Selected Abstracts of Thermal Spray Literature

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Applications

Biomaterials

Influence of Powder Characteristics on Plasma Sprayed Hydroxyapatite Coatings. Phase transformations, particle breakdown, and partial decomposition occur in hydroxyapatite (HA) powder feedstock during plasma spraying. The biological responses of the coatings consequently change from the bioactive nature of the starting material to a less biocompatible one. This paper investigates the influence of powder characteristics on the phase composition and microstructure of plasma sprayed HA coatings. The raw HA was prepared by chemically reacting calcium hydroxide with orthophosphoric acid. Subsequently, HA was either calcined and crushed, flame spheroidized, or spray dried. These three types of HA powders were plasma sprayed on steel substrates to form coatings. A previous study showed that the calcined HA powder suffered from particle breakdown in the plasma The plasma sprayed HA powders contained other calcium phosphate phases (amorphous and crystalline) apart from hydroxyapatite. The flow properties and stability of spheroidized HA were better than calcined HA and spray-dried HA. Standard metallographic preparation of the cross sections of the coatings revealed different microstructural features among the coatings. The HA coatings prepared from calcined HA were highly porous and lacking in intimate lamellar contact. The spheroidized HA powders produced the coating with the lowest porosity. Characterization of the powders and coatings was carried out using x-ray diffraction (XRD), scanning electron microscopy (SEM), and optical microscopy.

P. Cheang and K.A. Khor. Cited: *J. Thermal Spray Technol.*, Vol 5 (No. 3), Sept 1996, p 310-316 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199612-57-2249.

Characteristics of Plasma-Sprayed Bioactive Glass Coatings on Ti-6Al-4V Alloy: An In Vitro Study. Conventional bioactive glasses, in bulk form, are being considered as biomaterials in prosthetic applications. In this study, a new attempt was made to coat bioactive glasses on Ti-6Al-4V by plasma spraying. This method will coat the bioactive glass coatings (BGCs) onto metal substrate, potentially combining the excellent mechanical strength of metal and biocompatibility of bioactive glass. Analysis by x-ray diffractometry (XRD) of the BGCs, revealed that the amorphous structure of glass was preserved. BGCs were soaked in simulated body fluid (SBF) to evaluate their properties in vitro. After soaking in SBF for one day, precipitation of fiber structure was observed on the surface of the BGCs. After two and more days, the surface of the BGCs was completely covered with precipitates. The precipitates, identified as the apatite phase by XRD, contained carbonate and hydroxyl functional groups detected by Fourier transform IR reflection (FTIR) spectroscopy. After soaking for 16 days, a thin layer of about 10 μm, rich in calcium and phosphorus but poor in silicon, was observed on the surface of the BGCs. The composition of the Ca-P-rich layer was consistent with the apatite structure identified by various methods, but the apatite layer was significantly thicker than reported in bulk form. The formation of an apatite phase surface has been suggested to be indicative of biocompatibility. All findings in this study indicated the formation of apatite on the surface of plasma sprayed BGCs, and this material is expected to be biocompatible in vivo

T.M. Lee, E. Chang, B.C. Wang, and C.Y. Yang. Cited: *Surf. Coat. Technol.*, Vol 79 (No. 1-3), 1 Feb 1996, p 170-177 [in English]. ISSN 0257-8972. PHOTOCOPY ORDER NUMBER: 199612-57-2202.

Deuterium Permeation

Reduction of Deuterium Permeation through SiC/SiC Composites by Plasma-Spray Deposited Eutectic Al-Si. This paper deals with the formation of a deuterium permeation barrier on SiC/SiC composites, proposed as low-activation structural materials for the first wall of a fusion reactor. An Al-11.22 mass% Si eutectic layer has been applied to SiC/SiC substrate by a plasma spraying process and subsequently heat treated to maximize the interfacial bond strength. Permeation measurements were performed in the temperature range 300 to 750 K using deuterium at pressures in the range 0.5 to 150 kPa. A linear dependence of permeation rate on pressure was measured. The efficiency of the coating as a deuterium permeation barrier is discussed in terms of the heat treatment temperature. The best result was achieved by heat treating the sample (SiC/SiC + Al-11.22 mass% Si) at 933 K for 2 h.

C. Racault, P. Fenici, and E. Serra. Cited: *J. Nucl. Mater.*, Vol 227 (No. 1-2), 1 Nov 1995, p 50-57 [in English]. ISSN 0022-3115. PHOTOCOPY ORDER NUMBER: 199612-58-1860.

