CBN-AMX's Latest High Performance CBN Product CBN-AMX

- these crystals were removed from electroplated CBN wheel's (same manufacturer) after grinding 15,000 Specific Volume Material Removed Vol' (mm³/mm) of Inconel 718
- note the consistent 90 degree fracture mode fracture mode for the AMX which directly relates to the long, consistent grinding cycles (note in the Power vs. Volume chart below)
- note that the AMX (Pink line) consistently draws lower power and provides a more free cutting crystal
- note that the Competitor H crystal, also removed after grinding the same amount of workpiece materials, exhibits a non-uniform crystal breakdown that is clearly exhibited in the Power vs. Volume chart

![Power vs Volume Chart]

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COVER PHOTO
Photo of High Pressure High Temperature Cube Press used to manufacture polycrystalline diamond, courtesy of US Synthetic Corporation from INTERTECH 2017 technical presentation.

FINER POINTS is the longest running publication devoted exclusively to the understanding, selection and application of diamond, cubic boron nitride and related materials. It is edited for recipients who are involved in some way with these “superabrasives”, either as providers of the materials, producers of products containing the materials or users of these products (e.g., grinding wheels, dressing tools, drill bits, saw blades, sawing wires, cutting tools, polishing compounds, CVD film products, etc.).

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Featuring INTERTECH 2017 Conference Excerpts and Review
Thank you to the Members and the Board of Directors for the opportunity to serve as the President of Industrial Diamond Association of America for the coming year. I would like to thank my predecessor Ben Williams for the excellent job he has done leading us in the past year to a successful INTERTECH 2017 and Education Course in November of 2016. I look forward to building on this momentum to keep our organization moving forward in the coming twelve months.

Our organization is a community connected by relationships and superabrasives. With INTERTECH and the annual meeting we provide a place for members to network with other ED FRANCIS members for their personal and business growth and to those of you I haven’t met I look forward to meeting you during the coming twelve months.

We need to focus on bringing the best value we can to our members, and continue to educate the new and old generation in the use and application of superabrasives. The Industrial Diamond Association should be the Go To location for anyone needing to learn more about superabrasives and/or our member companies.

Our members look to our organization to provide up to date economic and technical information in these changing times. Finer Points gives us the traditional print method of getting information out to our members and superabrasives community. The IDA web sites provide a resource that can be accessed any time anywhere for people in search of superabrasive information. The monthly IDA eMail Newsletter gives members timely information about our industry and the issues that affect it. There may be other options we have not explored yet that may also become ways to expand the benefits of IDA membership.

I hope with the help and input of the members, we can continue to make this a world-class organization that the members are proud to say that they belong. In closing it is easy to connect the dots looking back but as we are in the midst of finding our way forward in challenging times I am reminded of the commencement address given to the 2005 graduating class at Stanford by Steve Jobs (http://news.stanford.edu/2005/06/14/jobs-061505/) about how the events in his life seemed disconnected but looking back it all made sense.

A small excerpt from Steve’s talk to get you interested; “I didn’t see it then, but it turned out that getting fired from Apple was the best thing that could have ever happened to me. The heaviness of being successful was replaced by the lightness of being a beginner again, less sure about everything. It freed me to enter one of the most creative periods of my life. During the next five years, I started a company named NeXT, another company named Pixar, and fell in love with an amazing woman who would become my wife. Pixar went on to create the world’s first computer animated feature film, Toy Story, and is now making animated movies, doing about everything. It freed me to enter one of the most creative periods of my life. During the next five years, I started a company named NeXT, another company named Pixar, and fell in love with an amazing woman who would become my wife. Pixar went on to create the world’s first computer animated feature film, Toy Story, and is now making animated movies, doing about everything.

This is why it is so important to keep moving forward and we will find that it all connects.

Best regards,

Ed Francis, President
Industrial Diamond Association of America
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The Industrial Diamond Association of America just finished hosting another INTERTECH. It is hard to believe that this conference has withstood the test of time to remain the premier conference on industrial diamond, cubic boron nitride and their applications. It was my pleasure to serve on the first organizing committee for INTERTECH 2000 and since that time I have been honored to serve as the Chairman for every INTERTECH. We have seen innovations and new technology in most industries, from diamond prosthetics and nanodiamond cancer killing drugs in Medical to composite drilling and superalloy manufacturing in Aerospace. Yes, in Optics, Automotive or Construction INTERTECH has heralded so many remarkable applications and new products it is impossible to list them all. Sometimes we forget that superabrasives keep evolving and new generations provide even more remarkable results. CVD Diamond has created new possibilities and coated mesh abrasives or polycrystalline innovations keep our industry new and exciting! INTERTECH 2017 was held this year in San Francisco and our attendees had the opportunity to hear excellent Keynote addresses from noteworthy and distinguished speakers representing leading industry businesses and innovative diamond research. Eminent diamond industry scientist Dr. James Butler retired from the Naval Research Laboratory in 2010 after 35 years of research. His current research interests lie primarily with understanding and exploiting the growth, characterization, properties, and applications of chemical vapor deposited (CVD) diamond materials. Dr. Butler spoke on Advances in Single Crystal Diamond: Enabling Active Diamond Electronics. Shane Collins also was a Keynote and is currently the Director of Additive Manufacturing Programs at CalRAM. Shane holds the position of Chairman of the American Society for Testing and Materials (ASTM) F42 materials and process subcommittee on additive manufacturing and spoke on the international development and publication of technical standards for a wide range of materials, products, systems, and services. Another Keynote address was given by Paul Zimnisky of Diamond Analytics in the New York City, he has worked in the capital markets industry for over 10 years where he has held leading roles as a metals and mining analyst, arbitrage trader, exchange-traded fund developer, and consultant. Mr. Zimnisky spoke on the State of the Natural Diamond Industry and covered the global supply and demand for natural diamond. Attendees also had an outstanding array of technical papers from international presenters representing multiple disciplines and a number of tabletop displays featuring various companies and their products. Judging from the evaluations submitted, this INTERTECH may have been the best yet in terms of technical papers, amenities, events and interest. Everyone seems very excited about participating in and/or attending INTERTECH 2019 in New Orleans!
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### Calendar of Events

