Selected Abstracts of Thermal Spray Literature

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Analysis

SIMS

An Investigation of a CoNiCrAlY Overlay Coating and Its Oxidation Behavior by Means of Imaging SIMS. A CoNiCrAlY overlay coating and its oxidation behavior have been studied by means of imaging SIMS. Maps of the coating and scale showed a highly uneven yttrium distribution which arose at least partly during the deposition of the coating. The implications of this for the resistance of the coating to oxidation and hot corrosion are discussed. There was no evidence of Y build-up at the scale/metal interface. The Y maps show the power of imaging SIMS for studying the distribution of elements which are present in very low concentrations. A preliminary experiment using $^{18}O^-$ as a tracer showed that the scale grew primarily at the scale/metal interface.

D.G. Lees and D. Johnson. Cited: *Oxidation of Metals, 38,* (3-4), Oct. 1992, 217-231 [in English]. ISSN: 0030-770X. PHOTOCOPY ORDER NUMBER: 199303-58-0308.

Application

Coatings on SiC Tubes

Ceramic Oxide-Coated Silicon Carbide for High Temperature Corrosive Environments. The evaluation of ceramic oxide coated silicon carbide tubes following corrosive exposure testing in simulated Al reclamation environment is discussed. The application of this coating technology to silicon carbide matrix containing composite materials was also evaluated following corrosive exposure. The overall results indicate that the ceramic oxide coatings, particularly mullite based coating compositions, were protective of the silicon carbide materials.

J.R. Price, M. van Roode, and C. Stala. Cited: *Key Engineering Materials,* Proc. Conf. Materials for Advanced Technology Applications, 4-6 Sept. 1991, 1992, 71-83 [in English]. ISSN: 0252-1059. PHOTOCOPY ORDER NUMBER: 199303-C5-C-0033.

Corrosion

Corrosion Protection From Homogeneous Lead Coating by Thermal Plasma. Homogeneous Pb coating by the thermal plasma method as an anti-corrosion measure in chemical plant and containers is discussed. The technique of plasma surfacing and the properties and resistance of these plasma Pb coatings are described and discussed. Process optimization and arc control by accurate and reproducible heat control permit homogeneous plasma Pb coatings with high corrosion protection. Quality control is improved, operating personnel are at less risk from Pb fumes, and productivity is increased. St52-3 and 18-8CrNi are coated.

U. Draugelates, B. Bouaifi, F. Schreiber. Cited: Original Title: [Korrosionsschutz Durch Homogenes Schmelzverbleien mit dem Thermischen Plasma], ***Schweisstechnik (Vienna), 46,*** (9), 1992, 142-144 [in German]. PHOTOCOPY ORDER NUMBER: 199303-58-0329.

Corrosion Resistance

Factors Affecting Adhesion on Concrete of Arc-Sprayed Zinc. Arc-sprayed Zn coatings are frequently used as anode for the cathodic protection of reinforced concrete structures. However, as with any other conductive coating, Zn should be applied with the highest possible adhesion in order to serve as a durable anode. Factors affecting the adhesion of Zn on concrete are discussed. Preheating the concrete surface prior to Zn application has been found to be particularly beneficial. The measured adhesion values have also been found to vary significantly with the pull out procedure.

R. Brousseau, M. Arnott, S. Dallaire, and R. Feldman. Cited: *Corrosion, 48,* (11), Nov 1992, 947-952 [in English]. ISSN: 0010-9312. PHOTOCOPY ORDER NUMBER: 199302-35-0375.

Diesel Engines

Diesel Coatings for Reducing Emissions and Boosting Performance. Based on technology borrowed from the aerospace industry, ceramic thermal barrier coatings (TBCs) such as zirconium oxide, are cost-effectively reducing emissions from diesel engines in power generation, marine, and other applications. TBCs help to boost engine performance and eliminate many of the problems associated with low-cetane fuels. Diesel engine TBCs are plasma-sprayed ceramics that insulate combustion system components—such as pistons, valves, and cylinder head fire decks—from heat and thermal shock. The TBCs protect metal components against high-temperature corrosion, reduce component temperatures and thermal-fatigue effects, and help convert more heat into useful energy. In three large stationary diesel engine plants in the US, in which engine combustion chamber components were thermal sprayed with diesel TBCs, the plants reported that NO_x, carbon monoxide, and particulates were reduced, and that there were significant improvements in fuel consumption and engine component wear. Similar results have been demonstrated in marine applications, including a ferry with twin Caterpillar D-3516 diesel engines, in which TBCs were applied to piston crowns, cylinder-head fire decks, and valve faces of the engines. The use of TBCs has been explored actively by major engine builders.

M.F. Winkler and D.W. Parker. Cited: *Worldwide, 24,* (6), July-Aug 1992, S8, S10, S12 [in English]. ISSN: 0278-5994. PHOTOCOPY ORDER NUMBER: 199302-61-0251.

High Temperature

Material Problems in High Temperature Corrosive Environments and Their Solution by Surface Technologies. The review of heat resisting steels and alloys for chemical plants covers forms of material corrosion, such as high temperature oxidation, sulfurization, carburization and metal dusting, nitriding, carbonyl-, hydrogen-, and halogenation-attack, naphthenic acid corrosion, fuel ash corrosion, vanadium attack, sulfidation, and molten salt attack; high temperature equipment including fuel oil firing furnaces, steam reformers, ethylene cracking furnaces, and waste heat boilers, etc. and their corrosion types; and the material technology for corrosion protection, for instance, aluminizing, thermal spray coating, PVD, and CVD.

T. Anzai and K. Shibata. Cited: *Materials Performance, 31,* (7), July 1992, 706-713 [in English]. ISSN: 0094-1492. PHOTOCOPY ORDER NUMBER: 199302-35-0293.

