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Simulation Analysis of Forging Process of Automobile Aluminum Alloy Swing Arm

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Abstract. To effectively shorten product development cycle, cut down the expense and reduce costs, in the production forging process of aluminum alloy swing arm, the technological process of sawing off, high temperature heat treatment, roll forging, blank making, flattening, die forging, residual edge removing and forging inspection are adopted. Taking Deform-3D software as the platform, the forging process of aluminum alloy swing arm is modeled and simulated by finite element method, and the flow law of cold extrusion metal during the forging process of aluminum alloy swing arm is analyzed. The results show that the forging process can achieve a better forming forging, which can provide a theoretical basis for the actual industrial production of forgings.

1. Determination of Material and Process of Swing Arm

The swing arm material used in this paper is the 6082 aluminum alloy in 6XXX series aluminum alloy. It has better manufacturability and is mainly used in roll forging, rolling, forging and stamping forming[1]. At the same time, the aluminum alloy has better ductility, corrosion resistance and excellent weldability[2]. Therefore, 6082 aluminum alloy is a very promising alloy material.

In the actual industrial production, the shape of swing arm is too complex, so it is difficult to form at once time. In order to meet the requirements of swing arm quality, strength and material utilization rate, it is very important to draw up a reasonable production process. The technological process adopted in this paper is: sawing off, high temperature heat treatment, roll forging, blank making, flattening (bending), die forging, edge removing and forging inspection[3]. Because the selected forging parts are the front suspension of the Passat or the front suspension of the Audi A6 (figure 1), bending in the general technological process is changed to flattening. In this way, the forging billet can be stably placed on the die under the die forging, and simultaneously, the material is fully filled to each branch of the die, thus avoiding the movement of the blank in the die forging process and insufficient filling.



Figure 1. Front suspension lower straight arm assembly



2. Simulation of Roll Forging Billet

The initial blank used in this paper is a cylindrical bar with radius R of 25 mm and height H of 245 mm. Through consulting relevant literature, it is found that the optimum forging temperature range of aluminum alloy 6082 is 440 °C-490 °C. In actual industrial production, the high temperature furnace is set at a temperature of 470 °C. The cylindrical bar is laid off and treated at high temperature, then the billet roll forging stage is carried out.

Because the selected section area of the initial blank and the blank section of roll forging are round, in order to achieve an ideal extension state, the oval-circular groove roll forging method is adopted in this paper[4-5]. The schematic of the groove section and the roll forging model are shown in figure 2.

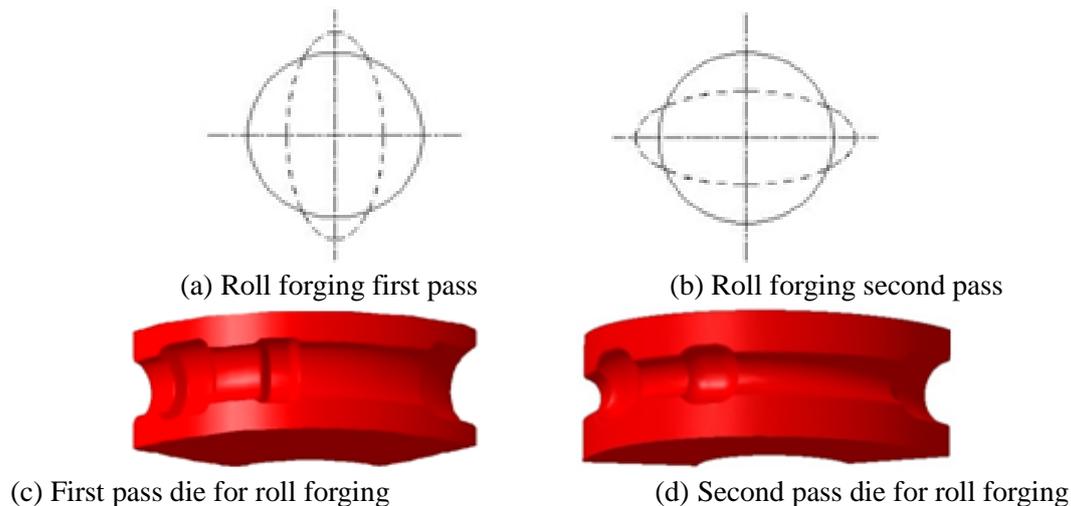


Figure 2. Roll forging groove system and roll forging die

The roll forging simulation stage is divided into two steps: billet clamping and roll forging. Among them, the first pass roll forging is designed to reduce the cross sectional area of the original bar, increase its axial elongation, prepare the corresponding cross sectional area for the second pass roll forging, reduce and avoid the formation of forging flash[6]. The second pass roll forging is to obtain the proper length of forging billet and reasonable cross sectional area, avoid insufficient axial filling in the die forging process, resulting in appearing imperfections of the swing arm, waste of manpower, material resources, and financial resources and so on.

