RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING VOL. 1 NO. 1 (2020) 153–159

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Study on Hot Press Forming Die Condition by using Vibration Monitoring System

Adam Arif Suhaimi[1], Ng Chuan Huat[1,*]

[1]Faculty of Mechanical Engineering and Manufacturing,
Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat, 86400, JOHOR

DOI: https://doi.org/10.30880/rpmme.2020.01.01.020
Received 28 October 2020; Accepted 2 November 2020; Available online 10 November 2020

Abstract: Hot Press Forming (HPF) was one of the most important forming processes in vehicle manufacture industries. In producing lightweight automotive, sheet metal forming was one of the essential manufacturing processes in producing vehicular parts. However, delayed fault detection was the issue that leads to great loss for industry. To resolve the problem, Tool Condition Monitoring System (TCMS) was implemented in manufacturing operation. In this case study, the sheet metal forming and vibration monitoring as a system health monitoring of the process were studied. The case study consists of different vibration sensors used in condition monitoring of the health of the machines. During hot press forming, the blank deformation produced vibration wave, which then received by vibration sensor that would be attached on stamping die wall. Then the vibration data signal results obtained by DAQ as a data acquisition system was viewed in time-domain analysis and frequency-domain analysis. The pattern and characteristic of amplitude in frequency domain graph obtained by accelerometer sensor was then analyzed and related with other types of sensors used in the case studies. The mount position of each types of sensors were also reviewed and compared and then, the best mount position of the sensor was then developed. All the case studies reviewed in this thesis had the same method of signal conditioning of the vibration signal wave. From this project study, the signal amplitude in stamping die of the normal conditioned machines were compared to the defected conditioned machines. Both average and peak amplitude were influenced by surface roughness and clearance of stamping die and punch. At the end of project, the correlation of stamping die condition with others factor in manufacturing process will be determined through recommended system health monitoring.

Keywords: Hot Press Forming, Vibration Monitoring, Accelerometer, TCMS

1. Introduction

Lightweight with high strength properties in automotive industry had gave tough challenges to automotive manufacturers and suppliers. By reducing the mass of metal used, fuel efficiency can be improved. Moreover, this also helps in decreasing the carbon emission which will result in the decrease of greenhouse effect towards the environment. For the past years, the increase in development of sheet metal forming enables the production of hundreds if not thousands of parts within short period of time with small dimension, inherent high speed, design adaptability and the capability to work on harden

**Corresponding author: ahuat@uthm.edu.my*

materials. As for the material selection, advanced high strength steel (AHSS) and ultra-high strength steel (UHSS) such as boron steel was used in automotive industry to build the chassis, pillar and the body frame of a car.

This matter plays a crucial role in reducing the weight of the automotive parts which results in an improve of the fuel efficiency, the environmental protection and safety of the drivers [1]. However, the increasing use of high strength steel (HSS) in manufacturing industry has resulted in higher forming forces, higher wear rates which will lead to failure of stamping tools during mass production in the production line. This could also lead to an untimely failure which requires unscheduled maintenance, expensive tool replacement and increased cost of production with the manufacture of poor quality of parts due to them subjected to wears [2].

This project emphasizes on the investigation of the use of vibration analysis to detect the need for maintenance of a press before anything fails and causes lengthy downtimes. Having vibration analysis as a complement to ocular inspections that are carried out by maintenance may help catch hidden faults before they lead to failure which can cause downtime in production line.

2. Literature Review

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

2.1 Hot Press Forming (HPF)

Hot press forming (HPF), also known as press hardening or hot stamping, was a recently new manufacturing process. It was a technology that had been used to produce Advance High Strength Steels (AHSS) for automotive application that have high crashworthiness. Hot press forming can be classified into 2 kinds of processes, which are direct hot press forming (DHPF) and indirect hot press forming (IHPF). For DHPF, the metal sheet is directly austenitized, then undergo forming process and cooled down rapidly. Eventually the part has excellent strength properties [4]. Hot press forming can be classified into 2 kinds of processes, which are direct hot press forming (DHPF) and indirect hot press forming (IHPF). For DHPF, the metal sheet is directly austenitized, then undergo forming process and cooled down rapidly. Eventually the part has excellent strength properties [11]. For IHPF, before transferred to heating furnace, the metal sheet is cold deforming to about 90%~95% of its final shape, also known as pre-forming stage [12].