Sink Rolls

Durability of WC/Co Sprayed Coatings in Molten Pure Zinc. To develop protective coatings for sink rolls used in a continuous hot-dip galvanizing, sprayed cermet coatings were formed on a mild steel (SS400) by high velocity flame spraying system using two commercially produced WC-12 mass% Co powders, and their durability in molten pure Zn (703-783K) has been studied by SEM, XRD, EDX and hardness tester. It was found that the durability of WC/Co sprayed coatings in molten pure Zn depended on the binding phases, which varied according to the powder-preparation process. The binding phase in WC/Co sprayed coatings made of powders prepared by a spray-dried process (SD-coating) mainly consisted of β-Co phase, but that prepared by a sintered and crushed process (SC-coating) mainly consisted of η-phase (Co_3W_3C and Co_6W_6C). In the case of SD-coating, the binding phase, β-Co, dissolved into molten pure Zn so that the thickness has decreased in a short time. Although in the case of SC-coating, a Zn-rich and cobalt-poor layer was built up under the surface and the hardness dropped to HV 500-1000 just below the surface, no changes of the thickness and microstructures have been observed for a long time. The apparent activation energy for the growth of Zn-invaded layer in SC-coating was 170 kJ/mol, which was nearly equal to that for dissolution ofβ-Co. It was suggested that a small amount of β-Co was also contained in SC-coating and such an excellent durability must have been obtained due to the different distribution manner of β-Co.

T. Tomita, Y. Takatani, Y. Kobayashi, Y. Harada, and H. Nakahira. Cited: *Tetsu-to-Hagane* (Journal of the Iron and Steel Institute of Japan), *78,* (4), Apr 1992, 608-615 [in Japanese]. ISSN: 0021-1575. PHOTOCOPY ORDER NUMBER: 199302-58-0150.

Superconducting Coatings

Possibility of Manufacturing Superconductive Film by Laser Treatment of Plasma Sprayed Oxide Ceramic Layer. The preparation of superconductive film through a laser treatment of a plasma sprayed oxide ceramic layer was studied. As the first step, an experiment was carried out to recover the superconductive crystal structure which was damaged during the plasma spraying operation. A superconductive ceramic powder of a Y-Ba-Cu-O system was first plasma sprayed onto a stainless steel substrate. A CO_2 laser beam was then irradiated onto the sprayed surface film together with the oxygen gas flow. Results showed that an appropriate combination of laser parameters produces a sprayed film having the superconductive crystal structure.

H. Miyazawa, K. Hotta, S. Watanabe, S. Miyake, H. Hirose, and M. Murakawa. Cited: *Advances in Superconductivity III* (ISS '90), Sendai, Japan, 6-9 Nov. 1990, 691-694 [in English]. PHOTOCOPY ORDER NUMBER: 199301-F2-C-0213.

Propagation of AC Magnetic Field Through High-T_c Coatings. Studies on the propagation of ac magnetic field through plasma-sprayed superconducting $Y_1Ba_2Cu_3O_{7-x}$ coatings show that complete shielding is achieved up to a certain critical magnetic field strength H^0 . Increase in the thickness or Jc of the specimen increases the H_0 value. Flux-trapping occurs in the specimen at high frequencies and the frequency at which it occurs increases with increase in specimen J_c.

J. Karthikeyan, A.S. Paithankar, P. Chaddah, N. Venkatramani, K.P. Kreekumar, and V.K. Rohatgi. Cited: *Bulletin of Materials Science (India), 14,* (4), 1991, 1141-1144 [in English]. ISSN: 0250-6327. PHOTOCOPY ORDER NUMBER: 199212-F2-C-2104.

Thermal Barrier Coating

Effect of Pre-Aluminization on the Properties of ZrO_2-8 wt.% Y_2O_3/Co-29Cr-6Al-1Y Thermal-Barrier Coatings. Specimens of investment-cast MAR-M247 superalloy were vacuum-plasma sprayed with Co-29Cr-6Al-1Y bond coat, and part of the specimens were further pre-aluminized at 980°C for 2, 4, 6, 8, and 10 h. All the specimens were then deposited with ZrO_2-8 wt.% Y_2O_3 thermal-barrier coatings (TBCs) and thermally cycled at 1050 °C to evaluate the effect of time of the pre-aluminizing treatment on the performance and failure mechanism of the modified system. Results showed that TBC specimens with pre-aluminized bond coatings exhibited lower oxidation rates and significantly higher cyclic life when compared with unaluminized specimens. The failure of bond-coat pre-aluminized TBC specimens was observed to propagate mainly along the lamellar splats of the top coat, whereas the failure of conventional TBC specimens occurred mainly along the top-coat/spinel oxides interface.

W. Lih, E. Chang, C.H. Chao, M.L. Tsai. Cited: *Oxidation of Metals, 38,* (1-2), Aug. 1992, 99-124 [in English]. ISSN: 0030-770X. PHOTOCOPY ORDER NUMBER: 199301-58-0049.

Composites

Carbon Fiber Reinforced Aluminum

Fabrication and Properties of Plasma Sprayed Carbon Fiber Reinforced Composites. A study was done on manufacturing methods and properties of plasma sprayed carbon-fiber reinforced Al-matrix composites. Rovings with 12,000 C-fiber filaments, each with an average diameter of 6.7 μm and average tensile strength of 3000 MPa, were wound on a mandrel and vacuum plasma sprayed with a mixture of AlSi12 and Al99.5 powders. With good C-fiber distribution, the plasma sprayed composite band had a longitudinal tensile strength of 184 MPa. Under optimal plasma spray and fiber distribution conditions, the composite material had excellent ductility, and the fracture surface showed good matrix-fiber adhesion. Hot pressed structures made from the plasma sprayed band can attain tensile strengths as high as 200 MPa.

K. Hoffmann, L. Hausdorf, H. Podlesak. Cited: Original Title: [Herstellung und Eigneschaften Plasmagespritzter C-Faserverbundwerkstoffe.] *Metall, 46,* (5), May 1992, 440-442 [in German]. ISSN: 0026-0746. PHOTOCOPY ORDER NUMBER: 199301-62-0101.

Powders

Fabrication of Sprayed Composite Coating and Evaluation of Its Thermal Property. Current studies relating to both fabrication processes of plasma sprayed composite coatings and evaluation of some thermal properties of these coatings were reviewed. The reports about the application of mechanically alloyed composite powders to plasma spraying for the fabrication of composite coatings were mainly introduced. Synopses of some researches on both definition of the fracture conditions of thermal shock testing and determination of the evaluation parameters of coating microstructure were also given.