Ice Breaker Hulls

Hot Gas Sprayed Coatings for Protecting Ice Breaker Hulls against Corrosion-Erosion Failure. The bonding strength, hardness, wear, and corrosion properties of hot gas sprayed combined amorphous alloy coatings were investigated and compared with the conventional metallic coatings to improve the properties of ice breaker hulls. The alloys were Fe-Ti-Si-C, Fe-Mo-Cr-B, Ni-Cr-Mo-B, a mixture of PG-10N-01 and PT-NA-01 powders, 04Kh15N19V3 corrosion-resistant steel, and PG-SR4 self-fluxing nickel alloy were deposited on steel plates. Pores in the coatings were sealed by saturating with hydrophobizing organic silicon liquid. The highest corrosion resistance in synthetic seawater was shown by the PG-10N-01+PT-NA-01 and PG-SR4 coatings. The former also exhibited the highest bonding strength, hardness, and relative wear resistance.

E.Ya. Lyublinskii. Cited: *Paton Weld. J.*, Vol. 3, 1992, p 195-197 [in English]. ISSN 0957-798X. PHOTOCOPY ORDER NUMBER: 199611-58-1784.

Review of Anilox Rolls

Technology of Thermally Sprayed Anilox Rolls: State of Art, Problems, and Perspectives. This paper deals with the surfacing technology of ceramic anilox rolls. The rolls are used in the printing industry to transport the precisely determined quantity of ink in the flexographic printing machines. The technology of roll surfacing is discussed by taking the following aspects into account: preparation of the powder to spray the ceramic coating, thermal spraying of the duplex (bond coating and ceramic top coating), postspray finishing by grinding and polishing, and laser engraving. The powder used as the top coating of the aniloxes is chromium oxide. This powder might be prepared by such techniques as agglomeration, fusing, and crushing, etc. The preparation technique influences coating properties, such as microstructure (tested with SEM, OM, XRD, and XPS), open porosity, microhardness, and modulus of elasticity. Comparison of these properties enables optimum powder preparation techniques to be found. APS technique is used to coat the anilox rolls. Optimization of the plasma spraying parameters is discussed. Aniloxes are submitted to the grinding and polishing of the ceramic coating before laser engraving occurs. The final roughness of the finished coating is discussed in view of an optimum absorption of the laser light energy at engraving. Possible ways of reducing the spraying time are discussed, and future research toward improving the anilox roll quality is proposed. Roll material was stainless steel.

L. Pawlowski. Cited: *J. Thermal Spray Technol.*, Vol 5 (No. 3), Sept 1996, p 317-334 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199612-57-2250.

Thermal Barrier Coatings

Thick Thermal Barrier Coatings for Diesel Engines. Application of thermal barrier coatings (TBCs) in diesel engines offers benefits through improved component lifetimes, better thermal efficiency, and lower environmental emissions. Work done in this area within COST 501 is summarized and proposals to improve coating quality through enhanced control of the plasma spraying process are put forward. The control system will use fuzzy logic to optimize spraying parameters for individual components. Of great importance is the cooling profile undergone by the component after coating, which must be designed to provide residual strains that will enhance coating lifetime.

I. Kvernes and E. Lugscheider. Cited: *Surf. Eng.*, Vol 11 (No. 4), 1995, p 296-300 [in English]. ISSN 0267-0844. PHOTOCOPY ORDER NUMBER: 199611-57-1987.

Thermal Barriers and Materials and Process for Constructing Them. The thermal barriers are made of materials comprising at least one refractory oxide of low thermal diffusivity and at least one quasi-crystalline aluminum alloy, the proportion of which is 2 to 30 vol%. They can be constructed by the vapor phase deposition of a blend of the refractory oxide and the quasi-crystalline alloy, or by starting with a blend of the refractory oxide and the quasi-crystalline Al alloy in the molten state, or also by deposition on a protecting support by means of an oxygen-gas torch fed with the materials through a flexible cord containing the refractory oxide and the quasi-crystalline alloy. They can be used for protecting aircraft and car engine parts, aeronautical and aerospace parts, chemical reactors, and accessories of domestic household appliances.

J.-M. Dubois and P. Cathonnet. Cited: European Patent No. EP0605273, 6 July 1994, Conv. date: 13 Dec 1993 [in French]. PHOTOCOPY ORDER NUMBER: 199611-54-1078.

