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IMPROVING PROPERTIES OF PIPES FOR OIL AND GAS TRANSPORTATION BY HEAT TREATMENT

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Abstract- The article discusses issues of improving the operational properties of pressure and drilling compressor pipes. For oil and gas production, three main types of pipes are used: drill casing and tubing. Taking into account production requirements and the importance of this element in the chain of work carried out, the service life of oil country pipes is complex and varied. In oil-producing and exporting countries, the requirements for the main technical parameters of pipes used in the oil industry differ from the requirements in other areas, the pipes and pipe fittings used. Taking into account the above, pipes intended for the production and transportation of oil and gas must have the necessary performance properties in terms of performance, reliability and safety. At the same time, taking into account operating pressures and other environmental factors, the issue of improving the properties (strength and stability) of the material from which pipes are made, while maintaining mechanical characteristics, is relevant. Improving the properties of pipes, especially the mechanical properties, is an important and important issue. Therefore, you should first be careful when choosing the material from which the pipe is made. Because the material from which the pipe is made must be of high quality in terms of mechanical properties. Considering that pipes, especially those used for oil and gas transportation, carry material for large kilometers. That is, the pipes pass through deserted and empty areas. In other words, if there is a malfunction in them, it can result in the loss of the transported material, which is considered undesirable for the economy. In this regard, their properties, especially mechanical properties, should be high. Corrosion can occur in the part where liquid flows through the pipes, which can also be cavitation corrosion. Cavitation corrosion is also considered a defect for pipes.

Keywords: Pipes, Oil, Gas, Heating, Vacation, Strength, Become, Fortresses.

1. INTRODUCTION

The service conditions of oil pipes are complex and varied: a wide range of operating temperatures from 60 to 150÷200 °C, alternating loads during the operation of drilling and tubing pipes, impulse loads during cumulative perforation of casing pipes, stress corrosion in a hydrogen sulfide environment, etc. Based on service conditions, oil field pipes must have high mechanical strength and ductility, resistance to fatigue and brittle fracture. For a number of operating areas, good resistance of the pipe material to sulfide cracking is of primary importance, and for the northern regions, high cold resistance [1].

Domestic and foreign experience indicates that, in addition to pipes of strength group D, it is advisable to manufacture all other pipes using the thermal hardening process. Oil pipes are manufactured predominantly seamless with diameters from 33 to 425 mm and wall thicknesses from 3.5 to 16.7 mm. A progressive design of a drill pipe is a pipe, to the thickened ends of which connecting locks are welded by electric welding or friction. In Table 1 shows the standardized values of the mechanical properties of drill pipe metal. Despite the complications introduced by this technology into the overall pipe production process, its technical and economic efficiency is undeniable in comparison with the manufacture of such pipes from alloy steel in combination with simple heat treatment [2].

Table 1. Standards for mechanical properties of drill pipe (no less than)

Indicators	Steel strength groups						
	D	K	E	L	M	P	T
σ_B, MPa	637	686	735	784	882	980	990
σ_T, MPa	372	490	539	637	735	882	980
δ_5, %	16	12	12	12	12	12	12
δ_5, %	12	10	10	10	10	10	10
ψ, %	40	40	40	40	40	40	40
KCU, kJ/m^2	392	392	392	393	392	294	294
Note: Mechanical properties samples are cut along upset end of pipe							

All three types of pipes are a working tool when drilling and operating oil and gas wells, therefore they are subject to strict requirements for the accuracy of geometric dimensions (especially for the accuracy of diameter, ovality and curvature). These requirements are determined both by service conditions and the need to obtain the specified parameters of the threaded ends. As a result of thermal hardening, the accuracy of the geometric dimensions of the pipes decreases; the diameter increases, the ovalization of the cross section and longitudinal curvature increases [3].

