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THE ROLE OF PARAMETERS CONTROLLING SERVICE LIFE OF DOWNHOLE DRILLING MOTORS POWER SECTION

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Abstract

Downhole motors are considered as principal parts of drilling machinery. Rotor and stator are two main parts of these motors. The rotor usually made of stainless steel 17-4PH is housed in a polymeric case (stator). Rotor drives forward the drilling fluid guiding it to drill heads. Since rotor works under severe conditions of temperature, pressure and corrosive environment of drilling fluid, its abrasion resistant coating becomes subject of various destruction mechanisms. The role of various factors in destruction of rotor coating, in the form of statistical information recorded from different drilling holes is analyzed in this research. Different parameters controlling service life of rotor such as type of drilling fluid, bottom hole temperature, amount of solid particles in the fluid and drilling mud weight have been statistically analyzed. Experimental results showed that the existence of corrosive ions such as chloride and hard solid particles in drilling fluid affect the destruction not only hard chromium coating, but also damage rotor.

Key words: Downhole motors; Rotors; Drilling fluid; Avulsion; Statistical information

Introduction

The two basic parts of drilling downhole motors are: rotor and stator. Hydraulic energy of high pressure drilling fluid converts torque force into mechanical energy to move the drilling bit [1,2]. The rotation of metal rotor inside fixed polymeric stator creates sealed cavities in which drilling fluid pressure increases. Due to this increased pressure drilling fluid is driven forward from cavity by cavity. Destruction of rotor coating and also local plucking off the stator are the main factors for rotor destruction. Many factors are involved in causing these problems, such as: elastometer material used for stator manufacturing, type of rotor coating, type of drilling fluid, exploitation

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temperature and pressure conditions, floating solid particles in drilling fluid and the space between the rotor.

Rotor is often made of CK-45 steel or 17-4PH which is protected by a hard and abrasion resistant coating. Rotor usually has one lobe less than stator. Number of blades is chosen according to the drilling condition. Elastometer material from which stator is made should resist abrasion and hydraulic destruction [3,4]. Being of the hi-tech type these devices are expensive and they are highly rated in the drilling industry.

Drilling fluid, i.e. drilling mud, can be based on water, oil or emulsion. Drilling mud was used to carry drilling chunks and bring them to the outdoor environment. However, with improved design and construction of the drilling units the role of drilling mud is increased according to its properties [5]. Drilling mud as a fluid may contain different additives each of them may have a great influence on rotor and stator performance and their service life. To confront corrosion and abrasion problems caused by the drilling fluid, hard chromium plating is the technique commonly used as a protective coating. High hardness, low friction and appropriate resistance to corrosion combined with resistance to abrasion and scratch made this coating suitable as protection in petroleum industries, downhole and out hole devices and also in places with the light corrosion intensity.

Thickness of the coating depends on the properties of the drilling mud [6]. Chlorine in drilling mud severely attacks the hard chromium coating of the steel rotor creating cavities on smooth and polished surface of the coating. The destruction caused by corrosion creates rough sharp surfaces on the rotor coating which may cause formation of scratches and cuts on stator surface. The digs in some sections of rotor made by this mechanism may provoke a severe decrease in applicability of rotor, stator plating and, at the end, may shutoff motor at low differential pressures.

Hard chromium coating is usually applied with a smooth and flat sublayer (such as nickel) to avoid corrosion of the base metal which is in direct contact with corrosive environment such as compounds of chloride, hydrogen sulfide and carbon dioxide [7]. Abrasion and mechanical stresses such as impact and torsion, as well as chemical reactions with environmental fluids could initiate formation of different damages on hard chromium coating.

Experimental procedure

Rotor was made of 17-4PH stainless steel with hard chromium coating. The chemical analysis of rotor is shown in Table 1.

Table 1. The chemical analysis of rotor (in wt.%)

Chemical element and its content					
C= 0.035	Cr= 17.24	Co= 0.039	Nb= 0.235	W= 0.010	P= 0.031
Si= 0.366	Ni= 3.510	Cu= 4.050	Al= 0.003	Ti= 0.011	Fe = Bal.
Mn= 0.484	Mo= 0.261	Sn= 0.030	V= 0.005	S= 0.030	

Figure 1 shows the schematic drawing of rotor and stator with different combination of lobes.

