Selected Abstracts of Thermal Spray Literature

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Applications

Biomaterials

Characterization of High-Velocity Oxyfuel Combustion Sprayed Hydroxyapatite. Bioceramic coatings, created by the high-velocity oxyfuel combustion spraying of hydroxyapatite (HA) powders onto commercially pure titanium, were characterized in order to determine whether this relatively new coating process can be successfully applied to bioceramic coatings of orthopedic and dental implants Fourier transform infrared spectroscopy, x-ray diffraction, and scanning electron microscopy were used to characterize both the HA starting powders and coatings. A 12-week immersion test was conducted and the resulting changes in the coatings were also characterized Calcium ion release during dissolution was measured with flame atomic absorption during the first six weeks of the immersion study. A comparison of powder and coating x-ray diffraction patterns and lattice parameters revealed an HA-type coating with some loss in crystallinity. Fourier transform infrared results showed a partial loss of the OH^- group during spraying; however, the phosphate groups were still present. Scanning electron microscopy analysis showed a lamellar structure with very close coating-to-substrate apposition The coatings experienced a loss of calcium during the immersion study, with the greatest release in calcium occurring during the first six days of the study. No significant structural or chemical changes were observed during the 12-week immersion study. These results indicate that the high-velocity oxyfuel process can produce an HA-type coating; however, the process needs further optimization, specifically in the areas of coating-to-substrate bond strength and minimization of phases present other than HA, before it would be recommended for commercial use.

J.D. Haman, D. Crawmer, and L.C. Lucas. Cited *Biomaterials,* Vol 16 (No. 3), Feb 1995, p 229-237 [in English]. ISSN 0142-9612. PHOTOCOPY ORDER NUMBER: 199602-57-0304.

Crystallite Orientation and Anisotropic Strains in Thermally Sprayed Hydroxyapatite Coatings. Thermally sprayed hydroxyapatite powders and coatings have been studied using x-ray powder diffraction and scanning electron microscopy. Preferred orientation of the crystallites has been found on a number of coated plates using x-ray powder diffraction, and full profile fitting of the patterns from the extracted powders indicates anisotropically thermally strained crystallites. This is a result of rapid crystal regrowth and associated thermal gradients on deposition. Electron micrographs of some coatings show a consistent picture of columnar crystallites oriented perpendicular to the substrate surface

C.D. Adam and C.M. Roome. Cited· *Biomaterials,* Vol 16 (No. 9), June 1995, p 691-696 [in English]. ISSN 0142-9612. PHOTOCOPY ORDER NUMBER: 199602-57-0198

Cookware

Thermal Spraying Upgrades Cookware Quality. Two ways in which the thermal spray process is used by cookware manufacturers are described. The processes comprise either spraying of aluminum onto the bottoms of stainless steel pans to form a heat spreader or spraying the inside surface of cookware before applying the PTFE nonstick coating to increase its bond strength to an aluminum substrate. As used in the cookware industry, the usual operating parameters are modified by increasing the compressed air pressure and lowering the amperage of the thermal spray unit to increase the surface roughness of the coating. The increased surface roughness provides a substrate that anchors the PTFE so it can be applied thicker. A proprietary Fe-Cr-Al alloy designated Alloy BCW recently patented for use in cookware and other equipment exposed to high continuous operating temperatures and development of a system that automatically applies the bond coat are also briefly described.

Cited: *Weld. J.,* Vol 74 (No. 10), Oct 1995, p 43-44 [in English]. ISSN 0043-2296. PHOTOCOPY ORDER NUMBER: 199603-57-0355.

Corrosion and Wear Resistance

Preparation of Plasma Sprayed Corrosion and Wear-Resistant Coatings. The plasma sprayed NiCoCrAlY coatings on Inconel 713C substrates were boronized or boronized and aluminized. The mechanical properties and hot corrosion resistance of the NiCoCrAlY coatings were studied. Mechanical properties were measured by the microhardness and abrasion tests, and hot corrosion resistance was examined by the cyclic hot corrosion test The microhardness at the 30 μm from the surface of the boronized samples was ~1200 HV, which is approximately five times, relative to the as-sprayed NiCoCrAlY coatings probably because of the formation of borides such as Ni_2B and Co_2B within the samples When the samples were aluminized after boronizing, the samples showed the cross-sectional hardness of 1200 HV because of the homogeneous distribution of the borides and good hot corrosion resistance, relative to the boronized samples. The heat-treated samples after the boronizing and aluminizing contained NiAl phase at the surface. The heat-treated samples showed increased cyclic hot corrosion resistance, compared with aluminized after boronizing. Also, the heat treatment enhanced abrasion resistance significantly, but did not affect the hot corrosion resistance. It can therefore be concluded that the heat treatment after boronizing and subsequent aluminizing for the NiCoCrAlY coatings is necessary to improve the mechanical properties and hot corrosion resistance

