SELF-EXCITED ACOUSTIC SYSTEM FOR NON-DESTRUCTIVE EXAMINATION OF INCLUSIONS IN ALUMINUM CASTINGS

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In this article, we present a study on the use of a self-excited acoustical system for the detection and characterization of inclusions in aluminum casting. The system is based on the principle of self-sustaining oscillations, and uses a piezoelectric transducer to generate and detect standing waves in the aluminum sample. The frequency and amplitude of the oscillations are analyzed to identify the presence and location of inclusions within the sample. The results of the study show that the self-excited acoustical system is effective in detecting and characterizing inclusions in aluminum casting, with a high degree of accuracy and sensitivity. This method has the potential to improve the quality and reliability of aluminum casting products, and may be applied to other materials in the future.

Keywords - Aluminum casting, Detection and characterization of inclusions, Non-destructive evaluation techniques, Self-excited acoustical system.

I. INTRODUCTION

The study of inclusions in aluminum castings is of vital importance in modern manufacturing processes, particularly in industries where complex supply chains require intercontinental shipping of finished products. Any imperfections or defects in the cast can lead to costly delays, as the cast must be shipped back and new parts must be created. One key aspect of this study is the ability to accurately locate these imperfections, particularly in elements that are meant to be drilled or machined.

Self-excited acoustical systems have emerged as a valuable tool in the detection of inclusions in aluminum casts.[1]–[4]These systems utilize the natural vibrations of the material to detect the presence and location of inclusions within the cast, providing a non-invasive method of analysis.[5] This is particularly useful for small inclusions, which may not be visible using traditional methods such as X-ray imaging.[6], [7]

The use of self-excited acoustical systems has several advantages over other methods of inclusion detection. [8]–[13]One key benefit is the ability to quickly and accurately identify inclusions in real-time, without the need for additional equipment or external excitation. This allows manufacturers to identify and address defects early in the production process, minimizing the risk of costly delays and rework.

In addition, self-excited acoustical systems are able to detect inclusions that may be missed by other methods, such as small or thin inclusions that may not be visible using traditional techniques. This is particularly important in industries where the presence of even small inclusions can have significant impacts on the performance and durability of the finished product.

Despite these benefits, there are also some limitations to the use of self-excited acoustical systems in the study of inclusions in aluminum casts. One key challenge is the need for specialized equipment and trained personnel to operate and interpret the results of these systems. Additionally, the accuracy of the results may be affected by factors such as the size, shape, and distribution of the inclusions within the cast.

The use of self-excited acoustical systems to study inclusions in aluminum casts can significantly improve the efficiency and accuracy of the quality control process, helping manufacturers to produce higher quality products with fewer defects. By quickly and accurately identifying the presence and location of defects in the early stages of production, manufacturers can reduce waste and downtime associated with defective parts.

In addition to accelerating the measurement process, self-excited acoustical systems can also be used to automate the identification and reporting of defects.By automating the measurement and analysis of the natural frequency response of the castings, manufacturers can streamline their quality control processes and reduce the reliance on manual inspection methods.

II. MEASUREMENT STAND

The measurement stand for a self-excited acoustical system for the study of inclusions in aluminum casting consists of a loudspeaker acting as the inductor, a piezoelectric accelerometer, a signal conditioner, a signal generator, a signal amplifier, and a National

Instruments (NI) data acquisition card. The signal produced by the generator is amplified and passed to the loudspeaker, which acts as the vibration emitter. The loudspeaker is then applied to the aluminum casting sample, and the accelerometer is placed in close proximity to the emitter.[14], [15]

The piezoelectric accelerometer is a key component of the measurement stand[8], as it is responsible for detecting the vibrations and oscillations of the sample. The accelerometer utilizes the piezoelectric effect, which refers to the ability of certain materials, such as crystals and ceramics, to generate an electrical charge in response to applied mechanical stress. When the accelerometer is subjected to an acceleration or deceleration, it produces a voltage proportional to the acceleration. This voltage is then processed and analyzed to determine the frequency and amplitude of the oscillations within the sample.

