Selected Abstracts of Thermal Spray Literature

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Applications

Aerospace Thermal Control

Measured Plasma Conductivity of Zinc-Oxide-Based Thermal Control Coatings. Z93, a coating composed of zinc oxide in a potassium silicate binder, has been widely used in the pace program as a thermal control coatings. Z93P is a similar composition material but uses a potassium silicate binder from another source. The plasma conductivities of Z93 and Z93P thermal control coatings were measured directly in a space simulation chamber. For Z93P, which is assumed to be the baseline formulation for all future applications, the conductivity was found to be a nearly constant 0.5 micro S/square meter. For Z93, the previous formulation, conductivity was approximately an order of magnitude larger and showed a somewhat more pronounced dependence on voltage. Experiments were carried out with aluminum disks.

G.B. Hillard, Cited: J. Spacecr Rockets, 31(5), Sept.-Oct. 1994, p 910-912 [in English]. ISSN: 0022-4650. PHOTOCOPY ORDER NUMBER· 199504-57-0490.

Automation

Automatic Plasma Flame Spray System for the Aircraft Engine Parts. Systems development of the process computer which controls the whole system has been achieved. What this system especially requires is thickness repeatability and 1-mil-order thickness accuracy of coating many engine parts. This system has fulfilled these requirements by using short-range repeated robotic motions and self-learning functions to obtain the most proper condition statistically after each process. It also has automated the flame spray process of many kinds of parts by a database which consists of various actual values.

I. Morioka, Y. Sasaki, N. Shiraishi, and H. Oonuki, Cited: *Kawasaki Steel, 26*(3), 1994, p 134-139, [in Japanese]. ISSN: 0368-7236. PHOTOCOPY ORDER NUMBER: 199503-57-0430.

Biomedical

Characterization of Thermal Sprayed Hydroxyapatite Powders and Coatings. Calcium phosphate materials such as hydroxyapatite (HA) have biocompatible properties that can promote osteogenesis or new bone formation Thermal spraying is an economical and effective process for coating the hydroxyapatite onto metal. It has been reported that plasma spraying changes the degree of crystallinity as well as the phase composition of the HA. This article reports the preparation and characterization of HA powders and coatings by two thermal spray processes (plasma and combustion flame) and suggests that the state of the starting powder adversely affects the coating characteristics. The raw HA powders are synthesized through a chemical reaction involving calcium hydroxide and orthophosphoric acid. Phase analysis using an x-ray diffractometer revealed that the synthesized powder consists of predominantly the HA phase. Calcined and crushed HA powders of various size ranges were fed into the plasma jet to produce HA coatings on metallic substrates. In addition, some HA powders were sprayed into distilled water by plasma spraying and combustion flame spraying to study powder melting characteristics. Other samples were plasma sprayed onto a solid rotating target to study atomization and impact behavior. The morphology of the rapidly solidified powders and thermal sprayed coatings were examined by scanning electron microscopy (SEM). An x-ray sedimentation particle size analyzer, laser diffraction particle size analyzer and image analyzer performed the particle size analysis. Preliminary results indicate that particle cohesion, size range and thermal treatment in the plasma affect the phase and structure of the as-sprayed coating and some post-spray treatment may be necessary to produce a dense and adherent coating with the desired biocompatible properties.

K.A. Khor and P. Cheang, Cited: *J. Therm. Spray Technol. 3*(1), Mar. 1994, p 45-50 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-57-0483.

Post-Deposition Treatment Effects on Hydroxyapatite Vacuum Plasma Spray Coatings. The purpose of this work is to evaluate the effects of post-deposition heat treatments on high and low crystallinity hydroxyapatite coatings on Ti6Al4V alloy. HA layers were produced by the vacuum plasma spray (VPS) technique, and the desired degrees of crystallinity were obtained by changing the deposition parameters. An analysis of the mechanical properties of the coatings and their adhesion to the substrate has been done by shear strength test. X-ray diffraction analysis was used to detect the structure and the chemical components in which HA dissociates during the deposition process and heat treatments. The data obtained indicate that heat treatments can increase the crystallinity of HA, but they also introduce a mechanical degradation of the coatings. After heat treatments, it was also observed that a large amount of tetracalcium phosphate was formed.

F. Brossa, A. Cigada, R. Chiesa, L. Paracchini, and C. Consonni, Cited: *J. Mater. Sci.: Mater. Med. 5*(12), Dec 1994, p 855-857 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199503-57-0367.

Brazing

Development of Brazing Method with Arc-Sprayed Coatings and Application to Assembly of Complicated Parts. Recently, brazing has been widely applied to the assembly of parts in which multiple portions must be joined simultaneously. Among all brazing methods, non-oxidation copper brazing is popular since this brazing method does not require flux. One of the typical complicated automotive parts joined by this method is the pump impeller (made of SAPH and SPCC steels) of a hydraulic torque converter for an automatic transmission. There, a number of blades are joined by preplaced brazing and pre-formed brazing metal or paste brazing metal have been used as brazing metal With this method, brazing defects and low productivity problems were common because the brazing metal was applied only to the top end of each blade. Therefore, a new brazing method using arc-sprayed coatings was developed to solve these problems, and it was applied to the assembly of the pump impeller. As a result, it was found that the more porous sprayed coatings have excellent brazeability.

T. Kusano, T Nakano, and M Kawaguti, Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spraying Soc.) 31*(3), 1994, p 37-42 [in Japanese]. ISSN: 0916-6076. PHOTOCOPY ORDER NUMBER: 199505-55-0601.

Electroconductive

Some Properties, Inhomogeneities, and Applications of Plasma Sprayed Electroconductive Copper-Based Coatings. The article reports on the effects of inhomogeneities on properties of plasma sprayed electroconductive Cu and CuSn coatings. These coatings, in combination with aluminum alloy based substrates, are of interest for applications in the power industry, particularly for the production of diverse types of power clamps and armatures for switching stations of high and very high tension electrical equipment. The properties of an Al alloy substrate with an electroconductive coating were examined, including coating structure, character of coating substrate boundary, strength, hardness and adhesion of the coating, as well as electrical conductivity and contact resistance between the substrate and coating. Aluminum substrate: Silumin (CSN424330).

M. Brezovsky, V. Palka, and V. Chovanec, Cited: *J. Therm. Spray Technol. 3*(1), Mar. 1994 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0457.

A Porosity Formation and Flattening Model of an Impinging Molten Particle in Thermal Spray Coatings. Thermal spray coatings have porosity, however, reasons for the production of porosity during the coating process are not known. This paper proposes a physical and mathematical model for the production of porosity by considering deformation of a molten particle during thermal spray coating processes. The theoretical model shows that the impinging velocity, the ambient gas pressure, the particle diameter and the molten material viscosity contribute to producing porosity. The paper also proposes that there is a porosity distribution along the splat radius and that most of the porosity exists in the periphery of the splat. Also, a flattened model proposed in this work agrees well with the results of Engel. Results are calculated for a copper substrate sprayed with Cu particles.

H. Fukanuma, Cited· *J. Therm. Spray Technol. 3*(1), Mar 1994, p 33-44 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0456.

