JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 6, Preprint 110 submitted 4 November 2010

Failure analysis of chrome plated rotor of down-hole drilling motors

Meysam Zarchi

Islamic Azad University Iran Dezful Branch

Sky_man1983@yahoo.com

Abstract

Down-hole drilling motors so called positive displacement motors (PDM), consist of a helically shaped metallic rotor rotating within a molded stationary elastomer lined stator. The heart of the positive displacement motor is the rotor-stator. This motor converts the hydraulic energy of high pressure drilling fluid to mechanical energy, thereby imparts torque to the rotor, causing it to turn eccentrically and finally turning the bit. Rotor is usually chrome plated to resist wear and corrosion. In this study, an attempt was made to analyze the failure of a hard chrome plated rotor made up of 17-4 PH stainless steel. Effect of various parameters on surface damages of this rotor was thoroughly studied by visual inspection, chemical analysis and metallographic examinations. Investigations revealed that, no under coat was applied. On the other hand, the hardness measured on surface coating was not up to the expectation. The main failure mechanisms were identified as erosion due to hard particles, and chemical corrosion due to some hostile elements in drilling fluids.

Key words: Drilling motors, Failure Analysis, Rotor- Stator, Erosion, Corrosion.

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 6, Preprint 110 submitted 4 November 2010

INTRODUCTION

Down-hole drilling motors of the type of motors with positive displacement motors (PDM) which have two main parts: rotor and stator (Figure 1). The circulation of rotor transforms the hyper pressure of hydraulic energy of drilling mud into the mechanical energy and finally causes the motion of the drill [1,2.]. Rotation of metallic rotor inside the fixed polymer stator causes sealed holes in which the pressure of mud increases hole by hole and moves forward (Figure 2). Coating failure and diffusion of holes into the base metal of rotor are among the main causes of rotor failure. There are more factors causing these problems, for example: elastomer material wich the stator is made of it, type of rotor coating, composition of drilling mud, temperature and working pressure. Solid particles floating in the mud, the space between rotor and stator are among other influencing factors. A rotor is often made of CK45 steel or 17-4PH stainless steel. These materials has a good erosion resistance in different environments. Rotor is protected by a hard coating abrasion resistant and has a blade is less than the stator, but stator is made of some kind of elastomer which can resist friction and is able to stand the damage by hydro-carbon [4,3].

Drilling mud may be water-base, oil-base, or emulation-base. In the early days, drilling mud was used for drilling carriers with the purpose of carry them to the surface; however, with the development of drilling industry, the functions of drilling mud and its quality have been increased and varied. [5]. whatever, the mud contains additives which affect the efficiency and usefulness of rotor and stator. To challenge the problems of corrosion and mechanical damage (erosion and abrasion) caused by drilling mud, Hard chromium electroplating was widely used as a technique of protection. Modern technological process such as High Velocity Oxygen Fuel (HVOF) thermal spray are widely spread. Although these processes are more expensive their protection Due to much higher life functioning as alternative methods are used [6]. High hardness, Low coefficient of friction and good resistance to friction With resistance to abrasion and scratching, has made the hard chromium coating an applicable and desired in oil Industries tools, The equipment inside and outside well and in places where erosion is mild. and there is a need to resistance against erosion. In these cases of appliance coating thickness is different than chrome coating for decorative type , coating thickness is usually more [7]. Chloride in drilling mud causes holes on smooth surface of rotor and brings about rough edges performing as destruction places on the edges of stator . Failure some areas of stator by this mechanism decreases the stator severe sealing efficiency rotor - stator and eventually cause the engine to stop the pressure differential be low. Usually covered with a hard chrome electrical applying a smooth and flat substrate (such as nickel coating) do - is to base metal corrosion in contact with the corrosive environment in the vicinity when the chloride compounds, hydrogen sulfide, or carbon dioxide are considered, comes prevents[8] Also, friction, mechanical stress such as stroke and distortion, chemical reactions with substances such as what was mentioned above that may cause partial or total destruction of the thin chrome makes it possible.

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 6, Preprint 110 submitted 4 November 2010

Experimental results

Studies done showed that the rotor material 17-4PH steel is coated with hard chromium. Chemical composition of the rotor is given in Table (1). Microstructural study sample rotor, routine operations and metallographic structural observations by light and electron microscopy was performed. Electron microscopy for further studies and more accurate levels and avulsion damaged hard chrome coating was used. Figure (2) how exposure and appearance separate rotor and stator, and the combination of shows.

