Selected Abstracts of Thermal Spray Literature 7/92 - 9/92

Application

Boiler Tubes

Thermal Spraying for Boiler Tube Protection. Power station steel boiler tubes are subject to corrosion and erosion by combustion products, and many techniques are used to reduce damage. Sprayed coatings are attractive because a thin layer can be applied without affecting the mechanical properties of the tubing. The selection of a spraying process and materials and the development of the technique to provide sound, durable coatings on the large scale necessary for power station applications are described.

E.J. Morgan-Warren. Cited: *Welding and Metal Fabrication 60*,(1), 1992, 25-26, 28, 30-31 [in English]. ISSN: 0043-2245. PHOTOCOPY ORDER NUMBER: 199208-35-1468.

Oxidation Resistant Crucibles

Plasma-Sprayed-Yttria Layers for Corrosion Resistance. Crucible corrosion in the growth of $YBa_2Cu_3O_{7-x}$ (YBCO) superconducting single crystals is one of the major obstacles in obtaining superconducting single crystals. Both metallic and ceramic crucibles have exhibited significant corrosion that affects the size and properties of YBCO crystals. Plasma spraying has been successfully used to produce yttria coatings on alumina substrates. Yttria coatings with thicknesses between 30 to 100 μm have shown corrosion rates of 3 to 4 μm/h; these rates are five to ten times lower than that of the alumina substrate.

M. Berkowski, P. Bowen, T. Liechti, and H.J. Scheel. Cited: *Journal of the American Ceramic Society, 75*, (4), 1992, 1005-1007 [in English]. ISSN: 0002-7820. PHOTOCOPY ORDER NUMBER: 199207-F2-C-0987.

Repair of Tube Welding Damage

Tube Weld Repair System. An overview covers the equipment of the metal spray process, the mechanical properties of the coating, and its application, particularly in repairing areas on precoated tube damaged during welding. The process involves a flame spray/arc spray technique to deposit metals in the form of a molten spray onto the component surface, which solidify to form a dense, adherent deposit. The heat generated from the weld and scarfing operation raise the surface temperature to approximately 400 °C, which is sufficiently high to provide the mechanism for excellent adhesion of the metal sprayed coating. Zinc, aluminum, Galvolume, Zincalume, Aluzinc, Zalutite, and Galfan coatings are discussed.

Cited: *Tube International, 10*, (44), 1991, 247-248 [in English]. ISSN: 0263-6794. PHOTOCOPY ORDER NUMBER: 199207-55-1032.

Slide Rails

Plasma Sprayed Slide Rails Have Proved Their Quality. Problems associated with the microwelds occurring in slide rails are considered, and details are given of the effect of plasma nitriding and plasma spraying on the rate of scoring and of the properties of various coatings on heat treated C45 steel. An assembly line for the milling of cast iron housings is described, in which scoring of the surface of the housings in contact with the slide rails occurs. It was found that the best spray material for plasma spraying was an FeCrB alloy containing silicon, manganese, and titanium, with additions of chromium and molybdenum. The practice for producing the spray coating is described. A 1 year's trial with 60,000 cast iron housings revealed no scoring. After 7 months, wear of the sprayed coating showed a thickness variation of only 0.2 mm, which was evened out by packing.

A. Oswald and H.J. Neumann. Cited: *Praktiker, 44*, (3), 1992, 135-138 [in German]. ISSN: 0554-9965. PHOTOCOPY ORDER NUMBER: 199208-58-1153.

