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Closed Forging of Car Gear Blanks on Hot Die Presses

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Abstract

This article mainly introduces the research of closed forging on 20MN hot die forging presses. After transforming of the equipments, optimizing of die design and improving of die-manufacturing precision, gear blanks used in car gearbox have been forged out without fins successfully.

Key words:　Closed Forging　Exploitation

1. Forewords

Forging on a quick upsetting machine is regarded as the optimum forming process to produce the forgings with high precision, such as the gear blanks in car gearbox. But investment in this kind of press is so high that we have to turn to other production styles. Because closed-die forging can't meet the precision request, we made up minds to develop closed forging process. There might be many kinds of equipments apt to closed forging. After having investigated two other forging plants, we thought that development of the new process needed such premises as transforming current equipments and improving forging process being used. Our current equipments are all hot die forging presses. So we had to exploit the new process on them in order to meet the development of car industry and exert their functions.

2. Analysis of closed forging process

Blanks are formed in closed impression without fins, so the precision and utilization efficiency of material are both higher. Utilization efficiency value can be up to 90 percent, even 95 percent. Obviously there are many difficulties.

Closed forging belongs to close-finish forging process, and it can bring remarkable economic benefits from material saved. So it should have developed speedily. In fact, few plants limited by various conditions are using it, and subsequently few correlative documents are available. The main factors that affect the usage of the process are as below:

- ✧ Applicability of equipments including forging force and ejecting functions such as enough ejecting force, ejecting stroke and ejecting delay.
- ✧ Precision of billets
- ✧ Heating conditions
- ✧ Die design
- ✧ Precision of dies
- ✧ Operating factors

Prime task is to ascertain forging presses and a process plan.

2.1 Selection of forging presses

Here we mainly consider the two factors: forging force and ejecting functions.

Theoretically forging force (abbreviated to F) is the product of projection area (abbreviated to A) and unit deformation force (abbreviated to P). Till now six gear blanks have been forged with the new process. Taking the forging of the biggest diameter (107 millimeters) as example, we calculate its forging force needed with the two formulas now:

$$P=Cp\,\delta_S[1.7+2.7\,\mu\, l/(D-d)+a_1 D/4.5(D-d)]^{[1]}F=P*A \qquad F=6.86MN$$

$$F=(64\text{-}73)A^{[2]} \qquad F=6.57MN$$

As the result, an 8MN or 10MN forging press is suitable. In our plant, the minimum presses are of 20MN forging force, which is enough obviously.

Ejecting functions should include enough ejecting force, ejection stroke and ejecting delay. Our current forging presses had the first function only, so they were necessary to transform.

2.2 Process plans

We have two plans: one is forging without fins and the other is forging with small fins. In the former plan redundant material should be controlled within allowed tolerance of forgings; Forgings are of high precision, and likewise there are many difficulties. In the latter plan we should make room for redundant metal which would be fins. If we adopt the latter plan, such conditions as shearing accuracy, forging temperature and die precision can be loosen to some degree. But close-finish forging wouldn't be actualized finally as the result, and it would be possible to turn back to close-die forging again. In addition stripping device is necessary when small fins are trimmed and forgings are pierced. Traditional compound die for trimming and piercing can't finish the two procedures simultaneously. Therefore production efficiency will be reduced.

2.3 Verification using computer simulation

After having designed the first gear blank, we did computer simulation to verify its rationality with QForm software. As we know, upsetting discs affect forgings' filling and forging force. From the simulation we got the most appropriate thickness value, which minimized forging force and could make forgings filled fully.

Ultimately we decided to develop closed forging process on a 20MN forging press to explore unknown acknowledge.

