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The Precise Forming of Automobile Start Gear Shaft

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Abstract

The start gear shaft is the key part of automobile starter, it is involute small module internal gear with addendum modification. It is step shaft with H/D>6 in the outline. Because of the concentric degree demand of the internal gear and the outline step shaft is higher, length of below shaft is large and diameter is small, So plastic forming of the shaft is very difficult. Meeting the needs of markets and improving comprehensive function of automobiles, the high efficient precision forming technology method of single-step chipless-forming for internal gear tooth surface and external step shaft is put forward based on analysis, study and repeated test. In the same time, a set of high accuracy die with simple novel structure and long service life is designed and manufactured. The advantages of the method have been verified that utilization ratio of material and production efficiency is high. For this reason, the method is profitable reference for producing the same type of complex shape gear shaft.

Keywords: Chipless-forming, Start gear shaft, Precise forming

1. Introduction

With speedy development of car industry in China, traditional processing technology cannot meet market needs of car start gear shaft. The start gear shaft is the key part of automobile starter, it is studied in the paper. Because it is involute small module internal gear with addendum modification, it is step shaft with H/D>6 in the outline, the coaxiality of the internal gear and the outline step shaft is higher, length of below shaft is large and diameter is small, So plastic forming of the shaft is very difficult. Meeting the needs of batch process and markets, improving comprehensive function of automobiles, the high efficiency precision forming technology method of single-step chipless-forming for internal gear tooth surface and external step shaft is put forward based on analysis, study and repeated test. The method can adapt at present efficiently, low consumption, superior quality of product demand. The economic benefit of the method is also notable.

2. Technology analyses

The key part of automobile starter-the start gear shaft is studied in the paper. Fig 1 shows the diagram of a light car starter gear shaft. It is involute small module internal gear at one end, it is step shaft with H/D>6 in the outline, and the coaxiality of the internal gear and the step shaft is higher. The originally manufacturing process of the shaft is: blanking—machining—shaped tooth, the process is not only low efficient, but also the size accuracy and coaxiality are low, in the same time ,utilization ratio of material for the process is low, it can't satisfy the demand of rapidly developing of car industry. Improving the production efficiency and the utilization ratio of material, and obtaining chipless-foming of internal gear and less or no cutting of outline step shaft, based on analysis, we think that precise plastic forming can replace originally manufacturing process. Because end diameter is large, step shaft is thin and long, plastic deformation goes beyond the plastic deformation limit, so it is difficult to fill material into internal gear tooth. Therefore according to the structure characteristics of the part, we use the process: cutting material--annealing--lubricating--making blank--extrusion forming--produce.

3. The design and machining of the die

3.1 The calculation of extrusion force

The extrusion force is the foundation which designs a die, it also is an important basis for choosing material of die and equipment of extrusion. According to ABAS, the extrusion force (p) of the start gear shaft is about 5000 kN, this is approximate as a result with the empirical formula p=c*p*f.

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3.2 The design and machining of the die

Because the accuracy of the cold extrusion parts is greatly depended on the accuracy of the extrusion die, when the die is designed, it is considered according to the cold extrusion technology project, the request of concentric precision of the parts and machining process etc. So the die design is brief, easy to machining process. For this, we define the parameter of cold extrusion, and design a set of the cave and convex molding tool that is simple in structure, and opposite side fixed position and split combined cave die so as to form the starter gear once. The diagram 2 shows the extrusion molding tool of the starter gear shaft. According to the structure characteristics of the extrusion parts, we adopt a bring shape object to push out the extrusion parts directly; For the convenience of the changing molding tool and machining accuracy, the cave mold is designed to be divided and sectional body, so as to become easy that the gear's mold is machined and skived etc.

We overcome many disadvantageous factors in the manufacturing process of the molding tool, Such as, the accuracy of EDM, the asymmetry error of the inside chamber of molding tool after combining etc. We adopt many valid measures to give reasonable compensation; When we programme the line cut, we should design with special care to calculate compensated magnitudes. The line is wanted not only to design carefully when line incised a plait a distance, and but is wanted to control the discharge clearance and speed of the idler pulley and to decrease the roughness of the part surface possibly so as to obtain even and consistent size of the molding tool, insure the tolerance in the permission scope for the runout of base tangent.

3.3 The heatment process of molding tool

To satisfy the high accuracy of extrusion piece in large batch quantity, the material of molding tool for precise forming should be chosen correctly, it must be resistant wear, small deformation and long life. After variable factors are considered, a new molding tool material LD(7Cr7M02V2Si) steel is chosen, the scope of quench temperature of LD is wide: $1100~^{\circ}\text{C}$ -- $1180~^{\circ}\text{C}$, the scope of temper temperature is also wide: $510~^{\circ}\text{C}$ -- $620~^{\circ}\text{C}$. But we want to obtain the advantages of the high strength, high tenacity of LD steel, the reasonable heatment process has to be chosen. The hardness of the LD steel, grain size , remaining austenite and machining function depend on the temperature of quench and temper. The technology test and experience summary are as following, for the molding tool material LD steel of the start gear shaft extrusion , heatment process is quench $1100~^{\circ}\text{C}$ -- $1150~^{\circ}\text{C}$, temper $550~^{\circ}\text{C}$.thus, the comprehensive function of the LD steel is better, the molding tool life is longer.

