WORLD PM2022
CONGRESS & EXHIBITION

ABSTRACTS – GROUP 12

POWDER PRODUCTION

WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225352502

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dipl-Ing Blitz Benedikt (SMR Premium GmbH, Germany)

Co-author(s):

Title: Update On The World Market For Metal Powders & Special Steels

Keyword(s):
Recent developments, Supply & demand situation, Technolgies, Materials, Players, Marketdata, Highlevel overview, Future outlook

Abstract:
The speech will focus on the production of Metal Powders and Powder Metallurgical Steels and especially its associated production technologies like HIP, MIM and AM. As they are and will become key future core technologies for a number of demanding products and thus for the usage in different associated industries. The presentation will also highlight the actual supply and demand situation of metal powders and the manufactured metal powder steels, will introduce leading manufacturers of both powders and steels, and summarizes installed capacity and new capacity that are on the way as well as new players that enter this high value industry. The presentation will also highlight the recent developments in the world of Forged Special Steels and remelted steels (nickel alloys, stainless steel, alloy tool steel and alloy steel) as well as will give an overview about end-user demand and structures of these special steels and also summarize the actual status of installations on a global scale.

Innovative Aspect(s):
The presenation gives an overview of Powder Technolgies as well as Production of Powders, different materials, recent developments of the market, latest data, suppy & demand situation, new applications in differnet industries, special steels, forgings, remeltings & powders, installed capacity & new payers on a global scale. The presented information is relevant for producers, end-users as well as traders and other industry members.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason: .....

Notes to author: .....

WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225359068

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Prof Zhang Baicheng (University of Science and Technology Beijing, China)

Co-author(s):

Title: A Comprehensive Study Of Ta Powder Preparation For Additive Manufacturing

Keyword(s):
Tantalum, Powder, Additive Manufacturing, Powder flowability, Laser absorptivity

Abstract:
As an alternative to the current expensive spherical Ta powder used in LPBF or EBM. A comprehensive study was conducted and explored to obtain a cost-performance trade-off Ta powder process. In this work, sodium reduced tantalum (Ta) powders were processed by fluidization, jet milling and plasma spheroidization respectively, in order to improve processing performance for additive manufacturing. The morphology, flowability, physical|chemical properties and microstructural evolution of the as-processed Ta powders were systematically studied. The modification effect via fluidization is moderate, although it worked well on the Ti powders as previously reported. Both jet milling and plasma spheroidizing can produce Ta powders with good flowability. However, plasma spheroidizing powder has higher laser absorption rate, and fully dense parameter region is wider. The powder deformation mechanism in each method is also revealed. Combining various Ta powder processes, the cost of the spherical Ta powder can be significantly reduced by jet milling.

Innovative Aspect(s):
This work aimed to find a low-cost way for additive manufacturing used Ta powder.. Fluidization, jet-milling and plasma spheroidization are used to process Ta powder.. Spherical Ta particle can be obtained by jet-mill process with a good flowability.. Plasma spheroidized Ta powder possesses higher laser absorption than others.. Jet milling can greatly reduce the cost of Ta powder for LPBF and EBM.

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: WP225361377

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Mr Wilkens Yannik (SMS group GmbH, Germany)

Co-author(s):

Title: Production Of High-grade Metal Powder For Additive Manufacturing By Using The Powder Atomization Plant Of SMS Group

Keyword(s):

Abstract:
A full-scale powder atomization plant for the production of high-grade metal powders is operated at SMS 3D Test Center in Mönchengladbach to gain detailed operator expertise and production expertise to develop and produce high quality AM powders. By understanding the different influencing factors during atomization and the influence of powder properties on the additive manufacturing process SMS group equipment is able to produce powder with improved quality and increased output. In this presentation, the Powder Atomization Plant and its technical features are described in detail to show the correlations of the powder processing and best results of the laser based powder bed fusion printer. Combining a high utilization grade of metal powder and the right particle size and shape for additive manufacturing at highest quality, the new plant concept of SMS group demonstrates customers how to become the leading supplier of the AM industry.

Innovative Aspect(s):
Innovative Approach to increase powder quality ; Strong Anti-Satellite-System ; Machine learning algorithems used to improve availability

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225366460

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Ing Franceschini Aurelie (IRT M2P, France)

Co-author(s): Dipl-Ing Deborde Agathe (MetaFensch, France) ; Dipl-Ing Cornu Jerome ; Dipl-Ing Vassa Alexandre ; Dr Ing CHEHAB Bechir (C-TEC, France)

Title: Effect Of Atomization Process Parameters On Properties Of Aluminium Alloy Powder For Additive Manufacturing

Keyword(s):
Gas atomization, Aluminium powder, Additive manufacturing

Abstract:
Constellium Technology Center (C-TEC) has developed new high performance aluminium alloy powders specifically designed for laser powder bed additive manufacturing processes. Rapid solidification metallurgy is used to bring properties which would not be achievable with conventional alloys. The alloys require higher melting temperatures than conventional aluminium systems. The specific optimization of the atomizing process is carried out on the new VIGA atomizer installed by IRT M2P. Effects of different process parameters on yield and process continuity were investigated: melt superheat, delivery tube diameter, gas pressure and oxygen content in the atomizing gas. Powder characterizations were then performed (PSD, morphology, oxygen content, flowability, density...). Finally, the powders were tested by Laser Powder Bed Fusion (LPBF) and the performance of the printed parts were evaluated by metallography and mechanical testing.