M. Fukumoto and M. Umemoto. Cited: *Zairyo-to-Kankyo* (Corrosion Engineering), *41,* (8), Aug. 1992, 570-577 [in Japanese]. ISSN: 0917-0480. PHOTOCOPY ORDER NUMBER: 199303-57-0308.

Stainless Steel/Aluminum

Fabrication of Secondarily Formable Long Fiber Reinforced Metals. Fabrication method of the long stainless steel fiber reinforced Al composite which has fiber/matrix interface layers to enable its secondary forming has been improved. By replacing the Zn insert foil to form the interface layers and adhere matrix plates with arc-spraying of Zn onto matrix plates, formation of uniform interface layers became possible. The interface layers obtained abruptly softened at the temperature just beyond the melting point of Zn and were even strengthened by heat treatment. Adhesion strength of matrix Al plates became twice larger and multi-layer composite of higher volume fraction came to be easily fabricated. The multi-layer composite could be successfully bent without fiber breakages and bucklings at the softening temperature of the interface layers.

H. Asanuma, M. Hirohashi, T. Kikuchi, and H. Kitagawa. Cited: Conference: How Concept Becomes Reality, Vol. 36. II, San Diego, California, USA, 15-18 Apr. 1991, 2055-2066 [in English]. PHOTOCOPY ORDER NUMBER: 199303-62-0430.

Material Properties

Thermal Expansion

Thermal and Elastic Anisotropy of Thermally Sprayed Coating. The dependency of the physical property of thermally sprayed coatings on the microstructure which is characterized by a composite of lamellae was examined. The thermal and elastic properties determined parallel to the coating plane have been proven to be different from those determined perpendicularly to it, which indicates that the thermally sprayed coatings have an anisotropy. The thermal conductivities of Cu, Mo, Type 316 austenitic stainless steel, alumina and WC-20 mass% Cr-7 mass% Ni cermet coatings are discussed. The values parallel to the coating plane were 1-2.27 times larger than those perpendicular to it. The behavior of anisotropy can be explained by the rule of mixture. Young's moduli in the two directions of WC-12 mass% Co cermet coatings were measured and the value parallel to the coating plane was about twice as large as that perpendicular to it. The thermally sprayed coatings may be characterized by a composite of rapidly solidified lamellae between which there is only limited real contact and they also contain pores and oxides. It is clear that the directionality characteristic of the thermal barrier behavior or the less cohesion among the lamellae is dominant over the anisotropy of thermally sprayed coatings.

K. Tani, H. Nakahira, K. Miyajima, and Y. Harada. Cited: *Materials Transactions, JIM 33,* (6), June 1992, 618-626 [in English]. ISSN: 0916-1821. PHOTOCOPY ORDER NUMBER: 199301-62-0065.

Mechanical Properties

Adhesion

A Study of the Adherence and Cracking by Deformation in a Multilayer Metallic Coating of Plain Carbon Steels. The effect of number of layers, in a multilayer metallic coating by plasma deposition in a plain carbon steel, on the adherence and cracking by deformation is discussed. The coating consists of one to three different layers; the first one is a high Ni content alloy 95Ni-Al-Mn, and the two others are ferrous alloys with 11Cr-6Ni and 16Cr-5Ni, respectively. This investigation was carried out performing bending tests and analyzing the lateral and frontal surfaces of deformed samples by SEM techniques. Microhardness tests were also performed to study the hardness evolution across the depth of layers and base material. Interdiffusion phenomena were analyzed by microanalysis EDS. The work established conclusions on the influence of coating composition and stiffness on cracking susceptibility by deformation, and its relationship with loss of bonding among layers and steel. The analysis done pointed out some of the variables with a higher effect on this relationship as roughness treatment and high temperatures obtained at plasma deposition.

L. Sanchez, F. Gutierrez-Solana, J.J. Gonzalez, and J.A. Alvarez. Cited: *Materials Science Forum, 102-104,* (2), 1992, 689-697 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199301-58-0107.

Shear Strength

Shear Strength of Brazed Joints in Austenitic Steel Fabricated With the Modified Nickel-Based Brazing Alloys Developed at WRI. Until recently, K40- and K50-type powders for gas- and plasma-arc surfacing were manufactured by air spraying at the Welding Research Institute, (WRI) of Bratislava, Czechoslovakia. Now, a new technique at WRI is producing Ni-based powders by spraying in a nitrogen-based shielding atmosphere. The latest results of experiments carried out at WRI on brazeability in vacuum on these high temperature Ni-based brazing alloys are described. The shear strength of a brazed joint in 17246 austenitic steel under static load at ambient temperature and high temperature was used as the criterion. Two types of joints were selected: a stepped joint using rolled bars, in which the effect of joint clearance width and brazing alloy in temperatures up to 700 °C was studied; and overlapped joints having two sizes of overlap. These were tested at 20 and +700 °C. For high temperatures, the creep shear strength of stepped joints was studied using a brazing alloy without boron content, a Ni-Cr-Si type. The effect of clearance width was also studied. Static shear strength tests proved that joint strength depends on temperature: at 500 °C fracture occurred in the brazing alloy, but above this it occurred in the base metal. At 700 °C, clearance width had no effect on shear strength. At the higher temperatures, the brazed joint strength depended on the testing temperature and the Cr + Si content of the brazing alloy.

V. Ruza. Cited: *Zvaracske Spravy* (Welding News) *41*, (4), 1991, 90-96. ISSN: 0322-9785. PHOTOCOPY ORDER NUMBER: 199302-55-0330.

Modeling

Impact Phenomenon

Simulation of the Collision Processes of Particles With Surfaces Under Gasothermal Coating Deposition. The phenomena of impact and static pressure correlation with the rate of particle surface collisions was considered. Three types of characteristic contact zones were revealed. They are distinguished by pressure level, duration, and particle flow mechanisms. A nondimensional criteria complex for describing collision processes is proposed.

Yu. A. Kharlamov, *Fizika i Khimiya Obrabotki Materialov*, (4), July-Aug. 1990, 84-89 [in Russian]. ISSN: 0015-3214. PHOTOCOPY ORDER NUMBER: 199302-58-0125.

