Effect of the forging process in a tool implementing alternating deformation on the structure and mechanical properties of AISI-5140H low-alloy structural steel

Sergey Lezhnev[1], Abdrakhman Naizabekov[1], Evgeniy Panin[2], Dmitry Kuis[3], Igor Stepankin[4], Vladislav Pichshikov[1]
Rudny industrial Institute, 50 let Oktyabrya str. 38, Rudny, 115000, Kazakhstan; e-mail: sergey_legnev@mail.ru
[2]Karaganda Industrial University, Republic av. 30, Temirtau, 101400, Kazakhstan; e-mail: cooper802@mail.ru
[3]Belarusian State Technological University, Sverdlova str. 13a, Minsk, 220006, Belarus; e-mail: dmitrykuis@mail.ru
[4]Pavel Sukhoi State Technical University of Gomel, Oktyabrya av. 48, Gomel, 246746, Belarus; e-mail: igor-stepankin@mail.ru

Abstract: *The article describes the concept of a new forging method of circular cross-section blanks in a forging tool, the design of which makes it possible to develop significant alternating deformations in the deformable metal. The results of comparative studies of the microstructure and mechanical properties of AISI-5140H low-alloy structural steel, formed in a new forging tool that implements alternating deformation and in flat strikers are presented.*

Keywords: FORGE, FORGING TOOL, ALTERNATING DEFORMATION, MICROSTRUCTURE, MECHANICAL PROPERTIES.

1. Introduction

One of the advanced methods of metal processing, which allows to significantly reduce the metal consumption coefficient in the manufacture of various metal products, and at the same time will ensure an increase in their quality, is metal forming, including such method as forging. Improving the metal quality when forging ingots and blanks largely depends on the chosen forging technology and the tool for its implementation. And it has long been proven that one of these technologies is forging technology, which allows additional shear deformations to be realized during deformation [1].

It is possible to achieve significant additional shear deformations during forging in practice for forging workpieces of circular cross-section by using a new forging tool [2] shown in Figure 1.

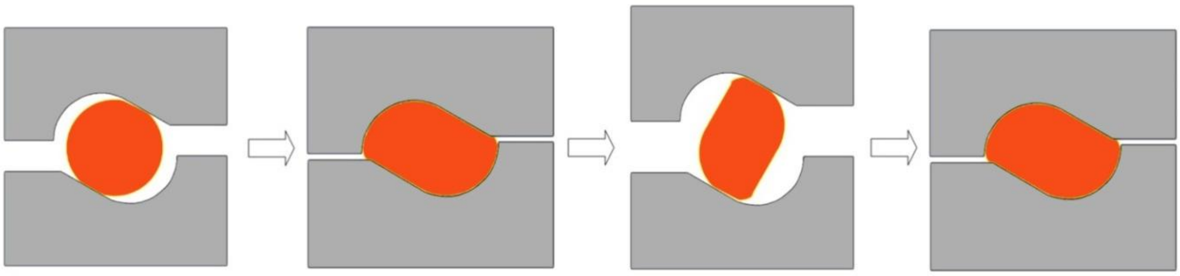


Fig. 1. *Forging tool and scheme workpiece deformation*

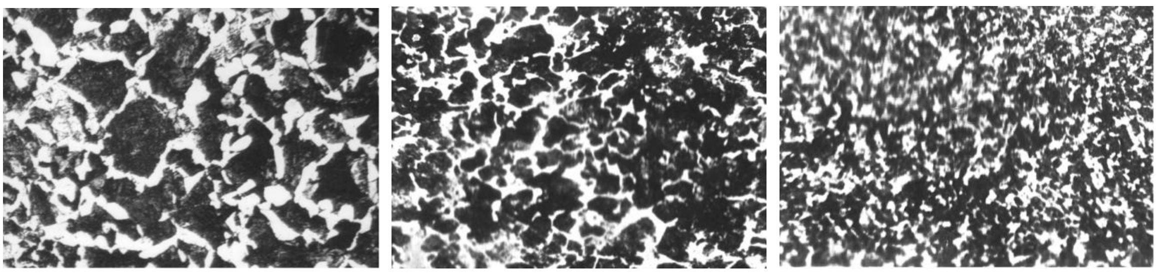
The purpose of this work was to study the influence of the forging process of round cross-section blanks in a forging tool that implements shear deformation in the entire volume of the deformed metal on the microstructure evolution and changes in the mechanical properties of AISI-5140H steel. The choice of AISI-5140H low-alloy structural steel for the experiment is justified by the fact that this steel is widely used in the manufacture of various machine parts and equipment.

2. Experimental part

An experiment on the deformation of AISI-5140H steel billets with dimensions D×L = 45×300 mm in a forging tool of a new design implementing alternating deformation was carried out in laboratory conditions on a hydraulic press with a force of 100 tons. All blanks of AISI-5140H steel were annealed at a temperature of 700°C with an exposure time of 45 minutes to ensure the restoration of the initial structure.