Innovative Aspect(s):
High performance aluminium alloy powders. Effect of atomization parameters on yield and process continuity. Link between atomization parameters, powder properties and LPBF parts performance.

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: WP225369983

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Jiang Huangyong (NBTM New Materials Group Co., Ltd., China)

Co-author(s): Mr Zhang Chen ; Mr Sun Zeyu ; Mr Feng Weili ; Prof Bao Chongxi (NBTM New Materials Group Co., Ltd., China)

Title: Effect Of A New Type Binder On Properties Of Premix Powder

Keyword(s):
Segregation, Hyperbranched polymers, Binder, Premix powder

Abstract:
The component segregation of premix powder is a major problem with products in many companies. Herein, we developed a novel binder based on hyperbranched polymers that could reduce the segregation of premix powder effectively. Fe-Cu-C, Fe-Ni-C and Fe-Fe3P were prepared by adding different binder concentration (0-0.5%). The morphology and composition distribution of premix powder were investigated by Scanning electron microscopy (SEM) and Inductive coupled plasma emission spectrometer (ICP). Subsequently, the effects of binder content (mass fraction) on the flowability, apparent density and compressibility of premix powder were studied. Comprehensive experimental results showed that the addition of binder effectively reduces the powder segregation, greatly reduces the dust in the process of blending and using, and improves the consistency of the samples. The comprehensive performance of premix powder is optimal when the binder content of 0.2%.

Innovative Aspect(s):
Hyperbranched polymers are a class of highly branched three-dimensional polymeric macromolecules. Compared with traditional linear polymer binders, hyperbranched polymer binders have a compact structure similar to spherical, less molecular chain entanglement, lower melt viscosity and solution viscosity under the same molecular weight. Therefore, hyperbranched polymers are expected to exhibit better binding effect. In addition, the abundant functional groups of hyperbranced polymer molecules are beneficial to improve the performance of premix powder. This project selects hyperbranched polymers as binders to prepare bonding premix powder, and further studies the effect of the novel bonder on properties of premix powder. The research results are of great significance for reducing the production cost and improving the production efficiency, and provide corresponding theoretical guidance for the subsequent development of new binders.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370728

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Ing Qaddah Baraa (IRT M2P, France)

Co-author(s): Dr Ing Chapelle Pierre ; Prof Dr Bellot Jean Pierre ; Ing Jourdan Julien (Institue Jean Lamour, France) ; Prof Dr Rimbert Nicolas (LEMTA, France) ; Ing Deborde Agathe ; Ing Hammes Raphael (MetaFensch, France) ; Dr Ing Franceschini Aurélie (IRT M2P, France

Title: Numerical Modeling And Experimental Study Of Swirling Supersonic Gas Flow In The EIGA Atomizer For Metal Powder Production

Keyword(s):
Free-fall atomizer, Swirling supersonic gas flow, Metal powder, Numerical simulation, Shock waves, Schlieren effect

Abstract:
The requirement of high-quality metal powders production with fine spherical particle size is growing rapidly for the metal additive manufacturing process. An attractive technique to produce such powders is the EIGA process (Electrode induction melting Inert Gas Atomization), which employs a swirling supersonic gas jet flow exiting a free-fall nozzle to atomize a molten metal stream. The gas dynamics have dominant influences on the atomization mechanisms. A numerical model is developed to simulate the gas flow behaviour through and downstream the EIGA nozzle. The numerical results are compared to experimental observations of the shock|expansion waves produced in the gas flow obtained using the optical Schlieren effect and a high-speed camera. A parametric study of the nozzle inlet gas pressure is presented and flow patterns that could contribute to reduce the produced powder size are discussed.

Innovative Aspect(s):
Perform a three-dimensional numerical model of the real geometry of the EIGA atomization nozzle via SolidWorks. Simulate the swirling supersonic flow behavior of the gas atomizer through and at the outlet of the nozzle via Ansys-Fluent and qualify its operation as the relationship between the inlet and outlet operating conditions (velocity, pressure, gas temperature). Develop an experimental setup using the Schlieren effect and a high-speed camera to visualize the shock|expansion waves in the EIGA-tower and compare them to the numerical results.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371389

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Fedorov Dmytro (Ladotherm, Ukraine)

Co-author(s):

Title: Modeling of hydrogen reduction of fine iron oxide

Keyword(s):
Hydrogen, Fine iron oxide, Fine sponge iron powder

Abstract:
Conventional steelmaking produces a lot of fine by-products as contamination of environment. So, such by-products should be purified and utilized by re-cycling. One of such purified sub product is fine iron oxide. Reduction of the oxide into fine iron powder by hydrogen is a way of re-cycling. Experimental studies had been conducted and mathematical model of the process has been developed. The problem with fine oxides is no flowability of such material. It has highly developed surfaces and may be flammable after reduction. In actual process hydrogen flow rate is much higher, than required for reactions. To decrease specific hydrogen consumption its recirculation with purification should be applied for semi-industrial process. Mathematical model predicts Reduction Degree, Hydrogen actual consumption for reaction balance, Hydrogen theoretical consumption to remove all initial oxygen, Hydrogen flow rate along furnace to provide optimal diffusion regime for reduction.