In the simulation, the 3D model drawn by CATIA_V5R20 is stored in the .stl format. Then, the model is imported into Deform-3D software, and the blank and die are meshed in Deform-3D, such as the blank is divided into 47733 units[7], as shown in figure 3.

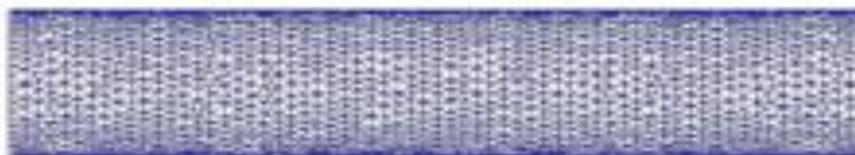


Figure 3. Blank mesh generation

Then the position adjustment of the billet and die, the blank material loading (blank: ALUMMINUM-6082, die: 25Crmo4 (ZA) (Machining)), actions and boundary conditions (temperature and heat exchange coefficient of billet are set as 470 °C, 2 N/sec/mm/C) and other parameters are set. According to the movement of the die, set the pace and the number of steps. Then, the relationship between the objects is positioned, that is, the type of friction is set as shearing friction with the friction coefficient of 0.3. After setting the relevant parameters, DB and KEY files are checked

and generated. The Deform-3D solver is used to perform the simulation calculation, after leaving the Deform-3D interface[8]. Finally, the corresponding roll forging results are obtained in the post process, as shown in figure 4.

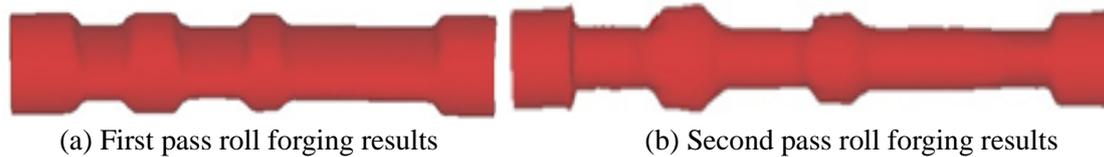


Figure 4. Simulation results of roll forging

As can be seen from figure 4, the axial extension of the first pass roll forging is ideal, without obvious folding and flash. But in the second pass roll forging, there are some defects in the design of the roll forging die, which leads to the partial folding and flash of the roll forging in the simulation of the second pass roll forging. The roll forging die needs further improvement and optimization.

3. Simulation of Flattening Process

The forging parts need to be flattened before the die forging process, so that the forging billet can be filled to the wider and deeper part of the die during the die forging process, which is beneficial to the filling of the branch in the die forging[9].

In the Deform-3D pre-process, select corresponding KEY file of roll forging, open Deform-2D/3D Pre, and select the “final” option. Replace the roll forging die with a pre-flattened die in .stl format, and fix the die, forging billet and fixture. Then, mesh generation is made to the die and fixture; materials of the fixture and die are loaded. The die and fixture materials are chosen as 25Crmo4 (ZA) (Machining) and 12Cr_Martensitic_Stainless_steel respectively. Set the upper die action along the -Z direction[10]. In order to reduce the simulation time and improve the simulation accuracy, this simulation simplifies the processing of the speed and the spacing between the upper and lower die. Set the speed to 1 mm/sec. According to the distance between the upper and lower dies of 70 mm, the number of steps is set to 60, and the upper die displacement increment is 0.5 mm/step. Then, the relationship between the objects is positioned, that is, the type of friction is set to shearing friction with the friction coefficient of 0.3. DB and KEY files are checked and generated. After leaving the Deform-3D interface, Deform in-built solver is used to perform the simulation calculation. In the after-treatment, the distribution of the forging billet after flattening and the direction and flow velocity of the metal billet in the process of flattening are obtained, as shown in figure 5.

