Research on Stamping Process Design and Forming Law of Floor Beam

Hua-jun YAN\textsuperscript{1,2,*}, Qi-qi ZANG\textsuperscript{1}, Shi-bo MA\textsuperscript{1,2}, Shuang-jie ZHANG\textsuperscript{1,2} and Yu-zhong LIU\textsuperscript{1,2}

\textsuperscript{1}School of Materials Science and Engineering, Hebei University of Science and Technology, Hebei Key Laboratory of Material Near-net Forming Technology, Shijiazhuang 050018, China
\textsuperscript{2}Hebei Engineering Technology Research Center of Precision Punching Process and Die, Cangzhou 061500, China

*Corresponding author

Keywords: Process parameter, Forming law, Thinning rate, Thickening rate, Wrinkling, Cracking.

Abstract. Aiming at the problems of cracking and wrinkling in the forming process of floor beam, the design of the drawing die is finished, and the finite element analysis software DYNAFORM is used to analyze the drawing process of the floor beam, and the effects of blank holder force and drawbead on the formed part are analyzed. With the maximum thinning rate and maximum thickening rate as the evaluation index, the optimized process parameters are that blank holder force is $F = 270$kN and drawbead is set to segmented drawbead. The results have important reference value for the forming application of floor beam.

Introduction

The floor beam of the car is the strengthening part of the floor, used to bear and pass the force and torque. When the car is collided, the floor beam can prevent deformation of the floor, thus protecting the person’s feet on the floor from injury. The floor beam can be fixed more firmly to reduce seat deformation[1]. The floor beam of the car can optimize the space, so that the person’s feet can move freely, also optimize the seat position. The special arrangement and connection between the stringers, the floor beams and the sills will bear and pass the forces under and behind the cab, the structure and strength of the floor beam are the important guarantee for the structure and safety of the car[2].

Stamping Technology Analysis of the Floor Beam

Figure 1 is a model of the floor beam of the car. As an important load-bearing part, the part is designed as the complex geometric structure. The outline of the part has the following characteristics: the overall shape is close to a "N" words, there is a depression on the top surface, the U-shaped depression is on the longitudinal middle section, there are several punchings and groovings, and high dimensional accuracy is required for the part. The processes required are drawing, punching, trimming and shaping, as drawing is the most important forming process, designing a reasonable drawing die makes the forming process more sufficient and reasonable to ensure the quality of forming parts.

Figure 1. Floor beam.

The part need to meet certain strength, also need to ensure the accuracy of forming parts. Due to the small cross-sectional dimensions, the forming of the end of the part is more difficult, ST16 with good drawing performance is selected, The performance is shown in Table 1.
### Table 1. Mechanical properties of the material.

| Material Type | Yield Strength/MPa | Tensile Strength/MPa | Elongation/% |
|---------------|--------------------|----------------------|--------------|
| ST16          | 110-170            | ≥270                 | ≥41          |

**Design of Drawing Die**

Design of drawing die is the first step for forming the cover, which is the key processes to ensure the quality of the part[3-5]. According to the model of floor beam, the design of drawing die is carried out, which is shown in Figure 2. By filling the cavity, supplementing the process of adding the end, setting the boundary smoothing and so on, the reasonable drawing parameter is designed.

Figure 2. Supplementing surface.

Figure 3 shows that the supplementing surface for end of part A and B is set, by adjusting the position and direction of the control lines of the supplementary surface, and then control the curve1 and the shape of the sidewall transition curve 2, the supplementary surface of the part exceeds the edge of part by a certain distance, and gradually transit to the flange of the part, and the new flange and the flange of the part have been smooth docking. Adding the process supplement of the end, as far as possible all the smooth surface of the die transits to ensure continuity and smooth flow of metal parts. Duo to the supplementing shape is outside the part, the supplementary surface will be trimmed after forming of the part is finished, so all of supplementing surface will meet the forming parts and try to set more smaller to improve material utilization.

Figure 3. Supplementary surface of the end.

After the addendum is completed, it is necessary to create the blank holder according to the shape of the flange of the part, and then design all of die, and finally the die, punch, blank holder and sheet designed is shown in Figure 4.
Effect of Process Parameters on Drawing Forming

The drawing quality is affected by many factors. The process parameters have great influence on the forming quality of the part, and the drawbead and the blank holder force are two important parameters[6]. In this paper, we will use the finite element analysis software DYNAFORM to simulate the forming process of the floor beam and analyze the forming quality of the part, the effect of process parameter on the forming of the part is analyzed, and the process parameter is optimized.

Effect of Drawbead on the Forming Parts

In order to obtain a good flow state of the metal, drawbeads need to set on the die surface and blank holder[7-8]. The cross-section type of the drawbead is usually arc, rectangular, etc., and the distribution of the drawbead is of the full-closed or segmented structure. The basic principle of setting drawbead is that the drawbead is set beside the straight-line position or shallow stretch position, or setting up multiple drawbead, or changing the cross-sectional shape and type. Setting the proper drawbead will adjust the metal flow characteristics to ensure the metal flow evenly. In this paper, the full-closed and segmented drawbeads are set up, which is shown as Figure 5.
The drawing process with two types of drawbeads are simulated by the DYNAFORM, and the effect of drawbead on the forming of the part is analyzed by the forming limit diagram and the thinning rate. The forming limit diagram of the part with two drawbead cases are shown in Figure 6, the forming quality of the part is shown in Table 2.

