A REVIEW ON USAGE OF WAVELET TRANSFORMATION ANALYSIS AND ACOUSTIC SIGNAL MONITORING USING DAQ IN FRICTION STIR WELDING

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Abstract: This review article presents usage of acoustic signal monitoring and wavelet transformation analysis used by several researchers in friction stir welding process. This article outlines several methods of placements of acoustic sensors, noise cancellation by taking non-welding only machine running acoustic signal, the selection of frequency band for effective study of acoustic signal for in process monitoring and wavelet transformation for decomposition of acoustic signal for analysis. This article presents an insight into acoustic signal monitoring and analysis for those who pursue research in these areas.

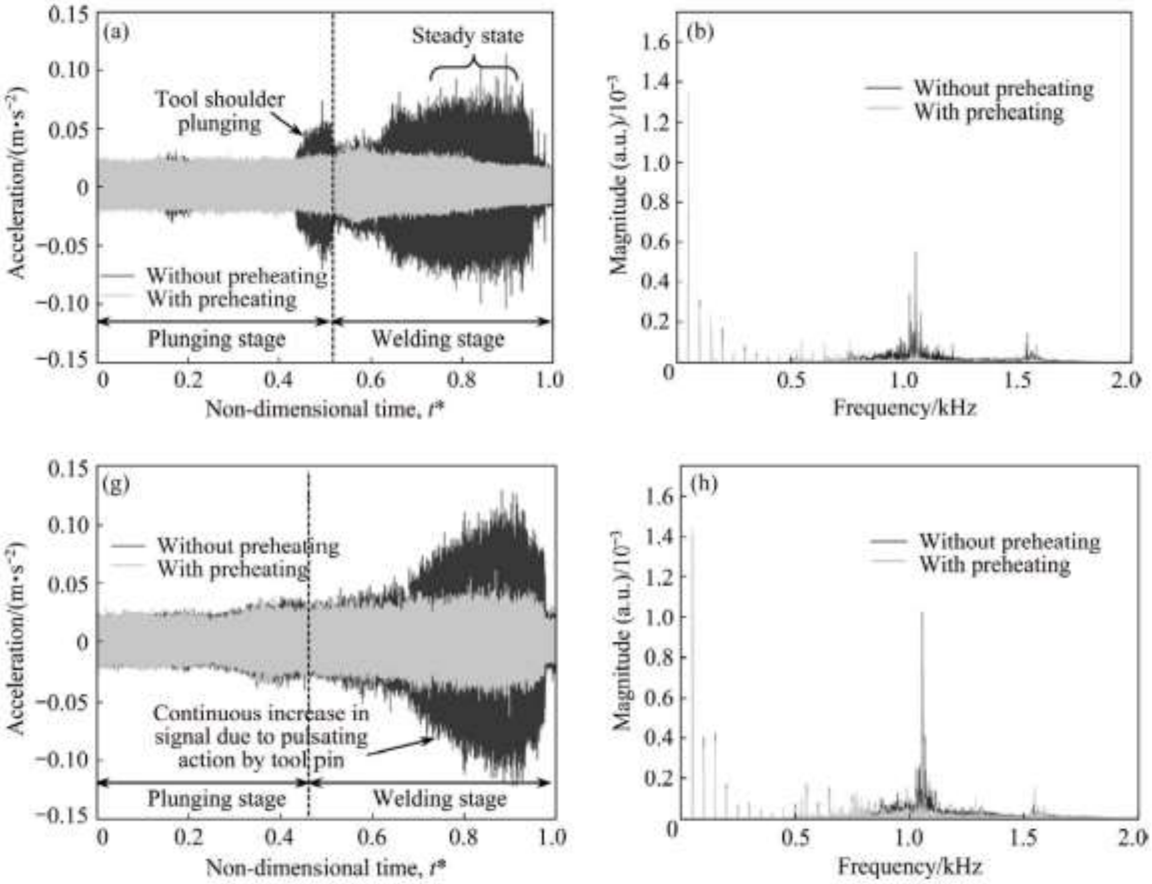
Introduction

Acoustic Emission (AE) is defined as the transient elastic wave generated by the rapid release of energy from a localized source or sources within a material (ASTM E1316, Revision 22A, June 1, 2022).

