WORLD PM2022
CONGRESS & EXHIBITION

ABSTRACTS – GROUP 1

HARD METALS, CERMETS AND DIAMOND TOOLS

WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225363762

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Raffalt Daniel (Institut für Fertigungstechnik (IFW), Germany)

Co-author(s): Dr Ing Bergmann Benjamin ; Prof Dr Denkena Berend (Institut für Fertigungstechnik (IFW), Germany)

Title: Manufacturing Of Graded Grinding Layers

Keyword(s):
Grinding wheel manufacturing, Mechanical testing, FAST sintering, Abrasive layer design

Abstract:
Grinding of end mill cutters leads to an unevenly radial wear of the grinding wheel due to varying geometric engagement conditions. This results in a decreasing precision of the resulting tool geometry. Previous studies showed that simulation-based load-adjusted grinding layers reduce the uneven wear. A grain concentration gradient across the grinding layer width enables the load-adjustment. For an effective reduction of the wear differences, an accurate and repeatable manufacturing method for smooth transitions between the concentration zones is required. This paper shows an approach for the manufacturing of graded grinding layers by Field-Assisted-Sintering. SEM images are taken of cross-sectioned grinding layer samples. An image analysis software was used to evaluate the grain concentration gradient. As a conclusion, the comparison of the manufactured gradients with the simulated gradients shows that the presented manufacturing method allows repeatable fabrication of graded grinding layers.

Innovative Aspect(s):
The innovative aspects of the project concern the availability of a reproducible and knowledge-based manufacturing process of graded grinding wheels that significantly increase the productivity of tool grinding. The production of graded grinding wheels with more than two discrete zones has not been investigated yet. A load-adjusted design of the graded grinding wheels requires as exact replica as possible of the gradient. This aspect has not been realized in manufacturing technology to date and represents a major challenge. The project aims to set continuous transitions between the grain concentration zones. Further, the influence of the graded zones with respect to the mechanical grinding layer properties was investigated. Both aspects are the basis for developing an innovative approach to optimize the wear behaviour during tool grinding. The presented work thus enables a knowledge-based production of graded grinding wheels, which can exactly represent the specifications of the grinding tool design.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225366399

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Mhadhbi Mohsen (National Institute of Research and Physicochemical Analysis, Tunisia)

Co-author(s):

Title: Spark Plasma Sintering Of Nanostructured TiCrC Carbide Processed Via High-Energy Ball Milling

Keyword(s):
Nanostructre, TiCrC carbide, Microstructure, Milling, Spark plasma sintering

Abstract:
In this work, spark plasma sintering (SPS) process was employed for the consolidation of nanostructured TiCrC carbide prepared via high-energy ball milling in order to prevent any important grain growth of the compact materials. The (Ti,Cr)C phase was obtained after 5 h of milling. The X-ray diffraction (XRD) study showed that towards the end of the milling process (after 20 hours), the nanocrystalline powders achieved a critical size value of less than 10 nm. Thus, some physical and mechanical properties of the bulk samples were investigated as a function of the starting grain size powders obtained after various milling time. The mean crystalline size of the bulk samples was found to be increased to reach a maximum value of 95 nm for carbides milled for 20 h. Indeed, the Vickers hardness showed to be improved to about 2650 HV for a maximum density of 97 % of the bulk material.

Innovative Aspect(s):
Innovative developments of material sciences and engineering have progressed. The present study will form the basis for the systemic selection of TiC content for the processing of TiCrC nano-carbides with target mechanical and tribological properties. In fact, this work aims to elaborate a new and competitive nanomaterials (nano-carbides) with interesting physical and mechanical properties using a simple and low cost process. Titanium carbide tools, which are used in machining but not other cutting tools like knives or punches, can be operated at cutting speeds many times higher than those used with high-speed steel. In addition to that, this work aims to improve the physicochemical and mechanical properties of the prepared nanomaterials (TiCrC nano-carbides) by optimzation of all the parameters during processing (milling and consolidation). The other innovative aspects in this work are the use of new materials, simple, easy, and not expensive route, the combination of two routes (milling and spark plasma sintering).

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225366866

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Oliveira Gonçalo (University of Coimbra, Portugal)

Co-author(s): Mr Mineiro Ricardo ; Prof Dr Rocha Senos Ana Maria ; Prof Dr Vieira Costa Maria Elisabete (University of Aveiro, Portugal) ; Dr Fernandes Cristina Maria ; Mr Figueiredo Daniel (Palbit S.A., Portugal) ; Prof Dr Vieira Maria Teresa (University of Coimbra, P

Title: Indirect Additive Manufacturing (Material Extrusion) As A Solution To A New Concept Of Cutting Tools

Keyword(s):
Material Extrusion (MEX), Filament Production, Cermets

Abstract:
Cermets are a staple among high-speed machining and finishing materials, given their high hardness at high temperatures, high thermal shock resistance, and thermal conductivity. Compared with hard metals (i.e., WC-Co) and even when coated, their machining performance is remarkable for the improved surface finish and longer tool life. New tools design obliges new manufacturing solutions, like additive manufacturing (AM). TiCN based on WC and 15wt.% Co|Ni binder and secondary carbides Mo2C and NbC prepared as the ceramic constituent to filament production for indirect AM process - Material Extrusion (MEX). The filaments result from the extrusion of a feedstock previously optimized. Firstly, in what concerns 4Ss (particle Size, particle Size distribution, particle Shape and particle Structure) powder of cermets and binder|additive optimization. Secondly, the suitability of polymer selection and critical powder volume percentage (CVCP) for different binders and additives will be evaluated through its "printability" and sinterability in the MEX technology.

Innovative Aspect(s):
Cermet cutting tools and parts with unconventional geometry impossible|costly to produce by conventional means. Filaments easily tailored|customized according to the part produced. Near net-shape manufacturing with almost no waste.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225367225

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Solodkyi Ievgen (Igor Sikorsky Kyiv Polytechnic Institute, Ukraine)

Co-author(s): Mr Teslia Sergii ; Prof Dr Yurkova Olexsandra ; Prof Dr Bogomol Iurii ; Prof Dr Loboda Petro (Igor Sikorsky Kyiv Polytechnic Institute, Ukraine)

Title: Metal-ceramic Composites Based On Reinforced Ceramics

Keyword(s):
Hardmetal, High entropy alloy, Spark plasma sintering, Structure, Hardness, Fracture toughness

Abstract:
The work contains results of the R&D of a new class of metal-ceramic composite materials based on reinforced composites and high entropy alloy (HEA) as a binder. AlCrFeCoNiV(Ti) HEA was used for the densification of WC-W2C(B4C–TiB2) eutectic particles by spark plasma sintering. Thermodynamic, kinetic, thermomechanical compatibility of AlFeCoNiCr(V)Ti –(WC-W2C)| (B4C–TiB2) composites were investigated. In the case of using WC-W2C eutectic particles, the W2C phase dissolves in the HEA matrix and forms a core-rim structure leads to the formation of a reinforced boundary and grain refinement. Also, the interaction of the boron carbide phase of the eutectic particles B4C-TiB2 with HEA leads to the formation of a unique reinforced grand boundary. As a result, the average value of the hardness of (WC-W2C) – HEA and (B4C–TiB2) – HEA composites reaches 93 HRA (HV = 16 GPa) and 21 GPa, respectively, while the Palmqvist toughness reaches 17 MPa·m1|2 and 14 MPa·m1|2.

