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Quenching Temperature Monitoring for Hot Press Forming by using Infrared Thermography

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Abstract: Nowadays, Hot Press Forming (HPF) was developed since the 20th century and Malaysia proud to be the first country in South East Asia to implement and apply this advance forming technology into the manufacturing of national cars. High strength steel such as 22MnB5 boron steel was the common material used in manufacturing. After that, the accurate measurement of temperature field in transfer where the temperature falls rapidly proves to be difficult due to the limitation of thermocouple. The infrared thermography could be used for accurate measurement of temperature field. In this project, the quenching process of boron steel in HPF was studied from the other journal. The strength of the blank material was directly affected by the cooling performance of the die. Therefore, the objective of this study was to observe the heat transfer distribution in the quenching of the hot press forming process. Hence, all the data are having been reviewed and analyzed from several journals which are conduct the experiment with infrared thermography. The parameter that involved which is sample images, temperature gradient, and emissivity. There is a total of three different specimens that are using but the infrared thermography will be used as the monitoring temperature. The temperature distribution of the thermography was displayed to observe the changes during the process. The study of the quenching process with the infrared thermography was to ensure and detect the damage during the hot press forming operation. Based on the value collected, the results showed a different color of contour. From there, the problem can be detected by review the sample images and the temperature gradient.

Keywords: Hot Press Forming (HPF), Boron steel, Quenching process, Infrared Thermography

1. Introduction

The application of the high fuel efficiency vehicles which was environmentally friendly and energy savings has been the future trend and guideline for most automobile manufacturing industry. Among the alternative ways discovered, the reduction of mass in vehicles was believed to be the highest potential method in increasing the vehicles' efficiency and performance. Based on the statistics from the media, the objectives to minimize of 6%-8% fuel consumption was achieved by reduce the mass of the vehicle of 10% (AzoMaterial, 2013). Aluminum with the material specification of high strength weight-stiffness and strong corrosion resistance as well as the recycle potential was one of the recommended choices for the raw material of lightweight vehicles.

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Hot press forming process (HPF) was developed for automobile industry aiming to form Ultra High Strength Steel (UHSS) such as boron steel. The use of HPF process to form boron steel allows the blank material to double its hardness and tensile strength after forming process. The product from the HPF process were widely use in the body structure of the vehicles in the Chinese automobile manufacturers which emphasize the safety of the car in order to improve their competitive advantages in the global platform (Hu et al, 2016). The continuously developing and the usage was extended to the sheet parts, for example the body fenders and the bumpers.

The cooling process was an important role to enhance the quenching process of the blank material after the Hot Press Forming (HPF) process. During the HPF process, the metal will be formed pass through the dies which have an instalment of cooling pipes to achieve the cooling quenching function. After that, for the perspective of material properties, the purpose of rapid cooling and uniform cooling needed to be achieved as the material of die have a high thermal conductivity. The cooling system of HFP not only affects the process of quenching and forming, but also the overall and final appearance and properties of the blank material.

2. Review of Literature

In this chapter, the Hot Press Forming (HPF) process have been describes and the detail process of HPF process based on the reference and the journal that done by the researcher. Besides, the factors that affect temperature of the quenching process was reviewed in this chapter as well. The results, data and relationship of those manipulating factors of the quenching process also being listed out. This is to ensure the result that produce have improvement in the performance.

2.1 Development within automotive industry

Light weighting in the automobile industrial means that the manufacturing of cars and trucks by using lightweight materials in order to improves the performance of the vehicles as well as minimize the manufacturing cost. For example, the car manufacturer was manufacturing the car parts by using the carbon fiber, the windshield by using plastics as well as the bumpers using the aluminum foam.

2.2 Hot press forming

In this study, the direct HPF has been studied. A blank material will be heated up in a continuous furnace until a certain temperature. It will later transfer to a specific die for the purpose of forming and quenching. There are cooling systems installed within the die for the cooling purpose. The formed metal sheet will transfer for the laser trimming process in order to finished through another follow-up process (Hu et al., 2016).

