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STRENGTHENING AND RECONSTRUCTION OF DRILLING CORE PIPE FOR ENGINEERING AND GEOLOGICAL EXPLORATION

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Abstract. Currently, there is a tendency to increase the depth of gaseous and liquid fossils extraction. Therefore, prospecting and developing new deposits is promising. There is also a need to create new freshwater sources and implement relevant geological work based on this need. It is essential to have information about the characteristics of the explored slabs and the geology of the fields in general. Implementation of engineering and geological core drilling exploration is the most acceptable and provides the necessary data. Here, the peculiarities of the technological schemes of the process implementation make it possible to obtain separate sections of structures at a depth of the drilling equipment. It is essential to use traditional equipment, recommended for decades and provides the necessary results [1–3]. In the drilling process, you can achieve different diameters and depths of wells execution, obtain fossil samples etc. Engineering and geological exploration drilling is now taking on increased use in various industries [3]. Therefore, the problem of providing high-quality drilling tools, the stability of their operating characteristics, and the possibility of usage in different conditions is an urgent need today.

Modern drilling problems determine the usage of components of the core set with the appropriate physical and mechanical characteristics. Especially it relates to elements close to the drilling tool and the place of fossil; destruction – drill pipe. It is installed immediately after the crown core drill and receives almost the same loads and effects during working [1–3].

Conditions for the implementation of the process of core drilling are characterized primarily by the effect on the elements of the significant axial and twisted core set forces. There is the influence of the corrosive and active environment of the fossil in the washing and lubricating liquids well, etc. High temperatures are also observed at the drilling sites [3], which negatively affect the working tool and speed up its operation.

As a result, there is an intensive shock, and abrasive core pipe wear and operation indicators change their constructive size. As a result, it is necessary to replace the operated drill string periodically. Considering modern technical and economic factors, it may be decided to repair a pipe to its original size in many cases. There are tasks for providing the appropriate characteristics of the core pipe surface. It is possible to model such properties of the new surface that functionally the best meet the conditions of the drilling process of a given geological formation.

The peculiarities of applying the therapeutic layer on the surface of the core pipe are investigated in work. The experience shows that using electric arc surfacing under the flux layer is expedient. This provides the necessary adhesion of the applied layer and promotes obtaining resistance to the operation surface of the core pipe. At the same time, there is high-quality protection and the possibility of additional alloying through the flux-slaggy welding bath.

Using electrode powder type wires creates conditions for flexibility to achieve the established characteristics of functional layers [4–6]. The filling flux, located in the cross-section of the electrode wire, can be easily changed by chemical composition. At the same time, it is possible to make relatively small parties of a wire with the set characteristics.

The technological scheme justification about the core pipe surfacing is performed. It provides the previous displacement of the electrode butt size from the zenith of the core pipe to prevent the welding bath from spreading. The structural pipe size , the requirements for residual deformations, and the conditions of shapping the welded layer show the practicality of welding on a helix.

Keywords: core pipe, geological and engineering prospecting, electric arc surfacing, running welding energy, electrode flux-cored wires, wear-resistant coatings, thermal impact zone, heating for surfacing, hardening structures, welding bath

Introduction and Problem Statement

The core drilling process is the most acceptable from the point of view of underground deposit engineering and geological study. Here is provided getting relevant information on the whole soil cut and its structure during passing into the depth of drilling equipment. A feature of the core set, which is the primary mechanism located directly in the well, is the implementation of the connected working elements. They include the crown core drill bit and the core pipe. They perceive significant axial static and shock loads during drilling [1–3]. There is also shock-abrasive tool wear. Elevated high temperatures are working, and a corrosive environment attends the process. As a result, periodically replacing the drilling set, including the core pipe, is necessary. Therefore, there is a need to consider technical and economic factors and opportunities to create appropriate functional coatings and increase service life. It is advisable to decide on the previous coating implementation on new core pipes and the restoration of existing ones to the original size after the long-term operation. Based on the analysis results, the following standard size of the core pipe was selected: diameter 127 mm, wall thickness 5.0 mm, length 1.5 m [2]. It makes it possible to unify the maximal linear size by screwing the pipes and reducing the influence of the thermal cycle during the welding work, and applying the technological process projection with the data usage about the formation of the welding bath, possible structural and phase changes of the surrounding areas, the possibility of auto-heating during surfacing. It is proposed to reduce special conditions of shock-abrasive wear at the expense of the corresponding covering with the set operational characteristics. The established running energy of surfacing by flux-cored cylindrical surface wires of the core pipe with the corresponding overlapped rollers is substantiated.