Gas-Fired Turbines

Gas-Fired Turbines Power US Utilities. Major developments in thermal coating materials and processes, inspection methods, repair and reconditioning of gas fired turbines are described. Gas fired power plants are well suited to handle peak load power demand compared to steam turbines which need up to several hours to come on stream. Iron, cobalt and nickel-based high alloys are used in high temperature sections of gas fired turbines, whereas grey iron and nodular iron casings are typically used in low temperature compressor and turbine sections. Thermal barrier and corrosion protective coatings are composed of high alloy materials such as chromium, platinum and ceramics and are applied utilizing thermal spray processes. The primary failure mechanism in gas fired turbines is identified as due to thermal fatigue resulting in cracks and crack-induced failures

R Brosilow, Cited: *Weld. Des. Fabr.*, Dec 1994, p 16-19, [in English]. ISSN: 0043-2253. PHOTOCOPY ORDER NUMBER: 199502-57-0228.

Non-Skid Surface

Arc Sprayed Aluminum Composite Non-Skid Coating for Airfield Landing Mats. A programme to assess the suitability of thermally sprayed Al-alumina composite coatings for antiskid applications in military landing mats has shown potential benefits in performance and cost over the currently specified epoxy coating system. Further advantages are the elimination of volatile organic compound (VOC) emission during coating and the fact that the sprayed coatings do not suffer from ultraviolet degradation.

R.A. Sulit, E. Call, and D Hubert, Cited· *Surf. Eng. 10*(1), p 36-39, [in English]. ISSN: 0267-0844. PHOTOCOPY ORDER NUMBER: 199502-58-0247.

Power Turbines

HVOF Thermal Spray Upgrades Power Turbines. Technological advancements made in thermal-spray coating using the high velocity oxygen fuel process (HVOF) have benefited power utilities through higher efficiencies and extended life for land based gas fired turbines. The MCrAlY family of alloys provide oxidation and corrosion resistant barrier coatings for components used in the hot section of gas turbines. Advantages of HVOF applied coatings over plasma are higher coating bond strength, lower oxide content and improved wear resistance. Additionally HVOF showed deposit efficiency of approx75% compared with 45% for plasma spray. The main characteristics of plasma and HVOF spray systems

and the resulting coating properties with aluminum polyester and Cu-Ni-In coatings are presented. The lower flame temperature of approx5000 deg F for HVOF vs. 20 000 deg F for the plasma spray system reduces the vaporization of the polyester which can reduce the powder costs by 20-25%.

D.W. Parker and G.L. Kutner, Cited *Weld. Des. Fabr.*, Dec 1994, p. 20-22 [in English]. ISSN: 0043-2253. PHOTOCOPY ORDER NUMBER: 199502-58-0195.

Tooling

Arc-Sprayed Steel-Faced Tooling. A process for building arc-sprayed steel-faced tooling is described. Strategies to create matched die sets for injection molding

applications are presented and the issues involving backing materials, spray conditions and wear resistance are discussed. Examples of stainless steel tools built with this process demonstrate improved durability over more conventional sprayed zinc-faced tools.

L.E. Weiss, D.G. Thuel, L. Schultz, and F.B. Printz, Cited: *J. Therm. Spray Technol. 3*(3), Sept 1994, p 275-281 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199501-58-0108.

Composites

Metal matrix

Preparation of MMC Structures Consist of Carbon Fibre/Aluminium Prepregs by using the High Velocity Flame Spraying. Preparation of MMC Strucures Consist of Carbon Fibre/ The application of the thermal spraying process is a new way to produce carbon fiber reinforced Al-matrix composites. Spreaded fiber rovings are enveloped in the matrix material with high velocity flame spraying. The advantage of the thermal spraying process is based in the low times for contacting between carbon fibers and liquid matrix material. Chemical reactions on the interface fiber/matrix, which are caused the decreasing of the fiber tensile strength can be excluded. The thermal sprayed prepegs are compressed to MMC by hot pressing process. The long fiber reinforced composites are used to increase for instance cast components of motors. The aim of the research was the estimation of possibility to apply the high velocity flame process for prepreg manufacturing. Test material: AlSi12.

B. Wielage and J. Rahm, Cited: *Metall 48*(12), 1994, p 961-966 [in German]. ISSN· 0026-0746. PHOTOCOPY ORDER NUMBER: 199505-62-0627

Microstructure

Microstructure and Properties of Plasma-Sprayed Mo-Mo_2C Composites. Thermally sprayed Mo coatings are used in a variety of industrial applications, such as automotive piston rings, aeroturbine engines and paper and plastics processing machinery. Molybdenum exhibits excellent scuffing resistance under sliding contact conditions. However, plasma-sprayed Mo coatings are relatively soft and require dispersion strengthening (e.g. Mo_2C) or addition of a second phase (e.g. NiCrBSi) to improve hardness, wear resistance and, thus, coating performance. In this study Mo-Mo_2C composite powders were plasma sprayed onto mild steel substrates. Considerable decarburization was observed during air plasma spraying)a beneficial condition because carbon acts as a sacrificial getter for the oxygen, thereby reducing the oxide content in the coating. Finer powders showed a greater degree of decarburization due to the increased surface area; however, the starting carbide content in the powder exterted very little influence on the extent of decarubrization. The friction properties of Mo-Mo_2C coatings were significantly improved compared to those of pure Mo under continuous sliding contact conditions. It also was found that the abrasion resistance of the coatings improved with increasing carbide addition.

S Sampath, S.F. Wayne, Cited: *J. Therm. Spray Technol. 3*(3), Sept 1994, p 282-288 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199501-58-0109

Design of Experiments

Taguchi

A Taguchi Experimental Design Study of Twin-Wire Electric Arc Sprayed Aluminum Coatings. An experimental study was conducted on the twin wire electric arc spraying of Al coatings. This Al wire system is being used to fabricate heater tubes that emulate nuclear fuel tubes for use in thermal-hydraulic experiments. Experiments were conducted using a Taguchi fractional factorial design parametric study. Operating parameters were varied around the typical process parameters in a systematic design of experiments to display the range of processing conditions and their effect on the resultant coating. The coatings were characterized by hardness tests, optical metallography and image analysis. The article discusses coating hardness, roughness, deposition efficiency and microstructure. The study attempts to correlate the features of the coatings with the changes in operating parameters. A numerical model of the process is presented, including gas, droplet and coating dynamics.