Acoustic Emission was used in many areas of manufacturing like identification tool wear [1], machined surface defects monitoring [2], prediction of surface roughness in machining [3], prediction of nugget diameter in resistance spot welding[4]. Use of AE in Friction Stir Welding (FSW) was tested by many researchers and this article mainly concentrates on use of AE in FSW.

Vibro-acoustic signal monitoring using DAQ

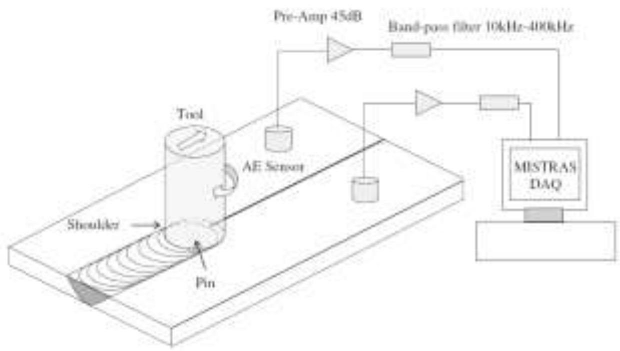
Ashu GARG [5] researched on vibro-acoustic signal pattern in Friction Stir Welding between AA6061-T6 and AA7075-T651 alloys and the effects of pin profiles (cylindrical and square), pin eccentricity (0.5 mm and 1 mm). Additional heating (preheating) of workpiece was provided with the help of butane gas torch prior to plunging and during welding. A slight drop in signal is observed when the shoulder reaches the desired depth and tool plunging stops to initiate transverse in the forward direction. the vibro-acoustic signal increases as the tool traverse begins along the weld line due to increase in the frictional resistance and the signal reaches steady state during the traverse due to steady state heat generation and softening of material. the square pin tool produced a higher magnitude signal compared to cylindrical tool. The vibro-acoustic signal is converted to frequency domain graph using Fast Fourier Transformation.



Measured vibro-acoustic signal in time domain (a, g), and converted signal to frequency domain (b, h)

Preheating the workpiece softened its material and allowed easy flow of material around the tool surface there by reducing the vibro-acoustic signal.

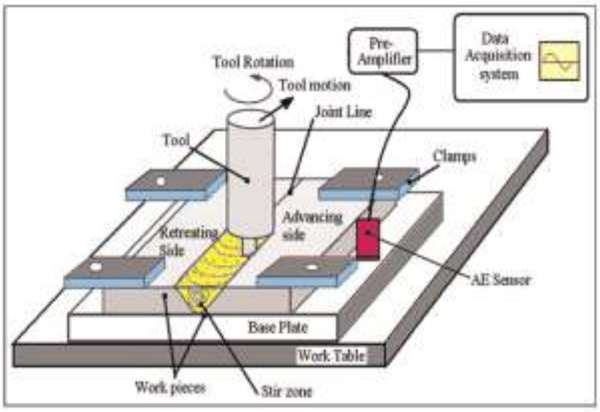
Soundararajan [6] used AE technique for in process monitoring during FSW and identified the frequencies during the process and analysing the wavelet decomposed signals in various levels or frequency bands. To cancel out noise generated by the machine due to machine vibrations a band pass filter is used to collect the signals in the range of 10 - 400KHz during the process.