**To have your event or conference listed, please send information to:** Finer Points Event Calendar • P.O. Box 29460, Columbus OH 43229 • Fax 614-797-2264 or email: tkane-ida@insight.rr.com

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FEATURING INTERTECH 2017 CONFERENCE EXCERPTS AND REVIEW

NEW BOARD OF DIRECTORS FOR INDUSTRIAL DIAMOND ASSOCIATION OF AMERICA (IDA) ANNOUNCED AT INTERTECH 2017

At the recent INTERTECH the new Board of Directors were inducted. Welcome to new officers: PRESIDENT - Ed Francis of Crystallume Engineered Diamond, VICE PRESIDENT - Shane Hollenabaugh of YG-1 USA, SECRETARY/TEAURER - Kevin Stiles of Radiac Abrasives A Tyrolit Company and PAST PRESIDENT - Ben Williams of FACT USA. Incoming DIRECTORS are Marc Modersitzki of US Synthetic Corporation, Michael Lew of MWI Eloquence Corporation, Jim Long of Greenlee Diamond Tool Company, Julie Griffin of Precision eForming, Eric Bieberich of Fort Wayne Wire Die and Aaron Nolan of Worldwide Superabrasives Solids Division. The IDA Management team of EXECUTIVE DIRECTOR Terry Kane and BUSINESS MANAGER Kathy Kane were also recognized.

BOEING'S LATEST PASSENGER JET ENTERS INTO SERVICE WITH METAL ADDITIVELY MANUFACTURED ENGINE COMPONENTS

GE has reported the first regular flight of the Boeing 737 MAX 8, an aircraft which is powered by two CFM International LEAP-1B engines. The LEAP engines are the first to be built with additively manufactured fuel nozzles. According to GE Reports, fuel nozzles made this way can be manufactured in a single, complex piece instead of requiring assembly. This makes them lighter and more durable, helping to improve the aircraft’s fuel burn. LEAP engines were developed by engineers with CFM International, a joint venture between GE Aviation and France’s Safran Aircraft Engines, and have been in operation since 2008. Altogether, GE states that LEAP-1B engines are providing 15% lower fuel consumption compared with the CFM56-7B engines operating on today’s global 737 fleet. With a running tally of 12,230 orders valued around $170 billion (US list price), the LEAP is the bestselling engine in GE Aviation’s history.

GLOBAL STEEL PRODUCTION CONTINUED STEADY RISE

World crude steel production for the 67 countries reporting to the World Steel Association was 142.1 million tonnes (Mt) in April 2017, a 5.0% increase compared to April 2016. China’s crude steel production for April 2017 was 72.8 Mt, an increase of 4.9% compared to April 2016. Japan produced 8.8 Mt of crude steel in April 2017, an increase of 3.0% compared to April 2016. South Korea’s crude steel production for April 2017 was 5.5 Mt, a decrease of -2.9% compared to April 2016. In the EU, Germany produced 3.9 Mt of crude steel in April 2017, an increase of 8.1% compared to April 2016. Italy produced 2.0 Mt of crude steel, down by -6.0% on April 2016. France produced 1.3 Mt of crude steel, up by 30.8% compared to April 2016. Spain produced 1.2 Mt of crude steel, down by -2.8% on April 2016. Turkey’s crude steel production for April 2017 was 3.0 Mt, up by 6.5% on April 2016. The US produced 6.7 Mt of crude steel in April 2017, an increase of 1.8% compared to April 2016. Brazil’s crude steel production for April 2017 was 2.9 Mt, up by 25.9% on April 2016. The crude steel capacity utilization ratio of the 67 countries in April 2017 was 73.6%. This is 2.5 percentage points higher than April 2016. Compared to March 2017, it is 1.7 percentage points higher.

THE RESHORING INITIATIVE AND PMA LAUNCH FIRST NATIONAL RESHORING AWARD

The Reshoring Initiative, in conjunction with the Precision Metalforming Association (PMA), invites companies that have successfully reshored parts or tooling made primarily by metal forming, fabricating or machining to apply for the first National Reshoring Award. There will be one award for buyers and one award for suppliers. To be eligible for the award, the reshoring work must have occurred between January 1, 2012, and August 1, 2017, and the work must have come back from outside North America to North America. Applications must be submitted by August 1, 2017. To view award details and enter to win, visit www.pma.org/sourcingsolutions/reshoring.asp.
ELEMENT SIX INTRODUCES THE FIRST ELECTRICALLY CONDUCTIVE CVD DIAMOND HEAT SPREADER, DIAFILM™ ETC700, FOR HIGH FREQUENCY & ADVANCED ELECTRONIC DEVICES

Diafilm™ ETC700 delivers exceptional heat dissipation combined with minimal resistive and RF losses, enabling smaller and more reliable high power density devices without impeding electrical performance. Element Six, a world leader in synthetic diamond supermaterials and member of The De Beers Group of Companies, announced today the development of a new thermal grade of synthetic diamond grown by chemical vapor deposition (CVD), Diafilm™ ETC700. The material is both thermally and electrically conductive and is uniquely suited to effectively manage heat in high frequency, high power density devices. With a thermal conductivity up to 700 W/mK, Diafilm ETC700 CVD diamond heat spreaders are three times more effective in spreading heat than alternative ceramic solutions. This electrically conductive all-diamond solution does not require the metal coatings typical of other heat management materials, resulting in reduced frequency dependent conductive losses. Diafilm ETC700 offers better electrical device operation, lower operating temperatures and improved reliability and longer lifespans of high frequency active semiconductors. If interested in learning more about Element Six’s advanced thermal management materials including the newly launched Diafilm ETC700, please visit www.e6.com/thermal.