D.J. Varacalle, Jr., G.C. Wilson, R.W. Johnson, T.J. Steeper, G. Irons, W.R. Kratochvil, W.L. Riggs, Cited· *J. Therm. Spray Technol. 3*(1), Mar 1994, p 69-74 [in English]. ISSN: 1059-9630 PHOTOCOPY ORDER NUMBER: 199504-58-0454

Diagnostics

A New Sensor for On-Line Diagnostics of Particles Under Thermal Spraying Conditions. The quality of coatings obtained by thermal spraying is strongly dependent on the velocity and temperature of the impacting particles. In order to control these parameters during coating deposition, a new compact optical system has been developed. In this system a specially designed lens is used to form the image of individual particles on a two-slit mask fixed at the end of an optical fiber. The treatment of signals from photodetectors allows one to localize the particle in the measurement volume without using an auxiliary laser beam. The velocity of the particles is obtained from their time of flight across the field of view of the two slits and the surface temperature from two-color pyrometry. Measurements were carried out in order to determine the size of the measurement volume defined by this optical system. In-flight particles were simulated by a rotating pinhole of known size, velocity and temperature. In a volume of 2600 mu m length x 330 mu m height x 200 mu m width it is shown that the precision on temperature and velocity measurement is better than 5%. The new system appears promising, based on first measurements on Ni-Al (5%) particles sprayed with an Ar-He plasma.
P. Gougeon, C. Moreau, V. Lacasse, M. Lamontagne, I. Powell, A. Vewsher, Cited: Conf: Advances in Powder Metallurgy and Particulate Materials-1994. *Advanced Processing Techniques, Vol. 6*, 8-11 May 1994, Metal Powder Industries Federation, p 199-210 [in English] PHOTOCOPY ORDER NUMBER: 199505-22-0534

Environment

Thermal Spray Industry Environmental Guideline. The work represents a comprehensive compilation of information that is to be used in tackling many of the laws and regulations with respect to the emissions and hazardous solid wastes emanating from thermal spray operations. The information included was derived from an in-depth review of literature, regulations, reviews with agencies and a collection task from corporate files of thermal spray industry members. The material is separated into five major sections. The summary section highlights the important issues and lays the foundation for the body of the Guideline. An education section reviews thermal spray's potential for hazardous waste materials and emissions, and a conclusions and recommendations section states the overall position of the thermal spray industry and indicates how many of the applicable regulations can be met. A supporting background section documents all the applicable laws, regulations, reporting requirements, and industry data. A final section refers the reader to sources of information and assistance.

Thermal Spray Industry Environmental Guideline, ASM International, 1994 [in English]. ISBN: 0-87170-523-0. PHOTOCOPY ORDER NUMBER: 199502-71-0045

Feedstock

WC-Ni Characterization

Characterisation of WC-Ni powder for High Velocity Oxyfuel Spraying. The morphology of a WC-17Ni thermal spraying powder has been studied. The structure and element distribution in the powder have been investigated using an SEM with energy dispersive spectroscopic microanalytical facilities. The results show that the powder particles consist of polycrystalline tungsten carbide particles and homogeneous nominally pure nickel coatings. No intermetallic phases or interdiffusion of tungsten into Ni or Ni into tungsten carbide have been found. The results obtained have been correlated with the structure of the coatings formed after high velocity oxyfuel spraying.

J.M. Guilemany, J.R. Miguel, and Z. Dong, Cited: *Powder Metall.* *37*(3), 1994, p 219-221 [in English]. ISSN: 0032-5899. PHOTOCOPY ORDER NUMBER: 199504-57-0450

Wear applications

Low Cost and High Wear Resistant Spray Material of C-Cr-Fe Alloy. The thermal spray of a hard material has the potential to improve the wear resistance of machine parts. Ceramics and cermet, the cost of which is so high that the application of these materials to practical use is limited, can be used for wear resistant spraying. In order to develop a lower cost and improved wear resistant spray material, 5.5C-25CrFe alloy, a low cost metal powder, was studied as a candidate for dense coat by the conventional plasma spray process. The alloy had a hypereutectic structure in which the primary crystal of hard M sub 7 C sub 3 carbide is the main phase and the alpha -Fe matrix. A field test of the heat exchanger tubes (made of STBA 12 and STB 52 steels) of a coal-fired boiler has revealed that the erosion wear rate of the developed sprayed coating is half that of Cr sub 3 C sub 2 /NiCr cermet coating

N. Akira, K. Yoshimi, and T. Yasuyuki, Cited: *Mitsubishi Juko Giho 31*(5), 1994, p 353-356 [in Japanese]. ISSN: 0387-2432. PHOTOCOPY ORDER NUMBER: 199504-58-0508

Mechanical Properties

Adhesion

Measurement and Analysis of Adhesion Strength for Thermally Sprayed Coatings. Thermally sprayed coatings have a distinctive microstructure which can be described as a three dimensional layered structure of discs which are interlaced to form a material of composite nature. The coatings are normally 25 mu m in thickness and can thus be described as bulk coatings. The minimum microstructural detail would be a single splat (a lamella) which is approx5 mu m (approx0.0002 in.) in thickness and up to 80 mu m (approx0.003 in.) in diameter. The paper focuses on methods used to define and measure the adhesion of coatings or deposits formed by thermal spray technology. The properties distinguished include strength and toughness. Measurements such as the tensile adhesion test (according to ASTM C633), the double cantilever beam test and the scratch test are detailed to illustrate their relevance to present industrial practice. Acoustic emission studies have also been used to assess the crack density function, a product of the number of cracks and crack size. Indentation tehcniques have been used to determine the fracture toughness of coatings and to demonstrate that the material properties of coatings are anisotropic. These techniques, among others, may be used to gain a fundamental understanding of coating performance or for quality control. A further focus concerns the highly variable nature of the material properties of coatings. Such variation leads to poor reproducibility during service and can cause unpredictable performance. Therefore, a section is presented on the statistical analysis of thermal spray coatings, with particular references to the Weibull distribution

C.K. Lin and C.C. Berndt, Cited: *J. Therm. Spray Technol.* *3*(1), Mar 1994, p 75-104 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0453

Effects of Coating Thickness and Residual Stresses on the Bond Strength of ASTM C633-79 Thermal Spray Coating Test Specimens. Wire-arc-sprayed nickel-aluminum is widely used in the aircraft industry for dimensional restoration of worn parts and as a bond coat for thermal barrier coatings and other top coats. Some repair applications require thick coatings, which often result in lower bond strength A mechanism being investigated to explain this decrease in bond strength is the free edge effect, which includes both coating residual stresses and coating thickness. The layer-removal method was used to determine experimentally the residual stresses in wire-arc-sprayed Ni-Al coatings of different thicknesses. Bond strength evaluations were performed using an improved ASTM C633-79 test specimen. Finite-element analysis and fracture mechanics were used to investigate the effects of coating thickness and residual stress state on coating bond strength.

D.J. Greving, J.R. Shadley, and E.F. Rybicki, Cited: *J. Therm. Spray Technol.* *3*(4), Dec 1994, p 371-378 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0441

Bond Strength Evaluation for Sprayed Coatings of High Temperature Equipment. The plasma spray coating method arouses much attention as a means of providing a new function for equipment for high-temperature applications. In order to assess the plasma-sprayed coating strength, the Young's modulus of the sprayed coating, residual stress and bond strength at the boundary zone between the sprayed coating (80 Ni-20Cr, 50 Ni-60Cr, 12 YSZ, 8YSZ) and parent metal (mild steel, SUS 304, FCD45) have been measured. As a result, it has become clear that it is important to assess the plasma-sprayed coating strength, giving full consideration to the residual stress occurring at the time of sprayed coating formation and to the stress singularity at the end parts of the boundary zone between the sprayed coating and the parent metal, for the prevention of the sprayed coating separation from the end parts of the boundary zone. This fundamental knowledge serves the purpose of reliability improvement on solid oxide fuel cell and an adiabatic engine now being developed.