Residual Stresses

The Residual Stress Analysis of Plasma Sprayed ZrO_2-8 wt.% Y_2O_3 Coating. As the residual stress in the ZrO_2 coating affects adhesion strength, toughness and strength of the plasma sprayed coated layer, it is important to predict the variation in residual stress distribution. The residual stresses and distortions are important parameters to determine optimum spraying condition. A stress model is proposed to predict the trend for residual stress developed in the plasma spray coating. Residual stresses based on this model are computed by finite element method. Results of the analysis of the plasma sprayed ZrO_2 coating by finite element analysis were compared with XRD experimental observations in PSZ coated layer. Residual stresses (radial, circumferential and axial stresses) which remain compressive mainly decrease with coating depth and turn into tensile state near the substrate (e.g. iron)/coating interface. In the direction of axes, relatively large shear stress develops in the ZrO_2 coating.

J.-D. Lee, H.-Y. Ra, K.T. Hong, and S.-K. Hur. Cited: *Journal of the Korean Institute of Metals and Materials, 30*, (6), 1992, 621-629 [in Korean]. PHOTOCOPY ORDER NUMBER: 199303-57-0311.

Spray Processes

Modeling of Formation of Deposited Layer by Plasma Spray Process. An analytical model is developed to describe the plasma deposition process in which average solidified thickness and coating and substrate temperatures are obtained. During deposition process, solidification rate is periodically varied due to the impingement of liquid splats, and the amount of liquid in the coating layer increases. Periodical variation of the solidification rate causes temperature fluctuation in coating and substrate. The nature of interfacial structure of plasma-sprayed NiCrBSi MA powder is compared with the result predicted using this model, which indicates that the liquid, which is residue at the coating surface during deposition, causes discontinuous boundaries within the coating. Spraying rate and solidification rate are reversed periodically with spraying process.

J.-D. Lee, H.-Y. Ra, K.T. Hong, and S.K. Hur, *Journal of the Korean Institute of Metals and Materials 30*, (3), Mar. 1992, 270-27 [in Korean]. PHOTOCOPY ORDER NUMBER: 199302-58-0139.

Patent

Composites

Arc Sprayed Continuously Reinforced Aluminum Base Composites. A metal matrix composite is produced by forming a rapidly solidified Al-base alloy into wire. The wire is arc sprayed onto at least one substrate having thereon a fiber reinforcing material to form a plurality of preforms. Each of the preforms has a layer of the alloy deposited thereon, and the fiber reinforcing material is present in an amount ranging from approx 0.1-75 vol.% thereof. The preforms are bonded together to form an engineering shape.

S.K. Das, M.S. Zedalis, and P.S. Gilman, Patent No. US5141145, 1989, USA [in English]. PHOTOCOPY ORDER NUMBER: 199301-62-0058.

Gold Deposition

Method and Layered Structure for Adhering Gold to a Substrate. A layered structure for adhering Au to a substrate and a method of forming such on a substrate are disclosed. An article of jewelry or the like which is formed by the method and which includes the layered structure is also disclosed. The layered structure includes a first layer overlaying the substrate. The first layer includes a member selected from the group consisting of metal nitrides, metal carbides and metal carbonitrides wherein the metal is selected from the group consisting of Ti, Zr and Hf. The layered structure also includes a transparent layer of refractory metal which overlies the first layer and underlies the Au or alloy thereof. Both the first layer and transparent layer are preferably formed or deposited on the substrate by a cathodic arc plasma deposition process. The method also includes forming a top layer of Au or an alloy thereof on the transparent layer. This Au layer is preferably formed or deposited by a magnetron sputtering process. The article of jewelry or the like includes a substrate and a multi-layered coating which can be formed on the substrate by the method.

H.S. Randhawa, European Patent No. EP0462228, 1990, Germany [in English]. PHOTOCOPY ORDER NUMBER: 199303-58-0243.

Ni-Mo Powders

Method for Preparing Powders of Nickel Alloy and Molybdenum for Thermal Spray Coatings. A method for preparing an intimate mixture of powders of Ni-B-Si alloy and Mo metal powder suitable for thermal spray coating comprises: (a) milling a starting mixture of the Ni-B—Si alloy and Mo powder to produce a milled mixture wherein the average particle size is more than ~10 μmm in diameter; (b) forming an aqueous slurry of the resulting milled mixture and a binder selected from the group consisting of an ammoniacal molybdate compound and polyvinyl alcohol; and (c) agglomerating the milled mixture and the binder to produce the intimate mixture.

V. Anand, S. Sampath, C.D. Davis, and D.L. Houck. Cited: European Patent: EP0459693, 1991, Germany [in English]. PHOTOCOPY ORDER NUMBER: 199303-58-0252.

Powders

Aluminum and Boron Nitride Thermal Spray Powder. A composite thermal spray powder is formed substantially as homogeneously agglomerated particles each of which comprises pluralities of subparticles of boron nitride and subparticles of Al or Al alloy, the subparticles being bonded with an organic binder. The powder is used to form abradable coatings for gas turbine engines.

M.R. Dorfman and B.A. Kushner. European Patent: EP0459114, 1991, Germany [in English]. PHOTOCOPY ORDER NUMBER: 199303-58-0251.

Powders

Fe-Al-C Alloys

Technological Applications of Powders of the Self-Decomposing Fe-Al-C Alloy. Possible applications of powders of a self-decomposing Fe-Al-C type alloy are presented, since the production costs for these high-Al containing powders are relatively low compared with other methods. Such procedures as flame and plasma spraying, flux cored surfacing and sintering were examined. In addition, investigations into the wear resistance, scaling resistance and bond strength of both the sprayed deposits made of these powders and the wear resistance of deposit welding were made. These investigations prove that these powders are suitable for making wear-reducing and scale-resistant coatings by plasma and flame spraying as well as by deposit welding. Additional applications in powder metallurgy and foundry are presented.

A. Gierek, F. Binczyk, A. Risse. Cited: Original Title: [Technologische Applikationsmoglichkeiten von Pulver der Selbstzerfallenden Legierung Fe-Al-C], *Neue Hutte, 37*, (2), Feb. 1992, 63-67 [in English]. ISSN: 0028-3207. PHOTOCOPY ORDER NUMBER: 199302-54-0182.

