Selected Abstracts of Thermal Spray Literature 4/92 - 6/92

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Application

Aqueous Corrosion

On Improvement of Bolt-Control Equipment in the Deposits of Natural Corrosion Gas. The corrosion wear resistance of various plasma spray coatings used on shut-off valves at sour gas deposits was studied. A comparative analysis was made of the corrosion wear resistance of type 20 steel and type 20 steel coated with Ni-base plasma spray powder coatings (PT-NA-01, PT-19N-01, and PG-12N-02) in a NACE medium with and without H_2S based on the NACE TM-01-77 test procedure. Saturation of the NACE medium, containing 5 g/l CH_3COOH and 50 g/l NaCl, with H_2S significantly raised the corrosion wear rate of the coatings and of the steel itself. The coatings offered varying degrees of protection in the NACE medium, with and without H_2S and with 40% quartz sand, but the PG-12N-02 coating (Ni base, with up to 15% Ti) gave the best protection against the corrosive wear in the medium that contained sand. The PT-NA-01 coating, however, was judged the best in terms of resistance against H_2S and it contained Ni base with up to 5% Al.

E.M. Gutman, V.G. Antoov, I.N. Isayev, V.K. Sydorenko, G.N. Osipova, and V.V. Galtykhina. Cited: *Fiziko-Khimicheskaya Mekhanika Materialov*, 1990, 26, (5), 122-123, [in Russian]. ISSN: 0430-6252. PHOTOCOPY ORDER NUMBER: 9205-1744448.

Corrosion Resistance of Plasma Sprayed Aluminia and Chromia Coatings. Effect of Coating Sublayers NiCr and NiAl. The corrosion resistance of plasma sprayed Al_2O_3 and Cr_2O_3 coatings has been studied in 3.5% NaCl and 10% NaOH solutions. In this context, the effect of intermediate coatings (NiCr and NiAl) on the protective efficiency of the ceramic coatings has been evaluated, too. The corrosion rates were determined by gravimetry, corrosion potential, and polarization resistance measurements. The two ceramic coatings afford efficient protection. In the alkaline solutions NiCr is superior, whereas in the chloride solution NiAl offers better protection.

J. Kunkel, T. Stefan, and F. Hasko. Cited: *Werkstoffe Und Korrosion*, 1992, 43, (1), 23-27, [in German]. ISSN: 0043-2822. PHOTOCOPY ORDER NUMBER: 9206-1747693.

Coating Repair

Reconditioning of Damage in Hot Dip Zinc Coatings. Caused by the necessity to repair damage in hot dip metallic coatings for corrosion protection maintenance, these procedures are described: Thermal Zn spraying after pretreatment (Sa 3) and spot repair painting with Zn dust paint after pretreatment (Sa 21/2, St3 or PMa). In addition to repair possibilities, thermal Zn spraying should be preferred, because it affords the highest corrosion protection. Information is given on pretreatment, the necessary thickness, and possible Zn dust paints. Repair of damages in hot dip metallic coatings is discussed.

K.A. van Oeteren. Cited: *Korrosion*, 1991, 22, (6), 301-304, [in German]. ISSN: 0023-4133. PHOTOCOPY ORDER NUMBER: 9205-1742841.

Electric Insulation

Insulate Alumina Spraying Film on Aluminum. Alumina is electric insulative. An experiment to produce sprayed alumina film on Al is carried out. RF plasma spraying is used in the experiment. Equipment for rf plasma spraying in atmosphere is first described. Spraying conditions for alumina particles are discussed for controlling temperature. Effects of film thickness on electric insulation ability and adhesion properties are evaluated along with SEM observations and X-ray diffraction.

N. Yamaji. Cited: *Kinki Aruminyumu Hyomen Shori (Journal Of Aluminum Finishing Society of Kinki)*, 1991, (152), 20-26, [in Japanese]. ISSN: 0285-6689. PHOTOCOPY ORDER NUMBER: 9205-1744271.

Mold Coating

Improvement of Durability of Injection Mold by Arc Spraying. The technique of making dies for press forming, injection mold, and vacuum forming by arc spraying was studied, and it was found that arc spraying was useful. Some problems concerning the strength of the injection mold occurred. To improve durability of the injection mold, a method of making the mold base, thermal expansion of spraying coating (e.g., Zn- and Cr-base alloys) and backup material (low-melting alloys), adherence between the coatings and backup materials, and castability of low-melting materials were studied. The results were as follows. The spraying angle should be >45° at any point on the model, and the shape of the master model should take into account arc spraying. Adherence between coating and backup materials was improved by using flux for stainless steel and preheating to approximately 370 K. Thermal expansion of the coating can be relieved by some types of spraying materials.

N. Hara, H. Noji, and N. Hata. Cited: *Hiroshima Kenritsu Seibu Kogyo Gijutsu Senta Hokoku (Bulletin of the Industrial Research Institute, Hiroshima Prefecture, West)*, 1991, 34, 78-80, [in Japanese]. ISSN: 0915-194X. PHOTOCOPY ORDER NUMBER: 9204-1740926.