I. Yoshiaki, N. Akira, T. Masao, and T. Noboru, Cited: *Mitsubishi Juko Giho, 31*(6), 1994, p 439-442 [in Japanese]. ISSN: 0387-2432. PHOTOCOPY ORDER NUMBER: 199503-57-0429

Indentation Adhesion

An Examination of the Validity of the Interface Indentation Test: Application to Thermal Sprayed Coatings. From indentation tests performed at the interface between an hypersonic thermal sprayed Cr sub 3 C sub 2 -25% NiCr coating and several metallic substrates, it is shown that it is possible to obtain a critical load which may represent adhesion. This critical indentation load is independent of the coating thickness if an appropriate annealing treatment is realized in order to remove the residual stresses appearing during the cooling of the sprayed material. From tests performed on as received specimens, the effect of residual stresses is also discussed.

Ph. Demarecaux, J. Lesage, D. Chicot, and G. Mesmacque, Cited: Conference: EURADH 94 Adhesion, Mulhouse, France, 12-15 Sept 1994, Societe Francaise du Vide, 1994, p 524-527 [in English]. PHOTOCOPY ORDER NUMBER: 199501-57-0087

Peel Strength

Peel Adhesion Test for Thermal Spray Coatings. A technique for determining the adhesion of a thermal spray coating was developed by modifying procedures commonly used to test adhesion by peeling. A coating is deposited on a metal foil that has been soldered to a massive copper block, which provides mechanical support and serves as a heat sink. Then the block, foil, and coating are glued to a

stiff aluminum plate, after which the Cu block is removed. The fold is peeled from the coating according to a procedure similar to the ASTM D 3167 peel test. This method causes a crack to propagate precisely along the coating/substrate interface in a stable fashion, with the movement of the crack tip controlled by the peeling speed. Sample preparation, test procedures, and initial results are discussed. The technique has been applied to testing the local variations in adhesion for plasma-sprayed Cr sub 2 O sub 3 and a Ni-Mo-Al composite on a stainless steel foil. Based on these results, testing procedures are recommended and a peel test jig is specified.

M. Sexsmith and T. Troczynski, Cited: *J. Therm. Spray Technol.* *3*(4), Dec 1994, p 404-411 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-22-0427

Residual Stress

Through-Thickness Residual Stress Evaluations for Several Industrial Thermal Spray Coatings Using a Modified Layer-Removal Method. Residual stresses are inherent in thermal spray coatings because the application process involves large temperature gradients in materials with different mechanical properties. In many cases, failure analysis of thermal spray coatings has indicated that residual stresses contribute to reduced service life. An established method for experimentally evaluating residual stresses involves monitoring deformations in a part as layers of material are removed. Although the method offers several advantages, applications are limited to a single isotropic material and do not include coated materials. This paper describes a modified layer-removal method for evaluating through-thickness residual stress distributions in coated materials. The modification is validated by comparisons with three-dimensional finite-element analysis results The modified layer-removal method was applied to determine through-thickness residual stress distributions for six industrial thermal spray coatings: stainless steel, aluminum, Ni-5Al, two tungsten carbides, and a ceramic thermal barrier coating. The modified method requires only ordinary resistance strain-gage measuring equipment and can be relatively insensitive to uncertainties in the mechanical properties of the coating material.

D.J. Greving, E.F. Rybicki, and J.R. Shadley, Cited: *J. Therm. Spray Technol.* *3*(4), Dec 1994, p 379-388 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0442

Residual Stress Measurement in Thermal Sprayed Hydroxyapatite Coatings. Hydroxyapatite coatings have been used for many years on dental and prosthetic implants to provide a biocompatible surface for long-term fixation of the implant to bone. In this study two thermal spraying processes, air plasma spraying (APS) and a high velocity oxy fuel process (CDS) have been employed to produce hydroxyapatite coatings on Ti-6Al-4V substrates. An X-ray diffraction technique (XRD) has been applied to measure the residual stresses in thermal sprayed hydroxyapatite coatings. It has been shown that such stresses are sensitive to spraying parameters and that the newer high velocity oxy fuel spraying process results in lower residual stresses than the conventional air plasma spraying process Heat treatment of the coating has been shown to significantly reduce the residual stress in the coating.

S.R. Brown, I.G. Turner, and H. Reiter, Cited: *J. Mater. Sci.: Mater. Med. 5*(9-10), Sept-Oct 1994, p 756-759 [in English]. ISSN: 0957-4530. PHOTOCOPY ORDER NUMBER: 199501-57-0026

Mechanical Testing

Improved Ring Shear Test for the Evaluation of Adhesion Strength of Thermal Sprayed Coating. The ring shear test was modified to evaluate the adhesion properties of plasma sprayed coatings. To ensure the ring shear test to be reliable, the conditions of some main factors, such as coating thickness, coating width, and rod-jig clearance, for the evaluation of the adhesion strength were evaluated. The results obtained in this research are summarized as follows: (1) In order to develop the accuracy of the loading exactly along the specimen's axial direction, the loading stress uniformity on the coating and the uniformity of the clearance between rod and jig, the conventional ring shear test was modified in shapes of both the shearing jig and the specimen and the loading manner. Consequently, the reproducible results with less scattering were obtained by using the modified ring shear test. (2) To ensure this modified ring shear test as the method to evaluate the adhesion strength of plasma sprayed coating, the necessary conditions of some main factors were evaluated. It was found that coating width, coating thickness, and rod-jig clearance should be fixed to some moderate values. NiCr coating on FC23 cast iron substrate is discussed.

M. Fukumoto, H. Murakami, I. Okane, and H. Harada, Cited: *J. Jpn. Inst. Met. 59*(1), Jan 1995, p 84-88 [in English]. ISSN: 0021-4876. PHOTOCOPY ORDER NUMBER: 199505-58-0545.

Microstructure

Coating Formation

Splat-Behavior of Plasma Sprayed Particles on Flat Substrate Surface. Size-restricted powder particles were plasma sprayed on flat substrate surface, and the effects of some factors on the splatting behavior of the particles were evaluated. The results obtained are summarized as follows: (1) From the observation of aluminum powder splatting on SUS304 substrate, flattening degree of the powder, xi , showed maximum in the higher plasma power used under the constant spraying distance and the xi maximum was recognized at the spraying distance of 300 mm. (2) Effect of the velocity on the flattening was not always remarkable from the results of the relation between xi and velocity observed, in which xi kept almost constant without depending on the velocity. (3) From the observation of Al powder splatting on heated SUS304 substrate, remarkable effect of the wettability due to the surface oxide layer on the flattening behavior was recognized. (4) In the splat behavior of nickel powder on the heated SUS304 substrate, in tense splashing of the powder was observed in the substrate temperature range up to 573K. The splashing behavior, on the other hand, did not occur in the substrate temperature range 623K. The splashing seemed to be caused by the impact pressure in the particle. Copper and Al alloy substrates are also discussed.

M. Fukumoto, S. Kato, and I. Okane, Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spraying Soc.) 31*(3), 1994, p 15-21 [in Japanese]. ISSN: 0916-6076. PHOTOCOPY ORDER NUMBER: 199505-58-0510.