AE signal acquisition, conditioning, and pre-processing

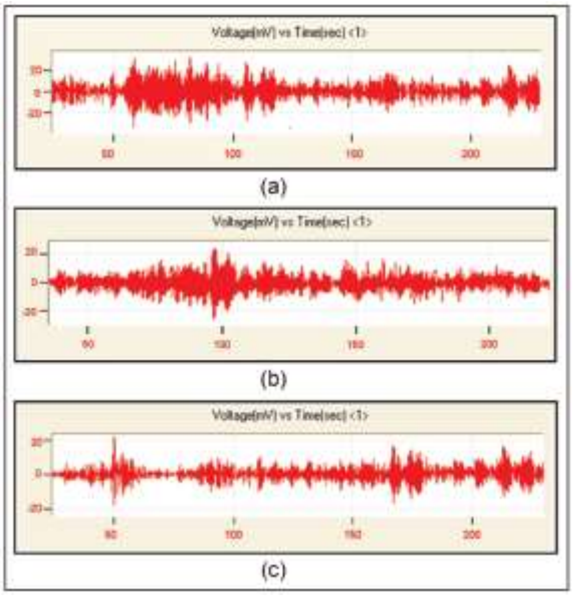
The frequencies of the AE signal from the FSW process lie in the ranges 100–170 kHz and 215–260 kHz. The power density spectrum increases as the rotational speed increases from 500 to 750 rpm but lies mainly in the frequency range 100–170 kHz. However when the tool rotational speed changed from 750 to 1000rpm the power density spectrum decrease in the region of 100 - 170 KHz but increases in the region of 220 - 260 KHz. This may be due to increase in temperature, the resistance offered by the material decreases to a minimum and material flows without resitance. When the process parameters are changed from 400 rpm and 75 mm/min to 750 rpm and 50 mm/min an increase in power density spectrum in the range of 90 -170 KHz is observed mainly due to sudden increase in temperature which induced high thermal stresses.

Senthilkumar Subramaniam [7] tested friction stir welding tools with square, circular, and triangular pin profiles to join the aluminum alloy AA6063-T6 flat plates. This study mainly focuses on in-process monitoring and control of the weld quality in friction stir welding process.



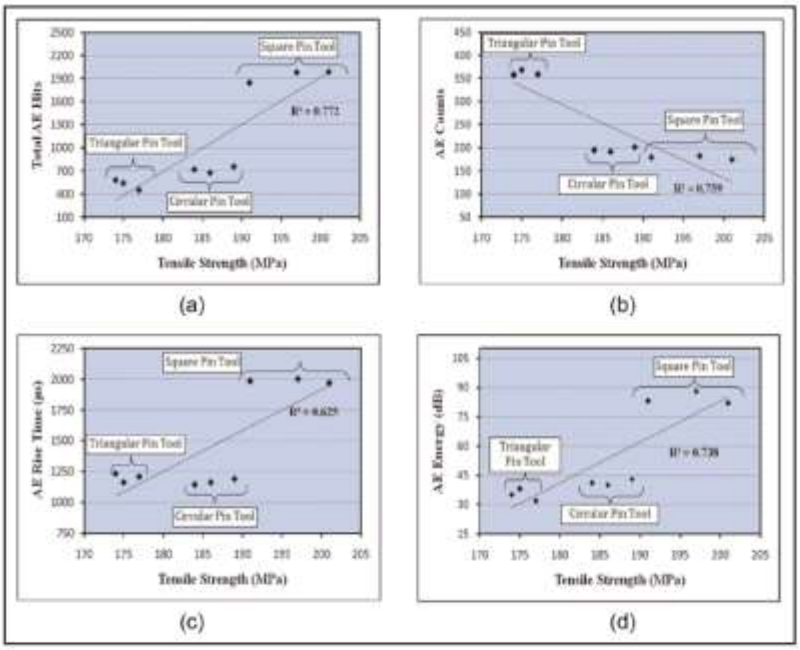
Schematic diagram of experimental setup for friction stir welding

The R80D AE sensor (Physical Acoustic Corporation) was mounted on base plate for monitoring the status of the FSW process and effective transmission of signals. A general purpose AE sensor of stainless steel case and ceramic face with an operating frequency range of 200–1000 kHz was utilized for experiments. To filter out noise due to machine vibrations the AE signals were recorded with the machine in the normal running mode and found to have noises due to machine vibration at amplitudes around 30–45 dB.
The acoustic signals recorded in different tools show distinctive patterns in time-domain graphs .



Time-domain AE signal: (a) circular pin, (b) square pin, and (c) triangular pin.

The square pin tool produces AE signal with higher amplitude and longer duration due to more number of edges in the tool pin as compared to other tools.



