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# FEATURES OF OBTAINING SPECIAL OIL AND GAS DRILLING PIPES

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**Abstract-** There are special requirements for the production of drill pipes used in oil and gas production. In addition to alloying steel, these pipes must undergo special metallurgical processing. At the same time, it is noted that liquid steel should be processed in an inert gas (argon) environment, using a special vacuum device to clean it from gases. Only after these operations is the liquid steel fed to the crystallizer by means of an inter-furnace chute for continuous casting, and this process must be strictly controlled. Liquid steel must be thoroughly cleaned of harmful additives, it is recommended to apply special technical methods of action in the crystallizer, including magnetic mixing and vibration treatment device, to maximize the removal of non-metallic compounds and obtain a denser structure. 32Г2 (ГОСТ 632-80) steel was selected as high-strength steel and new heat treatment regimens were defined to obtain strength corresponding to strength class "L". The results of mechanical tests confirmed the possibility of obtaining special properties of 32Г2 pipe steel with strength class "L".

**Keywords:** Drill Pipes, Smelting, Continuous Casting, Strength Class, Metallurgical Processing, Heat Treatment.

## 1. INTRODUCTION

The areas of application for the production of molded billets by continuous casting are constantly expanding. Currently, one of the most topical issues in the production of ferrous metallurgy is the purchase of a wide variety of billets for seamless oil and gas pipes. The complexity of oil and gas production causes the permanent increase in the requirements for the properties of steel pipe products. These requirements are especially associated with the improvement of the technological properties and quality indicators of continuous casting billets used for the production of seamless pipes [1]. It was determined that in order to increase the resistance to the destruction of seamless oil and gas pipes by the brittle mechanism at low temperatures and to ensure high strength characteristics, high-quality continuous casting billets with minimal chemical and structural inhomogeneity should be developed [1, 2].

Currently, the main attention of researchers and specialists on increasing the quality indicators of continuous casting billets is focused on the optimization of the technological parameters of individual nodes of the casting machine and constructive modernization based on known laws and generalized production experience. However, cardinal structural changes to continuous casting facilities are extremely complex and is associated with huge costs. In this regard, one of the most optimal ways to increase the quality indicators of continuous casting billets is to improve the chemical composition of steels for the production of seamless oil and gas pipes [3].

Decrease of the amount of carbon in steels, introducing of microalloying elements that ensure grain refinement and strengthening in the structure, beside other methods of impact, are effective measures to achieve the required quality indicators of continuous casting billets. It was determined that decrease of the amount of carbon in steel allows for reducing chemical and structural heterogeneity, and along with microalloying additives, increases the viscoelastic characteristics of pipe steel. Another important and insufficiently studied issue is the effect of the chemical composition of steel on the quality indicators of billets, especially the formation of hot cracks due to the insufficient hot plasticity of billets [4].

Thus, one of the main requirements for the production of special drilling pipes is to ensure the high quality of the billets used in pipe rolling in the melting process. In this regard, it is important to carry out the melting process based on innovative approaches, so that steel production is carried out in accordance with the standard requirements set by brands. Billets for pipes used in oil and gas production are mainly manufactured from 37Г2 steel (from 130 mm diameter billet - pipe with a final size of 114 mm) according to their purpose [5].

## 2. CURRENT SITUATION OF THE MANUFACTURING OF PIPE BILLETS

A mathematical model of three-phase, two-pole permanent-magnet synchronous motors should be developed. Three-phase, two-pole permanent-magnet synchronous motor is illustrated in Figure 1.

**2.1. Chemical Composition of Alloys**

After metallurgical processing in the furnace and the ladle furnace, the liquid steel for pipe billets produced at "Baku Steel Company" LLC is processed in an inert gas environment in the vacuum degasser for deeper purification from gases. In order to ensure high quality, the desulfurization process of the metal must be fully completed and the treatment process in the ladle furnace must be strictly controlled.

During the pouring of liquid steel in the continuous casting machine, strict measures must be taken in the relation to the temperature regime, the isolation of the distance between the main ladle and the intermediate ladle from the external environment, and the prevention of the ingress of the slag mixture into the metal flowing from the intermediate ladle to the crystallizer. In the 1st and 2nd cooling systems, the full completion of the crystallization should be strictly controlled based on the movement of the billet, as well as the adjustment of the casting speed. During casting, it should be ensured that the beginning and end of the billets are approximately the same as the casting path according to the steel grade.