The signal conditioner is used to adjust the voltage levels of the signal from the accelerometer to match the input range of the signal generator. In this case, the signal is conditioned to a range of +10 to -10 volts. The conditioned signal is then passed as positive coupling to the signal generator. The signal is also passed to the data acquisition card(DAQ) which reads and processes the data for further analysis.

The signal amplifier is used to increase the strength of the signal from the generator, which may be necessary if the signal is too weak or noisy to be accurately processed by the emitter.

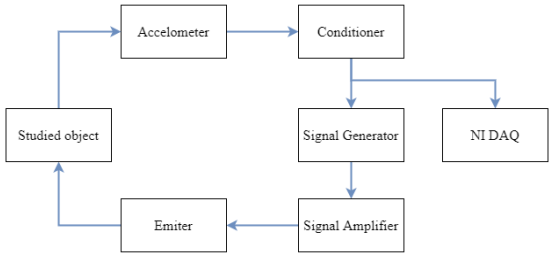


Fig 1. Schematic of the measurement system

This operation results in the self-excitation of the aluminum casting sample, which generates standing waves within the sample. The frequency and amplitude of these standing waves are analyzed to identify and characterize any inclusions, blow holes, porosity or other imperfections within the sample.

The system does not require the removal or destruction of the sample in order to perform the analysis, and therefore does not compromise the integrity or strength of the casting. This makes the system particularly useful for quality control and assurance purposes, as it allows manufacturers to identify and characterize inclusions within the casting without damaging the product.

The measurement stand enables the user to quickly and easily conduct the analysis and obtain reliable and accurate results in a short period of time. This feature makes it easy to integrate the stand into the production line by automating the measurement process.

III. OBJECT OF STUDY

The object of study in this research was aluminum castings used as subassemblies in the automotive industry. These castings are subjected to a variety of mechanical stresses during their service life, and it is important to ensure that they are free from defects that could compromise their strength and reliability.

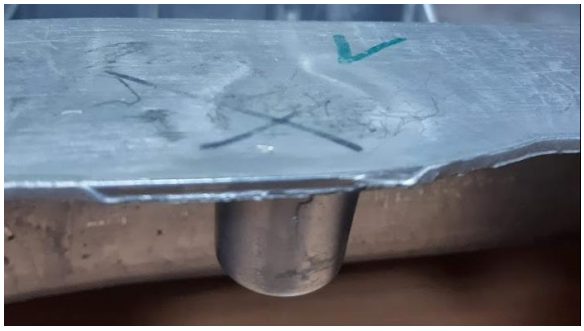


Fig 2. First measurement point

In this study, four identical aluminum casting samples were used, and eight corresponding points were chosen on each sample. These points were selected in places that were critical for further machining, such as drilling points, and were used as reference points for the analysis.

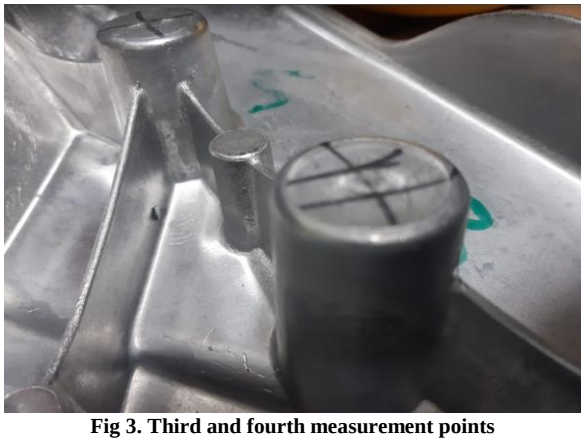


Fig 3. Third and fourth measurement points

All of the tested castings were previously marked as either valid or defective using other examination methods. These methods included visual inspection, ultrasonic testing, and radiographic inspection, and were used to identify and classify any defects or inclusions present within the castings. The results of these examinations were used to establish a baseline

for the analysis, and to verify the accuracy and reliability of the results obtained using the self-excited acoustical system (SAS) measurement stand.