Interfacial Interactions

Study of Interface Interactions for Metal-Metal and Metal-Ceramic Coatings Obtained by Plasma and HVOF Spraying. Metallurgical bonding makes plasma sprayed metal/metal interfaces stronger than ceramic/interlayer/metal inferfaces which are, in turn, stronger than plasma sprayed ceramic/metal interfaces according to adhesion/cohesion strength tests and microscope examinations of interfaces produced by plasma and high velocity oxygen fuel spray. Substrate materials included brass, aluminum, Al-Si alloys and 34CrMo4 steel (F1250). Powders were commercially used grades. Powder compositions, particle size, spray technique and system are tabled as are systems, adhesion and failure type. Ten micros show interfaces and analysis line scans. These show width of zinc and copper coexistence zone and possible micromelting zones in the BzAl/brass system and a very narrow melt zone in the Al sub 2 O sub 3 /F1250 system. Similar analyses are given for the Al sub 2 O sub 3 /NiCr/F-1250, ZrO sub 2 -8%Y sub 2 O sub 3 /NiCrAlY/Al(13%Si), WC-Co/F-1250, WC-Co/Al and (W,Ti)C-Ni/Al systems.

J.M. Guilemany, N. Llorca-Isern, M.D. Nunez, and J. de Paco, Cited· *Scr. Metall. Mater. 31*(8), Oct 1994, p 1121-1126 [in English]. ISSN: 0956-716X. PHOTOCOPY ORDER NUMBER: 199502-58-0234.

Porosity

A Porosity Formation and Flattening Model of an Impinging Molten Particle in Thermal Spray Coatings. Thermal spray coatings have porosity, however, reasons for the production of porosity during the coating process are not known. This paper proposes a physical and mathematical model for the production of porosity by considering deformation of a molten particle during thermal spray coating processes. The theoretical model shows that the impinging velocity, the ambient gas pressure, the particle diameter and the molten material viscosity contribute to producing porosity. The paper also proposes that there is a porosity distribution along the splat radius and that most of the porosity exists in the periphery of the splat. Also, a flattened model proposed in this work agrees well with the results of Engel. Results are calculated for a copper substrate sprayed with Cu particles.

H. Fukanuma, Cited: *J. Therm. Spray Technol. 3*(1), Mar. 1994, p 33-44 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0456.

Thermal Interaction

Thermal Interaction Between WC-Co Coating and Steel Substrate in Process of HVOF Spraying. A low alloy steel 34CrMo4 HVOF thermally sprayed with WC-12% Co powder was used to invetigate the structure of substrate-coating interfacial region by TEM. The coating microstructure exhibits the characteristics of rapid solidification and tempering, viz. formation of amorphous phase. Due to the HVOF thermal spraying, ferrite and pearlite structures in the interfacial region (50 mu m) change greatly. Within 3-10 mu m from the interface, martensite transformation occurs. Adjacent to the interface fine crystalline structure (0.1 mu m) is found similar to alpha iron with a bcc structure. The crystals consist of a delta phase and twinned high carbon martensite. Mathematical simulation of the coating process agrees well with the experimental data.

J.M. Guilemory, V.V. Soholov, J. Nutting, Z. Dong, and J.A. Calero, Cited: *Scr. Metall. Mater. 31*(7), Oct 1994, p 915-920 [in English]. ISSN: 0956-716X. PHOTOCOPY ORDER NUMBER: 199501-58-0099.

Modeling

HVOF

Simulation of Powder Particles in High Velocity Oxy-Fuel Spraying. By means of the mathematical simulation both mechanical and thermal behavior of the powder particles of the different materials are investigated in the process of the high velocity oxy-fuel (HVOF) spraying which permits one to obtain the high quality coatings at the various substrates. The particle fusion is studied during its movement from the gun exit to the substrate surface. On the base of the developed models and mathematical simulation, the particle velocity evolution is established at the spraying distance. It attains the maximum values which depend on the powder properties. The numerical results obtained for Al sub 2 O sub 3 , Ni and WC-12Co coatings agree well with the experimental data and confirm the feasibility of the developed model from the technological point of view.

V.V. Sobolev, J.M Guilemany, and J.A. Calero, *Deform. Met. 20*, Sept-Oct. 1994, p 25-31 [in Spanish]. ISSN: 0210-685X. PHOTOCOPY ORDER NUMBER: 199502-58-0147.

On the Gas Dynamics of HVOF Thermal Sprays. An experimental study of the gas-dynamic aspects of the high-velocity oxyfuel (HVOF) thermal spray process has been performed using commercially available HVOF equipment (Hobart-Tafa JP-5000, Hobart-Tafa Technologies, Inc., Concord, New Hampshire, USA). Optical diagnostic techiques, including microsecond-exposure schlieren and shadowgraph imaging, were applied to visualize the hot supersonic jet produced by this equipment without particle injection. Rapid turbulent mixing of the jet with the surrounding atmosphere was observed, which is an issue of concern in coating quality due to the possibility of oxidation of sprayed particles. This mixing appears to be a function of the ratio of densities of the hot jet and the cold atmosphere as well as a function of the velocity of the jet, rather than one of combustion-chamber pressure or barrel length. The supersonic core of the HVOF jet dissipates rapidly, due to the mixing, so that the jet is no longer supersonic when it impinges on the target surface being sprayed. Secondary issues also observed in this study include strong jet-noise radiation from the HVOF plume and the entrainment and induced bulk motion of the surrounding air.

C M. Hackett, G.S. Settles, and J.D. Miller, Cited: *J. Therm. Spray Technol. 3*(3), Sept 1994, p 299-304 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199501-58-0110.

Porosity

Analysis of Coating Gas Porosity Development During Thermal Spraying. The formation of gas porosity during thermal spraying is investigated. The development of pores is studied, taking into account the parameters of spraying, powder particle material and substrate, droplet flattening and solidification kinetics, heat and mass transfer processes and pore interaction The results obtained agree well with thermal spraying practice.

V.V. Sobolev, J.M Guilemany, *Surf. Coat. Technol. 70*(1), Nov 1995, p 57-68 [in English]. ISSN: 0257-8972. PHOTOCOPY ORDER NUMBER: 199501-57-0015.

Splat Behavior

Effect of Substrate Temperature on Splatting Behavior of Plasma Sprayed Nickel Particles. Size-restricted nickel powder particles were plasma sprayed on the flat SUS304 substrate surface, and the effect of substrate temperature on the splatting behavior of the particles was evaluated. The results obtained are summarized as follows: (1) In the splat behavior of Ni powder on the heated SUS304 substrate, intense splashing of the powder was observed in the substrate temperature range up to 573K. The splashing behavior, on the other hand, did not occur in the substrate temperature range 623K. (2) Transition temperature, Tt, was defined, on which the powder's splat pattern changed to the form without splashing from the one with splashing Transition temperature was approx600K in the case of Ni splat on the SUS304 substrate. (3) From the observation results of splat behavior on both the heat-treated substrate at room temperature and the Au coated substrate at elevated temperatures the transition behavior of splatting seemed to depend not on the oxide layer formed but on the other factors relating to substrate temperature.

M. Fukumoto, S. Kato, and I. Okane, Cited: *J. Jpn. Inst. Met. 58*(10), 1994, p 1191-1195 [in Japanese]. ISSN: 0021-4876. PHOTOCOPY ORDER NUMBER: 199503-58-0315.