LARSON ELECTRONICS ANNOUNCES THE RELEASE OF A NEW EXPLOSION PROOF HIGH BAY LED LIGHT FIXTURE

Larson Electronics, a leading industrial lighting company, announced the release of a new explosion proof high bay LED light fixture (EPL-HB-150LED-RT-NSF) to be added to its expanding catalog of products this week. This hazardous location light is approved for use within environments where flammable or combustible gases, vapors, dusts, and fibers exist or stand the potential to exist and is ideal for a variety of applications for safe lighting. This Class I LED light fixture has no exposed glass and provides 17,500 lumens of light while only drawing 150 watts.

LACH DIAMOND PRESENTS NEW PCD TWIST DRILLS TYPE PS

Super fast drills are ideal for machining composites, green carbide, ceramics and graphite. LACH DIAMOND’s newly developed PCD twist drill type PS saves up to 75% of time by reducing three previously necessary steps to one process. The new PCD twist drill completes piloting, drilling and reaming all in one “shot”. LACH DIAMOND looks back on a long tradition of developing and manufacturing PCD drills for the machining of composites – CFRP – GRP – especially for use in aircraft and automotive lightweight construction. LACH DIAMOND PCD twist drills with a point angle of 70° to 180° are available with either double cone or step drill geometry and a double margin for drilling qualities up to h6. The drills are available from ø 2.5 to 12 mm standard size.

SCHUNK EXPANDS MICRO-MACHINING PRODUCTS

TRIBOS polygonal clamping technology has been setting standards in highprecision micro machining for many years. Numerous companies in medical and dental technology, watchmaking, and jewelry, as well as mold making and optical engineering have put their confidence in SCHUNK’s patented toolholding system. Due to the high demand, SCHUNK has now further expanded the line of precision toolholders. The SCHUNK TRIBOS-Mini, designed for micro applications, is now available for high-speed spindle interface HSK-E 20. Compared to conventional steep-angle taper interfaces; the HSK-E 20 ensures exact contact of the toolholder, which allows outstanding change and positioning accuracy. In addition, the close tolerances of the tapered seat result in maximum precision and superior running smoothness at high speeds. SCHUNK has made improvements in other interfaces as well: the TRIBOS-Mini and TRIBOS-RM series with the interfaces HSK-E 25, and HSK-E 32, starting with clamping diameters of 0.5 mm are now optionally available in fine-balanced versions with a balancing grade of G 0.3 at 60,000 rpm. TRIBOS can also be used for applications with very high requirements for dimensional stability and surface quality.

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- Machining of Exotic Materials  
- Thermal Testing & Evaluations  
- And More!  

OBJECTIVE  
“Superabrasive Materials Principles and Applications” is sponsored by the IDA and designed specifically to educate on the use of industrial diamond, cubic boron nitride (cBN) materials classified as superabrasives. It is Non-commercial, unbiased and representative of accepted principles and practices. Content will include a wide range of products and applications for the automotive, aerospace, medical, electronics, optics and other industries using superabrasives. The attendee will be educated in the primary areas of grinding and machining with peripheral explanation for other uses, such as non-abrasive applications.  

WHO SHOULD ATTEND?  
This Course will educate End Users processing materials made from difficult to machine and grind materials such as hardened steel, stainless steel, superalloys, titanium, high silicon aluminum, composites, ceramics, bi-metals, metal matrix composites, cermets, glass, and more! It will also educate Machine Tool Builders, Abrasive suppliers, Raw Material Suppliers, Machine Operators, Wheel Makers, Tool Makers, Research Scientists, Academia, Engineers, Sales Personnel or anyone wishing to learn more about superabrasives.  

INSTRUCTORS ARE INDUSTRY EXPERTS WITH MANY YEARS COMBINED EXPERIENCE!  
Each one has with “real world” knowledge of superabrasives, applications and characteristics. They have already established manufacturing operations in aerospace, automotive and literally every other production operation around the world. Now, you can learn what superabrasives are, where they are used and the characteristics and properties that affect their performance in manufacturing operations. Do you want to understand wear mechanisms in machining and grinding? What is friability? What is a rake angle? What affects chip formation? What crystal is used in a given application? How does burn and thermal damage affect structural integrity of a part? What is residual stress in metal components such as turbine engine fan blades? Why true & dress a wheel? What are the different coolant types and delivery systems? What is edge prep on a cutting tool and why is it performed? What is the Modulus of Resistance and what abrasive performs best on a particular workpiece material and why? If you currently are using conventional abrasives you will learn the advantages of superabrasives and how they can be applied to increase productivity, reduce scrap and improve the cost effectiveness in manufacturing operations.
ABRASIVE WEAR PROPERTIES OF THERMALLY STABLE DIAMOND COMPOSITE MATERIALS

J.N. BOLAND, X.S. LI AND C. HARBERS
CSIRO Energy, 1 Technology Court, Pullenvale, Queensland AUSTRALIA 4069

Introduction

There are many parameters that influence the wear properties of diamond composite materials. Such parameters as manufacturing process, diamond grain size distribution as well as the addition of secondary phases that nominally act as bonding agents (Field, 1992 and references therein; Wilks, 1991 & 1992). The present study is focussed on characterising the specific class of diamond composites referred to as thermally stable diamond composite (TSDC) in which the binder phase is usually silicon carbide (SiC) and the manufacturing process involves the reactive sintering of the diamond phase with molten silicon metal via a carbide formation reaction that facilitates the bonding of the diamond grains (Boland and Li, 2010). The exceptional wear resistance of TSDC as an abrasive wear resistant material has been shown in an earlier study by Li and Boland (2005). Further, with the development of TSDC, tools with these cutting elements are able to operate up to 1300°C which is much greater than the usual limitation of ~800°C of PCD (polycrystalline diamond) class of diamond composites (Boland et al, 2014).