RESULTS AND DISCUSSION

Results of chemical analysis showed that samples of rotor steel in the American standard of type 17-4 PH (AISI 630) and the type of martensite stainless steels with niobium and conducive hard deposits of copper. Table (1) chemical analysis of samples shows. The martensite structure of steel has also been associated with aging is alpha ferrite, which forms (3) is shown. Hardly conducive stainless steels deposited first time in 1940 and later evolve increasingly due to heat their properties as well as a combination of high strength, low distortion, corrosion resistance and wear good, excellent welding quality and relatively high hardness in different applications and many devices were actually used. The steels according to the chemical composition and phases in the microstructure can be separated. The most conducive hard alloy deposition, steel 17-4 PH (AISI 630) stainless steel martensite contains 3-5% by weight is copper-rich copper deposits nm distributed in a blade form martensite strength has been temper. Previous studies have shown that a layer structure in microstructure 17-4 PH alloy aging at temperatures higher than 570 C ° There may be returned due to formation of austenite and ferrite or alpha phase crystallization is found in temper martensite. After solution annealing up to room temperature and cold dissolution, martensite structure of steel, but high hardness will not show themselves. Aging temperature in the range of 480-620 C °due to the formation of copper-rich phase, resulting precipitation hardening, increased in hardness and strength. If the aging temperature higher than 600 C °increase, formation non-coherent copper deposits of in the base and the amount of martensite to austenite transformation during martensite blades occurs. It also shows the measuring of hardness by 33-35 for base metal while for coating the hardness number is much lower for the base metal. Studies and observations showed that on the steel hard chrome coating was applied and no sub-layer is nickel. Structure obtained by electron microscopy and map the distribution of elements is shown in Figure 4. The coating thickness has been measured as 80 to 100 microns. On the other hand, the interspaced between the coating and the base metal was not observed (Figure 5). This can be the reason for the lower hardness of the coating, Which is less than 33-35 HRC. Also, coating was not permanent along its length since at different places of the rotor it has been broken due to the chemical corrosion and the process of formation of holes which in some cases has reached the sub-layer of the steel (Figure 6). Creation of these holes is the result of the reaction of the steel with drilling mud containing corrosive materials like chlorides. Previous studies have shown that the hard chrome coating does not possess the necessary resistance against corrosive environments containing chloride [5]. Alkaline substances such as sodium, potassium and chloride of them, carbonic gas and hydrogen sulfide in the mud there was always appropriate to increase drilling ¬ formation exist. In other words, the hard chrome coating constantly exposed to corrosion resulting from this Contract type factors. Remedy that cover applied on the rotor and revised coverage of hard carbides such as tungsten carbide is used [6]. Figure 7 shows some areas of rotor affected under the influence of friction imposed by the pressure of drilling mud or because of the collision of hard chrome coating with solid particles existing in drilling mud. . Thus, two main factors affecting the surface of coating may be distinguished as:

chemical (corrosion by chemical elements and their compounds),

mechanical (erosion and friction attributed to solid particles in the drilling mud).

Around the same direction was trying to drilling fluid content, size and type of abrasive particles is realized. Therefore, particle size analysis tests were drilling fluid and result in Figure (8) is given. It may be seen that the size distribution of particles is quite irregular showing two maxima, i.e. one at approximately 0.3 microns (with the share of 20%) and another at approximately 20 microns (with the share of 50%), whereas particles of 300 are present in negligible amount. Also in the rotors of tungsten carbide coatings have been used to cover the possible destruction of a cavity type, there are wear and chemical factors that contribute to the form (9) are seen. With the prolonged time of exploitation these pits may spread into the base metal causing its failure (Figure 10). Considering the results of the tungsten carbide coating it is clear that the degree of protection has not been improved compared to the chrome coating.

Conclusion

These results led to the destruction that comes on the rotor may be following factors:

1. there are small and big cracks on the chrome coating causing penetration of the corrosion agent into the base metal where pits are formed,

2. two main factors affecting the surface of coating may be distinguished as: chemical (corrosion by chemical elements and their compounds), and mechanical (erosion and friction attributed to solid particles in the drilling mud),

3. microscopic studies showed that chrome coating does not have the necessary resistance to chemical and mechanical parameters which may be found in the drilling mud. This behavior is the consequence of the poor consistency of coating with the base metal, low thickness of coating and relatively low resistance to corrosive environment.