J.-T Shin, H.-S. Kim, and S.-S. Kim. Cited: *J Korean Inst Met. Mater.,* Vol 33 (No. 5), May 1995, p 647-655 [in Korean] ISSN 0253-3847 PHOTOCOPY ORDER NUMBER: 199603-58-0312

Fatigue Tests

Fatigue Life of Parts with Thermal Sprayed Coating. Fatigue tests were performed using St20 substrate, coated by the plasma sprayed Fe-Cr and Ni-Cr powders. Molybdenum and nickel aluminide were used as interlayers. The coatings have been received via six processing variants It is concluded that the processing conditions are the determining factor in fatigue life of parts. The plasma sprayed coating is shown to be characterized with the highest fatigue strength.

D. Dzyubinski. Cited: *Probl. Prochn.,* No. 1-2, Jan-Feb 1995, p 77-83 [in Russian] ISSN 0556-171X. PHOTOCOPY ORDER NUMBER: 199601-31-0029.

HVOF for Wear

Applying Nickel-Base Alloys by HVOF. The characterization of nickel-base alloys applied using high-velocity oxyfuel (HVOF) is addressed to show how they compare to their spray/fuse counterparts. Other advantages that the HVOF process can bring to the industrial market are also explored. Abrasive wear performance relative to the fused state and coating morphology are compared and evaluated. Coating density and its impact on corrosion resistance as well as a discussion of successful applications utilizing nickel-base HVOF coatings are presented. Applications that have recently been successfully handled by nonfused NiCrB HVOF-applied coatings cited include plastics extrusion and injection molding screws, wire draw blocks, wire capstans, printing rolls, plastics feed rolls, airlocks, and shutes.

Cited: *Weld. J.,* Vol 74 (No. 10), Oct 1995, p 45-47 [in English]. ISSN 0043-2296 PHOTOCOPY ORDER NUMBER 199603-58-0304.

Infrastructure

Protecting Reinforced Concrete Using Thermal Sprayed Titanium Anodes. A thermally sprayed titanium-base anode has been developed for cathodic protection of reinforced concrete structures. A thin, tightly adherent coating of titanium may be applied to concrete by plasma, flame, or arc spray techniques Deposit efficiency and bond strength are high. A process also has been developed for catalyzing the titanium coating, which results in long-term operation at low anodic potentials This anode is expected to be useful especially where concrete overlays are undesirable and where long life and durability are important.

J E. Bennett, T J Schue, and G. McGill Cited: *Mater. Perform.,* Vol 34 (No 11), Nov 1995, p 23-27 [in English]. ISSN 0094-1492. PHOTOCOPY ORDER NUMBER: 199602-35-0241.

Pump Repairs

Pumps Reap the Benefits of Thermal Spray Repair. Benefits of the thermal spray process and the techniques used for repair of pumps are discussed. The two predominant thermal spray processes used in pump repairs are twin-wire arc spray and plasma arc spray. The most critical area of the process is surface preparation. This step in the process is viewed as critical since the thermal spray material depends on a mechanical bond only. Examples of actual pump repairs that the author has completed are given Pump components highlighted are the housing, the horizontal seal, the rotor, and the shaft. Coating materials were aluminum bronze, stainless steel, and chrome oxide.

Cited: *Weld J.,* Vol 74 (No 10), Oct 1995, p 53-56 [in English]. ISSN 0043-2296. PHOTOCOPY ORDER NUMBER: 199603-58-0305

Rapid Prototyping

Arc Sprayed Steel-Faced Tooling. Arc sprayed steel-faced tooling is a rapid and inexpensive method for making complicated geometry and large-size molds. The process of arc sprayed steel-faced tooling includes the preparation of prototype mold, spraying steel-faced metal sheet mold, hardening of metal sheet mold, and cleaning the mold release agent of PVA The metal sheet molds are made from the low melting point alloys, i.e., zinc alloy or tin alloy, then sprayed with steel. The technical requirements for arc sprayed steel-faced tooling are discussed.

H. Zhang. Cited: *Met. Ind. (China)*, Vol 29 (No. 3), May 1995, p 98-99 [in Chinese]. ISSN 0977-0379 PHOTOCOPY ORDER NUMBER: 199601-58-0072

Spray Forming with Polymers

Plasma Spraying at Controlled Temperature. Plasma spraying of relatively fragile substrates such as resins, polymer matrix composites, organic materials, and pieces with complicated geometry and thin sections can be accomplished by cryogenically cooling the substrate prior to spraying. Use of liquefied argon, carbon monoxide, and nitrogen cryogenic gases is discussed. The technique can be used also to plasma form thin ceramic shells by spraying aluminum alloy mandrels at room temperature and then separating the coating by cryogenic shrinking of the mandrel.