Patent

Braze Material

Brazeable Aluminum Material and a Method of Producing Same. A brazeable Al material is composed of an Al core and a brazing agent layer consisting of a brazing agent thermally sprayed onto and covering a surface of the core. A number of unmolten minute particles of the brazing agent are present in the brazing agent layer, which contains at least an Al-Si alloy and/or a mixture of Al and silicon. Characteristic features of a method of producing the brazeable Al material are the steps of· preparing a powder composed of minute particles, and thermally spraying the powder onto the Al core in such a state that only a surface of each minute particle is molten, with a pith of the particle remaining unmolten. The powder is an Al-Si alloy and/or a mixture of Al powder and Si powder.

T. Terada, M. Kojima, T. Oyamashi, K. Arakawa, I. Iwai, and M. Furuta, Cited: Patent: EP0595601 (European Patent), 26 Oct 1993, 4 May 1994 [in English]. PHOTOCOPY ORDER NUMBER: 199504-55-0415.

Hot Workability of Ti

Enhancement of Hot Workability of Titanium Base Alloy by use of Thermal Spray Coatings. The present invention relates to a process in which a metal or metal alloy is thermal spray coated onto a base alloy material prior to hot working. More specifically, the invention relates to the use of plasma coating of titanium over a Ti alloy plate for improved hot workability. This combination allows the crack-sensitive base alloy to be rolled with a minimum of surface and edge cracks. In addition, by using a plasma sprayed Ti coating there is a reduction in the roll force required to reduce the material during the hot working process.

P.A. Russo and S.R. Seagle, Cited: Patent: 5298095, USA 20 Dec 1991, N.P. 29 Mar 1994 [in English]. PHOTOCOPY ORDER NUMBER: 199503-52-0361.

Post-processing

HIP

Hot Isostatic Pressing of Plasma Sprayed Nickel-Base Alloys. The article reports the effects of hot isostatic pressing (HIPing) on the microstructure and properties of plasma sprayed Ni based alloy coatings Hot isostatic pressing was used as a post spray treatment on plasma sprayed Ni-5Al, Ni-20Al and NiCrAl coatings. The aim was to densify the coatings and modify physical properties such as strength, amount of porosity and hardness. The coatings were HIPed at 750-950 C at pressures of 50-200 MPa and held for 1 h. The treated coatings were examined by optical microscopy and scanning electron microscopy (SEM). Coating porosity was determined using a combination of an image analyzer and SEM Near-zero porosity levels could be obtained and HIP treatment at increasing temperatures and pressures changed the microstructure and increased the microhardness of the coatings. Mechanical testing of the coatings was performed on a dynamic mechanical analyzer (DMA) from ambient to approx1000 C. The results showed that the elastic modulus of HIPed coatings was greater than as-sprayed coatings up to approx750 C. These changes can be related to plastic flow, interlamellar diffusion and creep that occur at increased temperatures and pressures. Substrate: medium carbon steel

K.A. Khor and N.L. Loh, Cited: *J. Therm Spray Technol. 3*(1), Mar 1994, p 57-62 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0455.

Sealing

Subsequent Sealing of Thermally Sprayed Coatings to Increase Corrosion Resistance. Sealants are frequently applied to close the porosity in thermally sprayed coatings in order to improve corrosion resistance and a physical model has been developed to describe the penetration of sealant into the capillary pore system. It is concluded that a liquid intended for use as a sealant should have low viscosity, high surface tension, and a high wetting capability. However, measurements of coating adhesion have shown that gas trapped at high pressure within the pores can lead to a reduction in substrate-coating bond strength. Polarisation curves were measured for sealed and unsealed atmospheric plasma sprayed (APS) and high velocity oxyfuel (HVOF) WC-Co-Cr coatings in acid and alkaline solutions. Sealing was found to reduce the corrosion current density, but the effect developed strongly on the coating phase composition and microstructure. The WC-Co-Cr HVOF coatings showed better resistance because the higher chromium concentration in the matrix phase permitted a passive oxide layer to form, whereas when spraying Al sub 2 O sub 3 -TiO sub 2 ceramic coatings APS was found to give higher corrosion resistance as a result of a higher proportion of amorphous phase.

E. Lugscheider, P. Jokiel, V Messerschmidt, G. Beckschulte, Cited: *Surf. Eng. 10*(1), 1994, p 46-51 [in English]. ISSN: 0267-0844. PHOTOCOPY ORDER NUMBER· 199502-57-0301.

Solar Furnace Treatment

Solar Furnace Surface Treatment of Plasma-Sprayed Thermal Barrier Coatings. An original process of superficial thermal treatment is described This process has been successfully applied to partially stabilized yttria-zirconia coatings (ZrO sub 2 -Y sub 2 O sub 3) to increase the lifetime of the thermal barriers A thin superficial layer was melted, and morphological transformations were observed. A microstructural comparison between as-sprayed layers and thermally treated layers is presented. Substrate material used was cast iron.

A. Ferriere, L Lestrade, A. Denoirjean, A. Grimaud, P. Fauchais, Cited: *J. Therm. Spray Technol. 3*(4), Dec 1994, p 362-370 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER 199504-57-0465.

Post-treatment

Sintering

Applications of a Ni-P Alloy on the Sintering of Refractory Metals and Thermal Spraying. Wettability and diffusibility between a Ni-P alloy and tungsten, tungsten carbide, and cemented carbides have been investigated, and improved properties could be obtained by this special sintering additive. This addition may lead to several applied processes such as activated sintering of W, hot pressing of tungsten carbide and infiltrating into W carbide skeleton and post-treatment of thermal sprayed WC-Co coatings. Addition of Ni-P alloy in limited amounts to W powder are sufficient to obtain a fully dense sintered body when the compact is heated at only 1273K for 30 min. Similarly, pore-free cemented carbide can be produced by hot pressing of tungsten carbide powder coated with a Ni-P alloy. Another cemented carbide can also be fabricated by means of infiltration of a Ni-P alloy into tungsten carbide skeleton. At the same time, the infiltrated cemented carbide can be metallurgically bonded to a steel substrate, which is a kind of composite materials. Infiltration of a Ni-P alloy into thermal sprayed WC-Co coatings improves their resistance to abrasive wear.

H. Ito, Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spraying Soc.) 31*(3), 1994, p 43-49 [in Japanese]. ISSN· 0916-6076. PHOTOCOPY ORDER NUMBER: 199505-54-0406.

Process

Flame Treatment for Plastics

Flame Treatment for Adhesive Bonding of Polypropylene: The Influence of Filling Content and Storage Conditions. Bonding the polyolefins (and especially polypropylene) is still considered as hazardous because of their weak surface energy. This paper deals with the assessment of the flame treatment as a reliable surface treatment for polypropylene before adhesive bonding or painting. Processing and storage parameters are taken into account to find out the best conditions to obtain good and reproducible mechanical characteristics of the assembly.