Superconductivity

Critical Current Densities in Y-Ba-Cu-O Coatings Prepared Using Internal and External Feed Plasma Spray Systems. Plasma spraying of high T_c oxide superconductors offers the possibility of forming thin coatings over large areas. Sprayed Y-Ba-Cu-O coatings were formed on Ag substrates using two systems: a system in which the powder is fed into the plasma gun and a system in which the powder is fed externally. Observations indicate that the coatings formed by the external plasma spray are more consistent with respect to physical properties and chemical composition. X-ray fluorescence analysis shows that during internal spraying there is a loss of Cu. The net result is that the critical current densities of the heat treated samples are in the range 50-200 A/cm^2 for the external spray samples compared with values of <60 A/cm^2 obtained for internal spray samples.

D.M. Reddy, G. Swaminathan, S.R. Kumar, K. Venugopal, S. Ravichandran, M.V.T. Dhanajeyan, and S.C. Mohan. Cited: *Thin Solid Films*, 1991, 206, (1-2), 169-174, [in English]. ISSN: 0040-6090. PHOTOCOPY ORDER NUMBER: 9204-103000.

Resistive Transition and J_c (B) Curves in Plasma Sprayed Coatings of YBaCuO Superconducting Material. The critical current densities J_c of YBaCuO coatings on the order of 100 μm thick, sprayed using an 80-kW plasma spray system, were found to be in the range of 100-200 A/cm^2. Resistive transition and J_c (B) curves were obtained for low magnetic fields ranging from 0-77 Oe at 77 and 60 K. It was observed that the J_c increased by a factor of 4-6 at 60 K. It was also observed that, up to 8 Oe, the resistive transitions of the samples were identical, indicating complete shielding against field penetration. At 88 Oe, the J_c dropped to very low values. The observed trend in resistive transition and J_c (B) curves indicates that plasma spray coatings in the thickness range 100-150 μm can effectively be used for shielding applications in low magnetic fields.

G. Swaminathan, M.V.T. Dhanajeyan, K.A. Durgaprasad, and R. Somasundaram. Cited: *Thin Solid Films*, 1991, 206, (1-2), 175-178, [in English]. ISSN: 0040-6090. PHOTOCOPY ORDER NUMBER: 9204-103001.

The Structure and Electrophysical Properties of Gas-Thermal High Temperature Superconducting Coatings. The effect of deformation on the structure and electrical properties of superconductive $YBa_2Cu_3O_{7-\delta}$ coatings deposited on a stainless steel tape by plasma or flame spraying was studied. Cold rolling of the coatings deposited on stainless steel substrates with a total draft of $\varepsilon_\sigma \geq 25\%$ was found to result in degradation of superconducting properties, which then could not be restored by annealing. A stagewise deposition of such a coating with an intermediate rolling, followed by annealing, makes it possible to increase the density of the coating, its stability against external actions, the flexibility of tapes with the coating, and the critical current density, and as a whole to control the value of the possible total draft without loss of high-temperature superconductivity.

V.A. Makara, N.N. Dashevskij, S.L. Revo, and M.P. Semen'ko. Cited: *Thin Solid Films*, 1991, 206, (1-2), 179-182, [in English]. ISSN: 0040-6090. PHOTOCOPY ORDER NUMBER: 9204-103002.

Wear

WC-Co Type Thermal Spray Coatings as a Counterface Material for Adhesive Wear. Friction and wear of two commercial thermal spray WC-Co coatings were investigated using conforming block-on-ring geometry in distilled water at 23 °C. WC-Co type coatings were applied by a detonation gun and a high-velocity oxygen fuel (HVOF) thermal spray process to AISI 410 martensitic stainless steel. For comparison purposes, AISI 410 stainless steel mated against AISI 410 stainless steel exhibited high friction, high weight loss, and severe adhesive wear. WC-Co coated rings (HVOF) mated against AISI 410 stainless steel blocks reduced friction, weight loss, and exhibited minimal damage. However, WC-Co-Cr coated rings (D-gun) mated against WC-Co-Cr coated blocks (D-gun) produced high weight loss and severe damage. To determine the material dependence on the deposition process, a WC-Co-Cr coated ring was mated against an AISI 410 stainless steel block. It produced results similar to WC-Co coatings against AISI 410 stainless steel. Therefore, the wear behavior of these materials appears to be insensitive of the deposition process and sensitive to the counterface material.

K.R. Luer and A.R. Marder. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 1-13, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1738516.

Biomedical

Hydroxyapatite Splats

Microstructural Investigation of Hydroxylapatite Splats Produced via Plasma Spraying. Hydroxylapatite (HA) coatings have received considerable interest from biomaterials researchers due to the ability of HA to chemically bond to human tissue. These coatings, typically applied to metallic implants via plasma spraying, have been extensively studied in terms of their *in vivo* and *in vitro* properties. However, fundamental studies of the individual splats that comprise a bulk plasma sprayed coating are also necessary to understand the processing structure-property relationships in these systems. The characteristics of the splat "building blocks," particularly the first splat layer, will strongly influence the overall coating properties. Presented is a preliminary investigation of the microstructural characteristics of HA splats that were sprayed under several sets of conditions. Optical and SEM microscopies were used to examine the splat morphologies and dimensions. Variations in splat dimensions were related qualitatively to changes in the plasma spraying operating conditions.

S.J. Yankee, B.J. Pletka, and W.A. Johnson. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 271-285, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740685.