A Freslon Cited: *1995 Advances in Thermal Spray Science and Technology*, Proc. 8th National Thermal Spray Conf. (Houston, TX) 11-15 Sept 1995, ASM International, 1995, p 57-60 [in English]. ISBN 0-87170-541-9 PHOTOCOPY ORDER NUMBER: 199601-57-0060.

Sugar and Mining Industries

Arc Spray Works in the Sugar and Mining Industries. The advantages of arc sprayed coatings for the repair and wear and corrosion protection of components of sugar and mining industry equipment are described In the sugar industry, bearing journals from large, expensive rolls are sprayed with steel-chrome alloys to maintain their dimensions as they support the rolls that crush the beets and sugar cane Bearing blocks and saddle blocks are often coated with an aluminum bronze alloy to restore dimensional integrity. In the mining industry, sliding and bearing wear applications on fans, pulleys, bushings, and swing shafts have been successfully remanufactured using a bonding preparation to prepare the surface to accept top coats of chrome-steel and stainless.

Weld J., Vol 74 (No. 10), Oct 1995, p 35-36 [in English]. ISSN 0043-2296 PHOTOCOPY ORDER NUMBER: 199603-55-0455.

Thermal Barrier Coatings

Thermal-Fatigue Failure Behavior of MCrAlY/ZrO_2-8 wt% Y_2O_3 Thermal Barrier Coating and Effects of the Laser Treatment. Isothermal and thermal fatigue tests were carried out for plasma sprayed and laser-treated MCrAlY/ZrO_2-8 wt% Y_2O_3 thermal barrier coatings (TBCs) on Hastelloy C-276 to discuss the failure mechanism and the effects of laser treatment. Phase transformation of the ceramic coating did not occur during testing. In thermal fatigue test, at the temperature range of 1100 °C to RT, specimens were investigated prior to and after failure. Cracks initiated, grew, and combined by stresses due to thermal expansion mismatch and oxidation of the bond coating near the bond/ceramic coating interface So, failure of the TBC without laser treatment occurred suddenly. In case of laser-treated TBCs, vertical cracks arose from laser treatment and cracks that initiated and grew near the interface combined. But failure of the laser-treated TBC occurred gradually Thermal fatigue life of the laser-treated TBC was increased 1 7 times compared with the TBC without laser treatment.

C.Y. Kim, M.B. Jin, C S. Kang, and S.H. Lee. Cited. *J. Korean Inst Met. Mater.*, Vol 33 (No. 5), May 1995, p 671-676 [in Korean]. ISSN 0253-3847. PHOTOCOPY ORDER NUMBER: 199603-57-0356.

Thermal Barrier Using Mullite

Refractory Oxide Coatings on SiC Ceramics. Silicon carbide with a refractory oxide coating is potentially a very attractive ceramic system It offers the desirable mechanical and physical properties of SiC and the environmental durability of a refractory oxide The development of a thermal shock resistant plasma sprayed mullite coating on SiC is discussed The durability of the mullite/SiC in oxidizing, reducing, and molten salt environments is discussed. In general, this system exhibits better behavior than uncoated SiC Areas for further developments are discussed.

K N Lee, N.S. Jacobson, and R A. Miller. Cited "Refractory Oxide Coatings on SiC Ceramics," NASA Tech Memo 106677, National Technical Information Service, U.S. Dept of Commerce, 1994 [in English]. PHOTOCOPY ORDER NUMBER: 199603-E7-C-0070

Wear-Resistant Coatings

Wear-Resistant Coatings. The goal of this technical program is to develop wear-resistant coatings for piston ring and cylinder-liner components for low-heat-loss diesel engines. Friction and wear screening in phase I identified plasma sprayed high carbon iron-molybdenum and chromia-silica coatings as candidate piston ringwear coatings. Plasma sprayed chromia-silica and high carbon iron-molybdenum coatings, and a low-temperature arc vapor deposited (LTAVD) chrome nitride coating were identified as candidate cylinder liner wear coatings. The cast iron porcelain enamel coatings exhibited unsatisfactory wear rates because of porosity in the coating. The three main technical tasks for phase II are further optimization of the LTAVD chrome nitride and of the cast iron porcelain enamel wear coatings and the process scale-up of wear-resistant plasma coatings for cylinder liners. The optimization of the LTAVD chrome nitride coating involves the development of an adherent 15 µm thick coating that meets the friction and wear goals of this program. The cast iron porcelain enamel process optimization centers on developing a CIPE composition with a minimum of porosity. The process scale-up of the plasma coatings will first develop ID plasma spray parameters for coating cylinders liners. Next, simulated cylinder liner specimens will be coated, and the friction and wear properties of these coatings will be determined using reciprocating friction and wear testing using both new and "used" engine oil.

