6th Zhengzhou International Superhard Materials & Related Products Conference

Proceedings

——Devote to the 50th Anniversary of Industrial Diamond of China

Preface

"The 6th Zhengzhou International Superhard Materials and Related Products Conference & the 50 Anniversary Celebration of Synthetic Diamond in China" is held by Superhard Material (Industrial Diamond) Association of China, CMTBA, and co-sponsored by organizations & companies. Two proceedings, one in Chinese, another in English, are specially compiled and devoted to the conference as the great presents. The outstanding achievements got through 50 years are reviewed, and the latest results got in the recent years are revealed by 69 papers from various sides. The technology gap between China and the advanced countries is analyzed, and the direction for future development is pointed out.

50 years ago, the first synthetic diamond was made successfully in China by Chinese scientists under the very primitive condition. This is one of the brilliant scientific achievements in the history of Chinese science & technology development!

From then on, generations of scientists and engineers in our country have been unremittingly going forward without any fear of difficulties. They have not only established the solid base of research and development for superhard materials in China, but also made outstanding contributions to the development of Chinese machinery, electronics, geological prospecting, oil exploration and production, stone and building materials, roads, bridges and housing construction, and many other high-tech industries. A large scientific research and production industrial system of superhard materials has been formed from pressure transmitting and insulating medium, purified graphite, alloy catalyst, and man-made diamond, cubic boron nitride, PCD, PDC, CVD, nano-diamond, gem diamond to the final tools made by these various types of superhard materials.

After 50 years of hard work, China has become the major country in the international superabrasives and related products arena for the world's production, consumption and export. Especially, the superabrasives production accounts for 90 percent of the global output, and some products have reached the world advanced level. Everything mentioned above has converged intelligence and diligence of Chinese scientists, professors, engineers, managers and workers in the community of superhard materials. Without their unceasing work for 50 years, we could not have seized a great diamond industry in China today, and the people around the world will not be able to enjoy the tremendous benefit which is brought about by Chinese cheap and quality goods of superhard materials. Their efforts history is an epic, and we should remember their imperishable achievements for development diamond industry in China forever.

After 50 years of hard work, We have accumulated a wealth of valuable experiences from their effort history, especially pioneering and innovative spirit and tenacity of daring to take our own unique path of development. Having the two of them, with wisdom mind and the unprecedented and excellent environment that China has integrated into the world economic cycle, industries patriots who are good at learning and innovation will face their own weaknesses and shortcomings, with an open mind to learn from others, and promote our industry from victory to a greater victory.

After 50 years of hard work, China has established and run the State Key Laboratory of Superhard Materials, the National Engineering Research Center for Superhard Materials and Related Products, the National Industrial Base of Superhard Materials and a number of state-level enterprise technical centers. Many universities also have established the research centers related to the test. All these organizations gathered a number of highly educated, high-quality, and high standard of teaching, researching and testing personnel, and with the doctors, and post-doctors who are continuously returning from overseasjoining in. It should be said that, we have preliminarily formed an ambitious team with high quality, it has laid a solid talent base for us to become a powerful country in superhard materials field. We need a strong support for basic research of superbard materials continuously and to provide a perpetual source of techniques for the industry development in our country.

Now, Chinese superhard materials industry has gone through the stage of development from small to large, has entered a new era of creation of superhard material power. Colleagues who are fortunately working in the community of superhard materials in our country, let us do our best efforts to accomplish the great goal.

Academician of Chinese Academy of Sciences
Professor, State Key Lab of Superhard Materials, Jilin University
Oct. 18, 2013

Foreword

To celebrate the naissance of the synthetic diamond in China, "The 6th Zhengzhou International Superhard Materials and Related Products Conference & A Grand Ceremony for Celebrating the 50th Anniversary of Synthetic Diamond in China" is held by Superhard Material (Industrial Diamond) Association of China (IDAC), CMTBA, National Engineering and Technology Research Center for Superhard Materials and Related Products, Superhard Materials and Products Professional Committee of China Materials Research Society, National Engineering Research Center for Special Mineral Materials, Industrial Diamond Information Network and State Key Laboratory of superhard materials, co-sponsored by organizations & companies home and abroad, organized by IDAC & her president unit:Zhengzhou Research Institute for Abrasives & Grinding Co.,Ltd. As a major supporting activity, the 2nd China International Abrasives & Grinding Exposition is held at the same time.

In order to make the conference excellent, 69 articles in Chinese and 21 articles in English are carefully selected by the Conference Academic Committee from more than 100 articles received from home and abroad and compiled in two proceedings, one in Chinese and another in English. The outstanding achievements got in China through 50 years are reviewed on the points, and the latest harvests got in the recent years and developing trends in the world are revealed by the papers in both proceedings from different prospects. It is specially revealed that the brilliant achievements got in China through a lot of statistical data and extensive amount application examples of widely used products such as superabrasives, grinding & cutting tools in machining, sawing tools in stone & construction processing and drilling tools in construction & geological in fine details. The product technology gap which still exists between China & the world's advanced level is explained by data and real examples, the major problems in the development of industry are analyzed from eight aspects, the glorious future of the industry is predicted from the developing trends of the national macroeconomics and the customer industries in this paper. It can be said that this proceedings is a rare important document in the development of the industry which will play an important role to sustain the industry's transformation and upgrading in future development.

The brilliant achievements got though 50 years are worth to be celebrated! Our industry has completed the development courses from growing out of nothing and from small to large; has entered the senior development stage from weak to strong, and at the present, is the critical moment for the industry's transformation & upgrading. The situations of acroeconomy, application industries in China go on better and better continuously, especially emerging industries of strategic importance are booming, low-carbon economy is encouraged. Superabrasive tools which are the typical low-carbon and with extrem characteristics are facing an unprecedented opportunities for development. Although there are still some distance from the world's most advanced technology level, and there are many obstacles on our on-going way, but we have accumulated valuable experiences through 50 years of independent, self-reliance, courage to overcome difficulties and daring to develop the industry by our unique approach. Having adamant idea & strong will, ambitious teams of highly qualified personnel engaged in teaching, R & D, manufacturing and a large number of well trained workers; we have developed numerous advanced technologies, some high-quality products which have reached the advanced world level. Solid foundations and conditions have already been laid for China to become a powerful country in industrial diamond. Our goal will certainly be accomplished as long as we work hard together.

