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The Acoustic Emission De-noising Processing Based on the Wavelet Analysis

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Abstract: The acoustic emission signal excited by the electromagnetic loading is a class of burst-type signal which contains peak, mutation and other compositions generally. Similarly, the noise of this kind signal is not stable. Hence, it is the key to study and deal with the noise section. By using ANSYS finite element analysis software, the defect and zero defect models has been established are loaded the same current value. Meanwhile, with changing the input current value, the current distribution, magnetic flux density distribution, electromagnetic force and crack deformation of the two models are analyzed comparatively. Hence, the loading mechanism is proved by the analysis result of metal plate stimulating acoustic emission signal under the heavy current. This paper combines the wavelet analysis and mathematical to cancel noise for the moderating effect of external noise will influence subsequent processing signals in the signal transmitting by the electromagnetic excitation. Simultaneously, we deal with the signal by the hard threshold and soft threshold function to get the de-noising results contrast figure. Thorough the de-noising signals figure, it can be seen that the effect of wavelet-morphology is more apparent. It not only can eliminate the noise signal of high and low frequency, but also keeps the details of the characteristics of the original signal. And it is conductive to subsequent processing of the signal.

Keywords Wavelet analysis; Mathematical morphology; electromagnetically acoustic emission; De-noising

INTRODUCTION

Electromagnetically acoustic emission technology has applied electromagnetic loads to the acoustic emission nondestructive testing,the structure can be detected online without disassembling making tooling.Compared with the traditional method of loading,such as applying mechanical loads,container pressure and other measures,Electromagnetic loads can load partly on the designated area without loading on the entire structure and additional mechanical damage.Meanwhile,it can focus energy on the defects,strengthen the signal strength,lower the requirements of testing equipment.It can load at any time based on requirement as well,thereby reducing the Time requirements of traditional acoustic emission's long-term load[1].

SIMULATION BASED ON ANSYS

This paper focuses on finite element analysis of aluminum by using ANSYS Simulation software[3].By analyzing and comparing the simulation results, we can achieve the fundamental of generating acoustic emission signal in aluminum defects under conditions of electromagnetic loading. This paper has adopted rectangular thin aluminum, in the central position of which has a round hole with a linked triangle on the top .The triangle can represent fatigue effects and final crack situation of aluminum generated by long-term stress at round hole under external influence, as shown in Figure 1.

The corresponding model parameters are:(1)Geometric parameters: aluminum: Length × width × height = 200mm × 100mm × 1mm, the hole diameter is 5mm, the length of triangle crack is 5mm and the width is 0.1mm;(2)Physical parameters: The relative permeability $\mu_r = 1$,the resistance $\rho = 2.83E-8$,the elastic modulus $E = 6.9\times10^{10} Pa$, the density $m = 2.7E3$.

The sound waves are mechanical waves and are generated by media resilient movement, the transfer equation of sound waves in isotropic elastic medium of every direction is:

$$\frac{\lambda}{2(1+\gamma)}\left((\nabla\cdot\nabla)d+\frac{1}{1-2\nu}\nabla(\nabla\cdot d)\right)+F=\rho\frac{\partial d}{\partial t}$$

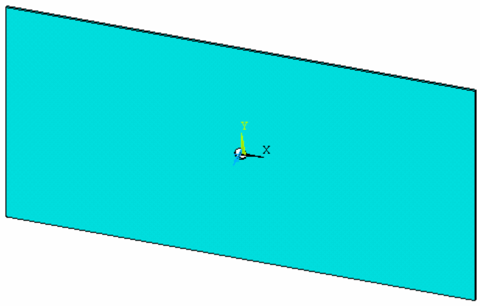


Figure 1. The model of sheet metal

In the equation, λ is elastic modulus, the d is mechanical displacement, ν is Poisson coefficient, F is electromagnetic force, the ρ is density of the object.

Electromagnetic acoustic emission is a phenomenon that the sound is excited to emit by electromagnetism, it is coupling of electromagnetic and stress essentially. Because the simulation model is aluminum, we can ignore the displacement current, what we have adopted is current source, so the electric field in aluminum is regarded as constant, therefore, the analysis of electromagnetic acoustic emission phenomena is the one of quasi-electromagnetic static field. Maxwell fundamental equations can be abbreviated as:

$$\nabla \times H = J$$

$$\nabla \times E = 0$$

The H is intensity of magnetic field, the J is density of current, the D is density of electric flux, E is intensity of electric field, the B is intensity of magnetic flux.