4. the attempt with tungsten carbide as a coating did not show better results.

References:

[1] R.A.R Mills, R.Gaymard,"New Applications for Wellbore Progressing Cavity Pumps". SPE,Kudu Industries Inc Copyright 1996.

[2] E.O.Cobo,R.A.Suarez Baldo,J.B.Bessone."Corrosion of chromium plated rotor in drilling fluid". Surface and coating technology,(1999) ,122, pp.39-43

[3] National Association of Corrosion Engineers, "Plated and Galvanized Coatings Oilfield Applications", Technical Committee Report ,1990,1G,290.

[4] K. M. Yin, C.M.Wang ,"A Study on The Deposit Uniformity of Hard Chromium Plating on The Interior of Small-Diameter Tubes" .Surface And Coatings Technology, (1999) ,114, pp213–223.

[5] M.Delpassand, "Mud Motor Stator Temperature Analysis Technique", ASME Drilling Technology, 1995,Book No. H00920.

[6] J. Kawakita, Seiji Kuroda, Takeshi Fukushima, Toshiaki Kodama "Development Of Dense Corrosion Resistant Coatings By An Improved HVOF Spraying Process. " Science And Technology Of Advanced Materials 4 (2003) 281–289.

[7] P.D.Spanos,A.M.Chevallier,N.P.PolitisandM.L.Payne."Surface Engineering For Corrosion and Wear Resistance". Asm Int,.Metal Park, 2001,pp.871-875

[8] National Association of Corrosion Engineers, "Plated and Galvamium Coating Lost Adherence and Became Detached by Ionized Coatings for Oilfield Applications", Technical Committee Report ,1990, 1G290.

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 6, Preprint 110 submitted 4 November 2010

Table 1: Chemical analysis of rotor, in wt.%.

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	

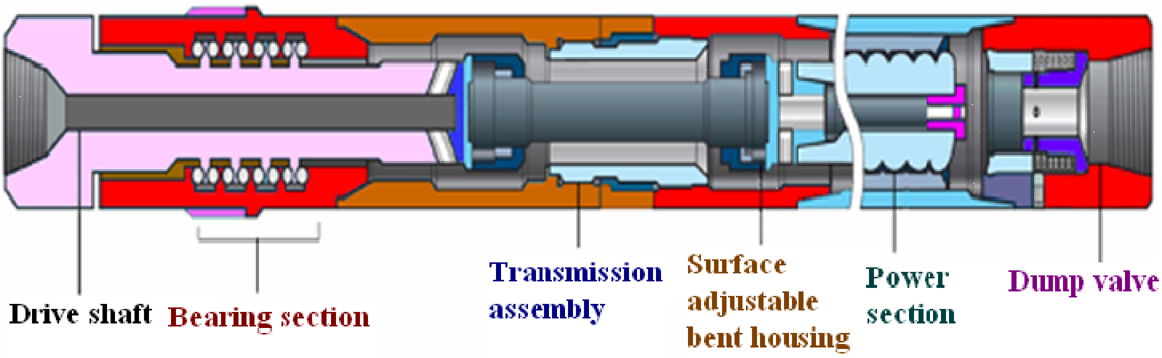

Figure 1. A scheme of drilling motor (drawn by the software 'Solid Work')