IV. RESULTS

Using the SAS measurement stand, the accelerometer signal was collected via the National Instruments data acquisition card and passed into LabVIEW software running on a personal computer. In LabVIEW, the signal was preprocessed and packed into TDMS (Technical Data Management Streaming) files[16], which are a proprietary file format designed for storing and organizing large amounts of data. The TDMS files were then transferred to DIAdem software, where they were further processed and analyzed.

DIAdem is a data analysis and visualization tool developed by National Instruments, and is commonly used in a variety of engineering and scientific applications. It provides a range of advanced features and functions for analyzing and interpreting complex data sets, including statistical analysis, curve fitting, and signal processing.

Due to the raw data collected by the SAS measurement stand being illegible, a series of data processing operations were conducted in order to extract meaningful information from the measurements. The first operation in this process was the Fast Fourier Transform (FFT), in order to decompose a time-domain signal into its frequency components.

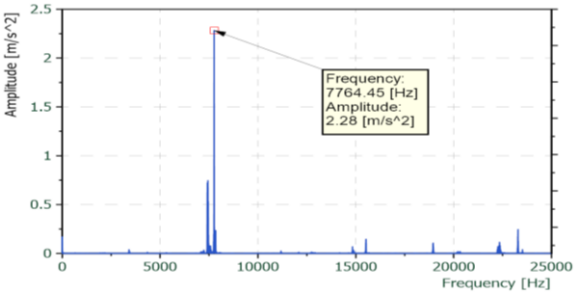


Fig 4. Sample signal waveform after FFT

As a result of the FFT operation, a signal waveform is obtained. The highest peak in the waveform is identified, as it corresponds to the natural frequency of the aluminum casting sample.

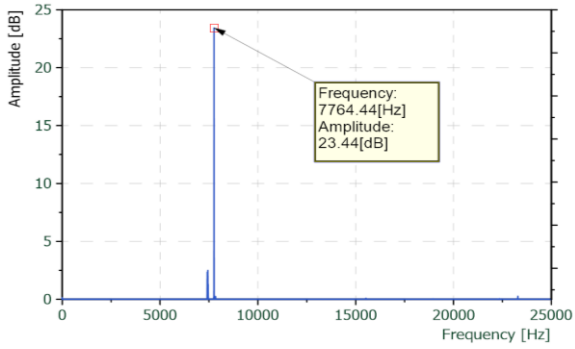


Fig 5. Sample signal waveform after PDS

Similarly Power Density Spectrum(PDS) operation was conducted. As it decomposes the signal into its frequency components and provides information about the power or energy of each component, it can used to identify the dominant frequencies in a signal, and to quantify their relative strength or importance.

Upon initial analysis, we found that the FFT and PDS results both presented the same highest frequency value. However, after further research, the FFT method was found to be more suitable for the purposes of this study. As a result, we chose to use the FFT method to determine the natural frequencies of the studied castings in our analysis.

This measurement was repeated for each of the 8 points on the 4 castings, allowing us to obtain a detailed understanding of the natural frequency response of the castings at each location. By analyzing the results of these tests, we were able to identify the presence and location of inclusions within the castings, providing valuable insights for manufacturers looking to improve the quality of their products.

