

Research regarding heat treatment influence on properties of chromic-manganese steel with quenching in polymer solution with purpose of matching drill-stem subs.

S N Dzhabbarov, E I Pryakhin

Saint-Petersburg Mining University, 2, 21st Line, St Petersburg, 199106, Russia

E-mail: Shah1-91@yandex.ru

Abstract. According to GOST 4543-71, steel refers to the group of chromium-manganese steels. It is a medium-alloy constructional steel of pearlite class. The paper presents a theoretical and experimental research activity carried out in order to improve the properties of the 38HGM steel. The results permit the selection of the right heat-treatment parameters that offer the best combination among the yield strength, tensile strength, elongation, necking, impact strength at low temperature and hardness, in order to obtain a better behavior of the material for production of drill pipe subs.

1. Introduction

This paper describes the research activity carried out in order to improve the drill string equipment quality and performance and to extend its field of application. The problems having been analyzed and studied refer to the key-elements of that type of equipment, namely the bodies being under pressure. Extending the field of application of the drill string equipment to its use under pressure requires the use of some material brands capable to meet the requirements [2].

The 38HGM steel, one of the pearlite steels, was selected to be studied. Its properties meet the requirements in order to be used for manufacturing castings used within the drill string equipment that works under high pressure working condition.

The steel smelting procedure and the influence of the steel chemical composition on the material behavior are of high importance. This paper presents theoretical and experimental research regarding the influence of the heat-treatment on the mechanical properties of the 38HGM steel.

2. Research methodology

The research regarding the heat-treatment influence on the mechanical properties was carried out by going deeply into the following fields of research:

- ♦ theoretical study of the recommendations offered by the specialty literature regarding the parameter values of the heat treatment applied to that steel;
- ♦ experimental study of the mechanical properties of samples with the same chemical composition; in those samples the authors applied a heat-treatment schedule, consisting in quenching at the certain temperature with cooling in polymer solution, and one temper operation;



Theoretical research

The 38HGM ferritic-pearlitic structure can be varied by the heat treatment so that a wide range of hardness (450 to 550HB) and other mechanical properties can be obtained. The structure of the pre-eutectoid steel after annealing consists of excess ferrite and perlite [5]. Depending on the temperature of heat-treatment, the hardened alloy exhibits a pearlitic to martensitic structure that results in a tough, erosion-resistant material.

The melting temperature is 1510°C. For maximum softness, castings may be annealed at minimum 788°C and usually between 843°C and 898°C and slowly furnace cooled.

The alloy is hardened by heating to 870°C and cooling in oil. [GOST 4543] After hardening, a part blank should be tempered as soon as possible in the range of 580 - 620°C. Tempering in the vicinity of the range of 250-480°C should be avoided because low impact strength will result [4]. The highest strength and hardness are obtained by tempering at 250°C or below, but this also leads to a sharp drop in the toughness (figure 1, where 1 - air cooling, 2 - water/polymer solution cooling).

Table 1. Mechanical properties of steel 38HGM mode of heat treatment according to GOST 4543-71

Heat treatment schedule				Yield Strength, 0.2% offset	Tensile Strength	Elongation	Reduction	Toughness	Sample size for heat treatment (Ø)
Quenching, °C	Cooling environment	Tempering, °C	Cooling environment	[MPa]		[%]		[J/cm ²]	mm
870	oil	580 - 620	air	785	930	11	-	78	25

It is important to note that the mechanical properties shown in Table 1 are given for samples with a diameter of 25 mm and a length of about 70 mm, and the indicated thermal treatment regime does not guarantee mechanical properties in large billets with a wall thickness of about 30 mm.

According to GOST 7360-82 Drill-stem subs, it is necessary to obtain the following mechanical properties for drill-stem subs:

Tensile strength, MPa - not less than 882.

Yield Strength, MPa - not less than 735.

Elongation, % - not less than 10.

Reduction, % - not less than 45.

Toughness, [J/cm²] - not less than 68.

Hardness - 285...341 HB.