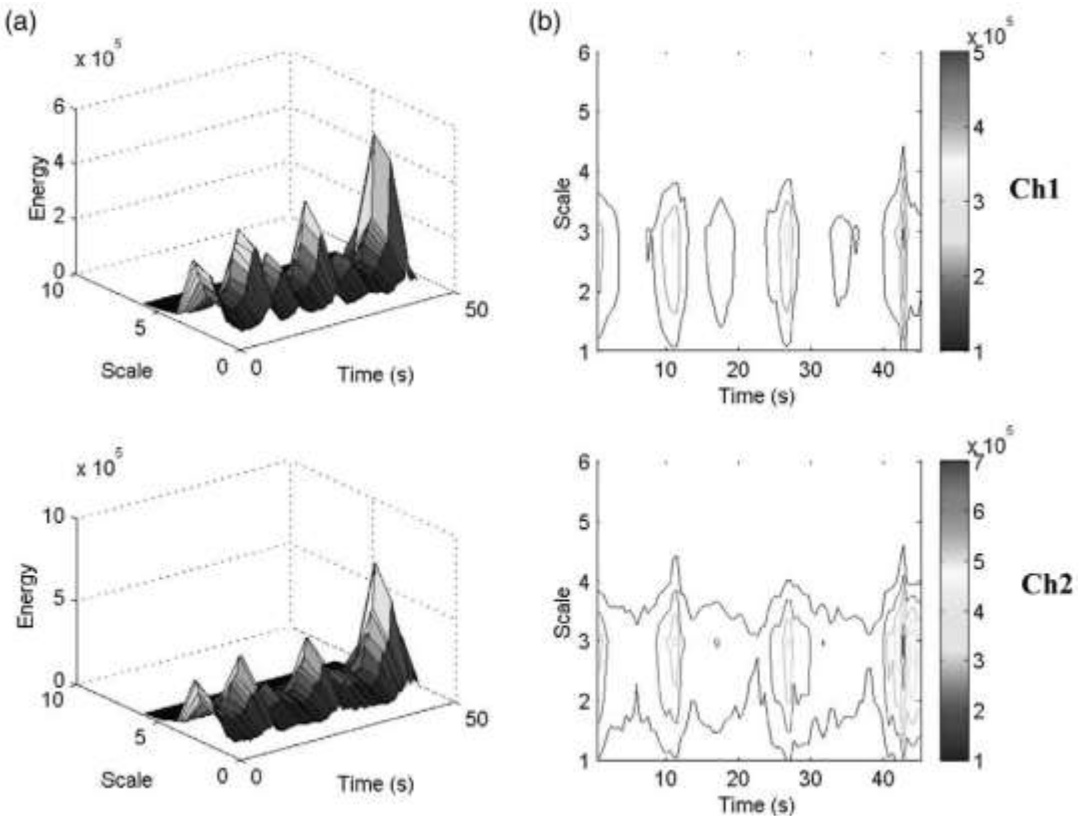
Relationship between AE parameters with tensile strength of FSW specimens produced by different tool pin profiles: (a) AE hits versus tensile strength, (b) AE average counts versus tensile strength, (c) AE rise time versus tensile strength, and (d) AE energy versus tensile strength.

The correlation of AE signal with tensile strength of the weld gives that an increase in AE energy shows an increase in tensile strength of weld specimen.

Wavelet Transformation Analysis

The wavelet transform is a mathematical technique which can decompose a signal into multiple lower resolution levels by controlling the scaling and shifting factors of a single wavelet function.

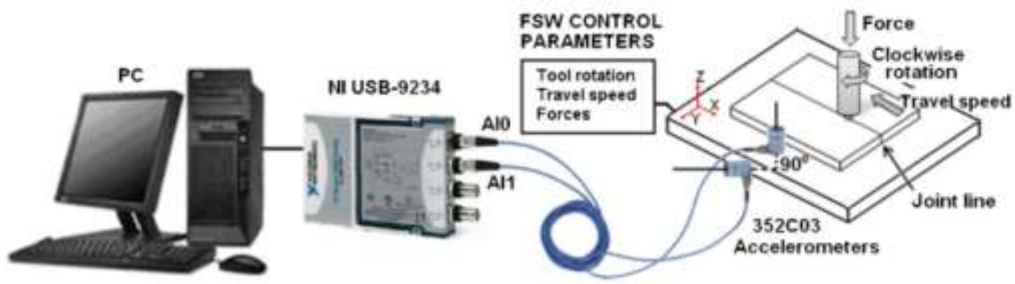
Changming Chen [8] performed FSW on AA 6061 Aluminium alloy plates of thickness 6.5 mm and 100 mm width. Tool shoulder diameter is 24 mm the pin is threaded with 6 mm diameter and 5.5 mm height. Two AE sensors were arranged on the either side of the weld line and are moved along with the tool. The wavelet transformation is used to decompose the AE signal into specific series of operations over different frequency bands. The AE signal obtained when the machine is kept running but not welding produced frequencies below 20 KHz, which can be filtered out using a high pass filter. Notches are machined on the plates to be welded at successive intervals.