Coatings

Functionally Gradient Materials

Repeated Thermal Shock Properties of Functionally Gradient Plasma Sprayed Coatings Under the Temperature Gradient Condition. In the study of the functionally gradient material (FGM) systems such as for high-temperature structural materials, design and evaluation of thermal shock properties under the temperature gradient condition are investigated. The 8 wt.% Y_2O_3-ZrO_2/NiCrAlY (Ni-16.88Cr-6.04Al-0.56Y) functionally gradient plasma sprayed coatings were produced on stainless steel (SUS 304) substrates. A simple heating-cooling thermal shock testing apparatus was made, and repeated thermal shock resistance properties of coating specimens under the temperature gradient conditions were investigated using this apparatus. A conventional thermal shock test regulated by JIS was also conducted. Moderate coating configuration for minimizing the thermal stress was estimated by the simple analytical model. The results are summarized. Feasibility of the functionally gradient coating was verified by the temperature gradient thermal shock testing conducted using the simple apparatus made. The effect of coating configuration on the repeated thermal shock resistance properties were evaluated by the temperature gradient test condition. From the results of simple numerical analysis, the moderate coating configuration profile of the functionally gradient coatings was given as the compositional distribution parameter *P* of less than one.

M. Fukumoto, I. Okane, T. Yamazaki, K. Mizobe, and M. Umemoto. Cited: *Quarterly Journal of The Japan Welding Society*, 1991, 9, (4), 104-110, [in Japanese]. ISSN: 0288-4771. PHOTOCOPY ORDER NUMBER: 9205-1744202.

General Overview

Introduction to Advanced Surface Coatings. A general classification of surface engineering techniques is provided and discussed. Advanced technologies can be subdivided into gaseous, molten, or semimolten state processes, which are dominated by dry methods. Dry processes make extensive use of glow discharge plasmas. Structure-property relationships for coatings deposited from the vapor and molten-semimolten state are compared schematically.

D.S. Rickerby and A. Matthews. Cited: *Advanced Surface Coatings: A Handbook of Surface Engineering*, 1-13, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740806.

Graded

Processing and Microstructural Study of Graded Plasma Sprayed Al-Cu Coatings. Graded Al-Cu composite coatings 1-mm thick (on Cu) exhibiting a continuous evolution from pure Cu to pure Al were obtained by low-pressure plasma spraying. Due to both processing and reaction between Al and Cu, this type of material is basically heterogeneous on a variety of scales. For studies on the macroscopic scale, glow discharge spectrometry, conventionally used for coating and surface analysis, was developed for these composites. At a lower scale, the various exhibited phases and more generally the sprayed microstructure depending on the processing parameters were analyzed using X-ray diffraction, scanning electron microscopy, and scanning transmission electron microscopy. In addition to Al and Cu, AlCu (η_2), Al_2Cu (θ), and Al_4Cu_9 (γ_1) phases were detected. Al-Cu-rich microcrystalline, fine-grained Al, and bimodal grain-sized (approx 0.5 μm and a few μm) Cu regions were observed, which corresponded to different material cooling rates. These regions exhibited some previously mentioned phases, the distribution of which was studied. The results are discussed in light of the Cu-Al phase diagram, although the material processing did not obey the equilibrium criteria. They were compared with those from analyses of both graded and eight single-content materials used as standards.

P. Luquet, S. Laurent, R. Molins, M. Jeandin, F. Barbalat, and C. Blain. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 909-913, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740803.

Polymer

Protective Thermoplastic Powder Coatings Specifically Designed for Adhesive Polymers. Properly designed and formulated thermoplastic powders applied in-tandem with suitable thermal spray, electrostatic, and fluidized bed equipment allow successful coating of small to large Al, carbon steel, stainless steel, concrete, asphalt, wood, plastic, and GFRP substrates/articles in the shop and field. A variety of unique properties obtained with the use of ethylene acrylic acid copolymers for these powder coating applications and the importance of proper formulation/stabilization and properly understood application parameters are included. The analytical methods used to determine when a coating is properly applied are also discussed.

T. Glass and J. Depoy. Cited: *Finishing '91*, 1991, Cincinnati, Ohio, [in English]. PHOTOCOPY ORDER NUMBER: 9204-102879.

Mathematical Models

HVOF Process

Particle Behaviour During High Velocity Oxy-Fuel Spraying. A comprehensive one-dimensional model is used to investigate particle behavior associated with the high-velocity oxy-fuel (HVOF) spraying process. Using the spraying of WC-12Co powder as a case study, it is shown that the Knudsen noncontinuum effects can have an immense influence on the gas-solid heat and momentum transfer processes. Consistent with actual practical experience during HVOF spraying, the results reveal that the low temperatures provided by the oxy-fuel combustion flame preclude complete melting of many ceramic powders possessing high melting points. However, it is shown that powders of metals and the low-melting-point alloys can be completely molten in the oxy-fuel flame. With WC-12Co powder, it is found that only particles <45 μm in size can be fully molten, and this is in excellent agreement with the empirically established HVOF coating practice. The results also indicate that the hypersonic flame accelerates the powder particles to very high velocities, approximately 700 m/s in some instances, and such high particle velocities are primarily responsible for the HVOF technique yielding dense and well-bonded coatings that are superior to plasma-sprayed coatings.

S.V. Joshi and R. Sivakumar. Cited: *Surface and Coatings Technology*, 1991, 50, (1), 67-74, [in English]. ISSN: 0257-8972. PHOTOCOPY ORDER NUMBER: 9206-1747593.