The research object is the core pipe outside the surface for engineering and geological drilling. The subject of the research is creating a wear-resistant core pipe surface and ensuring its structural dimensions in case of reusage.

In work is sustained the practice of creating particular functionally dependent on the coatings operating conditions on the surface of core pipes. It ensures their strengthening, improving technical characteristics during wearing, and restoring structural dimensions. The defined surfacing technology provides additional heating from the previous rollers and increases the process's energy efficiency conditions. As you can see, the significant increase in temperatures is provided by three to five rollers close to the surfacing zone. A study about the welding bath position during surfacing on a cylindrical surface was conducted. Substantiation and setting surfacing mode parameters of the core pipe under the flux layer were performed. The resistant zone of thermal influence analyses the running energy influence during surfacing on obtaining a crack. The necessary surfacing materials were chosen by taking into account the operating conditions of the core pipe. Here, it shows that it is advisable to use flux-cored wire in combination with welding flux according to technical and economic indicators.

Purpose and Objectives of the Study

The research aims to establish the possibilities of creating functional set core pipe coatings for engineering and geological exploration. Ways to restore existing column pipes for reusage.

A range of assignments was solved to achieve this goal:

– formation conditions of a thermal zone influence and admissible running energies during core pipes surfacing were investigated;

– were explored the temperature conditions of core pipe surfacing during the process along the helix;

– were selected the necessary electrode materials and the surfacing process conditions were determined.

Review of Modern Information Sources on the Subject of the Paper

Studying the specifics of the exploratory drilling shows that it is essential to use a high-quality core pipe with the fossil and destroying element in this case. It is installed immediately after the fossil-destroying tool, ensures the pipe's fastening, and transmits drilling forces to it [1–3]. The core pipe is subjected to equal force and abrasive effects: friction on the well outer fossils, twisting and axial pressure on the drilling tool, abrasive wear from the good walls, significant temperature loads during deep drilling, destruction of existent environments in the well which are duetted to geological effects in combination with cleaning agents [1]. The drill pipe wear is quite intensive and needs periodic repairs. Similar structural elements evaluation[4, 5] shows that you can use the processes of restoring geometric dimensions and physical and mechanical properties in this case. There is a practice of creating specific functional coatings on new products to ensure the technical surface characteristics [6, 7]. Here is essential not only operating conditions of the detail but also the environment [7, 8]. An important thing is achieving optimal technical and economic characteristics of the coating process, provided by the usage of appropriate technological parameters: core-fluxed electrode wires, specific filling fluxes [9], and external influences on the welding roller formation [10], post-welding machining[11]etc. We must single out the issue of the appropriate glorification and the thermal impact zone of the primary material structure. It is indicated works[12–14] the danger of obtaining hardening structures and the structure heterogeneity due to the excellent chemical composition with the primary metal. It is necessary to use various technological measures such as heating parts before surfacing and appropriate surfacing techniques to avoid residual deformation and reduce welding stresses, reduce the depth of the pipe worn wall penetration etc. [15–17].

Therefore, the issue of restoring the geometry and properties of drilling rigs for geological and exploratory drilling after the long operation and creating special coatings on work surfaces before introducing new drilling rings is an essential and urgent task. It allows for increasing the existing service life and new drilling equipment. At the same time, it is possible to adjust the characteristics of the working surfaces taking into account the geology of wells and the predicted characteristics of the formations.