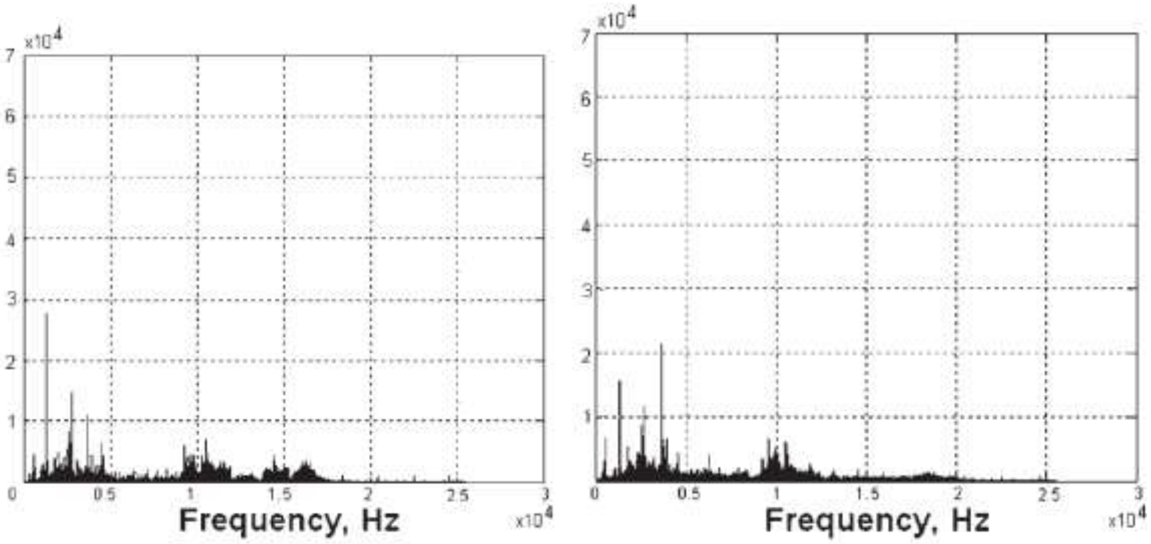
Three-dimensional profile (a) and contour map of wavelet transform (b) for the weld with gap defects.

The band energy peaks coincides with the location and size of the gap (machined notch). As the variations in the AE band energy in the case of gap can be attributed to a defect, the wavelet transform analysis can be used to detect defects during an actual FSW process if any.

Blanco Ferna´ndez [9] presented a study to evaluate effect of the tool profile on friction stir welding (FSW) process in the aluminium AA 1050, using vibro-acoustic signals. Two tools of different profiles were used - one with vertical grooves and another with horizontal grooves. Two AE sensors (piezoelectric based) were arranged perpendicularly on the top and lateral surface of the backing plate.

