CSCanada
Advances in Petroleum Exploration and Development
Vol. 10, No. 2, 2015, pp. 19-24
DOI:10.3968/7741

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

The Experimental Research of the Relationship Between Rock Surface Roughness and PDC Bit Wear

XING Enhao[a],*; LI Shibin[a]; ZHANG Ligang[a]; GUAN Bing[a]; WANG Yeqiang[a]; QU Zongwei[b]

[a] Northeast Petroleum University, Daqing, China.
[b] The Ninth Oil Extraction Plant of Daqing Oilfield Company Limited, Daqing, China.
*Corresponding author.

Supported by Northeast Petroleum University Innovation Foundation for Postgraduate (YJSCX2015-017NEPU).

Received 13 October 2015; accepted 3 December 2015
Published online 31 December 2015

Abstract

By using rock grinding experiment machine to grinding different groups of rock, Using the electron microscope scanning technology to analysis of the wear profile amplification and Contour arithmetic mean deviation R_a, outline of the root mean square deviation R_q and average roughness parameter R the three surface roughness parameters to measure the new grinding surface roughness, using the PDC diamond compact for further PDC grinding experiments in different roughness of the generated sections. Before and after the grinding experiment calculate the lose weight of PDC diamond compact with electronic balance scales, through the analysis of experimental result data concluded that the degree of wear of PDC bit and the roughness grinding profile had a certain linear relationship in the grinding experiments, namely with the increase of roughness the trend of PDC bit wear was from reducing to increasing, and the wear volume reached its lowest point in a certain roughness parameter. using the scanning electron microscopy to analyze the section of PDC wear, and concluded that the wear mechanism of PDC is mainly abrasive wear ,accompanied by fatigue wear and adhesive wear, the wear process of PDC is the process of cleavage. The better way of diamond abrasion wear is: Diamond from exposing to micro broken to cleavage to fall off in the end. The worst way is diamond directly fall off.

Key words: PDC bit; The surface roughness; Abrasiveness experiment; Scanning electron microscopy

Xing, E. H., Li, S. B., Zhang, L. G., Guan, B., Wang, Y. Q., & Qu, Z. W. (2015). The experimental research of the relationship between rock surface roughness and PDC bit wear. *Advances in Petroleum Exploration and Development, 10*(2), 19-24. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/7741 DOI: http://dx.doi.org/10.3968/7741

INTRODUCTION

Diamond-cemented carbide composite sheet (PDC), which is made up of the cemented carbide liner with a fine layer of synthetic polycrystalline diamond[1]. Diamond bit as a bit of high hardness in the industry has been widely used in drilling engineering, however, the main rock breaking mechanism of diamond bit is shear failure effect, in the case of long time contact with strata, the wear of diamond bit is also became a wide public concern over the problem. Starting from the physical essence of grinding effect, wear refers to the process of tool surface damage when the mechanical action happening between tools and rock. The mechanical action is mainly characterized by friction, called the frictional wear. Frictional wear is influenced by the following factors: The surface roughness, pressure, temperature, and so forth. Including the influence, roughness is the biggest one, therefore, we study the relationship between the wear of PDC bit and roughness in this paper[2-4].

There were many different opinions about the relation of roughness and wear. American Crysler car factory put forward in 1938: The smaller roughness indicates that the surface more smooth, so that the smaller amount of Wear quantity. Therefore, the parts of its' main product surface are made of super precision machining. This phenomenon actually reflects the opinion of frictional wear with rough surface peak mechanical action. According to the United States Buick factory in 1941, the main cause of frictional wear is the function of surface molecules, thus put forward that the roughness need to be certain to abrasion on the friction surface, thus argued that the surface of the parts of their products need to be used by the corrosion process.

The scholars of the Soviet academy of sciences institute of mechanical И М А Ш viewed on surface quality of the wear was: When two solid surfaces touch each other, because of the influence of the rough surface, the actual contact occurs only on a tiny part of the apparent area. The actual contact area of the size and distribution playing a decisive important influence on frictional wear, the shape of the actual surface rough peak is usually ellipsoid. As a result of the ellipsoid contact part size is far less than the radius of curvature of its itself, therefore, the rough peak can be approximately regarded as sphere, two plane contact can be converted into the touch of a series of high and low not neat sphere[5].

