H. C. JI, R. ZHANG, N. Z. KANG, J. H. HUANG

ISSN 0543-5846
METABK 64(1-2) 87-90 (2025)
UDC:669.14.018:621-47/:621-822:621.73:621.72:518.1=111

SIMULATION ANALYSIS OF WHEEL BEARING FORGING PROCESS BASED ON DEFORM

Received – Primljeno: 2024-05-28
Accepted – Prihvaćeno: 2024-08-15
Preliminary Note – Prethodno priopćenje

Aiming at the complex structure of wheel hub bearing parts, which is difficult to form, an upsetting-pre-forging-final forging forming process is adopted after process analysis. A three-dimensional finite element model is established by Deform software to study the process of wheel hub bearing forging, and the distribution law of temperature field, equivalent stress field and other important fields in the forging process are systematically analyzed. The influence of forging process parameters on the forming quality of wheel hub bearings is studied. Based on the results of Deform simulation, the optimal forging process parameters are used in the actual forging production, and the forging parts obtained have clear hierarchical levels in each region and good forming quality. The experiment verifies that the forging is complete and meets the product requirements under the optimized process parameters, which provides theoretical and technological guidance for the hot die forging of wheel hub bearing parts.

Keywords: 55 steel,wheel bearing, forging and forming, modeling, numerical analysis

INTRODUCTION

The current annual demand for wheel bearings in China is up to more than 100 million sets. Wheel bearing is a very important automotive component, its main role is to load-bearing and provide precise guidance for the transmission of the wheel hub. The working environment of wheel hub bearings is complicated and the quality requirement is high. According to the structural characteristics of the automotive wheel hub bearing mandrel using multi-station forging method for production processing and manufacturing, its structure is shown in Figure 1.

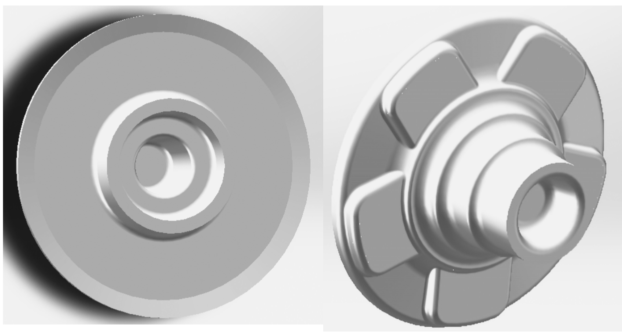

Figure 1 Product schematic diagram of hub bearing mandrel

H. C. Ji (E-mail: jihongchao@ncst.edu.cn), N. Z. Kang, J. H. Huang, Zhejiang Zhaofeng Mechanical and Electronic Co, Ltd, Hangzhou, China.
H. C. Ji, R. Zhang, College of Mechanical Engineering, North China University of Science and Technology, Hebei, Tangshan, China.

Forging forming mainly has obvious advantages in the following aspects:

– Eliminate the defects such as as-cast porosity generated during the smelting process of the metal and optimize the microstructure.

– The forging product has good compactness, stable product quality and good consistency.

– High material utilization

With the continuous improvement of the level of science and technology, forging forming has been widely used in industrial production and manufacturing. Many scholars have creatively put forward the processing technology of casting to forging for some complex parts. Through basic experiments combined with numerical simulation and laboratory trial production, the industrial application of the product is finally realized. In recent years, hot forging process has become a research hotspot.

Combined with the structural characteristics of the wheel hub bearing mandrel and the advantages of the forging process, this paper proposes an automotive wheel hub bearing mandrel upsetting-pre-forging-final forging molding process. Forging parameters directly affect the uniformity of the organization of forgings[1,2]. According to the research of relevant scholars, the factors that have an important influence on the organization uniformity of forgings mainly include forging temperature[3], forging speed[4], lubrication condition[5] and heat treatment processes. Firstly, we design the forging die for the composite process of wheel hub bearing mandrel, then we establish 3D finite element elastic-plastic model to study the influence of forging process parameters on the microstructure of wheel hub bearing mandrel forgings, then we verify the feasibility of the composite process through experiments, and finally we carry out the relevant tests on the experimentally formed wheel hub bearing mandrels in accordance with the standards, and the results show that all the performances are relatively good.

MATERIAL AND METHODS

55 high-quality carbon steel has good plasticity and appropriate strength, and has good process performance. It is widely used to manufacture various forgings and hot-pressed parts, cold-drawn and upset steel, seamless steel tubes, and parts in mechanical manufacturing. The mechanical properties and chemical properties of 55 steel are shown in Table 1 and Table 2.

The hub bearing mandrel is a part of the rotary structure. Combined with its structural characteristics, an upsetting-pre-forging-final forging forming process for the hub bearing mandrel of an automobile hub bearing is proposed, and a 3D finite element elastic-plastic model is established in Deform software. (Because the hub bearing mandrel is a rotary structure, a three-dimensional semi-symmetric finite element model can be used to simulate the forging process of the hub bearing mandrel) and study its forming process to provide theoretical guidance for subsequent experiments.