Titanium

Surface Property Modification Using Vacuum Plasma Coating. Pure titanium samples were plasma coated with aluminum, chromium, and Al+Cr+Y. Coating was carried out using atmospheric plasma spray method (APS) and using vacuum plasma spray method (VPS). Characterization of the coated surface was carried out in terms of its surface composition, morphology, and its adherence to the substrate. Oxidation behavior of the coated samples was studied by carrying out tests in air at 700 and 800 °C.

A.S. Khanna, K. Anuja, C.S. Harendranath, and C. Coddet. Cited: *Thermal Spraying—Current Status and Future Trends*, Vol 2 (Proc. Conf.), Kobe, Japan, 22-26 May 1995, High Temperature Society of Japan, Osaka, Japan, 1995, p 577-583 [in English]. PHOTOCOPY ORDER NUMBER: 199612-58-1923.

Wear of WC/Co

Annealing of Plasma-Sprayed WC-Co Coating. The effects of vacuum annealing on the physical soundness and resultant tensile bond strength and wear properties of plasma-sprayed WC-17%Co coatings on a ductile cast iron substrate have been investigated. The as-sprayed specimens were annealed at temperatures from 500 to 1000 °C for up to 12 h. The results showed that, due to differential sintering within the coating, vertical cracks were formed at the interface between darker cobalt-rich and lighter cobalt-deficient splats. The average length and density of cracks increased with increasing temperature at intermediate annealing temperatures from 500 to 700 °C, but decreased with increasing annealing temperature and time at higher annealing temperatures due to crack sintering and ovulation effects. Significant precipitation of WC crystallites and interdiffusion at the coating/substrate interface also occurred at the higher temperatures. The annealing-induced cracks produced a detrimental effect on the bond strength of plasma-sprayed WC-17%Co coatings. The decrease in tensile bond strength was especially pronounced for coatings annealed at intermediate temperatures from 500 to 700 °C. For coatings annealed at 800 °C and above, the tensile bond strength improved steadily over that of coatings annealed at the lower temperatures, their magnitudes increasing with increasing annealing temperature and time. Despite the above, bond strengths of the as-sprayed coating and those annealed at and above 900 °C were undetermined because failure occurred in the adhesive. Cylinder-on-cylinder wear tests showed that the wear behaviors of the as-sprayed coating and of coatings annealed under various conditions were comparable. Two wear mechanisms were identified: plastic deformation of the γ-Co matrix and spallation of splats. The wear test results were consistent with spallation being the dominant wear mechanism, both in as-sprayed and annealed conditions.

L.C. Lim, S. Alli, S.F. Chong, M.O. Lai, and S.C. Lim. Cited: *Surf. Coat. Technol.*, Vol 79 (No. 1-3), 1 Feb 1996, p 151-161 [in English]. ISSN 0257-8972. PHOTOCOPY ORDER NUMBER: 199612-58-1865.

Book

ITSC Proceedings

***Thermal Spraying—Current Status and Future Trends*, Vol 2.** ITSC '95. 14th International Thermal Spray Conference. 110 papers selected and abstracted.

A. Ohmori. Cited: *Thermal Spraying—Current Status and Future Trends*, Vol 2 (Proc. Conf.), Kobe, Japan, 22-26 May 1995, High Temperature Society of Japan, Osaka, Japan, 1995 [in English]. PHOTOCOPY ORDER NUMBER: 199612-72-0510.

Characterization

Fractal Dimension

Introduction of Fractal Dimension to Adhesive Strength Evaluation of Plasma-Sprayed Coatings. The adhesive strength of ceramic coatings depends on the surface roughness of substrates. Taking account of the bonding mechanisms, however, surface roughness may not be a proper measure to evaluate the surface topography of substrates. Here, fractal dimension is proposed for the evaluation of surface topography. Physically, the fractal dimension can include hook-shaped indentations that generate a mechanical interlocking force. By applying fractal dimension to the evaluation of the surface topography of substrates and relating it to the adhesive strength of alumina coatings, it was concluded that fractal dimension properly evaluates the adhesive strength as compared with surface roughness.

S. Amada and H. Yamada. Cited: *Surf. Coat. Technol.*, Vol 78 (No. 1-3), 1 Jan 1996, p 50-55 [in English]. ISSN 0257-8972. PHOTOCOPY ORDER NUMBER: 199612-58-1849.