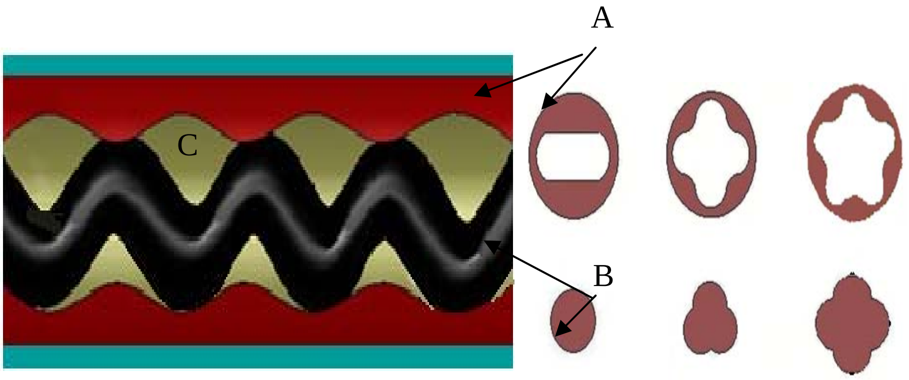

Fig. 1 Schematic drawing of rotor and stator: (A) stator, (B) rotor, (C) lobes.

For microstructural examination of rotor light and scanning electron microscopy (SEM) were applied. Damaged surfaces and avulsion of hard chromium coating were also studied by SEM.

Results and discussion

Microstructure of rotor consists of martensite with islands of alpha ferrite is shown in Figure 2. Hardness measurement of this structure showed a hardness number of 35 RC.

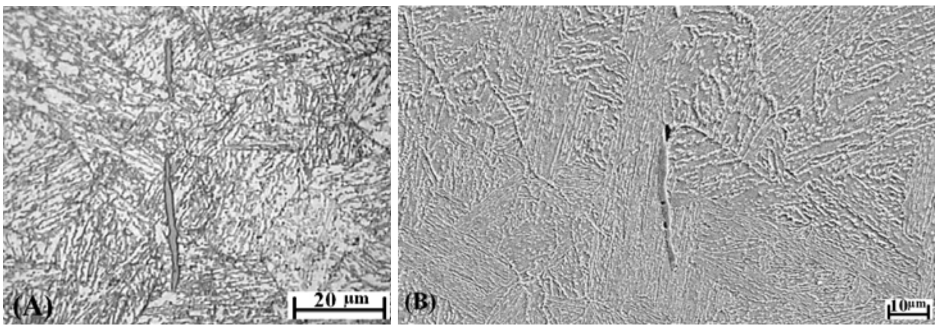

Fig. 2 Microstructure of rotor. (A) Light micrograph shows martensitic structure with alpha ferrite; (B) SEM micrograph.

The damaged section of hard chromium coating is shown in in Figure 3. SEM map analysis reveals the lack s of any nickel sublayer.

It may also be seen that hard chromium coating has been dug in various parts of the rotor and traces of fine and coarse cracks were visible in different sections of the coating (Fig. 4).

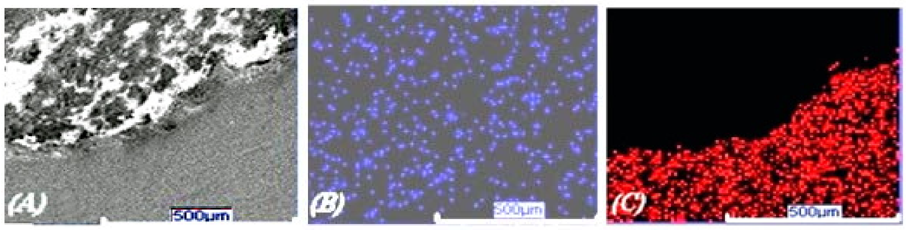

Fig. 3 SEM map analysis. (A) image of the destroyed metal coating; (B) distribution of nickel; (C) distribution of chromium.

