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Monitoring the Sheet Metal Defect of Stamping Process

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Abstract: In automotive manufacturing industry, among all the forming process the hot press forming was one of the most vital forming processes. The sheet metal forming process was very common in manufacturing industry for producing parts for lightweight vehicles. However, catastrophic failure resulted in high losses to the industry occurred due to late detection of defects. This had become an issue in the manufacturing industry. Therefore, in order to solve the problem, non-destructive test was employed in manufacturing process. At first the case study was made in this project regarding the hot press forming process, the material used in stamping process, and the common type of failure that occurred in sheet metal stamping. Next, the case study moved onto different types of ultrasonic monitoring system for monitoring the condition of metal. There were four case studies regarding the ultrasonic monitoring system in this thesis and each case study consisted of one ultrasonic monitoring system. The four ultrasonic monitoring systems were categorized into contact ultrasonic monitoring system and non-contact ultrasonic monitoring system. All the methods in each case study reviewed had different method in generating and receiving ultrasonic wave. Among the four case studies one of the presented results was in graph form while another 3 was in the form of image. The methods reviewed as well as the results from each method were compared. At the last part of this project, the ultrasonic monitoring method that possess the most advantages in hot press forming process was chosen. The supportive explanation is given in order to strengthen the chosen method.

Keywords: Hot Press Forming (HPF), Crack, Ultrasonic wave, Ultrasonic monitoring system

1. Introduction

In recent years, the growing demand for higher quality products to meet better features and performance is a challenge for manufacturers. High precision sheet metal stamping process is one of a potential method to improve the quality of products. The characteristic of ultrasonic wave, non-destructive, high penetrating power, high sensitivity, greater accuracy than other non-destructive method, non-hazardous to operations and human and able to provide immediate results has attracted many manufacturing industries. Further research on ultrasonic wave testing method has been carried out to make it the better option to improve method like servo presses [1].

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Nowadays, majority of the manufacturing industries that have hot press forming (HPF) process uses ultrasonic wave for monitoring. However, there are disadvantages of using ultrasonic wave like parts that are very small, thin, irregular in shape, or not homogeneous, are hard to inspect, micro cracks are difficult to be detected and due to high heat from the die during the hot press forming (HPF) process monitoring method that involved physical contact would not be feasible. Hence a non-contact and high accurate ultrasonic monitoring method is required.

2. Review of Literature

In this chapter, the literature review is about the previous studies on another research. Sheet metal forming which is very popular in automotive manufacturing industry was reviewed, the studies of condition monitoring system by other researchers that used multiple methods, the types of failure that usually occurred in the die of sheet metal forming process and how the failures are detected by monitoring and the method of analysing result were reviewed.

2.1 Hot Press Forming (HPF)

In this project the hot press forming (HPF) process has been studied. During the process, the blank material is heated to a certain temperature by using a continuous furnace. After heating, the blank is transferred to a die on the stamping machine for press forming. The heated blank material on the die will be cooled by the cooling system installed in the die. After the forming of sheet metal is completed, it is transferred for trimming process using laser.

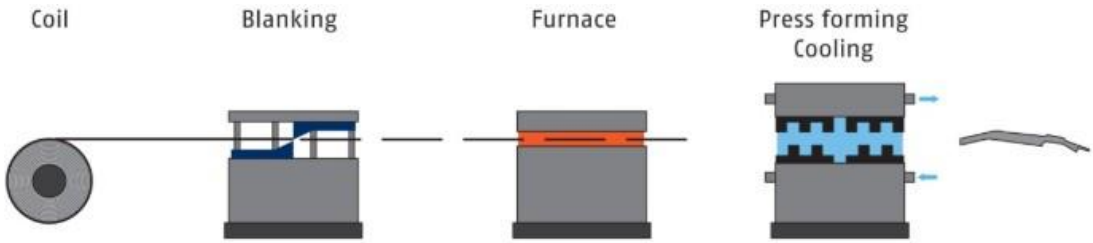

Figure 1: The Schematic diagram of HPF

2.2 Implementation of aluminium alloy in automotive industry

In automotive industry, the implementation of aluminium alloy has successfully reduced weight of vehicle in order to improve fuel efficiency and reduce greenhouse gas emissions [2]. The common applications of these alloys are in components like cylinder blocks, cylinder heads, pistons and valve lifters [3]. Other applications are on doors, hoods trunk lids and tailgates [4].