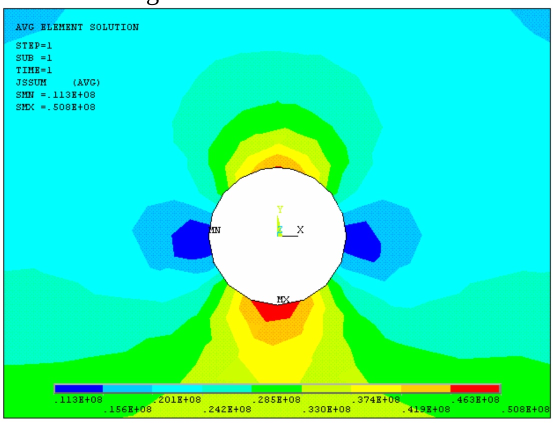
Due to the presence of an electromagnetic field, there will generate electromagnetic force on the power-aluminum, this is the power load which excites power-aluminum to generate acoustic emission phenomenon, its equation is:

$$F = J \times B$$

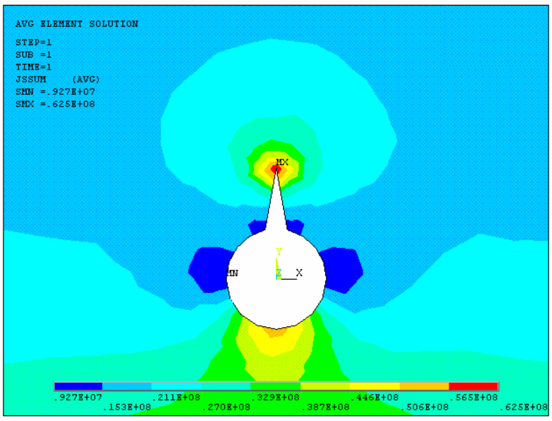
F is Lorentz force. By the formula above, it can couple the mechanical vibration and the electromagnetic force together, and we can achieve the corresponding expansion trend of crack if select the appropriate current, and then generate the phenomenon of acoustic emission.

Simulation of ANSYS

In order to explain the mechanism of electromagnetic acoustic emission more clearly, we have carried out ANSYS finite element analysis of intact model and cracked model based on intact one, and compare the difference between them in the case of the current distribution, the magnetic flux density, the electromagnetic force vector and so on.



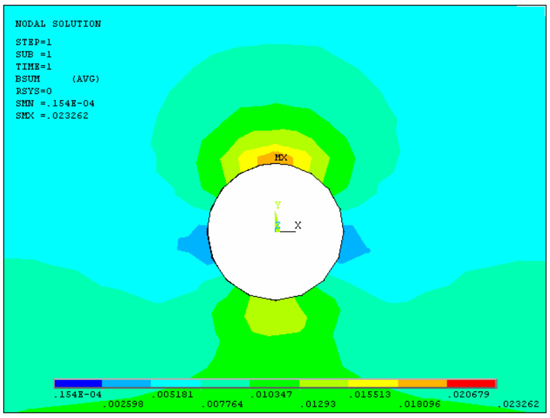
（a）Current distribution of intact model at 1000A



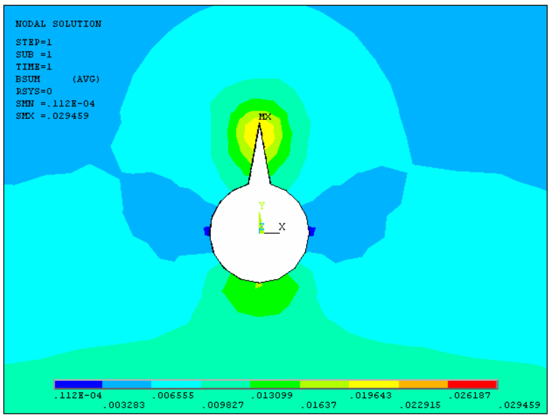
（b）Current distribution of defect model at 1000A

Figure 2.Comparison chart of current distribution

Under the condition of energized 1000A instantaneous high-current, the current distribution comparison chart of intact model and defect model are shown in Figure 2,we can see that the current distribution of defect model is more concentrated than that of intact aluminum model, in addition, with increasing current, the current difference will be increased.