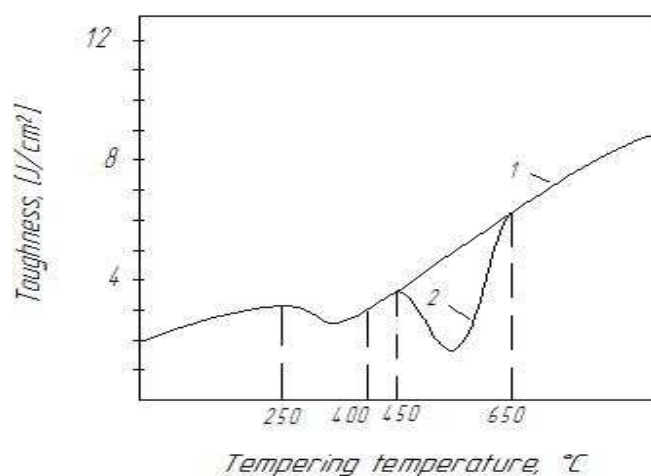


Figure 1. Dependence of impact toughness on temperature of tempering.

The study was performed on the blank shown in Figure 2. The billet is made of steel 38HGM, melting № 3072, a circle of assortment 210; the chemical composition is presented in table 2.

Table 2. Chemical analysis

Melting №	Content of elements									
	C	Si	Mn	Cr	Ni	Mo	W	V	S	P
3072	0.37	-	0.55	0.49	1.06	-	-	-	-	-

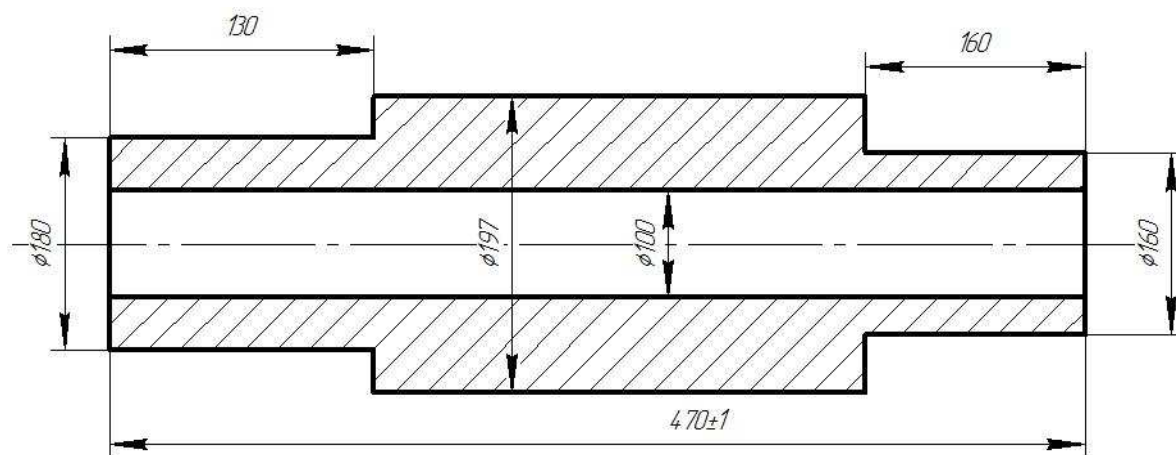


Figure 2. Workpiece for drill sub

Heat treatment was carried out with cooling in the polymer solution, named as UZSP-1. The concentration of the polymer solution is 2%. UZSP-1 (TU 38-403192-86) is a water-alkaline solution of methacrylonitrile copolymer. According to the study [2], the solution of this polymer composition with different concentrations can be used at temperatures of 20°C ... 40°C. It can be used for a long time without replacement and, most importantly, the cooling rate curve of this solution lies between the curves of water and oil. But the thermal conductivity of this system is much higher than the thermal conductivity of the oil (because the polymer is water-based), and due to this the authors obtain

a greater hardenability of the material and higher mechanical properties. The quench tank is 6 m³ in volume. The temperature of the solution is 35 °C. The main heat treatment (quenching + tempering) is presented in table 3.