1. THE MEASUREMENT METHOD OF SURFACE ROUGHNESS

1.1 Rock Core

The field rock coring, firstly, grinding out a bit wear profile on the rock core (Figure 1), and using scanning electron microscopy technology (scanning electron microscope Quanta FEG450) (Figure 2) measure and calculate the surface roughness, and grouping the core pattern.

Figure 1
Rock Sample Wear Section

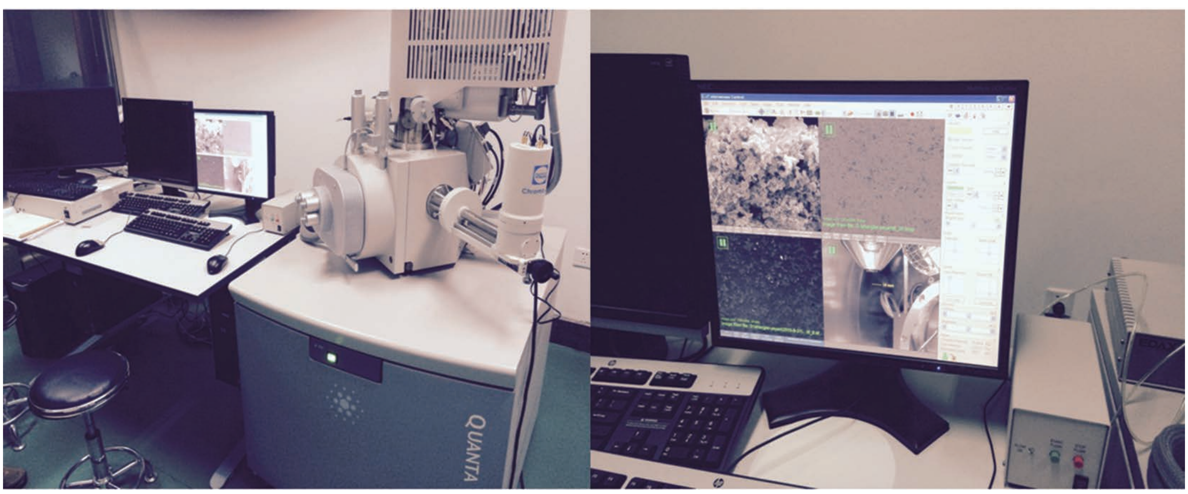


Figure 2
Scanning Electron Microscope Quanta FEG450

1.2 Scanning Electron Microscopy

Studies have shown that[6], contour arithmetic mean deviation R_a, outline of the root mean square deviation R_q and average roughness parameter R the three surface roughness parameters' selection range is consistent; maximum depth of profile valley R_m and maximum height of profile peak R_p these two parameters values range is large. So this paper select contour arithmetic mean deviation R_a, outline of the root mean square deviation R_q and average roughness parameter R the three surface roughness parameters as evaluation parameters of surface roughness of rock samples.

Contour arithmetic mean deviation R_a was the first parameter to ask for evaluation of surface roughness, was also the parameters accepted for the most part in the international countries. The definition of contour arithmetic mean deviation as shown in Figure 3, it is the result of arithmetic average of the absolute value between the sample length L (used to determine the characteristic of the surface roughness is a section efficacious length) and profile deviation z (the length from surface on the contour to the baseline) .

Mathematical formulas of the contour arithmetic mean deviation R_a is:

$$R_a = \frac{1}{L}\int_0^L |z-m|\mathrm{d}x\int. \tag{1}$$

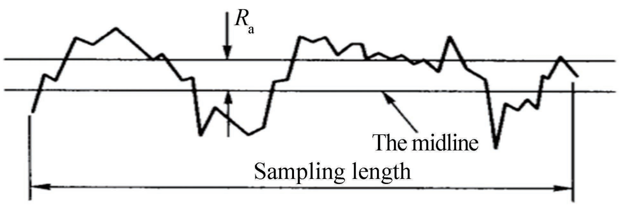


Figure 3
Contour Arithmetic Mean Deviation Calculation Principle Diagram

The parameters of R_q is often encountered in mathematical statistics. It is the same as the ordinate of contour curve of worth spreading, and has a certain relationship with the power spectrum and correlation function of the contour curve. It is important to theoretically analyze the nature of the contour curve[7].

$$R_q = \sqrt{\frac{1}{l}\int_0^l y^2(x)\mathrm{d}x}, \tag{2}$$

$$R = \frac{1}{k}\sum_{i=1}^{k}\left(\frac{1}{n}\sum_{j=1}^{n}R_j\right)_i. \tag{3}$$

1.3 Scanning Electron Microscopy Analysis

Electron scanning microscope, SEM for short, in a similar way of TV camera imaging, modulation imaging through a narrow focus on electron beam on the sample surface scanning excitation generated by some physical signal. SEM can be used for measurement of μm level structure, also can be used in the measurement of nm level structure[8]. Scanning electron microscope has many characters: Simple sample preparation, magnification the adjusting range is big, depth of field, strong resolution[9].

