Selected Abstracts of Thermal Spray Literature 10/92 - 12/92

Reprinted with permission from MATERIALS INFORMATION, a joint service of ASM International® and the Institute of Materials, Materials Park, Ohio, USA and London, England, respectively

Application

Biomaterials

Dual Constant Composition Kinetics Studies of the Demineralization of Ceramic Plasma Coated Apatite Surfaces. Calcium phosphate phases such as hydroxyapatite (HAP) and octacalcium phosphate (OCP) have long been considered as model systems for biological minerals. Moreover such phases are involved in ceramic and plasma coated Ti alloy (HPCTI) prosthetic devices. Most of these mineral preparations are mixtures of calcium phosphate phases, as evidenced by X-ray analysis. However, many mineralizing systems involve the formation of metastable intermediates which may subsequently undergo phase transformations. There is, therefore, considerable interest in investigating the simultaneous growth and dissolution of multiple mineral phases. Based on the constant composition (CC) method, the new dual constant composition (DCC) technique has been developed for kinetics studies of the dissolution of the mixed calcium phosphate phases frequently encountered in ceramic and plasma coated apatite surfaces.

E.P. Paschalis and G.H. Nancollas. Cited: State University of New York (Buffalo) Conference: Tissue-Inducing Biomaterials, Materials Research Society, 1992, 17-21 [in English]. PHOTOCOPY ORDER NUMBER: 199212-57-1506.

Hydroxylapatite Coating of Porous Implants Improves Bone Ingrowth and Interface Attachment Strength. The effect of a plasma-sprayed hydroxylapatite (HA) coating on the degree of bone ingrowth and interface shear attachment strength was investigated using a canine femoral transcortical implant model. Cylindrical implants were fabricated by sintering spherical Co–Cr–Mo particles 500-710 μm in diameter; the nominal implant dimensions were 5.95 ± 0.05 mm diameter by 18 mm in length. One-half of each implant was coated with hydroxylapatite, 25-30 μm in thickness, by a plasma-spray technique. Using strict aseptic technique, the implants were placed through both femoral cortices into defects approx 0.05 mm undersized. After 2, 4, 6, 8, 12, 18, 26, and 52 weeks, the implants were harvested and subjected to mechanical pullout testing and undecalcified histologic evaluation. The application of the HA coating to porous implants enhanced both the amount of bone ingrowth and the interface attachment strength at all time periods. These differences were statistically significant for the percent of bone ingrowth at the 4-, 6-, 12-, 18-, 26-, and 52-week time periods, and interface shear strength values were significantly different at the 6-, 8-, 12-, 18-, and 26-week time periods. The rate of development of interface strength and bone ingrowth was also more rapid for the HA-coated implants. No evidence of any disruption, mechanical failure, or biologic resorption of the HA coating was observed. The results of the present study—demonstrating a beneficial effect of the HA coating at all time periods—are believed to be due to the use of paired comparisons, which allow assessment of subtle differences that might otherwise have been obscured by normal biological variability.

S.D. Cook, K.A. Thomas, J.E. Dalton, T.K. Volkman, T.S. Whitecloud III, and J.F. Kay. Cited: *Journal of Biomedical Materials Research*, *26*(8), 1992, 989-1001 [in English]. PHOTOCOPY ORDER NUMBER: 199212-57-1499.

High Temperature

The High Temperature Corrosion Behaviour of Various Alloys and Coatings Under Coal Gasification Conditions. The corrosion behaviour of several alloys and of various protective coatings on 15Mo3 has been tested under conditions found in coal gasification processes. The experiments showed that of all the uncoated samples tested, only AISI 310 has a promising resistance to these corrosive atmospheres. On most of the other materials, spalling of the corrosion products was observed. The main corrosion products were Fe, Cr and nickel sulphides, chromium oxide and chromium carbide. Materials protected by different coatings showed very good corrosion resistance when coated by plasma spraying with FeCrAl, containing small amounts of yttrium. Good resistance by coating against the corrosion was also observed for alloys chromized by pack cementation. A small amount of vanadium added to the pack improved the quality of the diffusion coating considerably. Nearly two dozen specific alloys are also listed.

S. Besenicar, N.W.J. Haanappel, V.A.C. Haanappel, T. Fransen, and P.J. Gellings. Cited: *Materials at High Temperatures*, *9*(4), 1991, 193-200 [in English]. PHOTOCOPY ORDER NUMBER: 199212-35-2180.

Applications of Thermal Spraying for High Temperature Corrosion Environments. Boilers and gas turbines operate at high temperature which requires new materials. With operating temperature getting higher, high temperature corrosion under fuel conditions can hinder the operation. Applications of thermal spraying to prevent corrosion are investigated. For boilers, NiCr alloy and FeCrAl alloy plasma sprayed coatings in components of heat transfer tubes can obtain good protection. For gas turbines, ceramic thermal barrier coatings with MCrAlY undercoatings on cobalt-base alloys (e.g. ECY768) by low pressure plasma spraying can prolong service life and reliability.