Table 3. Heat treatment schedule

Steel grade	Quenching			Tempering		
	Heating, °C	Soaking time, h	Cooling environment	Heating, °C	Soaking time, h	Cooling environment
38HGM	860	2.5	Polymer solution UZSP-1	530	6	oil

The results of hardness measurements are presented in Table 4. Hardness was measured in accordance with GOST 9012-59 Metals. The method of Brinell hardness measurement (ISO 410-82) was used.

Table 4. Hardness test results

Hardness control after hardening		Hardness control after tempering	
Ø of indentation, mm	Hardness value, HB	Ø of indentation, mm	Hardness value, HB
2,6-2,6	555-578	3.45-3.4	311-321

After measuring the hardness of the billet, it was checked for cracks by the non-destructive testing method. During the control, cracks in the workpiece were not detected. Further, from the billet, three control blanks were prepared for making samples for mechanical testing. The sketch of cutting is shown in Figure 3.

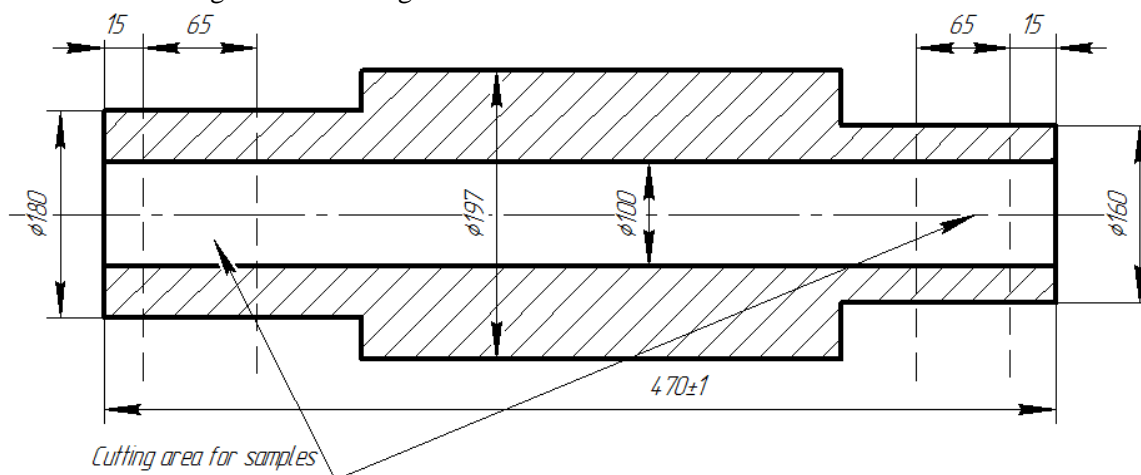
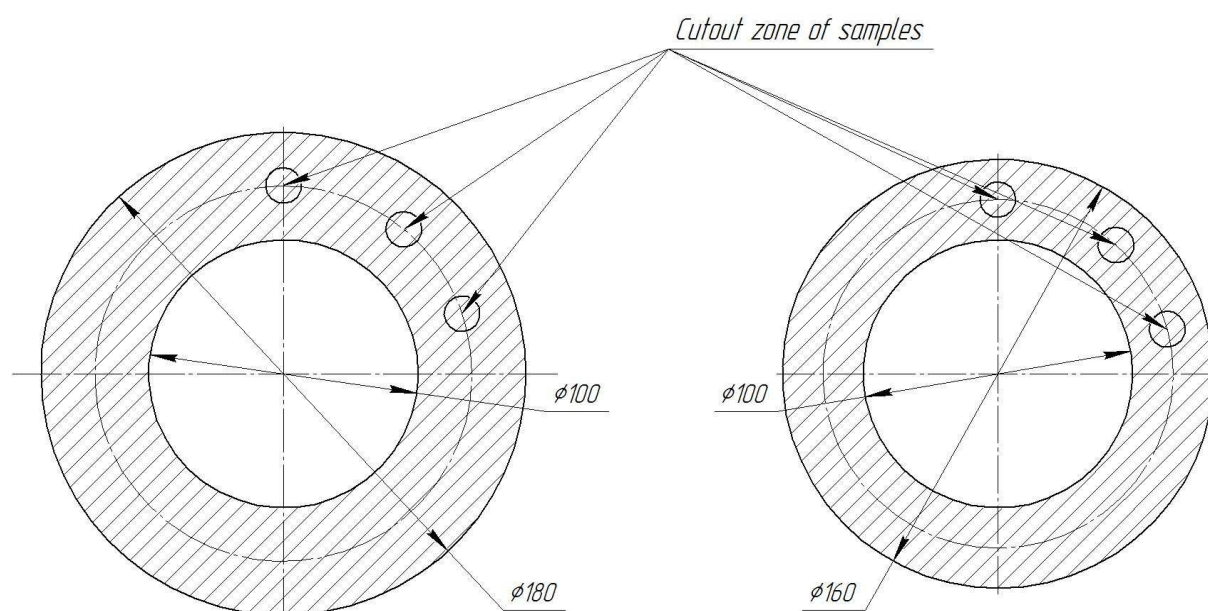


