IMPREGNATED DRILL BITS STRENGTHENED BY NANOPARTICLES FOR MINERAL EXPLORATION DRILLING

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Abstract : In order to improve the drilling efficiency and service life of impregnated diamond drill bit, WC and ZrO2 nanoparticles were introduced into traditional drill bit matrix. The matrix formula and fabrication process were optimized to utilize the dispersion strengthening effect of WC and ZrO2 nanoparticles, improving physical and mechanical performance of working layer. Indoor drilling experiment was carried out to compare reinforced drill bits and traditional bit. Results showed that drill bits with 2.5 wt% nano-WC and 1 wt% nano-ZrO2 shows better performance than traditional bits. WC nanoparticles have better dispersion strengthening effect on diamond drill bit than ZrO2 nanoparticles.

1. Introduction

Geological and mineral exploration work has gradually turned to deep and ultra-deep areas, severe service conditions and cost reduction put forward higher requirements for drilling technology and equipment [1,2]. As one of the important rock breaking tools, the performance of impregnated diamond drill bits has a direct impact on drilling efficiency, quality and cost. In particular, the deep drilling consumes lots of abnormal operating time, such as rising and descending drill pipes, so the long-life drill bit is beneficial to reduce the abnormal operating time. At present, the methods to improve the service life of drill bits mainly start from three aspects: material, structure and fabrication technology, such as using ultra-fine powder as the matrix material, high matrix structure bits and low temperature activated sintering technology [3-5].

With the rapid development of nanotechnology, the quantum dimension effect, surface effect and macroscopic quantum tunnel effect of nanomaterials have aroused the interest of researchers. Using nanoparticles to disperse and strengthen metal or alloy materials has become an important research direction, nanoparticles can uniformly disperse in metal or alloy matrix as second-phase particles, limiting dislocation movement and grain boundary slip during material deformation, thus improving the properties of materials [6-8].

It is known that WC nanoparticles have excellent properties, namely high hardness, high wear resistance, good thermal and chemical stability, so it has been widely used in enhancing composite materials and modifying coatings [9,10]. ZrO2 nanoparticles also have excellent properties, namely high, hardness, extreme thermal and chemical stability, and good mechanical performance, so it has been widely used in reinforcing plastic, ceramic, rubber, refractory, and metals [11,12]. Therefore, nano-WC and nano-ZrO2 are ideal material for strengthening drill bits, WC and ZrO2 nanoparticles were introduce into drill bit matrix formula in this work for investigation of their influence on drill bit performance.

2. Experiment

2.1 Drill bit matrix formulas design

The formula of drilling bit matrix is a key factor that influences the performance of drill bit. The formula design of the matrix mainly includes the content of each component in the matrix, the amount of nano-WC and nano-ZrO2 addition and diamond particle size and concentration. According to the analysis of the abrasiveness and drillability of the test rock, the drill bit designed in this work was improved on the basis of the traditional formula (as shown in table 1). When the diamond concentration was 80%, different concentration of nano-WC and nano-ZrO2 were introduced into traditional formula. The parameters of nano-WC and nano- ZrO2 are shown in table 2.

Table 1. Traditional formula of matrix

Element	WC	ZQSN-6-6-3	YG_6	Ni	Mn
Grain size (nm)	-200	-250	-200	-200	-250
Content, wt%	40	35	15	5	5
Density, g/cm^3	15.5	8.8	15.1	8.9	7.43

Table 2. Parameters of nano-WC and nano-ZrO2

Material	Grain size（nm）	Purity（%）	Volume density（g/cm^3）	Density（g/cm^3）	Crystal
Nano-WC	80	>99.9	3.2	15.5	Hexagonal
Nano-ZrO2	40	>99.9	0.71	5.85	Tetragonal

Two series of samples were prepared by hot pressing sintering and sintering parameters were as follows: uniform heating, sintering temperature of 980 ℃, 15-18 MPa pressure, heat preservation time of 5 min. The bending strength and grinding ratio of the samples were measured. The results showed that the samples with 2.5 wt% nano –WC and 1 wt% nano-ZrO2 were optimal. According to the test results of the performance of the tread sample, the formula of the reinforced diamond drill bits in this test was exhibited in table 3.

Table 3. The formula of the reinforced diamond drill bits

Drill bits	Formula
Tradition (T)	Traditional matrix material
Nano-WC reinforcement (W)	98 wt% Traditional matrix material +2.5 wt% Nano-WC
Nano-ZrO2 reinforcement (Z)	98 wt% Traditional matrix material +1 wt% Nano-ZrO2

2.2 Fabrication of drill bits

The designed reinforced diamond drill bits was fabricated by medium-frequency hot pressure sintering method, and the fabrication process was shown in figure 1. Sintering process parameters of the bits were as follows: temperature of 980 ℃, pressure of 5 MPa, hot-pressing pressure holding time of 10 min. The drill bits prepared were shown in figure 2.