Respectively after the electron microscope scanning, combined with contour arithmetic mean deviation R_a, outline of the root mean square deviation R_q and average roughness parameter R to evaluate and group the rock style of roughness.

Table 1
Rock Sample Group 1

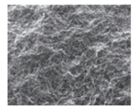
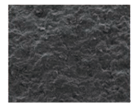
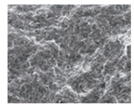
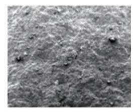
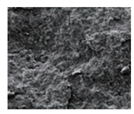
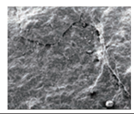
Group 1	R_a μm	R_q μm	R μm	
1	0.06	0.17	0.14	
2	0.15	0.26	0.34	
3	0.25	0.39	0.63	
4	0.52	0.71	1.03	
5	0.77	1.15	1.42	
6	2.22	3.04	5.5	

Table 2
Rock Sample Group 2

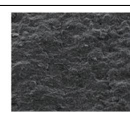
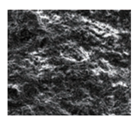
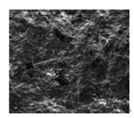
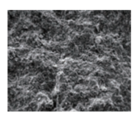
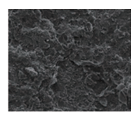
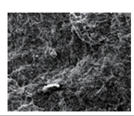
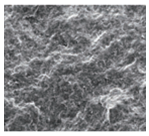
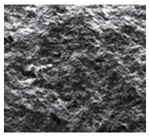
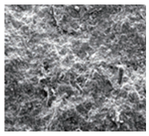
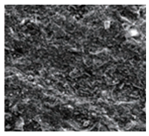
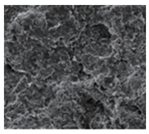
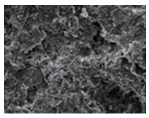
Group 2	R_a μm	R_q μm	R μm	
1	0.06	0.16	0.13	
2	0.18	0.30	0.38	
3	0.27	0.39	0.65	
4	0.49	0.68	0.98	
5	0.72	1.09	1.37	
6	2.01	2.89	5.22	

Table 3
Rock Sample Group 3

Group 3	R_a μm	R_q μm	R μm	
1	0.08	0.19	0.15	
2	0.16	0.28	0.35	
3	0.26	0.40	0.66	
4	0.47	0.67	0.98	
5	0.72	1.09	1.37	
6	1.98	2.85	5.19	

2. ABRASIVENESS MEASUREMENT

The rock grinding experiment instrument (Figure 4), with a diameter of 35 mm PDC experiment bit (Figure 5) in bit pressure 200 KN; the drilling speed of 200 r/min; temperature of 23 ℃; for different groups of rock specimens conduct respectively grinding experiments. Grinding experiment after grinding the same displacement, removes the PDC diamond compact on the electronic balance scale (Figure 6), calculates the weight of the consumption.

Figure 4
The Rock Grinding Experiment Instrument

Figure 5
PDC Experiment Bit

Figure 6
Electronic Balance Scale

3. THE EXPERIMENT RESULTS ANALYSIS

Through the grinding experiment, obtain the data relationship between the abrasion loss of PDC composite sheet and the surface roughness. Calculated data in the following table:

Table 4
Grinding Experiment Data Tables

	Rock sample	Bit	The initial weight/g	The final weight/g	Consumption /g
Group 1	1	PDC	7.796	7.786	0.010
	2	PDC	7.611	7.603	0.008
	3	PDC	7.662	7.658	0.004
	4	PDC	7.682	7.675	0.007
	5	PDC	7.704	7.693	0.011
	6	PDC	7.755	7.740	0.015
Group 2	1	PDC	7.796	7.785	0.011
	2	PDC	7.793	7.786	0.008
	3	PDC	7.663	7.658	0.005
	4	PDC	7.683	7.674	0.009
	5	PDC	7.705	7.695	0.010
	6	PDC	7.755	7.742	0.013
Group 3	1	PDC	7.794	7.785	0.009
	2	PDC	7.789	7.782	0.007
	3	PDC	7.662	7.658	0.004
	4	PDC	7.682	7.675	0.007
	5	PDC	7.705	7.794	0.011
	6	PDC	7.756	7.742	0.014