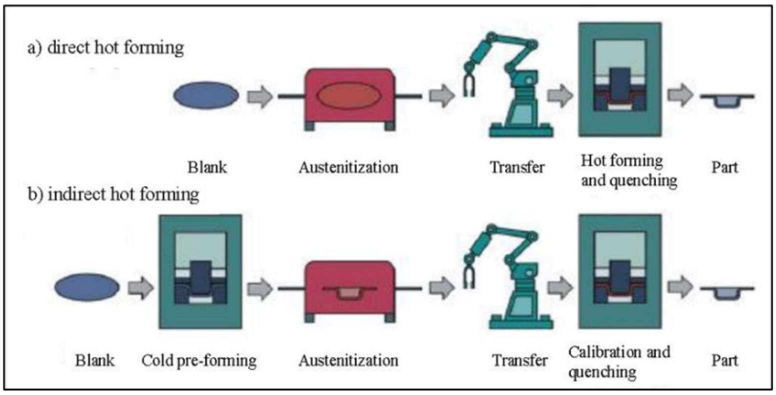

Figure 1: Type of processes in Hot Press Forming (HPF) [5]

2.2 Vibration monitoring

Vibration was a common phenomenon in the finishing machining of a flexible workpiece due to its low rigidity [6]. The great industrial interest was to avoid the vibrations that produce bad surface finish and may cause damage to the machining components [7]. Not only that, the vibration influences the dimensional accuracy during manufacturing process. According to Dimla [8], vibration signatures simulates the robustness, reliability, and applicability requiring fewer peripheral instruments than acoustic emission. Furthermore, the signals have the necessary rapid response time required to indicate changes for on-line monitoring. They used an analytical on-line TCM system based on vibration-signature features in the three major axis to correlate the tool wear and it was observed that it was possible to differentiate the different wear modes from an analysis in the vibration signals trend.

2.3 Tool Condition Monitoring System (TCMS)

In modern manufacturing systems, machine tools were the major equipment and they play a very significant role. The malfunction of machine tools may result in the downtime of the whole production line and would not be cost effective. With an effective tool condition monitoring to detect these damages on the machine tool, unexpected downtime in maintenance and wasted parts and components could be prevented. Typically, advanced TCMS (Tool Condition Monitoring Systems) consists of sensors, signal conditioners/amplifiers and monitor. Sensor plays an important role and had to be in close proximity towards the target location being monitored. Signal processing will then be carried out to obtain useful information from the signals received through the sensors. The monitor will then display the result by analyzing the signal from the sensor [7] [9].

3. Methodology

The flow process of the study was by reviewing 4 different case studies on vibration monitoring. All these case studies vary from its parameters such as type of sensors and its application on the machine that was monitored. These case studies were then reviewed and discussed on its vibration sensor mounting position and the vibration signal wave, which would then be compared and observed to choose the best method for condition monitoring of Hot Press Forming (HPF).

3.1 Problem identification

The problem that which are to be attended to is the die wear in Hot Press Forming (HPF) was first to be identified. There were many die wears that had to be studied based on its characteristics, effects, and root causes to be solved. Hence in this chapter, choosing the right condition monitoring to monitor the condition of the sheet metal material health was vital.

3.2 Vibration analysis

In the industrial engineering, it was important for them to avoid the vibrations that would result in bad surface finish. This would also cause damage to the machine components [7]. Vibrations also influenced the dimensional accuracy during the process of manufacturing which would result in inaccurate tolerance of finished materials. Study conducted by [10] on gear tooth fatigue and crack condition monitoring using vibration analysis to counter the problem.