M.H. Haselkorn Cited: "Ceramic Technology Project Semiannual Progress Report for October 1993 through March 1994," ORNL/TM-12778, Oak Ridge National Laboratory, 1994, p 131-133 [in English]. PHOTOCOPY ORDER NUMBER: 199601-31-0122.

Design of Experiments

APS Ni-Al Coatings

An Evaluation of APS Nickel-Aluminum Coatings. As part of an investigation of the dynamics that occur in the air plasma spray (APS) process, an experimental study of the plasma spray processing of Ni-Al powder was conducted. The Ni-Al powder system in this study is being used in the fabrication of aluminum heater tubes that emulate nuclear fuel tubes for use in thermal-hydraulic testing. Coating experiments were conducted using argon-hydrogen and nitrogen-hydrogen working gases. The coating experiments used typical process parameters that were varied in a statistical design of experiment fractional-factorial study. Operating parameters were varied around the typical spray parameters in the systematic design of experiments to display the range of plasma-processing conditions and their effect on the resultant coating. The coatings were characterized by hardness tests, optical metallography (i.e., image analysis), scanning electron microscopy, and x-ray diffraction. Coating qualities are discussed with respect to hardness, roughness, porosity, phase content, and microstructure Attributes of the coatings are correlated with the changes in operating parameters. An optimized coating design is presented for this specific application.

D.J. Varacalle, Jr., A W. Erickson, L.B. Lundberg, G.C. Wilson, W.L. Riggs, II, and T.J. Steeper. Cited: *Elevated Temperature Coatings: Science and Technology I* (Rosemont, IL), 3-6 Oct 1994, Minerals, Metals and Materials Society/AIME, 1995, p 167-182 [in English]. ISBN 0-87339-289-2. PHOTOCOPY ORDER NUMBER: 199602-58-0163.

Diagnostics

AE Signature

On-Line Monitoring of the Electric-Arc Spraying Process Based on Acoustic Signatures. The electric-arc spraying process for depositing metal particles on suitable substrates is described, and contributions of the process parameters and their interactions to the coating thickness are analyzed. Influences of the parameters on microhardness of the deposits are also discussed, and the spraying phenomena are characterized in terms of the sound signals generated during the process. Determination of the deposition profile and experimental proof of its Gaussian nature are also reported. A novel closed-loop control mechanism based on stochastic modeling of the acoustic signals is proposed, and a mathematical approach toward obtaining a uniform single-pass deposit thickness is presented.

R. Kovacevic, R. Mohan, M. Murugesan, and A.E. Seybert. Cited: *Proc. Inst Mech. Eng. B, J. Eng Manuf*, Vol 209 (No. B5), 1995, p 369-379 [in English]. ISSN 0954-4054. PHOTOCOPY ORDER NUMBER: 199603-58-0399.

Environmental

HVOF for Hard Chrome

HVOF Thermal Spraying: An Alternative to Hard Chrome Plating. Recent advances in high-velocity oxygen-fuel (HVOF) technology which make this process viable as an alternative to hard chrome plating are discussed. The advantages of the HVOF process cited include thick coating capability (>2.5 mm for certain materials), no part size limitations, no chemical solution maintenance, and lower installation and application costs. The HVOF process is also viewed as simpler due to the fact that it is a three-step process compared to a minimum of eight steps for chromium plating. Applications where HVOF coatings are being considered as replacements for chromium plating cited include large bore cylinder liners, hydraulic rods, and rotors for positive displacement pumps Four case histories of parts (pistons, glue rolls for the packaging industry, rolls from a major oil company, and a gear shaft assembly from a helicopter transmission test stand) that have been repaired using HVOF spray coating are used to illustrate the reliability and versatility of the process.

D.C Bolles (Sulzer-Metco). *Weld. J.*, Vol 74 (No 10), Oct 1995, p 31-34 [in English]. ISSN 0043-2296. PHOTOCOPY ORDER NUMBER· 199603-58-0303.

