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Numerical Simulation Study on Progressive Extrusion Forming Process of Clutch Hub Gear

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Abstract. The extrusion forming process of the clutch hub gear with uneven thickness and small fillet is studied. The numerical simulation is used to analyse the thinning process of the hub gear and the filling of the small fillet. The results show that progressive extrusion has lots of advantages in contrast to conventional one step extrusion in improving metal flow and deformation uniformity, reducing forming load, improving fillet filling and forming quality.

1. Introduction

In recent years, the demand for automatic cars has been increasing year by year due to its simple operation and comfortable driving. The quality of automatic transmission processing directly affects the use of automatic vehicles. As one of the main components of the automatic transmission, the clutch hub is difficult to produce because of complex shapes and strict limit in size and quality.

Casting and cutting as the traditional method of manufacturing clutch hub [1], not only wastes materials, but also has a low processing efficiency, highly the cost of production, and difficulty in ensuring product quality. With the development of metal plastic forming technology, the steel plate forming technology has been widely used to process the clutch hub, which could make significant economic benefit. In this paper, one step extrusion and progressive extrusion are selected to forming the cluth hub gear. The distributions of stress and strain, extrusion loads, gear forming and fillet filling are analyzed and compared based on numerical simulation.

2. Part analysis and finite element model

2.1. Analysis of gear clutch hubs

The clutch hub is a gear shaped part in the inner and outer surfaces of the side wall, and the thickness wall of the gear portion is divided into two types: uneven and uniform, and the round oil injection hole which is arranged at the positions of the inner surface of the side wall. Its role is mainly to facilitate the inflow of hydraulic oil. According to the characteristics of the gear shape, the clutch hub can be divided into two types: through type and non through. The clutch hub is required to cooperate with the friction plate and the steel sheet during the working process, and bear torsion. The forming precision and quality have a great influence on the useful and service life., so the quality of the clutch forming is very high, especially the formation of the gear round portion .It’s one of the difficulties[7-8].

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The object in this paper is the through type clutch hub. The thickness of the hub gear is not uniform. The thickness wall of the internal gear is less than that of the external gear. The solid model is shown in Figure 1.

Figure 1. The solid model of clutch hub

2.2. Establishment of the finite element model

The clutch hub material is AISI1010, and mechanical properties are shown in Table 1. Due to the excellent plasticity and toughness and low mechanical strength, the quality carbon steel is suitable for cold plastic forming. The solid model of the clutch hub shown in Figure 1 has 30 hub gears. Moreover, it's all symmetry in the geometry of the parts, the boundary constraints during the extrusion process, and the load conditions. In order to improve the simulation efficiency and calculation accuracy, the research based on the model symmetry takes 1/15 of the geometric model. The boundary friction is shear friction model, and the friction factor under lubrication condition is 0.12. Based on DEFORM, the rigid-plastic finite element numerical analysis of clutch hub extrusion are carried out. According to the extrusion forming process, it is designed that the descent velocity of the punch is 50 mm/s, the descent displacement is 80 mm, and the inclination of the die is 75°. The hub gear geometry model of the extrusion forming is shown in Figure 2.

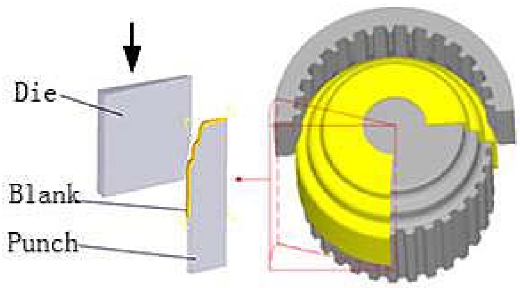

Figure 2. The hub gear geometry model of extrusion forming

Table 1. Mechanical properties of AISI1010

Material.	Yield Strength(MPa)	Tensile strength(MPa)	Elastic Modulus(GPa)	Elongation (%)	Material constant	Poisson's ratio
AISI1010	380.0	682.1	206.7	31.2	555.7	0.3

3. Forming technology

The clutch hub studied in this paper have uneven side wall thickness, especially the position of the hub gear. Since the final hub gear that has a 1.5 mm inner wall and a 2 mm outer wall is made from a 3 mm thick cylindrical blank, side wall thinning in hub gear forming is a key factor in the dimensional accuracy of the part[9-10]. What’s more, considering the shaping of the inner and outer hub gear, two hub gear thinning and extrusion forming schemes are proposed in this paper, which are as follows:

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The scheme 1: Forming the inner and outer hub gear in one step [11]. As a result, the thickness of the side wall reduces from 3 mm to 2 mm, with the thinning rate of 33.33% and the thickness of the inner gear is reduced to 1.5 mm, with the thinning rate of 50%.