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2. MODE OF SYNCHRONOUS OPERATION

For this reason, the thermal departments include mandatory means for correcting the geometry of strengthened pipes - sizing and leveling mills. To reduce residual stresses in finished pipes, it is preferable to carry out calibration and straightening operations immediately after tempering, i.e. in a warm state. The hardening process is presented in a technological diagram of the department for the production of high-strength pipes in workshop No. 4 of the pipe rolling plant named after K. Liebknecht, which is intended for heat treatment of casing pipes with a diameter of 168-351 mm and a wall thickness of 6.2-16.5 mm. The line operates as follows: pipes are placed on an inclined rack 1 by an overhead crane, a dispenser 2 transfers them one at a time to the driving roller conveyor 3 for insertion into the hardening furnace 4. Casing and tubing pipes are produced mostly smooth and a small part with upset (thickened) ends, drill pipes - only with upset ends. Table 2 shows the standardized values of the mechanical properties of drill pipe metal.

Table 2. Standards for mechanical properties of casing and tubing pipes (at least)

Indicators	Steel strength groups						
	D	K[1]	E	L	M	P	K[2]
σ_B, MPa	655	687	689	758	862	1000	1103
σ_T^4, MPa	379-552	490	552-758	655-862	758-965	930-1137	1034-1241
δ_5, %	14.3	12.0	13.0	12.3	10.8[2]	9.5	8.5
Seal pipes of strength group K are used until 01/01/85. The relative elongation for pump and compressor pipes is less than 11.3%. Strength group T applies only to casing pipes. The upper value of the yield strength is also normalized							

Normalization can be carried out in two streams simultaneously: a) from rack 1, pipes through furnace 4 are transferred to refrigerator 8 and straightening mill 21; b) from the rack 9, the pipes are transferred through the furnace 4 to the introductory roller conveyor 7 of the furnace 11, at the exit from which they go to the refrigerators 13 and 20 and then to the cold straightening 21. To ensure the mechanical properties required by the standards, it is necessary to carefully conduct the heat treatment process, one of the most important conditions of which is the synchronous operation of all line equipment and especially the hardening and tempering furnace.

Figure 1 [1] presents a nomogram for selecting conditions for synchronous operation of furnaces. By specifying the size of the pipes, the required heating temperature for hardening and the temperature of the hardening furnace, it is possible to determine the synchronous speed of movement of the pipes along the lines and the average temperature of the heating zones of the tempering furnace. Then, based on the average temperature, the oven temperatures in the zones are selected the described technological scheme in its main features is typical, and depending on the type of pipes and the requirements for them, individual additions and changes are made to the equipment. Depending on the type of pipes and the requirements for them, individual additions and changes are made to the equipment.

Thus, during thermal hardening of drill pipes with upset thickened ends to ensure high-quality heating and effective cooling in the thermal department. Baku Steel Plant used: 1) induction heating of thickened ends before the hardening furnace; 2) double-sided sprayer cooling of the ends of the pipe (front - by an internal sprayer moving along with the pipe, rear - by pouring water inside with inclined jets of an external sprayer); 3) induction heating of the thickened ends before the tempering furnace.

The chemical composition of steel for oil pipes is not specified by standards and the steel grade is selected by the manufacturer for technical and economic reasons (based on the specific composition of the equipment and the technological capabilities of producing billets and pipes) and is regulated by technological documentation In our plant abroad, when producing high-strength pipes, manganese steel (for example 32G2 or 32G2C) is used as a base steel, if necessary additionally alloyed with chromium, molybdenum, vanadium and other elements.

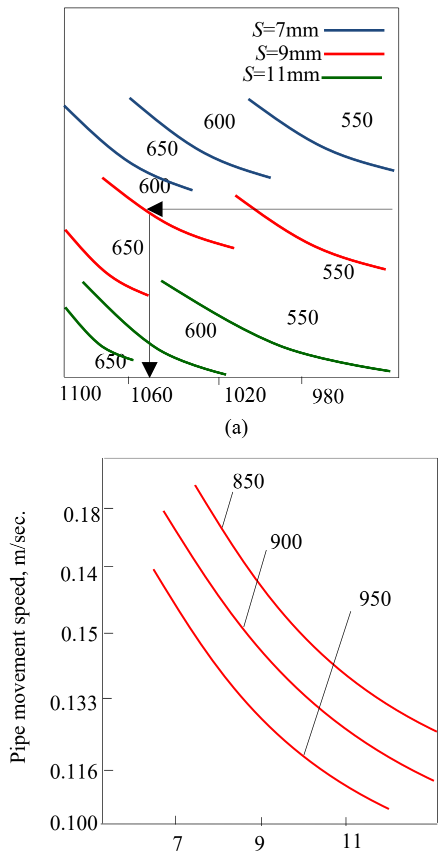

Figure 1. Nomogram for selecting the mode of synchronous operation of quenching (at an average temperature of 1200 °C) and tempering furnaces: 850, 900, 950 - metal heating temperature for hardening, °C, 650, 600, 550 - tempering temperature, °C, a) Average temperature of the heating zones of tempering furnace, °C, b) Wall thickness δ mm