Thermal Barrier Coatings

Study of High Durability Thermal Barrier Coatings for Heavy Duty Gas Turbines. II. The durability and thermal barrier effect of a four-layer thermal barrier coating, consisting of 8 wt.% Y_2O_3-ZrO_2 (partially stabilized ZrO_2:PSZ)/CoNiCrAlY/PSZ + CoNiCrAlY mixed layer/CoNiCrAlY on René 80 and HGTN 2, was studied by a plasma jet heating test and the gas turbine development test. Because of the results of thermal cycle testing under high temperature gradient conditions with plasma jet heating, vertical and horizontal cracks occurred in the PSZ layer, and these cracks increased with increasing temperature gradient. Horizontal cracks caused spalling of the PSZ layer. The thermal barrier effect of the coating increased with increasing temperature gradient. On the other hand, as a result of thermal cycle testing using the gas turbine development apparatus, spalling of the PSZ of the four-layer TBC-coated turbine vane did not occur after ten cycles. In this case, the temperature of the thermal barrier effect calculated from measuring the metal temperature of the turbine vanes with and without a thermal barrier coating was approximately 90 °C.

Y. Kojima, K. Wada, T. Teramae, and H. Furuse. Cited: *Journal of High Temperature Society of Japan, 17*, (6), 1991, 303-316 [in Japanese]. ISSN: 0387-1096. PHOTOCOPY ORDER NUMBER: 199207-57-0964.

Hot Corrosion Resistance of $8Y_2O_3$-ZrO_2/NiCrAlY Graded Thermal Barrier Coating Formed by Plasma Spraying Process. Two kinds of thermal barrier coatings (TBC), double layer coating of $8Y_2O_3$-ZrO_2 undercoated with NiCrAlY and graded coating whose composition was continuously changed from NiCrAlY as an undercoat to $8Y_2O_3$-ZrO_2 as a topcoat, were sprayed on a type 304 stainless steel substrate by plasma spraying. The hot corrosion resistance of the thermal barrier coating was evaluated by investigating damage of the coatings after heating in furnace for 3 h at 1273 K with corrosive ashes placed on the coating surface. The corrosion ash consists of V_2O_5 and Na_2SO_4. Cracking of the coating was also monitored by acoustic emission under the 1273 to RT thermal cycle with corrosion ashes. It was found that the fracture of double layer coating resulted from reaction between V_2O_5 and Y_2O_3. However, corrosive damage of the graded coating was very limited. During the thermal cycle test, the AE signal counts accumulation of double layer coating was increased with an increase in the number of cycle repetitions, and subsequently, spalling of the coating took place. On the other hand, few AE signal counts of the graded coating were detected from more than five cycles, and no significant damage of the coating was observed. The relationship between AE counts and fracture of the coating was examined. The AE monitoring method can provide useful information about the hot corrosion behavior of thermal barrier coatings.

H. Nakahira, Y. Harada, N. Mifune, and T. Doi. Cited: *Journal of High Temperature Society of Japan, 17*, (Suppl.), 1991, 406-414 [in Japanese]. ISSN: 0387-1096. PHOTOCOPY ORDER NUMBER: 199208-57-1049.

Biomedical

Radio Frequency Plasma

Coating of Hydroxyapatite on Zirconia Utilizing a Radio-Frequency Thermal Plasma Process. Many coatings of hydroxyapatite (HAp) on mechanically strong materials as substrates have been studied for increasing the mechanical strength of bioactive HAp. Coating of HAp on 3 mol% Y_2O_3 partially stabilized zirconia (PSZ) substrate, a bioinert and highly strong and fracture-resistant material, was studied using a new plasma spraying method of a rf thermal plasma. High contents of HAp in the coated layer were obtained by using larger HAp powders at smaller plasma powers and at lower substrate temperatures. The decomposition of the HAp phase was suppressed below the substrate temperature of approximately 1500 °C. Adhesive strength of the coated HAp layer to the substrate was measured to be 5 to 14 MPa. The surface of the coated layer had many pores. Thus, a possibility of coating HAp on the PSZ using a rf thermal plasma process was indicated. The HAp coated layer on the PSZ can be used as a mechanically strengthened and biocompatible material.

A. Hasegawa, K. Akashi, T. Kameyama, M. Ueda, K. Fukuda, and A. Motoe. Cited: *Nippon Seramikkusu Kyokai Gakujutsu Ronbunshi (Journal of the Ceramic Society of Japan)*, 100, 1992, 377-381 [in English]. ISSN: 0914-5400. PHOTOCOPY ORDER NUMBER: 199207-E7-C-0155.