3.3 Vibration monitoring through Accelerometer Sensor

There are a few parameters that vary with the change in machine condition and can be used to monitor the condition of machine. Mechanical vibration was one of the most reliable and widely used parameters for monitoring proposes because it provides directly the machine's health condition. Every component of machine vibrates with its exhibits directly machine vibrates with its natural frequency in running condition and coupled sections transmit these vibrations. Healthy machine behavior can be determined by its own unique vibration signature. When a machine met a defect, there would be a significant difference in the frequency components in the spectrum compared to a non-defect machine behavior. This technique would be able to detect more faults than other techniques and is a non-invasive method because it does not affect the working or operation of the machines.

3.4 Display of Time-Domain and Frequency-Domain Waveform

The electrical signal from the sensor processed by the signal conditioning would then be displayed as a waveform. This could also tell us if there were any abnormalities in the waveform by comparing the normal hot press forming and a faulty hot press forming. The time-domain would show how much the signals would change over time while frequency-domain would show us how much signals lie in the frequency range, theoretically signals are composed of many sinusoidal signals with different frequencies Fast Fourier Transform (FFT).

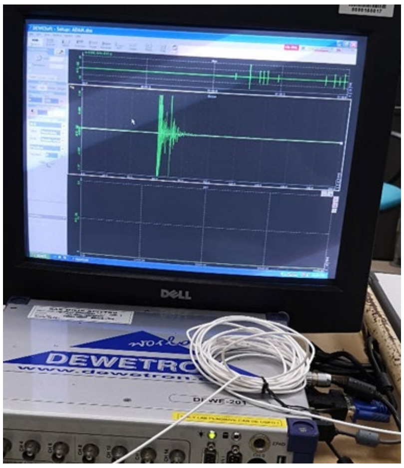

Figure 2: Signal Conditioned Wave from Vibration Sensor Through DAQ Board

3.5 Results justification and implementation

The data collected were justified based on the parameters of studies and the results need to undergo certain analysis and discussion. Those discussion were main related to the piping system which then can be related to the cooling channel of the HPF. Furthermore, previous research had also been done on the housing of the bearing motor to detect faulty bearings, this could also be related to the hot press forming since most machines would emit vibration wave throughout its body when there is no damper in place. The results also compared the effect to those results on the change in parameter. The data collected then can be justified by changing it parameters especially the sensitivity of the transducers for a lower range frequency sensor. Result can be obtained by efficient experimental setup and data acquisition as the vibration signature must be comprehensible to obtain results by converting time domain data to frequency domain data. The frequency domain spectrum can be further used to detect, isolate, and verify incipient problems providing in-depth analysis and scope.

4. Results and Discussion

In this section, plenty of research were conducted to be able to relate the role of vibration wave in tool condition monitoring system. Based on recent researcher's work, vibration wave monitoring was used mostly for the machines which has the process of rotating motion. Vibration wave monitoring was commonly used to detect the unbalance, bad bearing, looseness, and blade passing of machines. Although, taking all its parameters, vibration analysis may be applied on fault detection of sheet metal forming if the right sensitivity of the sensors and installation were to be used.

4.1 Case study 3

In case study 3, an experimental tool wear monitoring by [8] method based on vibration and force analysis of data were acquired on-line from a rotating machine which in this case was a turning process. The method consisted of using two differently coated unrecoverable inserts. The results gathered were based on the studies that were carried out. The vibration signal waves trend were studied to detect the defect in the turning process machine. Overall, the resulting pattern seems to suggest the vertical (z-direction) components of both. For nose wear, cutting forces and vibration signatures were the most sensitive to tool wear was the most important features of an impending failure of the device. The invariable cutting conditions are a big process parameter driving factor. The design of some TCMS were independent. Hence, the apparent variance in the intensity of the cutting powers cannot be ignored (static and dynamic) and vibration components to the wear and cutting conditions of both the devices.