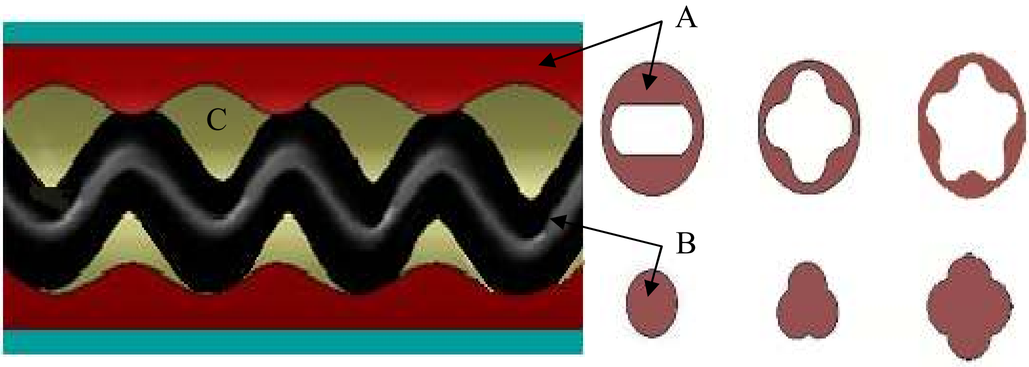

Figure 2: Schematic of rotor and stator: A- stator; B-rotor; C-hole

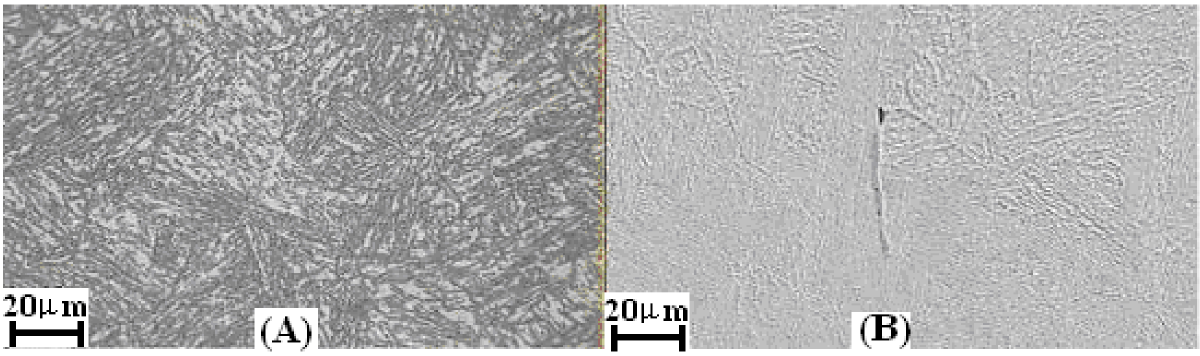

Figure 3. Microstructure of rotor; A) by light microscope with magnification x 800 B) by SEM.

JCSE The Journal of Corrosion Science and Engineering
ISSN er 2010

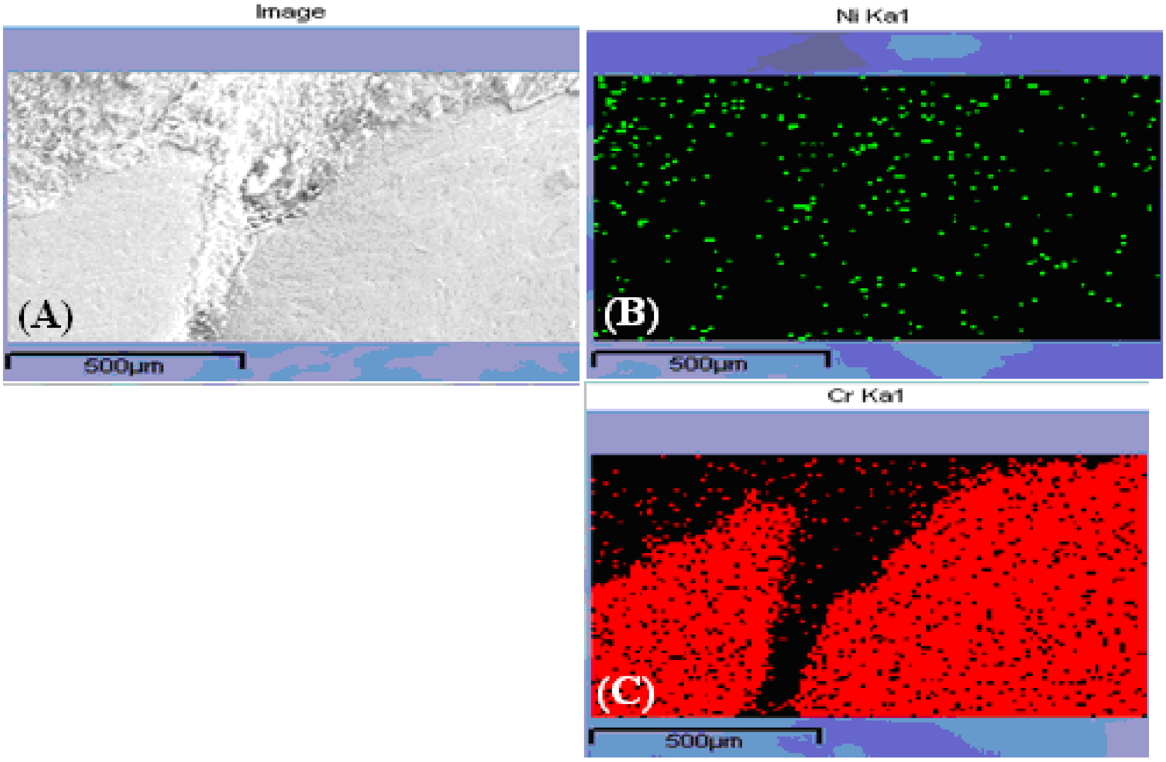

Figure 4. SEM. Microstructure of rotor. A) failed surface;
B) map of nickel distribution; C) map of chrome distribution.