Innovative Aspect(s):
WC|Co hardmetals are widely used in various industrial applications, where high wear resistance, hardness, and toughness are important. However, due to high cost, diffusion activity, and carcinogenicity, many studies have been carried out to find the suitable binder to replace Co metal. High entropy alloys (HEAs) are promising in this respect owing to their excellent mechanical properties. For the first time the application of reinforced ceramics (WC-W2C) and (B4C–TiB2) as hard and tough particles in metal-ceramic composite was proposed. As a result of controlled chemical interaction, an excellent adhesion between the ceramic particles and the HEA matrix is observed, suggesting the potential of using HEAs as alternative binders. Thus, substitution of Co for HEA in WC–Co can significantly improve the performance of hardmetals due to the combined effect of grain refinement and solid solution strengthening of HEA.

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WORLD PM2022 CONGRESS & EXHIBITION
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Paper number: WP225367422

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Prof Dr Llanes Luis (Universitat Politècnica de Catalunya, Spain)

Co-author(s): Dr Liu Chao (Xiamen Tungsten Co., Ltd., China) ; Prof Jiménez-Piqué Emilio (Universitat Politècnica de Catalunya, Spain) ; Dr Wang MS (Xiamen Golden Egret Special Alloy Co., Ltd., China) ; Dipl-Ing Ortiz Laia (Universitat Politècnica de Catalunya, Spain)

Title: Surface Machining Of Artificial Small-scale Flaws By Laser Ablation Routes In Hardmetals: Implementation And Potential Application For Assessment Of Damage Tolerance

Keyword(s):
Hardmetals, Small-scale flaws, Laser ablation, Damage tolerance, Mechanical strength, Fracture toughness

Abstract:
The precision offered for laser ablation has positioned it as an effective technique to generate micronotches used for evaluation of mechanical properties in structural materials. However, similar approach has not been attempted for hardmetals; thus, it becomes the main objective of this work. Dimple-like and elongated micronotches are introduced in a fine-grained 9%wtCo WC-base hardmetal using a laser machining platform consisting of a solid-state Nd:YLF, Q-switched laser set-up. In doing so, laser processing parameters are first optimized to attain micronotches with geometry and size similar to common critical flaws found in cemented carbide specimens. Success of the implemented approach is then validated through subsequent flexural testing and fractographic inspection of surface notched samples. The suitability of laser ablation for shaping artificial small-scale flaws opens a new route for introducing “controlled” defects, alike those intrinsic to processing or induced during service, key aspect for further understanding damage tolerance issues in cemented carbides.

Innovative Aspect(s):
First systematic studied involving laser ablation for machining artificial small-scale flaws in hardmetals. Suitability found for this technique and purposed in this research, opens a new route for introducing “controlled” defects in cemented carbides, key aspect for further understanding damage tolerance issues in these materials.

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WORLD PM2022 CONGRESS & EXHIBITION
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Paper number: WP225368056

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Cinca Núria (Hyperion Materials and technologies, Spain)

Co-author(s): Prof Olson Mikael (Dalarna University, Sweden)

Title: Friction, Material Transfer And Wear Phenomena In Sliding Contacts Between Cemented Carbide And Aluminium During Metal Forming

Keyword(s):
Cemented carbide, Wear, Abrasion, Metal transfer, Metal forming

Abstract:
In many metal forming processes, certain texturization of the tool is necessary to have some friction that can make the operation possible. One example of that is the use of crosshatching methods on cemented carbide punches to manufacture beverage cans. The deep drawing and ironing process of the aluminum foil during can production involves different wear mechanisms being active on the punch surface, i.e. microabrasion and metal transfer. The present work examines the abrasive wear performance and friction characteristics of two cemented carbide grades by means of scratch and linear reciprocating sliding wear testing with Al2O3 counterparts under dry and lubricated conditions, with smooth polished and textured cemented carbide surfaces respectively. Additionally, well-controlled tests in which an aluminum pin is sliding over the cemented carbide surface were performed to evaluate the initial metal transfer. Post-test characterization shows the influence of carbide microstructure on the friction, material transfer and wear

Innovative Aspect(s):
This work is not a simple fundamental tribology study of cemented carbides, but rather intends to correlate with what is observed in metal forming application. It considers not only the friction behavior, but also an accurate SEM study that tries to elucidate the abrasive and adhesion wear micromechanisms behind. For this purpose, two cemented carbide grades that are currently used in the field have been tested under dry and lubricated contitions, as well as with two surface treatments (polished and textured). The tribology testing uses aluminium and alumina as counterparts in order to evaluate adhesive and abrasion respectively. The results serve to determine a good correlation of the tribology testing methodology with the performance. Also, it is pointed out how important is the surface preparation to change the friction properties and affect the service life.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225368303

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Roa Rovira Joan Josep (STEROS GPA SLU, Spain))

Co-author(s): Dr Cinca Núria ; Miss Tarres Elena (HYPERION Materials & Technologies, Spain) ; Dr Monclus Miguela ; Dr Molina-Aldareguía Jon Molina (IMDEA MATERIALS, Spain) ; Prof Dr Miguel Llanes Luis ; Miss Riu Perdrix Guiomar (UNIVERSITAT POLITÈCNICA DE CATALUNYA, Sp

Title: Surface Integrity At Intermediate And High Temperature Of Constitutive Gamma-phases Of Cemented Carbide

Keyword(s):
Surface integrity, Hot hardness, Elastic modulus, Service-like working conditions, Plastic deformation mechanisms

Abstract:
The present work is focused on the surface integrity on g-phases of cemented carbide polished by means of the DryLyte® technology. A systematic nanomechanical study of a different γ-phases is investigated. In doing so, nanoindentation technique is implemented and the main deformation|damage mechanisms are investigated at different temperatures, from 25 up to 600°C. In general, two different approaches are followed to accomplish this research: (1) assessment of intrinsic hardness values as a function of crystallographic orientation from 25 up to 600°C and (2) the determination of effective hardness and flow stress through the Tabor's equation of the metallic binder. The preliminary results, highlight that the strength reduction as temperature increasing is attributed to metallic binder softening. On the other hand, the cemented carbide particles present an isotropic behavior when the testing temperature is over 500°C due to the high density of the main plastic deformation mechanisms confined inside each phase.

Innovative Aspect(s):
The main innovative aspects on this work are: (1) The DryLyte technology has been emploied on cemented carbides in order to get a flat surface with a roughness below a superficial roughness of around 20 nm (2) To evaluate the surface integrity (in terms of hardness and elastic modulus) under service like working conditions for each constitutive phase from room temperature up to 600°C (3) Determine the flow stress for the metallic binder (4) Investigate the main plastic deformation mechanisms by using advanced characterization techniques (i.e. transmission electron microscopy, scanning electron microscopy and atomic force microscopy).