Processes

D-Gun

Comparison of Plasma Sprayed and Detonation Gun Sprayed Alumina-Magnesia and Alumina-Titania Coatings. Al_2O_3 + 30MgO and

Al_2O_3 + 3-40% TiO_2 coatings were deposited by atmospheric plasma spraying (APS) and detonation gun spraying (DGS). The microstructures and microhardness values were studied from the cross-sections of the coatings after metallographic sample preparation. Corrosion behavior of the coatings was evaluated with potentiodynamic measurements and the abrasion wear resistance was tested using the rubber wheel abrasion test. The microstructural analysis revealed that the porosity in the plasma sprayed alumina-magnesia and alumina-titania coatings was higher than in the corresponding detonation gun sprayed coatings. The microhardness values of these plasma sprayed coatings were somewhat lower than those of the detonation gun coatings. Electrochemical corrosion measurements revealed that there is no big difference in the corrosion behavior of the coatings, except that the alumina-magnesia coating was clearly more corrosion resistant than the other coatings studied. Rubber wheel abrasion tests showed that the abrasion wear resistance of the studied detonation gun sprayed coatings was much higher than that of the plasma sprayed coatings.

K. Niemi, P. Vuoristo, A. Makela, P. Sorsa, and T. Mantyla. Cited: Conference: Surface Modification Technologies. V, Birmingham, UK, 2-4 Sept. 1991, The Institute of Materials, 1992, 571-580 [in English]. PHOTOCOPY ORDER NUMBER: 199302-57-0224.

Hypersonic Spraying

Adhesive Properties of Hypersonic Sprayed Coatings of Chromium Carbide and Tungsten Carbide on Steels. Hypersonic spraying is known to achieve more adhesive and denser coatings than usual thermal spraying. Unfortunately, standard tests used to evaluate adhesive bond strength give limited information when adhesion is very high. In recent years, new tests have been developed, one of which, based on linear fracture mechanics concepts, comes from indentation tests used to determine toughness of hard materials. In the special case of deposits, indentation is performed at or near the interface between the coating and the substrate. For two coating thicknesses and three substrates, it is shown that the parameter chosen to represent adhesion increases with the hardness of the substrate for the two carbides tested. Resistance to decohesion or to fracture of the coating is also studied by means of flexion tests. The results are in good agreement with those obtained by indentation.

J. Lesage and G. Mesmacque. Cited: Conference: Surface Modification Technologies. V, Birmingham, UK, 2-4 Sept. 1991, The Institute of Materials, 1992, 861-864 [in English]. PHOTOCOPY ORDER NUMBER: 199302-57-0170.

LPPS

Advanced Low Pressure Plasma Application in Powder Metallurgy. The low pressure plasma spray process (LPPS) was first introduced to the turbine industry some 15 years ago. Since then, it has evolved into a fully automated production process, and modern gas turbines would not be as far advanced without the low cost LPPS process. Spraying of composite materials, either as powder blends, agglomerates, or alloys with the LPPS process, has become a standard practice. New developments involve spraying up to eight different single element powders simultaneously with a single plasma gun. This feature opens up new possibilities in the composite materials field. New developments are showing that the LPPS process can also be used to produce free-standing structures and shapes of relatively simple geometries. Due to the advanced LPPS processing, structures can be produced using large (>100 μm) powder particles and material densities of 98% can be achieved without post treatments such as hot pressing or HIPing. Advanced LPPS processing is a closely controlled production process; allowing high quality materials with high deposition rates and good reproducibility to be obtained. New methods and advantages of the LPPS process are discussed. New "state-of-the-art" production equipment, fully computerized for complete process control, is shown. Examples are given with Ni superalloy, Ti, and metal matrix composite coatings on Ni superalloys and stainless steels.

A. Sickinger and E. Muehlberger. Cited: *Powder Metallurgy International, 24,* (2), Apr. 1992, 91-94 [in English]. ISSN: 0048-5012. PHOTOCOPY ORDER NUMBER: 199302-58-0152.

RF Spraying

Induction Plasma Spraying of Ceramics. A study is carried out on the influence of in-flight particle parameters on their splatting properties during the induction plasma deposition of ceramics. Results are presented for alumina powders with mean particle diameters of 21 and 82 μmm under soft vacuum conditions. The chamber pressure was varied between 46.6-66.6 kPa (350-500 torr). Measurements are carried out on the particle surface temperature and velocity prior to impact on stainless steel substrates. The form of the splat obtained is evaluated using SEM. The results are used for the parametric optimization of the induction plasma spraying process. Thick alumina coatings with total porosities as low as 2% were obtained.

X.B. Fan, F. Gitzhofer, M. Boulos, and P. Gougeon. Cited: Conference: Advanced Materials: Meeting the Economic Challenge, Toronto, Canada, 20-22 Oct. 1992, Society for the Advancement of Material and Process Engineering, 1992, T56-T69 [in English]. PHOTOCOPY ORDER NUMBER: 199303-57-0398.

Super D-Gun

Super D-Gun and D-Gun Coatings as Alternatives to Electroplated Chromium. There is a growing requirement to find alternatives to electroplated Cr for environmental and other reasons. Thermal spray coatings may satisfy this requirement, particularly in those applications where Cr is used primarily for wear resistance. Of the thermal spray coatings, detonation gun (D-Gun) coatings have been the standard of the industry for 30 years because of their excellent wear resistance, bond strength, corrosion resistance, and mechanical properties. Recently, a new generation of coatings, Super D-Gun coatings, has been developed with properties superior even to D-Gun coatings. These processes and the resultant microstructures of selected tungsten carbide-cobalt, tungsten carbide cobalt-chromium, and chromium carbide coatings are described. Mechanical and wear properties, including bond strength, adhesion, and abrasion properties, are also described. Where possible, direct comparisons between Super D-Gun, D-Gun, and electroplated Cr coatings are made. Substrates considered in the discussion include 4340 steel.