Feedstock

Filler Materials for HVOF

Filler Materials in Powder Form for Thermal Spraying. Important oxide and carbide-base material systems, in particular for high-velocity oxyfuel flame spraying, and oxide-based powders for plasma spraying, are presented. The influence on the coating properties of the structure and the spraying powders used is demonstrated on the basis of examples.

J. Beczkowiak. Cited: *Schweissen Schneiden*, Vol 48 (No. 2), Feb 1996, p E36-E38 [in German]. ISSN 0036-7184. PHOTOCOPY ORDER NUMBER: 199612-57-2216.

TaC Optimization

Influence of Plasma Spraying Parameters on the Carbon Content and Porosity of TaC Coatings. The optimization of a plasma sprayed TaC coating process under controlled atmospheric and temperature conditions is described. The use of an inert argon atmosphere allows coatings to be obtained from materials with high melting points that are sensitive to oxidation. Correlations were established between the nature of the plasma gas, the temperature and velocity of the particles in the plasma jet, and the chemical properties of the final coating. Increasing the arc current increases the particle velocity and decreases the coating porosity. The advantages of adding helium to the plasma gas mixture were confirmed. Increasing the He concentration in an Ar-H_2 plasma improves the melting of the TaC particles, but also lowers the C/Ta atomic ratio and results in the formation of small quantities of Ta_2C.

L. Trignan-Piot, M. B'rardo, J. Gastaldi, and S. Giorgio. Cited:*Surf. Coat. Technol.*, Vol 79 (No. 1-3), 1 Feb 1996, p 113-118 [in English]. ISSN 0257-8972. PHOTOCOPY ORDER NUMBER: 199612-57-2201.

Mechanical Properties

Fracture Resistance

Fracture Mechanics Approaches to Coating Strength Evaluation. The incidence of mechanical failure of flame sprayed molybdenum coating on piston rings prompted development of reliable methods of characterizing and improving bond strengths. A method of using the ASTM specimen with a small modification to estimate fracture toughness properties of the coating is proposed. Flame spraying process parameters are optimized to produce coatings of high adhesive strength using Taguchi techniques by using the modified ASTM specimen. Experiments are conducted using four-point bend specimen to study the coating behavior under complex stress conditions. The effect of coating thickness on the fracture resistance of the interface is studied. Coating strength is characterized in terms of fracture mechanics parameters fracture toughness and J_{cnt}; using modified ASTM and four-point bend specimens, respectively. The J_{cnt} values are determined by virtual crack extension technique, in conjunction with finite element analysis solutions. Theoretical investigations by finite element analysis are conducted on the test specimens to gain information about the stresses responsible for failure initiation and the failure initiation zones.

R.K. Kumar, N.G. Shankar, M.V. Babau, and O. Prabhakar. Cited: *Eng. Fract. Mech.*, Vol 55 (No. 2), Sept 1996, p 235-248 [in English]. ISSN 0013-7944. PHOTOCOPY ORDER NUMBER: 199612-58-1961.

Hertzian Contact Damage

Contact Damage in Plasma-Sprayed Alumina-Based Coatings. A study of Hertzian contact damage in plasma-sprayed alumina-based ceramic coatings on steel substrates has been made. Presectioned specimens are used to identify subsurface micromechanical damage processes within the coating and substrate layers as a function of increasing contact load, from both postcontact and in situ observations. Damage occurs principally by cracking in the ceramic coating and plastic deformation in the metal substrate, along with delamination at the coating/substrate interface. Coating thickness, cycling loading (fatigue), and processing history (coating microstructure) are shown to be important factors in the damage patterns and ensuing modes of failure. Indentation stress-strain curves are used to measure macroscopic mechanical responses, to quantify the maximum sustainable contact stresses, and to determine the relative roles of coating and substrate in the net deformation.

A. Pajares, B.R. Lawn, and L. Wei. Cited: *J. Am. Ceram. Soc.*, Vol 79 (No. 7), July 1996, p 1907-1914 [in English]. ISSN 0002-7820. PHOTOCOPY ORDER NUMBER: 199611-57-1954.