To analyze the experimental data, and establish a linear relationship between the wear and the roughness (Figure 7): Namely with the increase of roughness the trend of PDC bit wear was from reducing to increasing, and the wear volume reached its lowest point in a certain roughness parameter. The existence of the optimal roughness showed that the wear process is the surface of the friction pair between mechanical and combination of molecules. When the surface roughness is less than the best roughness, wear is caused by the surface molecular. And when the surface roughness is greater than the optimal value, the wear is mainly produced by surface mechanical action.

After the experiment amplification analysis the wear surface of PDC composite sheet with electron microscope scanning, the scanning electron microscopy image initial crack and wear the of PDC bit as following figure:

The wear of PDC surface is largely due to abrasive wear of PDC surface scratches produced, and the initial micro cracks (Figure 8) and the crack (Figure 9) produced under the action of stress (Figures 10-11).

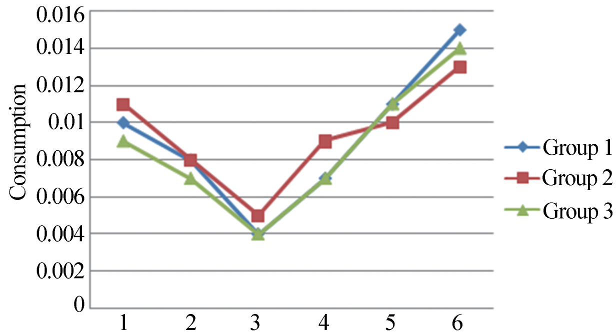


Figure 7
PDC Wear and Roughness Linear Relationship

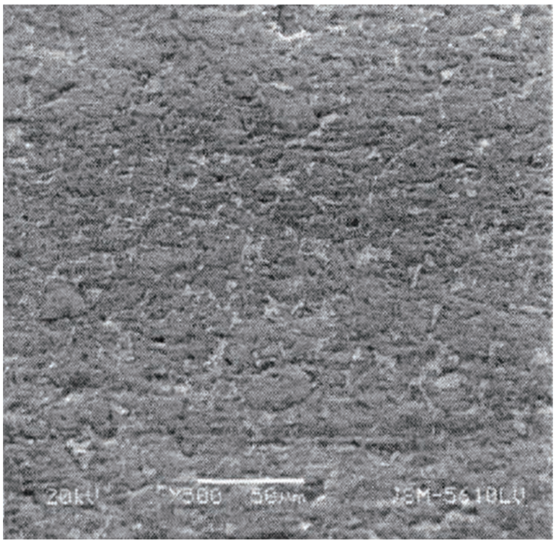


Figure 8
Initial Micro Cracks

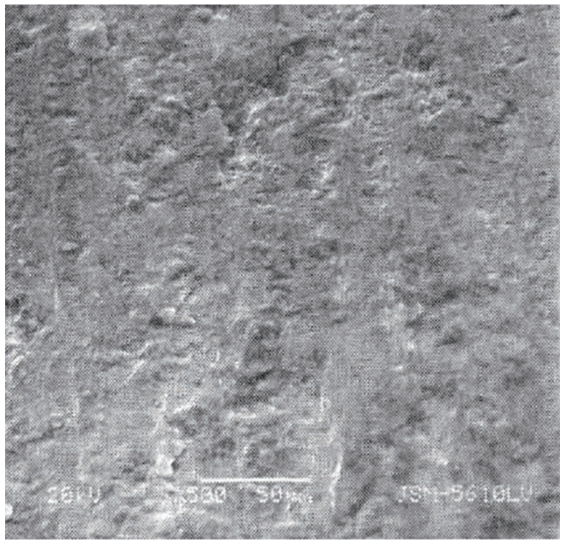


Figure 9
Scratch

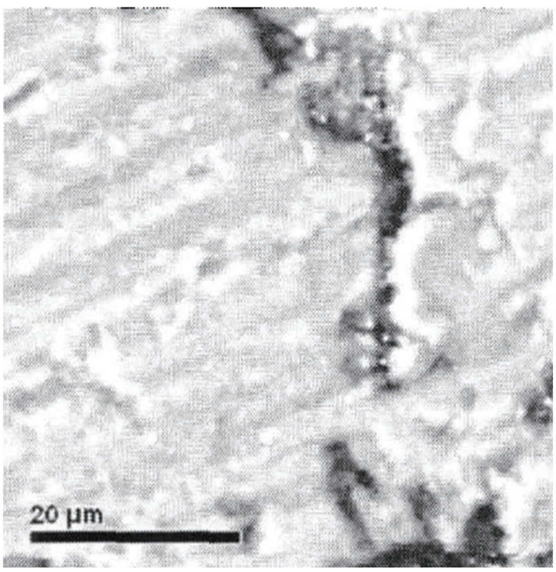


Figure 10
Cracks

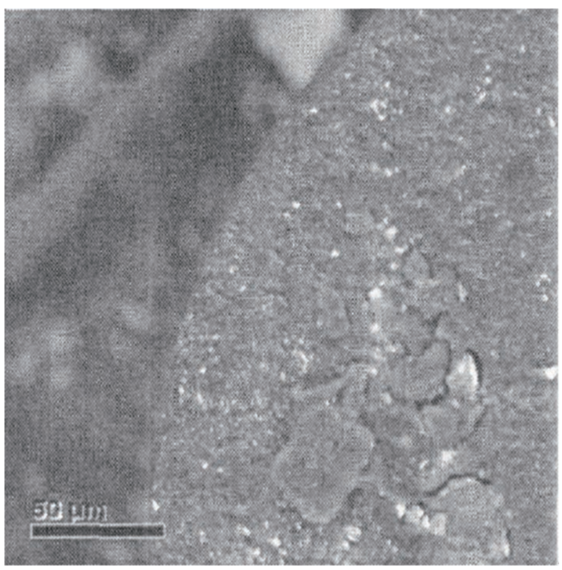


Figure 11
Cracks

Through the analysis by the microscopic of surface wear of polycrystalline diamond sintered body (polycrystalline) shows that there existed cracks and scratches on the wear surface of PDC. To show that during the process of grinding between PDC bit and rock core samples, the function of PDC bit on rock core samples by many times of abrasive wear, lead to some Polycrystalline particles on PDC bit had a micro cracks, and then under the action of abrasive, crack extension in the rock core sample, until stripping down in the form of brittle fracture as tiny particles from PDC bit wear surface, so leave cleavage fracture plane on the surface of the PDC bit. The cleavage fracture microscopic formation of cleavage steps is the result of the interaction in the process of crack propagation.