Factors that cause uneven heating of metal in a thermal furnace (productivity, heating regime, heating period, energy spent on heating the furnace, metal burning percentage) must be constantly monitored during the production of 32Г2 steel pipe made of billet with a diameter of 130 mm. The rolling temperature of the pipe billets coming out of the thermal furnace should be monitored with a pyrometer. During rolling of pipe in the rolling-mill equipment, the head of the punching machine (jamming, failure, damage of the punching machine) should be monitored in time.

After rolling the pipe, a sample should be cut from billets and structural analysis should be carried out. The analysis of the cut samples and the samples taken from the tested pipes showed that in some cases a crack appears along the length of the pipe. The reason for the appearance of the crack along the length of the pipe is the violation of the regimes during the thermal treatment of the pipe. If the correct thermal treatment of pipe steels is high-temperature normalization, after normalization in production, the re-quenching and then tempering process is carried out. For this reason, retained austenite was formed in the structure, which subsequently led to the formation of internal cracks. The fact that the fracture along the length of the pipe is white also confirms this hypothesis, i.e., the thermal treatment was unsatisfactory.

According to the thermal treatment technology for the pipe billets adopted at the plant, first of all normalization and at the last stage the quenching and tempering and straightening are carried out. In our opinion, such thermal treatment regimens lead to structure heterogeneity with the formation of retained austenite. During the testing of the produced pipes under high pressure, the pipes did not sustain the pressure and burst from the weak part. As a result of the analysis, it was determined that the burst in that part occurred during the test at a pressure of 550 MPa due to the ingress of the slag mixture into the liquid metal. In the structural analysis, the microstructure of the sample was studied by magnifying that part x1000 times, and it was determined that the mentioned slag mixture was clearly visible in the structure [6-8].

The above-mentioned measures should be taken in order to prevent the occurring of the mentioned defects. In order to eliminate these defects, it is necessary to strictly control the purchase of billets of good quality during casting and rolling. Each batch and grade steels used in pipe rolling should be studied, a detailed technological map of the billet and pipe production should be prepared and efficient thermal treatment regimens should be developed. At "Baku Steel Company" LLC, 21 experimental melting of 32Г2 manganese steel was carried out in 60-ton electric-arc furnace. Table 1 shows the chemical composition of these experimental alloys is given in Table 1.

**2.2. Preparation of Billets from Experimental Alloys**

In order to study the effect of the alloy's chemical composition on the quality of billets, in 16.04-20.05 2020 at the "Azerboru" production area 32G2 steel billets were rolled and thermally treated. The analysis showed that the chemical composition of the experimental alloys is characterized by being very close to each other. At the same time, the dimensions of the pipe billets obtained in the continuous casting machine were also very close to each other. In order to bring the strength of the pipes to "L" class after rolling, their thermal treatment (rolling and tempering) is performed in the following regimes.

In order to ensure the "L" strength class of 32Г2 steel in accordance with GOST 632-80 standard, the thermal treatment of pipes after rolling is provided. For this purpose, pipes made of 32Г2 steel and having 114×7.4 mm size were thermally treated. The rolling and tempering of pipes were carried out in the "Azerboru" production area on appropriate equipment with the participation of the authors and the specialists of "Baku Steel Company" LLC.

The stability of the regime parameters before and after thermal treatment of pipes made of 32Г2 steel was assessed. In thermal treatment furnaces, the temperature was controlled only by ceiling thermocouples during the rolling and tempering processes, and floor thermocouples were not provided in the furnaces. Since the temperature of the ceiling space in the furnace does not meet the technological requirements, the temperature of the pipes at the outlet of the furnace was monitored with stationary pyrometers [9, 10].

**2.3. Mechanical Tests of Billets**

Quenching of pipes was carried out in sectional furnaces. Pipe quenching temperature was 840-870 °C, heating time was 4.0-4.5 minutes. The rotation speed of the furnace rollers was 17 Hz. The ceiling temperature of the furnace was recorded by zones and in the thermal treatment log. Pipes with a wall thickness of 7.4 mm were rolled using external sprinklers. The length of the sprinkler is 1.7 mm, the sprinkler nozzles are tangential along the pipe. The water pressure in the sprinkler was not controlled. The temperature of the pipes at the outlet of the rolling furnace was measured by stationary pyrometers and recorded in the diagrams.