3. Calculating weight of forgings and controlling precision of billets

After having calculated nominal weight using AutoCAD software and manually, considering allowed tolerance and burning loss, we ascertained weight of billets. Shearing accuracy is critical to closed forging because of its great effect on forgings' precision. Targets of controlling billet precision are weight tolerance and side rake. Their values are analyzed as below:

We assume: $\eta = a / h$

Here a presents weight tolerance, and h presents weight caused by height tolerance of forgings. After calculating the ratios of the six gear blanks mentioned before, we think that the value of a equal to ± 0.5 percent of billet weight is more appropriate, because subsequently absolute value of η is within the range of 0.1 to 0.125. In the other word, weight tolerance of billets is 20 to 25 percent of that of forgings, and affects size fluctuation of forgings little.

As far as side rake of billets, smaller and better. When metal bars are cut into pieces with a high speed saw, side rake caused is about 0.5 degree.

So we ascertain weight tolerance is equal to ± 0.5 percent of billet weight and side rake is less than 0.5 degree.

4. Die design

Here we take a gear blank used in gearbox of CITROËN car as example. Its die structure shows as Figure 1. In order to guarantee its high precision requested, such subjects below are considered in design.

4.1 Design of upsetting dies should be emphasized highly

When we design upsetting dies, not only we should consider own orientation of billets, but also upsetting discs should be oriented well when put into the closed impression, thus coaxiality and filling of forgings can be guaranteed. So upsetting dies must have the orientation-function cavity, which is in accordance with that of closed dies.

As far as gear blanks with large flanges, upsetting dies are not only used to remove oxidized skin on billet surface but also designed as pre-forming or pre-forging dies for the purpose of forgings filled fully.

4.2 Structure design of shaping dies

In order to guarantee coaxiality of forgings, upper and lower dies must have good guiding function. So we design upper shoe (part 6 in Figure 1) and outside of impacting ring (part 11) fixed on lower shoe (part 1) as lock device which have played roles before puncher (part 10) reaches a billet.

To gear blanks used in gearbox, because inner diameters are less than 30 millimeters commonly, stripping style differs from traditional one. Here we design stripping device of springs. Furthermore the punch (part 3) and the convex die are separate, which makes teardown and installation of dies convenient and fast.

Design of die precision and cooperating clearance

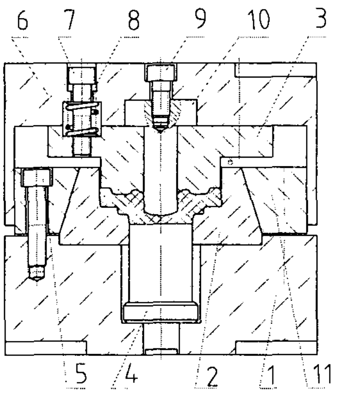
Manufacturing tolerance of dies must be controlled strictly, otherwise precision of forgings is difficult to guarantee. Such tolerances as parallelism, verticality and coaxiality must be controlled within the rage of 0.02 to 0.05mm, and cooperating clearance should be adjusted to be reasonable due to various forgings.

Selection of die material

Here convex dies, punchers, concave dies and ejecting rods are made of H13 die steel and hardened within the hardness range of 48 to 50 HRC.

Piercing die is designed of piloting device and rigid stripping device, so piercing accuracy can be guaranteed.

From the above, we can see that orientation problem is considered in all die structures. So precision of forgings is guaranteed wholly.



1、 lower shoe
2、 concave die
3、 convex die
4、 lower ejecting rod
5、 bolt
11、 impacting ring
6、 upper shoe
7、 bolt
8、 spring
9、 bolt
10、 puncher

Figure 1

5. Manufacturing of dies

Compared with closed-die forging dies, closed forging dies need higher precision. Because dies are of compound structure, not only individual die quality but also assembling and exchanging quality of dies are to be guaranteed. Obviously the manufacturing process of closed-dies forging process can't meet technological requests.

According to die structure designed and precision needed, we ascertain that manufacturing process of upper and lower shoe include such steps: rough machining, heat treatment, three-dimension inspection and finish machining. Its critical point is to eliminate the mismatches between locating key slots of dies and lock slot centers of insert dies, which are caused by artificial operating errors and deformation after heat treatment. According to coaxiality request and analysis result of cooperating gap value, the mismatch between upper and lower die must be less than 0.1 millimeter. So after heat treatment, three-dimension inspector is used to measure the center of die impressions which will be taken as the basis of figuring and milling key slots precisely.