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225368559

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Huang Shuigen (KU Leuven, Belgium)

Co-author(s): Ing Wong Eric ; Dr Göksel Berfu ; Dr Qian Jun ; Prof Vleugels Jozef (KU Leuven, Belgium)

Title: Direct Ink Writing Of Open And Dense NbC-Ni Matrix Cermet Structures

Keyword(s):
Direct Ink Writing, AM, NbC, Cermet, Sintering

Abstract:
Direct Ink Writing (DIW), also known as robocasting, is a paste extrusion-based layer-by-layer additive manufacturing technique suitable for manufacturing complex geometry green compacts. In this study, NbC-Ni matrix cermets with either a porous scaffold structure or a pore-free rectangular bar geometry were prepared using a combination of DIW and sintering. The water based feedstock ink contained 40 vol% cermet powder mixture and 25 wt% pluronic F-127 hydrogel. The ink was rheologically characterized and printed using a DIW device. Thermogravimetric analysis (TGA) of the paste was performed to define the thermal debinding cycle. After debinding, the printed parts were sintered for 90 min at 1420 °C in vacuum. The microstructure, phase constitution, room temperature hardness and fracture toughness of the printed parts were investigated and compared with cermets obtained by conventional press and sinter powder metallurgy.

Innovative Aspect(s):
The first time a NbC-Ni paste can be printed through direct ink writing. Both a open and dense structures were obtained through the printing and sintering methods. The processed material exhibited a similar microstrure and mechanical properties with a conventional press and sinter powder metallurgy.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225369168

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Ing Fang Shiqi (Saarland University, Germany)

Co-author(s):

Title: Assessment On Two-dimensional Methods Of Microstructural Characterization And Analysis For Cemented Carbides

Keyword(s):
Cemented carbide, Microstructural properties, Phase ratio, Grain size, Optical microscope, Scanning electron microscope

Abstract:
Cemented carbide is a group of hard materials, often made into cutting tools for chip-removal or forming processes such as turning, milling, and rolling. Cemented carbide is a composite based on metallic matrices, e.g., tungsten carbide and cobalt. Their microstructural properties often have deviations from the theoretical estimations, largely because of the sintering production and characterization methods. This work is focused on the characterization methods of the two properties, i.e., phase ratio and grain size, under laboratory conditions, namely, point analysis (PA), line analysis (LA) and area analysis (AA). Images were acquired by different microscopic techniques, i.e., optical microscope (OM), scanning electron microscope (SEM) using secondary electrons (SE) and backscattered electrons (BSE). Results are assessed in order to protocol these methods in line with accuracy, accessibility and operability.

Innovative Aspect(s):
Compare and protocol some characterization methods for laboratory use.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225369324

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Prof Dr Lengauer Walter (Vienna University of Technology, Austria)

Co-author(s): Dr Ing Scagnetto Fabio (Vienna University of Technology, Austria)

Title: Ti(C,N)-based Cermets For Sawblades: Preparation, Properties, Testing And Upscaling

Keyword(s):
Cermets, Titanium carbonitride, Sawblades, Chop saw, Stainless steel

Abstract:
While hardmetals are a common teeth material of both, circular and jigsaw blades for various cutting operations, cermets have long been considered as too brittle for such vibration-intensive applications. However, at the beginning of this century it turned out that cermets can indeed compete with hardmetal-equipped blades. We screened commercially available sawblades which served as a basis of an own development of Ti(C,N)-based cermet grades. Various alternatives of process parameters and composition such as milling|mixing routines, sintering profile and atmosphere and combinations of hard phases with respect to their manufacturing process and alloy status were investigated. The most promising grades were further optimised and subjected to chopsaw cutting tests on stainless-steel tubes at various stages of product development. We arrived at grades which outperformed commercial competitor grades and were put into production.

Innovative Aspect(s):
Ti(C,N) cermets to replace hardmetals outperformance of existing grades sawing of stainless steel sustainable raw materials.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225369576

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Ing De Gaudenzi Gian Pietro (F.I.L.M.S. S.p.A. - Gruppo OMCD, Italy)

Co-author(s): Ing Alleva Alessandro ; Miss Emanuele Elisa ; Ing Tavola Francesco ; Ing Travella Augusto ; Prof Dr Bozzini Benedetto (Politecnico di Milano, Italy) ; Miss Bagheri Sonia ; Prof Dr Mele Claudio (Università del Salento, Italy) ; Ing Garabelli Mattia ; Miss

Title: What Happens To The Surface Composition Of Hardmetal, When It Undergoes Corrosion? An Electrochemical And Spectroscopic Investigation

Keyword(s):
Hardmetal, Cemented carbides, Corrosion, Electrochemical methods, Ciclic voltammetry, EIS, Spectroellipsometry

Abstract:
Functional performance of hardmetal grades is strongly controlled by the poorly understood ambient-dependent nature and evolution of the near-surface chemistry, either in operational ambient or in metal-recovery processes.We carried out a systematic study on Co-Ni alloy grades without|with Cr|Mo additions in neutral aqueous ambient. Electrochemical investigations, based on CV, PS and EIS measurements, SEM|EDX microscopy, spectroellipsometry and ICP analysis of electrolytes, lead to the rationalization of the irreversibilities of the hardmetal surface properties. We could identify two limiting classes of behaviour: (i) controlled by binder dissolution, and (ii) controlled by pseudopassive film formation, involving both binder and WC corrosion products. By control of the binder composition and of the ambient oxidizing power, one can stir the behaviour of the grade towards one of the two regimes, in order to engineer the surface response to optimize: (i) corrosion and (ii) tribocorrosion resistance, (iii) room-temperature, green recovery of metal from scrap.

Innovative Aspect(s):
In order to deepen the study of the transient-state nature of hardmetal corrosion process, from the selective and progressive dealloying of the binder phase to the precipitation of mixed oxi-hydroxides, ciclic voltammetry and potentiostatic measurements were employed to highlight irreversibilities conditions. Employing EIS and spectroellipsometry, complemented by micrography and surface-composition analyses, combined in a physically transparent model of the evolution of the morphochemistry of the composite, the irreversibilities of the hardmetal surface properties were rationalized. The study was applied to CoNi and CoNiCrMo-base hardmetal grade with application interest.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370198

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Gordon Pozuelo Sandra (Universidad Politécnica de Cataluña, Campus EEBE, Spain)

Co-author(s): Dr Jiménez Piqué Emilio ; Prof Llanes Luis ; Dr Roa Joan Josep (Universidad Politécnica de Cataluña, Campus EEBE, Spain) ; Dr Rodriguez Suarez Teresa ; Dr Franca Luiz F.P. (Element Six (UK) Ltd, Global Innovation Centre, United Kingdom) ; Dr M'Saoubi Rach

Title: Influence Of Microstructural Assemblage Of Substrate On The Adhesion Strength Of TiSiN Coated PcBN Systems

Keyword(s):
PcBN, Coating, Conical indentation, Cracking, Spalling|delamination

Abstract:
The adhesion strength of two TiSiN-coated polycrystalline cubic boron nitride (PcBN) grades is studied in this work. Microstructural assemblage of the PcBN substrate, in terms of cBN content, binder chemical nature and average cBN grain size, is considered as main experimental variable. The present investigation implemented conical indentation to assess load levels at which cracking and delamination emerge and their evolution with increasing load. Tests were conducted on both coated and uncoated PcBN systems by using a conical diamond indenter of 200 µm in radius (Rockwell C) and applying loads from 98 to 980N. They were complemented by an extensive and detailed SEM inspection of fracture micromechanisms (i.e. type of cracking pattern and delamination). Results show that emergence and evolution of damage strongly depend on the substrate microstructural assemblage: the higher cBN-content grade (harder and tougher) exhibits a higher resistance to both cracking and delamination than the lower cBN-content one.

