Complex technology of stamping details “hub” from ball blank

M V Filippova, V N Peretyatko, E E Prudkiy, M V Temlyantsev and A G Nikitin
Siberian State Industrial University, 42 Kirova street, Novokuznetsk, 654007, Russia
E-mail: kafkshp@sibsiu.ru

Abstract: In order to reduce the amount of metal wastes and improve the quality of press forgings, the new energy-and resource-saving technological complex of warm volumetric forging was developed, which has the following features: the metal is divided into billets on the rolling mill of cross-screw rolling; the induction heating of the billet to the temperature of warm forging (850-900°C); pressing of metal is performed, as a rule, in one pass in closed dies.

1. Introduction
Currently, the most common method of manufacturing the main parts of machines and units subjected to increased dynamic loads is forging and stamping. The products obtained in this way have high strength, reliability and durability. However, due to the low accuracy of the initial blanks, the finished forging is characterized by relatively large allowances and overlaps. This is due to the presence of large tolerances in the diameter of hot-rolled metal and the difficulties of accurately measuring the length and evenness of the ends of blanks cut from the bar on presses [1].

Since in the cost of engineering products the cost of metal consumed for the manufacture of parts reaches 80%, the minimum consumption of metal should be taken as the main criterion for reducing the cost of products in the production of forgings. To reduce metal losses it is necessary to use complex non-waste production technologies in which resource saving is taken into account at all stages: cutting the initial billet into measured lengths, heating the metal for punching, stamping.

Modern technologies for obtaining axisymmetric forgings of round-shaped (stamped into the butt) hot stamping by serial and mass production include the following operations [2]:

- Separation of metal into billet. The most common way of dividing a bar into billets is cutting metal in dies or using a shear press. The advantage of this separation method lies in the non-waste process of cutting, rapid rearrangement of the die for different cutting lengths, low cost of cutting, simple design of the cutting tool. Significant disadvantages include errors in the form of deviation of the dimensions of the workpiece from the correct cylinder and the deviation of the mass of the workpiece. Moreover, the deviation of the mass of the billet from the nominal value when cutting metal is 7-10%. Thus, blanks obtained by cutting metal with shears, can be used only for stamping in open dies [3, 4].

- Heating of the workpiece for stamping. Heating of the workpiece for stamping is carried out to temperatures 1150-1200°C. The advantage of heating to high temperatures is a decrease in the resistance of the deformation metal and an increase in the plastic properties of the metal. The disadvantages of high-temperature heating include the formation of scale on the surface of the
workpiece, which reduces the quality of the forging surface and requires additional scale removal operations and a decarburized surface layer of the metal, which requires additional machining. Losses of metal due to scale make up 1-3% of the mass of the billet [3, 5, 6].

- Form change of the workpiece in the stamp. In connection with the non-precise dimensions of the billet, stamping in the open dies occurs with the burr formation. Losses of metal due to burr cutting make up to 25% of the forging weight [3].

Thus, the existing technology of hot stamping has big drawbacks and does not meet modern requirements for energy and resource saving.

2. Methods of research

In order to reduce the amount of metal waste and improve the quality of stamped forgings, a new energy-saving and resource-saving integrated technology for semi-hot volume forging [7] of a “hub” forging (figure 1) was developed, which includes:

- Separation of metal into billets on a ball rolling mill. It is carried out on a rolling mill of cross-screw rolling. The resulting blank has the shape of a ball or a cylinder, the mass fluctuation does not exceed 3% [1]. The ball blank has a good surface quality, is evenly heated in the inductor, stably centered in the die, does not require additional pre-settling operation and fills the die bed contour well. Statistical processing of the experimental data on ball weighing showed that the average mass of a ball with a diameter of 93 mm is: for rolling on a new rolls of a rolling mill (3307±19.63) g, for rolling on worn rolls of a rolling mill (3336±21.30) g and the maximum relative error is equal to ±0.63% [8].

- Induction heating of the workpiece to the temperature of half-hot forging (850-900°C). This heating technology ensures the production of forgings of good quality (by reducing the amount of scale) and reduces energy consumption up to 20% (due to a lower heating temperature). The preliminary calculation of the optimal temperature of the ball blank heating from 40Kh steel showed that the optimum temperature of the blank heating, taking into account the resistance of the deformation metal, the plastic properties of the metal and the formation of scale, is 860 ± 5°C. In the production environment, the temperature of the ball blank heating was increased to 900°C. The additional studies carried out on the effect of decreasing the final heating temperature showed that with a decrease in the temperature of the workpiece heating from 1200°C to 900°C, the metal deformation resistance of steel 40Kh increased by 52%, plastic properties decreased by 34%, metal burnt decreased by 92%, decarburization is absent.
Stamping of a heated blank without burr in the closed die, as a rule, in one transition. Such a resource-saving, non-burr stamping makes it possible to save metal due to the burr absence. Investigation of metal flow during stamping, filling of a stamp, as well as stress-strain state of a metal was carried out by computer simulation. For the numerical realization of mathematical models of stamping, the finite element method was used [8-11]. Simulations were performed using QForm-3D and Deform 3D software products. These software products make it possible to simulate the filling of a stamp with metal, the formation and development of defects, the change in the time and volume of the components of the stress tensor and deformations, the invariant characteristics of stress and strain, the change in the time of the deforming force, the temperature conditions of metal deformation, the wear of the die and other values in the course of metal shaping.

Modeling conditions: the initial ball blank with a diameter of 90 mm from steel grade 40Kh; deformation of the workpiece is performed on a crank press in the closed die at a temperature of 900°C with a coefficient of friction 0.4.