Convex and concave dies are critical to shape forgings. So their cavities are machined on NC lathes. Thus not only quality of individual die cavity but also accordance of same die cavities is guaranteed.

Puncher and lower ejecting rod are both of double functions of shaping and ejecting, their sizes must be exact and they must cooperate with dies well at the same time. So they must be machined on NC lathes.

6. Transforming of equipments

Partial mechanisms of equipments concerned were transformed in order to adapt to closed forging.

6.1 Transforming of lower ejecting mechanism of a 20MN forging press

Its former ejecting mechanism is cam ejecting style, and without delay device. Obviously it can't adapt to closed forging. The transformation includes three main aspects showed as below:

- Replacing cam mechanism with a gas cylinder;
- Adding delay device. The delay time can be adjusted arbitrarily to lower ejecting rod;
- Enhance ejecting stroke from 40mm to 60mm, even 75mm.

6.2 Heating billets using inductors of side heat preservation function

Some abnormal phenomena often occur on the heating step of closed-die forging. For example, temperatures of billets heated in a same inductor are different and individual side temperature is lower. These factors affect quality of forgings much. Former inductors were of cylinder style and hadn't heat preservation device on exit side, so the exit side temperature of billets was cooled easily. So we designed a kind of inductors with side heat preservation function to protect side temperature from falling down.

7. Critical points in shaping car gear blanks

Shapes of car gear blanks aren't too complex. But when we implement closed forging, such critical points should be paid more attention to.

Six kinds of gear blanks all request high precision. Their tolerances are ± 0.5 mm, machining margins are less than 1mm, and coaxialities are no more than 0.8mm. Precision of die design and manufacturing must be up to the requests.

Inner diameters of all car gear blanks are small, most of which are 28.6mm and minimum is 20.5mm. Traditionally holes diameters of which are less than 25mm are allowed not to be forged out or to be blind, and the ratio of punching depth (h) to hole diameter (d) is less than

0.5. But the ratio show as Figure 2 is 0.93 which is 1.85 times of traditional value. So it is important to ascertain proper size precision of parts, mutual gap cooperation, die material etc.

Paying attention to establishment of desk. If billets' diameter isn't appropriate to orient itself, orientation desk shall be shaped on the previous forging step. The figure marked "A" in figure 2 is the shape of orientation desk forged out in the first forging step.

Paying enough attention to concentricity and symmetry of upsetting discs. Traditional forging don't request precision of upsetting discs. But closed forging requests that material must be distributed well, otherwise vertical fins will occur locally and the opposite side will not be filled fully. In addition forgings would have the defect of thickness fluctuation. In order to guarantee symmetry of upsetting discs, closed upsetting dies can be used if necessary.

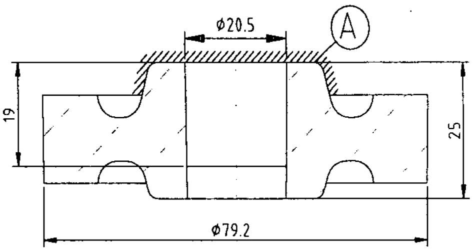


Figure 2

8. Summary

We have exploited six kinds of car gear blanks till now. Our analysis and design of closed forging process proves correct. It is feasible to implement close-finish forging on forging presses.

To closed forging, selection of presses is premise while shearing accuracy is critical, and improvement of heating condition, precision of die design and manufacturing and operating norm are all important guarantees. All these factors must cooperate mutually well. Any mistake would affect success or failure of the new process and quality of forgings. So application of closed forging process can be regarded as a sign of enhancement on technological and managing level of an enterprise to some extent.

Closed forging process needs to be solidified and enhanced. Some more abstract subjects are expected to be conquered. With the continuous development of car industry and more and more requirement of precise forgings, the development of closed forging process can be predicted.

Reference

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