WC Coatings

Cracking Process and Delamination Strength of WC Film Coated by High-Speed Flame Spraying. WC ceramic was coated on the smooth specimen of annealed tool steel (JIS:SKD6) by high-speed flame spraying, and the tensile test of the specimen was carried out to obtain interfacial energy, where the load was applied parallel to the film. With increasing load the film is divided repeatedly by occurrence of cracks, and the film delamination begins after the crack interval reaches a certain value. The crack interval of film at the delamination increases and the interfacial energy slightly decreases with an increase in film thickness. The finite element analysis shows that the tensile stress at the center of film and the shear stress at the edge of film decrease with a decrease in film length, and the difference between both stresses increases with a decrease in film thickness. The analysis not only shows that the repeating film division continues as long as the tensile stress in the film reaches a critical tensile strength σ_C before the shear stress at the interface reaches a critical shear strength τ_C, but also explains the film thickness dependency of crack interval. By considering the analysis and the result of experiment, the crack interval, L_C, at the delamination of film can be expressed by the following equation, $L_C/B_2 = \alpha(\sigma_C/\tau_C)\,(B_1/B_2)^{\kappa}$, where B_1 and B_2 are the thickness of film and substrate, respectively, and α and κ are the constants.

K. Nakasa, M. Kamata, F. Egawa, and M. Kato. Cited: *J. Soc. Mater. Sci., Jpn.*, Vol 45 (No. 6), June 1996, p 680-686 [in Japanese]. ISSN 0514-5163. PHOTOCOPY ORDER NUMBER: 199612-57-2254.

Microstructure

Amorphous

Characterization of Plasma Sprayed Fe-17Cr-38Mo-4C Amorphous Coatings Crystallizing at Extremely High Temperature. A Fe-17Cr-38Mo-4C alloy powder was plasma sprayed by three processes: an 80 kW low-pressure plasma spray (LPPS), a 250 kW high-energy plasma spray (HPS), and a 40 kW conventional plasma spray (APS). The as-sprayed coating obtained by the LPPS process is composed of only amorphous phase. As-sprayed coatings obtained by the HPS and APS processes are a mixture of amorphous and crystalline phases. The three as-sprayed coatings exhibit a high hardness of 1000 to 1100 DPN. The amorphous phase in these coatings crystallizes at a high temperature of ~920 K. A very fine structure composed of hard ψ-phase and carbides is formed after crystallization. The hardness of the coating obtained by LPPS reaches a maximum of 1450 DPN just after crystallization on tempering and retains a high hardness >1300 DPN after tempering at high temperatures of 1173 or 1273 K. The corrosion potential of the amorphous coating is the highest among the three coatings and higher than that of a SUS 316L stainless steel coating. The anodic polarization measurements suggest that the corrosion resistance of the amorphous coating is superior or comparable to SUS316L stainless steel coating in H_2SO_4 solution. Substrate was mild steel.

K. Kishitake, H. Era, and F. Otsubo. Cited: *J. Thermal Spray Technol.*, Vol 5 (No. 3), Sept 1996, p 283-288 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199612-58-1962.

Amorphous Coatings

Characteristics of Fe-17Cr-38Mo-4C Amorphous Coating Obtained by Low-Pressure Plasma Spraying. Fe-17 mass% Cr-38 mass% Mo-4 mass% C alloy was thermal sprayed by a use of 80 kW low-pressure plasma spraying apparatus. It is known that the amorphous phase of the same alloy has a very high crystallization temperature ~940 K. The as-sprayed coating is composed of perfectly amorphous phase and shows a high hardness of 1000 DPN. The amorphous phase in the coatings crystallizes at a high temperature of ~920 K. A very fine structure of hard γ phase and carbides is formed after crystallization bringing about an extremely high hardness of 1450 DPN. The hardness of the tempered coating retains a high hardness of 1300 DPN or over, even after tempering at 1273 K. The corrosion resistance of the amorphous coating is superior or comparable to SUS316L austenite stainless steel coating in H_2SO_4 solution.

K. Kishitake, H. Era, and F. Otsubo. Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spraying Soc.)*, Vol 32 (No. 3), Oct 1995, p 24-28 [in Japanese]. ISSN 0916-6076. PHOTOCOPY ORDER NUMBER: 199611-58-1735.

Phase Transformations

Oxy-Fuel Flame Spraying with Subsequent Remelting of a NiCrBSi Alloy on Heat Treated Steels. The growing shortage and increasing price of many raw materials make it necessary to use thermally sprayed and subsequently remelted alloys as surface coatings for heat-treated steels (C45, 42C4Mo4, 34CrNiMo6) on the bond characteristics between a remelted NiCrBSi coating and various heat-treatable steels, and the causes of possible cracking. It is indicated that the structural transformation of certain alloy steels during cooling took place only after the transformation of the hard material coating, so that cracks arose resulting from residual stress.