Because of the complex structure of the hub bearing mandrel, it is difficult to achieve only one forging forming. Therefore, the billet is upset first. According to the designed forging forming process scheme of the hub bearing mandrel, the Solidworks 2018 version software is used to establish the three-dimensional geometric model of the mold and the workpiece, and the stl. file is imported into the pre-processing of the Deform-3D software. As shown in Figure 2, the numerical simulation of the upsetting process of the hub bearing mandrel is established. The model establishment mainly includes five steps: meshing, material setting, boundary definition, model positioning and process parameter setting.

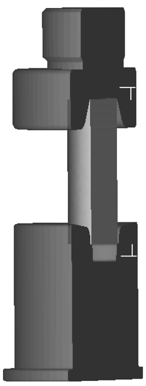

Figure 2 Upsetting finite element model

Table 1 **Mechanical properties of 55 steel**

Performance	values
Tensile strength R_m/MPa	≥645
Yield strength R_y/MPa	≥380
Elongation A/%	≥13

Table 2 **Chemical composition of 55 steel/wt.%**

Component	values
C	0,52~0,57
Mn	0,50~0,80
Si	0,17~0,37
S	≤0,035
P	≤0,035

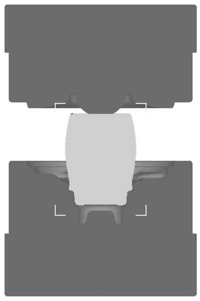

Figure 3 Pre-forging finite element model

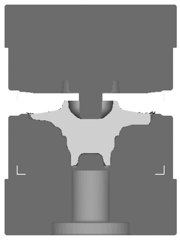

Figure 4 Final forging finite element model

After the upsetting is completed, the billet is pre-forged. According to the designed hub bearing mandrel forging forming process scheme, the three-dimensional geometric model of the mold and workpiece is established by using Solidworks 2018 software, and imported into the pre-processing of Deform-3D software in the form of stl file. As shown in Figure 3, the numerical simulation of the hub bearing mandrel pre-forging process is established. The model establishment mainly includes five steps: meshing, material setting, boundary definition, model positioning and process parameter setting.

The three-dimensional modeling of the upper and lower molds used in the final forging is carried out by using Solidworks 2018 three-dimensional software, and the pre-processing of Deform-3D software is imported in the form of stl. file. As shown in Figure 4, the numerical simulation of the final forging process of the hub bearing mandrel is established. The model establishment mainly includes five steps: meshing, material setting, boundary definition, model positioning and process parameter setting. The actual production process time of final forging is short, but the Deform software can be used to understand the deformation of any time point in the forging process. As the upper die presses the pre-forging, the pre-forging gradually fills the mold cavity under the action of pressure, and finally forms the preset forging.

RESULTS AND DISCUSSION

The upsetting process of the hub bearing mandrel forging is a positive forging process. The upper die gradually compresses the blank under the action of the press. The simulation of the forging process is shown in Figure 5. It can be seen from the figure that with the increase of the forging punch reduction, the metal flows along the moving direction of the upper die along the lower die cavity, and the bulging phenomenon appears on the left and right sides of the blank.