The merit of the published proceedings belongs to the authors, members of the Academic Committee, editors, President Zhu Feng of IDAC and all people who have made a contribution to this book – Sincere thanks to all of you!

There may be such-and-such defects and mistakes which have not been found by the editors because of their limited abilities. We would like to accept any suggestions and criticizing from our readers.

Compilers
Sep.10,2013

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Half a Century:the Struggle to Glory

To Celebrate the 50th Anniversary of Chinese Synthetic Diamond

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Abstract This paper consists of three parts. Using 24 statistical figures and tables, this paper briefly summarizes the remarkable achievements the Chinese superabrasive industry has achieved in the past 50 years since the birth of Chinese synthetic diamond, analyzes the major problems and shortcomings in superabrasive product development, provides the development data of superabrasive application areas in recent 10 years, and concludes with an outlook for future development. The statistical data show the historical development and technological advancement trajectory of the Chinese superabrasive industry: from inception to a small scale producer; from a small to a large-scale producer; from trailing to leading. The paper proposes that the quality of Chinese synthetic diamond monocrystals has reached the international advanced level. It points out the gap between the overall Chinese superabrasive industry and the worldwide counterparts. This paper also outlines the correlation between the growth in Chinese GDP and Chinese synthetic diamond yield. This paper predicts that the Chinese superabrasive industry will soon finish trasformation and upgrading, and win the world champion skip in individual products and eventually become competitive in all superabrasive products by 2020. It's a journey full of challenges and hope.

Key words synthetic diamond; birth; 50 years; achievements

0 Introduction

Fifty years have elapsed since the birth of the Chinese Superabrasive industry, which has now become a comprehensive industry with a large-scale The industry has gone through a few developmental stages: from inception to a small scale producer; from a small to a large-scale producer; from trailing to leading. The government officials and a few generations who worked in the industry have contributed to this achievement with their wisdom and efforts.

Suerabrasive materials and tools are high efficiency, high precision, energy saving, and environmental friendly products. Superabrasive industry highly supports other high-tech industries. The invention of superabrasives not only solved numerous challenging problems encountered when using conventional tools to process new materials, but also helped to develop some new industries. The application of superabrasives has greatly improved the conventional processing efficiency, and significantly

High Pressure Apparatuses for Saw Diamond Manufacture and Their Improverments

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Abstract History followed the path of inevitability and serendipity. For diamond synthesis, the rise of China was inevitable because China was returning to her glory as world's largest economy before the industrial revolution around 1800. On the other hand, Chinese employment of cubic presses as the production equipment for making diamond was the result of western's boycott of belt apparatuses, the mainstream technology for manufacturing high grade saw grits. The author has a Ph. D degree of MIT in high pressure technology (1976), was responsible for diamond manufacture at GE (1980), transferred the diamond technology to Iljin Diamond and Shenzhen Asia with 5000 tons belt apparatuses (1988), also supplied the first magnetic separator and friability tester to Korea and China for the qualification of saw diamonds. At the turn of this century, the author collaborated saw diamond technologies with Diamond Innovations, Element Six, US Synthetic, Zhongnan Diamond, Hounghe Whirlwind and developed the world's first patterned seeding technology for growing saw diamonds. This is the author's review of diamond world war between Western and Eastern cultures.

Key Words diamond synthesis；saw grit；belt apparatus；cubic press

0 Introduction

Diamond synthesis requires a pressure higher than 5 GPa (5000 atm) that is the state about 130 km deep in Earth or at the center of Moon. This type of high pressure was achieved in 1940s by Percy W. Bridgman, a Nobel laureate at Harvard University. He designed the first"massive support" anvils made of cemented tungsten carbide with truncated cones. By squeezing a thin graphite disk between two opposed anvils and pass electrical current, he was able to reach a pressure and temperature much higher than that required for diamond synthesis. However, Bridgman failed to make diamond with this brutal force approach. Even he did, the volume production of diamond with thin squeezed layer was still not possible.

Contemporal to Bridgman's effort in USA was the attempt made by Baltzar von Platen in Europe. He designed a cubic press by employing six anvils to enclose a large three dimensional sample. In 1953, ASEA (General Electrical of Sweden) used such a design and made a few small diamond crystals. This feat was accomplished by a charge that contained graphite and cementite, an iron containing compound. The significance of this diamond synthesis for materials science may be compared to the discovery of DNA for biology in the same year.

ASEA' s cubic press had to process a cumbersome split sphere that was immersed in

Development of Solid PCBN Grades with Low CBN Content

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Abstract The value of low CBN content PCBN tool materials has long been recognized in hardened steels machining, and is increasingly seen as a leading solution for nickel and cobalt-based superalloys. This research presents the development of low CBN content PCBN disks in large solid formats, of up to 91 mm diameter and 12 mm thickness, and presents benchmark machining tests and results which show that the new solid grades can significantly outperform their carbide-backed counterparts. Discussion of the brazing methods and flexibility in tool geometry afforded by these unique formats and the electrical conductivity of the new materials is also presented.

Key words PCBN; inconel; solid format; low CBN content

0 Introduction

Polycrystalline cubic boron nitride, PCBN, has been widely commercially available since the early 1980's, although the range of available grades and properties was, of course, more limited than today. The value of low CBN (cubic boron nitride) content material was quickly recognised, primarily for the continuous machining of hardened steels [1−3], and PCBN grades were thus broadly separated into high and low CBN content materials. This separation was between grades which had a higher than (approximately) 80% volume CBN content, and were used for cast irons, milling and other interrupted cutting operations, and those grades which had 60% or lower volume CBN content. Low CBN content materials were sold as carbide-backed materials, which allowed for easy processing by means of EDM (electrical-discharge machining) and brazing in air with flux using induction or torch methods.

The technical and commercial barriers to developing solid low CBN content grades in the past can therefore be said to be:

(1) the production of a solid material which is electrically conductive but performs competitively;

(2) the brazing of a PCBN microstructure directly to a carbide insert blank (active brazing);

(3) grinding (e.g. peripheral grinding) of inserts with a higher thickness of PCBN.

The development and now commercial availability of such materials can consequently be considered to be the outcome of both improvements in tool/insert-making technology (improved mechanical and electrical-discharge grinding technology, wider use of active brazing techniques) as well as the technical developments required in synthesis and pre-synthesis

Hard Part Turning :New Grade Series With Enhanced Craterwear Resistance and Edge Toughness for Applications Ranging from Continuous to Interrupted Applications

Anshul Singh

(Diamond Innovations, Inc.)