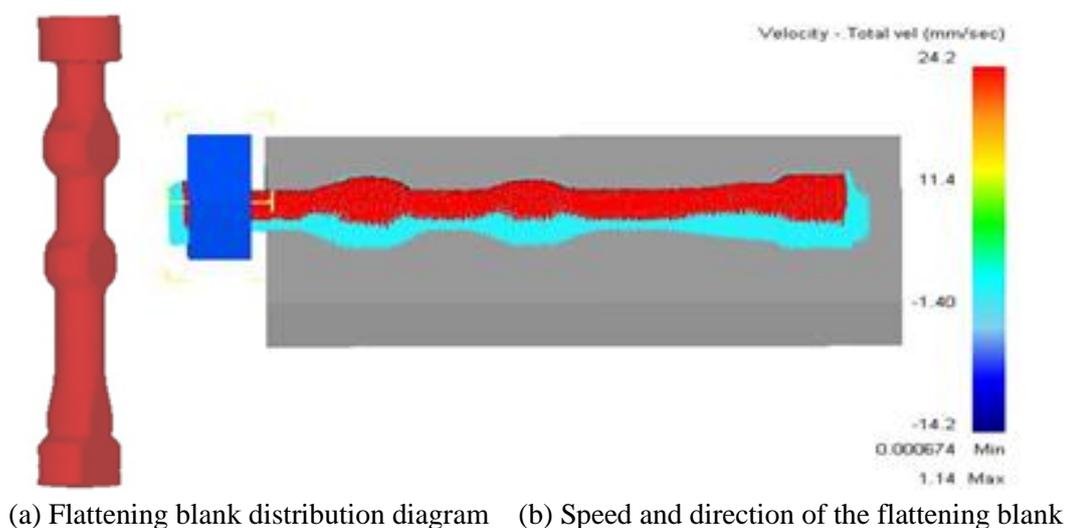


Figure 5. Distribution, speed and direction of flattening blank

As can be seen from figure.5, the deformation of the billet during flattening is similar to that of upsetting. As the velocity parameters are simplified, the reference value of the speed of forging billet in the process of flattening is not large, but the velocity direction is still of some reference value. The forging billet radiates outward along the axial direction, and its radial velocity is greater than that of the axial flow. Therefore, the flattening process mainly changes the axial deformation of the forging billet, which is advantageous for the forging billet to be stably placed on the die under the die forging, and is more favorable for the metal to be fully filled to each branch of the die[11]. However, there is no obvious difference between the deformation of the clamped end and the initial shape of the billet during the flattening process.

4. Simulation and Analysis of Die Forging

According to the three-dimensional model of the swing arm parts, a three-dimensional model of the final forging die cavity is established (figure 6). According to the characteristics of the corresponding branches in the middle and end of the swing arm, a round corner and a groove are arranged between the swing arm and the branch to reduce the friction force so that the metal can flow to the corresponding branch better[12]. After the forging, the blank is treated by trimming, and the initial swing arm forging parts are obtained.