2.3 Monitoring System

In all manufacturing industries, there is a monitoring system in order to find out the operating condition of the machine such as deflection of tool, tolerances of dimension, surface texture, performance of machine tool, classification of chip shapes and formation and features of work piece. In a standard monitoring system, the system will warn the operator in order to pause or stop the operation before any unsound or unexpected incident occur. Among the existing methods of non-destructive testing, ultrasonic waves is one of the suitable method for estimating the defect in a structure. In ultrasonic monitoring system the ultrasonic wave is emitted into the specimen. The emitted ultrasonic wave is either transmitted or reflected. The transmitted wave is received by a computer or an ultrasonic detector. The result is shown in numbering, graph form or visualized image. In this section, the review started with the preliminary study in this project which is Ultrasonic Pulse velocity (UPV) test and followed by the other ultrasonic monitoring method.

3. Methodology

In this section, the method and process of completing the case study were shown and explained. First, flowchart of overview of the project procedure was shown followed by explanation for each subtopic. Finally, process of ultrasonic monitoring system was shown in flowchart and each stage of process were explained in detail.

3.1 Problem Identification

First, a brief introduction about the topic on sheet metal forming process was stated in the beginning. Second, based on research the common problems that occur on the stamping die of sheet metal forming process were identified. Third, different side effects caused by the problems and what would the problems and side effects lead to were clarified. After that, the current inspection method in the manufacturing industry was recalled. The disadvantages and inefficiencies of the current monitoring system were emphasized. Lastly, the importance of condition monitoring system in sheet metal forming was mentioned.

3.2 Data Collection

The data in this project were collected from journals and experimental reports from the previous researchers. The journals and experimental reports referred are related to HPF and different methods of ultrasonic monitoring system. All the research found were first make sure to be the most recent or latest research and related to the topic of the project. The data that are not relevant were excluded.

3.3 Data Analysis and Discussion

The analysis of this project was done by discussion. In the beginning of this phase the introduction regarding each of the different methods were mentioned briefly in order to remind the reader about the basic understanding on each method in literature review. The details of research for each method was made by highlighting the author cited in the paper and the reference from the authors were included in this case study. After the details of the different ultrasonic monitoring method were included, the methods and results were discussed and compared. The advantages, and disadvantages in each method were made. Comments were given to each method in relation to their advantages and disadvantages. Lastly, after the discussion and comparison were completed the best method was chosen. The reason for the chosen method was discussed and explained in detail. Other studies and researches regarding the chosen method were included as evidence in order to strengthen the chosen method.

4. Results and Discussion

This section consists of the results obtained from the studied journals and articles regarding ultrasonic monitoring technique. The results were explained clearly. In the last section of this chapter the methods and results of different ultrasonic monitoring system were compared and the best and the most suitable method for hot forming process was chosen.

4.1 Case Study 1: Ultrasonic Contact Probing

This monitoring system has one emitter transducer and one receiver transducer that were mounted directly on the upper die and the lower die, as shown in Figure 1. The ultrasonic waves were generated by the piezoelectric transducer and travelled through the die. The ultrasonic waves emitted were either reflected or transmitted and received by the receiver transducer. In Figure 2 by observing the reflected and transmitted wave the contact condition between the upper and lower die can be determined. The defect in the die can be found by observing the position of the reflected wave on the horizontal axis [1].