Abstract Hardened steels (45~68HRC) are utilized in a multitude of applications ranging from power traincomponents, bearings, and gear shafts etc. The exceptional hardness, good thermal resistance, and high thermal conductivity of polycrystalline cubic boron nitride (PCBN) have helped it thrive in machining of hardened steels for several years. A new series of PCBN grades focused on hard part turning is presented in this paper. The emphasis of the research was on improvement in tool life, productivity and hence reduced part cost for hard part turning applications. The new PCBN grades demonstrate improved crater wear resistance and edge toughness corresponding to applications ranging from continuous to interrupted turning.

0 Introduction

Hard turning is widely accepted as a method to finish hardened components and offers advantages in terms of high material removal rates with acceptable part geometry and surface finish. Reduced steps during operation, environmental impact and reduced overall cost are some of the documented benefits of hard turning over finish grinding. Several detailed studies on pros/cons of hard turning have been published over the last several years.

Cubic boron nitride (CBN) has been widely accepted as the choice of material for most hard part turning applications. Exceptional hardness, toughness, and thermal properties make it the most suitable material for a wide variety of applications. Historically, the CBN content and binder chemistry have governed the application space that a particular CBN grade is utilized. Typically a high CBN content grade demonstrates superior toughness and abrasive wear resistance. However, for hardened steel applications, typically a low to medium CBN content grade is considered suitable as it provides "chemical or crater wear" resistance to the insert,which are dominant wear modes in these applications. The chemical composition of the CBN grade is thus an important aspect and can affect properties and performance tremendously and is one of the focus areas for the grade series documented in this paper.

Machining of hardened steels (58~64HRC) presents the challenge of severe and rapid wear progression. Tool life is defined as the number of parts that can be machined before the tool needs to be changed. The timing of change (and hence tool life) could depend on a few factors namely loss of surface finish or dimensional accuracy due to flank wear, cutting edge breakthrough due to excessive crater wear (causing weakened edge) and notch wear leading to poor surface finish. Assuming suitable tool geometry used for machining hardened steel in a particular application, wear progression and tool life can be affected by machining conditions that are used during the operation.

Water Jet Laser: for Cutting Single Crystal Diamond, CVD Diamond and Other Ultra-hard Materials

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Abstract The Laser Micro Jet (LMJ) is a precision cutting machine in which the laser pulses are directed down a very fine jet of water. As a result the laser pulses are taken to the bottom of the cut and the sides of the cut remain parallel. The water jet follows the contour of the work piece so no focussing is required and the water cools the material as it is being cut.

Diamond manufacturers and toolmakers can use the wet laser to cut, slice, dice and drill materials such as natural and synthetic single crystal diamond, polycrystalline diamond, polycrystalline PCBN and CVD diamond. Cuts up to 25 mm deep have been achieved with a width of only 50 microns. As the water jet cannot bend, the cuts are perfectly straight.

Wet lasers are already replacing dry lasers for the cutting of high value gem diamond stones as thermal shock breakage is reduced by 50% and the parallel sided cut improves yields and reduces polishing times.

With industrial natural and synthetic diamond, the wet laser can significantly reduce the time taken for shaping the profiles of tools and, as with gem quality diamond, the cutting is cool and much cleaner than with dry laser cutting.

Low CBN content PCBN is thermally shock sensitive and dry lasers can cause cracking. The wet laser prevents local overheating and hence cracking can be reduced or eliminated.

This paper looks at the many advantages water can make to the laser cutting process

0 Introduction

Dry lasers have been used for many years to cut difficult ultra-hard materials. But, in comparison to wet lasers, dry lasers show a number of disadvantages and the introduction of water brings many significant benefits.

The wet laser has been used for the last 10 years for precision machining applications in the watch, semi-conductor, electronics and medical device industries. In the last 2 years it has established itself in the gem diamond industry and more recently for industrial diamond applications.

The optical principle on which the wet laser depends was first explored by Prof. Daniel Colladon in 1841. He found a non-turbulent stream of water could be used as a liquid light guide (Figure 1). He noted that very little light escaped from the sides of the water stream and that: "…when the stream encounters a solid body that obstructs it, the light it contains escapes and the point of contact becomes luminous."

Nanometer Diamonds Development and Application for Polishing Glass Substrates

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Abstract Magnetic storage hard disk drives (HDDs) have been used widely to provide storage of digital information in modern computer systems and consumer electronic products. Hard disk substrates play a key role in the data storage process of HDDs. However, a potential failure mode exists to the head burnish induced clearance requirements by variation induced by substrate nano-asperities. Developing a polish process to eliminate surface asperities and residual surface defects on the glass substrate is therefore a necessity to meet the challenges of future technology. Three distinct diamonds of A, B and C were utilized in this study. The major difference among these three distinct cluster diamond types is the diamond percentage. The differing diamond percentage content in turn induced a different structure and changed the polish properties. HRTEM, XPS, Raman, BET, AFM, Optical Surface Analyzer and disk defect tester were used for the diamond particles, polished substrate and disk analysis. Based on analysis results, the percentage of crystalline diamond in A, B and C solutions is 90%, 80% and 70%, respectively. A, B and C diamond particles exhibited an average primary crystalline size of 8, 6 and 6 nm. The C graphite/diamond ratio is 4.45 which is higher than that of B (3.29) and A (2.88). The C slurry generates relatively smaller R_a as compared to A and B. This is due to the lower diamond percentage with smaller particle density and higher particle surface area in C. Its lower polish penetration depth causes a smoother polish surface, which in turn reduces surface scratches thus improving the disk quality. On the other hand, all of the three slurries show similar polish stock removal amounts.

Key words nanometer diamond; polish; glass substrate; hard disk

0 Introduction

Magnetic storage hard disk drives (HDDs) have been used widely to provide storage of digital information in modern computer systems and consumer electronic products. The disk arial recording density of hard disk drives will keep grow at 50% growth rate per year as the video-audio digital application system and data storage capacity requirements keep moving higher progressively[1,2]. Consequently, to develop a higher recording density disk with good head read/write performance becomes more important to meet the future requirements[3,4]. Hard disk substrates play a key role in the data storage and data accessing process in hard disk

Preparation of Nano-vitrified Bond Diamond Grinding Wheel with Ultra-fine Grain by Polyacrylamide Gel Method

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Abstract Polyacrylamide gel method is used to prepare the monocomponent or multi-component nano-powders and the bond powders. In this paper, the vitrified bond diamond grinding wheel with ultra-fine grain was prepared by polyacrylamide gel method. At the same, the grinding performance was tested on the monocrystalline silicon wafer. Results show that under the conditions of the experiment of grinding process, the grinding wheel prepared by polyacrylamide gel method has the ability to grind the silicon wafer. The surface quality of ground silicon wafers is much better by the grinding wheel prepared by polyacrylamide gel more than that by the grinding wheel prepared by tradition method.