Materials

Intermetallics

Coatings of Aluminide Intermetallic Compounds on Steel Utilizing a Hybrid Technique of Spraying and IR-Laser Fusion. Titanium aluminide coatings were produced using a hybrid technique of arc spraying followed by IR laser fusion in an argon atmosphere. A titanium coating free of oxides was deposited onto a low-alloy steel by dc arc spraying in argon. Optimal laser irradiation conditions and the amount of preplaced aluminum powder on the sprayed titanium were determined to obtain a composite coating of $TiAl_3$+Al of 150 μm thickness. Metallurgical and mechanical properties were examined using acoustic emission. The oxidation resistance of the coating was excellent up to 1173 K because of a protective alumina layer Growth of the $TiAl_3$ interlayer by diffusion of aluminum into titanium improved the corrosion resistance. The intermetallic coating showed microcracking at ambient temperature, but possessed capability for filling and healing of cracks with alumina and titanium nitride during high-temperature exposures. However, at temperatures >1200 K, the oxidation performance decreased by diffusion of iron into the coating.

Y. Longa, M. Shinya, and M. Takemoto Cited: Seventh International Conference on Surface Modification Technologies (Sanjo, Japan), 31 Oct-2 Nov 1993, *Surface Modification Technologies. VII*, Institute of Materials, 1994, p 977-992 [in English]. ISBN 0-901716-60X. PHOTOCOPY ORDER NUMBER· 199602-58-0188.

WC Carburization

A Study on the Carburization of Plasma Sprayed WC-12% Co Coatings. Tungsten carbide (WC) coatings were formed on mild steel (SM45C) substrates using the plasma spray process. As a means to enhance the mechanical properties such as microhardness and wear resistance, as-sprayed coatings were annealed and then were subsequently subjected to the carburization under methane and hydrogen atmospheres. When the heat treatment was carried out under the hydrogen atmosphere, the amounts of WC phase were decreased and the amounts of alpha-W_2C and tungsten phase were increased with the increase of temperature, which led to a slight reduction of the microhardness. In the case of carburization under methane atmosphere, the microhardness of the coatings was increased with the increase of temperature and showed the highest value of 1540 HV at 1100 ° C The wear resistance also was increased with the increase of carburization temperature. The wear resistance of the coatings heat treated at 1000 °C were 17 times higher than the as-sprayed coatings. The increase of methane concentration at constant temperature at 900 °C showed the improvement of the microhardness and the wear resistance of coatings. The highest microhardness and wear resistance were obtained at the methane concentration of 11%.

H -S Kim, S.-S. Kim, and H -J. Rhee. Cited· *J. Korean Inst Met Mater.*, Vol 33 (No. 5), May 1995, p 640-646 [in Korean]. ISSN 0253-3847. PHOTOCOPY ORDER NUMBER: 199603-58-0311.

Microstructure

Mo and Co Alloys

Microstructures and Mechanical Properties of the Plasma Sprayed Molybdenum and Cobalt Alloy Coating Layers. Microstructures and mechanical properties of molybdenum and cobalt alloy coating layers made by plasma spray coating method have been examined by means of optical microscopy, x-ray diffraction, scanning electron microscopy, microvickers hardness tests, surface roughness tests, and wear-resistance tests. The splat is relatively flat with the boundary in molybdenum layers, whereas it is wavy with interfaces at the same angle to the surfaces in cobalt alloy layers The molybdenum coating layers were shown to be crystalline, but the cobalt alloy layers were amorphous in x-ray diffraction profiles. The surface roughness, hardness, wear resistance of the cobalt alloy layers were superior to those of the molybdenum layers. The wear mechanism in plasma coating layers was splat delamination in which the wavy splat is much harder to delaminate than the flat splat

T.-H. Nam, G.-C. Hur, B.-K. Kim, G -H. Ha, and S.W. Lee. Cited· *J. Korean Inst. Met. Mater.*, Vol 33 (No. 4), April 1995, p 556-562 [in Korean] ISSN 0253-3847 PHOTOCOPY ORDER NUMBER· 199601-58-0061

Quasicrystalline Coating

Effect of Starting Powders on the Control of Microstructural Development of Al-Cu-Fe Quasicrystalline Plasma-Sprayed Coatings. Powders and plasma-sprayed coatings of an $Al_{63}Cu_{25}Fe_{12}$ alloy containing a quasicrystalline phase on mild steel substrates were characterized by x-ray diffraction, electron microscopy, and differential thermal analysis The relationships between powder and coating microstructures were examined Powders were produced by casting and crushing and by gas atomization Both techniques produced powders with multiple phases; cubic and monoclinic ternary structures were formed along with the face-centered icosahedral quasicrystalline phase. These phases were also produced in the plasma arc sprayed coatings formed using different starting powders. Cooling rates during powder processing greatly affected the phase equilibria and scale of segregation of this alloy Finer grain sizes in the plasma sprayed coatings were obtained from the more chemically homogeneous gas-atomized powders