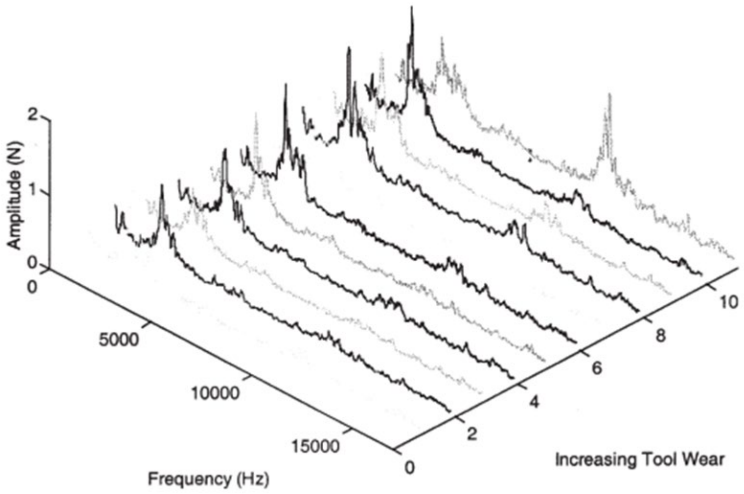

Figure 3: Vibration signal wave of spectra-flank wear of the cutting tools (V= 300 m/min and f= 0.1 mm/rev) [8]

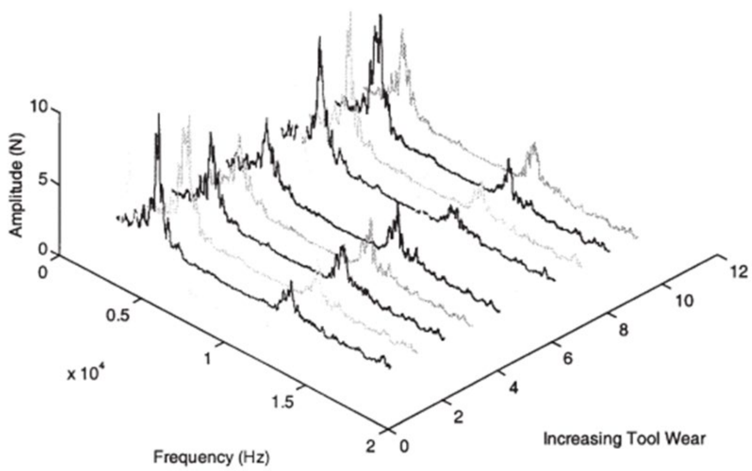

Figure 4: Vibration signal wave of spectra-flank wear of the cutting tools (*V*= 300 m/min and *f*= 0.3 mm/rev) [8]

4.2 Discussion on vibration sensors mount position

Four main methods are used to attach sensors to predictive maintenance locations. They were mounted on studs, adhesive mounted, magnetically mounted and could be equipped with probe tips or stingers. Each method affects the accelerometer 's high frequency response. Stud mounting provides the widest frequency response and the safest and most reliable mounting. The advantages and disadvantages of each technique should be closely considered when choosing a mounting method. Features such as location, roughness, range of amplitude, accessibility, temperature and portability may be very critical. However, often the most important and overlooked consideration is its effect on the high frequency operating range of the mounting technique. Both types of the accelerometer sensor MEMS and piezoelectric accelerometer were the most widely used in Tool Condition Monitoring System (TCMS). The fact that these accelerometer sensors were relatively easy to be used and installed onto the subject to be monitored. Accelerometer sensors could be easily be mounted on through adhesives, studs, or even magnetically mounted on machines that generally are uninterrupted by magnetic fields.

In Hot Press Forming (HPF) condition monitoring, based on the research gathered, accelerometer sensor had the most versatile way of mounting it on any machines. The accelerometer sensor could be mounted on the baseplate, upper plate, the hydraulic press or even the die holder. This could be a burden relief for predictive maintenance works for condition monitoring of the Hot Press Forming. This mount method would be the easiest to install and removed when they are not needed anymore.