As a rule, the carbon content in it does not exceed 0.35%, and manganese 1.45% in order to avoid the formation of quenching cracks and pronounced segregation in the ingot (blank) [6]. The level of properties obtained depends on the melting composition of the steel (characterized by the strength coefficient and for manganese steel expressed through %C + 0.25% Mn) and tempering temperature. The influence of these factors on the mechanical properties of pipes made of steel 32G2 is presented in Figure 2.

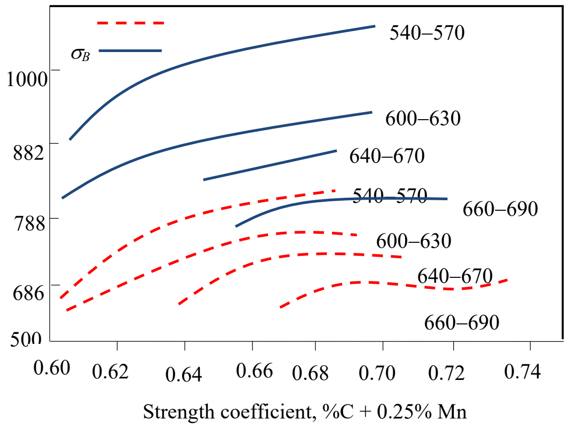

Figure 2. The influence of the strength coefficient of steel 35G2 and tempering temperature (numbers near the curves, °C) on the strength characteristics (G.P. Prozorov, V.M. Yankovsky, T.V. Soboleva)

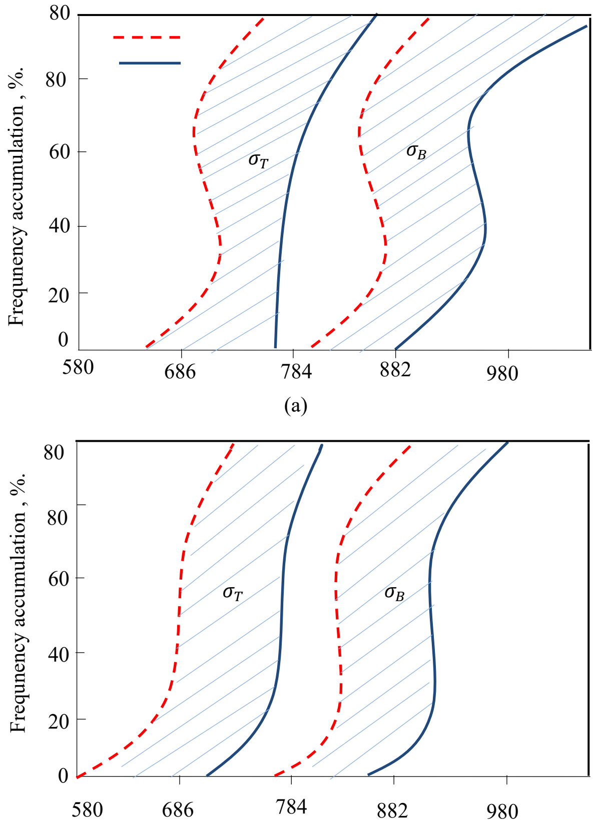

Figure 3. Cumulative curves of changes in strength properties depending on the strength coefficient and tempering temperature (V.Ya. Yankovsky, G.P. Prozorov, T.V. Soboleva):
a) at a tempering temperature of 540-570 °C; b) 600-630 °C;
1) strength coefficient <0.67; 2) >0.67

