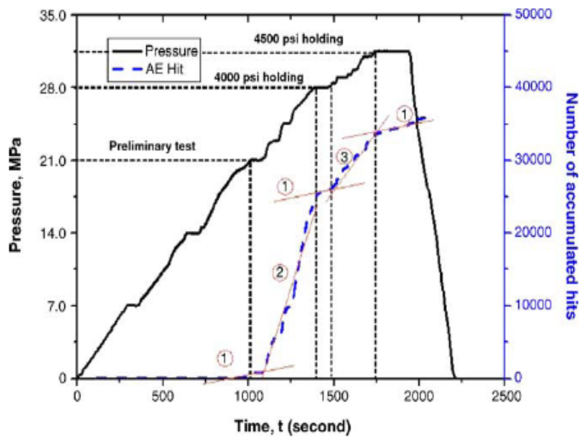

Figure 4. AE signals in the criteria Active –not Intensive

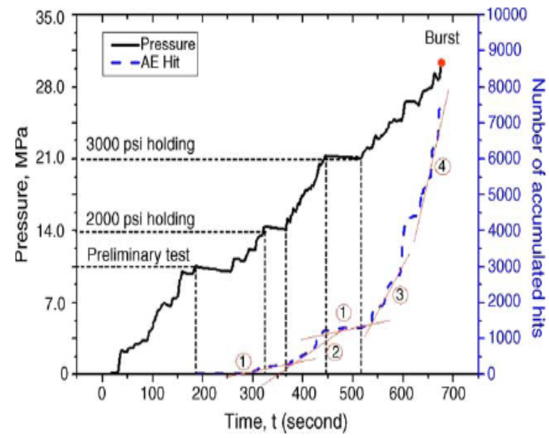

Figure 5. AE signals in the criteria critically Active – critically Intensive

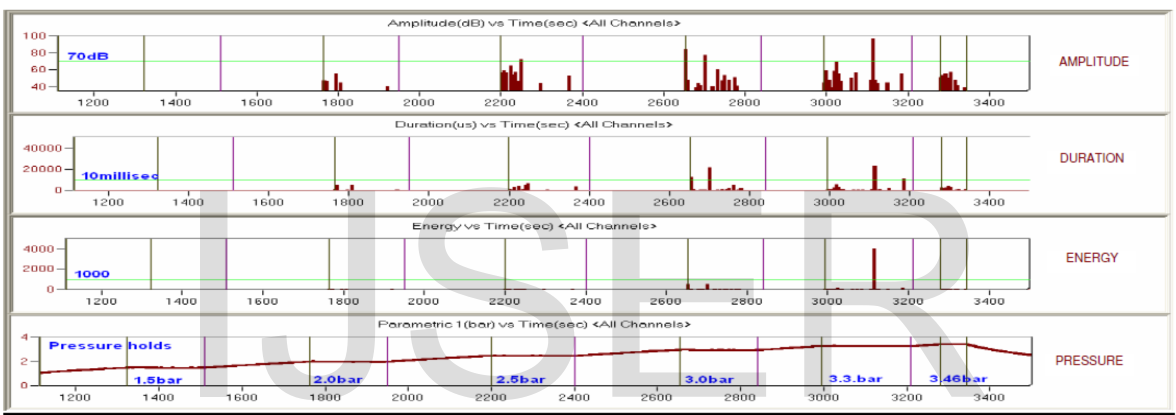

Figure 6. Test data with basic AE parameters

Precise interpretation can be done with the basic AE parameters like energy, amplitude, counts, etc. Another typical result of a proof testing with basic parameters of AE is shown in figure 6. Hold phase data alone be considered for the interpretation. The result shows very peak amplitude in between the time range of 3000 and 3200 at 3.3 bar pressure hold. Comparable increase is observed in energy at the same pressure. This shows the presence of a dangerous flaw in the material.

Hence it is advisable to go for other NDT methods like radiography or ultrasonic testing before put the vessel in use to assure the health of the vessel.

4. CONCLUSION

Acoustic emission testing is a dominant NDT tool for structural integrity assessment as it is capable of detecting micro level dislocations of any material. The evaluation of the structural integrity of Aluminium pressure vessel by pneumatic proof testing was discussed in the study. The role of the basic AE parameters like amplitude, count, energy and duration were also revised. The results show that the AE emissions of critical flaws will have more amplitude, count and energy in comparison with the emission from elastic and plastic deformations. Acoustic emission technique is also capable of predicting the bursting of the pressure prior to its occurrence, since a drastic increase in the number of accumulated hits was observed just before the bursting of the pressure vessel. The remnant life of structures and pressure vessels can also be evaluated by proper interpretation of AE signals obtained during testing. Hence a safe and controlled proof testing is possible when it is integrated with the powerful NDT tool Acoustic Emission Testing.

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