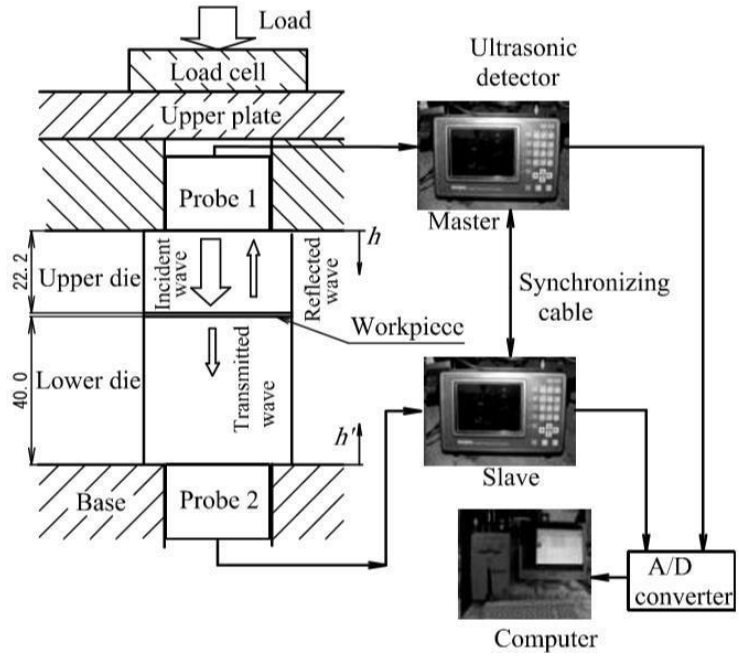

Figure 1: The setup for ultrasonic contact probing.

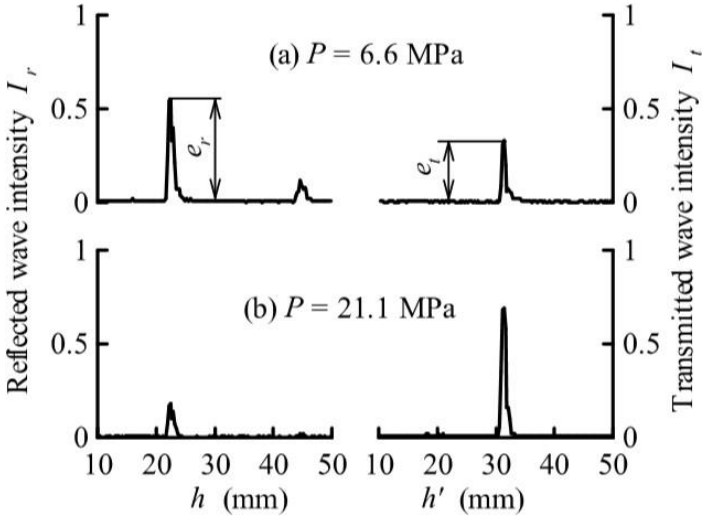

Figure 2: The reflected and transmitted wave.

4.2 Case Study 2: Wireless Ultrasonic Transducer Network

In this method the disc transducers or sensors were directly attached to the test specimen. There were 8 ultrasonic sensors attached to the specimen, as showed detail in Figure 3. The 8 transducers took turn to generate ultrasonic signals while the others listen. The ultrasonic signals were received by the ultrasonic diagnosis device through wire connection from the sensors. After the signals were processed, they are sent to the computer through a wireless receiver. The result obtained was shown in Figure 4 in form of probability density map after processed by the RAPID technique. From the result shown, the severity level of the defect was determined by the probability value or the tonnage of colour on the probability density map. The higher the severity level, the higher the probability value and the tone of the colour will become darker [5].