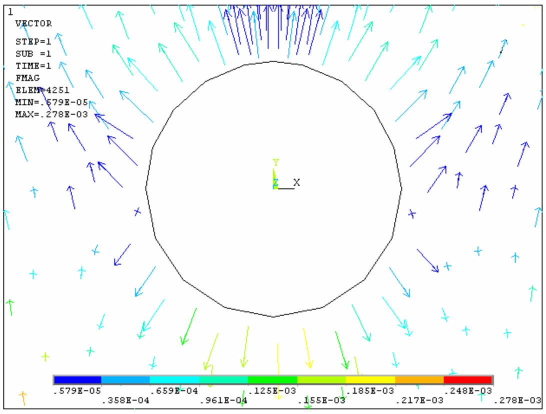
（a）Magnetic flux density of intact model at 1000A



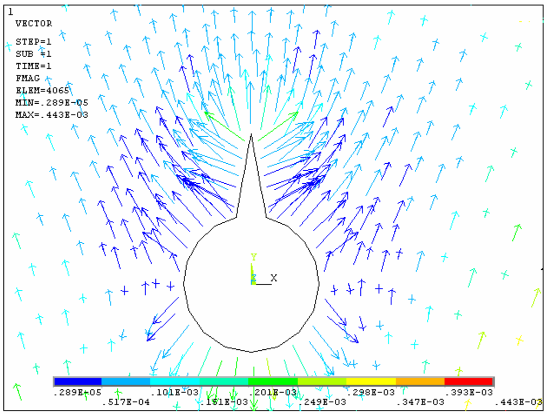
（b）Magnetic flux density of defect model at 1000A

Figure 3. Comparison chart of magnetic flux density

Under the condition of energized 1000A instantaneous high-current, the electromagnetic force vector comparison chart of intact model and defect model are shown in Figure 3, we can see from the chart that the extreme of defect model's magnetic flux density is higher, the distribution of it in crack is gradually concentrated. Therefore, the density of current and magnetic flux in cracked aluminum are both higher than that of intact model.



（a）Electromagnetic force vector of intact model at 1000A



（b）Electromagnetic force vector of defect model at 1000A

Figure 4. Comparison chart of magnetic flux density

Under the condition of energized 1000A instantaneous high-current, we can see from the resulting electromagnetic force vector that electromagnetic force at the crack tip is higher than that of intact model, in addition, with increasing current, the electromagnetic force in crack will be more concentrated, the direction of electromagnetic force vector arrow represents the trend of widening cracks, which make it possible to apply metal plate stimulating acoustic emission signal to non-destructive testing.

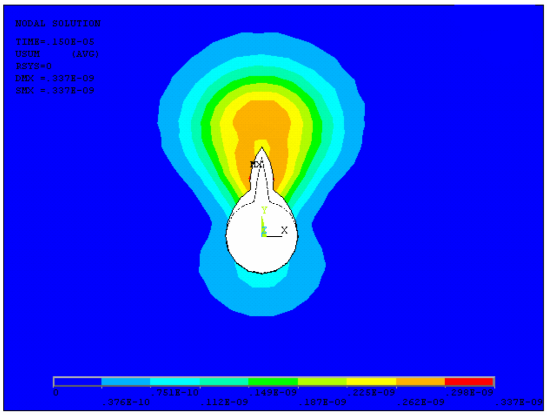


Figure 5. Comparison chart of magnetic flux density

We can see that deformation occurred in crack in the role of electromagnetic force's through finite element analysis of stress field, as shown in Figure 5. Crack is enlarged, the trend of expansion is the crack tip-centric, so we can determine location of crack by acoustic emission phenomenon.

As can be seen from the above de-noised waveform, when the SNR is 7-dB, the de-noising method that combines the wavelet transform and mathematical morphology can suppress noise more effective while recover the original signal waveform more completely, the effect is more obvious than that of hard threshold and soft threshold de-noising.

In order to observe the de-noising effect of these three methods more directly, set out the signal to noise ratio and the mean square error of all the above methods by calculating. And compare with that of applying soft threshold and hard threshold directly, the combined de-noising method based on the wavelet analysis and mathematical is more effective. The experimental data are shown in Table 1-3.

Table 1. First decomposition results of different de-noising methods

De-noising method	Signal noise ratio（SNR）	mean square error（MSE）
hard threshold	2.742665	1.257428
soft threshold	3.632146	1.846599
wavelet - morphology	5.642235	0.632546

Table 2. Second decomposition results of different de-noising methods

De-noising method	Signal noise ratio（SNR）	Mean square error（MSE）
Hard threshold	3.134285	0.936657
Soft threshold	3.830698	0.732436
Wavelet - morphology	5.979263	0.316465

Table 3. Third decomposition results of different de-noising methods

De-noising method	Signal noise ratio（SNR）	Mean square error（MSE）
Hard threshold	3.693564	0.672595
Soft threshold	3.845823	0.456981
Wavelet - morphology	7.131658	0.237428

According to the analysis of the data above, we can see that with the wavelet packet decomposition of each level, the SNR and RMSE of hard threshold，soft threshold and the wavelet-morphology de-noting methods are both increased, The effect of combining wavelet and morphological is more effective. This method depends only on the local shape features of signals to be processed during signal processing. Decompose a complex signal into various parts of the physical meaning by mathematical morphology transformation, and then stripped its background, maintain the main shape characteristics of the signal.