Innovative Aspect(s):
Application of hydrogen reduction with its re-circulation for recycling of fine iron oxide byproduct. Average size of iron oxide byproduct particles is within 3-10 mkm. It has highly developed surface and no floability. With using our method of reduction and consequent passivation is possible to realize semi-industrail production of such fine sponge iron powder.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371442

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Wimbert Lars (GKN Powder Metallurgy, Germany)

Co-author(s): Mr Lindenau René (GKN Sinter Metals Engineering GmbH, Germany) ; Mr Lindsley Bruce (Hoeganaes Corporation, USA) ; Mr McQuaig Kylan (Hoeganaes Corporation, USA)

Title: Advanced Lubricants For Modern PM Applications

Keyword(s):
Powder additives, Advanced lubricants, Powder compaction

Abstract:
Most mechanical properties of powder metallurgical components significantly depend on the materials density. Considering the higher complexity of modern PM parts and the demand for higher strength with less weight, increased green and sintered densities are required. The development of new advanced lubricants is one key factor for this, providing additives with superior lubricity, clean burn-off and unsophisticated usability. This contribution documents recent developments in lubricant technology with experimental results from lab scale to serial production. The presented lubricant solutions allow the powder compaction to higher density levels using lower lubricant additions without the need for heated tooling into a tight temperature range. Especially for complex shaped parts the broader temperature range helps to keep the lubrication sufficient for tool sections with higher friction resulting in ejection pressures less than 50% of the values seen for amide waxes.

Innovative Aspect(s):
The paper presents results the experimental results (lab and production scale) for new developed advanced lubricants. These allow higher green densities for green components together with less tool wear, reduced lubricant contents and clean burn-off.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371452

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Prof Avello Alejo (CEIT, Spain)

Co-author(s): Dr Urionabarrenetxea Ernesto ; Dipl-Ing Amatriain Aitor ; Dr José M. Martin (CEIT, Spain)

Title: Efficient Modeling Of Primary And Secondary Atomisation In Close-coupled Gas Atomisers

Keyword(s):
Close-coupled gas atomisation, Gas atomiser, Computational Fluid Dynamics (CFD), Particle Size Distribution (PSD)

Abstract:
Computer simulation of metal powder gas atomisation aims to better understand the complex phenomena involved in the interaction between gas and liquid metal, in order to maximize productivity and to avoid common issues. An efficient axisymmetric simulation of primary and secondary atomisation is proposed, which reduces calculation time in conventional desktop computer to the range of few hours. Primary atomisation is modeled using a Eulerian model that predicts the gas|liquid ratio in the neighborhood of the melt delivery tube. The secondary atomisation uses a Lagrangian particle tracking approach with a multimodal breakup model to predict particle breakup, and thus particle size distribution. Transition from the primary to the secondary atomisation takes place at the iso-surface of void fraction equal to 90%, which is adopted as injection surface. Particle size distributions of gas-atomised copper powder obtained with simulations are compared with experimental results.

Innovative Aspect(s):
The simulation of metal powder gas atomisation is extremely challenging due to huge differences in geometric and temporal scales, supersonic gas velocities, high temperature gradients, high heat transfer speeds and solidification. Although accurate modeling of these phenomena is beyond current calculation capabilities, efficient simplified methods can be used as an effective tool to gain insight and to quantify the impact of changes in geometry and operating conditions on the PSD. The main innovation of this work is an efficient simulation method that combines a Eulerian method for primary atomisation with a Lagrangian Discrete Phase Method for secondary atomisation that models particle breakup until solidification. This translates into new capacities to design more efficient atomization nozzles, to better understand their behavior and to avoid pitfalls during operation. Comparisons between simulations and experimental atomisations prove that the method correctly captures trends and is able to quantify PSD with acceptable error margin.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371614

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Ing Bustamante Valencia Lucas (AIR LIQUIDE FRANCE INDUSTRIE, France)

Co-author(s): Dr Ing Briand Francis ; Dr Ing Mandou Quentin (Air Liquide R&D, France) ; Dr Ing Januard Fabien (AIR LIQUIDE FRANCE INDUSTRIE, France)

Title: Metal Powder Production Optimisation By Increasing The Inlet Gas Temperature

Keyword(s):
Gas Atomization, Additive Manufacturing, Particle Size Distribution, Helium, Nitrogen, Argon, Temperature, Gas Preheat

Abstract:
With the booming of additive manufacturing, metal powder manufacturers are facing a growing demand of gas atomized powder complying with very stringent technical specifications in terms of oxidation or particle size distribution (PSD). From a metal powder producer perspective, optimizing the PSD makes it possible to be more selective in terms of targeted markets and result in a direct increase of profitability also limiting waste and thus carbon footprint. Most of the atomization processes deal with a complex interaction between the metal and a gas jet. The literature of metal powder production stands for a narrowing of the particle size distribution with the optimization of the momentum of the gas jet. It could include the change of the flow, pressure and temperature of the inlet gas but also its composition, considering gas mixtures. This work presented results of trials conducted on an industrial gas atomization unit.

Innovative Aspect(s):
In this work, trials were performed to assess the effect of an increasing temperature of the gas inlet. A proper setting of the inlet gas temperature showed to be a critical process parameter to optimize the particle size distribution suitable for additive manufacturing applications and improve the powder yield. Different gas compositions including Helium mixtures have been also tested.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371750

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dipl-Ing Chivel Yuri (MerPhotonics, France)

Co-author(s):

Title: New Approaches To Powder Production Using Conical Laser Beams

Keyword(s):
Continuous near-surface optical discharge , Plasma, Inert gas flow, Condensation, Spherical powders

Abstract:
A process is presented for obtaining a spherical powder in a wide range of sizes 50 nm - 50 µm, in which a continuous near-surface optical discharge with a temperature of 20 kK is formed using conical laser beams in an argon flow, into which material is introduced in the form of a wire. The condensation are strongly and rapidly quenched by an inert gas flow at atmospheric pressure, producing high supersaturation . The process capacity is 0.5 kg|kWh with a laser power of 10 kW. The process of nanoparticle formation using inert gas condensation of metal vapour produced by conical laser beam vaporization of micropowder 40-60 µm stream with a particle concentration of 104-106 cm -3 has been investigated. Experimentally obtained nanoparticles 20-50 nm are collected in the form of conglomerates up to 100 nm in size. The productivity of the process reaches 0.2 g | W h .