Table 2. Quality index of the part under different drawbead.

| Drawbead       | Maximum thinning rate /% | Maximum thickening rate /% | Whether wrinkled | Whether cracked |
|----------------|--------------------------|----------------------------|------------------|-----------------|
| Full-closed type | 46.72                    | 1.16                       | No               | Yes             |
| Segmented type  | 24.67                    | 3.73                       | Slight           | No              |

Figure 6 and Table 2 show that using the full-closed drawbead, there are significant cracking defects on the intersection between entire sidewall and the top of the of the edge. Table 2 shows the maximum thinning rate of the part is 46.72%, The maximum thickening rate is only 1.16%. Figure 6b using segmented drawbead, the part does not appear on the rip zone, the maximum thinning rate is 24.67%. The value of the permissible value in the flange area is reasonable, there is a slight wrinkling trend, the maximum thickening rate is 3.73 %. The wrinkling value is very small, the forming quality of the part need to meet the forming requirements, which indicates that the type of drawbead is more reasonable.
**Blank Holder Force on the Forming of the Part**

The theoretical calculation formula of Blank holder force (BHF) is shown in formula 1.

\[ F = A \times P \]  \hspace{1cm} (1)

In the formula, \( F \) is BHF (N); \( A \) is the projected area of the blank under the blank holder (mm\(^2\)); and \( P \) is the unit of blank holder force (MPa).

The blank holder area of this part is 51865 mm\(^2\) and the value of \( P \) is 3-4.5MPa. According to the formula (1), the blank holder force is 233.39KN. Four blank holder forces, such as 150kN, 200kN, 270kN and 350kN, are set up. Four kinds of blank holder forces are simulated by finite element software, and the corresponding values are shown in Table 3.

Table 3 shows that when the blank holder force is 130kN, the thinning rate is only 18.54%, but the maximum thickening rate is 15.37%, which shows the wrinkling is obvious. When the blank holder force is 350kN, the maximum thinning rate is 33.65%, and the crack is not obvious. When the blank holder force is 270kN, the maximum thinning rate is 27.74%, the maximum thickening rate is only 3.71%, there is no wrinkling and cracking. So the \( F = 270 \)KN is the best blanking conditions.

| BHF/kN | Maximum thinning rate /% | Maximum thickening rate /% | Whether wrinkled | Whether cracked |
|--------|--------------------------|----------------------------|-----------------|----------------|
| 130    | 18.54                    | 15.37                      | Yes             | No             |
| 200    | 23.33                    | 11.52                      | Slight          | No             |
| 270    | 27.74                    | 3.71                       | No              | No             |
| 350    | 33.65                    | 2.19                       | No              | Yes            |

**Conclusion**

The finite element software was used to design the drawing die of the floor beam, and the rule of metal flow in the forming process was analyzed.

The effects of drawbead and blank holder force on the forming quality of the part are analyzed. By comparing the forming limit diagram and the thinning rate, the ideal process parameters are obtained as follows: the blank holder force is \( F = 270 \)kN, drawbead is selected the type of segmented drawbead.

**Acknowledgements**

This work was financially supported by the Natural Science Research Youth Fund Project of Hebei Province (QN2016229).

**References**

[1] Guiyan Ke, Ping Lu, Kaiyong Jiang, et al. Quality control of front beam for rear floor part used in car. Forging & Stamping Technology, Volume 41, Issue 8, 2016, Pages 39-42.

[2] Dehai Zhang, Daiping Bai, Jibin Liu, Zhe Guo, Cheng Guo. Formability behaviors of 2A12 thin-wall part based on Dynaform and stamping experiment. Composites Part B: Engineering, Volume 55, 2013, Pages: 591-598

[3] Brabie G., Costache E.M., Nanu N., et al. Prediction and minimisation of sheet thickness variation during deep drawing of micro/milli parts. International Journal of Mechanical Sciences, Volume 68, 2013, Pages 277-283.
[4] Hezam L.M., Hassan M.A., Hassab-Allah I.M., et al. Development of a new process for producing deep square cups through conical dies. International Journal of Machine Tools and Manufacture, Volume 49, Issue 10, 2009, Pages 773-780.

[5] Jian Lan, Xianghuai Dong, Zhigang Li. Inverse finite element approach and its application in sheet metal forming. Journal of Materials Processing Technology, Volume 170, Issue 3, 2005, Pages 624-631.

[6] Hongyang Qiu, Yajuan Huang, Qiang Liu. The study of engine hood panel forming based on numerical simulation technology. Journal of Materials Processing Technology, Volume 187-188, 2007, Pages 140-144.

[7] Guijie Gao, Junxiang Lei. Research on stamping of rectangular box using binder. Journal of Plastic Engineering, Volume 21, Issue 5, 2014, Pages 30-34. (in Chinese)

[8] Wei Wang, Chun Liu, Dongsheng Li. Cylindrical deep drawing test and finite element simulation of 2024 aluminum alloy sheet. Forging & Stamping Technology, Volume 39, Issue 11, 2014, Pages 1-5. (in Chinese)