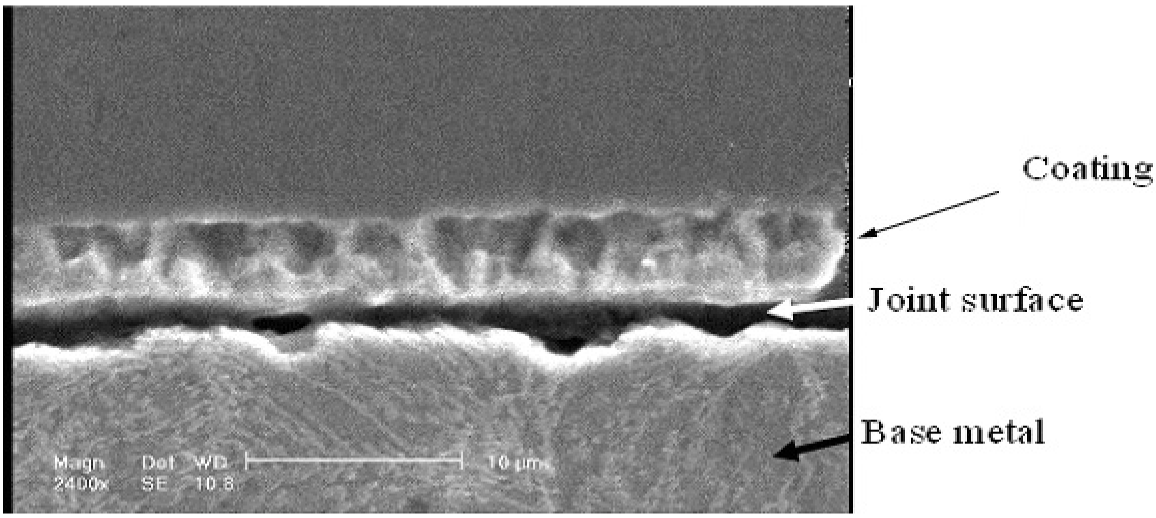

Figure 5. The cross-section of rotor with coating.