F Demblon, Cited: EURADH 94 Adhesion, Mulhouse, France, 12-15 Sept 1994, Societe Francaise du Vide, p 394-397 [in English]. PHOTOCOPY ORDER NUMBER: 199501-E5-P-0032

HVOF

Interaction of Particles with Carrier Gas in HVOF Spraying Systems. Several designs of high-velocity oxygen fuel (HVOF) thermal spray systems have been created during the last decade The most advanced systems are now producing coatings comparable in quality to detonation (D-gun) coatings This paper presents numerical analysis of the interaction of dispersive particles with the carrying gas flow for three different HVOF systems, along with a method to calculate the parameters of sprayed particles that highlights the advantages and limitations of each design. The method includes gas dynamical calculations of the gas flow in an accelerating channel and calculations of the injected particle motion and thermal state (temperature and melted mass fraction). The calculations were performed for particles of tungsten carbide, aluminum oxide, and zirconium oxide with size distributions of 10 to 80 mu m. Two conventional types of HVOF systems were considered. those with a supersonic accelerating channel and those with a subsonic accelerating channel (without a de Laval nozzle). A novel design is proposed that contains a combined gas dynamical path with functionally separated regions of heating and acceleration. The regularities and distinctions in the behavior of the metallic and ceramic oxide particles are discussed for different jet configurations The results obtained indicate that it is possible to significantly affect particle parameters by using the new configuration solutions without creating construction complications.

E. Kadyrov, F. Worzala, Y. Evdokimenko, V. Kisel, and V. Kadyrov, Cited *J. Therm. Spray Technol. 3*(4), Dec 1994, p 389-397 [in English]. ISSN: 1059-9630 PHOTOCOPY ORDER NUMBER: 199504-57-0466.

HVOF+Arc

The Sonarc Process: Combining the Advantages of Arc and HVOF Spraying. Electric arc spraying has been successfully used for many industrial applications for 30 years High-velocity oxygen fuel (HVOF) spraying is another well-established technology. Coatings produced by the HVOF process, especially carbide-containing coatings, exhibit excellent quality in terms of density and hardness. One approach to obtaining both high deposition rates and dense coatings is to combine electric arc spraying and HVOF spraying in a technique known as the Sonarc process. This process allows many feed combinations through the simultaneous use of wire and powder. This paper presents the development of a prototype. Examples of composite materials, (Al/SiC, Ni-20Cr/Al sub 2 O sub 3) and structures, their properties, and potential applications are given.

H.-D. Steffens, K. Nassenstein, S. Keller, and G. Barbezat, Cited *J. Therm. Spray Technol. 3*(4), Dec 1994, p 398-403 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0443

HVOF Blocked Nozzles

Blockading Phenomenon of Sprayed Materials on the Internal Surface of Jet Kote Gun Nozzle. In the Jet Kote system that is one of typical high velocity oxygen fuel (HVOF) thermal spraying systems, it has been an unsolved problem that a part of sprayed powders deposit on the internal surface of the Jet Kote gun nozzle. It causes to block up the gun nozzle and consequently to interrupt the operation of the Jet Kote system. Effects of vartiations in the Jet Kote spraying conditions, such as melting point of sprayed powders, powder size and internal surface roughness of the gun nozzle upon the deposition of sprayed powders were examined. Sprayed powders used are Sn-7.5 mass% Sb-3.5 mass% Cu, aluminum, Cu-10 mass% Al, NiCrAlY, WC-12 mass% Co, Al sub 2 O sub 3 , and molybdenum. The substrate is SUS304. States of the deposits are influenced by melting point of sprayed powders. The deposition tends to occur on the internal surface near tip region at the nozzle. The blockading occurred in the Jet Kote spraying of NiCrAlY can be controlled by finishing the internal surface of the gun nozzle smoother and by selecting powder size more appropriately (phi 40-40 mu m). Including the behavior and the properties of powders in the nozzle, the causes for blockading phenomenon of sprayed powders on the internal surface of Jet Kote gun nozzle are complicated.

K. Sakaki, Y. Shimizu, K. Yaejima, and N. Saitoh, Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spraying Soc.) 31*(3), 1994, p 29-36 [in Japanese]. ISSN: 0916-6076. PHOTOCOPY ORDER NUMBER: 199505-57-0529.

RF Thermal Spray

Fundamental Study on Reaction Plasma Spraying by Means of Radio Frequency Thermal Plasma. The RF thermal plasma nitriding process of a titanium alloy was fundamentally investigated. Based on the results obtained in the nitriding process, reaction plasma spraying was carried out to fabricate the nitride coating on SUS304 substrate The results obtained are summarized as follows· (1) As a result of RF thermal plasma nitriding of the Ti alloy, the titanium nitride surface layer, followed by the titanium nitride, Ti

sub 2 N and Ti mixed layers in the order of depth direction, was observed on the surface region of the alloy substrate. (2) A linear relationship was recognized in the relation between the thickness of the nitride layer and the square root of treatment time. Therefore, the thermal plasma process seemed to be a diffusion dominating process From the comparison of the nitride layer thickness under the same conditions of substrate temperature, the effect of hydrogen addition on nitrogen was investigated. (3) The diffusion rate of N in the Ti alloy substrate: Rd was estimated from the experimental results obtained, and the plasma spraying of Ti powder was conducted under the deposition rate of less than Rd. Consequently, the possibility of the reaction plasma spraying was found.

M. Fukumoto, S. Itoh, and I. Okane, Cited: *J. Jpn. Inst. Met. 58*(11), p 1337-1342 [in Japanese]. ISSN: 0021-4876. PHOTOCOPY ORDER NUMBER: 199503-57-0366.

Single Wire Vacuum Arc

Recent Developments in Single-Wire Vacuum Arc Spraying. Reactive materials such as titanium and tantalum are not suitable for the manufacture of pure and corrosion-resistant layers by atmospheric spraying processes, and thus are normally processed by vacuum plasma spraying. However, because of the large specific area of the feedstock, large amounts of previously adsorbed oxygen and nitrogen are included in the coating, often resulting in unsatisfactory corrosion behavior. This can be avoided by vacuum arc spraying using a single wire. The spraying material is a cathodic poled wire that is led without contact through a nonconsumable, water-cooled nozzle. The wire is melted by a high-frequency arc that burns between the wire and the nozzle. The process gas (argon) atomizes the wire and accelerates the particles onto the component being coated. The process parameters strongly influence the stability of the process and the resulting microstructure of the deposit. H.-D. Steffens and K Nassenstein, Cited: *J. Therm. Spray Technol. 3*(4), Dec 1994, p 412-417 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0444.

Processing

Intermetallic Compounds

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 techique of arc-spraying followed by IR laser fusion in an argon atmosphere. A Ti coating free of oxides was deposited onto a low alloy steel (SCM-440) by d.c. arc spraying in Ar. Optimal laser irradiation conditions and the amount of preplaced aluminum powder on the sprayed Ti were determined to obtain a composite coating of TiAl sub 3 +Al of 150 mu m thickness. Metallurgical and mechanical properties were examined using acoustic emission. The oxidation resistance of the coating was excellent up to 1173K because of a protective alumina layer. Growth of the TiAl sub 3 interlayer by diffusion of Al into Ti 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, the oxidation performance decreased by diffusion of iron into the coating

Y. Longa, M. Shinya, and M. Takemoto, Cited *Mater. Manuf. Process. 9*(3), 1994, p 493-506 [in English]. ISSN: 1042-6914. PHOTOCOPY ORDER NUMBER 199505-58-0534.