Characterisation of Materials and Experimental Methods

The materials used in this study constitute an integral part of a much broader research program aimed at optimising the wear resistance and mechanical properties of thermally stable diamond composite materials for industrial applications. All samples were reactively sintered in the diamond stability field (1550°C, 5.5 GPa) by a commercial manufacturing company. The major sintering additive was metallic Si which, at these high pressure, high temperature (HPHT) conditions, melted and infused through the interstices in the diamond powder. The specifications of the specific subset of samples used in this study are given in Table 1 in which the composition of the samples is listed as the weight percentage of the starting granular phases (silicon and diamond).

Material Characterisation

All samples – both the starting powder mixes and the reactively sintered products - were examined using (a) a Malvern Mastersizer
As an alternative material for a natural diamond, synthetic diamond is used for dressing tools. For excellent performance, it is necessary to understand the orientation dependence on wear resistance and to select proper orientation when making and using a dresser. In regard to synthetic diamond for dressing tools, its characteristics and using method are described in detail.

1. Synthesis Methods of Single Crystal Large Diamond

As it is well known, there are various methods for diamond synthesis such as temperature gradient (difference) method or solubility difference method under static high pressure, dynamic high pressure (shock wave) method, and chemical vapor deposition method. Among these methods, using the temperature gradient method under static high pressure is thought to be most effective to grow large, good quality diamond crystals of several millimeters. In this method, a carbon source is placed at the hotter part above the solvent (made from ferrous metals, such as Fe, Ni and Co) and the seed crystal is positioned at the cooler part under the solvent in the high-pressure reaction cell. The driving force for crystallization arises from the difference in the solubility of diamond in the solvent that is caused by the temperature gradient in the reaction cell (Fig. 1).

2. Orientation Dependence on Wear Resistance

2-1 Experimental

Rectangular solids (0.8x0.8x3.0 mm³) with end face of (100), (110), (211) and (111) plane were prepared using synthetic diamond. Each solid was ground with metal-bond diamond wheel (Allied Diamond #800) in the wheel speed of 50m/sec. under dry condition for 2 minutes. Pressing load was 0.5kgf. To prevent initial chippings or no uniform wear, some pre-dressing on the testing surface was put to make it smooth. Wear length was measured after grinding for each plane changing dressing direction on the plane. Hereinafter "(110) <110>" denotes <110> direction on (110) plane for convenience sake.

2-2 Result and Discussion

Comparisons of wear volume in various directions on each plane were shown in Fig. 2. The results were almost consistent with the previous works. We found that wear resistance on (211) <110> and (211) <110> are then highest next to (111) plane.
The aerospace industry has pioneered the use of carbon fibre reinforced polymers (CFRP) for numerous years and in many shapes, sizes and types. For applications where CFRP alone might fail, further materials such as Aluminium and/or Titanium are combined to make a multi-material stack. In a safety-conscious industry, mechanical fastening is the method of choice for joining components. This results in the requirement to produce many thousands of holes per aircraft. Hole production to tight tolerances, typically H8, and high economic efficiency requirements, mean CFRP alone is a significant challenge. When adding dissimilar materials in a stack format, hole production becomes highly problematic.

Diamond tooling has proven to be highly successful in drilling CFRP due to its extreme properties such as high hardness, abrasion resistance and thermal stability. There has previously been a gap between the ability to produce the complex cutting geometries required for extreme applications and the shapes of formats available in solid diamond materials. Attempts to bridge this gap using Diamond-like Carbon Coating (DLC) and Chemical Vapour Deposition (CVD) diamond coating of Tungsten Carbide (WC) tool geometries have been partially-successful. However, the unpredictable chipping performance of coatings leads to variable performance and tool life. Combined with the high economic cost of resharpening, this makes coatings less desirable as a tool material than solid diamond in the form of PCD (Polycrystalline Diamond). The advancements in recent years of 3D PCD formats such as Element Six’s Aero-Dianamics™ range, coupled with state of the art tool processing methods such as Electro-Discharge Machining (EDG) and laser processing, has brought PCD to the forefront of cutting tool technology for extreme applications.

So why is a multi-material stack so difficult to machine, even with such an extreme tool material like diamond? The three most common materials utilised in stacks are CFRP, Titanium (Ti) and Aluminium (Al), with configurations such as CFRP/Ti, CFRP/Al or Ti/CFRP/Al. CFRP alone is very difficult to machine due to its anisotropic and non-homogeneous structure combined with highly abrasive reinforcing constituents. Added to this, the resin matrix material typically has a very low temperature resistance. Once the resin’s critical temperature is reached, permanent damage occurs which increases quality issues such as delamination, fibre breakout and uncut fibres. Controlling the process parameters such as cutting speed and feed rate are critical in order to control the temperature generation during cutting. While maintaining a sharp cutting edge enables more effective cutting of each fibre by brittle fracture. In comparison, Aluminium presents a much easier material to machine, by ductile shearing and little abrasive wear results. However, issues such as chip control, built-up-edge and exit burr formation can be difficult issues to control when the tool begins to wear. Contrasting to Aluminium, Titanium is typically extremely difficult to machine due to its low thermal conductivity and high chemical affinity. These cause excessive adhesion of Ti material to the cutting edge which causes a plucking phenomenon to occur, and eventually premature tool failure. Titanium’s low thermal conductivity means all the heat generated at the point of cutting is transferred into the tool. And of course its high strength, retained even at high temperatures, causes high forces during cutting.
ABSTRACT
A lot of automotive parts are made with hardened steel having hardness of 40 ~ 60 HRc. When machining hardened steel, PCBN cutting tool offers many benefits such as increased productivity, high efficiency and environmentally friendly operation. In this paper, newly developed low content PCBN grade, specifically engineered for moderate to heavy interrupted hard turning of hardened steel, is introduced.