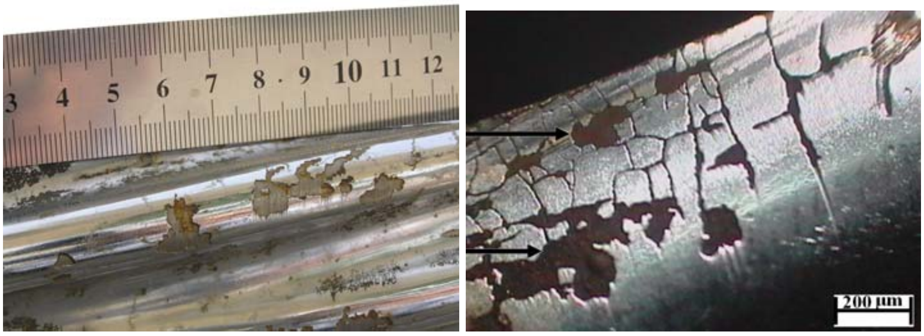

Fig. 4 Light micrograph. Surface damage on the rotor, including avulsion, holes and tiny and large cracks.

Corrosion damage may be seen in some sections of the coating. This seems to be caused by the chemical reaction of the drilling fluid containing corrosive substances such as chlorides. Previous surveys also showed that hard chromium coating does not show required resistance against environments containing chloride [5]. The presence of alkaline substances such as sodium, potassium and their chlorides, carbonic gases and hydrogen sulfide always exist in drilling mud and increase with the drilling stage. Thus, hard chromium coating is always subjected to corrosion attacks of these chemicals.

Recorded statistics for downhole drilling motors showed that the rotor and stator should be continuously replaced since their service life is less than 100 hours. Variables influencing rotor service life include parameters such as bottom hole temperature (BHT), weight on bit (WOB), solid particle percentage in drilling mud and drilling mud weight (MW). The rotor service life (expressed through drilling time) is illustrated in Figures 5-8 as column charts based on these variables.

Figure 5 illustrates the effect of bottom hole temperature on rotor service life. With increase in temperature service life should acquire a descending character. Contrary to expectations exceptions in rotor service life were found in motor M 6 3.4. This motor is 6 inches in diameter and has three lobes on the rotor and four lobes on the stator.

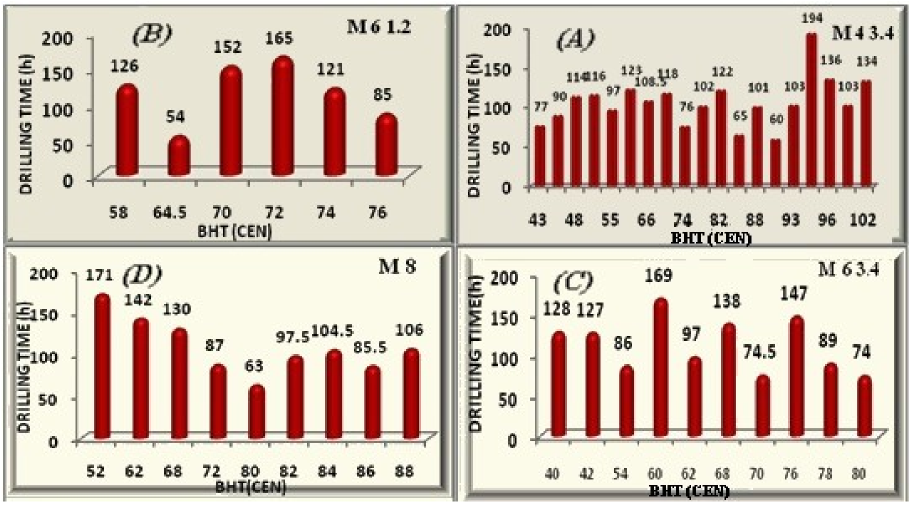

Fig. 5 Service life of rotor as a function of changes in BHT for the same mud. A– 4 3.4 motor, B - 6 1.2 motor, C – 6 3.4 motor, D - 8 motor.