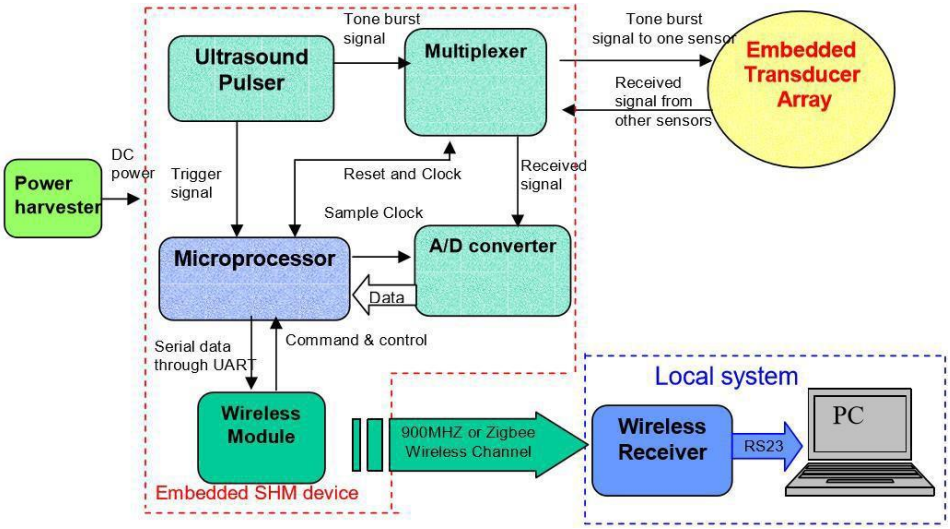

Figure 3: The system of wireless ultrasonic transducer network

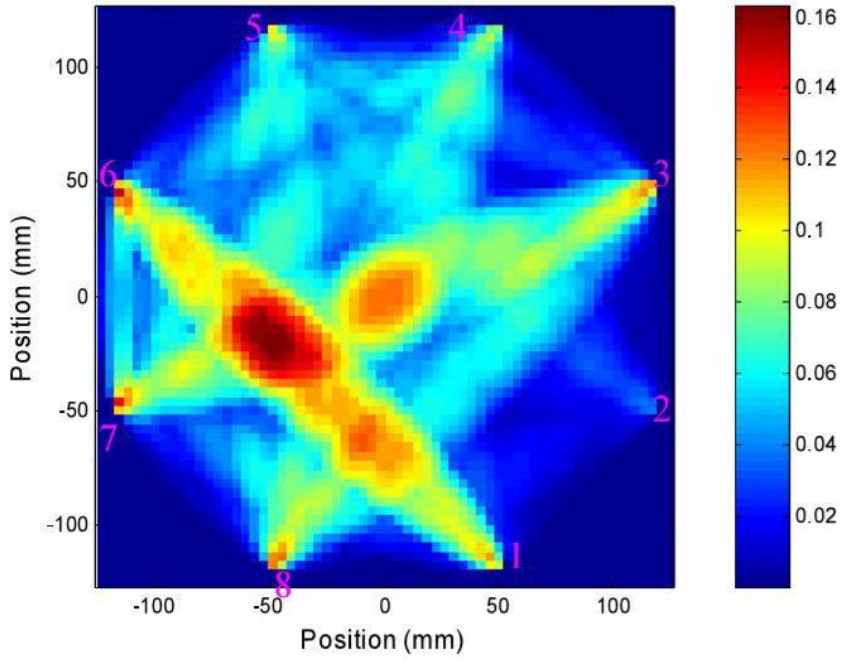

Figure 4: The example of result obtained by using reconstruction algorithm for the inspection of damage (RAPID).

4.3 Case Study 3: Air coupled Ultrasonic Monitoring System

The ultrasonic waves in this monitoring system were emitted by using air coupled transducers. Air was acted as the coupling agent for the ultrasonic wave to travel through air and into the specimen and received by the receiver transducer, as in Figure 5. Hence, no physical contact between the monitoring system and the specimen is required. The ultrasonic wave received was processed by the computer software and the result was presented in the form of imaging algorithm as shown in Figure 6. The severity level of the defect can be seen by observing the colour tone in the picture as well as the number that indicate the severity level [6].