Innovative Aspect(s):
Scientific research on PcBN has been conducted mostly from a mechanical tool performance point of view whereas information from a material science point of view is scarce. Within this context, this work includes two innovative aspects: coating|substrate systems (coated PcBN grades) studied and testing methodology employed. The research here presented offers knowledge for optimizing PcBN performance based on microstructural-mechanical properties correlation as well as development of characterization protocols for such hard and stiff system. On the other hand, although conical indentation has been successfully used for coating delamination evaluation on other coated systems such as cemented carbides or steels; no publications are found regarding coated PcBN.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370589

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Geschwind Thomas (Institute of Production Engineering and Machine Tools, Germany)

Co-author(s): Dr Ing Bergmann Benjamin ; Prof Dr Denkena Berend (Institute of Production Engineering and Machine Tools, Germany)

Title: Determination Of The Influence Of The Mixing Quality On The Grinding Tool Bond After Sintering

Keyword(s):
Sintering, Grinding tools, Process chain

Abstract:
The powder mixture properties determine the sintering results of vitrified bonds for grinding tools. In this paper the influence of the mixing process on porosity of the sintered bonds through the bulk density is shown. Therefore, the bulk density of the mixture and the abrasive concentration and sintering temperature and holding time were varied. Porosity, shrinkage and bending fracture stress were determined to evaluate the influence of these parameters on the sintering result. It was shown that there is no significance influence of abrasive concentration, sintering time and temperature on porosity, shrinkage and bending fracture stress. Instead the influence of the abrasive concentration on the porosity of the powder mixture and the influence of the porosity of the powder mixture on the shrinkage was shown. These outcomes are important for designing moulds and optimizing sintering results.

Innovative Aspect(s):
The innovation about these investigations are the understandig of the effect mechanism of sintering grinding tool bonds and the correlation to the properties which were set during the mixing process. This will help to design grinding tolls, sintering moulds and ecen the mixing process, to better meet customers requirements and develop a sustainable manufactoring process.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371462

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dipl-Ing Cabezas Laura (CIEFMA – Department of Materials Science and Engineering (UPC), Spain)

Co-author(s): Dipl-Ing Berger Christian ; Dr Pötschke Johannes (Fraunhofer Institute for Ceramic Technologies and Systems, IKTS, Germany) ; Prof Dr Jiménez-Piqué Emilio ; Prof Dr Llanes Luis (CIEFMA, Department of Materials Science and Engineering (UPC), Spain)

Title: Influence Of Printing Direction On The Mechanical Properties At Different Length Scales For WC-Co Samples Consolidated By Binder Jetting 3D Printing

Keyword(s):
Additive Manufacturing, Binder Jetting 3D Printing, WC-Co, Microstructural characterization, Mechancial characterization, Printing orientation

Abstract:
Additive Manufacturing (AM) is rapidly growing as a revolutionary technique. It provides an interesting ability to produce complex geometries, a key feature for enhancing performance and widening application fields of hardmetal components. Within this context, all the samples produced by AM [AMed] are expected to exhibit characteristics linked to the shaping route followed, which are also vital for defining their mechanical integrity. This work aims to study the correlation of the printing direction to the final microstructure, mechanical properties and layer assemblage at different length scales for a 12%wtCo–WC grade hardmetals of medium grain size consolidated by binder jetting 3DP and subsequent SinterHIP. Vickers macro- and micro-hardness as well as scratch tests, using different loads and indenter tips, are conducted. The results are analysed and discussed in terms of printing orientation effects on microstructural variability, mechanical response determined, intrinsic physical behaviour of the material and feedstock used.

Innovative Aspect(s):
Evaluation and analysis of the direct linking between microestructural and mechanical integrity for Additive Manufactured WC-Co; by studying the mechanical propiertes at different length scale and the interface | interlayer region between each deposited layer. Assessment of the active role played by processing-related flaws or heterogeneities, introduced or inherited from the AM process on mechanical integrity, reliability and durability of Additive Manufactured specimens. Evaluation of potential anisotropic effects on mechanical properties of AMed WC-Co samples as related to an intrinsic layered assemblage of these materials.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason: .....

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371523

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dipl-Ing Zanon Matteo (Kymera International | Ecka Granules Germany GmbH, Germany)

Co-author(s): Mr Kossakowski Darek ; Dr Mais Bernhard (Kymera International | Ecka Granules Germany GmbH, Germany)

Title: Development Of Premixed Materials For Diamond Cutting Tools

Keyword(s):
Diamond tools, Cobalt-free

Abstract:
As an alternative to pure cobalt, "prealloyed" powders have by now firmly established themeselves as metallic matrixes in the diamond cutting tools industry. While technically high performing, they must rely on an elaborated production process and face increasing supply chain pressure with regard to cobalt. Moreover, the low compressibility implies high green-to-sinter dimensional change, thus compromising the achievable dimensional precision via free sintering. A new family of cobalt-free premixed materials for diamond cutting tools was developed to fill such gaps. Pressing and sintering results will be presented for several grades; their interaction with syntethic diamonds and their degree of metallurgical bonding was studied as well.

Innovative Aspect(s):
There exists a still unmet need in the market for products which show a performance comparable to hydrometallurgical powders but produced via simpler, less energy-intensive, environmentally friendlier processes. Desirable is also a high compressibility, which automatically leads to relatively low shrinkage in free sintering processes, thus allowing for further efficiencies throughout the value chain.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371527

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Govender Preyin (Stellenbosch University, DSI-NRF Centre of Excellence in Strong Materials, South Africa)

Co-author(s): Prof Blaine Deborah Clare ; Prof Sacks Natasha (Stellenbosch University, DSI-NRF Centre of Excellence in Strong Materials, South Africa)

Title: Influence Of Base Plate Coating On LPBF Of WC-Co

Keyword(s):
Laser powder bed fusion, Tungsten Carbide Cobalt, Base plate selection

Abstract:
Laser powder bed fusion (LPBF) is a popular AM technique for building metal components from powder. The powder is spread over a base plate and a laser beam melts the footprint slice of the component, layer-by-layer, and builds the part. A critical aspect of the LPBF process is the selection of base plate material, especially for building materials such as WC-Co, where manufacturing a solid base plate from the same material is impractical. In this study, the influence of base plate design on LPBF of WC-Co is evaluated. Simple cubes of WC-Co composite powders are built on tool steel base plates that are uncoated or coated using HVOF spray coatings. The influence of the base plate coating is assessed by evaluating the macrostructural, microstructural and chemical properties of the as-built cubes.

Innovative Aspect(s):
Base plate selection criteria with WC-Co components. Macrostructural influence on As-built WC-Co component.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371559

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Ing Mégret Alexandre (University of Mons, Belgium)

Co-author(s): Prof Dr Vitry Véronique ; Prof Dr Delaunois Fabienne (University of Mons, Belgium)

Title: Influence Of The Amount Of Recycled Cemented Carbide Powder On The Mechanical Properties Of WC-Co Parts Sintered By HIP And SPS

Keyword(s):
Recycled WC-Co, SPS, HIP, Hardness, Grain size

Abstract:
The trend in the cemented carbide field is to reduce the use of raw cobalt powder in tungsten carbide parts and to develop new binders: indeed, the cobalt price fluctuates extremely due to different factors, mainly its massive use in batteries of electrical vehicles, and its extraction as by-product of copper and nickel mining. The use of a recycled tungsten-cobalt carbide powder skirts the cobalt problem and allows the sintering of WC-Co parts without raw Co powder. In this study, the material is composed of two powders: a powder made from raw materials (WC and Co powders mixed togethers) and a recycled powder (crushed powder containing 7.5 wt% Co). HIP and SPS are used as sintering technologies before morphological and mechanical characterizations. Mechanical properties of these samples can be tuned with the addition of recycled powder and the parts resulting from the experiments are in total competition with conventional ones.