Coatings

Oxides

Properties of Plasma-Sprayed Oxides on Metallic Substrates. Metallic substrates were coated with Cr_2O_3, Al_2O_3, ZrO_2-$7Y_2O_3$ by a plasma spray technique. An aim was the investigation of the bonding mechanism between substrate and coating. From the results achieved by several analyzing methods (SEM and SNMS), it was concluded that mechanical bonding of the spray particles on rough metallic substrate surfaces was the dominant adhesion mechanism. In a second step, the influence of substrate material and temperature on residual stress condition in chromia coatings was investigated. As an analyzing method, X-ray diffraction was applied. Also, composition of oxides was determined in relation of the different process variants applied—atmospheric plasma spraying, vacuum plasma spraying, and inert gas plasma spraying. Post-heat treatment of coated samples influenced the phase composition and produced chemical reactions at the coating/substrate interface.

H.G. Schuetz. Cited: *Forschungszentrum Julich,* 1991, 150 [in German]. ISSN: 0097-9007. PHOTOCOPY ORDER NUMBER: 199209-57-1223.

Post Treatment by Electric Field

Electric Field Assisted Treatment of Various Plasma Sprayed ZrO_2 Coatings. A systematic experimental investigation was carried out to clarify the phenomena that occur during the electric field-assisted treatment of various ZrO_2 coatings sprayed on Cu or SS41 steel substrates, and the possibility of improving the adhesive strength between substrate and coating by the electric field-assisted treatment was examined. It was found that the occurrence of a Zr-Cu-O layer was clearly recognized at the interface between the ceramic coating and the copper substrate, which was arranged as the cathode in the experiment. The formation of the Zr-Cu-O layer was greatly dependent on the kinds of ZrO_2 coatings. It was revealed that the adhesive strength of the coating can be raised by the electric field-assisted treatment to over three times that for a sprayed ZrO_2 (8 wt.% Y_2O_3) coating. The electric field-assisted treatment was also applied to ZrO_2 (8 at.% Y_2O_3) sprayed onto mild steel, but no improvement in adhesive strength resulted. However, when the coated steel was heated in air to form an iron oxide at the coating/substrate interface, the adhesive strength was nearly doubled by a subsequent electric field treatment.

A. Ohmori, K. Aoki, S. Sano, Y. Arata, K. Inoue, and N. Iwamoto. Cited: *Transactions of the JWRI (Japan Welding Research Institute), 20,* (2), 1991, 35-42 [in English]. ISSN: 0387-4508. PHOTOCOPY ORDER NUMBER: 199209-57-1206.

Conference Proceedings—NTSC in Pittsburgh

Thermal Spray Coatings: Properties, Processes and Applications. 67 papers selected and abstracted.

T.F. Bernecki. Cited: *Thermal Spray Coatings: Properties, Processes and Applications Conference Proceedings,* 1991 [in English]. ISSN: 0-87170-437-4. PHOTOCOPY ORDER NUMBER: 199207-72-0320.

Modeling—Effective Energy of Particles

Influencing the Properties of Heat-Sprayed Layers by the Controlled Technology of Spraying. A method was developed for investigating the effect of technological parameters of heat spraying on the melting of particles of additional materials and on the amount of heat brought to the substrate. The method consists of determining "the specific effective energy" of a particle, which is formed by (1) the enthalpy of the particle, (2) reaction heat of phase transformations, (3) the heat increment due to conversion of the kinetic energy of a particle to the heat, and (4) reaction heat between the base and the particle. The effect of individual technological parameters of plasma spraying on the specific effective energy was investigated experimentally on copper specimens of 30 × 40 × 20 mm. The results indicated a possibility of influencing (1) the heat regime of the spraying itself and, in turn, (2) the result and physical-mechanical properties of the sprayed layer, by the specific effective energy criterion.

J. Kaspar, V. Kovar, and O. Ambroz. Cited: *Zvaranie, 40,* (12), 1991, 235-240 [in Czech]. ISSN: 0044-5525. PHOTOCOPY ORDER NUMBER: 199209-58-1305.