K.-J. Matthes. Cited: *Schweissen Schneiden*, Vol 48 (No. 2), Feb 1996, p E27-E29 [in English]. ISSN 0036-7184. PHOTOCOPY ORDER NUMBER: 199612-58-1886.

Modeling

Substrate-Coating Interaction

Substrate-Coating Thermal Interaction during High Velocity Oxy-fuel Spraying. II Structure Formation. Mathematical simulation of the formation of the structure of both the substrate and the coating during high velocity oxyfuel (HVOF) spraying is presented. The variation in the solidification velocity, the thermal gradient, and the cooling velocity in the first coating layer as well as the fusion (solidification) velocity, the thermal gradient, and the heating (cooling) velocity in the substrate are studied. The formation of the amorphous structure in the coating and the crystalline structure in the substrate are discussed. The optimal conditions for the development of the fine and dense crystalline structure in the substrate are investigated. The results obtained agree well with the experimental data.

V.V. Sobolev, J.A. Calero, and J.M. Guilemany. Cited: *Mater. Sci. Technol.*, Vol 11 (No. 10), Oct 1995, p 1052-1059 [in English]. ISSN 0267-0836. PHOTOCOPY ORDER NUMBER: 199611-57-1986.

Optimization

Taguchi Methods

Simultaneous Optimization of Flame Spraying Process Parameters for High Quality Molybdenum Coatings Using Taguchi Methods. Flame sprayed molybdenum coatings are extensively used in industrial applications to enhance the performance of engineering components such as pistons, piston rings, and shafts. Improved resistance to thermal degradation, corrosion, and wear can be achieved. In all these applications, the performance of the coating is dependent upon its cohesive and adhesive strengths, which are affected by the spraying process parameters employed during the coating deposition process. In the present study, an attempt is made to produce high-quality coatings by optimizing the spraying process parameters using Taguchi techniques. Experiments are conducted using ASTM specimens to produce coatings that have high cohesive strengths. A new test specimen is proposed by modifying the ASTM specimen to give a fracture mechanics specimen that can quantify the adhesive strength of the coating. Microstructural studies are conducted on the sprayed coatings and the changes in the microstructure with different spraying conditions are correlated with the strength variations of the coating.

M.V. Babu, N.G. Shankar, R.K. Kumar, and O. Prabhakar. Cited: *Surf. Coat. Technol.*, Vol 79 (No. 1-3), 1 Feb 1996, p 276-288 [in English]. ISSN 0257-8972. PHOTOCOPY ORDER NUMBER: 199612-58-1872.

Patent

Feedstock

Metallic Powder for Producing Wear-Resistant Surface Layers By Means Of a Thermal Spraying Method, Process for Producing It, and Spraying Method Therefor. The metallic powder consists of one or several transition metals, in particular, mainly nickel and iron, and in each case chromium as alloying element and in addition contains at least one metalloid, in particular boron, carbon, silicon, or phosphorus. The powder granules contain intercalations consisting of solid particles derived from the metalloid. The invention further relates to a method of producing the powder as well as to a preferred application method.

P. Heinrich and H. Kreye. Cited: European Patent No. EP0608468, 3 Aug 1994, Conv. date: 14 May 1993 [in German]. PHOTOCOPY ORDER NUMBER: 199611-58-1722.

System Development

Installation and Process for Producing Protective Coatings. An installation for producing protective wear and corrosion-resistant coatings by thermal spraying, and in which wires from which the spray is produced are processed in a spraying plant at a distance, has a nozzle system for bringing hard-material and hard-phase particles into the sprayed jet without fusion or remelting arranged around the nozzle atomizing molten metal droplets. In addition, a wire drive unit operating on the push-pull principle and propelling the wire is arranged at 2 to 10 m from the wire spraying plant.

W. Simm and H.-T. Steine. Cited: European Patent No. EP0493695, 8 July 1992, Conv date: 1 Jan 1992 [in German]. PHOTOCOPY ORDER NUMBER: 199611-57-2031.

Wear Resistance

A Process for the Production of Wear Resistant Edges on Turbine Blades. The invention concerns a process for the production of wear resistant edges on turbine blades in areas, for example, of leading entry and top lamination, preferably for steam turbines made from chromium steels and/or titanium-base alloys. According to the invention: (1) the protection of an edge on a specific position is imparted preferably by forging or by a stress imparting operation and (2) protection is conferred by spraying powder with a plasma torch on a corresponding position or by an encapsulation technique.