CONCLUSION

The degree of wear of PDC bit and the roughness grinding profile had a certain linear relationship in the grinding experiments, namely with the increase of roughness the trend of PDC bit wear was from reducing to increasing, and the wear volume reached its lowest point in a certain roughness parameter.

When the surface roughness is less than the best roughness, wear is caused by the surface molecular. And when the surface roughness is greater than the optimal value, the wear is mainly produced by surface mechanical action.

The main reason of PDC wear is the diamond grains inside produced microscopic cleavage breakage. Wear surface is made up of many microscopic cleavage plane and irregular fracture surface.

REFERENCES

[1] Hu, H. (2012). Personalized PDC bit development status and application prospects. *Mechanical and Electronic*, *9*, 140.

[2] Wan, R. F., & Luo, Y. J. (1993). *Production technical manuals*. Beijing: Petroleum Industry Press.

[3] Zhang, Q. (2002). *Principle and design of oil production engineering*. Dongying, China: Petroleum University Press.

[4] Ramey Jr., H. J. (1962) Wellbore heat transmission. *Journal of Petroleum Technology*, *14*(4), 427-435.

[5] Wen, S. Z., & Huang, P. (2002). *Tribology principle*. Beijing: Tsinghua University Press.

[6] Han, W. M. (2012). *Rock slide friction property and influence factors analysis* (Doctoral dissertation). Taiyuan University of Technology, Taiyuan, China.

[7] Wang, Y. T. (1983). Characterization of the surface roughness parameters and its relationship with surface features. *Journal of Northeast Heavy Machinery Institute*, *7*, 50-55.

[8] Zhu, S. X. (2007). *Grinding surface texture characterization and friction properties of research* (Doctoral dissertation). Nanchang University, Nanchang, China.

[9] Chen, B. (2009). *PDC wear resistance research* (Doctoral dissertation). Wuhan University of Technology, Wuhan, China.