Innovative Aspect(s):
New efficient processes for obtaining spherical powders have been developed.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371784

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Sears James (AMAERO Inc, USA)

Co-author(s): Dr Sears James (AMAERO Inc, USA)

Title: What Makes Titanium Alloys Such A Good Fit For Additive Manufacturing?

Keyword(s):
Titanium, Additive, Atomization, Recycling

Abstract:
Over the last 50 years there have been many developments in the techniques used to fabricate components using Titanium Alloy powders. The reasons for using PM Ti for part fabrication has been well established, i.e., the associated reduction in fabrication costs (e.g., reduction in Buy-to-Fly ratio). A major impediment to a wider acceptance for the use of PM Ti has been the high cost of powder production. Now, with the recent focus on Additive Manufacturing, the interest in using PM Ti has increased and more titanium powder producers are becoming online. A brief history of where Additive Manufacturing came from will be discussed along with past and present developments in titanium powder production.

Innovative Aspect(s):
New developments for higher efficiencies in titanium gas atomization.

TPC Reviewer name: .....

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371868

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Samokhin Andrey (Institute of Metallurgy and Materials Science, Russia)

Co-author(s): Dr Alexeev Nikolay ; Mr Sinaisky Michael ; Mr Fadeev Andrey ; Mr Dorofeev Alexey (Institute of Metallurgy and Materials Science, Russia)

Title: Production And Processing Of Tungsten-Based Powders In Thermal Plasma Systems

Keyword(s):

Abstract:
The report presents the results of R&D of plasma-chemical production of W nanopowders, W-Cu, W-C, W-Ni-Fe powder nanocomposites, WC tungsten monocarbide, as well as spherical micropowders of these compounds for their use in modern 3D printing technologies. Plasma-chemical synthesis of tungsten nanopowder is based on the reduction of tungsten oxide compounds powders in a stream of hydrogen-containing low-temperature thermal plasma generated in an electric arc plasma torch. The synthesis of W-Cu and W-Ni-Fe nanocomposites is carried out using the reduction of a mixture of the metal oxides, Using the synthesized tungsten-based nanocomposites powders, spherical composite micropowders with a submicron structure can be manufactured by granulation of nanopowders and subsequent spheroidization of granules by melting in a low-temperature thermal plasma. The results of the development of DC arc plasma systems for the synthesis of nanopowders and micropowders spheroidization are presented.

Innovative Aspect(s):
Among the applications of additive technologies, the most in demand is the manufacture of functional products for the needs of the most high-tech industries such as aerospace and defense industries, nuclear power.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371880

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Mr Nakamura Koki (Toyohashi University of Technology, Japan)

Co-author(s): Dr Yokoi Atsushi ; Dr Tan Wai Kian ; Dr Kawamura Go ; Prof Matsuda Atsunori ; Prof Muto Hiroyuki (Toyohashi University of Technology, Japan)

Title: Fabrication Of Monodispersed Spherical Composite Granules By Electrostatic Integrated Granulation Of Nanopowder Suspensions

Keyword(s):
Granulation, Composite, Electrostatic adsorption, Ceramics

Abstract:
In nanocomposite materials fabrication, nanopowders are commonly used to obtain the desired properties. However, the drawbacks of nanopowders are agglomeration and poor handling ability. To overcome these issues, one solution is to fabricate composite granules using electrostatic integrated granulation of aqueous nanopowder suspension. By adjusting the surface charge potential of the nanopowders, electrostatic integration during the granulation process enabled the fabrication of monodispersed spherical composite granules, exhibiting good homogeneity of raw nanoparticles and improved handling ability. In this study, the parameters for composite granules formation using electrostatic integrated assembly method were investigated. From the results obtained, a process map, which enables the prediction of the granule's formation is also proposed.

Innovative Aspect(s):
In this study, composite granules with excellent monodispersity were formed using electrostatic integrated granulation of nanopowders. In comparison with the commonly used spray-dry method where hollow-structured and wide particle size distribution of granules were formed, this method enables the formation of spherical monodispersed composite granules. Moreover, incorporation of several raw nanomaterials as well as different nanostructures such as nanoplate or nanotubes is also possible using this method. In addition, by adjusting the composition ratio of incorporated materials during the granulation process, composite granules with desired composition can be obtained. The innovative aspects for composite granules formation via electrostatic integrated assembly method will be beneficial for composite materials fabrication such as graded materials.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371916

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Altenberend Jochen (Tekna Plasma Europe, France)

Co-author(s): Dr Dolbec Richard (Tekna Plasma Systems Inc, Canada) ; Dr Vert Romain ; Dipl-Ing Van Wijk Pierre (Tekna Plasma Europe, France) ; Dipl-Ing Reijonen Joni (VTT Technical Research Centre of Finland, Finland) ; Dr Riegg Stefan ; Dipl-Ing Schäfer Lukas (Technis