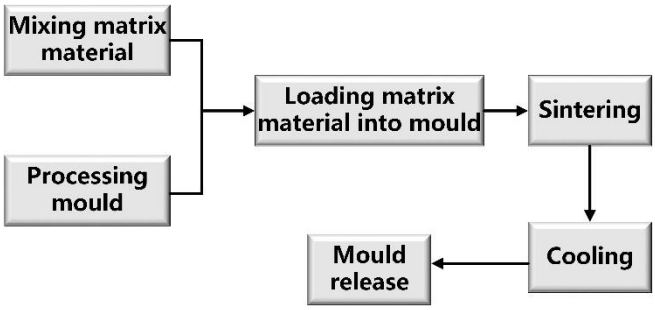

Figure 1. Fabrication process of drill bits

Figure 2. Drill bits prepared

2.3 Drilling experiment

The indoor drilling experiment of three diamond drill bits (T, W, Z) was carried out. The main equipment used in the test was XY-1 core drill rig (as shown in figure 3) and PMB-50 mud pump. The rig was equipped with multiple sensors which can input the collected data into the computer and record it in real time, including rotate speed, drilling pressure, pump volume, mechanical drilling speed and drilling footage. The rock samples used in the drilling experiment were medium coarse granite with grade X hardness, strong abrasion and grade VII drillability.

Before the experiment, the old drill bit was used to open the hole, forming a circular groove about 5mm deep. Then experiment bits were installed for drilling experiment and collect data. Drilling parameters were as follows: drilling pressure was 7kN, rotate speed was 500 r/min, the amount of drilling fluid was 35-40L/min, and the drilling fluid was clean water. Part of the core taken out by drilling was shown in figure 4.

Figure 3. XY-1 core drill rig Figure 4. The core taken out by drilling experiment

3. Results and Discussion

The drilling experiment data are shown in table 4, it can be noted that drill bit reinforced by nano-WC show the best performance. So the wear condition on the bottom lip of the drill bits (T, W) is illustrated in figure 5 for further analysis.

Compared with traditional diamond drill bit (T), the mechanical drilling speed of nano-WC reinforced diamond drill bit (W) is increased by 24.9% and nano-ZrO2 reinforced drill bit (Z) is increased by 6.0%. So WC and ZrO2 nanoparticles have a good dispersion strengthening effect, improving the physical and mechanical properties of the drill during drilling, and thus improving the mechanical speed. Compared with drill bit T, the estimated service life of drill bit W is increased by 28.9% and Z is increased by 17.0% .The introduction of WC and ZrO2 nanoparticles effectively

improve the service life of drill bits and reduce the drilling cost. WC nanoparticles have better dispersion strengthening effect on diamond drill bit than ZrO2 nanoparticles. Since ZrO2 has lower wettability with the metal matrix metal bronze than WC.

Table 4. The drilling experiment data

Drill bit	Number of holes	Drilling footage	Drilling time	Average Drilling speed	Wear of working layer	Estimated service life
T	5	931.19mm	45min6s	0.337mm/s	0.10mm	46.73m
W	6	963.93mm	38min7s	0.421mm/s	0.08mm	60.24m
Z	4	888.08mm	41min49s	0.354mm/s	0.08mm	54.67m

In figure 5, a, b and c are the bottom lip of drill bit T and d, e, and f are it of drill bit W. The working layer of drill bit T has lost part of edge working layer, but the reinforced drill bit W does not appear this phenomenon. The drill bit W has lower wear and shallower annular groove than T and the drilling process of drill bit W is more stable. This indicates that the introduction of WC nanoparticles has achieved a good strengthening effect.

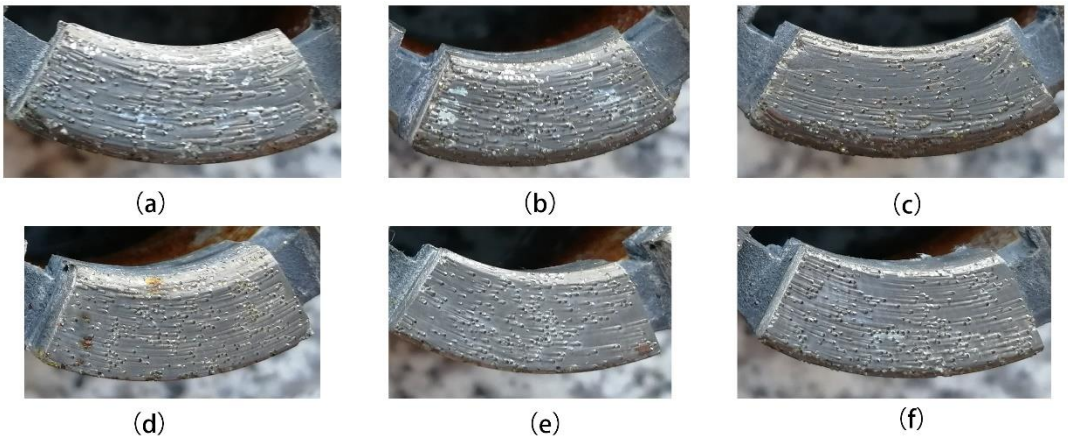

Figure 5. The bottom lip of drill bit T and W

4. Conclusions

WC and ZrO2 nanoparticles were introduced into traditional drill bit matrix to develop the reinforced impregnated diamond drill bits. Drill bits with 2.5 wt% nano –WC and 1 wt% nano-ZrO2 shows better performance than traditional bits. Compared with traditional diamond drill bit, the mechanical drilling speed of nano-WC reinforced diamond drill bit is increased by 24.9% and nano-ZrO2 reinforced drill bit is increased by 6.0%. And the estimated service life of nano-WC reinforced drill bit is increased by 28.9% and nano-ZrO2 reinforced drill bit is increased by 17.0%. WC nanoparticles have better dispersion strengthening effect on diamond drill bit than ZrO2 nanoparticles. Thus paving the way for further research and application.

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