Key words polyacrylamide gel method; vitrified bond; diamond grinding wheel with ultra-fine grain; grinding

With the improving requirement on precision machining, the precision and ultra-precision machining of hard and brittle materials, such as semiconductor wafers, optical glass, engineering ceramics, sapphire, relies heavily on grinding, polishing and other processing methods. Although these methods can achieve high accuracy and low roughness, but it is of low processing efficiency and easy to produce pollution. In recent years, people begin to use ultra-precision grinding instead of lapping, polishing and etching[1], especially in surface grinding of hard and brittle material. With the characteristic of small surface damage layer, low surface roughness, high surface form accuracy, the ultra-precision grinding technology reduces the processing costs and pollution [2], which has attracted wide attention.

Besides high-precision grinding machines, the ultra-fine-grained grinding wheel with excellent performance is an important prerequisite to achieve ultra-precision grinding technology. However, since ultra-fine-grained abrasive is easy to gather , it is difficult to uniformly disperse the grain in the bond in the preparation process of ultra fine- grained grinding wheel, which seriously affects the accuracy and surface roughness of the workpiece. It becomes a hot issues on how to effectively solve this bottleneck problem of ultra-precise wheel all over the world.

High Friable Superabrasive Particles for Tough Material Grinding

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Abstract Superabrasives such as diamond and CBN particles provide extreme performance for grinding tough materials when productivity, precision, and surface quality are keen needed. While diamond and CBN are generally well known for their unique properties of hardness and thermal conductivity, their detail levels of friability actually delivers the ultra performance we are looking for. We look at three relative friable levels of diamond at 1, 2.8, and 4.9, respectively. The grinding results on hard metals indicate that there are significant differences in terms of tool life, surface finishing and grinding power. The friable diamond shows better performance in grinding tough materials such as tungsten carbide alloys.

Key words diamond particles; tough material; friability; grinding

0 Introduction

With increasing demands on productivity, surface finishing, tighter tolerance, superabrasive grits, such as diamond and CBN have been used as bonded or loose abrasive particles in machining tools, traditionally also called grinding/cutting/polishing wheels or slurry. Abrasive machining is a machining process where material is removed from a workpiece using a multitude of small harder abrasive grits. The reasons for using superabrasives grain are well known such as the hardness (see Fig. 1) thermal conductivity and low friction coefficient.

In presumption, the harder abrasive, the better cutting ability. In past several decades, machine tool builders have maximized superabrasive grinding by developing machines whose capabilities not only meet performance specifications of current wheel design but exceed them. Superabrasive grinding, specifically diamond, is currently being swept into the stream of "match this if you can." The grinding speed has exceeded over 20,000 sfm. At higher grinding speeds, it becomes very critical that the diamond grits need keeping constant sharp cutting edges without becoming dull. How to refresh the sharp cutting edges without breaking away grits from wheel bond prematurely becomes a key for a good performance of the diamond tool. Diamond friability, which is defined how easy diamond grit is micro fractured, not diamond hardness is subject of this investigation.

ABN800A: A New High Strength, Sharp CBN Abrasive for Improved Productivity in Aerospace and Automotive Grinding Applications

Wayne Leahy, Cormac Lee, Karolina Hannersjö,
Lars-Ivar Nilsson, Mark O'Sullivan

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Abstract In the automotive and aerospace industries, advances in workpieces materials as well as the constant drive for increased productivity in the manufacture of components from existing materials place increasing demands on the abrasive tooling used and ultimately the abrasives selected. In response to these demands, a new stronger and sharper CBN abrasive, ABN800A, has been developed for vitrified bond tools. Its increased performance is demonstrated in creep feed grinding studies on cast iron and nickel based super alloys. In cast iron grinding, a 23% increase in the G-ratio is observed, while in grinding of Inconel 718 a 10% reduction in the grinding forces is demonstrated-in both cases, the performance is measured relative to the leading CBN abrasives in the market ABN800. ABN800A is expected to find applications in the manufacture of aerospace gas turbine components such as vanes, blades, nozzles and seals and in automotive tooling for engine and drive train components such as camshafts, crankshafts, gears, valves, drive shafts and CV joints, as well as for other tools for grinding hardened ferrous metals and super alloys.

Key words CBN；vitrified bonds；Inconel；ductile iron

0 Introduction

The contribution of the tool cost to the total part cost can be minor in comparison to machine and labour costs. Selection of high performance cubic boron nitride (CBN) abrasives can enable end-users to reduce machine and labour costs per part. This can be achieved by increasing material removal rates and reducing machine downtime by extending redress interval and increasing G-ratios.

These productivity improvements are priorities for the automotive and aero parts industries. Vitrified bonds systems are key to these productivity improvements but the ABN abrasive is the key enabler, it allows the tools to be used a high speeds and feeds and to a large extent determines the tools life. This study compares the characteristics and grinding performance of ABN800 a leading ABN abrasive for vitrified bonds with the newly developed ABN800A . Automotive crank shafts and aero engine components, shown in figure 1 are amongst the most likely applications and so performance is compared in the creep feed grinding of typical materials used for these components, cast iron and Inconel respectively.

Saw Diamonds Grown with Patterned Seeding in Cubic Presses

James C. Sung

(President of Right Diamond Company, and Licensor of Kinik Company)

Abstract Saw diamonds (20-60 mesh) are indispensable for cutting stone and concrete. Hence, their consumptions are correlated with constructional activities. The decades long construction of buildings and highways in China has made the country the largest (in quantities) user and maker of saw diamonds in the world since 1995.

Saw diamonds were typically made by high pressure belt apparatuses (e.g., GE, DB, ID) with a costly die that is easily breakable under hoop tension due to the stretching of the compressed cell. Chinese's cubic presses are equipped with six anvils with no die, and they managed to make more diamond than anvils consumed. Moreover, there are dozens of companies that are competing fiercefully. Consequently, the cost of making diamond in China has been greatly reduced.