Now apply the combined program based on the wavelet analysis and mathematical to the de-noising section of the electromagnetic acoustic emission signals.

In the period of signal detection, the primarily noise can be divided into two parts: mechanical noise and electromagnetic noise. It has been found from a large number of experimental studies that the noise is mostly caused by electrical repulsion below the frequency of 50kHz, so this part is mainly the noise signal which has no practical significance and is filtered.

Reconstruct by wavelet decomposition of sym6 and apply the new combined program based on wavelet-morphology to the de-noising processing of the electromagnetic acoustic emission signals, Simultaneously, we deal with the signal by the hard threshold and soft threshold function, the de-noising results contrast figure are shown in Figure 5- Figure 9. Thorough the de-noising signals figure, it can be seen that the effect of wavelet-morphology is more apparent. It not only can eliminate the noise signal of high and low frequency, but also keeps the details of the characteristics of the original signal. And it is conductive to subsequent processing of the signal.

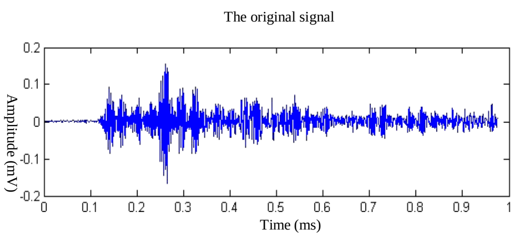


Figure 5. Original signal waveform after decomposition and reconstruction

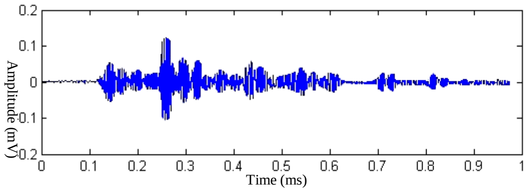


Figure 6. Signal waveform of soft threshold processing

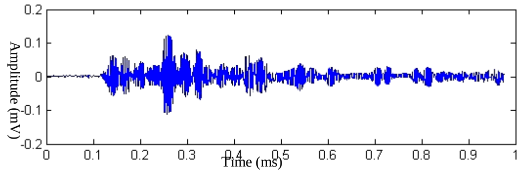


Figure 7. Signal waveform of hard threshold processing

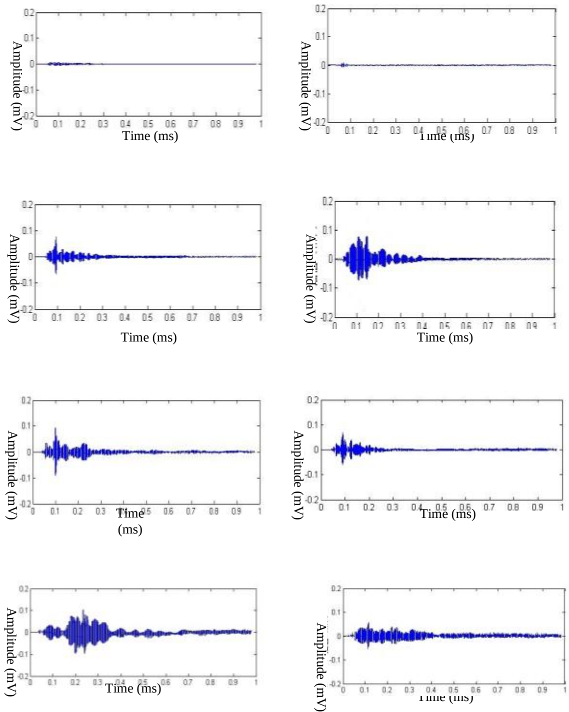


Figure 8. Process of combined de-noising

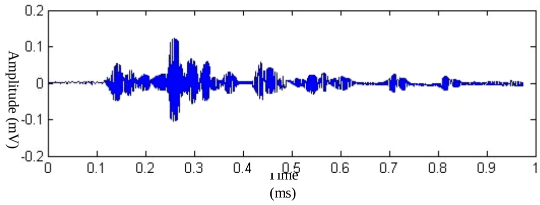


Figure9. Signal waveform of wavelet - morphological processing

CONCLUSION

This paper verify the principle of electromagnetic acoustic emission by using ANSYS finite element analysis software, according to the characteristics of noise signal, combines the advantages of wavelet analysis and mathematical morphology and applies it to the electromagnetic acoustic emission signal de-noising, then compares the combined de-noising program to that of normal soft or hard threshold, The results show that the effect of wavelet-morphology is more apparent. It not only can eliminate the noise signal of high and low frequency, but also keeps the details of the characteristics of the original signal. And it is conductive to subsequent processing of the signal.

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