The technology of forging blanks in the new forging tool was as follows: the blanks were preheated to a forging start temperature of 1100°C and were kept at this temperature; then the first billet was fed into a forging tool of a new design and deformed according to the scheme shown in Figure 1. After the entire billet (along the entire length) was formed according to this scheme, another series of compression of the billet along the entire length was carried out in the same forging tool, but already at first with its edging at 45°, and then at 30°. This made it possible to approximate the shape of the cross-section formed in the new forging tool of the workpiece to a circle having a diameter of 35 mm. The second batch of blanks made of AISI-5140H steel, heated to the temperature of the beginning of forging, was formed according to the current technology - broaching in flat strikers, also up to a diameter of 35 mm. Section reduction in both cases was 1.65.

Metallographic studies of blanks formed according to the proposed and current technologies were carried out on a metallographic microscope DM IRM of Leica (Germany) in accordance with the requirements of GOST 5639-82. Also, non-deformed (annealed) billets made of AISI-5140H steel were subjected to metallographic studies. The results of the microstructure evolution study are shown in Figure 2.



a) b) c)

Fig. 2. *Microstructure of AISI-5140H steel: a – initial, b – shaped in flat strikers, c – shaped in a new forging tool*

Comparison of average grain sizes with reference scales showed that in the initial state, the dimensions correspond to 5 points; after deformation in flat strikers the average grain size lies in the range 6-7 points, and after deformation in a new forging tool - 9 points.So, the grain size of AISI-5140H steel, deformed in a new forging tool, the entire cross-section is 2-3 points higher than when deforming it in flat strikers. At the same time, when deforming workpieces in a new forging tool, there is also a more uniform distribution of equiaxed grains over all sections of the workpiece, compared with flat strikers.

Also, standard tensile samples (type III) were prepared from all experimental blanks (deformed and not deformed) in accordance with GOST 1497-84 "Metals. Tensile testing methods". To conduct tensile tests, the TCB – 101-50 installation was used. During mechanical tests, the following mechanical properties of AISI-5140H steel were determined: tensile strength, yield strength, elongation, contraction. The average values of these mechanical properties obtained after statistical processing of test results are shown in Table 1.

Table 1 – Mechanical properties of AISI-5140H steel

Tool	Property	Average values of properties	
		Initial	After deformation
new forging tool	Tensile strength, MPa	579,7	684,6
	Yield strength, MPa	265,4	344,8
	Elongation,%	10,8	18,7
	Contraction,%	23,7	35,6
flat strikers	Tensile strength, MPa	579,7	654,7
	Yield strength, MPa	265,4	302,4
	Elongation,%	10,8	14,1
	Contraction,%	23,7	28,9

Analysis of mechanical properties shows that the strength characteristics of AISI-5140H steel blanks forged in the proposed forging tool increase more intensively, compared with the strength properties of blanks formed in flat strikers. Thus, when using a new forging tool, the strength characteristics of the workpieces increase on average after one deformation cycle: the tensile strength increased by 18.1%, and the yield strength increased by 23% of its initial values (after annealing). When using flat strikers for forging, this increase is: the tensile strength increased by 12.9%, and the yield strength increased by 13.9%. The plastic characteristics of the workpieces forged in the proposed tool increase in comparison with their initial values, too, more significantly than when forging with flat strikers. For example, the relative elongation during forging in a new forging tool increases on average by 7.3%, and the relative narrowing by 5%, and when forging in flat strikers, the relative elongation increases by only 3% and the relative narrowing by 2.2%. A more intensive increase in the mechanical properties of blanks forged using the proposed technology in a new forging tool is primarily due to the fact that the compression of blanks in this tool is accompanied by intense shear deformations and, accordingly, more intensive grinding of the initial microstructure, which was proved earlier.

3. Conclusion

The conducted studies have once again proved the advantages of forging workpieces in forging tools, which allow additional shear or alternating deformations to be realized in the entire volume of the deformed metal during the deformation process. Also, the above studies suggest that the introduction of the proposed technology into production will allow to obtain an economic effect, since this technology will allow to obtain forgings and billets of circular cross-section with a given level of mechanical properties with less forging than using flat strikers.

4. Acknowledgments

This research was funded by the Science Committee of the Ministry of education and science of the Republic of Kazakhstan (Grant № AP09259236).

4. References

1. Найзабеков А.Б. Научные и технологические основы повышения эффективности процессов ковки при знакопеременных деформациях. - Алматы: Изд.-во РИК по учебной и методической литературе, 2000.–336 с.

2. Патент на полезную модель Республики Казахстан №5700. Инструмент для протяжки заготовок. Найзабеков А.Б., Лежнев С.Н., Волокитина И.Е., Панин Е.А., Волокитин А.В., 2020. Бюл.52.