The conventional saw diamond manufacture employed cells that contained alternative layers of graphite and catalyst (e.g., Invar metal or Fe_2Ni). This layout limits the interface for nucleation of diamond. At the turn of this century, following the lead of Winter's process, Chinese began to use the mixture of graphite and catalyst to grow saw diamonds. As a consequence, the diamond crystals grown became tighter in size, and stronger in toughness.

In 2003, the author developed patterned seeding for growing saw diamonds in powdered cells for cubic presses. The tests at Zhongnan Diamond (now world's largest saw diamond maker) and Huanghe Whirlwind (now world's second largest saw diamond maker) demonstrated that the diamond sizes were even more uniform, and diamond shapes, much better controlled.

Fig. 1 The three cell designs for growing saw diamond and their optimized yields in carat per cubic centimeter (ccc) of compressed cells. These cells were pressed at Huanghe Whirlwind in 2003.

Production of Thin Diamond Wire

Gerhard Weber

(Dr. Fritsch GmbH, Germany)

0 Introduction

With the growing demand for solar panels, the use of thin diamond wire has been boosted in recent years. However, this thin diamond wire has many more applications than only cutting slices of silicon crystal.

Fig. 1 Wire spool with diamond wire

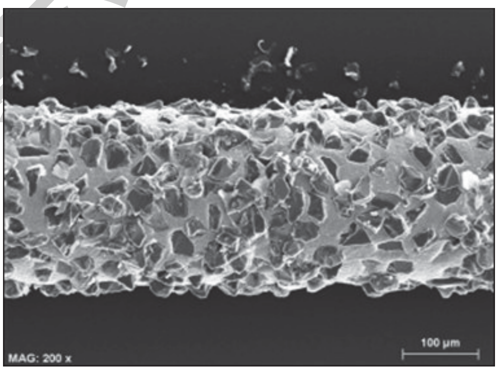

Fig. 2 REM picture of electroplated wire

Previous to the use of this diamond wire, normal, uncoated steel wire (piano wire) has been used together with abrasive grit like silicon carbide. This silicon carbide was mixed with glycol alcohol into slurry and together with the wire, this slurry performed the cutting. Although the price of the slurry and the wire was quite low, the cutting was slow, the cutting surface was unclean and the environmental aspects of the slurry system were questionable.

The slurry method is still state of the art for silicon cutting but has been widely replaced for cutting of sapphire and other hard materials.

The thin diamond wire, produced by electroplating, is completely different to the "thick" diamond wire that is used to cut stone or concrete (Fig. 3 and Fig. 4) . However, there are some interesting parallels in the market development of both kinds of wire.

Fig. 3 Stationary machine for stone cutting wire

Cobalt Powders Used for Diamond Tools and Gang Saws

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(Eurotungstene Metal Powders)

Abstract Cobalt is a bond used as matrix in diamond impregnated tools. Particularly, it is widely used in gang saws to cut marble. In this paper different cobalt powders were analysed in order to evaluate their potential for diamond retention and therefore cutting ability. With this purpose mechanical properties, hardness and tensile strength were investigated. The superior structure stability of Eurotungstene powders was proven by hardness measurements and microstructure examinations at different sintering temperatures. Also, no graphitization was observed even at high sintering temperatures. All these results contribute to high diamond retention and explain the success of cobalt in the alternating movement of gang saws.

Key words cobalt powder ; diamond tool ; gang saw

0 Introduction

With more than 60 years of international experience in powder metallurgy, Eurotungstene operates in business sectors like Diamond Tools, High-Density Materials, Cemented Carbides and recently Metal Injection Molding industry, as a manufacturer of micron-size metal powders.

Eurotungstene's ability to innovate in the Diamond Tools industry has allowed the company to be considered as a technological leader.

In some applications like gang saws, cobalt is the most common material and has always been used with success. For this severe application, there is a need for high diamond retention, which is brought by several mechanical and chemical characteristics. Among these, the effect of as-sintered grain size and hardness in relation with sintering temperature, and bond-diamond interaction visible as graphitization were studied on Eurotungstene powders. All results were compared to a standard cobalt produced by competitors, referred as extrafine Co in this study.

1 Experimental methods

1.1 Powders description

The cobalt powders used in this study (Figure 1) were fine powders ranging from 0.9 to 3.5 μm Fisher size and specially designed for stability in diamond tools hot press processes. This large range of cobalt powders allows covering all diamond impregnated tools applications.

The extrafine Co powder is 1.45 μm in Fisher size and shows similar texture as shown by the SEM aspect (Figure 1). The SEM microscope is a FEI SIRION XL30. The fisher size was measured on cobalt powders with a Fisher equipment, following the ISO standard 10070: 1991.

Development of a Thin BD-PCD Wheel-tool and Research of a Microscopy Examination Biochip-mold Fabrication

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Abstract This study presents the development and application of a thin BD-PCD (Boron-Doped Polycrystalline Composite Diamond) wheel-tool t hat combines reverse RWEDM (Rotary Wire Electrical Discharge Machining) with HSFSG (High-Speed & Fast-Shallow Grinding) for directly generating precision microgrooves onto NAK80 mold steel. The good electrical conductivity of BD-PCD allows for a thin grinding-edge of 5-mm thickness to be produced. The HSFSG technique is used to successfully grind micro-grooves in NAK80 mold steel. The proposed method overcomes the traditional obstacles when using diamond to machine steel by excellent metal removal rates. Experimental results prove the precision of the microgrooves generated. A biochip-mold, possessing micro checkerboard-like layout, is successfully machined by the developed machine tool, the BD-PCD wheel-tool and the designed process. The factors influencing formability, graphitizing of the BD-PCD tool and the accuracy of microgroove are discussed in detail.

Key words BD-PCD wheel-tool；biochip-mold

0 Introduction

Industrial diamond is widely utilized as a tool material. It gives an extremely hard, sharp, and reproducible cutting edge that can be used to fabricate various and high precisie parts with excellent surface integrity and dimensional accuracy. However, two innate weak points of diamond material including the native affinity between iron and carbon atoms that affect tool life allow diamond to transform back to the graphite phase at temperatures above 800°C (Westraadt et al., 2007). The reasons above explain why mold steel is traditionally never machined by diamond tools. In this study, however, the obstacles to machining mold steel with diamond tool are reexamined in the light of advances in tool manufacturing technologies and grinding methods for fabricating microgrooves on mold steel. On the other hand, electrochemical co-deposition of diamond wheel-tools allows for them to be mass produced. The use of thin wheel-tool is effective in die separation or machining micro fluid channels in biochips and microstructures in optoelectronic products. However, this process to form the wheel blank is extremely difficult to maintain uniform dispersal of diamond grits so as to give 8- μm thick cutting edge. More importantly, the thinner the wheel-tool, the higher the co-axial accuracy needed to maintain the required microgroove width.