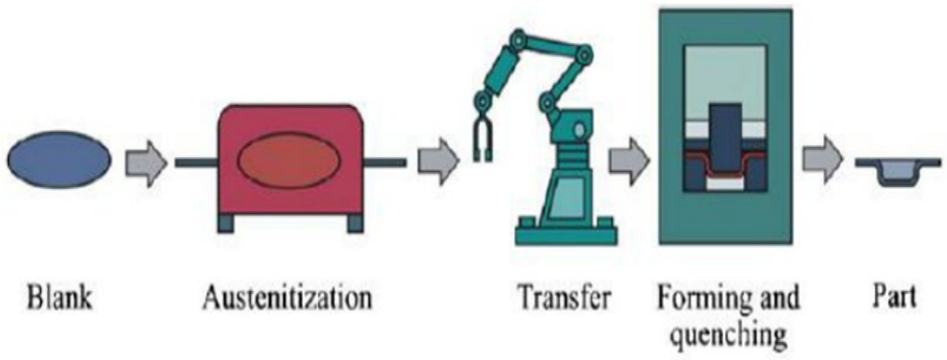

Figure 1: The schematic diagram of direct HPF

2.3 Infrared thermography

Thermography is based on the detection and measurement concept of through infrared radiation from the natural or induced thermal radiation of an object or component. The competency of human vision has been expanded to view an object in the infrared from. The technique is commonly used for cement kiln inspection, quality control of petrochemical and refinery complexes, insulation performance assessment of refractory and other materials, as well as hotspot identification in electric distribution lines and transformers. All objects emit electromagnetic radiation, and these are especially infrared radiations at or above ambient temperatures.

3. Methodology

In this chapter, the project procedure was illustrated in a flowchart. The numerical model for the effect of temperature through quenching process by thermography was briefly explained. The review of the result leaded to the improvement of the project which was used to improve the performance of the project. Finally, forecast of the infrared thermography and the process was discussed as well.

3.1 Problem identification

Nowadays, Hot Press Forming (HPF) components are becoming increasingly popular in the automotive industry due to the demand for vehicle weight reduction and improved crashworthiness. The ultra-high strength steel (UHSS) a mechanical property of these materials has led to their application in chassis components (George, 2012). From the study, the problem identification is based on the quenching process in the Hot Press Forming (HPF). There are around 50 journals were looked into and it was identified that temperature monitoring in HPF is very vital and important.

3.2 Data collection

All the data has been collected for this project was based on both experimental report and the review article from the previous research. Previous experiment that done by the researcher which were related to the quenching process and the infrared thermography was referred. Throughout all the experiment, a lot of data which included the dependent variable from the experiment was be obtained. Besides, the shorter the forming process, the higher the temperature of final the blank material. The longer in the quenching time, the more time for the cooling effect to approach to the blank material, hence the lower the final temperature (Lei et al., 2012).

3.4 Method identification

For this project study, the method identification supposed emphasized on quenching stage. For example, duration of quenching process and temperature of coolant etc. The most common process parameters that affected to the performance of quenching process was the diameter of the cooling duct. The smaller diameter of the cooling channel enables the cooling duct to place closer to the tool surface as well as increase the amount of the cooling duct within the die (Hoffmann et al.,2007).

3.5 Results implementation

The results implementations were justified based on the most suitable monitoring temperature on Hot Press Forming (HPF). The results also compared the effect on the changing in parameter to those results from the other experiment report. The data that collected can justified by referring to the journal as from the collection. Besides, the cooling of blank material also justified by referring the temperature distribution of the desired parts or section of the blank material. The thermography also has the function to detect the temperature of the quenching effect on the different parts of the blank material, and the final temperature of the blank material.

4. Results and Discussion

This chapter was presented the results that obtained from the other journal, with different parameters. The result was justified with review the others experimental results report. All the results have been compared. The parameters of the infrared thermography also have been discussed in this section.

4.1 Sample images result

In this section, the temperature monitoring will be used on the Hot Press Forming (HPF). There are several journals has been reviewed. The monitoring temperature equipment that has been chose is the infrared thermography. All the parameters result has been explained in this section. For example, the sample images result from the infrared thermography which is obtained through journal and experiment results. All the results have been collected.