Table 1. Chemical composition of alloys

| Seq. No. | Alloy No. | C | Mn | Si | P/S | Cr/Ni | Cu | Ti | W/V | Mo/Nb | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 99846 | 0.31 | 1.26 | 0.25 | 0.019/0.019 | 0.13/0.14 | 0.20 | 0.002 | 0.002/0.003 | 0.002/0.002 | |
| 2 | 99847 | 0.32 | 1.26 | 0.28 | 0.019/0.009 | 0.12/0.14 | 0.21 | 0.002 | 0.002/0.004 | 0.002/0.002 | Residual |
| 3 | 100123 | 0.32 | 1.22 | 0.30 | 0.017/0.012 | 0.08/0.10 | 0.18 | 0.003 | 0.002/0.004 | 0.001/0.002 | Residual |
| 4 | 100124 | 0.35 | 1.25 | 0.27 | 0.018/0.013 | 0.07/0.11 | 0.22 | 0.002 | 0.002/0.003 | 0.001/0.002 | Residual |
| 5 | 100126 | 0.32 | 1.31 | 0.27 | 0.018/0.012 | 0.06/0.10 | 0.24 | 0.003 | 0.002/0.004 | 0.001/0.002 | Residual |
| 6 | 100129 | 0.31 | 1.36 | 0.33 | 0.022/0.009 | 0.16/0.11 | 0.30 | 0.002 | 0.002/0.005 | 0.001/0.002 | Residual |
| 7 | 100131 | 0.30 | 1.26 | 0.27 | 0.019/0.010 | 0.08/0.09 | 0.25 | 0.002 | 0.002/0.005 | 0.001/0.003 | Residual |
| 8 | 100132 | 0.31 | 1.31 | 0.23 | 0.020/0.011 | 0.08/0.09 | 0.26 | 0.002 | 0.002/0.004 | 0.001/0.002 | Residual |
| 9 | 100133 | 0.31 | 1.25 | 0.23 | 0.019/0.015 | 0.15/0.14 | 0.23 | 0.002 | 0.002/0.004 | 0.001/0.002 | Residual |
| 10 | 100134 | 0.31 | 1.36 | 0.27 | 0.024/0.014 | 0.22/0.16 | 0.26 | 0.002 | 0.002/0.005 | 0.002/0.002 | Residual |
| 11 | 100135 | 0.32 | 1.35 | 0.32 | 0.023/0.015 | 0.22/0.17 | 0.23 | 0.002 | 0.002/0.005 | 0.001/0.002 | Residual |
| 12 | 100137 | 0.30 | 1.22 | 0.25 | 0.020/0.015 | 0.28/0.14 | 0.25 | 0.001 | 0.002/0.004 | 0.002/0.002 | Residual |
| 13 | 100138 | 0.31 | 1.26 | 0.28 | 0.019/0.013 | 0.15/0.10 | 0.22 | 0.002 | 0.002/0.004 | 0.002/0.002 | Residual |
| 14 | 100139 | 0.32 | 1.34 | 0.23 | 0.019/0.014 | 0.13/0.11 | 0.20 | 0.002 | 0.002/0.005 | 0.001/0.003 | Residual |
| 15 | 100142 | 0.30 | 1.28 | 0.27 | 0.023/0.013 | 0.22/0.14 | 0.28 | 0.001 | 0.007/0.006 | 0.001/0.002 | Residual |
| 16 | 100144 | 0.31 | 1.30 | 0.31 | 0.020/0.012 | 0.10/0.10 | 0.25 | 0.003 | 0.002/0.005 | 0.001/0.003 | Residual |
| 17 | 100147 | 0.30 | 1.19 | 0.27 | 0.020/0.012 | 0.15/0.20 | 0.24 | 0.002 | 0.002/0.005 | 0.001/0.003 | Residual |
| 18 | 100149 | 0.31 | 1.27 | 0.31 | 0.023/0.018 | 0.18/0.15 | 0.21 | 0.003 | 0.002/0.004 | 0.001/0.002 | Residual |
| 19 | 100152 | 0.34 | 1.29 | 0.31 | 0.021/0.014 | 0.15/0.13 | 0.24 | 0.002 | 0.002/0.001 | 0.002/0.002 | Residual |
| 20 | 100153 | 0.30 | 1.32 | 0.27 | 0.022/0.017 | 0.20/0.11 | 0.23 | 0.002 | 0.002/0.001 | 0.002/0.002 | Residual |
| 21 | 100154 | 0.31 | 1.29 | 0.24 | 0.025/0.020 | 0.15/0.12 | 0.22 | 0.002 | 0.002/0.004 | 0.001/0.001 | Residual |