D J Sordelet, M.J Kramer, O. Unal. Cited· *J Therm Spray Technol*, Vol 4 (No 3), Sept 1995, p 235-244 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER· 199602-58-0216

Reactive Spraying

Microstructure Evolution during Reactive Plasma Spraying of $MoSi_2$ with Methane. The mechanisms that govern microstructure evolution during reactive plasma spraying of $MoSi_2$ on a stainless steel plate using 100% methane were investigated, with particular emphasis on the thermodynamics and kinetics of the relevant phase transformations and chemical reactions. The reactive plasma-sprayed $MoSi_2$ exhibited a dense, multilayered microstructure. In addition to the $MoSi_2$ matrix, significant amounts of Mo_5Si_3 and elemental carbon were observed, along with a small amount of SiC. Thermodynamic and kinetic analysis predicted a large volume fraction of Mo_5Si_3 and a small amount of SiC in the as-deposited reactive plasma sprayed $MoSi_2$, in agreement with the experimental observations.

X Liang, A Sickinger, E.J. Lavernia, and J. Wolfenstine. *J. Therm. Spray Technol.*, Vol 4 (No 3), Sept 1995, p 252-260 [in English] ISSN 1059-9630 PHOTOCOPY ORDER NUMBER 199602-58-0217.

Thermal Barrier Coating

Characterization of Microstructural Defects in Plasma Sprayed Thermal Barrier Coatings. Thermal barrier coatings with a NiCrAlY bond coating and a 1.5 mm thick zirconia top coating were air plasma sprayed onto a nickel-base substrate (Hastelloy X) The top coatings were deposited with the same spraying parameters except for the amount of external cooling, which varied from no cooling to the maximum available This resulted in four sets of samples produced with different cooling conditions where substrate temperature varied from 100 to 830 °C. The coatings were examined by electron microscopy on polished surfaces and on fracture surfaces. The crack structure in the top coating was correlated to the substrate temperature. The density both of horizontal delaminations and of vertical microcracks was shown to decrease at higher substrate temperatures. The grain structure was columnar, and smaller grains were found at lower temperatures Explanations for the differences in defect densities are discussed.

P. Bengtsson and T. Johannesson. Cited: *J. Therm Spray Technol.*, Vol 4 (No 3), Sept 1995, p 245-251 [in English] ISSN 1059-9630. PHOTOCOPY ORDER NUMBER· 199602-57-0253.

Thermal Cycling Behavior

Influence of Powders Microstructure on the Thermal Cycling Behavior of ZrO_2-8% Y_2O_3 Plasma Coatings. Six different ZrO_2-8% Y_2O_3 powders coming from different manufacturers were characterized (density, particle size distribution, shape and internal microstructure, phase composition) and plasma sprayed with the same deposition parameters onto a NiCrAlY bond coat that had been plasma sprayed onto a Hastelloy X substrate The ceramic coatings showed very different thermal shock resistance, which was correlated with the structural features of coatings and powders, particularly the relative amounts of t′ and monoclinic zirconia. Quantitative crystallographic analysis revealed a wide variation of the phase composition between initial powders, as-deposited coatings and thermally cycled coatings. From the data, three necessary conditions for good thermomechanically resistant ZrO_2-8% Y_2O_3 coatings were established: (1) a regular shape (almost spherical) and narrow size distribution for the powder, (2) a layered and microcracked coating structure, and (3) a t′ amount higher than 90% in the coating.

B Pieraggi and F Crabos Cited: *Elevated Temperature Coatings· Science and Technology I* (Rosemont, IL), 3-6 Oct 1994, Minerals, Metals and Materials Society/AIME, 1995, p 63-72 [in English] ISBN 0-87339-289-2. PHOTOCOPY ORDER NUMBER· 199602-57-0188.

Thermal Diffusivity Effects

The Relationship between the Microstructure and Thermal Diffusivity of Plasma Sprayed Tungsten Coatings. Tungsten and tungsten alloy coatings are candidate materials for plasma facing components of divertor plates in future fusion reactors In normal operation, the sprayed coatings will be submitted to intense heat fluxes and particle bombardment. This work investigated the relationship between the microstructure of plasma sprayed tungsten coatings and their thermal diffusivity as determined by the laser flash method The microstructural investigation was carried out on copper-infiltrated coatings Such a preparation technique permitted the measurement of the total true contact area between the lamellae within the tungsten coatings. The spraying atmosphere was found to strongly influence the interfacial contact between lamellae and coating thermal diffusivity