M.M. Antony and R.C. Tucker, Jr. Cited: Conference: Environment in the 1990s—a Global Concern, San Diego, California, USA, 21-23 May 1991, Society for the Advancement of Material and Process Engineering, 1991, 239-247 [in English]. PHOTOCOPY ORDER NUMBER: 199303-57-0358.

Twin Anode Torch

Thermal Stability of NiCrAlY/PSZ FGM by Plasma Twin Torches Method. Fundamental researches were carried out to improve thermal stability of NiCrAlY/PSZ FGM in uniform and gradient temperature fields. NiCrAlY/PSZ NFGMs, NiCrAlY/PSZ FGMs and NiCr/PSZ FGMs were prepared on SUS310S substrates by plasma twin torches method under atmospheric or low pressure. Designed compositional gradient of FGMs could be sprayed. Porosity in NiCrAlY/PSZ FGMs was increased with volume fraction of PSZ. When the FGMs were heat treated in a uniform temperature field of 1473K, PSZ part was sintered and vertical cracks were formed by shrinkage. At the same time, metal which contained a number of Fe atoms went into the cracks, and climbed up to the surface. The Fe atoms migrated from the substrate through NiCrAlY part. Therefore, it is most important to decrease porosity in PSZ area and to control the distribution of pores to restrain crack formation. Coating metal with the same composition as the substrate is desirable for the thermally stable FGM. When the FGM was heat treated in a gradient temperature field of 1473-873K, there was little change in the FGM structure. The FGM showed a high potential for protective coatings of turbine blades.

Y. Shinohara, Y. Imai, S. Ikeno, I. Shiota, and T. Fukushima. Cited: *ISIJ International, 32,* (8), Aug. 1992, 893-901 [in English]. ISSN: 0915-1559. PHOTOCOPY ORDER NUMBER: 199301-57-0065.

Processing

Substrate Effects

Effect of Plasmochemical Spraying on the Structure and Properties of Tool Steels With Reduced Heat Resistance. The effect of different regimes of plasmochemical deposition of a hardening coating and the preliminary volume heat-treatment on the structure and stress state of steel 40Kh type is considered. It is shown that plasmochemical treatment with this deposition regime gives no phase transformation in the steel but considerably influences the level of stress and thin structure characteristics.

V.B. Trigub, A.I. Orlova, I.V. Likholet, and V.M. Rubinshtein. Cited: *Fizika i Khimiya Obrabotki Materialov* (4), July-Aug. 1991, 95-101 [in Russian]. ISSN: 0015-3214. PHOTOCOPY ORDER NUMBER: 199303-57-0418.

Surface Preparation

Gradual Formation of Coating of CoNiCrAlYTa and NiBCrSiFe (K50) Powders. The results of plasma spraying after different intervals of spraying interruption are given. Surface roughness of substrate after abrasive cleaning and that of coating deposited by use of CoNiCrAlYTa and ZrO_2 + Y_2O_3 powders is discussed.

V. Palka, M. Brezovsky, and J. Sith. Cited: *Zvaranie 41,* (10), Oct. 1992, 223-226 [in Czech]. ISSN: 0044-5525. PHOTOCOPY ORDER NUMBER: 199303-58-0325.

Review

General

Perfect Coatings Through Specialist Know-How. Gotek GmbH in Germany is divided into four product areas: specialized production; hard materials technology which coats by thermal spraying, sintering processes, and merchandising of sprayed alloys and high temperature brazing; plastic powders; and Gotekplast, production/merchandising of special liquid plastics for extreme corrosion protection. The merchandising program at the company includes: self-flowing hard alloys based on NiCrBSi as well as NiBSi; hard alloys on the basis of CoCrW(Mo)C; spraying guns and accessories; corrosion-resistant welding materials; and additives for high-temperature brazing technology. The coatings program at the company uses: spraying of metals and alloys, plasma spraying of metals and ceramics; thermal post-treatment of sprayed layers, high-energetic powder spraying processes, and welding application via plasma, TIG and MIG. A review of Gotek covers: the strength of the company rooted in its processing of applied layers, several products produced at the company, the four layer strength in the hard materials, the secrets of the company's success, and customer benefits.

Cited: *Powder Metallurgy International, 24*, (2), Apr. 1992, 95-96 [in English]. ISSN: 0048-5012. PHOTOCOPY ORDER NUMBER: 199302-57-0177.

Wear Applications

Friction and Wear of Hardfacing Alloys. Hardfacing is the application of a wear-resistant material, in depth, to the vulnerable surfaces of a component by a weld overlay or thermal spray process. Categories of weld overlay materials are build-up alloys, metal-to-metal wear alloys, metal-to-earth abrasion alloys, tungsten carbide and nonferrous alloys. Levels of abrasion resistance available within each category are discussed.

P. Crook and H.N. Farmer. Cited: *ASM Handbook*, Vol. 18, *Friction, Lubrication, and Wear Technology*, ASM International, 1992, 758-765 [in English]. PHOTOCOPY ORDER NUMBER: 199303-55-0419.

Thermal Spray Coatings. Thermal spraying reduces wear and corrosion and greatly prolongs part service life by allowing use of a high-performance coating material over a low-cost base metal. Commercially-available thermal spray methods are oxyfuel wire spray, electric arc wire spray, oxyfuel powder spray, plasma arc powder spray and high-velocity oxyfuel powder spray. Adhesive wear, abrasive wear and surface fatigue wear of sprayed coatings are addressed.

B.A. Kushner and E.R. Novinski. Cited: *ASM Handbook*, Vol. 18, *Friction, Lubrication, and Wear Technology*, ASM International, 1992, 829-833 [in English]. PHOTOCOPY ORDER NUMBER: 199303-57-0282.

Spray Forming

Aluminides

Arc Spray Forming of Nickel Aluminides. The manufacture of nickel aluminides by arc spray forming was investigated. It is concluded that NiAl, Ni_3Al and Ni_2Al_3 can be manufactured by arc spray forming with elemental wires, but there are problems with controlling composition and porosity. Nickel aluminides can be manufactured by arc spray forming with cored wires producing low-porosity equiaxed microstructures.

A.P. Newbery, B. Cantor, R.M. Jordan, and A.R.E. Singer. Cited: *Scripta Metallurgica et Materialia, 27*, (7), 1 Oct 1992, 915-918 [in English]. ISSN: 0956-716X. PHOTOCOPY ORDER NUMBER: 199301-54-0002.