Innovative Aspect(s):
Unconventional sintering technologies are used to consolidate powders made with a recycled amount. The samples are characterized in terms of density, grain size distribution, microstructure, and mechanical properties. The use of recycled powder allows a reduction of the raw WC and Co powders that are usually used in the cemented carbide field, which means time, energy, and above all cost savings.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371810

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Wiśniewski Jakub (Łukasiewicz Research Network - Poznań Institute of Technology, Poland)

Co-author(s): Dr Marczewski Mateusz ; Dr Garbiec Dariusz (Łukasiewicz Research Network - Poznań Institute of Technology, Poland) ; Dr Adamek Grzegorz (Poznan University of Technology, Poland)

Title: Microstructure And Properties Of Composites Manufactured By High-Energy Ball Milling And Spark Plasma Sintering From WC|Ti Powder Mixtures

Keyword(s):
WC-Ti composite, Tungsten carbide, Titanium, Cemented carbides, HEBM, FAST|SPS

Abstract:
The constant development of technology involves the need to enhance materials, including those used for machining, for instance for cutting inserts. The most common material from this group is WC-Co, which is characterized by high hardness and fracture toughness. Nevertheless, cobalt has a high and unstable price, its resources are limited and it is considered a toxic element. All those disadvantages have led to many studies focused on replacing cobalt with other binders. One of the most promising solutions may be titanium, with a similar melting point, much lower price and confirmed biocompatibility. The desired phase composition and good homogeneity of WC-Ti composites may be induced by milling of the initial powders. The mechanical properties and microstructure are also strongly connected with the sintering process. FAST|SPS as advanced technology allows the manufacture of materials with finely tailored properties. The microstructure and mechanical properties of WC-Ti composites were investigated.

Innovative Aspect(s):
Several authors have already reported some research on WC-Ti composites. The novelty of the presented research is the use of the combined technologies of HEBM and FAST|SPS to obtain cobalt-free WC-Ti cemented carbides. This innovative manufacturing route leads to the receipt of a new type of composite materials characterized by high hardness and fracture toughness, with a high application potential.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371811

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Schade Chris (Hoeganaes Corporation, USA)

Co-author(s): Mrs Junghetu Corina ; Miss Horvay Kerri ; Mr Murphy Tom (Hoeganaes Corporation, USA)

Title: Development Of Wear Resistance Alloys For Use In Laser Powder Bed Fusion

Keyword(s):
Laser Powder Bed Fusion, Materials, Wear Resistance

Abstract:
In general, hard materials for tooling and wear resistant applications are very difficult to machine with the most common forming method being grinding. Utlizing a grinding operation severly limits the shape of the final product which can be acheived. Additive manufacturing, specifically Laser Powder Bed Fusion (LPBF), alloys for intricate shapes to be formed form most all alloy materials. However due to their brittle nature many of the materials with high hardness tend to crack in the LPBF process. This paper highlights the mechanical properties and microstructure of a family of wear resistance alloys that can be used in LBPF for a range of applications (from alloy steels to stainless steel). In addition to mechanical properties, case studies of the materials in real-life applications are presented and the wear mechanisms are reviewed and compared to their machined counter parts.

Innovative Aspect(s):
The alloys developed, while exhibiting a high hardness, can be laser printed without cracking and have been used to actually produce parts that are running on a daily basis and provide a operational and ecnomic benefit over traditional wrought and machined materials. Different levels of hardness and corrosion resistance are presented that can cover a range of product applications.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371814

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Garbiec Dariusz (Łukasiewicz Research Network – Poznań Institute of Technology, Poland)

Co-author(s): Miss Wiśniewska Maria (Łukasiewicz Research Network – Poznań Institute of Technology, Poland) ; Dr Mościcki Tomasz ; Mr Psiuk Rafał ; Mrs Chrzanowska-Giżyńska Justyna (Institute of Fundamental Technological Research Polish Academy of Sciences, Poland) ; M

Title: Spark Plasma Sintering Of Tungsten Boride With Transition Metals Admixture

Keyword(s):
Ternary tungsten boride, FAST|SPS, Reactive sintering

Abstract:
To enhance the properties of tungsten diboride, solid solutions of this ceramic with transition metals such as titanium, zirconium, tantalum, chromium, molybdenum or rhenium were synthesized by FAST|SPS from the pure elements. Various contents of these metal elements ranging from 0 to 24 at.% were used. The elemental and phase purity of the samples were examined using energy-dispersive X-ray spectroscopy and X-ray diffraction. Microindentation was utilized to measure the Vickers hardness. The addition of transition metals caused a decrease in density and an increase in the hardness and electrical conductivity of the sintered compacts. The very good usable properties of the obtained materials mean that W–TM–B compounds may in the future be competitive with currently used materials such as WC-Co cemented carbides.

Innovative Aspect(s):
Due to the fact that the proposed materials possess a reduced density, and at the same time electrical and mechanical properties comparable to or better than tungsten carbide, the presented research suggests the possibility of their implementation in everyday life. The simple and fast manufacturing process of the proposed materials should also be emphasized.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371914

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dipl-Ing Hutsch Thomas (Fraunhofer IFAM, branch lab Dresden, Germany)

Co-author(s): Dr Rittner Martin (Robert BOSCH GmbH, Germany) ; Dr Zetterer Thomas (SCHOTT AG, Germany) ; Dr Ing Weißgärber Thomas (Fraunhofer IFAM, branch lab Dresden, Germany)

Title: Metal Diamond Composites - A Way For Industrial Production And Material Integration Into Power Module

Keyword(s):
Copper diamond composite, Sintering, Thermal conductivity, Power module

Abstract:
The ongoing development of power modules for electronics in the field of electro mobility, charging infrastructure and photo voltaic based on SiC chips come up with a strong demand on tailored thermal management materials with high thermal conductivity, tailored coefficient of thermal expansion, soldering workability and a way for industrial production. In this paper the developed routine for the industrial production of metal diamond composites inspired by the wafer technology for semiconductors will be presented using the example copper diamond composite. For the material integration into power modules by soldering the composite needs a cover with pure copper on both sides. The cross section, thermal conductivity and thermal coefficient of thermal expansion will be dispayed for the single composite, the covered composite and after integration into AMB subtrate. Aspects fort he further integration into a power module design will be discussed and shown for one example.