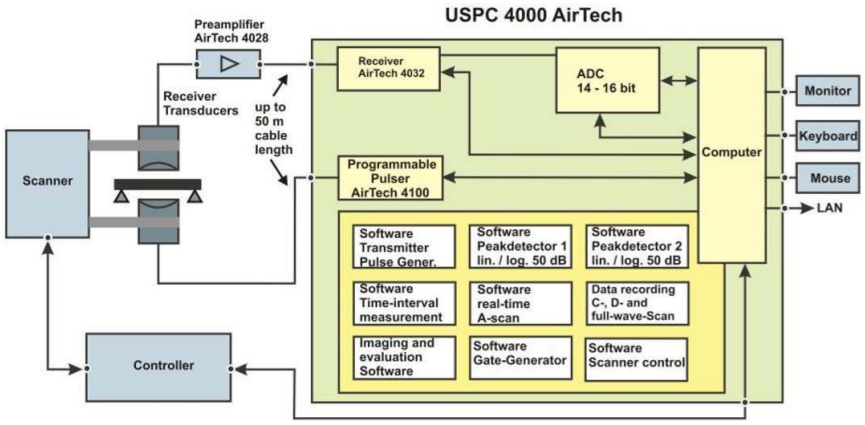

Figure 5: Block diagram of air-coupled ultrasonic monitoring system

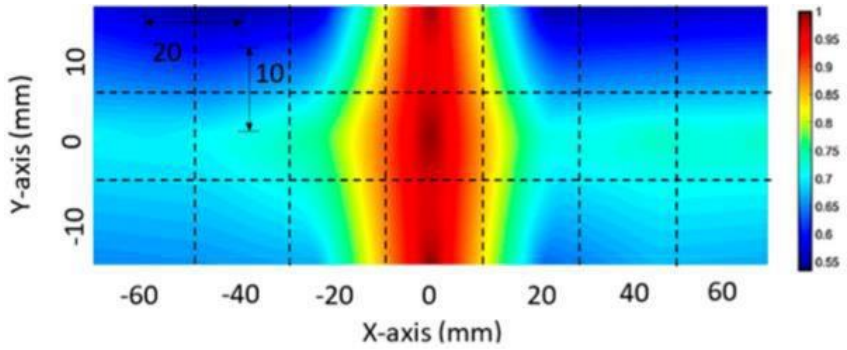

Figure 6: The example of result obtained from imaging algorithm

4.4 Case Study 4: Hybrid and Fully Non-contact Laser Ultrasonic Monitoring System

In this method, the ultrasonic waves were generated by laser beam that focused at a region on the test specimen and received by the air coupled transducer. Although the air coupled transducer had a low sensitivity due to high impedance mismatch, the 2-D dense laser excitation scanning made it suitable as a fully non-contact receiver for the monitoring system. The ultrasonic waves received were processed by the computer. In Figure 8 the results were presented using Ultrasonic Spectral Imaging (USI) and Wavelet Ultrasonic Propagation Movie (WUPM). The results were shown in visualized image. In USI imaging method, the darker colour represents through or deep hole while crack which is small was presented to be a shape with brighter colour. For WUPM imaging method, the surface crack was shown to be in a shape with red colour. The size of crack or defect can be determined also by reading the scale on the vertical or horizontal axis [7].

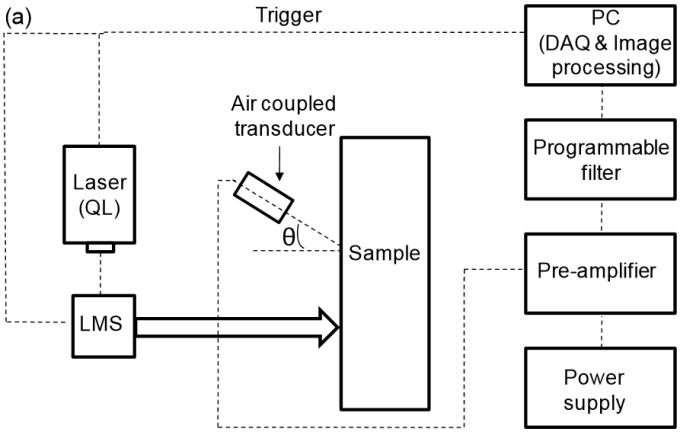

Figure 7: The system for hybrid and fully non-contact laser ultrasonic monitoring system