C. Willems and A. Luckow. Cited: European Patent No. EP0618310, 5 Oct 1994, Conv. date: 23 March 1994 [in German]. PHOTOCOPY ORDER NUMBER: 199612-61-1573.

Process

Gas Tunnel Plasma Spray

Characteristics of High Hardness Alumina Coatings Formed by Gas Tunnel Plasma Spraying. High hardness alumina coatings were formed at atmospheric pressure by gas tunnel plasma spraying, and the characteristics of these coatings were investigated. The hardness on the cross section of the alumina coating at a short spraying distance was >1300 HV, and the thickness of the hard layer increased with an increase of power input. The microstructure of the alumina coating was investigated by microscopy and x-ray diffraction (XRD) methods. It was ascertained that the cell size was small (~10 μm), and α-alumina was dominant in the high hardness layer of the coating. Finally, the effect of plasma energy was estimated from these results. A commercially available SUS304 plate was used as the substrate.

A. Kobayashi. Cited: *J. Thermal Spray Technol.*, Vol 5 (No. 3), Sept 1996, p 298-302 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199612-57-2248.

High-Temperature Synthesis

Comparison between Ni-Cr-40 vol% TiC Wear-Resistant Plasma Sprayed Coatings Produced from Self-Propagating High-Temperature Synthesis and Plasma Densified Powders. Plasma sprayed Ni-Cr-40 vol% TiC coatings produced from powders obtained by self-propagating, high-temperature synthesis (SHS) and plasma-densification (PD) processes are characterized. Chemical composition, microstructure, and mechanical properties, such as microhardness and wear resistance, are evaluated and compared. SHS coatings exhibit good sliding-wear performance. The exact stoichiometry of titanium carbide inclusions in the metallic matrix affects the dimension of the crystal lattice parameter and was investigated by examining the shift of x-ray diffraction (XRD) peaks of the TiC. A value of the combined carbon/titanium ratio of ~0.6 was calculated for both powders, thus excluding the influence of the stoichiometry of the carbide inclusions on the wear properties of the coatings. Coatings were deposited onto 4140 steel specimens.

C. Bartuli and R.W. Smith. Cited: *J. Thermal Spray Technol.*, Vol 5 (No. 3), Sept 1996, p 335-342 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199612-58-1963.

HVOF and Material Properties

High Velocity Oxy-Fuel Flame Spraying of Molybdenum. High velocity oxy-fuel flame spraying (HVOF) can be used to produce dense and highly adherent molybdenum coatings. By suitable choice of powders and spray parameters the oxygen content in the coating can be influenced and thus enable the hardness and wear resistance to be specifically determined and varied within wide limits. Furthermore, spray tests with molybdenum are effective for analyzing more precisely the melting and oxidizing of the powder particles in the flame jet and for comparing the heating efficiency of the various spray methods and the oxidizing effect of different fuel gases.

S. Zimmermann. Cited: *Schweissen Schneiden*, Vol 48 (No. 2), Feb 1996, p E24-E26 [in English]. ISSN 0036-7184. PHOTOCOPY ORDER NUMBER: 199612-58-1885.

Properties

Corrosion/Erosion Resistance

Corrosion Resistance and Gas-Abrasive Wear of Plasma Coatings. The electrochemical behavior and corrosion resistance in HCl solutions of different concentration, gas-abrasive wear of the plasma coatings of alloys based on iron and nickel were investigated. Alloys coated were Fe-Cr-Mo-B and Ni-Cr-Mo-B. Abrasive wear resistance for different angles of the abrasive in the sliding friction conditions was measured at a constant rate and different loads. The highest corrosion resistance was exhibited by a coating of the Fe-Cr-Mo-B system. Spraying this coating resulted in the formation of an amorphous microcrystalline structure.

V.F. Gal'nik Cited: *Paton Weld. J.*, Vol 3, 1992, p 187-190 [in English]. ISSN 0957-798X. PHOTOCOPY ORDER NUMBER: 199611-58-1782.