1 Properties of the BD-PCD

Diamond is an excellent insulator because four

Catalytic Mechanism of Saw Diamond

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(1. Right Diamond Company)

(2. Kinik Company)

Abstract As a historical note on the litigation of GE (General Electric) against DB (De Beers) on patent infringement of diamond synthesis under ultrahigh pressure, GE contended that the molten alloy used for diamond synthesis was used as a catalyst, but DB insisted that diamond was crystalized from the solvent solution that was oversaturated with carbon. It is now clear that for the commercial production of diamond grits under ultrahigh pressure, catalytic function is predominant and the solution mechanism is secondary. If the molten alloy is thick and the temperature is high, graphite may be fully dissolved. In this case, solution mechanism can be dominating. However, even so, the catalytic function is not completely ruled out as solution itself is a result of weak catalytic interaction between solvent atoms and solute atoms. In fact, the catalysis may take the path to pucker graphene to form octahedral (111) lattice plane of diamond. On the other hand, the power of catalysis is manifested in the solubility of carbon atoms in the molten solvent under ultrahigh pressure so the catalysis-solution may be unified as two sides of the same coin. In this report, we examined the template mechanism of carbon solvent to assemble diamond by puckering the suspended graphene under high pressure. We also demonstrated that the same molten catalyst can also reconstitute dissolved carbon atoms to form pristine graphite at ambient pressure. The recrystallized graphite, also known to iron makers as kish, can be the best precursor material for making graphene for many applications.

Key words diamond synthesis; catalytic mechanism; carbon solution; kish; graphene

During WWII, natural diamond grits were indispensable for grinding cemented tungsten carbide, the preferred cutting tools material for making weaponry. After the war, USA stockpiled tons of mined diamond. In 1955, GE made a public announcement of their success in making diamond. The natural diamond cartel De Beers' chairman Ernst Oppenheimer once said that only God could make diamond. However, he immediately set up a team to crack the diamond code.

In 1955, GE applied the patent related to belt apparatuses and Group VIIIa elements (Fe, Co, Ni, Ru, Th, Pd, Os, Ir, Pt) and three other transition metals (Mn, Cr, Ta) (Bundy et al 1955) as the catalyst for graphite to diamond transformation. However, US government suspended these applications by a secret order due to a national defense concern. Knowing De Beers' progress, GE persuaded U.S. Patent Office to issued the patents just a few months before De Beers succeeded in making the first diamond in 1959. In 1960s, GE sued De Beers in South Africa for patents infringement. However, the litigation dragged on for years. One of De Beers defense in the court relied on the term used by GE's patents that described molten metal as catalyst. De Beers argued that the precipitation of oversaturated carbon atoms as

Modern Multi-wire Production

Ute Wilkinson

(Dr. Fritsch Germany)

0 Introduction

The following paper will cover the comparison between Mono-Wire and Multi-Wire applications and the alternative ways to produce Multi-wire. It will also recommend the steps of building an efficient and modern Multi-Wire production.

1 Comparison of mono-wire and multi-wire and its applications

The typical mono-wire has a diameter of approximately 10 to 13 mm. Its main applications are:

1.1 Marbel cutting

In this case the wire is mainly uncoated and with beads, springs, spacers and stoppers.

1.2 Granite cutting

This application again is divided in quarry cutting wire with rubber or plastic coating and with beads and springs and block saw cutting wire which is mainly plastic coated and without springs. The main problem for the granite cutting wire is the life time of the steel cable.

1.3 Construction cutting

In this case the wire can be coated with plastic or wire and usually has springs. Here the main problem is the life time of the beads.

The typical Multi-Wire is used for granite block cutting. The saws vary but have typically 20, 40, 60 or even up to 80 wires cutting simultaneously. The standard diameter today is 6.2 or 7.2 mm. However the trend is going to even smaller diameters of only 5.2 mm. The main problem today with the Multi-Wire saws is again not the life time of the beads but of the steel cable.

2 Alternative ways of producing multi-wire

Today there are 4 main methods of producing Multi-Wire. However, some of the manufacturing processes can be mixed or varied.

2.1 Hipping

HIP stands for hot isostatic pressing. This is the simultaneous application of high pressure (200 MPa) and temperature (up to 2 000 ℃). This process enables the consolidation of metal powders to wire beads.

The main disadvantages of this manufacturing process are the high investment cost of a HIP machine, the low flexibility and the complex process of putting the beads into glass tubes prior to sintering it in the HIP. Especially this complex process requires high labor costs. In addition, a further process of drilling a hole into the steel body of the bead is required. These factors combined make the entire process of Hipping expensive. The main advantage is the very high density of the beads. This ensures a good quality of the final product.

2.2 MIM

MIM stands for Metal Injection Moulding. This

Study on Mechanical Grinding of Large Area Free-standing Diamond Film

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Abstract Mechanical grinding was applied to flat the free-standing diamond film deposited by 100 kW high power DC Arc Plasma Jet CVD system. The influences of grinding speed and pressure on the surface morphology, diamond removal rate and diamond removal mechanism were studied by scanning electron microscopy, digimatic micrometer and X-ray photoelectron spectroscopy, respectively. The results showed that speed and pressure had significant effects on the surface morphology and diamond removal rate. While the grinding speed and pressure were 40 r/min and 0.50 MPa respectively, the diamond removal rate could reach 80.5 μm/h. No iron atoms were detected on the surface of the grinded diamond film. The speculated diamond removal mechanism was mainly the combination of micro-cleavage and stress-induced local graphitization.