Residual Stress

Residual Stress Profile in Plasma-Sprayed Ceramic Coatings. Upon cooling, plasma-sprayed ceramic barrier coatings generate large residual stresses, produced by the thermal expansion mismatch, the temperature profile, and the anisotropy of the phases. A scheme for the purely elastic analysis of this stress formation is given, accounting for the different microstructure of successive coating layers. The presently considered microstructural data include the morphology and orientation pattern of the porosities. The coatings structure and temperature profile are computer-simulated.

M. Ferrari and J. Harding. Cited: *Composite Material Technology 1990*, 1990, New Orleans, Louisiana, 197-202, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740677.

Temperature Profiles

Comparison of Measured and Calculated Temperature Curves in Coating-Substrate Composites During Plasma Spraying. To reduce the test-effort, simulative calculation is a good means of optimizing coating-substrate composite systems. Before residual stress models can be designed, knowledge of the time- and place-related temperature fields must be acquired. The results of calculations, based on a numerical solution of the Fourier equation, are compared with temperature measurements, e.g., Hastelloy X. The excellent agreement leads to the conclusion that the model used for these experiments is sufficiently accurate to form the basis for a stress-calculation model.

U. Balting. Cited: *Metall*, 1991, 45, (12), 1238-1241, [in German]. ISSN: 0026-0746. PHOTOCOPY ORDER NUMBER: 9205-1744280.

Metallizing

Metallizing. Formation of a metallic coating on a ceramic body involves the synthesis or creation of the depositing species, transport from source to substrate, and film growth and interaction with the substrate. These three steps can be individually varied and controlled, giving a high degree of flexibility to the metallizing process. Major ceramic metallization techniques are categorized as atomistic, particulate, or bulk process. In atomistic deposition, atoms condense onto a ceramic substrate, and a continuous film is formed by nucleation and growth. Particulate depositions start with finely divided particles of the metal. A common technique for applying dispersed particles is screen printing. Flame spraying is an example of a liquid state being used to apply a metallization of the ceramic. Bulk metallization involves the application of large amounts of material in a short period of time. The ceramic can be coated by techniques such as dipping, spraying, brushing, or spinning. Mechanical adhesion and compound adhesion are described. Materials addressed in the discussion include lead zirconate titanate/electroless Ni, alumina/Cu, and alumina/Au.

J. Steinberg. Cited: *Engineered Materials Handbook. Vol. 4: Ceramics and Glasses*, 1991, ASM International, Materials Park, Ohio, 542-545, [in English]. PHOTOCOPY ORDER NUMBER: 9204-102860.

Microstructure of Coatings

Composites

An Electron Microscopic Examination of Composite Coatings Produced by Thermal Spraying. Ceramic/ceramic and ceramic/metal composites have been manufactured by a plasma spraying technique. The processing technology includes the manufacture of a composite powder and then feeding this powder with the intended matrix material through dual ports. The fiber morphology can be preserved if appropriate thermal spraying parameters are maintained. Different heat transfer characteristics of the fiber alter the solidification behavior of the thermally sprayed matrix materials, as is revealed by electron microscopy. New relationships between microcracks and the lamellar thermal spray structure have been determined. This processing technology may be used to design coatings with more robust mechanical properties. The matrix studied was NiAl or Al_2O_3 with and without TiO_2 and fibers were SiC, Si_3N_4, and YSZ.

J.H. Yi and C.C. Berndt. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 299-310, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1741019.

MCrAlY

The Development of Reaction Products at the Interface Between Partially Stabilized Zirconia and the MCrAlY Bond Coat in Thermal Barrier Coatings. The development of reaction products at the interface between partially stabilized zirconia (PSZ) thermal barrier coatings and the NiCrAlY bond coat has been experimentally investigated using plasma sprayed or physical vapor deposited two-layer thermal barrier coatings on René N4 superalloy substrates and cold isostatically pressed compacts of PSZ and NiCrAlY powders, and PSZ and Al_2O_3 powders. It was found that Al_2O_3 developed first followed by a Cr_2O_3-rich $(Al,Cr)_2O_3$ solid solution at the PSZ/NiCrAlY interface. For long-term exposure at 1100 and 1300 °C, it was found that $Ni(Al,Cr)_2O_4$ spinel formed within the $(Al,Cr)_2O_3$ solid solution. For compacts of PSZ and Al_2O_3 powder, a glassy-appearing oxide containing Al, Si, magnesium, and Ca developed after heat treatment at 1300 °C at the PSZ/Al_2O_3 interface. These elements are typical impurities in the PSZ. The formation of spinels and glassy oxides between PSZ ceramic coating and NiCrAlY bond coat is an important factor to the service life of TBC systems.

E.Y. Lee, R.R. Biederman, J. and R.D. Sisson, Jr. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 15-21, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1739360.

Ni-base Alloys

Structure and Properties of Vacuum Plasma Sprayed Hard Coatings. Vacuum plasma spraying (VPS) is used extensively in the aerospace industry to produce overlay coatings of Ni-based alloys, both for oxidation reistance and as bond coats for thermal barrier coatings. Such coatings have excellent wear properties when sprayed so as to achieve high density and good adhesion. In this study, wear-resistant Ni-based alloys have been VPS sprayed (on mild steel) and characterized for microstructure, hardness, and wear properties. In addition, coatings were also formed by high-velocity oxy-fuel spraying and tested. A comparison between the microstructure and the wear properties of deposits formed by the two processes is discussed in relation to differences in process variables.