The actual rolling temperature in the furnace varied between 840-860 °C and the tempering of the pipes was carried out at a temperature of 650-680 °C. The temperature of the pipes at the outlet of the furnace is also measured with a pyrometer and is recorded in the diagram. The actual tempering temperature varies between 660-680 °C. For 114×7.4 mm pipes, the period of tempering was 3.0-3.5 minutes. Since there is no roller table speed control in the tempering furnace, the pipes have not been tested for cold and corrosion resistance.

The analysis of the data given in Table 2 showed that it is possible to get positive results by strictly following the thermal treatment (rolling + tempering) regimes of pipes after rolling [11-15]. Pipes with alloy numbers 99847-1, 100131-7, 100132-6, 100138-8, 100149-12, 100147-26, 100153-32, 100126-41 according to GOST 632-80 standard at a pressure of 690 MPa after mechanical tests and fixing of coupling are subjected to hydrostatic tests. In accordance with the contract requirements, the pipes made of each alloy were ultrasonically tested, delivered according to the "L" strength class according to the GOST 632-80 standard and sent to the consumer's address [16-19].

### 2.4. The Structure of Billets after Thermal Treatment

The microstructure of thermally treated 32Г2 steel pipes is presented in the figure. As can be seen, the microstructure of the steel is homogeneous even at high magnifications and consists mainly of troostite and in some areas troostite and sorbite structure. However, during rolling, in some pipes made of 32Г2 steel the occurrence of various shaped cracks and other defects were observed. Additional study and measures have been implemented to eliminate such defects.

After conducting laboratory studies and consultations with pipe-rolling experts, certain considerations have been put forward. The conclusion about the quality of pipe steel is that the results of the conducted laboratory studies do not raise doubts. The microstructure of the primary steel samples considered is quite heterogeneous, and this is due to the violations that occurred in the electro steel production technology. For melting the electrical steel, the composition of the furnace burden, especially the amount of cast iron scraps and iron balls in the furnace burden, is also important.

It is known that when the steel scraps are contaminated, a large amount of slag is formed, which should be removed regularly and the time of careful mixing of the steel should be increased. If no cast iron was added to the furnace burden, then the boiling of the liquid steel was insufficient, which prevented the leakage of carbon batch and didn't allow the steel to boil properly.

(a)

(b)

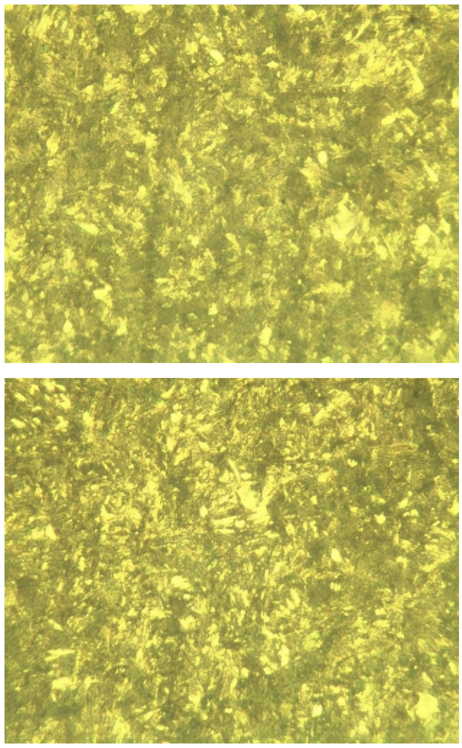

Figure 1. Microstructure of 32Г2 steel after thermal treatment, x1000: (a) troostite, (b) troostite+sorbitol