Key words large area free-standing diamond film; mechanical grinding; stress-induced; local graphitization

0 Introduction

Since chemical vapor deposition (CVD) diamond film is a very promising material with a series of unique and chemical properties, they have a broad application prospect in today's high-tech areas[1,2]. However CVD diamond films tend to produce some defects,such as non-uniform thicknesses, different grain sizes and surface irregularities, especially for thick CVD diamond films, which seriously limits the widespread application[3, 4]. Therefore, the studies on smooth technique of CVD diamond films have an unusual significance. Domestic and foreign scholars have put forward numerous polishing methods, including mechanical polishing[5,6], thermal-chemical polishing[7], chemical-assisted mechanical polishing [8] , ion beam polishing[9], laser polishing[10], or a synergistic combination of these methods[11].

Because they were prepared by high power microwave plasma CVD or high power DC arc plasma CVD deposition system, only a few companies and research institutes have the ability to prepare large area optical grade free-standing diamond films. Expensive equipment and complex requirement in the deposition process make it difficult to produce large area free-standing diamond films. Polishing of diamond is a very arduous task since it is the hardest and the most chemically inert material known in nature and at the same time the overall strength is low [12]. In this study, mechanical grinding which is regarded as the most original, the most convenient and the simplest method, was used to process the deposited diamond film. The

Research Progress of Nano-polycrystallline Diamond (NPD)

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Abstract In this paper, we would introduce the research progress of NPD as well as our recent works. By direct converting graphite into diamond under high pressure of about 17 GPa and high temperature of about 2 300 ℃, using a two-stage multi anvil apparatus based on the DS6×8MN cubic press developed at Sichuan University, we synthesized the first bulk NPD material in the domestic. We also analyzed the synthetic samples through X-ray diffraction (XRD), scanning electron microscope (SEM), Vickers hardness test. Our preliminary work may be regarded as the pioneering attempt for the industrialization of NPD in China.

Key words nano-polycrystallline diamond; high pressure; research progress

0 Introduction

Nano-polycrystalline diamond (NPD) refers to the diamond products prepared by direct converting of graphite into diamond under static high pressure without any catalysts. This type of product has a single-phase nano-polycrystalline body with strong and direct bonding of fine diamond grains of several tens of nanometers. In 2003, Irifune's group (Geodynamic Research Center (GRC), Uhime University, Japan) prepared the first Nano-polycrystalline diamond by direct converting of graphite to diamond at high pressure of about 15 GPa, and temperature of about 2 300 ℃[1]. Up to now, they can synthesize NPD samples with both diameter and height more than 10mm, as can be seen in Fig.1 (a)[2]. And now the company 'Sumitomo Electric Industries' works with GRC, and has developed a series of "SUMIDIA BINDERLESS" cutting tools using NPD products for ultra-precise cuttings, as shown in Fig.1 b[3].

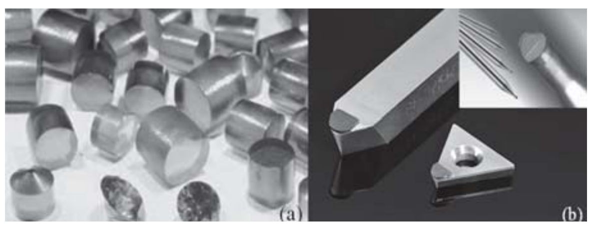

Fig. 1 (a) Nano-polycrystalline diamonds (NPD) synthesized in Irifune' group, with maximum diameter and height up to 10 mm[2]; (b) cutting tools for ultra-high precision machining developed by A.L.M.T. Corp, and the inset shows ball end mills and turning bites tipped with Sumidia Binderless developed by Sumitomo Electric.[3]

Nano-polycrystalline diamond (NPD) is regarded as a new generation of high-performance superhard material. It not only has good performances that a natural single crystal diamond has, such as high density, high hardness and transparency, but also has better physical and chemical properties than those of single crystal and traditional polycrystalline diamond products[4-8].

Study on the Cutter's Abrasion Rule of PDC bit

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Abstract In order to decrease the PDC's abrasion and improve the PDC bit's drilling performance, academic analysis is implemented using PDC to abrade rock in the lathe, as PDC bit cuts rock. In the experiment, the effects on PDC abrasion rule according to the cutting angle, the height of protrusion, linear velocity and the indentation hardness are researched. Under the same stress and friction distance but five different groups of cutting angle, height of protrusion, linear velocity and the indentation hardness, PDC abrasion volume have been measured respectively. The results indicate that, in the same node of the PDC，the smaller the cutting angle is，the bigger the stress is, so is the abrasion volume and the abrasion volume, and thus leading to a shorter life of bit. Secondly, the different cutting angles are suitable to different height of protrusion, like the optimal value of 15° is 2 mm. Thirdly, the PDC abrasion volume and the linear velocity are in direct proportion when drilling, and the PDC abrasion volume can be obtained by the formula $V=\delta\mu PSvt$. Fourthly, the PDC cutter's abrasion volume is in inverse proportion to indentation hardness.

Key words PDC bit; cutting angle; height of protrusion; linear velocity；abrasion rule

0 Introuduction

PDC is short for polycrystalline diamond compact. It consists of two layers, namely the polycrystalline diamond cutting layer (artificial superhard materials) and the cemented carbide (tungsten carbide) substrate layer[1]. PDC bit is a kind of drag bit[2] that made of the drill steel body, set with polycrystalline diamond compact (or welding in drill bits). Besides, it depends on the PDC cutter, welding in the bit body, to cut and shear rock, and some factors as the cutting angle and kinematic velocity of the cutting teeth determine the service life of PDC bit cutter. Many drilling experts and scholars in China and abroad conducted various studies on how to increase the efficiency of breaking rock of the PDC bit and improve the performance of PDC bit[3]. However, the inherent problem of the bit have not been solved effectively.To be specific, how to reduce abrasion of PDC bit remained to be further studied[4]. Once, foreign scholars had used single tooth bench test to research the abrasion rule of the cutter, but the results and the actual wear situation of the cutter could not match well due to the test conditions different from the actual drilling conditions[5]. Therefore, PDC is used to abrade rock in the lathe as PDC bit cuts rock in this paper. By the experiment, the abrasion rules of PDC bit cutter are researched ，which could provide the theoretical basis of reducing the PDC abrasion and certain theoretical basis for the design and application of the PDC bit. It is conducive to improve the comprehensive economic benefits of drilling as well[6].

1 Test

1.1 Test equipment and instruments

The test was conducted on the vertical lathe

Synthesis of PCBN Using on Various Adhesive

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Abstract PCBN is prepared under high temperature and high pressure condition (HTTP) with WC+Co as the matrix. Four kinds of adhesive systems are selected, namely no added adhesive, metal adhesive, the ceramic adhesive and metal-ceramic adhesive. The results show that the synthesis of PCBN has the overall best performance by using metal-ceramic adhesive. Adhesive Al may react with CBN to form AlB_2 and AlN under HTHP.