S. Boire-Lavigne, R G. Saint-Jacques, and C. Moreau. Cited: *J. Therm. Spray Technol*, Vol 4 (No. 3), Sept 1995, p 261-267 [in English] ISSN 1059-9630 PHOTOCOPY ORDER NUMBER: 199602-58-0218

Modeling

HVOF Processing

Gas Dynamical Parameters of Detonation Powder Spraying. An investigation is conducted of the gas dynamics of a gas detonation coating process and the mechanism of particle acceleration by the shock wave inside the coating apparatus Velocities of gas detonation in different gas mixtures are analyzed by applying the conventional hydrodynamic theory of detonation, and the effect of addition gases on the velocity of detonation in oxygen/hydrogen and oxygen/acetylene mixtures is studied. A model that allows calculation of particle acceleration and final velocity is proposed. This model utilizes the Chapman-Jouquet picture of detonation and assumptions about the linear distribution of the velocity of detonation products behind the front of the detonation wave The kinetics of particle acceleration by a detonation wave exhibits several novel features and is distinctly different from particle acceleration in other methods of spraying, such as plasma and high-velocity oxyfuel There is a nonmonotonic dependence of particle velocity upon its coordinate and change in the direction of particle acceleration. Loading distance and total barrel length are important parameters that affect final particle velocity. Results indicate that final particle velocity and, as a consequence, the quality of detonation coatings can be significantly affected by changing the gas mixture composition and the powder loading distance while keeping the remaining operational parameters constant Al_2O_3 and tungsten are discussed.

E Kadyrov and V. Kadyrov Cited: *J. Therm. Spray Technol.*, Vol 4 (No. 3), Sept 1995, p 280-286 [in English] ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199602-57-0255

Patent

Engine Bore Coating

Thermal Spray Method for Coating Cylinder Bores for Internal Combustion Engines. A tenacious wear-resistant coating is applied with a high-velocity oxygen-fuel thermal spray gun using a composite powder of aluminum and an iron-base metal The metal may be iron-chromium, iron-molybdenum, cast iron, or a combination A particular combination is a blend of a first powder and a second powder, the first powder consisting of a composite of aluminum subparticles and iron-molybdenum alloy subparticles, and the second powder consisting of a composite of aluminum subparticles and cast iron subparticles. An internal combustion engine block has such a coating applied to the cylinder walls.

M R. Dorfman, J E Garcia, and B A Kushner Cited: Patent No US5334235 (USA), 2 Aug 1994; Conv date: 22 Jan 1993 [in English]. PHOTOCOPY ORDER NUMBER: 199602-58-0167.

Nonstick Coating

Surface Preparation for a Nonstick Coating and a Cooking Utensil. A method for preparing a surface for the application of a nonstick coating comprises thermally spraying a stainless steel alloy that contains ≤6.0% Al, and that is substantially nickel free. Preferably the chromium content of the alloy is ≤23.5% This method is particularly useful for cooking utensils.

A.C Oak, L C. Brumbaugh, and D E. Crawmer. Cited Patent No EP0643150 (European Patent), 15 March 1995, Conv date: 12 Sept 1994 [in English] PHOTOCOPY ORDER NUMBER: 199603-58-0396

Process Parameter

Microstructure of Fe-Al Alloys

The Influence of Process Parameters on the Microstructure and Properties of Fe_3Al-Base Coatings. Coatings based on Fe_3Al composition have been applied to carbon and ferritic stainless steel using high-velocity oxygen-fuel (HVOF) and plasma spray techniques Diagnostic instruments have been used to determine the average particle velocity and temperature in the particle flow field as a function of the process parameters. The microstructure of the resulting coatings has been characterized using optical metallography. It has been determined that the coating density, volume fraction of unmelted particles, and coating thickness can be correlated with the in-flight particle characteristics of temperature and velocity Correlations between process parameters, microstructure, and coating adhesion are presented.

R.N. Wright, C.R Clark, J R. Fincke, D C Haggard, and W.D Swank. Cited. *Elevated Temperature Coatings: Science and Technology I* (Rosemont, IL), 3-6 Oct 1994, Minerals, Metals and Materials Society/AIME, 1995, p 157-166 [in English]. ISBN 0-87339-289-2 PHOTOCOPY ORDER NUMBER: 199602-58-0162.

