Experimental Analysis on Cooling Channels Parameters in Hot Stamping Tools (SKD61)

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Introduction

The hot stamping technology is an innovative manufacturing process in automotive industries to produce complex geometric shapes and high strength automotive components. The yield strength and ultimate tensile strength (UTS) of the hot stamping final component can reach the maximum value up to 1000MPa and 1600MPa, respectively. Besides that, the hot stamping technology will also affect the environment in which the carbon dioxide (CO2) emission can be minimized while reducing the vehicle weight [2]. There are many past researches about hot stamping processes but very few in designing the cooling channels system. Therefore, an investigation on the cooling channel system is necessary.

This paper presents an experimental approach in designing the hot stamping die with cooling channels system. In order to achieve the maximum ultimate tensile strength of the hot stamping parts, the cooling channels system should be designed accordingly. The objective of this research is basically to study the effect of the cooling channels parameters, which includes cooling channel configurations, water flow rates through the cooling channels and stamping time in die. The optimum distance cooling channel and tool-part interface is important to achieve maximum cooling rate and homogeneous temperature distribution of hot stamping part [1]. The cooling channels system must have the capability to lower the die temperature in order to enhance the blank cooling rate while the heat can be absorbed by the cooling fluid as fast as possible [4]. The proper cooling channel design also will reduce the process
cycle time where it will recover the initial die temperature in the shortest time period [3].

In our previous study, we have mentioned that several cooling channels parameters such as the distance between cooling channels, and the distance of cooling channel to the tool-part interface should be taken into account when designing the cooling channels system [5]. By using the finite element analysis, the parameter of the distance of the cooling channels to the tool-part interface seems to give significant effect on the tool surface temperature rather than the distance between cooling channels.

Methodology:
In this research, the material investigated was a set of the quenchable, ultra high strength boron manganese 22MnB5 sheet metals (USIBOR 1500), which were cut based on ISO 6892 tensile standard. A preliminary experiment had been conducted where ten samples were heated to the austenization temperature of 950 °C and immediately quenched in a water tank. This experiment results in an average ultimate tensile strength of 1550 MPa, compared to original value of 600 MPa.

The experiment began with the samples being heated in a furnace to the austenization temperature of 950°C and held for 5 min to ensure full austenization. Then, a sample was immediately transferred to the stamping die integrated with cooling channels to prevent the heat loss to the air. The transfer time was approximately 10 s for each sample. Next, the sample was pressed by the stamping die (Fig. 1). The hydraulic pressure was kept constant at 35 bar for all experiments. Simultaneously, the water was flowed through the cooling channels. Here, the cooling channel flow rates varied from 3.3 to 20 l/min while stamping time in die ranged from 20 to 30 s. The temperature of the sample was measured by a thermocouple type-K that was fitted in the stamping die. The thermocouple was connected to a data logger in order to monitor and analyze the temperature readings over the time. Finally, the stamped sample was tested with the universal tensile strength machine for the ultimate tensile strength value.

The other samples were experimented according to the above procedures with different cooling channel configurations (Fig. 3), water flow rate and holding time in stamping die. In this experiment, there were 6 types of cooling channel configurations, which were categorized by the distance from the cooling channels to the tool-part interface (Fig. 2).

Results and Discussions:
The experiment began with an analysis on the effect of stamping time in die to the cooling rate. Here, the stamping time in die has been varied (20s, 25s and 30s) and was conducted at different cooling channel configurations (D, E and F) while the water flow rate was kept constant at 20 l/min through each cooling channel. From the graph in Fig. 4, the cooling rate of the 22MnB5 sheet metal is escalated by the increment of stamping time in die. The quenching time in die enhances the cooling rate by providing adequate time for the tools to absorb the heat from the sample.
In order to study the effect of stamping time in die to the ultimate tensile strength, the stamping time in die has been varied as in previous experiment (20s, 25s and 30s) and conducted at 6 different cooling channel configurations, namely A, B, C, D, E and F. The water flow rate was still kept constant at 20 l/min through each cooling channel. From the graph in Fig. 5, the ultimate tensile strength of the 22MnB5 sheet metal is increased by the increment of stamping time in die. The quenching time in die acts by providing adequate time for the tools to absorb the heat from the sample, thus accelerates the cooling rate in which can enhance the formation of martensite in the microstructure of the 22MnB5 sheet metal. It then leads to the increment of ultimate tensile strength.

Meanwhile, the configuration D still shows the highest cooling rate at all stamping time in die, especially at 30s where it achieves the highest value of 1365 MPa at 30s. This is due to the closeness of the cooling channel to the tool-part interface which helps the heat to be absorbed faster. The cooling
channels in both punch and die also help to cool down the sheet metal efficiently. As mentioned earlier, a preliminary experiment showed the average ultimate tensile strength of the 22MnB5 sheet metal was 1550 MPa. It was found that by quenching the samples in the water-cooled die with the closest cooling channel to the tool-part interface, this ideal value can be achieved.

Fig. 6: Graph of tensile strength changes over cooling rate.

Fig. 6 shows the relation of the cooling rate and the ultimate tensile strength of the hot stamped 22MnB5 sheet metal. It can be concluded that the ultimate tensile strength of the 22MnB5 sheet metal is increased by the acceleration of the cooling rate in all configurations (D, E and F).

Fig. 7: Graph of tensile strength changes over stamping time with various flow rates.

On the other hand, the experiment on the effect of stamping time in die to the ultimate tensile strength with various water flow rates through the cooling channels was also conducted. The stamping time in die has been varied (20s, 25s and 30s) and conducted using cooling channel configuration B as the representative of the other configurations, while the water flow rates were varied to 3.33 l/min, 6.67 l/min and 10 l/min through each cooling channel. From the graph in Fig. 7, the ultimate tensile strength of the 22MnB5 sheet metal is increased by the escalation of water flow rate. The water flow basically acts by absorbing the heat from the tool and release them through the cooling channels. In this manner, the tools can absorb the heat effectively and the cooling rate of the sample can be escalated. As mentioned before, the escalation of cooling rate leads to the increment of ultimate tensile strength of the samples.

Conclusion:

In this research, the optimum cooling channels parameters have been investigated through several experiments. The findings revealed that the highest tensile strength of the ultra high strength boron manganese 22MnB5 sheet metals could be achieved at the parameter of the lengthiest stamping time in die, the fastest water flow rate through the cooling channels and the nearest cooling channel to the tool-part interface. Hence, these cooling channels parameters have to be taken into account in designing the tool for hot stamping process. Further research will be conducted to study the effect of these cooling channels parameters in hot cutting and bending processes.
References