The scheme 2: The inner and outer hub gear are progressively formed by a combined die and punch. As shown in Figure 3, the combined die structure and function mainly have three portion, including preformed gear region, progressive hub gear forming zone, gear finishing area. The first step of the processing is to produce a contour with a certain curvature. Then, inner and outer hub gear was obtained by a certain die, which could control the flow of metal. Finally, the product is produced by the process technology of finishing. In the process of forming the inner and outer hub gear, the thinning of the side wall is a gradual process due to the certain inclination of the die.

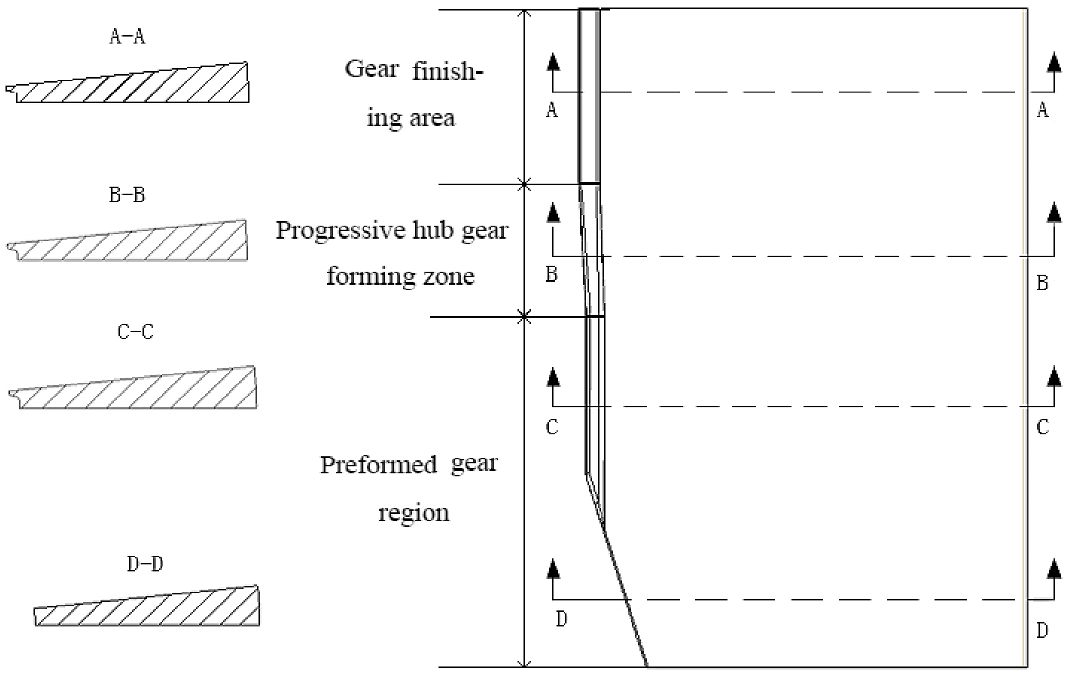


Figure 3. Schematic diagram of the progressive die structure

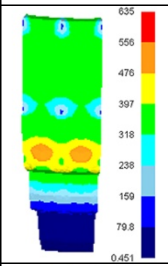
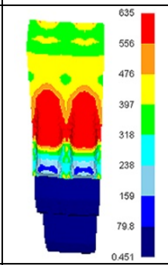
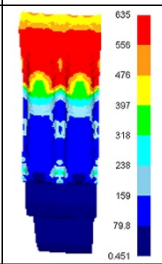
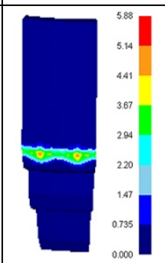
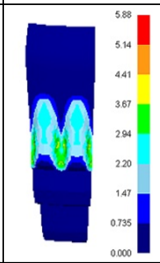
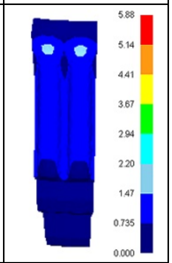
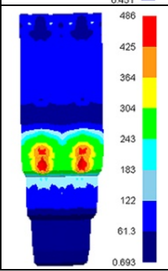
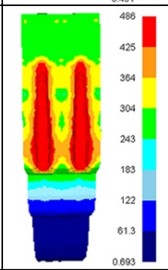
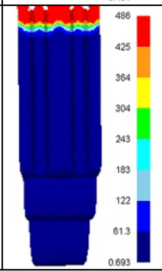
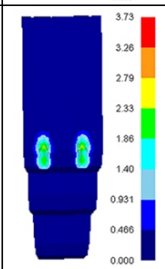
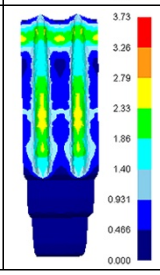
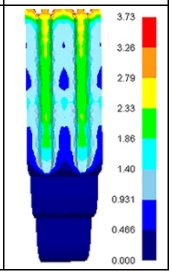
4. Results of numerical simulation

4.1. Distributions of stress and strain

The distribution of equivalent stress and strain for two hub gear forming schemes is shown in Table 2. It can be seen that two forming schemes can manufacture the hub gear. The reason why the maximum value of stress and strain over the period of forming process is located in the area of crest and gear fillet is that materials in this area are likely to getting thinner, which causes the high degree of deformation and stress, though all diameters are within the strength range of the material, meeting the requirements of the material.