Processing

Residual Stresses

Simulation of the Effect of Creep on Stress Fields during Vacuum Plasma Spraying onto Titanium Substrates. Boron carbide has been deposited by vacuum plasma spraying onto thin substrates of Ti-6Al-4V alloy. Substrate/deposit curvature histories have been measured by analysis of a series of video images These results, together with thermal histories, have been compared with predictions obtained from a numerical process model describing the development of residual stresses. It is shown that, when using the standard form of the model, a discrepancy arises between predicted and observed curvature histories. This is attributed to the effect of creep in the substrate under the influence of the residual stresses. A modification to the model accounting for the effect of creep allowed good agreement to be obtained between theory and experiment It is shown that creep effects can be significant with titanium, although they become less significant as the substrate thickness increases. In general, the effect of creep is to lower the stress levels during spraying, although the final residual stresses can actually be higher than would be the case in the absence of creep

Y.C. Tsui, T W. Clyne, and S.C. Gill. *Surf. Coat. Technol.*, Vol 64 (No. 2), May 1994, p 61-68 [in English]. ISSN 0257-8972 PHOTOCOPY ORDER NUMBER: 199602-57-0260

Wear Protection

Plasma Spraying of Titanium Hard Materials—New Possibilities for Wear Protection. In the search for more effective materials for wear protection, titanium-base hard materials are becoming increasingly important in development work. Titanium carbides, nitrides, carbonitrides, and diborides are far less susceptible to oxidation. Their specific weight is barely one-third that of tungsten carbide Because of their material-specific features, processing of titanium hard materials and wear protection coatings by spraying has up to now been possible only to a limited extent The "shrouded plasma spraying process" represents a cheap alternative to vacuum plasma spraying The effective use of this technology, however, requires suitably adapted powder production. The fusion of titanium hard materials to form spray coatings requires high power and accurate process conditions The addition of even small proportions of a metallic matrix is reflected in much improved coating strength.

E. Lugscheider, H Jungklaus, A Henker, and B. Wielage. Cited: *Schweissen Schneiden*, Vol 10, Oct 1995, p E190-E193 [in English and German]. ISSN 0036-7184. PHOTOCOPY ORDER NUMBER· 199602-57-0250.

Review

Research in China

Advances and Applications in China of Thermal Spray Technology. Thermal spraying is a group of processes in which finely divided metallic surfacing materials are sprayed in a molten or semimolten condition onto a substrate to form a deposit About 80 years have elapsed since the appearance of the thermal spray technique, but it was introduced into China in the 1950s as flame spraying. Since the mid-1970s, it has rapidly grown as raw materials, spray equipment, and processes become increasingly sophisticated. The following sections deal with the recent developments of thermal spraying equipment, materials, and processes in China.

S. Zhu and B. Xu Cited· *Weld. World*, Vol 35 (No. 6), Nov-Dec 1995, p 411-414 [in English]. ISSN 0043-2288. PHOTOCOPY ORDER NUMBER· 199602-57-0252.

Structure

Post-Processing

Effects of Post-Coating Processing on Structure and Erosive Wear Characteristics of Flame and Plasma Spray Coatings. The effects of post-coating processing by means of flame, laser, and vacuum furnace heating on the structure and erosive wear characteristics of flame and plasma spray coatings were studied The results show that post-coating processing can modify the microstructure, reduce its porosity, increase its plasticity and toughness, and improve the metallurgical bonding to the substrate. Therefore, the erosion resistance of these deposits is increased substantially and is even more significant when the erodent impact angle and impact velocity are higher The mechanism of erosive wear has obviously changed from brittle to plastic erosion. The application of different spray methods and post-coating processing in terms of erosive wear was analyzed and compared.

D.Z. Guo, J.S. Sun, J.Y. Wang, and F.L. Li Cited· *Surf Coat. Technol.*, Vol 73 (No. 1-2), 1 July 1995, p 73-78 [in English]. ISSN 0257-8972. PHOTOCOPY ORDER NUMBER: 199603-57-0410.

Testing

Thermal Cycling

Evidence of Accelerated Thermal Cycling Test Schedules Influencing the Ranking of Zirconia-Base Thermal Barrier Coatings. Thermal barrier coatings (TBCs) often encounter temperature cycling in the course of normal operation. In the absence of actual or simulated engine test facilities, accelerated furnace thermal cycling experiments are frequently devised to evaluate the response of various TBCs. This study, which deals with yttria-stabilized and magnesia-stabilized zirconia systems, shows that the performance of a TBC is significantly governed by the severity of the time-temperature schedule employed. More importantly, the ranking of the two zirconia-base TBCs also is influenced by the adopted thermal cycling test schedule These findings have ramifications in the design of suitable accelerated tests for TBC evaluation The nickel-base superalloy Nimonic-75 is used as the substrate.

S.V. Joshi, M P. Srivastava, and G Sundararajan Cited: *J. Therm. Spray Technol.*, Vol 4 (No 3), Sept 1995, p 275-279 [in English]. ISSN 1059-9630. PHOTOCOPY ORDER NUMBER: 199602-57-0254.

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