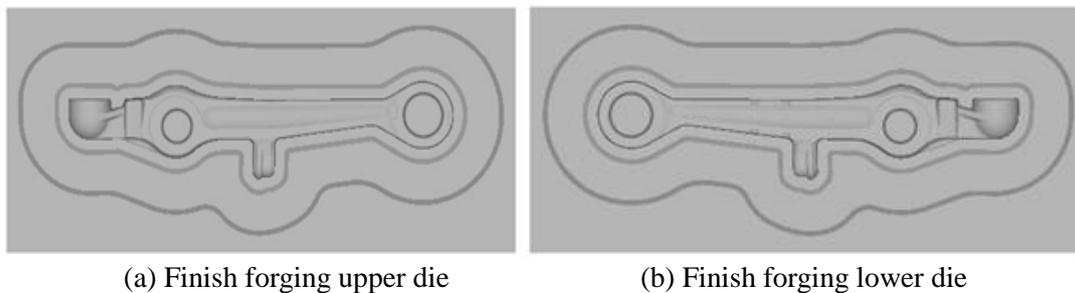


Figure 6. Final forging die

In the Deform pre-process, select corresponding KEY file of flattening, open Deform-2D/3D Pre, and select the “final” option. Replace the flattening die with the forging die in .stl format, and fix the flattening die and forging billet. Then, mesh generation is made to the flattening die with the fixture materials of 25Crmo4(ZA)(Machining). Set the upper die action along the -Z direction. In order to reduce the simulation time and improve the simulation accuracy, this simulation simplifies the processing of the speed and the spacing between the upper and lower die. Set the speed to 1 mm/sec. According to the distance between the upper and lower dies of 60 mm, the number of steps is set to 120, and the die displacement increment is 0.5 mm/step. Then, the relationship between the objects is positioned, the type of friction between the forging parts and die is set to shearing friction with the friction coefficient of 0.4. The heat transfer coefficient between the die and the swing arm forgings is set to 2 N/sec/mm/C. After the above operations, DB and KEY files are checked and generated. After leaving the Deform-3D interface, Deform in-built solver is used to perform the simulation calculation. After the solution is completed, the deformation distribution of the forging during the forging process is checked in the post-processing interface (figure 7).



Figure 7. Deformation distribution diagram of forging

As can be seen from figure 7, after completion of the final forging process, the parts of the forging and the filling of the branch in the die are more adequate. The amount of material in the head and middle part of the forgings is more reasonable, but the amount of material used in the end of the forging is too much. In order to improve the utilization ratio of material, the selection of billet size and the optimization of roll forging die should be carried out.

In order to better understand the internal stress of forgings, in the post processing of Deform software, the equivalent stress and equivalent strain (as shown in figure 8) of finish forging are opened and checked, and the data are computed to Table 1.

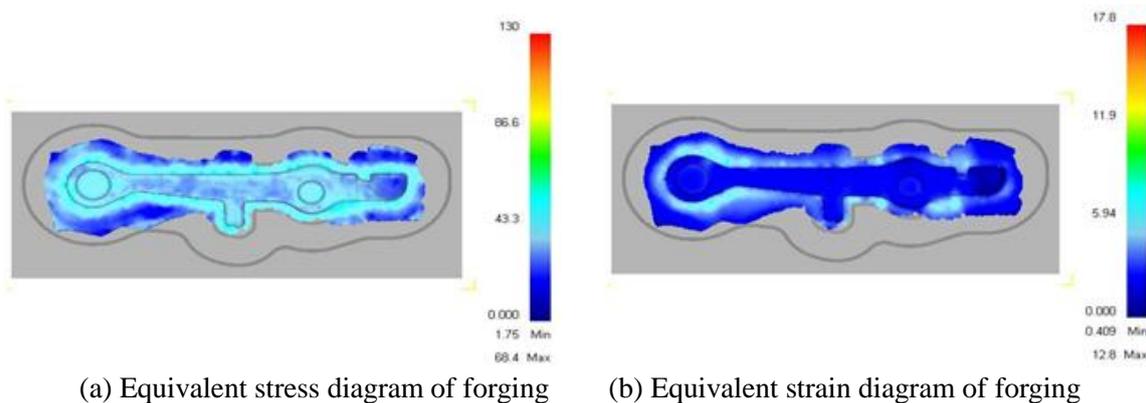


Figure 8. Equivalent stress and strain diagram of forging

Table 1. The maximum and minimum of stress and strain of forging

Type	Max	Min
Stress/Mpa	68.4	1.75
Strain/m\m/mm	12.8	0.409

From the above data, the equivalent stress and equivalent strain of the forging body are more uniform, and the simulation is basically consistent with the requirements. When the final forging is finished, the forging residual edges are removed at the end and the quality is checked. After the forgings have been inspected, the swing arm should be machined, cleaned and treated so as to obtain the qualified swing arm parts.

5. Conclusion

(1) Through the analysis of the shape and structure of swing arm, a reasonable process flow is proposed. By using Deform-3D software platform, three processes of roll forging blank making, flattening and die forging forming of swing arm are simulated, and the swing arm forgings without folding, break and size and shape meeting the requirements are obtained.

(2) The simulation can effectively shorten the product research and development cycle, cut down the expense and reduce costs. It provides a certain theoretical basis for the actual application of the forging of swing arm, and has certain research and guiding significance.

(3) In the simulation process, in order to reduce the simulation time and improve the calculation accuracy, the die motion speed is simplified. Therefore, the speed of forging billet in the forging process has little reference value and needs further simulation verification.

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