Title: Plasma Spheroidization Of Nd-Fe-B Powder For Additive Manufacturing

Keyword(s):
Powder, Additive manufacturing, Plasma technology, Inductively coupled plasma, Metal powder, AM powders, Spherical powder, Material development, Plasma system, NdFeB, Magnets

Abstract:
High-performance electrical motors and generators, used in numerous applications including wind power, electric vehicles and drones, are heavily relying on Nd–Fe–B magnets. With the development of compact and highly efficient motor designs, complex magnet shapes can be required, and Additive manufacturing represent a very resource efficient approach to produce them. However, additive manufacturing requires highly spherical powders with good flowability in order to produce dense magnets. In this study, angular Nd-Fe-B powders obtained through strip casting and jet milling were spheroidized by induction plasma under inert atmosphere. In a process optimization study, the impact of the powder feedrate on the sphericity was evaluated. The powder spheroidized with the optimized parameters showed a highly spherical shape, a narrow PSD and an excellent flowability.

Innovative Aspect(s):
The plasma spheroidization process has already been developed for several materials but not for NdFeB powder. Dedicated process parameters were developed for this materials and the spheroidized material was analyzed. It could be shown that the powder spheroidized with the optimized parameters had a very high sphericity and an excellent flowability and is thus well adapted for additive manufacturing.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371917

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Hunt Adam (Materials Processing Institute, United Kingdom)

Co-author(s): Mr Rahimi Ehsan (Materials Processing Institute, United Kingdom) ; Mr Ashby James (Liberty Powder Metals Ltd, United Kingdom)

Title: Morphological Evaluation Of Metal Powder To Predict Performance In Powder Bed AM

Keyword(s):
Powder characterisation, Morphology classification, Laser powder bed fusion

Abstract:
Physical properties of metal powder, such as flowability, spreadability and packing density, are critical to the performance of powder bed additive manufacturing (AM) processes. This research begins to standardise the evaluation of metal powders for the laser powder bed fusion (L-PBF) process by correlating morphological classifications against the physical properties of the powder and mechanical properties of the AM built parts. Static image analysis was used to measure and classify the powders by a predefined set of rules based on shape descriptors of the powders. These classification groups quantify the powders in terms of highly spherical, spherical, minor satellited, major satellited, elongated, agglomerated and undersized particles. These classifications were compared against data from a rotating drum test and an automated dynamic tap density analyser. A new weighted index has been proposed to represent the combined influence of size and morphological classifications on the flowability and spreadability of powders for L-PBF.

Innovative Aspect(s):
There is currently a lack of appropriate standards to measure the performance of metal powders for additive manufacturing (AM). Historic standards for powder characterisation are often unrepresentative of the AM process and provide confusing results. There is therefore a need to create standards that are representative of the AM process and how the power functions in this process. Image analysis, either static or dynamic, can give useful information about the powder in terms of shape and size. Classification of powder morphology has been found to be directly related to the performance of the powder during laser powder bed fusion (L-PBF). A new weighted index allows the performance of the powder to be predicted from the size and shape of the powder alone. This information is fed back to the powder producer so that targeted optimisation of the atomisation process can be made, increasing both powder quality and yield.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371983

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dipl-Ing Cabrol Elodie (Centrale Lyon ENISE, France)

Co-author(s): Ing Missemer Florent ; Dr Si-Mohand Hocine (Centrale Lyon ENISE, France) ; Dr Ing Sasaki Layla (Aubert & Duval, France) ; Ing Deborde Agathe (MetaFensch, France) ; Dr Ing Delfosse Jérôme (SAFRAN TECH, France)

Title: Flowability Improvement Of A Powder By Thermal Plasma Treatment

Keyword(s):
Powder, Thermal plasma, Flowability, Spheroïdization, Morphology, Apparent and tap densities

Abstract:
In this work, we have investigated the influence of the presence of satellites on the flowability properties of a TA6V powder. Thermal plasma treatments have been performed to spheroidize the powder at various feed rates (1 to 8 kg|h) and under two atmospheres (Ar|H2 and Ar|He). The physical and chemical properties of the initial and treated powders have been characterized: morphology, particle size distribution, flow rate, apparent and tap densities, hydrogen and oxygen contents. The results have shown that the best powder produced by plasma treatment was spherical, satellites-free and without noticeable effect on the particle size distribution. Contrary to the Ar|H2 atmosphere, the Ar|He atmosphere leads to very low hydrogen contamination (13 ppm). In addition, an improvement in flow rate of 31 % was observed as well as an increase in apparent and tap densities of 20 % and 11 % respectively.

Innovative Aspect(s):
The innovative aspect of this work is the use of thermal plasma to optimize powders: spheroidization, densification, flowability, satellite-free particles and controlled chemical composition. This process is suitable to prepare powders that meet the requirements of additive manufacturing processes.

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: WP225371989

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Wrona Adriana (Łukasiewicz Research Network – Institute of Non-Ferrous Metals, Poland)

Co-author(s): Dr Ing Hryniszyn Alicja ; Ing Czechowska Kinga ; Ing Janoszka Anna ; Ing Osadnik Małgorzata ; Ing Pęcak Krzysztof (Łukasiewicz Research Network – Institute of Non-Ferrous Metals, Poland)

Title: Manufacturing Silver Coated Copper Particles Dedicated For Production Of Conductive Layers On The Elements Of Power Contacts By The Thermal Silvering Method

Keyword(s):
Powders, Copper, Silver, Chemical synthesis, Silvering, Thermal silvering, Electric power contacts

Abstract:
The aim of the research conducted as part of the project was to develop a composite for the production of conductive layers on elements of electric power contacts by thermal silvering with the addition of ultrafine copper particles, copper oxide or copper particles coated with silver. The document will focus on the production of silver coated copper powder. First the copper powder with the assumed parameters such as: particle size distribution, shape, purity was produced using chemical method. Then, the silvering of copper particles was carried out by means of a chemical method, using silver nitrate as the silver precursor. The following silver | copper molar ratios were used during the process: 0.1 | 1M; 0.6 | 1M; 1|1 M. The produced powders were analysed for specific surface area, phase composition, particle size distribution, morphology, layer appearance, chemical composition.