INTRODUCTION
PCBN (Poly Cubic Boron Nitride) is made of cbn and many different binder materials by sintering under HPHT (High Pressure High Temperature) condition and widely used as cutting tool material when machining cast iron, hardened steel or hard to machine alloys such as Ni-based superalloy. This paper introduces a new cbn grade developed by a novel method of powder mixing and microstructure design.

PCBN
Low content PCBN is generally used for the machining of hardened steel parts. When manufacturing PCBN, strength, shape and the size of cbn powder are important. Also suitable choice of binder materials and microstructure design are key factors. This study is about a new PCBN grade, specifically developed targeting interrupted machining of hardened steel parts. The PCBN grade has good physical properties of hardness, impact and chipping resistance. And electrically conductive secondary composites are distributed along the grain boundary leading to smooth WEDM cutting. Fig. 1 shows the SEM image of a) conventional low content PCBN, b) new low content PCBN. It is clear that the microstructure of the new PCBN is highly uniform. Fig. 2 is the TEM image of secondary composites such as TiB2, TiN and AlN distributed along the cbn grain boundary.

PERFORMANCE TEST
Machining tests of hardened steel were carried out with the new PCBN and competing PCBN grades in the market. The work material was SCM440H (42CrMo4 / ASTM4140). Performance test 1 is the interrupted turning of hardened steel.
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A Study on Fracture Characteristics of Micron Diamond Powders Under Static High Pressure Conditions

ION C. BENE, PH.D., BENJAMIN R. ROSCZYK
Engis Corporation
Wheeling, IL 60090, USA

CONCLUSIONS

In this paper, we present a novel technique and the associated apparatus developed to assess the crushing strength (expressed as high pressure crushing strength index, HP-CSI) and mode (expressed as the amount and size distribution of fine particles generated), following high pressure treatment of the precursor micron diamond powder used for HPHT sintering of polycrystalline diamond compacts (i.e. PDC cutters for oil and gas drilling, PDC tool blanks and dies, etc.).

ABSTRACT

The manufacturing process of polycrystalline diamond compacts (PDC) consists primarily in sintering of micron size diamond particles into a coherent and homogeneous polycrystalline diamond (PCD) layer on top a tungsten carbide substrate, under high pressure and high temperature conditions (i.e. \( P > 5.5 \) GPa; \( T > 1,400 \) °C).

During ramp-up to sintering pressure at room temperature, many diamond particles are crushed, due to compression and shear stresses. Thus, subsequent to pressure ramp-up, particle size distribution of the precursor micron diamond powder withstands a significant change.

Consequently, besides the HPHT sintering process, fracture characteristics (fracture strength and mode) of precursor micron diamond powder used for high pressure-high temperature (HPHT) sintering of PCD layer, may have a critical contribution to impact strength and abrasion resistance of polycrystalline diamond compacts (i.e. PDC cutters for oil and gas drilling, PDC tool blanks and dies, etc.).

Current technique used to assess the fracture strength and mode of micron diamond powders is based on subjecting the micron diamond powder sample to mechanical forces similar to those encountered in the lapping process [1, 2]. This technique is based on crushing a, virtually, single layer of diamond particles between two sintered polycrystalline diamond surfaces, which rotate in opposite direction, under low compressive force. Thus, larger particles are crushed, mainly due to shear stresses, while smaller particles are not crushed.

The objective of this study is to develop a high pressure apparatus designed to study the fracture characteristics of micron diamond powders under high pressure, and the associated technique to measure the crushing strength of micron diamond powder under static high pressure conditions, corresponding to those used for HPHT sintering of PDC. The crushing strength was investigated by subjecting different micron size diamond powder samples to static high pressure conditions. Prior to high pressure treatment, micron size diamond powder samples were characterized with respect to particle size, particle shape and concentration of crystalline defects. After high...
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Abstract: Thick film chemically vapour deposited (CVD) diamond films have extreme wear resistance, exceptional thermal conductivity and can be attached to tool bodies using commercially viable brazing techniques. Cutting tools fabricated with CVD diamond materials are done so more easily today using laser processes and often in conjunction with superabrasive grinding. The properties of extreme wear resistance make CVD diamond ideally suited to the new challenges of the cutting tools industry today of difficult to machine materials, including composites. This paper will outline the advances in CVD diamond technology and associated processing making it suitable for defined edged applications in continuous and interrupted cutting. In addition, a case study will be outlined demonstrating the type of performance possible when high speed routing carbon fibre reinforced plastic composites.

INTRODUCTION

Unsurpassed hardness of diamond and associated wear resistance is one of the most important properties when considering its use as an abrasive [1]. The major contributing factors to the extreme hardness of diamond are the tetrahedral geometry of the crystalline structure with only C-C covalent bonds and elastic constants in all directions that are among the highest of any material [2]. Diamond also has outstanding thermal conductivity due to phonon transfer and very stiff hybridized sp3 bonds, although the specific thermal conductivity of a diamond crystal is dependent on the origin of the diamond, monocrystal or polycrystallinity structure and the crystal purity [3].