From the cumulative curves of changes in strength properties depending on the strength coefficient of 32G2 steel for two tempering temperature ranges (Figure 3) it follows that it is difficult to ensure standardized values of strength characteristics, especially the yield strength, even in one heat; with such fluctuations in the melt composition for carbon (0.30-0.35%), an individual selection of the tempering temperature is required for each heat. Therefore, to improve the quality of pipes, it is necessary to further improve thermal equipment in the direction of ensuring narrower temperature ranges during tempering (not ±15, but for example, ±150 °C from the nominal value) and narrowing the range of permissible values of carbon content in steel [7]. Approximate heat treatment regimens for casing pipes made of steel 32G2 to obtain different strength groups are presented in Table 3.

Table 3. Heating modes for hardening and tempering of casing pipes, °C

Pipe wall thickness (mm)	Strength group	Strength coefficient 0.60–0.67		Strength coefficient more 0.67	
		Hardening	Vacation	Hardening	Vacation
8-10	E	860–890	640–670	860-890	660–690
	L	860–890	600–630		640–670
≥11	M	860–890	570–600		600–630
	E	810–900	620–650	860-890	640–670
	L	810–900	600–630		600–630
	M	810–900	540–570		580–610

3. HEAT TREATMENT OF DRILL PIPES

Unlike smooth casing and tubing pipes of strength group D, supplied to the consumer without heat treatment, all drill pipes are subject to mandatory heat treatment after upsetting the ends, while pipes of strength group D are normalized. To obtain the same strength of drill pipes along the length, steel with a higher strength coefficient or more alloyed is used. Thermally strengthened drill pipes work better under conditions of alternating loads than normalized ones (Table 4, Figure 4) [4]. Most of the casing and tubing pipes, as well as some of the drill pipes, are connected to each other by couplings with internal threads. The mechanical properties of couplings must comply with the standards of mechanical properties of pipes of similar strength groups [8, 15, 16].

Table 4. The influence of heat treatment on the properties of drill pipes

Heat treatment mode	Strength group according to GOST 631-75	Tensile tests				Fatigue tests, endurance limit, MPa	Curve Number in Figure 4
		σ_B, MPa.	σ_T, MPa.	δ	ψ		
Normalization 880-900 °C, air cooling	D	723	436	19.5	54.4	16.7	1
Normalization 880-900 °C, hardening in water 880-900 °C, vacation 660-680 °C	E	742	614	21.7	52.8	20.6	2
Normalization 880-900 °C, hardening in water 880-900 °C, vacation 660-620 °C	L	828	717	13.4	41.5	21.6	3
Sample type according to GOST 2860-65 UP (with notch)							

Heat treatment of couplings can be carried out in two different ways: 1) by hardening and tempering of coupling pipes; 2) hardening and tempering of individual coupling blanks. The second option is divided into two technological sub-options: a) hardening and tempering of coupling blanks, cut into measured lengths and their subsequent mechanical processing; b) hardening and tempering of coupling blanks, cut into cut lengths and undergoing preliminary rough boring (and turning), and their subsequent finishing mechanical processing.

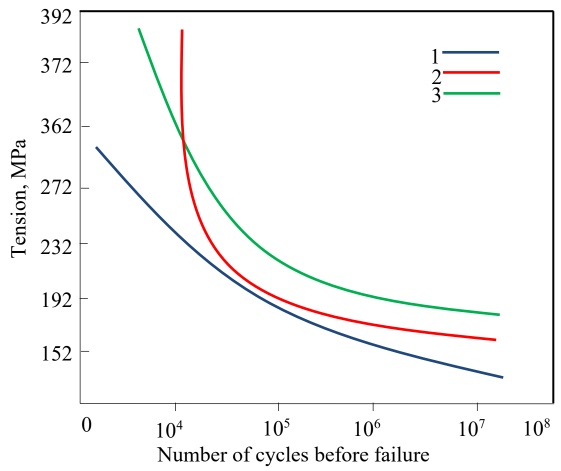

Figure 4. The influence of heat treatment conditions on endurance limit of drill pipe metal (designations of curves are deciphered in Table 3)

4. HEAT TREATMENT OF COUPLING PIPES

Heat treatment of coupling pipes is carried out on the same equipment as the treatment of drill pipes; steel of the same composition is used as for drill pipes (i.e. with a strength coefficient close to the upper limit) [11]. This technological direction leads to additional difficulties during machining. The second technological direction requires special thermal equipment, but it will remove a number of difficulties in machining. For large coupling sizes (diameter more than 166 mm), it is advisable to use the second direction, since the wall thickness of the couplings becomes significant, therefore, in the production of large-sized high-strength casing pipes, special coupling thermal departments are provided, as, for example, at the plant named after K. Liebknecht.