Innovative Aspect(s):
There exist chemical methods of silvering copper powders but our process is based on different methodology. The used methodology is simple compared to other chemical methods.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372000

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dipl-Ing Deborde Agathe (MetaFensch, France)

Co-author(s): Dr Franceschini Aurélie (IRT M2P, France) ; Dr Delfosse Jérôme (Safran Tech, France) ; Dr Hans Stéphane (Aubert&Duval, France)

Title: Effect Of Alloy Composition On The Atomization By EIGA Process

Keyword(s):
Gas atomization, EIGA, Additive manufacturing

Abstract:
Powder metallurgy is used in various industries such as aerospace, medical, defence, etc. For high cleanliness materials, metal powders can be produced using the EIGA process (Electrode Induction melting Gas Atomization). The EIGA process involves the crucible-free melting of an ingot followed by atomization using high-pressure argon. A full-scale EIGA is installed at MetaFensch|IRT M2P for R&D purposes (alloy development, atomization behavior, upscaling, etc.). Process parameters such as electrode size and gas parameters have a predominant influence on powder size and yields. On the other hand, chemical composition of the alloy and the associated thermophysical properties have a significant impact on the atomization process, and therefore on the quality of the powders. To better understand the effect of the composition, several alloys were selected (Ti64, titanium aluminide, nickel-based alloys, etc.) and atomized using the EIGA process. The properties of the powders, especially particle size distribution and morphology, are compared.

Innovative Aspect(s):
Comparison of the properties of powders of different families of alloys obtained by the EIGA process.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372008

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Dopler Martin (Metalpine GmbH, Austria)

Co-author(s): Mr Peyha Mario ; Prof Dr Weiß Christian (Montanuniversität Leoben, Austria)

Title: The Role Of Surface Tension In Gas Atomization

Keyword(s):
Instability theory, Spherical powder, High speed imaging, Melt breakup

Abstract:
In many contemporary powder metallurgical applications (e.g. powder bed fusion, powder injection moulding or electronics surface coating), very fine powders with a narrow particle size distribution are requested. To meet these criteria, powder producers using gas atomization techniques struggle with a low product yield as well as high production costs caused by bad energy conversion during melt breakup process. Primary and secondary breakup are strongly guided by melt surface tension. In a first part of this study, the influence of surface tension during these processes is described by a theoretical model based on instability theory. In a second part, numerical calculations of typical atomizer models are carried out to achieve a deeper understanding on the role of surface tension. Finally, these calculations are compared to experimental atomization results (water, tin) using inline particle size analysis and high-speed imaging.

Innovative Aspect(s):
The work gives a deeper understanding on the melt break-up process in melt atomization. By estimating the role of melt parameters in the breakup process ("The role of viscosity" was already presented 2 years ago at a EPMA 2020), main influences on the whole process chain can be evaluated. Gas atomization processes are not efficient in terms of energy consumption, and by profoundly investigating the breakup process, the efficiency of these processes can be improved (e.g. by reducing inert gas consumption, or by increasing product yield). This study intends to combine the existing theoretical understanding of breakup (instability theory) with practical atomization problems on the one hand by exercising the calculations, and on the other hand by comparing the calculations with practical results (droplet size distributions of water, particle size distribution of atomized tin). Finally ultra high speed imaging of the breakup process shall support the results.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372037

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dipl-Ing Weck Christian (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Co-author(s): Mrs Schinderling Andrea (Universität Bremen, Germany) ; Dr Hein Sebastian Borsi (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Title: Influence Of Air Humidity On Water Content And Flowability Of Different Metallic Powders

Keyword(s):
316L, Ti6Al4V, AlSi10Mg, Moisture, Flowability, Processability

Abstract:
The flowability of metal powders is crucial for all powder bed-based Additive Manufacturing processes. To ensure a defined and reproducible flowability of powders and therefore a robust AM process, a good understanding of the influence of the air humidity on the flowability is important. The flowability of powders is a result of the complex interaction of intrinsic powder properties (e.g. particle size distribution, particle morphology, chemical composition) and the water content. To investigate the influence of the particle size as well as the chemical composition, four different metal powders (316L, Ti6Al4V, AlSi10Mg) were selected. The powders were exposed to different air humidifies between 30% and 80% for different times between 1 hour and 4 hours. All powders were characterized regarding their particle size and morpholopy, their flowability and their water content. Based on the results the influence of the exposition parameters and the powder properties on the flowability was investigated.

Innovative Aspect(s):
Based on the description of the setup of a low-cost and easy-to-use "climate chamber", the influence on the water content of different AM powders is presented. The correlation between ambient humidity, particle size and morphology and the dynamic flow properties has not yet been investigated (to our knowledge).