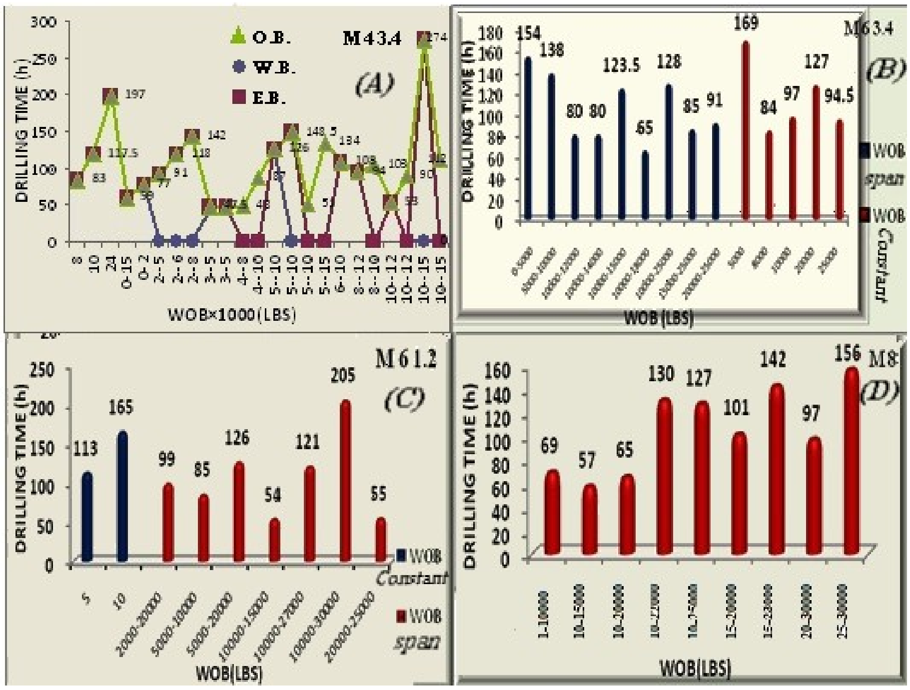

Fig. 6 Rotor service life as a function of changes in WOB for a variety of motors. A– 4 3.4 motor, B - 6 1.2 motor, C – 6 3.4 motor, D - 8 motor.

With increase in temperature the gap between rotor and stator changes. Expanding of stator elastometer with temperature causes an increase of the elastometer strain which could cause elastometer destruction.

Fig. 6 shows that the change in WOB does not have any particular effect on rotors of different types of motors.

It was expected that the effect of percentage of solid particles in drilling mud will be more severe on the rotor service life than other parameters. Except rotors of M 6.1.2 and M 8 motors, increase in solid particles percentage like in the case of previously described parameters does not show any particular influence in increasing or decreasing service life (Fig. 7). This result was unexpected considering that hard and coarse solid particles in drilling mud work as hard and abrasive particles. By sticking between rotor and stator these particles form scratches and abrasive damage on the rotor surface coating. These scratches on the rotor surface coating enable the drilling fluid to reach the base metal triggering the start of the local corrosion. With advanced corrosion these areas become cavities and expanding into the base metal they generate serious damage of stator causing the motor stoppage. Thus, with increase of size of solid particles and their amount of in drilling fluid it should be expected that the service life should decrease. However, statistical analysis does not support this expectation.

