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Study on the Influence of Magnetism and Specific Gravity of Synthetic Diamond Abrasive Particles on Their Mechanical Performances

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Abstract. In this paper, static-pressure strength, toughness index (TI) and thermal-toughness index (TTI) of each sample have been analyzed on the basis of the experimental studies on the magnetic separation and heavy liquid separation of diamond abrasives. The results show that the magnetism of synthetic diamond abrasives has an obvious influence on their mechanical performances. With the increase of magnetism, synthetic diamond abrasive particles becomes darker and darker in appearance color, and have more bubbles, impurities and defects inside the particles, furthermore, their surface fineness observed under the microscope will be found worse. While, the static-pressure strength, the TI under the normal temperature and TTI all become lower and lower. But the influence on the static-pressure strength and the TI is smaller, however the influence on TTI is the greater. The specific gravity of synthetic diamond abrasives has little influence on their mechanical performances.

Introduction

Synthetic diamond, a kind of superhard abrasive, it's mechanical performances have closely related to its ability of withstand impact and friction when working. Diamond is a modification of carbon, containing low level ash, but it is a very high purity substance. Nickel, Manganese, Cobalt, and Iron alloys are usually used as the catalyst in diamond synthesis. Therefore, synthetic diamond has certain magnetic property since the inevitable exist of the magnetic inclusion of the catalyst alloys. And the mechanical performances of synthetic diamond related to its micro-structure [1]. Generally speaking, the magnetic susceptibility of synthetic diamond is $(156\text{-}0.6)\times10^{-6}$cm/g, linearly increased with the magnetic elemental content and the dimension of the crystal. So a crystal with high magnetism has poor wear resistance, grinding capacity and heat resistance. In our previous research, the relationship between the magnetism of synthetic diamond and static-pressure strength has been presented [2].

In China, the quality of diamond is usually evaluated on the basis of the main index of static-pressure strength over the years, while it has been found to be less representative with more man-made errors. Toughness Index (TI) at normal temperature simulates the real state of diamond under the action of impact and friction. Since it measures the group effect of diamond, it is more representative for the real effect of tools during the practice. While Thermal Toughness Index (TTI) is the TI of a cooled diamond after treated at 1100°C . Based on the heating demand of fabrication and usage, the thermal stability of diamond abrasive particles are considered. So TI can evaluate the quality of diamond more scientifically and comprehensively [3]. In this paper, static-pressure strength, TI and TTI of each sample have been analyzed on the basis of some experimental studies on the magnetic separation and heavy liquid separation of synthetic diamond abrasives, and then the influence of magnetism and specific gravity on their mechanical performances has also been discussed.

Testing equipment and method

Samples and methods. Sample for the test is a single-crystal synthetic diamond with medium grade. It is fabricated by belt-type press in one domestic synthetic diamond company, and then separated by vibrating sorting according to the different figurations.

For the magnetic separation test, a self-made permanent magnetic separating apparatus with continuously adjustable magnetic intensity is adopted. Beginning with the upper material, the magnetic materials are classified by grades from low to high intensity in different magnetic fields [4].

The heavy liquid separation test is conducted in a constant temperature bath. Samples are divided into three parts which are floating material, suspending material and settling material.

Testing equipment and method.

Test of static-pressure strength: Static Fracture Strength Tester produced by German Vollstaedt-Diamant GmbH Co. was employed in the following test steps: Sample after binary splitting, was put into feeder to test its compressive fracture force (CFF) — the force resistant to fracture under pressure.

Test of Toughness Index (TI): Friability Index Tester designed by Italian RETEK Company is used here: firstly, put 400mg diamond with some grade size into a quenched steel container together with a steel ball; after being impacted under a certain frequency and times, diamond is then placed on a sieve that is one size smaller than their nominal sizes, and the weight fraction that do not pass through the sieve is measured. TI is the ratio of this weight to the total weight of samples.

Test of Thermal-toughness Index (TTI): The fundamental particles were put into Model TF 1100 Tube Furnace with Gas Protection. They were heated at a high temperature of 1100°C under the protection of Ar for 10 minutes. Then the TI was measured after it was cooled down - that is TTI.