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372042

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Ing Gobber Federico Simone (Politecnico di Torino, Italy)

Co-author(s): Prof Dr Actis Grande Marco (Politecnico di Torino, Italy)

Title: Effect Of Processing Parameters On The Characteristics Of UNS 32760 Duplex Stainless Steels Powders

Keyword(s):
Duplex stainless steel powders, Gas atomization, Powders characterization

Abstract:
Duplex stainless steels represent a very promising alternative when aggressive|marine atmospheres characterize the component's final application. In this frame, grades with higher Pitting Resistance Equivalent Number (40 or above) may be used in hydrogen sulphide and chloride-containing environments. UNS 32760 Duplex Stainless Steel powders have been obtained by means of close coupled gas atomization, starting from wrought bars. The paper analyses the effect of different parameters on the characteristics of the final powder, in terms of granulometry, orphology, microstructure, and chemical composition (compared to the starting material), also taking into account light elements as N, O, H, C, and S.

Innovative Aspect(s):
No DSS powders showing the chemical composition investigated in the research work appear to be present in literature or in the market as a commercial product.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372113

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dipl-Ing Middelhof Thorsten (RHEWUM GmbH, Germany)

Co-author(s): Dr Huhn Vito (RHEWUM GmbH, Germany)

Title: High-frequency Screening Of Metal Powder

Keyword(s):
Screen, Screening, Sieve, Sieving, Frequency, Efficiency, Recovery, Recovering, Purit, Yield

Abstract:
The increasing scarcity of resources requires sustainable management of raw materials at all levels. Additive manufacturing is a process that conserves raw materials and offers further potential for saving raw materials such as metallic powder. In addition to the manufactured end product, residual powder in the form of agglomerated or dust remains. In order to achieve the desired quality of the metal powder, all impurities, undersized particles and dust need to be removed and agglomerates have to be loosened. This can be achieved in a screening machine that is tailored to the needs of the specific metal powder in order to maintain a high quality. The machine needs to be gas-tight for an inert gas atmosphere, shall be easy to access and clean and sieve the metal accurately at high throughputs. This paper presents the parameters such as different frequencies that have an impact on the screening efficiency.

Innovative Aspect(s):
Several available screening technologies were examined and tested with various settings to analyze the impact on the screening efficiency in terms of product purity and yield. These technologies included linear-motion screens at up to 100 Hz as well as screens with direct-exitation of the screen mesh as well as air jet sieves. The investigation has shown that a high frequency correlates with a product high yield. Other parameters as the implementation of a self-cleaning cycle and the machines geometry were foudn to have an impact on the consistency of the screening efficiency. This resulted in the design of new prototype that concerts the most important parameters of high precision screening of metal powders.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372154

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Dr Ceroni Marta (Politecnico di Torino, Italy)

Co-author(s): Dr Ing Maddalena Lorenza ; Prof Carosio Federico ; Prof Dr Actis Grande Marco (Politecnico di Torino, Italy)

Title: Coated Elemental Cu Powders With Improved Absorbance In Red Light Laser Sources

Keyword(s):
Cu coated powders, Reflectivity, Graphene Oxide

Abstract:
Cu powders show high reflectivity when exposed to a laser having wavelengths of 1064-1080 nm, hindering the processability when manufacturing by red-light L-PBF. Green or blue lasers help overcoming this issue, as well as the change of the chemical composition of the powder. However, other approaches may also be used. The present paper analyses the effect of coatings applied on elemental Cu-powders on the absorbance of the resulting material. Different amounts of Graphene Oxide (GO) have been deposited on the surface of metal powders by means of an electrostatic method, producing different coating thicknesses. Powder systems have been characterized evaluating the absorbance in the red, green, and blue light wavelengths using UV-Vis spectroscopy and, among others, also using Raman spectroscopy to check the uniformity of GO deposition on copper powders.

Innovative Aspect(s):
Several aspects represent an innovation in the research work. The use of an innovative coating technique for the processing of the elemental metal powder required a large set of tests to optimize the coating parameters. A new and rapid technique for the evaluation of the absorbance and the quality of coating has been developed and implemented by means of the use of UV-Vis and Raman spectroscopy respectively.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372157

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Mr Tareq Foysal Kabir (University of Agder, Norway)

Co-author(s): Prof Aune Ragnhild Elizabeth (Norwegian University of Science and Technology, Norway) ; Prof Sætre Tor Oskar (University of Agder, Norway)

Title: Influence Of Process Parameters On Laser Metal Deposition (LMD) Of Inductively Coupled Plasma Spheroidized (ICPS) NiSi16 Powder

Keyword(s):
Spherical nickel silicide powder, Plasma spheroidization, Laser metal deposition, Process parameters, Additive manufacturing

Abstract:
The laser metal deposition (LMD) process is a promising additive manufacturing (AM) technology that enables to build high precision near-net-shape metal components from metal powders. The quality of the LMD parts is highly dependent on the powder properties and processing parameters which need to be optimized to obtain accurate geometry with favorable properties. In the present study, spherical NiSi16 powder was prepared by an inductively coupled plasma spheroidization (ICPS) process from irregular-shaped NiSi16 powder particles and later used during LMD to manufacture cladding beads on a steel substrate. The influence of powder deposition speed and feeding rate on the properties of the LMD cladded beads were investigated using different techniques such as X-ray diffractometer, scanning electron microscope, energy dispersive spectroscopy and micro hardness tester to evaluate the surface porosity, microstructure, and mechanical properties. The results showed that the deposition speed and feeding rate significantly influenced the properties of cladded beads.