Main Material Presentation

During the investigation, the core pipes made of steel belong to low-carbon, low-alloy structural materials, according to their strength indicators, which are agreed to be the material of core pipes, such steel applied to the strength category D, operation group B [2, 3]. Based on the comparative analysis of the established strength indicators and applied chemical composition, steel of 18G2AFps grade was used further in the work. The computations that were carried out in work showed that the values of the equivalent carbon content [18] and the applied alloying systems [12, 18], make it difficult to provide high-quality welded connections during surfacing. There is a tendency of materials to form hardening structures during surfacing and a high probability of spawning cold cracks. It is primarily related to thermal impact, where it is difficult to ensure the effective effect on crack resistance only by using different electrode wires [14, 19]. We can well regulate the latest properties of the weld metal. Still, the diffusion processes of the elements are not so active that they also enable to affect the main metal properties [13–15]. In this case of core pipe surfacing, the thermal cycle will affect the structural-phase composition formation of the central metal thermal influence zone. It determines a range of negative factors, including the transience of geyser arc surfacing processes, the existence of a significant temperature gradient (from maximal metal fusion to the surrounding workshop conditions) in a limited volume, the presence of cold pipe sections that hurt the temperature range of material, the fragility of availability temperature and residual stresses in the surfacing process, etc. [13–15]. The most critical factor that impacts the structural-phase composition formation of the material in the zone of welded core pipe thermal influence is at the same time a cooling speed. Therefore, it is advisable to research the studied peculiarities of ensuring the favourable formation and crack-resistant structure in the thermal impact zone.

It is established that the optimal cooling speed interval is from 0.1 to 12 deg/sec for the explored steel and core pipe wall thickness. The surfacing process conditions and possible changes in thickness according to wear were also taken into account. For a given interval of cooling speeds, it was determined that the Brinell scare (BR) hardness can vary from 1900 to 2750 MPa. The permissible martensite content in the metal in the thermal zone is up to 30 % [12, 19]. Under such conditions, the core pipe material's required crack resistance is maintained after cooling the welded connection. In case of non-compliance, the optimal speed necessary range must be taken special measures.

The allowable linear energy of the core pipe surfacing was established. In particular, it is possible to allocate some area of linear surfacing energies for the used standard size of pipes and primary material. It is limited to the limits of the optimal range of cooling speeds. In this case, it is recommended to comply with surfacing for the value of linear energies from 6.280 kJ/cm to 58,615 kJ/cm. It shows that the ferrite content can reduce from 55 % to 3.1 % in the recommended range of cooling speeds, the perlite-bainite structure content varies around 73 %, and the martensite content can increase to 23.5 %. The strength characteristics of studied steel at a growing cooling rate increase while reducing the ductility properties. Therefore, to ensure the formation of a high-quality welded junction, it is advisable to take extraordinary measures to increase the crack resistance of the joint. The most effective are pre-heating the welded core pipe or the appropriate techniques to restore the worn surface.

The carried out analysis of possible ways to restore the worn surface of the core pipe, its constructive dimensions and performance requirements characteristics show the following. It is advisable to use electric arc surfacing under the flux layer with flux-cored wire along the helix. The reasons for this choice are detailed below.

It is known [8, 18] that surfacing under the flux layer provides reasonable protection of the welding zone, smooth transition to the primary metal and minimal roller surface scaling. The typical for this method is stream concentration and, accordingly, increases in penetration depth are reduced due to the usage of flux-cored wires. The technological feature of such surfacing materials provides a reduction in the depth of the main metal penetration and a sufficiently significant surfacing coefficient. The paper proposes to apply the process of surfacing on the direct current of reverse polarity.

