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Development and investigation of resources-saving process of shafts forging

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Abstract
The article deals with description of advantages of application of 3 and 4-rayed ingots for forging of shafts n comparison with round-shaped ingots.
The design of profiled heads and a mode for broaching for forging 3 and 4-rayed ingots from a standard ingot was developed.
The article presents the results of experimental investigations regarding the comparison of the character of distributions of deformations, the degree of removal of axial defects, alternation of the grain size at forging of shafts from round shaped and 3-4-rayed ingots.
The appropriate recommendations were given regarding new processes of forging of, the essence of which is in elimination of the necessity to perform upsetting operations, due to application of profiled heads for preliminary ingot forging into 3 and 4-rayed ingots.
Key words: FORGING, INGOT, REDUCTION, DRAWING, SHAFT, PROFILED HEADS, AXIAL DEFECT, DEFORMATION, STRESS.

Efficiency of application of forging and pressing production depends primarily on optimal technological processes of treatment of large-size forgings of shafts type.

Traditional forging of shafts comprises three main operations: billet roughing up, intermediate upsetting and broaching until forging dimensions. These operations are largely power and labor consuming, which leads to high production costs of ready-made forgings. Moreover, shafts forging, performed by applying of conventional technology is characterized by unfavourable deformation mode, which not always promotes getting high-quality forged shafts, which meet the requirements of the European standard (SEP 1921).

It was found out that there were reserves for further improving of metal quality and they are first and foremost connected with the possibility of modifying plastic metal flow at broaching.

“Control over plastic metal flow in macro-volumes” plastic working of metals research school was established in 1960s at Moscow Institute of Steel and Alloys (MISA) at the department of “Forging and Stamping”. The method of macro-shifts, developed by specialists of the department (namely, by professors Y. M. Okhrimenko and V.A.Tyuirin), is the main tool of controlling metal flow, by application of which metals and alloys at plastic deformation are affected in a totally new way. [1,2].

It is proposed to carry out technical solutions for realization of micro-shifts [3] by creating a forging billet of a special shape, ensuring accumulation of deformation in specified areas, staring with the first stages of forging in order to ensure a positive effect at broaching.

A blank, having three big concave edges, forming three ledges (see Fg.1.) was termed as ”three-rayed” by the authors.

The results of laboratory and industrial investigations [4] of shafts forging from a cast “three-rayed” ingot proved their advantages.

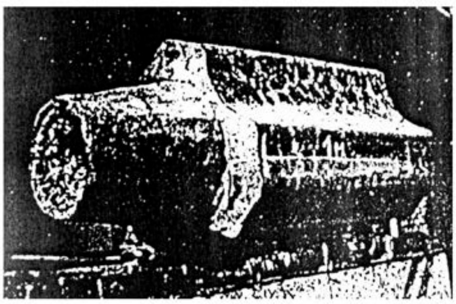


Figure 1. External view of a three-rayed ingot, 7mt. in weight (according to Tyurin)

The research school of Donbass State Mechanical-Engineering Academy (Kramatorsk), headed by L.N.Sokolov, I.S. Aliev, L.L.Roganov made a great contribution into development of technology of forging large-size ingots. Particularly, with the aim of ensuring a better working out of the axial zone with maximum deformations in it during first stages of ingot roughing up, when bases of high quality of inner areas of the forging are laid down, the structure loosening being absent, at Kramatorsk New Heavy Engineering plant [5] a mould was designed and an ingot, 39.5mt in weight wand three-rayed in cross section as prepared. Such shape of cross-section, as L.N. Sokolov and other scholars point out, takes into account the metal flow at initial forging operations and creates favorable distribution of forces, acting upon metal. At small value of forging (1.5) and with the proposed shape of ingot 7-fold increase of deformation in the axial zone is reached, as compared to an ingot of octahedral shape.

Despite its evident advantages, mentioned above, three-rayed ingots for shafts forging possess some drawbacks, which are conventional for any cast ingots. Besides, manufacturing of three-rayed ingots involves creation of some additional foundry production, manufacturing and maintenance of moulds stock, feeder heads, mould stools and other special devices for special ingots.

Having analyzed the existing tendencies of improvement of the processes of forging of shafts, we specified the following ways of developing the process of their forging: elimination of the operation of upsetting from the process; application of profiling heads[6,7] for obtaining 3-or 4-rayed ingot, made of a conventional ingot and application of 3 and 4-rayed ingots for manufacturing of shafts.