Innovative Aspect(s):
Actual the mass production of metal diamond composites only can be done with high cost single sintering steps. The developed manufacturing way inspired by wafer technology has a great potential to lowering the manufacturing costs. Combined with the thermal performance and solderability of the composites a industrial production is efficient. Using high thermal performance materials the heat losses of the semiconductor can be effectivly dissipated. This result in a reduction of the necessary chip area for power modules and leads to cost reduction and a highly dense packaging for power modules.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371921

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Ing Pötschke Johannes (Fraunhofer IKTS, Germany)

Co-author(s): Mr Von Spalden Mathias ; Dipl-Ing Vornberger Anne (Fraunhofer IKTS, Germany)

Title: Novel FeCoNiCuMn High Entropy Alloys As Binders For TiCN Based Cermets

Keyword(s):
Cermets, Hardmetal, Alternative binders, High Entropy Alloys, Mechanical properties

Abstract:
Cermets and hardmetals are made conventionally from carbide hard phases like WC, TiC or TiCN and binder phases consisting of single elements or simple mixtures of Co, Ni or Fe. To limit the use of Co and Ni alternative binders[SMv1] systems have to be investigated. Within our study, novel high entropy alloy (HEA) compositions of FeCoNiCuMn which do not contain (strong) carbide forming elements were investigated for the fabrication of TiCN based cermets. Adjustments in regard to[SMv2] carbon and copper content were made to successfully design a composition with just a single FCC binder phase. The developed TiCN based HEA cermets show conventional two phase microstructures and mechanical properties comparable to conventional CoNi binder based TiCN cermets.

Innovative Aspect(s):
A novel HEA composition free of carbide forming elements such as Ti, Al, Cr etc. was investigated in regard to its use as a novel low Co and Ni containing binder for cermets and potentially also WC based hardmetals.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371924

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Von Spalden Mathias (Fraunhofer IKTS, Germany)

Co-author(s): Dr Ing Pötschke Johannes (Fraunhofer IKTS, Germany) ; Dr Rosiński Marcin (GeniCore, Poland)

Title: Low Temperature Sintering Of WC Based Diamond Enhanced Cemented Carbides With Novel Co-free Binder Systems

Keyword(s):
Hardmetal, WC, Diamond enhanced cemented carbide, DECC, Diamond tools, FAST, DSC, Direct current sintering, PPC, Pulse Plasma Compaction

Abstract:
In this work, Co-free WC based diamond enhanced cemented carbides (DECC) have been prepared and studied. Two approaches regarding the manufacturing process and the metallic binder system were applied to minimize degradation of the metastable diamond into graphite. Two types of FAST were used, which allows the consolidation of the powders at lower temperatures within a much shorter dwell time compared to conventional sintering techniques. The binder systems were optimised to achieve a further decrease in sintering temperatures while maintaining a fully dense composite. Instead of Co, which is toxic and rated as critical raw material, Ni, Fe and their alloys with Mn, Cu and Si were used as metallic binder, which formed in-situ. These novel composites are compared to conventional Co based DECC by means of microstructural and mechanical properties. SEM observations revealed that less diamond is degraded into graphite with the use of the novel binder systems.

Innovative Aspect(s):
To the authors' knowledge there has not been any approach to minimize the formation of graphite in diamond enhanced cemented carbides by simultaneously applying a FAST process and optimising the composition of a Co-free binder system.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371931

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Jonsson Carl (The University of Melbourne, Australia)

Co-author(s): Dr Molla Tesfaye ; Prof Schaffer Graham (The University of Melbourne, Australia)

Title: Computational Design Of Alternate Binders For WC Hardmetals

Keyword(s):
Integrated Computational Materials Engineering (ICME), Alloy Design, Tungsten Carbide Cobalt, Alternate Binders, WC Hardmetals, Cemented Carbides

Abstract:
Interest in the field of alternate binders for WC hardmetals has increased due to the health implications surrounding the use of cobalt as a binder material. Here, an Integrated Computational Materials Engineering (ICME) approach was used to search for alternate binder compositions using a reduced order model. The model was derived by combining the densification mechanisms present in cobalt containing compacts with the rate enhancing factors governing early onset densification. The model incorporates thermodynamic and kinetic components coupled to a multi-objective genetic algorithm. It allows alloys with compositions optimized for sintering to be ranked against those optimized for mechanical properties to form Pareto sets. By incorporating the sinterability and mechanical properties of the system simultaneously, alternatives that are manufacturable using existing procedures can be determined.

Innovative Aspect(s):
The reliance of the tool and resource extraction industries on WC Hardmetals has placed emphasis on finding a cobalt free alternative. However, materials design is expensive because it is a multi-faceted problem requiring the simultaneous optimisation of material properties and processes. The use of design based philosophy coupled with reduced order modelling has been used successfully in adjacent fields to accelerate alloy development. Adopting a similar approach, this method has now been expanded and applied to the field of WC Hardmetals. The model is applied to developing alternate binder compositions to cobalt, optimising its sinterability and mechanical properties.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372032

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dipl-Ing Rosenblad Louise (KTH, Sweden)

Co-author(s): Prof Larsson Per-Lennart ; Dr Larsson Henrik (KTH, Sweden) ; Dr Staf Hjalmar (Sandvik Coromant, Sweden)

Title: Constitutive Modelling Of Solid State Sintering Of Cemented Carbides

Keyword(s):
Cemented carbide, Constitutive modelling, Sintering, Sensitivity, Optimization

Abstract:
Based on an existing constitutive model for sintering of cemented carbides, the material parameters are investigated using a sensitivity study and an optimization. The sensitivity shows the influence of each parameter and its effect on the densification. This makes it possible to deduce which parameter best represents physical factors by observing experimental changes to the shrinkage in different sintering conditions. In the optimization the possibility to capture an experimental sintering curve of WC-Co powder is investigated, where both simplification and improvements of the constitutive model can be suggested. These improvements are both including the effect when the pressing agent is removed and the effect liquification of cobalt has on the shrinkage. This will make it possible to use the results of a compaction simulation as an input in a sintering simulation, which better represents the manufacturing process.

Innovative Aspect(s):
Constitutive models describing sintering of cemented carbides is often complicated, using many parameters. This study focuses on how the experimental efforts for material characterization can be reduced without reducing the accuracy.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372061

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Prysiazhna Olena (V. Bakul Institute for Superhard Materials NAS Ukraine, Ukraine)

Co-author(s): Prof Dr Prikhna Tatiana ; Dr Barvitskyi Pavlo (V. Bakul Institute for Superhard Materials NAS Ukraine, Ukraine) ; Dr Muratov Valeriy (Institute for Problems of Material Sciences NASU, Ukraine)

Title: Synthesis Of Ceramic From Aluminum Dicarbododecaboride And AlB12C2 With A-AlB12+C Powders

Keyword(s):
Hight temperature, Boride, Lightweight ceramics, Hot pressed, Powder, Mechanical properties

Abstract:
The work presents the results of the study on sintering of the AlB12C2 submicron powder and synthesis of AlB12C2–based ceramics from the submicron α-AlB12 powder with C additions by hot pressing at 30 MPa. The material sintered at 1950 °C from AlB12C2 which contained about 100% of AlB12C2 according to the X-ray analysis, demonstrated the low density, γ=2.57 g|cm3, and high mechanical characteristics. Additions of 17% C to the α-AlB12 powder lead to the formation of a system 86% AlB12C2 and 14% AlN composition with density γ=2.7 g|cm3. The results of X-ray and SEM structural studies showed the main matrix phase of the AlB12C2.-based materials exhibited essential deficiency of Al and some deficiency of boron, while the large amount of boron was present in the phase with the Al2O3 structure. The higher concentration of Al-B-O-based phase having the Al2O3 structure correlated with higher fracture toughness.

