Simulation of Hot Stamping Process Based on Deform Software

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Abstract. Taking the U-shaped part of 22MnB5 ultra-high-strength steel as an example, a finite element model of hot stamping was established. The DEFORMV11.0 software was used to simulate the deformation process and the temperature field distribution of the sheet during hot forming. The results show that the temperature of the sheet varies with the different locations in the hot stamping process. The side wall of the sheet cools faster. Meanwhile, the temperature changes in the different positions of the concave mold and the convex mold are not uniform. The temperature change of the punch with the largest contact with the sheet is more obvious.

1. Introduction

In the automotive industry, the parts prepared by hot stamping can significantly improve the collision safety of the vehicle body, reduce the weight of the vehicle, and meet the requirements of the automotive industry for safety, energy conservation, environmental protection, comfort [1-3]. At present, the major automotive manufacturers in Europe, America, and Japan have adopted the hot stamping technology to produce the ultra-high-strength steel structural parts, such as the door crash bars, the bumper reinforcement beams, the A, B, C pillars, the door frame reinforcement beams, etc.. The application proportion is increasing year by year [4-5]. When the cooling rate of the sheet is enough high, the austenite will be transferred into the martensite structure. If the cooling effect is not good, the bainite will be generated and the mechanical properties of the part are finally affected. Therefore, the process control during the hot forming process is vital. Simulation technology is an effective tool for thermoforming research. In this paper, the hot forming process of the sheet metal and the change rule of the temperature field are analyzed by applying the numerical simulation technology. This can provide a reference for the application of numerical simulation technology and the selection of process parameters in the hot forming process.

2. Establishment of finite element model during hot stamping

2.1. Establishment and meshing of geometric models

Among the automobile parts, B-pillar parts are the safety structural parts of automobile bodies. It plays a decisive role in the prevention performance of side collision. Figure 1 (a) is a B-pillar part of the automobile. It is a U-shaped part. In this study, the partial U-shaped feature of a B-pillar part is used as the geometric model. The material is 22MnB5. The initial thickness of the material is 1.8mm. The U-
shaped parts are shown in Figure 1 (b). In order to improve the efficiency of numerical calculation, the geometric model is treated symmetrically according to the characteristics of the U-shaped part. The minimum size is set to 1mm and the size ratio is 5. The meshed finite element model is shown in Figure 2.

![Figure 1. U-shaped stamping geometry](image1)

![Figure 2. Meshing](image2)

2.2. Selection and establishment of material models

During the hot stamping process, the material of the mold is the steel H-13 commonly in the Deform-3D material library defined as a rigid body. The sheet material was 22MnB5 defined as a plastic body. The corresponding material properties for the blank and mold are summarized in Table 1.

| Material | Density (kg/m$^3$) | Yong’s modulus (GPa) | Poisson’s ratio | Specific heat (J/kgK) | Thermal conductivity (W/mK) | Linear expansion (1/C) |
|----------|---------------------|----------------------|----------------|-----------------------|-----------------------------|------------------------|
| Blank    | 7380                | 150                  | 0.30           | 650                   | 32                          | 1.3×10$^{-5}$          |
| Mold     | 470                 | 470                  | 28             |                       |                             |                        |

3. Analysis and discussion

3.1. Simulation of hot stamping process

In the numerical simulation process, the hot stamping process parameters are the initial temperature of the sheet of 800°C, the stamping speed of 40mm/s-1, and the holding time of 120s. As shown in Figure 3, the forming process is divided into three steps. The first step: during the mold clamping process, the sheet is free to dissipate heat in the mold for 4 seconds. The second step: the stamping and bending forming process of the U-shaped part takes about 1.5 seconds. The third step: the process of holding and cooling of the U-shaped part in the mold lasts for 120 seconds.
3.2. Analysis of thinning rate

The thinning rate of the sheet is an important index to evaluate the quality of the part. The thickness distribution diagram of the cooled part is obtained by simulation. It can be found from the figure that the minimum thickness of the sheet after hot stamping is 1.57mm. The maximum sheet thickness is 2mm. The maximum thinning rate is 21.5%.

3.3. Analysis of temperature field

The temperature change of the sheet in the hot stamping process reflects the change of the microstructure and affects the mechanical properties of the part. In addition, the sheet temperature difference makes the sheet thickness inconsistent and increases the maximum thinning rate. It can also cause residual stress in the sheet. In the mold clamping stage, as shown in Figure 5 (a), the temperature drop rate of the middle part of the sheet is higher than the other locations of the sheet. As a result, the overall temperature distribution of the sheet is uneven after 4s. It is generally low on both sides and high on both sides. In the forming stage, as shown in Figure 5 (b) and (c), the sheet temperature at the side wall position (P2-P5) decreases rapidly. In the holding cooling stage, as shown in Figure 5 (d), the extensive heat exchange takes place between the sheet metal, mold and cooling system parts. The temperature difference between the sheet and the mold at this stage is very different because of the larger contact surface and the larger heat transfer coefficient.
(a) Start stamping (t = 4s)

(b) Stamping process (t = 4.9s)
Figure 5. Change of sheet temperature field during hot stamping.

Figure 6 is the temperature change curve of each point in the punch and the die obtained by simulation. It can be seen that the temperature change of the mold surface is also uneven. On the one hand, the mold heats up due to contact heat exchange with the sheet. The convective heat exchange occurs between the mold and the flowing water in the cooling water channel.
4. Conclusion
The hot stamping process is performed in three steps. The minimum thickness of the sheet after stamping is 1.57mm. The maximum sheet thickness is 2mm. The maximum thinning rate is 21.5%. The temperature of the sheet varies with different positions in the forming process. The sidewall of the sheet cools faster. The temperature changes of different positions in the concave mold and the convex mold are not uniform. The temperature change of the punch because of the largest contact with the sheet is more obvious.
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