S. Sampath, B. Katz, and H. Herman. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 287-297, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740789.

Patent

Coated Metal Foil

Process for Producing Metal Foil Coated With Flame Sprayed Ceramic. A process for producing a metal foil coated with flame sprayed ceramic comprises flame spraying a ceramic on a surface of a metal foil, while contacting the back side of the metal foil to be flame sprayed with water for cooling and providing tensile strength.

N. Okano, M. Inoue, and H. Hasegawa. Cited: *Auszuge Aus Den Europaischen Patentanmeldungen, Teil I*, 1990, 6, (13), 1793, [in English]. PHOTOCOPY ORDER NUMBER: 9205-1744325.

Fiber Reinforced Composites

Silicone-Carbide-Reinforced Composites of Titanium Aluminide. The method of forming filament-reinforced metal matrix materials comprises disposing an array of aligned high-strength temperature filaments on a receiving surface, providing, in powdered form, a Ti base metal to serve as a matrix to the fibers, radiofrequency plasma spray depositing the metal onto the array of filaments to at least partially impregnate the array and embed the filaments in the metal foil deposit formed by the plasma spray.

P.A. Siemers. Cited: *Auszuge Aus Den Europaischen Patentanmeldungen, Teil I*, 1990, 6, (12), 1650, [in English]. PHOTOCOPY ORDER NUMBER: 9205-1744759.

Method for Continuous Fabrication of Fiber Reinforced Titanium-Based Composites. The method for fabrication of filament-reinforced Ti base alloy in sheet form comprises providing a source of multiple strands of silicon carbide filaments, providing means to continuously align and closely space the filaments onto a polished refractory metal drum to form a continuously advancing tape, rotating the drum to pass the tape of aligned and closely spaced filaments on the drum into a low-pressure plasma deposition zone, providing a source of Ti base alloy metal in powder form having relatively large particles, supplying the powder to a low-pressure rf plasma deposition gun so as to pass through the plasma flame of the gun, aiming the plasma flame from the gun at a portion of the drum in the low-pressure plasma deposition zone to continuously deposit the Ti base alloy metal powder in molten form on and among the filaments of the tape of aligned and closely spaced filaments and continuously separating the Ti base alloy bearing tape from the drum after it passes from the plasma deposition zone.

P.A. Siemers. Cited: *Auszuge Aus Den Europaischen Patentanmeldungen, Teil I*, 1990, 6, (12), 1651, [in English]. PHOTOCOPY ORDER NUMBER: 9205-1744760.

Polymer Coatings

Thermal Spraying of Stainless Steel. A method of preparing a roughened substrate surface for subsequent coating with a fluorocarbon polymer in a liquid medium is disclosed. The surface of the substrate is thermally sprayed with a stainless steel alloy containing 25-35 wt.% Cr. A metal-coated substrate produced by this method and an article with a fluorocarbon surface coated by this method are also described.

N.J. Wall. Patent: US5069937, USA 26, 1991, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740699.

RF Plasma Process

Radio Frequency Plasma Method of Forming Multilayer Reinforced Composites. The method of forming a high-strength fiber-reinforced Ti base alloy composite comprises providing the Ti base alloy in powdered form with particle sizes >100 μm, radiofrequency plasma spray depositing the powder onto a receiving surface to form a high-density layer of the Ti base alloy, depositing a mat of filament reinforcement on the high-density layer, radiofrequency plasma spray depositing the powder into and onto the fiber reinforcement foil to form a second high-density layer bonded to the first high density layer as a composite, depositing at least one more additional mat of filament reinforcement on the second high-density layer, radiofrequency plasma spray depositing the powder into and onto the additional fiber reinforcement to form a third high-density layer bonded to the second high-density layer, and heating and isostatically pressing the composite to compress the contents thereof to high density.

P.A. Siemers. Cited: *Auszuge Aus Den Europaischen Patentanmeldungen, Teil I*, 1990, 6, (12), 1652-1653, [in English]. PHOTOCOPY ORDER NUMBER: 9205-1744761.

Spray Forming

Method for Finishing the Surface of Plasma Sprayed Titanium-Based Alloy Foils. A method of forming a thin sheet of Ti alloy comprises providing a rf-powered plasma gun, providing a supply of powder of the Ti alloy to be formed into a sheet, the powder having a particle size of greater than approximately 100 μm, supplying the powder to a plasma in the gun to cause a plasma deposit of the powder to form on a receiving surface, separating the plasma deposit from the surface as a free-standing sheet having at least one rough surface, and rolling the sheet to reduce its thickness and to increase the smoothness of the surfaces thereof.

P.A. Siemers. Cited: *Auszuge Aus Den Europaischen Patentanmeldungen, Teil I*, 1990, 6, (12), 1650-1651, [in English]. PHOTOCOPY ORDER NUMBER: 9205-1743832.

Titanium Alloy Foil

Method for Fabricating Titanium Alloys in Foil Form. The method of forming foil of alloys of Ti with other metals comprises providing a powder of the Ti-based alloy to be formed into a foil, providing a drum adapted to being rotated in a low-pressure plasma spray deposit apparatus, mounting a preformed foil of a metal of high melting point onto the drum to cover the cylindrical surface thereof, disposing the drum and foil in a low-pressure plasma spray deposit apparatus, low-pressure spray depositing the powder onto the surface of the foil on the drum, separating the preformed foil and the Ti alloy deposit from the drum, and separating the preformed foil from the Ti alloy foil formed by the low-pressure plasma deposit.