Properties

Corrosion Behavior

Corrosion Behavior of Laser Consolidated Chromium and Molybdenum Plasma Spraying Coatings on Fe-28Mn-7Al-1C Alloy. Fe-Mn-Al-C alloys are possible substitutes for stainless steel due to their high strength to weight ratio, excellent cryogenic properties and good oxidation resistance. However, they exhibit poor corrosion resistance in aqueous environment owing to the absence of Cr. Plasma spraying offers protective coatings to these alloys. Porosity and cracking deficiencies can be overcome by laser remelting and solidifying the coating. Alloy coupons were coated with Mo and Cr and remelted. Laser processed layer is found to exhibit dendritic morphology for Mo. EDS analysis of dendrites showed the Mo shows a lower tendency to segregate. Potentio-dynamic curves revealed that the laser modified Mo coating passivates with difficulty in sulfuric acid solution. Chromium coating, however, shows an improvement in attaining passivity.

S C Rjong, J.S. Ku, and C.S. Wu, Cited: *Scr. Metall. Mater. 31*(7), Oct 1994, p 835-839 [in English]. ISSN: 0956-716X PHOTOCOPY ORDER NUMBER: 199501-58-0098.

Residual Stress

Corrosion Resistance and Strength Characteristics of Hot Gas Sprayed Coatings Saturated with Low-Temperature Alloys. Development of a tinning alloy for saturating metallized and other hot gas sprayed coatings is described. The alloy is lead based on contains antimony, lithium, bismuth, tin, and molybdenum powder. Tests in the field indicated that metallized welded joints used in equipment for heating liquid phosphorus lasted over one year without effect while uncoated joints in the same environment failed in less than three months. The alloy has also been tested as a method of repairing casting defects such as porosity of erosion damage in large castings.

A.M. Sedenkov, A.V. Granovskii, V.M. Dotsenko, V.A. Gorbachev, Cited: *Sov. Mater. Sci. 26*(3), 1990, p 351-353 [in English]. ISSN: 0038-5565. PHOTOCOPY ORDER NUMBER: 199501-58-0077.

Residual Stresses in Plasma-Sprayed Ceramic Coatings. Residual stresses are of decisive importance in plasma-sprayed coatings. The state of residual stresses of the coating varies in dependence on the various spraying parameters. In addition to other examination methods, the x-ray method is mainly used for the measurement of stresses. Another important criterion for the evaluation of sprayed coatings is the Young's modulus, which comes with sprayed coatings to approx10% of that of solid ceramics. Substrates were St37-2 and X8CrNiTi 18.10. Coatings were Al sub 2 O sub 3 on a Ni-5% Al undercoating.

H.-D. Tietz, B. Mack, and S. Bohm, Cited: Proceedings of the Fourth International Conference on Residual Stresses, Baltimore, MD, USA, 8-10 June 1994, Society for Experimental Mechanics, Inc., 1994, p 654-661 [in English]. PHOTOCOPY ORDER NUMBER: 199501-57-0001.

Measurement of Residual Stress in Plasma Spray Coating Layers. The present paper describes thermal and residual stresses in laminated layers deposited by thermal spraying on a low carbon steel (SS41) substrate Laminated layers were made of Al sub 2 O sub 3 /NiAl with various combinations of mixing ratios. X-ray diffraction was used to measure residual stress in the outermost surface layer. The effect of annealing and grinding on the residual stress state was investigated. In situ thermal stress measurement was performed by using a vacuum furnace mounted on the diffractometers. The results of FEM analysis were compared with the x-ray experimental results.

M. Nishida, T. Hanabusa, and H. Fujiwara, Cited: Conference: Proceedings of the Fourth International Conference on Residual Stresses, Baltimore, MD, USA, 8-10 June 1994, Society for Experimental Mechanics, Inc., 1994, p 767-776 [in English]. PHOTOCOPY ORDER NUMBER: 199501-31-0029.

Review

Thermal Spray Coatings. Thermal spray is a generic term for a group of processes in

which metallic, ceramic, cermet and some polymeric materials in the form of powder, wire or rod are fed to a torch or gun, heated to near or above their melting point, accelerated in a gas stream and impacted against the surface of the part to be coated. Types of such processes include flame spraying, wire-arc spraying, plasma spraying, high-velocity oxyfuel and detonation gun spraying. Surface preparation prior to thermal spraying includes cleaning and degreasing and surface roughening. Finishing treatment involves sealing, coating finishing and coating repairing. Quality assurance of thermally-sprayed coatings is effected by metallography, hardness testing and bond strength testing. Health, safety and environmental concerns and coating structures and properties are described. Thermally-sprayed coatings are used to improve wear resistance, provide friction control, improve corrosion resistance and restore dimensions.

R.C. Tucker, Jr., Cited: *ASM Handbook, Vol. 5: Surface Engineering*, ASM International, Materials Park, Ohio, 1994, p 497-509 [in English]. PHOTOCOPY ORDER NUMBER: 199502-57-0196.

Impact and Solidification

Review of Impact and Solidification of Molten Thermal Spray Droplets. The unique properties of coatings created by thermal spray deposition depend on the rapid solidification of individual splats created by impinging molten droplets. However, the impact process has been little studied because of the difficulty of measuring or numerically simulating the process, which occurs very quickly over a small area. Other scientific fields have investigated the impact of liquid droplets on solid surfaces. This paper reviews these studies, along with those conducted specifically on the thermal spray process. Modelers have almost universally ignored droplet solidification during impact; however, some experimental evidence suggests that the solidification process plays a significant role in splat formation. Splashing of impacting liquid droplets, another topic that has been largely ignored, affects deposition efficiency, porosity, and bond strength, and may also affect the amount of oxides incorporated in the coating. The scaling of data from impacting millimeter-size droplets travelling at low velocities to thermal spray conditions is questioned.

R.C. Dykhuizen, Cited: *J. Therm. Spray Technol. 3*(4), Dec 1994, p 351-361 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199504-58-0440.

Wear properties

The Effect of Cerium Dioxide on the Friction and Wear Properties of Flame Spraying Nickel-Based Alloy Coating. Flame spraying nickel-based alloy coatings containing CeO sub 2 or without it were prepared. A Shimazu-M model microhardness tester and a D-Max/RB model x-ray diffractomer (all made in Japan) were performed to determine the microhardness and phase structure of the coatings respectively. A block-on-ring friction and wear tester (similar to Timken tester, made in China) was used to examine the friction and wear properties of the coatings. Then the friction and wear properties of the coatings were correlated to their microhardness, phase structure, and compositions and characteristics of the surface film, etc. on the basis of observing and determining the morphologies and elemental distributions in the worn surfaces with an electron probe micro-analyzer and an x-ray photo electron spectroscope respectively. It was found that the addition of CeO sub 2 can increase the microhardness of the coating, and the optimal adding amount of CeO sub 2 is between 4 and 6 wt %. Moreover, CeO sub 2 had little effect on the frictional coefficient but caused higher wear of the frictional counterface. Meanwhile the CeO sub 2 contained in the coating can enhance the formation of oxide film in the worn surface and abate the adhesion action during friction process. Since the CeO sub 2 particles are quite harder than the base nickel metal, so adhesion and abrasion dominated for CeO sub 2 -containing coating, while adhesion dominated for the coating without CeO sub 2 .

Y. Lian, L. Yu, and Q. Xue, Cited. *Wear* 181-183(I), Feb 1995, p 436-441 [in English]. ISSN: 0043-1648. PHOTOCOPY ORDER NUMBER: 199505-31-1329.

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