Innovative Aspect(s):
Possibility of synthesizing the materials based on AlB12C2 phase with low density and high mechanical properties. Principal possibility of sintering materials based on refractory borides at sufficiently low temperatures 1950 °C and low pressure 30 Mpa.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372088

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Hadian Amir (Empa, Switzerland)

Co-author(s): Mr Hosseini Nia Mir Mohammad Reza ; Dr Zamani Cyrus ; Dr Hadian Ali Mohammad (University of Tehran, Iran) ; Mr Salimi Mahdiar (Politecnico di Milano, Italy) ; Dr Clemens Frank (Empa, Switzerland)

Title: Post-heat Treatment Of NbC-M2 High-speed Steel Cemented Carbides: The Effect On Microstructure And Mechanical Properties

Keyword(s):
NbC, Cemented carbides, M2 high-speed steel, Heat treatment, Tempering

Abstract:
In this work, the effect of post-heat treatment on microstructure and mechanical properties of M2 high-speed steel (HSS) bonded NbC cemented carbides were studied. Heat treatment cycles consisting of austenitizing and tempering steps were performed under inert atmosphere on as-sintered NbC-M2 HSS specimens. Vickers hardness and indentation toughness results revealed an improvement in the mechanical properties compared to untreated cemented carbides. An optimal combination of hardness and toughness was achieved by double tempering at 600 ˚C. Based on microstructural analysis using a scanning electron microscope (SEM), the transformation of retained austenite to martensite and martensite to tempered martensite within the M2 HSS metallic binder during the double tempering process are responsible for improved mechanical properties of NbC-M2 HSS cemented carbides.

Innovative Aspect(s):
Development of an environmentally friendly cemented carbide based on NbC and M2 high-speed steel. Improving mechanical properties of cemented carbides by toughening the metallic binder. Heat treatment of cemented carbides bonded with ferrous based alloys.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372149

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Wagner Stephanie (Hartmetall Estech AG, Switzerland)

Co-author(s): Prof Dr Lengauer Walter (Vienna University of Technology, Austria)

Title: Properties Of Hardmetals With Different Fe-Co-Ni Binder

Keyword(s):
Cemented Carbide, Alternative binder, Fe-Co-Ni-binder, Grain growth Inhibitors, V and Cr, Properties hardmetals

Abstract:
The present work deals with a screening of Fe-Co-Ni hardmetals and investigations of their mechanical and physical properties. To improve the properties of hardmetals doping elements, such as grain-growth inhibitors (Cr, V) were added. In order to obtain the largest effect it is important to add the maximum soluble amount of the doping elements in the binder. The main part of this study used the results of the solubilities to prepare hardmetals. To point out the possible application areas of each binder alloy the mechanical (hardness and toughness) and magnetic (coercivity and magnetic saturation) properties as well as density and porosity were measured. Furthermore, the hardmetal properties of four binder alloys for the carbon window (from the three-phase area (WC+binder+η) over the two-phase area (WC+binder) into the three-phase area (WC+binder+C)) were analysed in 9-13 steps. In comparison to WC-Co hardmetals different trends were observed.

Innovative Aspect(s):
Fe-Co-Ni binder system of cemented carbides, mechanical and magnetic properties of cemented carbides with different Fe-Co-Ni binder.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372172

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Aleksandrov Fabijanić Tamara (Faculty of Mechanical Engineering and Naval Architecture, Croatia)

Co-author(s): Dr Pötschke Johannes ; Dipl-Ing Mayer Markus (Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Germany) ; Dr Šnajdar Musa Mateja (Faculty of Mechanical Engineering and Naval Architecture, Croatia)

Title: Influence Of NbC And TaNbC Addition And Ni Binder On Nanostructured Hardmetal Properties

Keyword(s):
Nanostructured hardmetals, Ni, NbC, TaNbC, Cr3C2, Microstructure, Mechanical properties

Abstract:
The need for Co replacement with alternative binders is imperative in hardmetal research due to environmental and health issues, high cost, and inferior corrosion properties. In combination with nano WC powder, alternative binders could approach the properties of WC-Co hardmetals with improved corrosion resistance. Nickel as a binder is one of the best cobalt alternatives due to its similar properties and enhanced electrochemical corrosion resistance. Previous studies indicated that adding niobium carbide to WC-Co hardmetals significantly refines grain size and limits grain growth. Depending on the amount of NbC in hardmetals, transverse rupture strength, hardness, and wear resistance can be improved. In contrast, TaNbC significantly improves oxidation, thermal and wear resistance, and hot-hardness. In this work, microstructural characteristics and mechanical properties were investigated by observing the influence of adding NbC and TaNbC to starting mixtures with Ni content of 9 wt.% and WC particle size of approximately 150 nm.

Innovative Aspect(s):
Previous studies indicate that adding niobium carbide to conventional WC-Co hardmetals with grain sizes bigger than 200 nm has a significant effect on refining the grain size and limiting the grain growth. Besides grain refinement, NbC improves mechanical properties such as transverse rupture strength, hardness, and wear resistance. In the literature, there is no published research on NbC and TaNbC influence on mechanical properties and microstructural characteristics of nanostructured hardmetals with alternative binders. Parts for the petroleum and chemical industry require good mechanical properties in combination with excellent corrosion resistance. Conventional WC-Co hardmetals are not the best solution considering they exhibit low corrosion stability but superior mechanical properties. Therefore, there is a need for new innovative materials with comparable mechanical properties to cobalt bonded nanostructured hardmetals. To achieve desired and similar mechanical properties, the solution to that problem could be using WC nanoparticles with NbC and TaNbC as multifunctional powder and Cr3C2 as.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371483

Requested paper type: Oral Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Prof Missiaen Jean-Michel (Univ. Grenoble Alpes, France)

Co-author(s): Dr Labonne Mathilde ; Dr Lay Sabine (Univ. Grenoble Alpes, France) ; Dr Lavigne Olivier ; Dr Garcia Luis (Hyperion Materials & Technologies, Spain)

Title: Effect Of Mo2C Additions On Grain Growth In NbC-Ni Cemented Carbides

Keyword(s):
Cemented carbides, Grain growth, Grain growth inhibition, Secondary carbides

Abstract:
Cemented carbides are widely used for cutting and drilling tools. They usually combine a WC hard carbide phase and a Co-based ductile binder. NbC-Ni materials are considered as a possible alternative, especially for wear applications. The advantageous economic situation for raw materials sourcing, their interesting mechanical properties and low density have raised a new interest for these materials. However, mechanical properties can be limited by the rapid grain growth during liquid phase sintering, as compared to WC-Co. Grain growth can be controlled by the addition of secondary carbides such as Mo2C. In this paper, a quantitative EBSD analysis of grain growth is performed for NbC-12vol%Ni materials sintered at 1360°C with controlled addition of Mo2C. The average grain size decreases continuously with Mo2C content. The results are discussed based on a more detailed interface characterization and on a previous model for the cooperative migration of phase boundaries and grain boundaries.