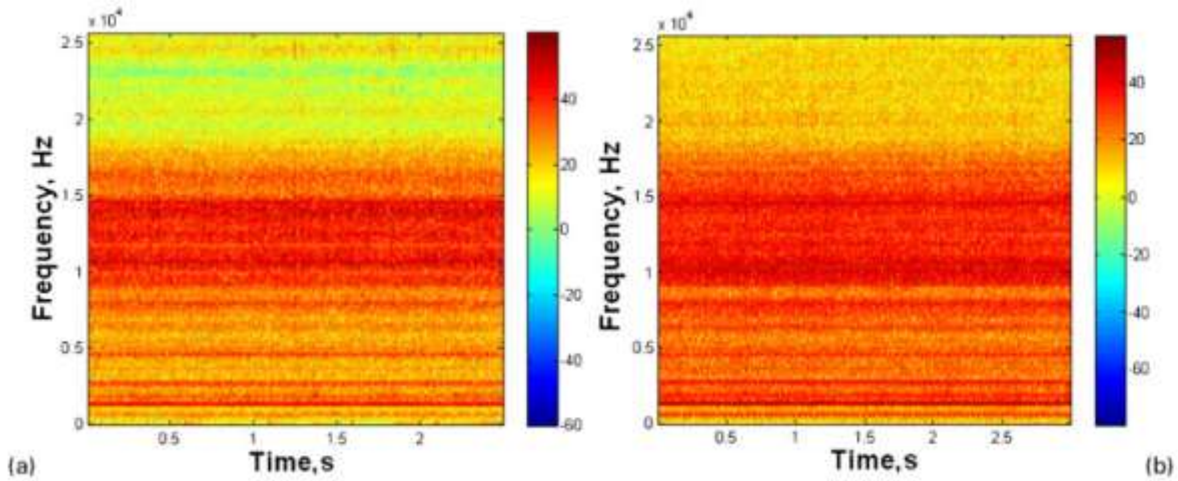


The vibro-acoustical signals of acceleration in Z and Y directions were acquired by using the AE instrument NI USB-9234 connected to PC. The vibro-acoustic signal in the Z axis before tool contact with the workpiece and during welding donot show significant difference in the frequency domain graph. For this reason signals only in the Y axis were analysed.

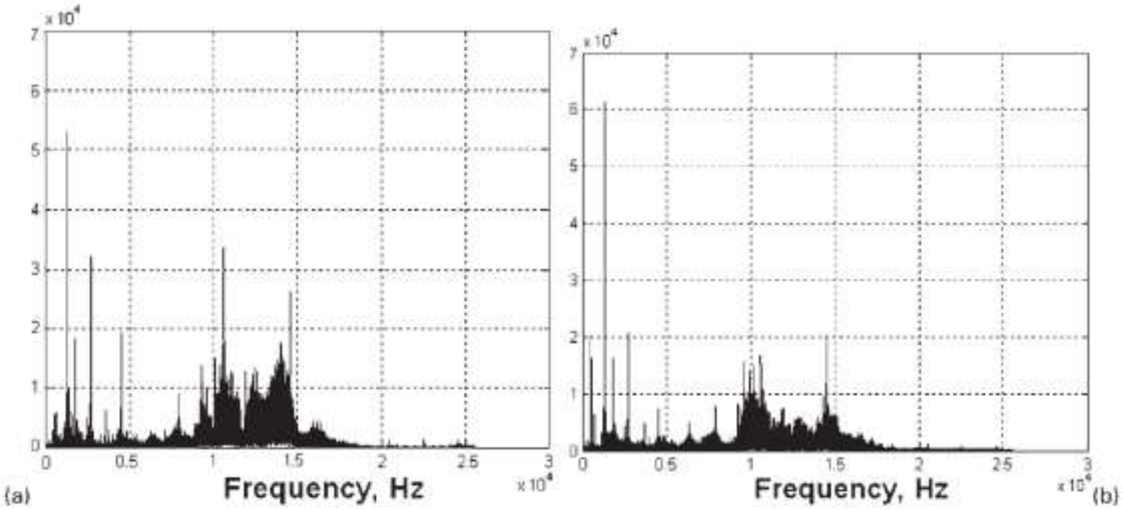


Frequency domain graph before too contact (left) and during welding (right)

The red regions in the time-frequency diagrams indicate high intensity on the power spectrum. This red region exists around the frequency range 9-15KHz. These frequency -time diagrams were obtained for parameters of 450rpm of tool rotational speed and 100 mm/min of tool traverse speed for both vertical grooved and horizontal grooved pin profiles.



Time- frequency diagrams obtained by using vertical grooved and horizontal grooved pin profiles



Frequency diagrams obtained by using vertical grooved and horizontal grooved pin profiles.

The amplitude in the frequency band between 12 and 16 kHz for probe with vertical grooves, is bigger than that for the condition with cylindrical probe with horizontal grooved pin profile.

Conclusion

Acoustic signals can be effectively used for in process monitoring of FSW process. Noise during machining can be effectively eliminated by designing a filter by taking recorded acoustic signal during normal running of the machine. Several correlations have been made by comparing time-domain and frequency-domain graphs with output parameters.

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