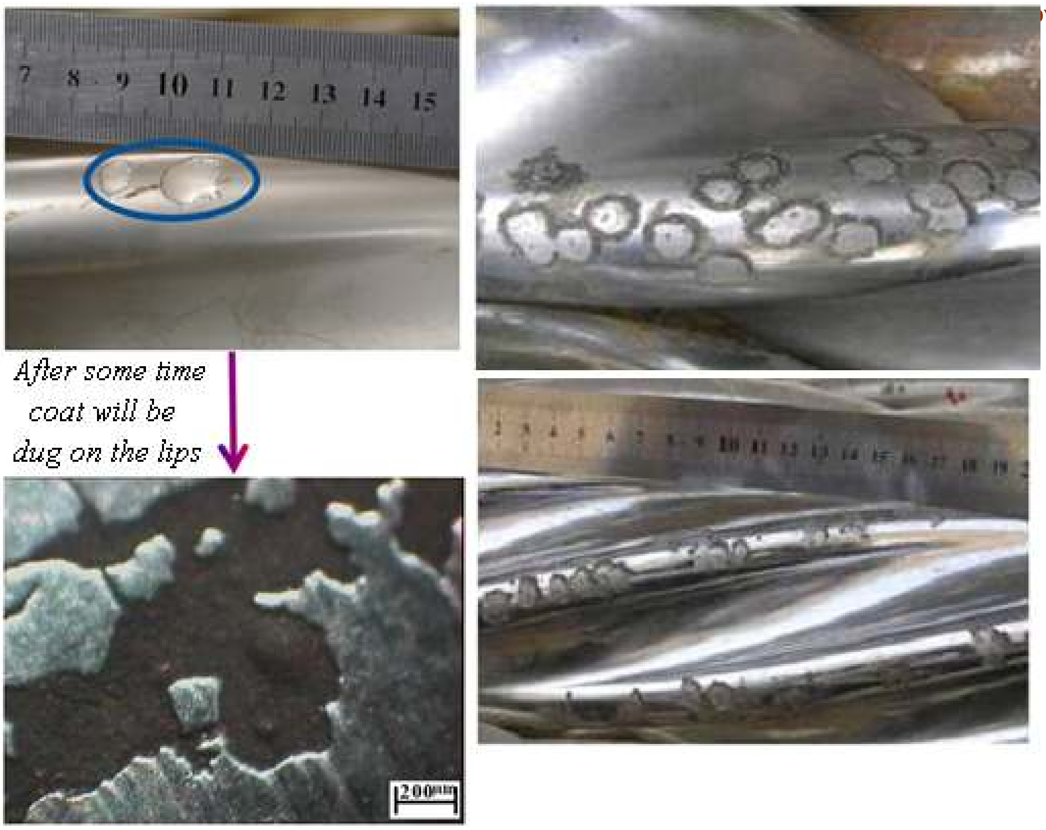

Figure 6. surface damage on the rotor, including avulsion, and the cavity

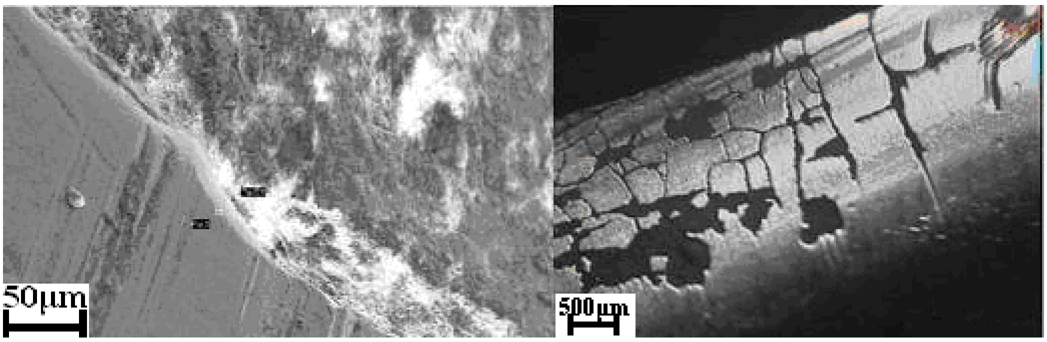

Figure 7. Coating cracks due to friction.

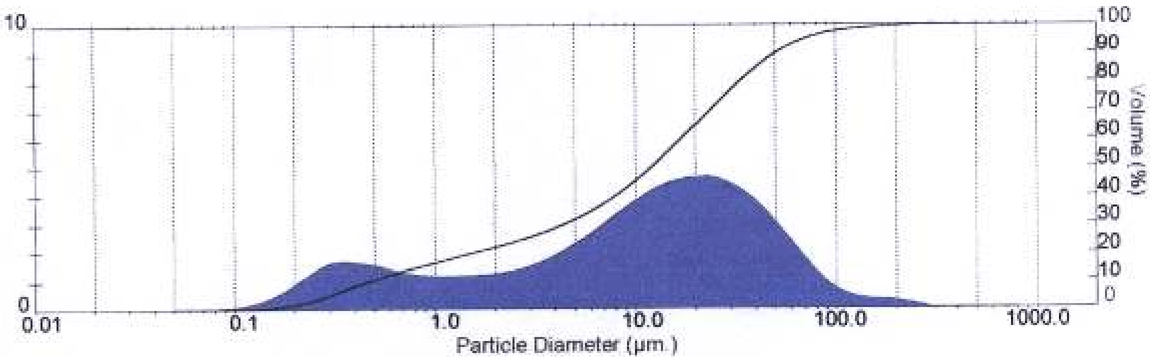

Figure 8. Distribution of the size of solid particles in drilling mud. full line indicates the destructive effect of particle on the part.

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 ed 4 November 2010

Figure 9. Surface failures of rotor coated with WC. Friction cuttings and the beginning of hole achieve into the base metal due to coating thinning.

Figure 10. Surface failures of rotors coated with WC. Friction cuttings, and hole achieve into the base metal as a result of corrosive influence of mud with WC coating. The figure on the right is enlarged detail of the left figure.