Review

Use of Spray Techniques to Synthesize Particulate-Reinforced Metal-Matrix Composites. In an attempt to optimize the structure and properties of particulate-reinforced metal-matrix composite, a variety of novel synthesis techniques have evolved over the last few years. Among these, the technique of spray processing offers a unique opportunity to synergize the benefits associated with fine particulate technology, microstructural refinement and compositional modifications, coupled with in situ processing, and in some cases, near-net shape manufacturing. Spray technology has resurrected much interest during the last decade and there now exists a variety of spray-based methods. These include spray atomization and deposition processing, low-pressure plasma deposition, modified gas welding techniques and high velocity oxyfuel thermal spraying. Spray processing involves the mixing of reinforcements with the matrix material under non-equilibrium conditions. As a result, these processes offer an opportunity of modifying and enhancing the properties of existing alloy systems, and also developing novel alloy compositions. In principle, such an approach will inherently avoid the extreme thermal excursions, and the concomitant macrosegregation associated with conventional casting processes. Furthermore, the spray processing technique also eliminates the need to handle fine reactive particulates associated with powder metallurgical processes. Recent developments in the area of spray synthesis or processing of discontinuously reinforced metal-matrix composites are presented and discussed with particular emphasis on the synergism between processing, microstructure and mechanical properties. A variety of Al alloy/SiC_p composites are cited.

T.S. Srivatsan and E.J. Lavernia,. Cited: *Journal of Materials Science, 27*, (22), 15 Nov. 1992, 5965-5981 [in English]. ISSN: 0022-2461. PHOTOCOPY ORDER NUMBER: 199302-62-0237.

Surface Finishing

A Comparison of the Properties of Coatings Produced by Laser Cladding and Conventional Methods. Wear resistant coatings of hardfacing alloys can be produced with powders by different techniques such as laser cladding (LC), plasma-transferred arc welding (PTA), plasma spraying (APS), etc. Coatings produced by these techniques show slightly different properties due to the manufacturing process, despite having the same chemical composition. On coatings of Ni base hardfacing alloys produced on mild steel substrates by LC, PTA and APS the coating microstructures and properties such as hardness, wear resistance and corrosion resistance have been studied. Estimates of realistic coating thicknesses, coating rates, powder consumption and the influence of temperature on the substrate material during the LC, PTA and APS coating processes are given. Application areas for coatings produced by LC, PTA and APS are shown.

E. Lugscheider and B.C. Oberlander. Cited: Conference: Surface Modification Technologies. V, Birmingham, UK, 2-4 Sept. 1991, The Institute of Materials, 1992, 383-400 [in English]. PHOTOCOPY ORDER NUMBER: 199302-58-0141.

Aluminum Alloys

Surface Treatment of Aluminum Alloys With High Power CO_2-Laser. In the future, Al alloys will be a very important construction material. For many applications, it is necessary to cover the surface of Al substrate with a protective layer to prevent wear or corrosion. With the CO_2-laser, it is possible to clad or alloy the Al alloys in the one-step or two-step process. Base materials are wrought and cast Al alloys. This work shows the difficulties of the two-step process, where the substrate is coated by high velocity flame spraying and electroplating systems in the first processing step. In the one-step process, the coating powders, Ni-base alloys, are put on the Al surface simultaneously with the laser treatment. By this method, under special consideration of the used shielding gas and powder feeding system, load bearing hardfacing coatings with no formation of cracks and pores are produced as single and overlapping traces. The one-step process yields many advantages in reference to industrial processing and economical aspects.

R. Volz. Cited: Conference: Laser Applications in the Automotive Industries, Florence, Italy, 1-5 June 1992, Automotive Automation Limited, 1992, 301-310 [in English]. PHOTOCOPY ORDER NUMBER: 199301-58-0056.

Laser Glazing

Superficial Laser-Glazing of Sprayed Alumina Coatings for Anti-Corrosion Performance. The laser glazing of gas-flame sprayed alumina was attempted to produce a coating resistant to hot corrosion with insulation capability. Superficial laser glazing was achieved by scanning a carbon dioxide laser with a large beam diameter at low velocity over the sprayed alumina coating impregnated with silicone sealant. Successful laser-glazing could be achieved by controlling the temperature of the metallic substrate (e.g. AISI 304 steel). The laser-glazed alumina exhibited high insulation capability and good resistance to hot corrosion by Na_2SO_4-$V_2O_5$5 at 900 °C.

Y. Longa, T. Yamashita, and M. Takemoto. Cited: *Zairyo-to-Kankyo* (Corrosion Engineering), *41*, (8), Aug. 1992, 542-549 [in Japanese]. ISSN: 0917-0480. PHOTOCOPY ORDER NUMBER: 199303-57-0307.

High-Temperature Corrosion of Laser-Glazed Alloys in Na_2SO_4—V_2O_5. Laser glazing of gas flame sprayed NiCrAl, FeNiCrAl, and NiCr alloys was used to produce coatings highly resistant to hot corrosion. Laser irradiation made it possible to glaze the thin surface layers of the sprayed porous coatings. The laser-modified layer of the coating possessed a new surface composition and morphology. Hot corrosion tests, in the presence of a mixed salt of 15 wt.% Na_2SO_4/V_2O_5 at 900 °C, showed that the modified coating offered excellent corrosion resistance compared to the as-sprayed coating. Alloy compositions used were Fe-19.8Cr-3.5Al-3.5Ni, Ni-19.5Cr-4.0Al and Cr-49.02Ni-0.02Fe.

Y. Longa and M. Takemoto. Cited: *Corrosion, 48*, (7), July 1992, 599-607 [in English]. ISSN: 0010-9312. PHOTOCOPY ORDER NUMBER: 199302-35-0210.

A Study of a Laser Irradiated Molybdenum Plasma Sprayed Coating on Steel. Pure Mo was deposited on the surface of mild steel specimens by plasma spraying technique. A KrF excimer laser was employed to modify the surface layer of the plasma sprayed coating. The effect of the laser irradiation on the Mo coating was examined by the use of several experimental techniques. The corrosion behavior of the uncoated and coated steel before and after the laser treatment was also studied. The corrosion of the coated specimen was found to be lower than that of the uncoated specimen and to be improved after the laser treatment.