Patent

Abrasive Layers

Method for Applying Abrasive Layers to Blade Surfaces. This invention relates to abrasive layers for use in the gas turbine industry. The preferred embodiment of the invention comprises nickel-coated, yttria-doped silicon nitride particulates dispersed within a nickel-base superalloy matrix that is substantially free of oxides. The layer was formed using low-pressure plasma spray processes.

H.E. Eaton, Jr. and M.J. Wallace. Cited: Patent No. US5104293, 1990, USA [in English]. PHOTOCOPY ORDER NUMBER: 199208-58-1127.

Cu-Sn-Si Wire Feedstock

Wire Made of Copper-Based Alloy Compositions. Metal filler compositions and methods of using the same are discussed. The compositions are copper based with the addition of tin and silicon. When used for thermal spraying applications, aluminum is included in the formulation. By practice of the invention, substantial improvements in bond strength and quality of the surface finish are achieved.

D.D. Kiilunen and D.A. Sartor. Cited: Patent No. US5100617, 1990 [in English]. PHOTOCOPY ORDER NUMBER: 199207-55-0991.

Dental Restorations

Methods of Manufacturing Dental Restorations. A method for the production of full or partial dental restorations include veneers, crowns, inlays, onlays, bridge structures, and dental restorations produced by the method is disclosed. The method uses the technique of flame spraying to form a basal layer of a technical ceramic-based material upon which porcelains are applied to produce a strong, aesthetically acceptable and custom-made dental restoration. The technical ceramic-based material may be alumina, zirconia, titania, or combinations thereof, and the flame spraying may be a direct method or an indirect method. The technical ceramic-based material may include small amounts of silicate-based materials.

P.A. Evans and P. Harrison. Cited: Patent No. US5104319, 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199207-F1-C-0428.

High-Temperature Corrosion

Metallic Object, in Particular Gas Turbine Blade With Protective Coating. The invention concerns multilayer protective coatings for metallic objects, in particular gas turbine blades. Given the existence of two different corrosion mechanisms that determine the service life of such objects, two superimposed protective layers are applied. The inner layer protects against attack by corrosion at temperatures of 600 to 800 °C (HCTII), and the outer layer affords optimal protection against corrosion at temperatures of 800 to 900 °C (HTCI). In addition, an outermost coating layer forming a thermal barrier can be provided. The first coating layer is preferably a diffusion layer with a chromium content greater than 50% and an iron and/or manganese content greater than 10%, and the second coating layer is preferably a MCrAlY layer containing, for example, approximately 75% chromium, approximately 7% aluminum, and approximately 0.7% yttrium, applied by low-pressure plasma spraying.

F. Schmitz, N. Czech, and B. Deblon. Cited: *Auszuge aus den Europaischen Patentanmeldungen, Teil I 6,* (47), 1990, 5775 [in English]. PHOTOCOPY ORDER NUMBER: 199207-58-0986.

Hot Dip Galvanizing Application

Immersion Member for Hot Dip Galvanizing Bath and Method for Preparing the Same. A flame-sprayed layer, consisting of (wt.%) 1.0 to 1.5 carbon, 2.0 to 4.0 boron, 2.0 to 4.0 silicon, 1.0 to 6.0 iron, 10.0 to 16.0 tungsten, 4.0 to 21.0 chromium, and 10.0 to 15.0 nickel, with the balance being cobalt, is formed on the surface of an immersion member for a hot dip galvanizing bath. This surface layer has improved corrosion resistance and abrasion resistance and excellent peeling resistance (adhesion). The life of the immersion member is prolonged and a galvanized product with uniform quality and no flaws can be prepared by using an immersion member with this flame-sprayed surface layer. These effects are enhanced when the flame-sprayed layer is heated at a rate of 10 to 100 °C/h and maintained at a preheating temperature of 300 to 600 °C for not less than 0.5 h, the fusing treatment is conducted at a temperature of not less than 1000 °C for up to 30 min once or twice, the temperature is dropped, a soaking treatment is carried out at 500 to 800 °C for not less than 1 h and a cooling treatment is then carried out at a rate of 10 to 50 °C/h.