1st point			5th point		
casting	natural freq.	defect	casting	natural freq.	defect
1	7580	yes	1	7951	yes
2	7768	yes	2	8012	yes
3	6830	no	3	7932	no
4	7115	no	4	7985	no
2nd point			6th point		
casting	natural freq.	defect	casting	natural freq.	defect
1	8187	yes	1	9203	yes
2	7859	no	2	9150	yes
3	7937	no	3	8925	no
4	7938	no	4	9539	no
3rd point			7th point		
casting	natural freq.	defect	casting	natural freq.	defect
1	9224	yes	1	3694	no
2	3971	yes	2	3320	yes
3	3849	no	3	3604	no
4	4675	no	4	3717	no
4th point			8th point		
casting	natural freq.	defect	casting	natural freq.	defect
1	3858	yes	1	7844	no
2	3764	no	2	8404	yes
3	3316	no	3	7979	no
4	3818	no	4	7920	no

Tab 1. Natural frequency examination results

V. CONCLUSION

Upon analyzing the results of these tests, it was observed that for the first studied point, the two first castings presented similar natural frequency results.

However, these results were different from the latter two castings, which exhibited lower natural frequencies. This difference in frequency enabled us to conclude that the points of higher frequency were likely the defected ones, which is consistent with previously conducted studies that had shown the first point on the first and second casting to be defective.

The second point on the first casting exhibited higher frequency results than the other three castings, which suggests that it may be defective. This conclusion is supported by previous research indicating that the second point on the first casting is indeed defective.However, it is worth noting that the relatively small difference in frequency between the valid and defective castings may indicate that the defect may be small in size, or that the measurement was not entirely accurate. This could be due to factors such as inaccurate placement of the emitter and accelerometer, which can affect the accuracy of the measurement.

The third studied point on the first casting exhibited significantly higher frequency results compared to the other three castings, leading to conclusions that it may be defective. However, this conclusion is not in line with previous research indicating that the third point on the first casting was not the only defective one The complicated geometry of the studied part may have contributed to the discrepancy.

The results for the fourth point are not precise enough to draw reliable conclusions. While the only defective casting had the highest measured natural frequency, the differences between the measurements for this point were too small to accurately determinethe correctness of the measurement. Similarly results for the fifth and sixth measurement point show small differences between valid and invalid castings.

Unlike the previous points, which tended to show higher frequency values in the defective castings, seventh point exhibited lower frequency values in the defective castings.This change in tendency may be due to the different geometry of this studied point, which may affect the natural frequency response of the castings. Despite this anomaly the flaw was recognized correctly.
It was observed that the results for the eighth studied point were similar to those for the first point. Correctly recognized defected part has shown higher frequency values than the undamaged ones.

In conclusion, study of inclusions in aluminum casts utilizing self-excited acoustical systems has demonstrated the effectiveness of this technique in detecting the presence and location of these defects. By analyzing the natural frequency response of the castings at different points, we were able to identify the points that were likely to be defective, providing valuable insights for manufacturers looking to improve the quality of their products.
However, we also observed that there were instances where the results of the measurements were not entirely reliable. This may be due to a variety of factors, such as inaccurate placement of the emitter and accelerometer, or the complicated geometry of the studied parts.To address these issues, it is important to carefully consider the limitations of self-excited acoustical systems and to ensure that accurate measurements are obtained in order to obtain reliable results. This may involve the use of more advanced equipment or techniques. One potential solution to the issues of inaccurate measurements in the study of inclusions in aluminum casts is the development of a more sturdy and reliable measurement stand. Such a stand could be designed to better withstand the stresses of the measurement process, ensuring that the emitter and accelerometer are properly positioned and that the data is accurately captured. Additionally, a more advanced measurement stand could be equipped with features such as the ability to conduct repetitive measurements with high accuracy, further improving the reliability of the results.It is worth noting that we cannot be certain of the accuracy of the previously conducted research that our results were compared to. This is because both our study and the previous research utilized non-invasive techniques, which may not provide the same level of accuracy as more invasive methods. As a result, we cannot be certain that the data used in the previous research is completely correct, which may have affected our ability to accurately compare our results.

Overall, it is important to carefully consider the limitations of non-invasive techniques when studying inclusions in aluminum casts, and to ensure that accurate measurements are obtained in order to obtain reliable results. By improving the accuracy and reliability of these measurements, manufacturers can take steps to further improve the quality of their products and minimize the risk of costly delays and rework.

VI. REFERENCES

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