Figure 3. Sketch of cutting workpiece

Blanks with a wall thickness of 30 and 40 mm were cut, samples for mechanical tests were made, and control was carried out. The results of the hardness test on the core preforms and mechanical tests are shown in table 5. Samples are made according to GOST 1497-84 (ISO 682-84) type III with 61 mm length and GOST 9454-78 Metals. Methods for testing the impact strength at low, room and high temperatures for producing samples were used in toughness control. Samples were cut from the middle part of the blank. A cutout of the samples is shown in figure 4.

**Figure 4.** Sketch of cutout zone of samples**Table 5.** Results of mechanical testing of blanks

Wall thickness, mm	Hardness of surface, HB	Core hardness, HB	Tensile Strength, MPa	Yield Strength, 0.2% offset MPa	Elongation, %	Reduction, %	Toughness, J/cm ²
30	311	302-311	1047	921	14	57	94
			1027	895	13	53	92
			1021	897	13	56	89
			1028	873	13	54	75
40	321	311-302	1117	984	12	51	83
			1011	886	13	56	81

3. Conclusion

Theoretical and experimental studies indicate that it is necessary to study heat treatment technologies with quenching in a polymer solution in order to satisfy the requirements of GOST 7360 Drill pipe adapters.

Analyzing the obtained mechanical properties, the conclusions are as follows:

1. Thermal treatment in a polymer solution can significantly improve the mechanical properties of the steel.
2. Technological processing of blanks in the polymer environment ensures compliance with the requirements of GOST 7360.
3. A solution with this concentration provides protection against cracking, in contrast to quenching in water.

References

- [1] GOST 7360-82 1982 Drill-stem subs. Technical conditions (Moscow, State committee of USSR) p 19

- [2] Shevchenko S Y 2014 Comparative estimation of technological capabilities of polymer quenchants, *Science and education* **3** 340-343
- [3] GOST 4543-71 1971 *Structural alloy steel bars. Specifications* (Moscow, FSUE Standartinform) p 40
- [4] Novikov I I 1984 *Theory of heat treatment, Edition 4* (Moscow: Metallurgy) p 479
- [5] 1972 *Metals Handbook vol VII, - Atlas of microstructures of industrial alloys* (American Society for Metals, Edition 8)
- [6] Gudremon E 1959 *Special steel sin two volumes* (Moscow: Metallurgizdat) p 952
- [7] Burns K W, Pickering F B 1964 Deformation and fracture of ferrite-perlite structures *Of the Iron and steel institute* **202** 899 - 906
- [8] Moroz L S 1957 *The fine structure and strength of steel* (Moscow: Metallurgizdat) 159 p
- [9] Shaposhnikov N A 1936 *Fundamentals of mechanical testing of metals* (Moscow: DSTI NCHI) p 324
- [10] Ganina N I, Zakharov A M, Olenicheva V G, Petrova L A 1986 *Diagrams of the state of metallic systems* (Moscow: VINTI) p 247
- [11] Belyaev N I, Gudtsov N T 1914 Review of theoretical research and practical work on the definition of the elastic limit *Journal of the Russian Metallurgical Society* **3(1)** 375-414