Key words adhesive; PCBN; synthesis

0 Introduction

Polycrystalline cubic boron nitride (PCBN) composite sheet is prepared under HTHP(1400～1800 ℃, 6～9 GPa) condition, with the cubic boron nitride (CBN) laying powder, adhesive on the top, and cemented carbide as the matrix. The tool can process difficult-to-machine materials such as hardened steel, die steel, white cast iron, die castings, alloy steel, tool steel , cobalt-based and nickel-based superalloys, thermal spray materials, cemented carbide, ceramics, achieving finish machining requirement in application for CNC machine tools, multi-purpose machine tools, automatic lines, dedicated high-speed machine tools, flexible production units or turning flexible production system. Through turning instead of grinding and milling , PCBN is the best tool for machining hardened parts, which can greatly shorten the process by a single process instead of multi-channel processes[1,2].

PCBN is usually synthesized by CBN atoms without or with adhesive. The former has high hardness and brittle because of high CBN content. The latter is variety in different proportions of adhesive which include metal adhesive and ceramic adhesive.

Adhesive for PCBN may be classified into three classes:

(1) Metal adhesive: metal or alloy;

(2) Metal+ceramic adhesive: ceramic and metal or alloy;

(3) Ceramic adhesive: only ceramic.

Different PCBN adhesive systems products have various performance characteristics and purposes [3]. PCBN with metal adhesive generally has high CBN content, good toughness, and better thermal conductivity than that of PCBN with ceramic adhesive. But metal usually will soften at 700~800 ℃,which will lead to the decreasement of PCBN wear resistance. And linear expansion coefficient of CBN and metal are much dissimilar, at the high temperature which will lead to changes in the structure of CBN and the red hardness decrease. The relatively high melting point of the ceramic will not soften. Thus PCBN with ceramic adhesive has a strong wear resistance at high temperature and resisting chemical corrosion. But the ceramic has a poor thermal conductivity at high temperatures, which may concentrate cutting temperature on the material

Research on Impregnated Diamond Bit with Weakening Matrix

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Abstract Weakening matrix theory is applied on design of the drilling bit in order to improve the drilling efficiency of impregnated diamond bit in hard compact rock formation and a weakening matrix of impregnated diamond bit is developed. The results show that drilling efficiency is increased by 68% compared with the conventional impregnated diamond bit. Under the process of drilling, the weakening particle can easily drop from matrix developing non-smooth surface; the working surface area in contact with the rock was reduced; the weakening particle participate in wearing matrix, increases abrasive power of rock powder..

Keywords weakening matrix; impregnated diamond bit; non−smooth surface; particle of weakening matrix; rock fragmentation mechanism

0 Introduction

Ultrahard and weak-abrasion rock have three characters: ① high rock hardness, high quartz. ② high strength, thin rock forming mineral and grain size is 0.01~ 0.20 mm, siliceous cement, high binding power. Uniaxial compressive strength often reaches 150 MPa. ③Weak abrasiveness. The wear of the matrix of a bit is little and diamond is difficult to self-sharpen becaues of less rock powder. Common bit often slips when drillng ultrahard and weak-abrasion rock, causing construction cycle to extend and reducing economic profits. So how to solve this phonenon has practical significance[1-2]. In diamond cutting tool, in order to increase cutting efficiency, some methods are used to decrease wear resistance of matrix under the condition that strength of matrix can meet the operational requirement[3-4]. In this paper, authors take the concepts of weakening and design of diamond bit together, providing new ideas on designing diamond bit that drilling hard compact rock formation.

1 Design of bit

1.1 The method of matrix weaken

Recent studies have shown that different kinds of diamond tools can take different kinds of weaken methods in line with different needs. The methods can be roughly divided into four kinds: technological parameters control method, additive method, non-smooth surface and grain coarsening method. Additive method means adding element such as Si, B ,Re element which can decrease wear resistance of matrix[5]. Non- smooth surface means adding graphite material into matrix, forming non- smooth surface and decreasing wear resistance of matrix. When diamond bit is drilling ultrahard and weak- abrasion rock, it forms thin rock forming mineral, which weakens grinding capacity and diamond self- sharpness, so it requires diamond bit having preferable self-sharpness[6]. So we take additive method and non- smooth surface together to design

Application of PCD Tools in CFRP Machining of Composites

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Abstract With the development of new materials and material synthetic technology, CFRP which has the advantages of high specific strength, high specific modulus, good fatigue resistance, and excellent heat resistance, are widely used in aviation, aerospace, new energy, automotive and other fields. The process of CFRP composite materials by traditional cutting tools shows the defects of short life, low processing efficiency and bad machining quality. Due to the high hardness, high wear resistance and other advantages of PCD tools, special PCD drilling tool for CFRP were developed, by the analysis of CFRP mechanical processing properties and the affection of the micro failure mechanism and the PCD DTH Drill geometry parameters on the processing quality of CFRP composite materials, which provides some help for the process of CFRP composite materials.

Key words CFRP；PCD；DTH drilling；cutting parameters

0 Introduction

CFRP composite (the composites combined of carbon fiber and epoxy resin composite material, referred CFRP composites) has some advantages，such as light weight, high modulus, high specific strength, low thermal expansion coefficient, good thermal shock resistance, good corrosion resistance and good shock absorption, etc. When the weight of CFRP composite is 60% of aluminum alloy, it has three times the strength of the aluminum alloy. CFRP composite has equal strength or stiffness of steel parts while its weight is 30% of steel. In recent years, CFRP composite materials are widely used in automotive, aerospace, aviation, chemical industry, and electronics fields.

But, CFRP composite has some defects, such as anisotropy of mechanical properties, low interlayer strength, easy stratify and tear under the action of the cutting force[1]. So, currently CFRP machining technology has fallen severely behind the development of the material development, which limits its application. In particular, it's so difficult to obtain the components with high surface quality and high geometric shape and position accuracy. In this regard, this article will obtain further research and analysis of CFRP composites processing characteristics through test from the perspective of drilling in order to obtain better processing results.

1 CFRP composites removal mechanism analysis

Due to it's good material toughness and the hardness which is far less than that of the tool material,