Natural diamond is typically the result of volcanic processes containing kimberlite but the resultant diamond crystals can be found in volcano shafts or basically wherever nature has re-distributed the volcanic lava [4]. Commercial quantities of synthetic diamond can be produced using static and dynamic compression (direct or with catalysts) or by using chemical vapour deposition (CVD) [5]. Polycrystalline diamond free standing films produced with chemical vapour deposition (CVD) are produced in the metastable region for diamond since it occurs at low pressures.

Diamond products, consisting of a matrix of cobalt, with micron sized particles of diamond on a tungsten carbide substrate are commonly referred to as polycrystalline diamond (PCD) or a polycrystalline diamond compact. PCD is produced using static high temperature pressure processes and due to the presence of cobalt is electrically conductive [6]. Many variants exist and the particle size distribution of the diamond in the cobalt matrix can vary from 0.5 microns to 50microns or multimodal combinations of various grain sizes. PCD finds widespread use today in the cutting tool industry as well as in the oil and gas exploration, drilling and mining industries.

Although CVD diamond has been synthesized from the gas phase since the 1950’s [7], thick film CVD diamond has failed to find a broad acceptance in the cutting tool industry, although has been used extensively in diamond dressing tools. Polycrystalline diamond CVD thick films can be produced using hot filament or plasma processes, but the CVD process used, as well as the selection and processing of the produced diamond film all have major implications on the performance of the cutting tool. The ideal properties of a cutting tool, their coatings and performance is discussed in
Active Brazing Methods for Joining Thermally Stable Diamond Composites

Author – THOMAS C. EASLEY, Ph.D.
Presenter – ABDS-SAMI MALIK, Ph.D.
Sandvik Hyperion

ABSTRACT
Several experiments were conducted to determine the effects of alloy composition, test temperature, brazing atmosphere, thermal residual stress, and use of Cu interlayers on the strength of braze attachment of silicon carbide diamond and tungsten carbide. Alloys in the Ag-Cu-In-Ti system with brazing temperatures between 650°C and 920°C were evaluated. All alloys produced good quality braze joints with shear strengths over 250MPa. The results show that thermal residual stresses lower the braze joint strength considerably. Strength can be increased by using alloys with lower brazing temperatures. The use of ductile Cu interlayers can reduce residual stresses without lowering braze shear strength.

INTRODUCTION
Silicon carbide/diamond composites (SCD) comprise a range of materials consisting of diamond particles bonded within a silicon carbide (SiC) matrix. The composites are formed by infiltrating diamond particles with liquid silicon. Silicon reacts with diamond to form silicon carbide in which the diamond particles are embedded. Commercially available SCD have diamond content ranging from 20% to 80% by volume. These materials can be produced using sintering conditions ranging from atmospheric pressures up to 8 GPa and at temperatures ranging from 900 to 1600°C. They are typically formed as monolithic solids, with no supporting substrate.

SCD are prized for their high hardness, abrasion resistance, and thermal stability. SCD produced using high pressure–high temperature (HPHT) apparatus can have diamond content over 80% by volume and have double the strength (TRS) and toughness (K_{Ic}) of other engineered hard ceramic materials such as boron carbide (B_{4}C) and silicon carbide (SiC), making them attractive candidates for many applications requiring a combination of mechanical durability and wear resistance in extremely abrasive environments. However, their widespread use has been hindered due to limitations in brazing technology. To successfully use these materials in applications, they usually must be joined to a suitable supporting substrate, most commonly tungsten carbide (WC). Due to the very low coefficient of thermal expansion (CTE) of SCD (~2 x 10^{-6}) compared to WC (4 to 6 x 10^{-6}), thermally induced residual stresses will be present in the brazed articles, which may lead to reduced strength or cracking.

In this study, active braze alloys, containing titanium, have been investigated for joining SCD to WC. The braze alloy compositions were chosen based on their ability to wet diamond surfaces by the formation of TiC at the SCD surface, and form strong bonds between the alloy, SCD, and WC components. The SCD used in this work was Versimax™, which has a typical diamond particle size of 20mm, diamond content of 80% by volume, TRS of 935MPa, and K_{Ic} of 9.5 MPa(m)^{1/2}. The material is electrically conductive, allowing it to be easily machined using electrical discharge machining (EDM) processes. The brazing and braze shear strength results presented here will be generally applicable to other SCD materials and thermally stable diamond composites because the same surface reaction forming TiC from Ti and diamond will occur, although the properties of the resulting tool will vary greatly depending on the properties and quality of the SCD material.

Due to the good thermal stability of Versimax™ SCD lends it to use in high temperature applications. At elevated temperatures, two competing mechanisms operate which affect the shear strength of braze joints. At elevated temperatures, the braze metal will soften, reducing its strength. However, thermal residual stresses will be reduced at higher temperatures, which may result in higher joint strength. Therefore, there is a need to better understand the mechanical behavior of SCD-WC joints at elevated operating temperatures.

EXPERIMENTAL METHODS
Braze filler metals, in the form of paste or foil, were purchased from Morgan Advanced Materials and Prince-Izant. Brazing was conducted using a vacuum level of < 5 x 10^{-3} Torr or under inert argon atmosphere, and temperatures ranging from 650 to 920 °C. The temperature for brazing was specified by the manufacturer. Brazie coupons were weighted during brazing with > 1 g/mm^2. The braze alloys are listed in Table 1, and the alloy compositions are given in Table 2.
SKYTEC BOLT – A NEW GENERATION of metal bonded diamond wheels for grinding of indexable inserts with electrical discharge conditioning

This paper presents a new generation of metal bonded grinding wheels which are dressed in process using electrical discharge conditioning (EDC). This combined process called “PowerGrind” was developed and introduced by the machine builder Agathon, Switzerland. There are some basic requirements to grinding wheels dressed by electrical discharge conditioning:

Firstly, a highly electrical conductance of the diamond wheel is necessary: Due to the high current flow (up to 60 Amperes discharge current, discharge time 1-2µs) during the electrical discharge the body (carrier) of the wheel, the rim and the interface (glue or thin copper layer) between the body and the diamond layer have to be electrical conductive. It was found out, that the resistance between the diamond layer and body should be lower than 20mΩ, respectively the conductance should be greater than 50S. Usually the rims are glued on aluminum cores which have a sufficient specific electrical conductivity (38*106 S/m).