Innovative Aspect(s):
Additive manufacturing (AM) market transferring from prototype to commercial production components using different types of standard metal alloys materials. Among different types of materials, silicon-based materials especially nickel silicides are promising candidates for AM due to excellent corrosion resistance, high wear resistance, and high-temperature oxidation resistance. In the present study, spherical NiSi16 powder was prepared by an inductively coupled plasma spheroidization (ICPS) process from irregular-shaped NiSi16 powder particles and later used during LMD to manufacture cladding beads on a steel substrate. This project will help to evaluate and develop a process route (ICPS) for powder production of nickel silicide tailored for AM. The powder production route shall be developed so that the prepared powder fulfills the additive manufacturing requirements.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225377310

Requested paper type: Oral Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Mr ALTINOK Sertaç (Turkish Aerospace Inc., Turkey)

Co-author(s): Dr Yavas Hakan (Turkish Aerospace Inc., Turkey)

Title: From Chips-to-powder: Ti6Al4V Metal Powder Recycling Approach For Sustainable Additive Manufacturing

Keyword(s):
Plasma Spherodization, Ti6Al4V, Powder-based, Additive Manufacturing, Sustainable

Abstract:
Additive manufacturing (AM) is a powerful technique which can allow fabricating parts with complex geometries by CAD-directed melting of powder beds. Different types of metallic alloys have been utilized to integrate AM technologies and may offer great benefits in terms of sustainability and lightweight. There are, however, outstanding questions about sustainability and its economic impact outside of the use phase. For example, the cost of metal powders per kilogram is one of the major challenges that both industry and academia have to overcome. In particular, Ti6Al4V has remained at the forefront especially in aerospace and medical industries owing to the combination of its thermo-mechanical properties. This study presents a sustainable approach of recycling scrap chips to an additive manufacturing quality powder using pulverization and spheroidization processes.

Innovative Aspect(s):
In the aerospace industry, the majority Ti6Al4V parts of airplanes are produced by conventional machining process using plates as raw materials. During the machining of those material, approximately 90% of the materials turn into scraps. These scraps particularly Ti6Al4V chips are processed to convert into small aggregates as an additive for other compositions i.e. ferrotitanium. For this process, the chips are sold at a bargain rate with 2 $|kg at most depending on the titanium value. However, the composition of Ti6Al4V chips and that of powder form for powder-bed fusion additive manufacturing is the same and the powder form costs al least 350 $|kg. This work focused on the conversion of scraps into powder feedstock suitable for AM to capture 175 times of added-value into the company by revealing the process. As long as the aim is achieved, the cost of the AM built with Ti64 will be drastically reduced.

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Poster ☐ Poster & Reserve Oral ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225368537

Requested paper type: Poster Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Prof Dr Ilyushchanka Aliaksandr (O.V. Roman Powder Metallurgy Institute, Belarus)

Co-author(s): Dr Letsko Andrey ; Prof Dr Talako Tatiana ; Mr Reutsionak Yury ; Mr Machnev Vladimir ; Mr Parnitski Nikolay (O.V. Roman Powder Metallurgy Institute, Belarus) ; Prof Dr Yukhvid Vladimir ; Prof Dr Sanin Vladimir (Merzhanov Institute of Structural Macrokinet

Title: Investigation Of Cobalt-based Composite Material Powders Hardened By The Inclusion Of Titanium Carbide Obtained By VIGA Method

Keyword(s):
SHS-Metallurgy, Gas Atomization, Granules, Composition, Structure, Sprayed Powders

Abstract:
A powder of a heat-resistant cobalt-base composite material reinforced with titanium carbide inclusions has been produced by the method of vacuum induction melting and inert gas atomization (VIGA). Phase composition and structure of the powder obtained have been investigated. The size of carbide inclusions in the powder has been reduced to less than 2 μm compared to the original alloy obtained by SHS-metallurgy. The technological properties (bulk density, flowability) of the powders of different fractions have been determined.

Innovative Aspect(s):
Minimization of losses of alloying elements and preservation of the composite structure of the material during vacuum induction melting of ingots of heat-resistant composite material obtained by centrifugal SHS. Obtaining spherical granules of a given size without significantly changing its chemical composition.

TPC Reviewer name: .....

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371733

Requested paper type: Poster Presentation

Topic: Powder production / **Subtopic:** Powder production

Author: Mr Becker Malte (Fraunhofer IAPT, Germany)

Co-author(s): Mrs Ludwig Ina (Fraunhofer IAPT, Germany)

Title: Effects Of Reinforcing AlSi10Mg With Silicon Carbide On LPBF Processability And Mechanical Properties

Keyword(s):

Abstract:
Additive Manufacturing (AM) stands out in lightweight construction, material efficiency and geometric freedom. But as it is still a relatively young technology only a small number of alloys has been developed and thus there is a lack of material diversity especially for highly stressed AM components. One way to increase mechanical properties is using composite alloys that are reinforced by ceramic particles. Subject of this investigation are the effects of reinforcing AlSi10Mg with different volume fractions of silicon carbide (SiC), by either mixing or milling and the processability of the reinforced powder in a LPBF process. The used powders are characterized including optical inspection, particle size distribution, particle morphology and flowability. The manufactured parts analyzed regarding the density and tested for their mechanical properties. Based on the results correlations between the powder manufacturing process, alloy composition and mechanical properties are evaluated.

Innovative Aspect(s):
Using reinforced materials in AM. Analyzing the effects on the LPBF process depending on the different volume fractions of silicon carbide. Analyzing the effects on the LBPF process depending on the powder manufacturing process (milling | mixing).

TPC Reviewer name: .....

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Poster ☐ Poster & Reserve Oral ☐

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