P.A. Siemers. Cited: *Auszuge Aus Den Europaischen Patentanmeldungen, Teil I*, 1990, 6, (12), 1651-1652, [in English]. PHOTOCOPY ORDER NUMBER: 9205-1743833.

Powder

Centrifugal Manufacture

Microporosity of Powders Produced by Centrifugal Spraying. The mechanism for formation of gas micropores in particles of metal powder produced as a result of centrifugal spraying of a rotating billet is described. Methods for decreasing the quantity of porous particles in the total mass of the powder are suggested.

V.Ya. Koshelev and V.T. Musienko. Cited: *Poroshkovaya Metallurgiya*, 1991, (12), [in Russian]. ISSN: 0032-4795. PHOTOCOPY ORDER NUMBER: 9205-1743771.

Metal/ceramic Composites

Plasma Spraying of Metal-Ceramic Composite Powders Produced by MA Method. High-performance metal matrix composite coatings could be fabricated by using the highly mixed metal-ceramic composite powders. Composite powders both of Cu-Al_2O_3 system and of Cu-AlN system were produced by the mechanical alloying (MA) method. Composite coatings on Cu were made by plasma spraying of these pre-composite powders. For comparison with composite coatings, conventional coatings were made using the conventional Cu and Al_2O_3 powder. The quality of the coatings obtained were evaluated by abrasion wear tests, and the electric properties were also investigated. In the case of spraying of MA powders, the separation of the ceramics from the metal occurred due to the relative difference of specific gravity between them. Nonetheless, the sprayed coatings made with MA precomposite powders had a finer microstructure and higher wear resistance than those made with conventional powders. The electric resistivity of the coatings made with MA powders did not scatter largely compared with those of the conventional coatings because of the homogeneous structures. High-quality composite coatings with fine and homogeneous structure can be obtained using MA powders.

M. Fukumoto, I. Okane, N. Yaegashi, M. Umemoto, and M. Shimanuki. Cited: *Quarterly Journal of The Japan Welding Society*, 1991, 9, (4), 25-30, [in Japanese]. ISSN: 0288-4771. PHOTOCOPY ORDER NUMBER: 9205-1744201.

Rapid Solidification Processing

Recent Trends and Developments With Rapidly Solidified Materials. Excellent progress is being made in demonstrating the significant improvements in metallic structures and properties through rapid solidification (RS) and rapid solid-state quenching. A number of atomization techniques are able to achieve solidification rates on the order of 10^5 K/s at economical production rates, yielding excellent refined microstructures with resultant outstanding mechanical, physical, and chemical properties. Powder production rates need to be significantly improved, and several techniques offer realistic promises in this area. The spray deposition processes, which bypass the powder production phase, achieve excellent solidification and solid-state cooling rates and offer high tonnage rates for preforms with outstanding hot, warm, and cold working response and with excellent physical and mechanical properties. Materials include 2024, 7075, 7150, X2020, IN100, and MERL 76.

N.J. Grant. Cited: *Metallurgical Transactions A*, 1992, 23A, (4), 1083-1093, [in English]. ISSN: 0360-2133. PHOTOCOPY ORDER NUMBER: 9205-1743714.

Reports

Brite Final Report

Reliability of Interfaces in Newly Designed Ceramic-Ceramic and Metal-Ceramic Systems. Brite Final Report. The objectives of common research are to improve the reliability of components containing ceramic materials by optimizing their manufacturing technologies and to develop test methods and evaluation criteria for different interface systems on a fracture mechanics base. A major objective of the experimental work of IWM was to provide selected test methods and the application of these methods to metal-ceramic and ceramic-ceramic components manufactured in these different processes. The following manufacturing technologies were developed and analyzed by the different partners: joining of SiSiC (IWM), laminating of SiSiC (Hoechst CeramTec), and plasma spraying of ZrO_2 on Nimonic or stainless steel (CSM).

R. Schoenholz, G. Kleer, and W. Doell. Cited: *Government Research Announcements and Index*, 1990, 34, [in English]. ISSN: 0097-9007. PHOTOCOPY ORDER NUMBER: 9206-1747464.

Review

Thermal Spray

Thermal Spraying. Thermal spraying is the generic name for a family of thick overlay processes in which a material is heated rapidly in a hot gaseous medium and simultaneously projected at high velocity onto a prepared substrate surface where it builds up the desired coating. Most metals, alloys, many ceramics, cermets, and even plastics can be thermally sprayed. Wire, electric arc, powder flame, high-velocity combustion, arc plasma, and laser spraying processes are described. An advantage of thermal spraying, and especially plasma spraying, is that there is relatively little heat transfer to the substrate. It is thus possible to coat wood, glass, and composite materials and metals.

K.T. Scott and R. Kingswell. Cited: *Advanced Surface Coatings: A Handbook of Surface Engineering*, 217-243, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740669.

Spray Process

Cathodic Arc Plasma

The Cathodic Arc Plasma Deposition of Thin Films. Cathodic arc plasma deposition is an ion plating process. The CAPD method uses a vacuum arc to generate vapor emission from a target, which is the cathode in an arc discharge circuit. Ionized vapor of the target material is deposited onto the substrate, which is normally biased negatively with respect to the chamber and anode. The CAPD method is characterized by a very high percentage of emitted vapor that is ionized, emission of ions that are multiply charged, and the high kinetic energy of the emitted ions. Such characteristics promote high film adhesion and density, high deposition rates, high quality, stoichiometric reacted coatings over a wide range of processing conditions, low substrate temperatures during deposition, and retention of alloy composition from target to deposited film. Applications of CAPD to depositing titanium nitride coatings on cutting tools, refractory metal nitrides to gas turbine engine components, and also decorative coatings are described.