4. The technology test and batch production

4.1 The blank softening

For lowering transform resistance of the blank, raising plastic deformation of the metal, the blank should be softened to improve the internal organization before cold extrusion. If annealing technology to soften is not appropriate, it will make the blank anticipate of the degree of hardness is high and low and different, and it will lead to increase pressure or the molding tool wear, the service life of the equipments and molding tool and the surface smooth of the piece are directly effected. The softening technology of the starter gear shaft blank is temperature to 840°C -- 880°C , remaining 6h--10h, cooling to 350°C , out furnace. Random sampling, the hardness is between 130°HRB -- 150°HRB , it feat in cold extrusion to transform.

4.2 The blank making

According to size, shape and the constant principle of the metals physical volume of product parts, cutting material of blank is determined. After reducing diameter and upsetting, the blank is shown in fig.3.

4.3 The blank lubricating

The lubrication processing of cold extrusion blank surface is an important process, surface quality of cold extrusion piece and molding tool life are greatly influenced by lubricating. For cold extrusion of black metals, for long time, traditional processing method of bonderizing and saponification is used, but defect of the method is following: it takes up the large work place, the cost is high, the environment is polluted, and the control of quality is difficulty. Therefore, we have adopted a kind of hydro-high polymer lubricant to lubricate. This lubricant uses convenience in brief: Put directly the blank after cleaning oxidize skin into the lubricant to immerse, then nature dry or oven dry, make the lubricant adhere to anticipate surface of blank, become a layer of black gray lubrication film. When extrusion forming, friction resistance can be greatly reduced, and surface of the pieces is smooth and bright, the request of application is satisfied.

4.4 The technology experiment and batch quantity production

During the experiment, the molding tool should be carefully fixed to promise size accuracy of piece. Based on experiment, it has been verified that molding tool design is reasonable, technology project is right, the internal gear tooth of the piece is filled with good, there is not any crack in internal surface, machining of internal surface and gear tooth is not needed. Through the customer detection and application, the customer think that the quality of the start gear

shaft is good, the accuracy is high, the function is superior and the request is satisfied completely.

5. Economic benefits

The start gear shaft is manufactured by using the precision forming technology, its material structure is dense, fibre structure is not damaged, the wear-resistant ability, size accuracy and concentric degree is high. So the service life of the start gear shaft is long. In the same time, it can short manufacturing cycle, save material, lower cost, So its economic benefit and social benefit is good.

6. Conclusions

Precision forming technology is the key technology which raises product function and quality, not only it can short a product manufacturing cycle, lower cost, reduce weight, but also it can raise the end size accuracy of part and the coarseness degree of the surface. The safety, the credibility and life of part are raised. The comprehensive function and quality of product also are raised, and the utilization ratio of material is raised. So the advantage of the precision forming method for the type of complex gear parts has been verified that utilization ratio of material, production efficiency are high ,the accuracy is high and the service life is long. Technology method of single-step chipless-forming of internal gear surface and external step shaft is an ideal method. So the method is profitable guide and promote for producing the same type of complex shape gear shaft.

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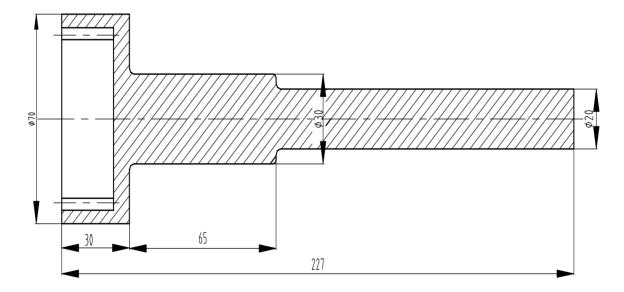


Figure 1. The diagram of the start gear shaft of a light car

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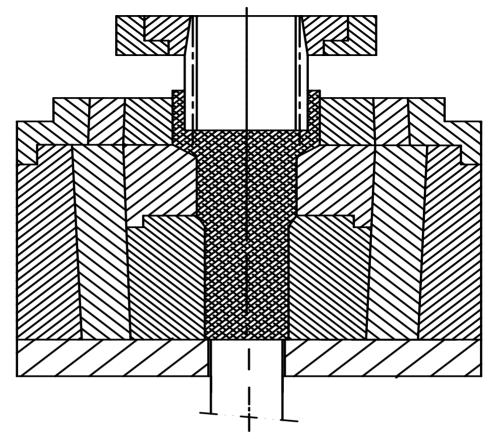


Figure 2. The diagram of chipless-forming die for the start gear shaft

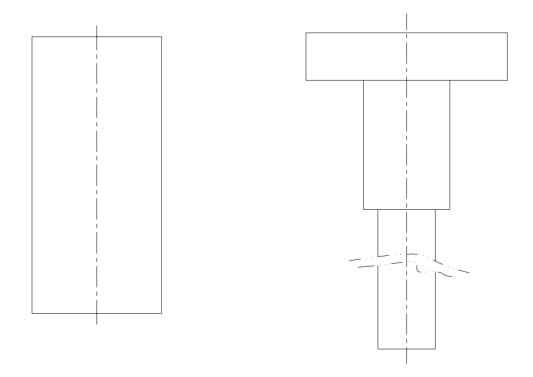


Figure 3. The diagram of the shape for the semi-finished product