Compared with the one step extrusion forming, the stress and strain distribution in the progressive forming is relatively uniform, and the maximum value of the equivalent stress is 486MPa, which is significantly less than the 635MPa of the one step extrusion forming. Therefore, the worn condition of the molds by progressive extrusion are better than those by one step extrusion.

Table 2. Distribution of equivalent stress and equivalent strain

Forming schemes	Equivalent stress.			Equivalent strain		
	steps 110	steps 160	steps 250	steps 110	steps 160	steps 250
The scheme 1						
The scheme 2						

4.2. Comparative of forming loads

The curve chart the mold load during the forming of the hub gear is shown in Figure 4. The load sharply increases at the beginning of the forming until it reaches at the end of the process. In the one step extrusion forming process, the load is dramatically rises and towards peak at 15.9KN. However, in the progressive extrusion forming process, the load gently increased to 12.8KN, as the blank gradually contacts die and thinning performs steadily. It is interesting to see that 80.5% ratio of forming load used by the progressive extrusion process that of one-step is calculated, as well as the load curve changes relatively uniform and reasonable.

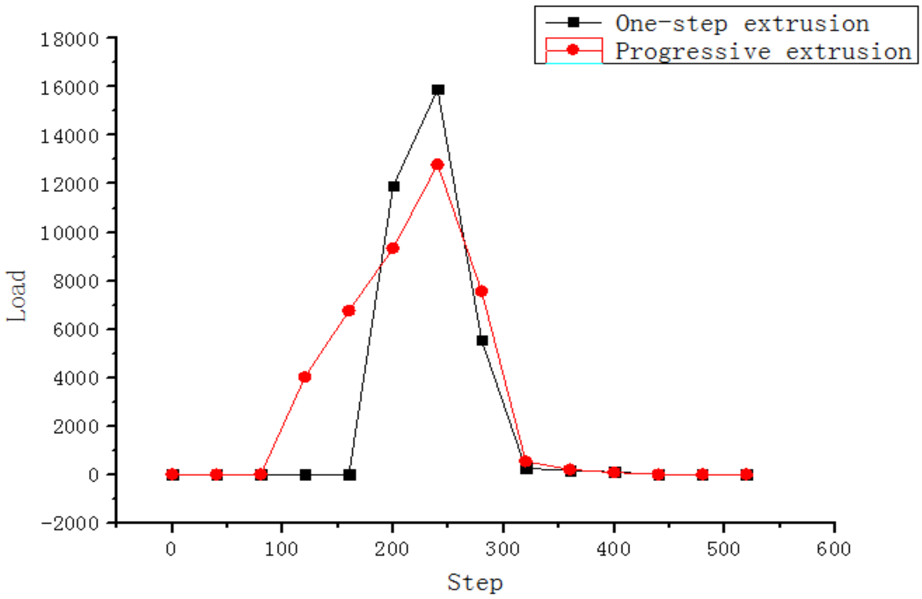
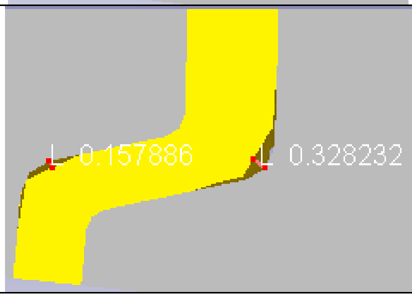


Figure 4. Comparison with forming loads of two schemes

4.3. Gears forming and fillet filling

The maximum gap between the material and the mold of the two forming schemes is presented in Table 3. The maximum clearance of the punched outer fillet and the inner fillet through one step extrusion are 0.8870 mm and 0.2508 mm, while those by progressive extrusion are 0.3282 mm and 0.1578 mm. It is clear that the filling effect of the rounded corner by progressive extrusion is relatively better than the other.

Table 3. Geared mold fillet filling

Forming Schemes.	Unfilled maximum normal gap between material and mold
The scheme 1	
The scheme 2	

5. Conclusion

In the paper, a progressive extrusion forming process of the cluth hub gear is proposed and numerical analysis is carried out based on the characteristic of uneven thickness of inner and outer gear, small inner and outer round corners, and through gear shape. Compared with the traditional one step extrusion forming process, the distribution of stress and strain during the progressive extrusion forming process is more uniform. What's more, the results show that the forming quality of products made by the progressive hub gear extrusion forming process are better than the former ones, since load of the later one is relatively smaller and the inner and outer fillet filling is fuller.

Acknowledgments

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