The usage of flux-cored wire expands the possibilities of creating an appropriate alloying system. It considers the specific operating conditions and wear of the core pipe of the well [1 - 3]. In work were used wires of PD 80X20P3T brand with Fe-Cr-B-C alloying system, which was examined in detail in the research [8–10]. These flux-cored wires consider the possibility of operation in shock-abrasive wear. The presented alloying system provides additional bromine alloying in the deposited layer and increases wear resistance. The usage of this wire was evaluated in works [8, 9] by special methods using unfixed and fixed abrasives. As an abrasive was used dried quartz sand which is constantly applied to the study area. As a result, it was found that such a wire has advantages over analogues in longer service life under difficult conditions of impact and abrasive wear. The cost of such a wire is significantly lower.

Using flux-cored wire PD 80H20R3T, you can get the coefficient of the seam shape in the range from 3.5 to 6.87 as shown in Fig. 1 [8].

Fig. 1. Sections of welded rollers with flux-cored wire PD 80X20P3T under the flux layer at different linear welding energies [8]

The process of surfacing with PD 80X20P3T wire was realized under the flux layer of the OSC-45 brand. In work [4] it was shown that the obtained deposited samples contain ferrochrome (FeCr) phases and boride structures of two types $(FeCr)_2B$ and (FeCr)B. These phases provide good resistance of the deposited metal on the surface of the core pipe to wear during drilling.

The cylindrical structure of the core pipe leads to the formation of uneven nature of the distribution and temperature and residual magnitude stresses due to the surfacing process. Therefore, depending on the sequence of the renewable layer formation on the core pipe surface, it is possible to implement schemes for moving the arc along the generator parallel to the axis of the pipe or in the annular direction. There are also varieties of these schemes, which consist of more complex movements of the electrode end. However, due to asymmetric heating along the generatrix, there is a risk of the structure angle residual deformation in the case of the core pipe. Such a technique is used more for stiff, rigid elements with increased thickness or diameter and thickness. A variation of this method is the implementation of particular surfacing areas. Here, the individual layers are spread over the surfacing squares along the generatrix and in a circular direction. It ensures the levelling temperature in the transverse cut and promotes mutual compensation of residual deformations. However, the process demands a more complicated implementation technique. Also, the comparatively small diameter of the core pipe determines regular control over the displacement step and the possibility of fusil metal spreading. The joints of separate regions require the applied layers to overlap, leading to the volume increase of turning operations.

While restoring in the circular direction, it is possible to carry out seams with a transverse electrode displacement on a preset step or provide a movement around the helix. The first option is characterized by the stable formation of the weld surface with the controlled overlap. However, the disadvantage of this option is the overheating in the transverse displacement area of the electrode butt. As a result, are possible worn surface burning, insufficient formation of the roller and the local deformations appearance.

Roller formation around the helix is more complicated. It requires the harmonization of two simultaneously movements: onward and circular. However, the continuity and welded roller adjustable duration ensure receiving a needed homogeneous surface. The set properties of surfacing are reached at observance of the established routine parameters and overlapping of separate passes. The surfacing process should ensure deformations reduction and more renewable homogeneous core pipe heating from the central cut to the borders

Therefore, the conducted analysis shows that surface restoring is more appropriate in the case of the worn core pipe to use the surfacing technique on a helix from the central cut to the borders. However, to reduce the probability of deformation, combining the two previous options is advisable. So that to divide the surface of the pipe into separate renewable sections. Then we have to weld alternately different areas along the helix. As a result, the influence of the welding cycle on the formation of deformations will be reduced. It makes it possible to consider the peculiarities of the structure geometry, particularly the tiny diameter of the core pipe and its residual thickness.