Laboratory investigations were carried out on a hydraulic pressing unit with 0.63MN force. A special insertion block was designed and manufactured for specimens deformation. The angle of heads notch was 120°, as this value is the most often used in industry. Profiled heads in their cross-section had the radii of the working parts R_{σ}=15,12,9 mm. The original ingot had a radius R_3= 15mm. The relation R_{σ} / R_3 was 1.0; 0.8; 0.6 Specimens were deformed in stages alongside with roughing up 7%; 14%; 21% until reaching a shape of a regular three-rayed ingot in cross-section. ($R_1 = R_2 = R_3$) , or a regular four-rayed ingot ($R_1 = R_2 = R_3 = R_4$). The diagram of roughing up is pictured in Figures 2-3.

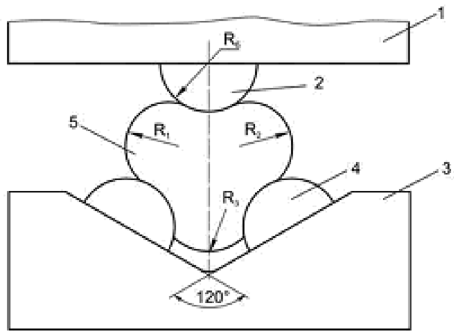
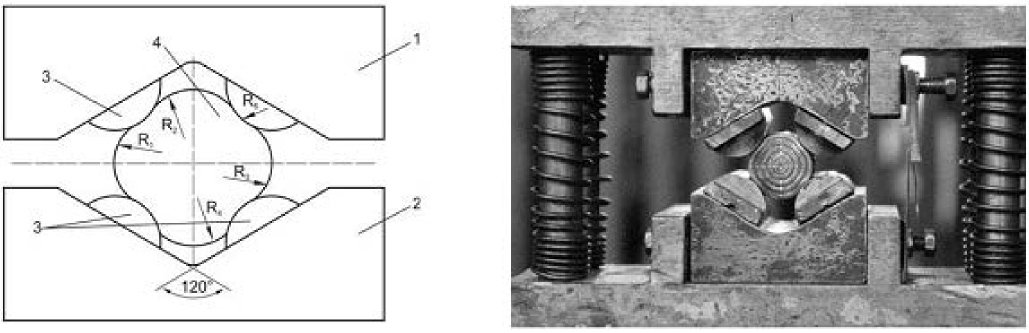


Figure 2. The diagram of roughing up of a round – shaped ingot by combined profiled heads.
1-upper flat head, 2-upper concave insertion, 3-lower blanking head, 4-two concave insertions, 5-ingot.

Distribution of deformations was investigated by the coordinate scale method. On steel specimens (made of 40Cr steel grade) a degree of welding of internal defects was simulated, as well as macro- and micro-structure.

It was found out by the researchers that a local protrusion of the ingot material upwards and sideways near the contact of the ingot with concave profiles of the working insertions, located on the upper and lower heads happened after the beginning of deformation by combined profiled heads. Metal protrusion was equal in both ways, forming two upper concave ingot lobes. Alongside with the acting pressing force metal flows towards the lower blanking head (pushed out) forming the third concave ray (see Figure. 2.). After commencing deforming by profiled blanking heads (see Fig.3.) a local protrusion (widening) of the ingot material takes place, in a horizontal plane towards each side from the vertical axis. Metal flows in upward direction of the acting force (pressed out) and it flows downward between the concave insertions.



a) the process diagram b) photograph of the process

Figure 3. The diagram of roughing up of a round-shaped ingot by profiled blanking heads: 1-upper blanking head, 2-lower blanking head, 3- four concave insertions, 4-ingot.

The investigations resulted in discovering the fact that in order to obtain an ingot of a regular three-rayed shape ($R_1 = R_2 = R_3$) and also a regular four-rayed ingot ($R_1 = R_2 = R_3 = R_4$), the value of reduction had to be within $\varepsilon = 21\text{-}23\%$ limit.

Configuration of the obtained forging ingot acts ,in this case, as factor of ingot shape for realization of the effect of macro-shifts at subsequent broaching.