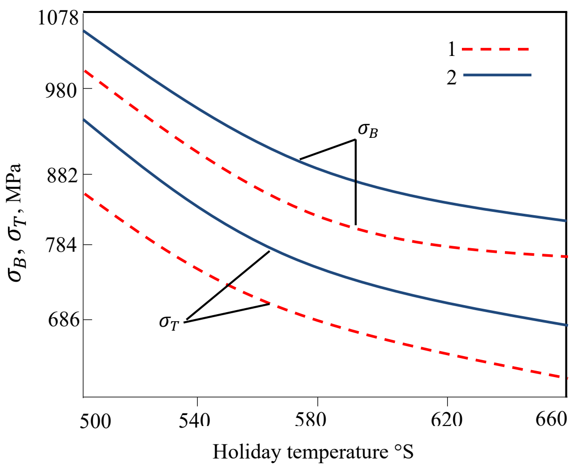

Figure 5. Dependence of strength characteristics of coupling metal on strength coefficient and tempering temperature, 1) $CC = 0.73$; 2) $CC = 0.64$

Bored rough coupling blanks are fed into a special container from which they are sequentially fed into the hardening furnace. From this moment, the coupling blanks are moved with a rotational-translational motion through all units of the line (during heating for hardening, hardening and tempering) [10]. According to G.P. Prozorova, Z.N. Kholyavko, M.M. Khanina (Figure 5) to obtain couplings (with a wall thickness of 24 mm) with mechanical properties of strength group M and higher, additional alloying of steel with carbide-forming elements is necessary (for example, the use of steel grade 25 G2CFB).

The discovery of new fuel deposits poses the task of not only increasing the static and cyclic strength of pipes, but also increasing cold resistance, resistance to brittle fracture in various aggressive environments accompanying oil and gas and, primarily, sulfide cracking (stress corrosion in a wet hydrogen sulfide environment). Resistance against [12, 13, 14] decreases with increasing yield strength and the appearance of non-martensitic products or untampered martensite in the steel structure. The maximum resistance to sulfide cracking is achieved by steels with a structure of spheroidized small carbides uniformly distributed in a ferritic matrix. Such a structure can be created if, after quenching, martensite is obtained and subsequent tempering and long-term exposure are applied. To ensure complete hardenability over the entire wall thickness, in most cases steels alloyed with chromium and molybdenum are used, which forces the use of long-term tempering (1 hour exposure) to obtain the required structure. Therefore, in the production of high-strength pipes that are resistant to sulfide cracking, attention is paid to the accuracy of heating for quenching and tempering, hydrolysis of scale from the surface of the pipe is used before quenching, and tempering furnaces with walking grooved beams are used, which ensure uniform heating and long exposure during tempering.

5. CONCLUSIONS

1. As a result of research, it has been established that the cause of premature failure of pipes used for drilling is the roughness of the structure.
2. In order to obtain a fine-grained structure, austenitic steels were used as the object of study.
3. The steels were subjected to a normalization operation to obtain a fine-grained austenitic structure. We carried out the normal normalization operation at a temperature 100-150 °C higher than the normalization temperature.
4. The proposed steel grades are subjected to self-tensioning operation in air along their entire length after rolling and good normalization.
5. As the next operation, the pipes were heated to 800-850 °C in a furnace with a moving floor and subjected to a normalization operation.
6. Pipes made of some steel brands are usually annealed at a temperature of 650 °C after normalization.
7. The normalization temperature was increased by 100-150 °C to obtain a fine-grained austenite structure.
8. It was found that the yield strength and plasticity properties of some pipe steels increase after the normalizing operation.

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