A. Koutsomichalis, H. Badekas, C. Panagopoulos. Cited: *Materials Science Forum, 102-104*, (2), 1992, 699-708 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199301-16-0028.

Testing

Photo-Acoustic Spectroscopy

Prototype Instrument for [Photo-Acoustic Spectroscopy] and Examples of PA Characteristics of Solid Specimens. I. Study of Non-Destructive Testing Method for Thermally Sprayed Specimens by Photo-Acoustic Spectroscopy. Studies have been performed with the objective of using photo-acoustic spectroscopy (PAS) as a non-destructive testing (NDT) method for thermal-sprayed coatings. A prototype PAS instrument was developed for solid specimens, and its performance was examined. Furthermore, the basic PA characteristics of uncoated mild steel substrates and those of Cu sprayed coating are described. The principal results obtained are as follows: The prototype PAS instrument can be applied to solid specimens with or without thermally sprayed coatings by using a double-beam method. The PA signal intensity of uncoated mild steel substrates increased when incident light wavelength was decreased and specimen volume increased. Conversely, the PA signal intensity was almost constant with specimen thickness >2 mm. As for the PA signal intensity of a mild steel specimen with Cu sprayed coating, it decreased with an increasing incident light wavelength.

M. Futamata, A. Fuji, I. Atsuya, and C. Sato. Cited: *Transactions of the Japan Welding Society, 23*, (1), 3-8 Apr. 1992 [in English]. ISSN: 0385-9282. PHOTOCOPY ORDER NUMBER: 199301-22-0018.

Wear

Composite Powders

Examination of the Properties of Hot Gas Sprayed Coatings of Nickel-Titanium and Chromium Carbide Composite Powders. The heat resistance and tribological properties of plasma coatings on steel 45 specimens, formed from composite powders (CP) obtained by Ni plating of titanium and chromium carbides with four different compositions are studied. Coatings obtained from high Cr CP are more heat-resistant. The tribological properties make these coatings suitable for use as antifriction materials.

I.N. Gorbatov, V.M. Shkiro, A.E. Terent'ev, L.K. Shvedova, I.S. Martsenyuk, and S.V. Karpenko, *Fizika i Khimiya Obrabotki Materialov* (4), July-Aug. 1991, 102-106 [in Russian]. ISSN: 0015-3214. PHOTOCOPY ORDER NUMBER: 199303-58-0367.

Oxyacetylene Powders

Studies on Tungsten Carbide Embedded Nickel Base Hard Surfacing on Mild Steel by Gas Thermal Spraying of Powder. The hard surfacing of mild steel using commercially-available Ni-base tungsten carbide powder was carried out under oxy-acetylene gas thermal spray technique. During deposition of powder, the preheating of the substrate and the torch speed were varied and their effects on the deposition characteristics, interfacial bonding, and microhardness across the coating were studied. The coated samples were given a post-spray heat treatment at different temperatures and its influence on the coating was studied by microhardness measurement. For satisfactory coatings, the wear characteristics were also studied and correlated with the pre- and post-heating temperatures. It was observed that a torch speed of 10 cm/min and a preheating at temperature of 300 °C minimum are necessary to produce a satisfactory coating on mild steel. The use of post-spray heat treatment was beneficial in enhancing the hardness and wear resistance of the coating.

S.K. Sharma, P.K. Ghosh, and O.P. Kaushal, *Tool and Alloy Steels, 26*, (9), Sept. 1992, 237-247 [in English]. ISSN: 0377-9408. PHOTOCOPY ORDER NUMBER: 199303-62-0355.

WC Materials

Characteristics of WC Type Anti Wear Deposits With 17% of Cobalt Obtained by Plasma. This paper describes work carried out by Sochata (part of SENECMA), specialists in repair of turbo machinery by plasma projected metallization. These deposits now meet the various stipulations of the original manufacturers and now require no machining after deposition. The method used is briefly described. The powder used is one of tungsten carbide with 17% of a special type of cobalt. The characteristics of the deposits can be enriched in tungsten and a change is made from a crystalline structure to an amorphous one.

M.G. Medici, J.P. Berbot, M. Grosbras, and D. Manesse. Cited: Original Title: [Characterisation de Depots Anti-Usure de WC a 17% de Cobalt Obtenus par Projection Plasma], Conference: Colloquium: Powder Metallurgy Materials Featuring Specific Physical Properties (Colloque sur les Materiaux a Proprietes Physiques Particulieres Obtenus a Paretir de Poudre), Paris, France, 6-8 Apr. 1992, Societe Francaise de Metallurgie et de Materiaux, 1992 [in French]. PHOTOCOPY ORDER NUMBER: 199303-31-1264.

Wear Coatings

Parameter Optimization

The Effects of Plasma Spray Parameters and Atmosphere on the Properties and Microstructure of WC-Co Coatings. Wear- and corrosion-resistant coatings deposited by plasma spray process are increasingly used in severe environments in resource industries, such as oil and gas, oil sands, mining, pulp and paper, etc. While there is a large volume of literature in the area of plasma spray coatings, comparatively few papers deal with the co-relation between coating properties and microstructure as a function of plasma spray processing parameters. In this study, the effect of some plasma spray processing variables and atmosphere (air or inert gas) on the microstructure and the properties of WC-Co coatings on low carbon steel substrates were studied. The properties of the coatings measured include: microhardness, porosity by image analysis, wear resistance by dry sand/rubber wheel abrasion test (ASTM G 65-91) and corrosion properties by ac impedance technique. Phase analyses of the coatings were also performed by X-ray diffraction. From the above, optimized coatings were developed for oil and gas industry applications.

D. Ghosh, D. Lamy, T. Sopkow, I. Smugga-Otto. Cited: Conference: Advanced Materials: Meeting the Economic Challenge, Toronto, Canada, 20-22 Oct. 1992, Society for the Advancement of Material and Process Engineering, 1992, T28-T42 [in English]. PHOTOCOPY ORDER NUMBER: 199303-57-0397.

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