Secondly, the bond must be machinable by EDC in order to dress, sharp and clean the grinding wheel. In consequence metal bond with a low melting temperature is preferred for a controlled wheel wear. Theoretically, a conductive highly metal (e.g. copper) filled resin bond diamond wheel could be conditioned by EDC. But due to the locally high temperature (T > 4000 K) caused by the spark discharges, the resin bond would be decomposed. Also a electrical conductive ceramic bond would work.

Thirdly, there are some requirements due to the grinding process: The grinding parameters (peripheral speed, infeed, stock) and the
Cutting Diamond Tools By Laser MicroJet®

New developments in the wet laser machining of industrial diamond tools

SEBASTIEN KURZEN, NITIN SHANKAR

LMJ PROCESS

In the Laser MicroJet system, a laser beam, passing through a pressurized water chamber, is focused into a nozzle. The low-pressure water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the water/air interface. The water jet diameter is usually 50 microns and the laser power required is between 25 and 30 watts. While the principle looks simple, years of experimentation and optimization were required to fine-tune the process. The LMJ process works in two stages. The energy of the laser pulses vaporizes the workpiece material by heating while the water cools and cleans the surface in the interval between the pulses. Through a scanning process, a trench is formed that becomes deeper with each pass. As compared to traditional dry lasers, the LMJ “wet laser” technology has many advantages. The most important advantage is that Laser MicroJet cuts with a parallel beam and the cutting depth can extend up to several centimetres. This is not the case with conventional lasers where the focused laser beam has a limited working distance of just a few millimetres due to beam divergence. The beam converges at a focal point and then diverges. Therefore, a focus distance control is required and the working distance is short. The technology behind the Laser MicroJet is based on creating a laser beam that is completely reflected at the air-water interface, using the difference in the refractive indices of air and water. The laser is, therefore, entirely contained within the water jet as a cylindrical beam, similar in principle to an optical fibre. The LMJ process offers several advantages. There is no need for focal adjustment and one obtains parallel kerf sides. There is a minimum heat affected zone thanks to the cooling effect of the water. Finally, there is a high removal rate with debris washed from the kerf. Synova LCS 50-5 Laser Cutting System The Synova LCS 50-5 laser cutting system can cut extremely hard materials with high precision. It is a compact
Measurement of Residual Stress of Polycrystalline Diamond Cutter (PDC) by X-ray Diffraction Technique

D.K. MUKHOPADHYAY and K.E. BERTAGNOLLI
US Synthetic Corporation
260 South 1600 West, Orem, Utah, 84058, USA

Introduction

Since their introduction over 30 years ago, polycrystalline diamond cutters (PDC) have made a significant impact on the oil and gas drilling industry [1]. High penetration rate and long life are some of the attributes of PDC bits. However, PDC cutters may fail prematurely during hard rock drilling. Fig 1. shows a typical PDC failure mode which may be attributed to residual stress. Conventional PDC inserts are made by sintering diamond powder on a cobalt-cemented tungsten carbide (WC-Co) substrate under high pressure-high temperature (HTHP) conditions around 6 GPa and 1400°C. During sintering, cobalt from the substrate melts and infiltrates through the pores among the diamond crystals, producing a zone of depleted cobalt in the substrate near the interface. The molten cobalt dissolves carbon atoms from the diamond crystals and quickly saturates. The dissolved carbon precipitates and forms diamond-diamond bonding among the diamond crystals [2]. As the pressure is released and the PDC cools from sintering, the diamond layer and the carbide substrate shrink at different rates, thus giving rise to residual stress in the PDC. There are several techniques to measure residual stress in PDC [3]. Diffraction methods include X-ray diffraction (XRD), neutron diffraction, synchrotron X-ray, and Raman scattering. Diffraction techniques are generally non-destructive methods of residual stress measurement in PDC. Both neutron and synchrotron techniques have high penetration depth in comparison to X-ray diffraction or Raman but they need special
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New Orleans has many visitor attractions, from the world-renowned French Quarter; to St. Charles Avenue, (home of Tulane and Loyola Universities, the historic Pontchartrain Hotel, and many 19th-century mansions); to Magazine Street, with its boutique stores and antique shops. According to current travel guides, New Orleans is one of the top ten most-visited cities in the United States. A recent poll of “America’s Favorite Cities” ranked New Orleans first in ten categories, the most first-place rankings of the 30 cities included. According to the poll, New Orleans is the best U.S. city as a destination and for stylish boutique hotels, cocktail hours, singles/bar scenes, live music/concerts and bands, antique and vintage shops, cafes/coffee bars, neighborhood restaurants, and people watching. The city also ranked second for friendliness, hotels/inns, and ethnic food. The French Quarter (known locally as “the Quarter” or Vieux Carré), which was the colonial-era city and is bounded by the Mississippi River, Rampart Street, Canal Street, and Esplanade Avenue, contains many popular hotels, bars, and nightclubs. Notable tourist attractions in the Quarter include Bourbon Street, Jackson Square, St. Louis Cathedral, the French Market (including Café du Monde, famous for café au lait and beignets), and Preservation Hall. Also in the French Quarter is the old New Orleans Mint, a former branch of the United States Mint which now operates as a museum, and The Historic New Orleans Collection, a museum and research center housing art and artifacts relating to the history of New Orleans and the Gulf South. To tour the port, one can ride the Natchez, an authentic steamboat with a calliope, which cruises the Mississippi the length of the city twice daily. Unlike most other places in the United States, New Orleans has become widely known for its element of elegant decay. The city’s historic cemeteries and their distinct above-ground tombs are attractions in themselves, the oldest and most famous of which, Saint Louis Cemetery, greatly resembles Père Lachaise Cemetery in Paris. The city and area boosts numerous museums and attractions of major interest and historical value. New Orleans ranked No. 7 on Newsmax magazine’s list of the “Top 25 Most Uniquely American Cities and Towns,” a piece written by current CBS News travel editor Peter Greenberg. In determining his ranking, Greenberg cited the city’s rebuilding effort post-Katrina as well as its mission to become eco-friendly. The New Orleans area is home to numerous celebrations, the most popular of which is Carnival, often referred to as Mardi Gras. Carnival officially begins on the Feast of the Epiphany, also known as the “Twelfth Night”. Mardi Gras (French for “Fat Tuesday”), the final and grandest day of festivities, is the last Tuesday before the Catholic liturgical season of Lent, which commences on Ash Wednesday. The largest of the city’s many music festivals is the New Orleans Jazz & Heritage Festival. Commonly referred to simply as “Jazz Fest”, it is one of the largest music festivals in the nation, featuring crowds of people from all over the world, coming to experience music, food, arts, and crafts.
Progresses of Grinding Technology of Monocrystalline Silicon Carbide; for Longer Tool Life and Higher Quality Finished Surfaces