At the following stage of our investigations characters of distribution of deformations at forging were compared, with regard to a shape of original ingot. It was found out that application of 3- and 4-rayed ingots ensured a better working out of the axial zone, as compared to conventional round-shaped ingots. So, at the total forging value in cross-section (У), equal to 1.5 in the axial zone of a three-rayed ingot , deformation value was equal to $e=In(s_{ή}/s_{к})$ =0.68, while in four-rayed ingot e=0.78, these values being by almost 50% higher than at forging of round-shaped ingots. Thus, it was found out that at manufacturing of forgings of shaft type from 3- 4-rayed ingots it was possible to reduce by 1.5times the forging value , as compared to forging of round-shaped ingots.

At forging of steel ingots it was revealed that the degree of shortening of axial defects when 3-4-rayed ingots were applied was higher than at application of round-shaped ingots. Micro-structure analysis showed that preliminary deformation of a round-shaped ingots with profiled heads into 3-4-rayed ingot ensures at У=1.5 a complete repair of the axial defect, while treatment without profiling ensured only 70% cover of the defect (when combined heads were applied and 85% cover (blanking heads). Grain size becomes 3-4 points finer , as compared to the intact structure.

Forging of ingots of 3-4-rayed shape may be termed as preliminary profiling. For process engineers the diagram of the final broaching of the profile with combined and blanking heads is of great importance. So, the corresponding recommendations for forging of 3 and 4-rayed ingots were developed.

Forging of three-rayed ingots. Broaching in this case can be carried out in two ways : with insertion of the ledge of the 3-rayed ingot into the cut-out of the lower head, or towards the upper flat head. Theoretically, (applying the method of finite elements –MFE) it was discovered broaching made with application of the second method ensured more uniform distribution along the ingot's section, as compared to the first method.

Forging of four-rayed ingots. In this case broaching should be done with blanking heads. Here, also two variants of placing of 4-rayed ingot are possible. It was found out that, broaching according to method along the diagonal with 90° fringing is preferable, as it permits to obtain practically round-shaped section, forging productivity also being increased.

A new tool was designed (concave profiled heads) with application of the described recommendations and a new resources-saving forging process was developed, allowing to forge shafts without upsetting. Industrial forging according to the specified technological process made it possible to raise productivity of the process of shafts forging by some 18..20%, expenses on electric power, required for deformation reduced approximately by 16…19%, forgings productions costs were also reduced.

Conclusions

1. A design of combined and blanking profiled heads was developed allowing to obtain three and four-rayed ingots.

2. Recommendations were prepared and new resources-saving technologies were prepared for shafts forging, the essence of which is in elimination of upsetting operations due to application of profiled heads for preliminary forging of ingot into 3-4-rayed shaped blank with subsequent deformation by combined or blanking heads. An efficient position of 3 and 4-rayed ingots at forging with these heads for obtaining a round-shaped section was established.

References

1. Okhrimenko Y.M. (1974). Increase of efficiency and quality of work at forging practice. *Forging-pressing production*. No 8 p.p.2-8.
2. Tyurin V.A. (2007). Innovation forging technology with application of macro-shifts-*Forging-pressing production*. No 11 p.p.11-20.
3. Tyurin V.A., Baluyev S.A. (1978). Peculiarities of forging of three-rayed ingots –News of higher education establishments. *Iron and steel publisher house.* P.p.104-107.
4. Baluyev S.AV.A. Tyurin V.A. (1985). Influence of ingot's shape and the process of forging upon the quality of shaft forgings. *Forging-pressing production*. No 1 p.p.7-10.
5. Sokolov L.N., Pestov V.S., Efimov V.A., Tsygura N.G., Bobrov A.A., Kononenko V.O. (1985). Process technique, ensuring working out of the axial zone of forged ingots. *Forging-pressing production.* No2 11 p.p.25-27.
6. Patent 50412 MPK (2009) An appliance for forgings broaching. Kargin S.B., Kargin B.S. et al. (Ukraine) No U 200912274, application date 30.11.09, published 11.06.10.Bulletin No11-4 p.
7. Patent 52289 Ukraine MPK (2009) B 2115/00 An appliance for forging broaching/ Kargin S.B., Kargin B.S. et al. No U201000628, application date 22.01.10; published 25.08.10, Bulletin No16-2 p.