P.C. Johnson. Cited: *Thin Film Processes II*, 1991, 209-280, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740717.

Laser Remelting

Surface Sealing of Plasma Sprayed Yttria Stabilized Zirconia Coatings With an Excimer Laser. Surface sealing of plasma sprayed ceramic coatings with CO_2 lasers is always associated with the problem of cracking on melted layers. Although some attempts, such as preheating, have been used to overcome the problem, formation of cracking is still not solved, especially in zirconia-based ceramic coatings. The present work investigates an alternative method of surface sealing of plasma sprayed 8 wt.% Y_2O_3-ZrO_2 coatings (on mild steel) using a high-energy pulsed excimer laser. The results show that smooth, crack-free, and crater-free sealing can be obtained. Effects of operating parameters on the sealing quality are also discussed.

Z. Liu, W.M. Steen, and W. O'Neill. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 23-36, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740679.

Laser Remelting of Plasma-Sprayed Coatings to Improve Their Wear Resistance at High Stress and High Temperature. The purpose was to study the realization of a coating that can resist high stress and intense conditions of erosion and wear at high temperatures on a metallic substrate. A coating has been developed by plasma spray deposition of a powder of a Ni alloy, on a substrate of 30NC11 steel. This kind of coating is very sensitive to oxidation and wear at high temperatures. Laser remelting of this coating improves its properties. Laser surface remelting of the plasma sprayed coating has been studied as a function of processing parameters such as power density and interaction time. Because of the width of the remelted pass and the geometrical complexity of the realized pieces (conoidal form), overlapping between successive laser passes, is involved in the experiments. The microstructures obtained in the remelted coating have been characterized by optical microscopy, scanning electron microscopy, and microhardness measurements. Microprobe analysis has been used to define the oxides appearing on the surface of the coating, after tests in industrial conditions. A microstructural study of the coatings, before and after laser processing, shows elimination of the coating oxide content and porosity, and the development of a metallurgical bonding at the coating/substrate interface for better coating adhesion. Tests in industrial conditions have been conducted on the laser remelted plasma spray coating, and these results are very satisfactory for corrosion and wear resistance.

D. Pantelis, J.P. Montagnon, Ph. Poupeau, and B. Mulot. Cited: *Surface Modification Technologies. IV*, 1990, Paris, France, 903-908, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1740802.

Laser-Arcs

Film Deposition by Laser-Arcs. This method of laser-induced vacuum arc evaporation includes advantages of the laser pulse vapor deposition (LPVD) technique and technologically utilized vacuum arc evaporation. It combines pulse deposition of LPVD with the high-energy efficiency of a vacuum arc. An Nd:YAG laser beam is focused on a target having cathodic potential. This laser beam induces a plasma that initiates a vacuum arc discharge. First results for carbon and Ti film deposition are presented.

W. Pompe, H.-J. Scheibe, P. Siemroth, R. Wilberg, D. Schulze, and B. Bucken. Cited: *Thin Solid Films*, 1992, 208, (1), 11-14, [in English]. ISSN: 0040-6090. PHOTOCOPY ORDER NUMBER: 9206-1747676.

Reactive Spraying

Synthesis and Deposition of TiB_2-Containing Materials by Arc Spraying. Wear-resistant coatings containing TiB_2 have been previously synthesized and deposited using the plasma spray process. The technique consists of plasma spraying micropellets comprising the reagents (ferrotitanium and boron or ferroboron) and depositing the as-reacted products on a substrate. To facilitate the deposition of the materials, to lower the cost, and to increase the spray rate, a different approach has been tried. It consists of depositing TiB_2-containing material by using the flexible arc-spraying technology. Coatings containing TiB_2 have been synthesized and deposited by arc spraying core wires containing the reagents mentioned above. Even though the process appears simpler, it was found that wire fabrication, as well as its deposition, must be carefully controlled to obtain the desired coatings. Nickel and type 304 austenitic stainless steel wires were used as substrates.

S. Dallaire and H. Levert. Cited: *Surface and Coatings Technology*, 1992, 50, (3), 241-248, [in English]. ISSN: 0257-8972. PHOTOCOPY ORDER NUMBER: 9206-1747562.

Review

Molten Particle Deposition. Molten particle deposition represents a group of processes in which finely divided surfacing materials are deposited in a molten or semi molten state on a prepared substrate to form a spray deposit. Properties and applications of carbide, boride, oxide, and cermet coatings commonly used in MPD are tabulated. Among the devices used to process ceramics are the detonation gun, hypersonic flame spraying, and the direct current plasma gun. In addition to coatings, MPD is used to produce free-standing ceramic bodies of near-net shapes that are costly to produce using conventional processing methods and to internally coat carbon fiber-reinforced graphite tubes with ceramics.

P. Fauchais. Cited: *Engineered Materials Handbook. Vol. 4: Ceramics and Glasses*, 1991, ASM International, Materials Park, Ohio, 202-208, [in English]. PHOTOCOPY ORDER NUMBER: 9204-102196.