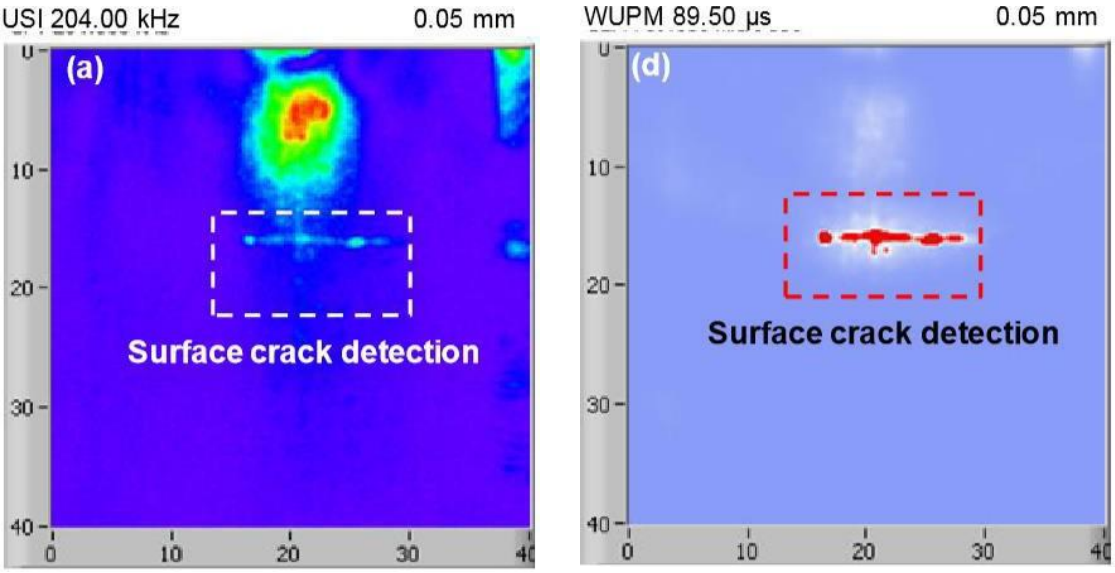

Figure 8: The result presented using USI and WUPM imaging method

4.5 Comparison

Among the four methods, Hybrid and Fully Non-contact Laser Ultrasonic Monitoring System is the most suitable monitoring system. This is because Hybrid and Fully Non-contact Laser Ultrasonic Monitoring System possessed many advantages compared to the other three methods when used in monitoring HPF process. First, there is no physical contact required between the hot stamping die and the component of the monitoring system. Second, the problem of acoustic impedance mismatch between the air and specimen has been overcome, because the 2-D dense laser excitation scanning made it suitable as a fully non-contact receiver for the monitoring system. Besides that, the variation of result due to alteration in humidity of air because of heat from the die can be avoided. Lastly, the presented result is more accurate compared to the results from the other 3 methods which is vital in HPF process for early detection of damage.

5. Conclusion

In conclusion, the two objectives stated in this project which are to observe the ultrasonic wave character and behaviour for monitor the die condition of sheet metal stamping process and to analyse ultrasonic wave for damage identification in sheet metal forming process was achieved. The different methods of employing ultrasonic wave, the types of results, efficiency of the method in monitoring defect was studied and reviewed from the journals. From the overall project, it was observed that the travel ability of the ultrasonic wave is highly affected by the type of material and quality of the material. This is because ultrasonic wave is very sensitive to the rate of conductivity as well as the acoustic impedance between solid material and air. Furthermore, the hybrid and fully non-contact laser ultrasonic monitoring system will be used as the monitoring system. The hybrid and fully non-contact laser ultrasonic monitoring system can monitor the defect during the quenching process also.

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