M. Suhara, M. Takagi, Y. Okuzaki, K. Tashiro, and M. Mizunuma. Cited: *Auszuge aus den Europaischen Patentanmeldungen, Teil I 6,* (46), 1990, 5677 [in English]. PHOTOCOPY ORDER NUMBER: 199207-58-0982.

Paper Rolls

Rolls for Use in the Production of Paper and Method for the Manufacture of the Roll. A roll for use in the production of paper, in particular a center roll in a press, with which the web is in direct contact and from which the web is detached, forming a composite structure on the cylinder mantle of the roll, is characterized. The roll face is provided with a surface layer that protects the roll from wear and provides good properties for detaching the web. The surface layer is formed by thermal spraying of a powder in which the metal and ceramic phases are in the same powder particle. A dense layer provides protection against corrosion. This layer is made of stainless steel with a chromium content of 10 to 29%. The layer is placed between the surface layer and the roll mantle to protect the roll mantle from corrosion and to promote the adhesion of the surface coating.

J. Leino, J. Salo, J. Vestola, and A. Telamas. Cited: *Auszuge aus den Europaischen Patentanmeldungen, Teil I 7*, (18), 1991, 1722-1723 [in English]. PHOTOCOPY ORDER NUMBER: 199209-58-1245.

Post Processing—Laser Remelting

Laser Beam Remelting of Thermally Sprayed Titanium Coatings. Residual porosity in plasma sprayed titanium coatings often limits the applicability of such coatings if highly concentrated solutions occur. Laser beam radiation can be used preferably for remelting of the coatings to improve corrosion resistance. Nevertheless, it is important to adapt the process parameters to material properties. Some aspects about surface treatment of titanium coatings (on mild steel) by laser beam radiation are given.

W. Brandl, H.-D. Steffens, and C. Buchmann. Cited: *Eurojoin 1: First European Conference on Joining Technology Conference Proceedings*, 1991, 271-278 [in English]. PHOTOCOPY ORDER NUMBER: 199207-58-0940.

Review

Plasma Spray Coating

Plasma Spraying Used as a Coating Method in Series Production. Since its beginning approximately 100 years ago, thermal spraying has grown into a versatile, demanding coating method. It is possible to carry out processes with various ranges of pressures using reactive gases. Plasma spraying allows providing components made of carbon fiber-reinforced plastics with coatings that stand out for their good adhesiveness and high resistance to wear.

H. Eschnauer. Cited: *Werkstoff und Innovation, 5*, 1992, 24-28 [in German]. ISSN: 0934-732. PHOTOCOPY ORDER NUMBER: 199209-E7-D-0195.

Ceramic Plasma Sprayed Coatings

Advanced Ceramic Coatings by Plasma Spraying: A Technology for the 1990s and Beyond. Ceramic coatings gain market acceptance more easily than monolithic structural ceramics because many design engineers look at coatings as an improvement of a familiar metals manufacturing technology rather than a shift to a completely new and exotic materials technology. Thus, unique market niches are opening for coatings that include such well-established markets as aerospace and consumer industries, but also more slowly developing markets such as in the automotive, computer, and telecommunications industries. In addition to these high-tech applications, a major market exists in the resource industries including oil and gas, mining, forestry, pulp and paper, and agricultural industries. Materials properties optimization of wear-resistant tungsten carbide/cobalt composite ($Ni_{50}Cr_{50}$) and alumina/titania coatings are described, as are thermal and chemical barrier coatings based on partially stabilized zirconia, hot erosion-resistant coatings, bioceramic coatings, and diamond thin films and coatings, all applied by plasma and flame spray technology. This is not a comprehensive review of state-of-the-art ceramic structural and functional coatings applied by plasma spray technology, but is a survey of promising routes toward future developments in which ceramic coatings will likely play a very important role. Substrates discussed include steel and Inconel 716.