Industrial researches were carried out at the the rolling-mill and the crank hot-stamping press AK KB8544.

3. Results of computer simulation
The simulation results of stamping the hub from a ball blank showed that the metal flow during the filling of the die occurs without the formation of clamps and cracks. The stamp is completely filled with metal, there are no unfilled corners. Hub stamping in the closed die can be carried out in one pass.

4. Industrial research
According to the existing technology of stamping “hub” forgings, the rolled bars with a diameter of 75 mm and a length of 3000 mm after preliminary heating in the furnace to a temperature of 400-600°C on a crank press are cut into blanks of 106±2 mm in length. The cylindrical part of the workpiece is 24 mm, the oblique cut is 8 mm and the crumpling of a cylindrical part is up to 6.5 mm (figure 2). According to the technological map, the mass of the cylindrical billet must be at least 3675 g.

Further, the cylindrical blank is heated in the induction heater to a forging temperature of 1150-1200 °C. The heated billet is stamped in three passes in open dies: preliminary settling of the blank for descaling, stamping in the blocker, and then in the finishing impression. Further, the forging is
transferred on the conveyor to the edged crank press, where the burr cutting and wad removal are performed.

The mass of the forging is 2800 g, the mass of the burr is 675 g, the mass of the wad is 145 g, and the mass of the loss is 55 g.

The hot stamping of the pilot batch of hub forgings from a ball billet with a diameter of 93 mm and a mass of 3300 g (according to the factory technology 3675 g) was performed to test the possibility of stamping the hub from a ball blank in the industrial conditions. Heating and stamping were carried out by the factory technology. Heating: in the induction heater to the temperature of 1200°C with a discharge rate of 16-18 s. Stamping on a crank hot-stamping press was carried out in three steps: pre-settling of the billet, stamping in the blocker, and then in the finishing stamp. For accurate centering of the ball, the design of the blocker and finishing impression was changed – the configuration of the marking for the punching. After stamping the cutting of bur and wad removal were performed. Inspection and measurement of forgings showed that all dimensions in height are fully satisfied, the quality of the surface meets the requirements of the technical control department. The mass of the burr decreased almost twofold.

Several forgings of the hub were stamped from the ball blank without preliminary settling. The measurements showed that, despite the absence of preliminary settling and a smaller mass of the ball in comparison with the cylinder, all dimensions of the finished forging are satisfied.

Thus, based on the results of computer simulation and experimental studies, the technology of the non-burr hub stamping from a pre-rolled ball blank was recommended for implementation.

After carrying out a number of preliminary studies of individual operations, an industrial approbation of the technology of warm forging of a hub from the ball blank was carried out:

A spherical blank with a nominal diameter of 90 mm was heated in the induction heater KINZ 750/2.4, installed with a slope of 15°, so the balls were easily moved by rolling along the guides of the inductor. The ball rolling promoted a good warm-up of the workpiece along the section, and also eliminated the possibility of jamming in the inductor. In addition, this way of moving the metal protects the guide tubes of the inductor from premature wear. The heating temperature was 900 °C. The temperature of the heating was monitored by means of an optical pyrometer. The measurements of the surface temperature of the sphere with an optical pyrometer and the central layer of the ball (thermocouple) showed that the ball blank was heated up faster than the cylindrical blank, therefore, the heating time of the ball billet could be reduced to 12-14 s.

The heated spherical blanks were fed to the crank hot-stamping press AK KB8544 and stamped in one non-burr finishing gauge. The draft of the new stamp is shown in figure 3.

![Figure 3](image-url)

**Figure 3.** The design of the stamp for the non-burr stamping of the hub: 1 – punch; 2 – forging; 3 – matrix; 4, 5 – ejector.
The process of unbroken hub stamping showed that the die is filled with metal completely, the metal is not displaced into the burr. After removing the wad on the edging press, inspecting and measuring the forging of the hub, it was established that the forging dimensions correspond to the dimensions of the forging drawing, the clamping of destruction and other defects are absent.

The possibility of forgings without preliminary settling is due to the design of the finishing gauge of the die, in which the accuracy of the ball blank centering is effected by the cavity in which the ball blank is formed. The expediency of excluding the operation of settling from the technological process is that this stream is used to bring down the scale and ensure the forging a good fixation in the subsequent gauge. But on the ball blank, which is heated to lower temperatures and having a smaller surface area than the cylindrical blank less scale is formed.

Figure 4 shows the operational drafts of the hot hub stamping according to the existing factory technology with the burr from the cylindrical blank (4a), and the new non-burr hub stamping from the ball blank (4b). As can it be seen from the figure, according to the existing technology the cut cylindrical billet is heated in the inductor, its settling takes place, then stamped in the blocker and finishing impression, the burr is cut.

It can be noted that when stamping from a ball blanket, the number of operations is reduced by two passes. The press for cutting with a force of 2500 kN is not used in full production in the technological process, and is only needed to make a the hub hole.
5. Conclusions
1. A new energy and resource-saving technology for forging a hub has been developed, which can be characterized as a complex technology of warm volume forging from a ball blank.
2. The ball blank obtained by rolling on a cross-screw rolling mill has a stable mass and it can be used for the non-burr stamping of axisymmetric forgings.
3. Induction heating of the blank from steel 40Kh to the temperature of warm forging (850-900 °C) ensures the production of forgings of good quality (by reducing the amount of scale) and reduces energy consumption by 20-25%.
4. Resource-saving non-burr die stamping allows 26% of the metal to be saved due to the absence of burr.

6. References
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