Wire Arc Plasma

Wire Arc Plasma: A New Contender in Metal Spraying. The wire-arc-plasma (WAP) spray process utilizes a plasma transferred-arc gun, which establishes a transferred arc between the cathode within the gun and a single wire (anode), with an external feed to a pilot plasma nozzle. Benefits of the wire-arc-plasma system include the ability to spray any material that can be put into a conductive wire form. High-melting-point materials and low-melting materials can be sprayed with WAP. It also has the ability to successfully deposit tube wire and the ability to produce composite coatings. A review of WAP covers how the process works; equipment used; controlling coating quality; and properties of the coatings including macrohardness and microhardness, cohesive and adhesive strengths, tensile adhesion tests, and deposition efficiency tests. Various materials have been sprayed using the wire-arc-plasma spray process, ranging from high-melting-point materials such as Mo through the low-melting-point materials such as Al, and a wide range of materials in the form of tube or cored wires. Included in these materials are Ni-based and cobalt-based materials; Al, Cu, and Ni-based alloys reinforced with alumina; and types 410 and 308 stainless steels.

D.R. Marantz and K.A. Kowals. Cited: *Welding Journal*, 1991, 70, (8), 46-50, [in English]. ISSN: 0043-2296. PHOTOCOPY ORDER NUMBER: 9205-1744362.

Testing

High Temperature

Hot Corrosion Behavior of Plasma Sprayed Thermal Barrier Coatings and Acoustic Emission Response to Corrosion Monitoring. Four kinds of stabilized zirconia coatings—$8Y_2O_3 \cdot ZrO_2$, $7.6MgO \cdot ZrO_2$, $10CaO \cdot ZrO_2$, and $15CeO_2 \cdot ZrO_2$—undercoated with Ni-21Cr-10Al-0.8Y were sprayed on type 304 stainless steel substrate by plasma spraying. The hot corrosion resistance of these materials was evaluated by investigating the coatings after heating in furnace for 3 h at 1273 K with corrosive ashes, and by monitoring the acoustic-emission (AE) of coatings with corrosive ashes in the 1273 K to RT thermal cycle test. Corrosive components such as vanadium, Na, and sulfur penetrated the porous sprayed coatings and caused the coatings to peel off due to corrosion of the undercoat. The stabilizing elements MgO and CaO readily reacted with V and S compounds, but Y_2O_3 and CeO_2 were relatively resistant to hot corrosion. In the thermal cycle test, the AE signal counts were detected immediately at the beginning of the test for coatings with corrosive ashes, and the coatings spalled or broke down. On the other hand, the sprayed coatings without corrosive ashes required a number of cycle repetitions before the AE signal could be measured. AE analysis allows not only the beginning of coating damage but also corrosion progress to be detected in satisfactory response. These results also show that the AE monitoring method is applicable to evaluate the hot corrosion resistance for thermal barrier coatings.

H. Nakahira, Y. Harada, N. Mifune, and T. Doi. Cited: *Journal of The Society Of Materials Science, Japan*, 1991, 40, (455), 989-995, [in Japanese]. ISSN: 0514-5163. PHOTOCOPY ORDER NUMBER: 9205-1744283.

Infrared Thermal Wave

Infrared Thermal Wave Studies of Coated Surfaces. Recent results of infrared thermal wave studies of plasma-sprayed coatings, coatings on automotive metal panels, and metal to polymer adhesive joints are discussed. The purpose was to develop a reliable NDE technique to assess the quality and test the integrity of these coatings and bonding. The experimental method is a pulsed heating and synchronous infrared thermal wave detection technique commonly referred to as box-car thermal wave video imaging. The thermal wave propagation times for plasma-sprayed coatings and adhesive bonds are usually long enough for many NDE applications so that the method used here can be considered to be a real-time technique. In the IR thermal wave imaging method, the sample surface is pulse-heated by a bank of flash lamps, and the thermal response of the surface is monitored as a function of time and space by means of an infrared video camera. The resulting video signal is sent to a fast signal processing system and averaged synchronously on a pixel-by-pixel basis. The final data are displayed in the form of two-dimensional or three-dimensional gray scale or pseudocolor images of subsurface thermal features.

L.D. Favro, H.J. Jin, T. Ahmed, X. Wang, P.K. Kuo, and R.L. Thomas. Cited: *Review of Progress in Quantitative Nondestructive Evaluation*, Vol. 10B, 1990, La Jolla, California, 1201-1206, [in English]. PHOTOCOPY ORDER NUMBER: 9204-1738261.

Thermal Analysis

Application of Differential Thermal Analysis Method to Study Phase and Structural Transformations in Coatings Obtained by Gas-Thermal Spraying Methods. Differential thermal analysis (DTA) was used in the spraying procedure of gas-thermal coatings. The DTA data on interaction in materials used for gas-thermal spraying of coatings permit estimating the temperature range within which it occurs, the character of the process proceeding, and the melting point of the reaction products. These characteristics, in turn, make it possible to estimate prospects of using one or another composite for spraying of coatings. The coating of Ti with chromium nitride is described.

L.K. Doroshenko, A.L. Borisova, and G.M. Grigorenko. Cited: *Poroshkovaya Metallurgiya*, 1991, (9), 102-107, [in Russian]. ISSN: 0032-4795. PHOTOCOPY ORDER NUMBER: 9206-1747581.

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