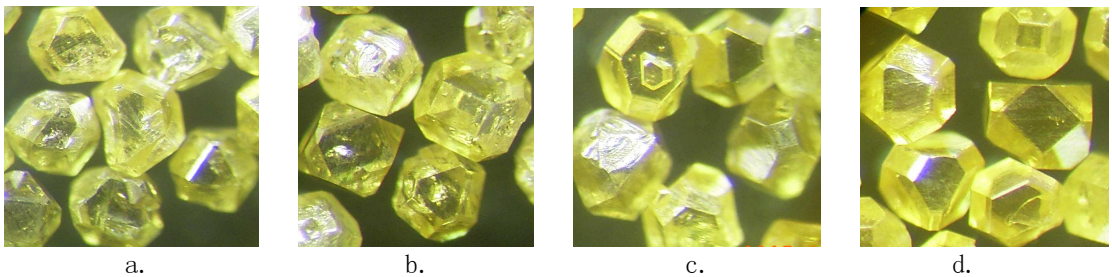
Testing results and discussion

The influence of magnetism on mechanical performances of synthetic diamond with the same particle size and similar crystal shape. After vibrating sorting, 35/40 (Grain size 425~500μm) medium-grade diamond sample No.1, which has the same particle size and crystal shape, are separated in three different magnetic-field intensities.

The product from the weakest magnetic field (240mT) is called highly magnetic product C1; from the medium (360mT), medium-intensity magnetic product C2; from the intensest magnetic field (480mT), feebly magnetic product C3;.The rest material after the magnetic separation is called non-magnetic product C4.

After that, observing each diamond, we can see from C1 to C4, the magnetism tends from strong to weak, and the color gradually changes from dark green to light yellow.

Then micro-structure of each diamond was observed under microscope. It was found that from C1 to C4, the magnetism changed from strong to weak, the color tended to be nearly gold yellow, the crystal shape tended to be perfect, and the surface fineness increased. Conversely, bubbles, defects and impurity content decreased.



a. b. c. d.

Fig.1 Photos of products with four different magnetism

In Fig. 1, it shows photos of products with four different magnetism: (a) the magnetic product with high-intensity, (b) the magnetic product with medium-intensity, (c) the magnetic product with low-intensity and (d) the non-magnetic product under microscope.

At last, the performance test has been done on each product with different magnetism by different kinds of instruments. Results are shown in Table.1.

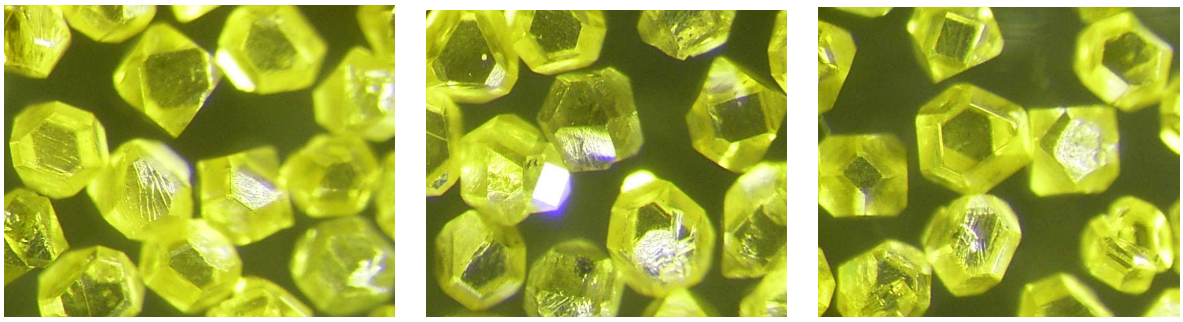
Table 1 Product performance test results with different magnetism

number	weight %	CFF(N)	TI	TTI	thermal stability (TTI / TI)
C1	5.49	217	41.25	18.5	0.448
C2	7.37	249	51.5	35.0	0.680
C3	7.74	315	64.0	46.2	0.722
C4	79.40	426	75.0	73.5	0.980
average	100.00	392.7	70.56	65.5	0.928

Analyzing the results in Table 1, we can see that the magnetism of abrasive particles of synthetic diamond has an obvious influence on their mechanical performances. The stronger the magnetism is, the lower the static pressure strength will be. TI at normal temperature and TTI are lower as well. However, comparatively, static pressure strength and TI at normal temperature from non-magnetic C4 to magnetic C1 with high-intensity only decreased by about 1 time, when TTI is even decreased by nearly 4 times. Thus it is known that the static-pressure strength and TI at normal temperature of synthetic diamond abrasive particles has been comparatively influenced less, but TTI has been greatest influenced by the magnetism.

Thermal stability is the ratio of TTI to TI. So the higher the thermal stability is (closer to 1), the better the quality will be. It appears that magnetic product has a bad thermal stability, while non-magnetic product has a good one.