4.3 Discussion on vibration signal wave

In vibration measurement, there are a few challenges other acquiring its vibration. One of the few challenges were analyzing the data acquired by the vibration sensor. The types of waveforms affiliated with vibration analysis, the distinctive features between them and when was the right time for each type of vibration measurement tool. One of the vibration-signal waves analysis method was time domain vibration analysis. Time domain vibration analysis were the most used method of analysis of vibration signal waves. It starts with a time-varying, real-world-application signal from a transducer or even a sensor. The amplitude, peak-to-peak value, and root mean square of the signal were defined as simple sine wave. Although, analyzing vibration data in the time domain of amplitude against time were limited slightly in parameters of a vibration profile mentioned.

5. Conclusion

Throughout the experimental process of preliminary study on the material piece of stamping-die aluminum alloy 7075 (AA7075), the objective of this study of analyzing the vibration behavior of die condition in hot forming process using Vibration Data Acquisition Systems (DAQ) can be dissected. The advanced method in vibrations analysis technique used for condition based monitoring methodology has been conducted with practical measurements on mill machines, plastic extruder machines, motors and many more by using the data acquisition hardware/software which in this case is the Data Acquisition System (DAQ). Therefore, this study can be continued by adopting the research methodology in previous studies. Although the experiment could not be proceeded, several case studies with similar objectives and parameters were studied in this thesis. The case studies were then reviewed and compared to find the right criteria for vibration monitoring in Hot Press Forming (HPF). Choosing the right sensor for the right application was key in this monitoring process. The most suitable proposed vibration sensor to be used in Hot Press Forming (HPF) were the accelerometers. The accelerometer sensor was the most versatile in frequency range hence could be easily applied on Hot Press Forming (HPF) through its uncomplicated process of mount.

Acknowledgement

I would like to thank to University Tun Hussein Onn Malaysia (UTHM), for giving me the opportunity to use the facilities in Noise and Vibration Laboratory for my research. This research would be impossible without the guidance from the lab instructor of Noise and Vibration Lab in FKMP UTHM, Mr Md Zainorin Bin Kasron.

References

[1] Zhu, B. Z.-S.-C. (2011). Simulation research of hot stamping and phase transition of automotive high strength steel. In Materials Research Innovations (pp. 426-430)

[2] Shanbhag, V. V. (2018). Investigating galling wear behaviour in sheet metal stamping using acoustic emissions. Journal of Physics Conference Series, (pp31-42)

[3] Wang, X. Z. (2011). Tool Wear Prediction Modelling for Sheet Metal Stamping Die in Automotive Manufacture. Hawthorn, Australia: Swinburne University of Technology.

[4] Mikl, T. (2014). Hot Press Forming in Sheet Metal Forming. 1-9

[5] Karbasian, H. &. (2010, November 19). A review on hot stamping. Journal of Materials Processing Technology, 2103-2118. doi:https://doi.org/10.1016/j.jmatprotec.2010.07.019

[6] Kakade S, V. L. (1994). In process tool wear and chip from monitoring in face milling operation using acoustic emission. Journal of Mater Process Technology.

[7] G. Terrazas, P. B. (2018). In-process Tool Wear Prediction System Based on Machine Learning Techniques and Force Analysis

[8] Dimla, E. (2016). Development of an innovative tool wear monitoring system for zero-defect manufacturing. International Journal of Mechanical Engineering and Robotics Reseach Vol. 7, 305-312

[9] T. Norfazillah, S. A. (2018). Tribological evaluations of modified RBD palm olein-based lubricants in machining processes. Journal Tribologi.

[10] F. A. Andrade, I. E. (2000). A New Approach to Time-Domain Vibration Condition Monitoring: Gear Tooth Fatigue Crack Detection And Identification By The Kolmogorov-Smirnov Test.

[11] Mikl, T. (2014). Hot Press Forming in Sheet Metal Forming. pp1-9.

[12] Lee, M. G. (2009). Application of hot press forming process to manufacture an automotive part and its finite element analysis considering phase transformation plasticity. International Joirnal of Mechanical Sciences.