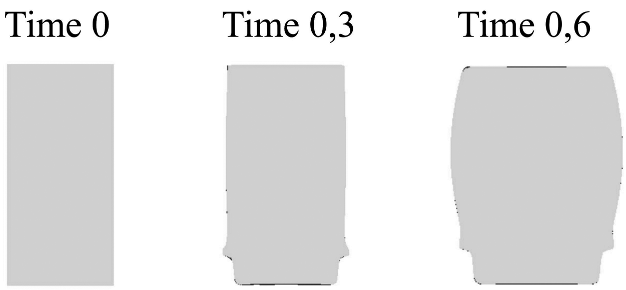

Figure 5 Simulation results of upsetting process

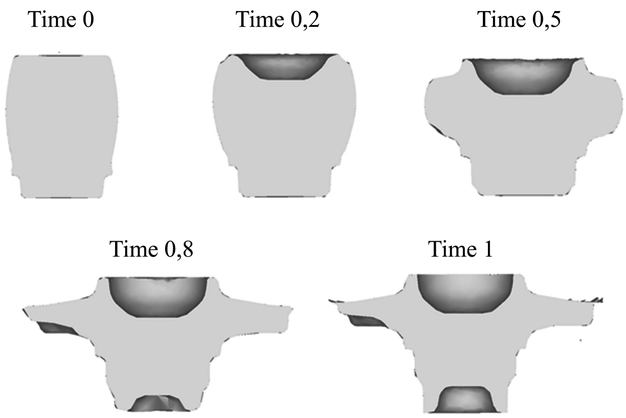

Figure 6 Simulation results of pre-forging process

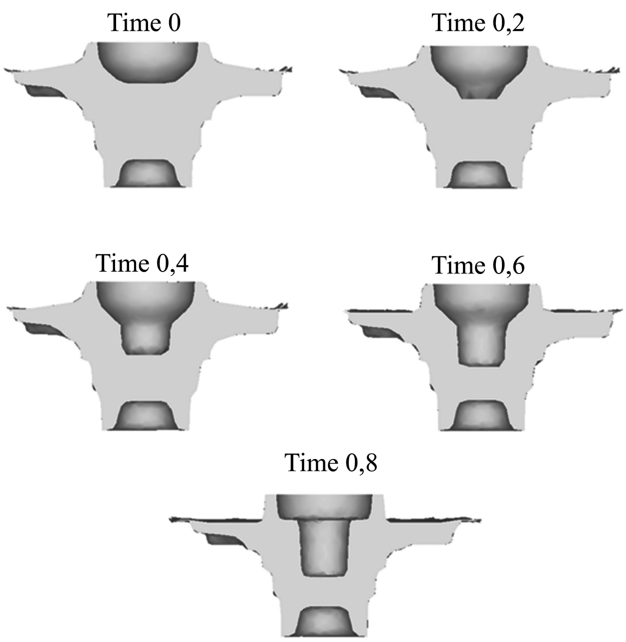

Figure 7 Simulation results of final forging process

Figure 8 Forged hub bearing mandrel

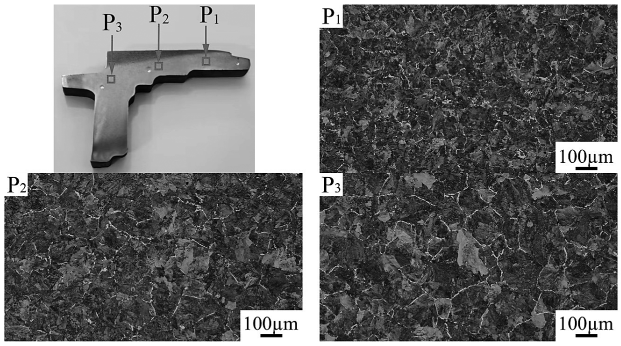

Figure 9 Microstructure of final forging

The pre-forging process of the hub bearing mandrel forging is a positive forging process. The upper die gradually compresses the blank under the action of the press. The forging process simulation is shown in Figure 6. It can be seen from the diagram that with the increase of the forging upper die reduction, the metal flows along the moving direction of the upper die along the lower die cavity, and the bulging phenomenon appears on the left and right sides of the pre-forging. The left and right ends of the pre-forging are gradually formed, and the pre-forging of the forging is finally obtained.

The final forging process is the process of pressing the upper die, and the forging process simulation is shown in Figure 7. In order to prevent the defects such as filling dissatisfaction during the forging process, with the increase of the upper die reduction, the metal flows along the moving direction of the upper die along the lower die cavity, and the metal gradually fills the cavity. There are no defects such as filling dissatisfaction or folding, and the pre-forging of the final forging is obtained.

Figure 8 shows the hub bearing mandrel formed by hot forging. The billet material is 55 steel, and the billet is heated to 1 200 °C by medium frequency induction furnace before upsetting, and the heating time is about 15 s.

Observing the forged hub bearing mandrel, it can be seen that the forming is good, and there is no defect of filling dissatisfaction. It is tested according to the quality standard of the hub bearing mandrel, and the results show that the performance is up to standard.

The final forgings were cut into metallographic samples for light microscope images. As shown in Figure 9, it can be seen that the distribution of pearlite and ferrite is not uniform. The pearlite is matrix flake, and the ferrite is distributed along the grain boundary in a semi-network and the ferrite is fine.

CONCLUSION

A set of die for upsetting- preforging- finishing of hub bearing mandrel was designed, and the hot forging process of hub bearing mandrel was analyzed. The final forging cavity is filled during the forming process of hub bearing mandrel. The forged hub bearing mandrel has complete filling and no folding phenomenon, indicating that the full-filling final forging can be hot forged.

The simulation analysis and experimental verification show that the forging method can meet the forming and performance requirements of the hub bearing mandrel. A forging process of hub bearing mandrel was designed: firstly, the billet was upset to remove the oxide skin, then the pre-forging was carried out to make the billet present the basic shape of hub bearing mandrel, and finally the final forging was carried out to obtain the ideal forging.

REFERENCE

[1] H. Ohnishi, K. Takamoto, H. Matsumoto, et al., Microstructural evolution of a Ti- 6Al-4V alloy produced by forging process combined with torsional motion, J. Manuf. Process 58 (2020) 1161–1170.

[2] B. Gu, X. Han, L. Hua, Processing design and optimization on rotary forging of thin- walled structure, Thin Wall Struct. 162 (2021), 107567.

[3] T. Wang, H.Z. Guo, Y.Q. Zhang, et al., Effects of hot forging temperature on microstructure and mechanical property of tg6 high temperature titanium alloy, Acta Met. Sin. 46 (8) (2010) 913–920.

[4] Q. Zhang, M. Cao, D. Zhang, et al., Research on integrated casting and forging process of aluminum automobile wheel, Adv. Mech. Eng. 6 (2014), 870182.

[5] S. Luo, D. Zhu, L. Hua, et al., Effects of process parameters on deformation and temperature uniformity of forged Ti-6Al-4V turbine blade, J. Mater. Eng. Perform. 25 (11) (2016) 4824–4836.

Note: The responsible translator for English language is W. Liu - North China University of Science and Technology, China