The influence of specific gravity on mechanical performances of synthetic diamond with the same particle size and similar crystal shape. 35/40 (Grain size 425~500μm) medium-grade diamond sample No.2 after vibrating sorting, with the similar particle size and crystal shape, is divided into three parts: floating material G1, suspending material G2 and settling material G3. The heavy liquid separation test is conducted in a constant temperature bath.



a. b. c.

Fig.2 Photos of products with three specific gravity different

After that, observing the appearance color of each diamond with eyes, we can not see difference. Then observed under microscope, there is no difference in micro-structure of each diamond as well. They have not been influenced too much. In Fig. 2, it shows photos of products with three different specific gravity: (a) the floating material, (b) the suspending material, (c) the settling material.

Table 2 Product performance test results with heavy liquid separation

number	weight %	CFF(N)	TI	TTI	thermal stability (TTI / TI)
G1	19.22	437.4	67.11	57.30	0.854
G2	74.37	346.8	65.62	54.75	0.834
G3	6.41	339.9	64.45	56.04	0.869
average	100.00	363.8	65.83	55.32	0.840

At last, performance test has been done on each product with different specific gravity by different kinds of instruments. Results obtained are shown in Table.2.

Results shown in Table 2 prove that the specific gravity of synthetic diamond abrasive particles has not a remarkable impact on their mechanical performances.

The influence of magnetism on mechanical performances of synthetic diamond with the sample No.2. The diamond sample No.2 are separated into two different magnetic-field intensities. The product from the weak magnetic field (240mT) is called highly magnetic product C1; from the intense magnetic field (480mT), feebly magnetic product C2; the rest material after the magnetic separation is called non-magnetic product C3.

The appearance color and the micro-structure observed under microscope of every diamond samples are almost the same with that magnetic product of diamond sample No.1**.** Obtained results are shown in Table.3.

Table 3 Product performance test results with different magnetism (Synthetic Diamond Sample No.2)

number	weight %	CFF(N)	TI	TTI	thermal stability (TTI / TI)
C1	14.21	220.5	39.74	22.39	0.563
C2	24.65	280.3	59.41	39.72	0.669
C3	61.14	430.7	74.48	69.27	0.936
average	100.00	363.8	65.83	55.32	0.840

Analyzing the results in Table 3, It can be proved that the magnetism of abrasive particles of synthetic diamond also has an obvious influence on their mechanical performances.

After analyzing influence of different magnetism on the quality of synthetic diamond abrasive particles, it is considered that: the magnetic diamond has a bad inner structure with much more defects, bubbles and impurities. Its crystalline shape, integrity and the surface fineness are all bad, resulting in its disadvantages of high brittleness, low plasticity and impact-sensitive, thus TI is apparently reduced. However, due to the strong framework that can support greater static pressure, the compressive strength of the magnetic diamond is not quite low [5].

The decrease in TTI of synthetic diamond is principally due to the metallic inclusion existing in the crystal [6]. The presumption is as follows: Since the thermal expansion coefficient of metal is much higher than that of diamond, metallic inclusion that is formed during the synthesizing process of abrasive particles will expand at a high temperature.

Therefore there will be a large stress generating from the inside of crystal, resulting in a lot of defects. Then those defects will also move and grow up themselves at high temperature. In addition, back-conversion of diamond to graphite around the inclusion may occur upon heating at the temperature higher than 700°C. And it will be more graphitized with temperature increasing. Those three effects will all contribute to the decrease in the TTI of diamond.

Conclusion

In this paper, static-pressure strength, toughness index (TI) and thermal-toughness index (TTI) of each sample have been analyzed on the basis of the experimental studies on the magnetic separation and the heavy liquid separation of diamond abrasives.

Results show that magnetism of synthetic diamond abrasives has an obvious influence on their qualities. With the magnetism increases, synthetic diamond abrasive particles will become darker and darker in appearance colour, and have more and more bubbles, impurities and defects inside the particles. The static-pressure strength, thus TI at normal temperature and TTI become lower and lower. The static-pressure strength and TI of synthetic diamond abrasive particles has been comparatively influenced less, but TTI has been greatest influenced by the magnetism. The magnetic product has a bad thermal stability, while non-magnetic product has a good one.

It is an effective method to divide synthetic diamond abrasive particles into different qualities by their difference in magnetism among particles, and also indicates that reducing the magnetized material in the crystal is an important way to improve the mechanical performances of diamond products. Synthetic diamond abrasives with high TTI and good thermal stability can improve the performance of diamond tools and also prolong their service lives.

And that specific gravity of synthetic diamond abrasives has not an obvious influence on their mechanical performances.

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