## 3. RECOMMENDATIONS FOR CONTINUOUS CASTING PRODUCTION OF BILLETS

Based on the conducted experimental studies, a number of effective recommendations for the production of pipe billets by continuous casting method have been put forward:

1. It is necessary to correctly calculate the composition of burden in steel, to sort clean steel and cast-iron scraps. In order to ensure good boiling and mixing of steel in the electric arc furnace (EAF), it is necessary to increase the proportion of cast iron in the burden.
2. It is necessary to carry out steel deep processing in the ladle furnace, to pay special attention to Al and other components in the steel. The serious negative effect of silicates and aluminosilicates on the quality of steel should be taken into account. Late application of deoxidizers is unacceptable, the time of processing of liquid metal with them should be sufficient.
3. The first and last billets should not be used in the production of pipes, because they have big shrink holes. Observations show that in some cases the last billet was also used in serial pipe production. A significant liquidation of the chemical compositions of the first and last billets from the central parts is observed. The structure of non-metallic elements should be studied, since they are found in the latter billets more often. These elements consist of traces of various additives and residues of slag, and are caused by the plugging of the intermediate ladle, as well as the fall of the badly coated cover of the ladle itself in the stream.
4. Special attention should be paid to the pouring speed and cooling mode of the liquid metal. Our observations have shown that the considered billets were poured at a high speed, and in this case, the non-metallic elements could not float up in the liquid part of the stream in the crystallized billet, and this led to their entry into the billet.
5. In the external view of the billet, first of all, it is necessary to pay attention to the traces of the table swinging and the undulation of the billet. At large undulations, the rolling defects in the form of scabs can lead to further collapse of the pipe during the tests. It is necessary to pay special attention to the presence of cracks on the surface of the billet. At a high casting speed and intensive cooling of the billet, a network of cracks appears on the surface, they are hidden under scale (burning) and are not always visible with ordinary eyes. It is also necessary to study the integrity of the central part of the billet and the chemical composition on the cross-section of the billet.
6. Revision of pour and cooling speeds is recommended. So, in accordance with the technological instructions, it is necessary to enter the additives in Traub machine. It is necessary to etch the templates cut from the initial billet and control the structure. Attention should be paid to the quality of the outer surface of the billet, its undulation and the presence of cracks. The integrity of the central part of the billet and its compliance with the technical conditions should be monitored.
7. Conclusions based on the results of laboratory studies: a large number of non-metallic elements in steel is indicative of excessive impurity of the used burden material. Therefore, there is no doubt that the rolling process is basically correct, because this process never affects the distribution of non-metallic elements in the billet. The negative factors that appear during the testing of the operational properties of the rolling product are related to the heterogeneous structure of electric steel, internal and external defects caused by disturbances in the melting and casting processes, deviations from the nominal in the geometric dimensions of the product, troubles that occur in thermal treatment.

Of course, other disturbances are also possible in complex technological processes such as melting and rolling. However, based on the presented studies, it can be said that one can start with the improvement of the quality of the primary metal and only then to share ideas about the rolling process. To confirm the above-mentioned and to study the effect of the rolling process, a small amount of pipe billets can be purchased from other metallurgical plants and compared. In order to improve the quality of the metal of the billet, the installation of the vacuum degasser should be accelerated. In order to carry out deeper studies, in the next stages the macrostructure of the cross-cut templates from the billets treated before rolling, and the internal structure of the billet after etching should be analyzed. Attention should be paid to the integrity of the central zone of the template cut from the billet and 150-200 mm long templates should be prepared for the analysis of the central part of the billet.

## 4. CONCLUSIONS

Thus, in accordance with the requirements of the GOST 632-80 standard, the thermal treatment regimens of 114×7.4 mm hot-deformed seamless pipes produced of 32G2 steel, made it possible to obtain strength class "L" at the "Azerboru" production site. The necessity to apply innovative metallurgical processing methods and efficient thermal treatment regimens of liquid steel in out-of-furnace processing and casting processes was justified.

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Scientific Publications: 37 Papers, 2 Books, 4 Textbook, 1 Patents, 29 Theses