Hot Corrosion

Hot Corrosion of Nickel-Chromium and Nickel-Chromium-Aluminum Thermal Spray Coatings by Sodium Sulfate-Sodium Metavenadate Salt. The hot corrosion behavior of low-pressure plasma sprayed (LPPS) 80 wt% Ni-20 wt% Cr and flame sprayed (FS) 75 wt% Ni-20 wt% Cr-4.0 wt% Al coatings on type 304 (UNS S30400) stainless steel (SS) by thin fused films of sodium sulfate (Na_2SO_4) and 0.7 mol fraction Na_2SO_4-0.3 mol fraction sodium metavanadate ($NaVO_3$) at 900 °C in a 1% sulfur dioxide (SO_2)-oxygen (O_2) atmosphere was studied using an electrochemical method. The 80% Ni-20% Cr coatings were tested in the as-sprayed condition. The 75% Ni-20% Cr-4% Al coatings were tested under as-sprayed and laser-glazed conditions. Evolution of the fused salt film chemistry, in terms of the thermodynamic activities of O_2 and sodium oxide (Na_2O), was monitored using a ZrO_2 probe and a fused-silica Na sensor. Results permitted qualitative evaluation of the corrosion resistance of the coatings and could be interpreted in terms of previously proposed hot corrosion mechanisms.

Y. Longa-Nava, M. Takemoto, R.A. Rapp, and Y.S. Zhang. Cited: *Corrosion*, Vol 52 (No. 9), Sept 1996, p 680-689 [in English]. ISSN 0010-9312. PHOTOCOPY ORDER NUMBER: 199612-35-2428.

Microstructure/Adhesion

Relationship between Particle's Splat Pattern and Coating Adhesive Strength of HVOF Sprayed Cu Alloy. The dependence of particle's splat pattern and coating adhesive strength on substrate temperature just before spraying has been verified for HVOF sprayed Cu-alloy. The results obtained are summarized as follows: (1) The transition behavior in the splat pattern of the plasma sprayed particles attendant to the substrate temperature increasing was observed in HVOF sprayed Cu-alloy particles. (2) Particle's velocity is not suspected to be responsible for the transition behavior in the splat pattern of HVOF sprayed particle attendant to the substrate temperature increasing. The substrate temperature seems to be the dominating factor for this phenomenon. (3) As the substrate temperature increases, both the adhesive strength of the coating and the fraction of the disk-splats have a tendency to increase. From this result, the deposition of the disk-splats is suspected to be responsible for the formation of the higher adhesive strength coatings.

M. Fukumoto, H. Hayashi, and T. Yokoyama. Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Thermal Spraying Soc.)*, Vol 32 (No. 3), Oct 1995, p 29-36 [in Japanese]. ISSN 0916-6076. PHOTOCOPY ORDER NUMBER: 199611-58-1736.

Review

Practical Orientation

Practice Oriented Thermal Spraying on Repairable and New Components. Modern spraying technology, with the variants available in terms of material and equipment, today offers a broad range of solutions to problems in the repair and new component fields. Alongside the proven conventional methods, such as flame spraying, arc spraying, plasma spraying and the recently established high-velocity oxyfuel flame spraying, more recent developments are concerned with rotating torch systems for internal coating of cylinders and torch concepts that are operated with liquid fuel such as kerosene, diesel or gasoline. Consequently, the basis for the practical success of the optimization of components for spraying lies in the dialogue with the maintenance engineers and designers in the various industries that derive economic benefit from this technology.

E. Schwarz. Cited: *Schweissen Schneiden*, Vol 48 (No. 2), Feb 1996, p E41-E44 [in English]. ISSN 0036-7184. PHOTOCOPY ORDER NUMBER: 199612-58-1889.

Surface Treatment Technology

Thermal Spraying in the Context of Surface Treatment Technology—Current Situation and Prospects. The significance of thermal spraying in comparison with other methods of surface treatment is presented. Typical areas of use are illustrated on the basis of application examples. Following a review of the market, the development prospects of thermal spraying are discussed. Examples of cemented carbide, nickel alloy, and ceramic coatings used in various applications are used to illustrate the text.

H. Reimann. Cited: *Schweissen Schneiden*, Vol 48 (No. 2), Feb 1996, p E22-E24 [in English]. ISSN 0036-7184. PHOTOCOPY ORDER NUMBER: 199612-58-1884.

Thermal Spray Industries

Thermal Spray Industry Continues to Develop. The thermal spray industry has developed into a major consumer of metal powders since its development in the 1920s. The industry now consumes in excess of 400,000 kg/year of a variety of materials including tungsten and chrome carbides, and nickel- and iron-base powders. An overview is given of the industry and its latest developments.

W.A. Saywell. Cited: *Met. Powder Rep.*, Vol 51 (No. 4), April 1996, p 34-37 [in English]. ISSN 0026-0657. PHOTOCOPY ORDER NUMBER: 199611-54-1086.

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