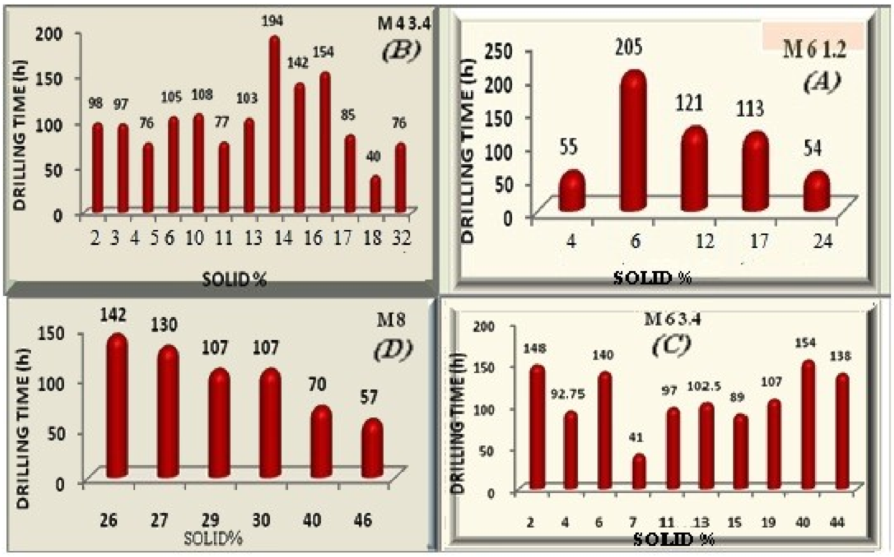

Fig. 7 Effect of the amount of solid particles in the drilling mud on the rotor service life. A– 4 3.4 motor, B - 6 1.2 motor, C – 6 3.4 motor, D - 8 motor.

The same applies to motor with 8 inches in diameter. However, this is not the same situation with other motors since decrease in the rotor life in these motors should be the influence of other parameters.

Figure 8 shows the dependence of the rotor service life on the drilling mud weight. In general, service life decreases with increase in MW. The exception of this behavior is rotor of M 6 3.4 motor.

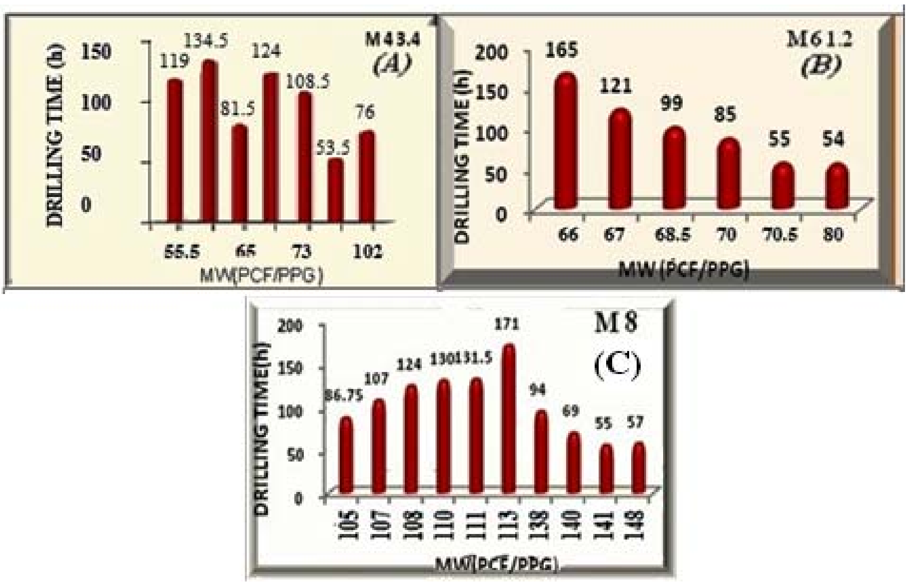

Fig. 8 Rotor service life as a function of MW. A– 4 3.4 motor, B - 6 1.2 motor, C - 8 motor.

Conclusion

The results proved that the hard chromium coating on the rotor of downhole motors was deposited without nickel sublayer. In this situation the coating did not behave as a barrier against corrosion attack from the component contained in the drilling mud. A number of fine and coarse cracks were detected on the coating causing additional avulsion and corrosion.

The effect of different parameters controlling the service life of downhole drilling rotors, such as the bottom hole temperature, solid particle percentage, weight on drill and mud weight have been statistically analyzed. Apart from a few exceptions, it was found that the effect of these parameters was negative on the service life of rotors.

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