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ABSTRACT
In order to accelerate the mass production of SiC power semiconductor devices, which possess a higher performance than Si based power semiconductor devices, lowering the machining cost and obtaining higher-quality finished surfaces in the wafer thinning process are crucial. This paper will introduce the latest progresses of grinding technologies of SiC wafers, which can significantly reduce the machining cost and improve the quality of finished surfaces.

INTRODUCTION
Power semiconductor devices and SiC

Due to the growing concern of energy depletion, power semiconductor devices that enable more efficient use of electricity in many fields such as automobiles, trains, and power grids, are gathering more attention and projected to be increasingly prevalent. Currently, the most commonly used material for power semiconductor devices is silicon (Si). However, the performances of Si-based power semiconductor devices have almost reached the limitation of the physical property of Si, and it is said that it cannot meet the forthcoming requirements for power semiconductor devices, e.g., higher operating temperature and voltage resistance.

Silicon carbide (SiC), on the other hand, possesses superior physical properties and is considered as a more promising material for next-generation power semiconductor devices. By employing SiC, power semiconductor devices can work in the said severe conditions and reduce the losses of electricity thanks to its high switching performance.

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Patents – a key facet of IP protection for the superabrasive/industrial diamond industry

DUSTIN JOHNSON AND KEVIN HARDAWAY
Haynes and Boone LLP

Patent filings continue to increase each year in the United States and across the developed world. Many developers in the superabrasive industry use patents to protect their investment and obtain strong market positioning.

Fundamental Patent Principles and Rights Granted

Of the different types of intellectual property, patents and trade secrets are best suited for most inventions in the superabrasive industry. Each has advantages and disadvantages. Trade secret protection is best suited for intellectual property that cannot be easily reverse engineered. Trade secrets have no expiration date, but require reasonable efforts to protect against disclosure. So long as competitors do not develop the same product, trade secret protection may be a good avenue to protect intellectual property. Many corporations, however, employ business strategies that include reverse engineering or otherwise copying successful products.

Patents can protect products and processes that may be reverse engineered. They provide a limited monopoly to a patent holder enabling them to prevent others from making, using, selling, offering...
PCD Bits for UNDERGROUND Roof Bolting

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Sandvik Mining and Construction G.m.b.H

ABSTRACT

This work first describes briefly some of the roof bolting technologies available in the market for soft and hard rock conditions. For targeting particularly roof bolting in coal mines, Sandvik has developed a new PCD drill bit line giving an increase in performance productivity for Sandvik continuous bolter miners. Experimental work during product development was mainly carried out by laboratory drilling with one instrumented Sandvik DO100 drill-rig and incremental improvements were observed by analyzing drilling parameters data logs, bit failure mechanisms and estimated total bit lifetime. PCD characteristics including different finishing conditions were tested and analyzed. A final design was qualified at the laboratory and confirmation with mine field tests collected. Tests beyond the original target are highlighted including hard-rock granite drill experiments with an adapted Sandvik Axera 5 at Sandvik’s Tampere test mine in Finland.

INTRODUCTION

Roof bits are used to drill holes in the strata before anchoring bolts are utilized to secure the roof of mines. The first application of diamond for roof bits dates to more than 20 years ago [Brady], [Sheirer et al.]. Originally those bits were targeted for North American coal mines trying to replace traditional carbide bits. The main objective for using PCD was to extend the life of the tools and simplify the logistics of the operations by reducing the number of bit-changes per time period. The perceived reliability of operation by the customers has been the main problem for extending the usage of these drill bits.

DRILLING FOR ROOF BOLTING

Two types of roof bolting technologies exist primarily based on the rock type to be drilled. For hard rock mines like copper or platinum mines, roof rock drilling with percussion bits has shown to be the most economical choice. For more soft rocks like coal or potash/salt mines pure rotary drilling is used since higher drilling speeds are theoretically achievable [Feistkorn]. The drilling equipment and consumable tools are more economical for the case...
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