R.B. Heimann. Cited: *Processing of Advanced Materials, 1*, (3-4), 1991, 181-192 [in English]. ISSN: 0960-314X. PHOTOCOPY ORDER NUMBER: 199209-62-0972.

Spray Process

Laser Reactive Spraying

Reaction Spray by Laser-Plasma Jet—Synthesis of Titanium Nitride Coatings. The synthesis of a titanium nitride coating has been investigated by using laser plasma spraying. A titanium sprayed coating was formed by a N_2 plasma jet, and it was irradiated with CO_2 laser beam in a low-pressure nitrogen atmosphere. The Ti sprayed coating can be nitrided with irradiation of CO_2 laser in N_2 atmosphere, and the degree of nitridation of the Ti sprayed coating was increased with increasing laser output and the number of laser irradiation times. The hardness of the titanium nitride coating obtained was approximately 1300 HV. SS41 substrates were used.

A. Ohmori, Y.-C. Zhang, S. Hirano, and Y. Arata. Cited: *Transactions of the JWRI (Japan Welding Research Institute), 20*, (2). 1991, 27-33 [in English]. ISSN: 0387-4508. PHOTOCOPY ORDER NUMBER: 199209-57-1205.

Water-Stabilized Plasma

Plasma-Sprayed Aluminium Coating. Results are reported for correlation studies of spraying parameters and properties of resultant strip deposits for a water-stabilized plasma system. Results indicate that water-stabilized systems may not be as oxidizing as previously thought and that both spray distance and feed distance are important in water-stabilized systems. Coating porosity and substrate temperature are controlled by a combination of feed and spray distance, with a shorter feed distance producing a higher substrate temperature for the same spray distance.

J. Ilausky, J. Forman, and P. Chraska. Cited: *Journal of Materials Science Letters, 11*, (9), 1992, 573-574 [in English]. ISSN: 0261-8028. PHOTOCOPY ORDER NUMBER: 199209-58-1227.

Testing

Thermal Wave Interferometry

Potential Applications of Thermal Wave Interferometry for Nondestructive Evaluation and Characterization of Surface-Coated Components. The thermal wave inspection technique is reviewed, and its application to the nondestructive evaluation of thermal sprayed surface coating is discussed. The technique can provide useful information on the coating or component integrity near the surface and has potential for the assessment of coating thickness. Thermal techniques can compete with established ultrasonic and electric methods, being generally applicable wherever there is a thermal mismatch between a coating and its substrate. The application of this technique to aluminum, stainless steel, nickel-chromium carbide, yttria-stabilized zirconia, and epoxy coatings is discussed.

P.M. Patel, D.P. Almond, and J.D. Morris, Cited: *European Journal of Non-Destructive Testing, 1*, (2), 1991, 64-76 [in English]. ISSN: 0947-767X. PHOTOCOPY ORDER NUMBER: 199209-22-0712.

Ultrasonics of Adhesion

On Ultrasonic Testing for Evaluating the Adhesion of NiCr Alloy Sprayed Coating to Substrate. The adhesion of a plasma-sprayed coating to the substrate was determined by ultrasonic testing. An immersion-type probe was used. Sprayed coatings were obtained by spraying NiCr alloy powder onto SS41 mild steel plate using the plasma jet spraying process. The adhesion of the sprayed coating to the substrate can be inspected by ultrasonic testing. Bottom echo increases with increasing adhesion strength of the coating to the substrate. Some computerized image displaying methods, by which location and shape of peeling of the coating and adhesion distribution are visualized, were constructed. Parameters to evaluate the adhesion of the coating were proposed. Although some correlations between these ultrasonic parameters and adhesion are recognized, they exhibited relatively large scatter in results.

Y. Suga and J. Takahashi. Cited: *Quarterly Journal of the Japan Welding Society, 10*, (1), 1992, 132-138 [in Japanese]. ISSN: 0288-4771. PHOTOCOPY ORDER NUMBER: 199209-58-1219.