Innovative Aspect(s):
Understanding the effect of secondary carbide additions on grain growth.Cooperative grain boundary and phase boundary migration.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225368032

Requested paper type: Poster Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Miss Riu Perdrix Guiomar (UNIVERSITAT POLITÈCNICA DE CATALUNYA, Spain)

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Title: Micromechanical Characterization Of Gamma-phases Of WC-Co

Keyword(s):
Mechanical properties at the submicrometric length scale, Hardness cartography, Elastic modulus cartography, Statistical approach, Flow stress determination

Abstract:
Achieving a proper surface finish in cemented carbide parts to accomplish customer tolerances is a laborious work that usually requires different grinding steps and a final manual job where operator skills are very valuable. The present work evaluates a dry electropolishing process that has emerged as an attractive alternative to conventional surface finishing processes. The feasibility of using this process has been assessed for conventional WC-Co alloys and the influence of Co|Ni binder as well as the addition of γ-phase (i.e. TiC, TaC, NbC and Cr2C3) is further explored. The surface finish of three grades is optimized and the mechanical integrity of the bulks compared to the near surface is studied at the submicrometric length scale. In doing so, nanoindentation technique is implemented to determine the effective hardness of each constitutive phases and flow stress of the metallic binder though massive nanoindentation and statistical analysis.

Innovative Aspect(s):
The innovative aspects of this work are: (1) The dry-electropolishing technology used in this study leads to polish the surface and be able to get a roughness below 20 nm without leaching effects in the metallic binder (2) Due to the polishing technology emploied does not exist any anisotropy effect in terms of roughness for the different WC crystallographic phases (3) The mechanical properties at the submicrometric length scale for each constitutive phase has been evaluated by using high-speed nanoindentation technology and the hardness and elastic modulus cartography obtained (4) A systematic protocol to surface integrity evaluation is implemented for composite and hard materials

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225368306

Requested paper type: Poster Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Zakarian Dora (Institute for Problems of Materials Science, Ukraine)

Co-author(s): Dr Khachatrian Aik ; Dr Kartuzov Valery (Institute for Problems of Materials Science, Ukraine)

Title: First Principles Calculation Of The Theoretical Hardness Of Diamond-like Materials

Keyword(s):
Theoretical compressive strength, Interaction of densely packed atomic planes, Energy of the outer surface of the material

Abstract:
For diamond-like materials with a cubic structure (diamond, BN, SiC, AlN), the theoretical strength is calculated from first principles through the interaction energies of close-packed atomic planes (perpendicular to the <111> unit cell diagonals). When evaluating hardness (from first principles), it was taken into account that hardness is not a property of the entire sample, but of the surface layer of the material. Using the technique developed by us, the energy of interaction between particle-packed atomic planes was calculated with reference to the surface and taking into account the influence of the energy of the outer surface on the state of the electron-ion system in the surface layer. The obtained values of the ultimate compressive stress represent the theoretical hardness of diamond-like materials, which fail brittle at low and medium temperatures. The obtained values of hardness for covalent crystals are comparable with experiment.

Innovative Aspect(s):
Hardness is a complex characteristic of a material, because it depends on the elastic stiffness, plasticity and yield strength of the substance. For elastoplastic materials, hardness is not calculated from first principles. The models used are semi-empirical, obtained on the basis of phenomenological theory. Despite the variety of these models, they all depend on an adjustable parameter to ensure the convergence of the calculation with the experiment. The fitting parameters depend on the concentration of defects and cannot be constant when trying to obtain a material without impurity atoms. It is relevant to create mathematical models for calculating physical characteristics without adjusting parameters. Such models are necessary for predicting mechanical properties when creating new materials. For a special class of materials that are elastically deformed, a model has been created in which the concept of "theoretical hardness" is defined and a method for calculating it from first principles is shown.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370611

Requested paper type: Poster Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Mr Lang Roman (Leibniz Universität Hannover, Germany)

Co-author(s): Dr Ing Bergmann Benjamin ; Prof Dr Denkena Berend (Leibniz Universität Hannover, Germany)

Title: Macro- And Microscopic Characteristics Of The Grinding Behaviour Of Cu-Cr-diamond Composites In Deep Feed Grinding Of Cemeted Carbide

Keyword(s):

Abstract:

Copper is the main element within the bonding matrix of metal-bonded diamond grinding wheels that are used for the machining of cemented carbides. Copper shows an inert behaviour towards diamond and therefore only results in a form fit connection with a relatively low grain retention within the bond matrix. The here presented study shows that an addition of chromium results in a formation of chromium carbide (Cr3C2) within the diamond-copper interface that significantly enhances grain retention and thermal conductivity. The ductility of the composite material is reduced due to the chromium addition. The carbide formation enhances the grinding behaviour in form of a decrease in grinding forces and wear of the grinding layer. Furthermore, the breakout behaviour of single grains is investigated using a shear force tester. Besides the increase in grain retention, the decrease in ductility can be observed, preventing the grains from ploughing within the copper-chromium matrix.

Innovative Aspect(s):

There is only little scientific work within the scope of the fabrication of grinding tools. Fundamental research is necessary to understand the influences of the fabrication route on the thermal and mechanical properties of a grinding layer. This is the first time that the application of a sintered copper-diamond composite material in deep feed grinding of cemented carbide has been studied. Furthermore, the grain retention and the breakout behaviour have been studied using a shear force tester. Therefore, single diamond grains with a diameter of 600-1200 µm were embedded at various protrusions and were sintered within a copper-chromium matrix. Through this new method on a macroscopic scale, it is possible to explain the microscopic and difficult to study effects that occur during the grinding process using the sintered composite material.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371864

Requested paper type: Poster Presentation

Topic: Materials / **Subtopic:** Hard metals, cermets and diamond tools

Author: Dr Singh Shweta (Indian Institute of Technology Bombay, India)

Co-author(s): Ms Pareek Shiwani ; Mr Gurjar Ankit ; Dr Kolay Santa ; Prof Bhargava Parag (Indian Institute of Technology Bombay, India)

Title: Effect Of Sintering Parameters On Microstructure, Mechanical Properties And Anti-Microbial Characteristics Of Alumina-Silver Nanocomposites

Keyword(s):
Nanocomposites, Silver nanoparticles, Alumina-silver

Abstract:
Alumina based ceramics are used in many applications though their fracture toughness is relatively low and they suffer from poor thermal shock resistance. The motivation of this work is to improve the mechanical properties and incorporate anti-microbial characteristics in alumina ceramics. In this work, alumina-silver nanocomposites are prepared by addition of 5, 10 and 15 wt. % silver nano-flakes. Sintering parameters like temperature and dwell time are optimized in order to obtain superior mechanical properties. The microstructural analysis is performed using scanning electron microscopy (SEM) and phase analysis is done using the x-ray diffraction (XRD) technique. Mechanical properties like flexural strength, fracture toughness and microhardness are evaluated. Silver addition is expected to impact sintering|densification behaviour, resulting in improvement of fracture toughness | thermal shock resistance and anti-microbial characteristics. The detailed results of the study will be shown during the presentation.

Innovative Aspect(s):
The research of alumina-silver nanocomposite is in a nascent stage. Alumina ceramic's performance is significantly hampered by its low fracture toughness. Reinforcement through nanoparticles is an effective way to improve their fracture toughness. In the present work, a novel alumina-silver nanocomposite is synthesized by optimizing the sintering parameters. The unique blend of alumina and silver nanoparticles prepared in the present work improved its compaction in terms of green body strength, handling and low-pressure compaction. This also removes the need for a binder and improves the dimensional stability of green parts leading to more densified samples. Additionally, silver nanoparticles impart antimicrobial|antibacterial properties which makes current nanocomposite suitable for biomedical applications.

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