In this journal, the direct hot stamping has been studied. A typical material for hot stamping is 22MnB5 steel. The steel blank is heated above 900 °C for a complete transformation to an austenitic microstructure. Then, the red-hot blank is transferred to the stamping tool and directly formed into its final shape. Once the tool is closed, the quenching process enables superior mechanical properties due to phase transformations to martensite. The steel possesses yield strength up to 1500 MPa (Penter, 2018).

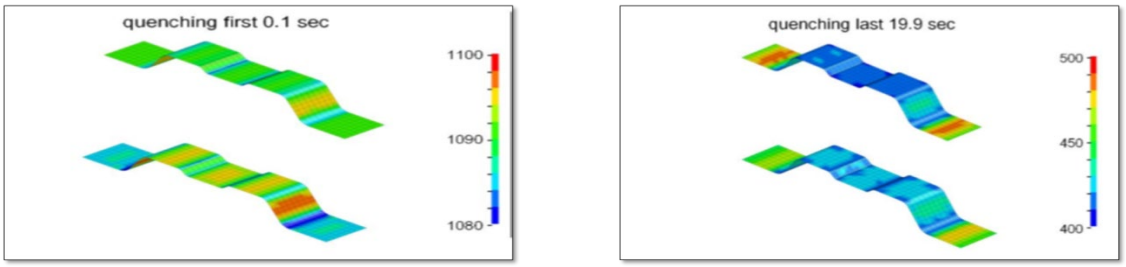

Figure 2: Sample Images of Thermography

4.2 Temperature gradient

In this section, the temperature monitoring will be used on the Hot Press Forming (HPF), the results were got from the previous journal and experiment report. The graph of the temperature versus time is been review. There are several journals that have been review which is the result is get from the experiment that has been conducted.

In this journal, is shows that about 50% of diabetes subjects are hospitalized due to foot complications which are the most common problems with diabetes mellitus subjects (Lahiri, 2012). They observed that, temperature gradients indicating abnormal blood flow in the affected regions are correlated with clinical findings. From the thermal image, it can be clearly seen that the distal portion (indicated by an arrow) of the foot is at a lower temperature, due to slow blood circulation and varicosity induced inadequate venous drainage (Lahiri, 2012).

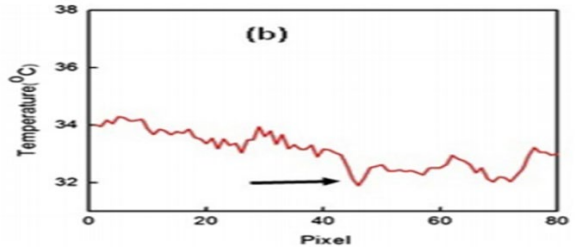

Figure 3: Temperature Gradient for Diabetic Patient

4.3 Emissivity

In this section, the temperature monitoring will be used on the Hot Press Forming (HPF). There are several journals has been reviewed. The emissivity has been studied. Emissivity is to measure the ability of an object. So, there are several journals that shows their emissivity parameters. All the results have been collected.

In hot stamping, the forming forces are relatively low but the quenching step needs high pressure between upper and lower die for a sufficient heat flow. The mechanical interaction between press and process lead to elastic deformations of the forming tool and entail negative effects on the pressure distribution between tool and workpiece (Penter, 2018). This applies to both cold and hot forming. So, 22MnB5 or Boron steel is the typical material used in Hot Press Forming (HPF). The emissivity for the Boron steel is 0.6 (Penter, 2018).

5. Conclusion

In conclusion, the two objectives of this project which is to analyze the heat transfer behavior in hot stamping using infrared thermography was achieved. The data of sample images, temperature gradient and emissivity were studied throughout the reviewed other journals. In this project, it was observed that the temperature take time to cool down. Sometimes it takes a lot of time to cool down. This is because of the problem during the quenching process or the cooling channel. Furthermore, the infrared thermography will used as the temperature monitoring. The infrared thermography also can detect the problem during quenching process.

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