It is known [16, 18, 20] that during cylindrical elements, the surfacing can be divided into three main borders positions of the electrode relative to the upper generatrix: at the generatrix; the offset against the direction of rotation; offset in the direction of rotation. Their position is determined by the diameter of the element, the parameters of the regime and affects the heated roller characteristics. In particular, the first two positions are possible conditions when the fusil metal of the welding bath intensively floats under the butt of the electrode. Then the heat transfer to the primary metal, and the melting ability of the arc decrease. The welded seam's penetration depth and width increase are typical for the welded seam cut. However, if the gravitational forces exceed the surface tension, excessive molten metal leakage under the arc will lead to non-fusion with the parent metal. The third option of the electrode displacement in the direction of pipe rotation stipulates the metal. As a result, the primary metal will be partially naked, and the arc pillar will directly contact the substrate. Such conditions lead to the depth increasing of penetration. In the case of core pipe restoration, such technology can lead to central metal burning because the residual thickness of the pipe is relatively small.

In this case, we accept the option of surfacing, when the butt displacement of the electrode from the zenith of the core pipe proceeds against the direction of its rotation. This provides a stable formation of a wide roller at a relatively small penetration depth. The surfacing bath length calculation was held to evaluate the peculiarities of the cylindrical surface surfacing of the core pipe. It is established that the magnitude of displacement, in this case, should be no more than 15 mm. It will secure the process of surfacing the drill core pipe from unforeseen slag-metal bath spreading.

The simulation of temperature conditions was performed separately by an electric arc surfacing of the drill core pipe surface along the helix [16, 20]. Here the main geometric dimensions (diameter and wall thickness) of the membrane have a significant impact on the calculation scheme choice: a) large diameters - similar to the infinite flat slab; b) small diameters – the imposition of heat frows from adjacent weld seam; c) significant thicknesses of remembrance- the need for two-layer welding. In this case, in the restoration of core drill pipes, there is an overlap of heat flows, and therefore there is a must to sum on the principle of superposition. To simplify the calculations, the scheme of a fast-moving linear heat source was adopted.

The obtained results showed that the temperature decreased significantly during the studied point moving away from the place of surfacing. For the investigated standard size of drill core pipes, at a distance of 40 mm relative to the surfacing arc, the temperature of the primary metal is about 100 °C. Therefore, the most significant contribution of the temperature increase to the primary metal occurs for three up to five welded rollers. Thus, while researching the temperature conditions of surfacing on the helix, it is advisable to consider the contribution of only heat from these approximate seams. Changing the amount of pipe wear within acceptable limits does not significantly impact the obtained results of temperature. The obtained results point to creating conditions for additional renewable core pipe heating. This specialized technique ensures the energy efficiency of the process and improves the characteristics of the thermal impact zone. Theoretical research shows that introducing two-layer surfacing would provide an even higher heating temperature. At the same time, it is necessary to apply the technique in the case when the second layer is performed in reverse to the first direction to provide the equability of construction heating in general.

After surfacing, it is necessary to check the restored core pipe for compliance with the requirements of the technical conditions. Visual and optical control of the surface is also realized to detect uneven filling and overlapping of the rollers, ensuring the established requirements for welds.

Conclusions

The peculiarities of core pipe restoration for engineering and geological drilling have been explored. It shows that the usage of arc surfacing makes it possible to create a functionally dependent layer that considers operating conditions: dynamic and static loads, abrasive-shock wear, the action of a corrosive-active environment and so on.

The formation of the thermal zone, which is low-carbon and low-alloy steel, which is typical for the considered class of core pipes, is observed. As we saw, it is necessary to ensure the cooling rate after welding ranges from 0.1 deg/sec to 12 deg/sec. The admissible running energy of surfacing is established by results of researching special nomograms and features of constructive pipe performing. The peculiarities of the structural-phase composition of the material depending on the cooling rate during the surfacing of the core pipe had been observed.

The research on the temperature formation conditions of a welded joint while surfacing a pipe along a helix has shown that the following 3–5 rollers provide a noticeable increase in temperature to the surfacing zone. The size of the welding bath during surfacing was calculated.

The usage of surfacing along helix under the flux layer with flux-cored wires is justified. Necessary materials are selected: wire PD 80X20R3T in combination with flux OSC-45. The parameters of the surfacing mode were set, and the running energy was checked to obtain a crack-resistant zone of thermal influence.

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