M. Nakamori. Cited: *Tetsu-to-Hagane (Journal of the Iron Steel Institute of Japan)*, *78*(6), 1992, 854-859 [in Japanese]. PHOTOCOPY ORDER NUMBER: 199211-57-1407.

HVOF

Properties and Applications of CDS Coatings. High quality coatings of metallic alloys, cermets, or synthetic-base materials can be deposited by the continuous-detonation spraying (CDS) process developed by Plasma Technik AG. At present the most important coatings are tungsten carbide or chromium carbide in a cobalt matrix but other combinations have been tested. These are surveyed and possible applications put forward.

A.R. Nicoll. Cited: *Materials and Design*, *13*(3), 1992, 145-148 [in English]. PHOTOCOPY ORDER NUMBER: 199212-62-1480.

Review

Thermal Spraying—Processes, Possibilities, Limitations. Thermal spraying has proved an effective process for producing high performance coatings and components. New trends, possibilities and the limitations of thermal spraying technology are reviewed. Newer developments in flame, arc, and plasma spraying and new trends in the development of spraying media are described. New process variations such as high frequency plasma and laser spraying and atomising from the liquid phase are also presented. Ni_3Al, Ni/Cr alloys, metal-ceramic composites, Al and Zn are coatings commonly spray-applied. Substrates include stainless, offshore drilling platforms and bridges.

H.-D. Steffens, R. Kaczmarek, Z. Babiak. Cited: *Wire*, *41*(4), 1991, 374-376 [in English]. PHOTOCOPY ORDER NUMBER: 199210-58-1370.

Thermal Spray Processes for Applying Protective Coatings to Technical Parts. Thermal coating processes using plasma sprays, arc sprays, and flame sprays are discussed. Plasmas are versatile and can be activated in air, in vacuum chambers, and under water. Flame plating uses acetylene-oxygen nozzles at temperatures >3000 °C. Detonation coating is a special high-velocity type of flame spray. Spraying of Ti, Ta, Nb, and cobalt-based or Ni-based superalloys is discussed. An Al-alloy substrate is cited.

K. Kirner. Cited: Original Title: Thermische Spritzverfahren zum Auftragen von Schutschichten. *Maschinenmarkt*, *98*(16), 1992, 34-36, 38-39 [in German]. PHOTOCOPY ORDER NUMBER: 199212-58-1719.

Sheep Shears

Coatings for Sheep Shears. Various surface treatments have been applied to high carbon steel shearing combs and cutters. These include flame sprayed tungsten carbide-cobalt (WC-Co), FARE gun coated tungsten carbide-cobalt and reactively sputtered (PVD) titanium nitride. A series of laboratory and field tests have been carried out to evaluate their relative merits. Initial tests indicate that PVD coatings of titanium nitride show promise in reducing wear of sheep shearing components. The high density of PVD titanium nitride and its ability to form thin, highly adherent layers give it advantages over other hard coatings (e.g. WC-Co D-gun coatings), where porosity can be a serious problem. Another advantage is its relatively low process temperature, which minimizes distortion and thereby improves retention of optimum comb/cutter severing mechanics. Future work will optimize the composition of PVD coatings to attain the best shearing performance.

R.H. Mair and C.C. Berndt. Cited: Monash University (Australia) Conference: High Performance Ceramic Films and Coatings, 1991, 661-669 [in English]. PHOTOCOPY ORDER NUMBER: 199211-31-3422.

Superconductivity

Effect of Oxide Additions on the Properties of Plasma-Sprayed Y-Ba-Cu-O Coatings. Plasma-spraying is a potential technique for forming flexible tapes from the brittle high T_c oxides. It is possible to obtain superconducting $YBa_2Cu_3O_x$ coatings by a suitable heat-treatment after spraying. In an effort to improve the critical current densities of the coatings, the effect of additions of Ag_2O, Bi_2O_3, and SnO_2 to the $YBa_2Cu_3O_x$ powder used for spraying was studied. The maximum J_c value of 75 A/cm^2 was obtained for the sample doped with 5% SnO_2.

K.A.D. Prasad, K.C. Lahiry, D.M. Reddy, S.C. Mohan, S.R. Kumar, N. Ramadass, S. Ravichandran, R. Somasundaram, G. Swaminathan, and K. Venugopal. Cited: International Conference on Superconductivity—I, *Bulletin of Materials Science (India)*, *14*(2), 1991 [in English]. ISSN: 0250-6327. PHOTOCOPY ORDER NUMBER: 199211-F2-C-1787.

Wear

Wear Characteristics of Plasma Sprayed Coatings Subjected to Abrasion Blasting Stress. The object of the study was the resistance of plasma sprayed coatings to abrasion by blasting. Tests were conducted on sprayed coatings consisting of a range of materials. The influence of various post-spraying heat treatments was also investigated (temperature aging under shielding gas, chemical vapour coating with TiC or TiC/titanium nitride followed by hardening, gas oxi-nitration). The results obtained were compared with the values achieved for solid samples of St37.

A. Oswald and K. Husemann, Cited: Original Title: Verschleissverhalten Plasmagespritzter Schichten bei Strahlbeanspruchung. *Schweissen und Schneiden*, *44*(8), 1992, 432-436 [in German]. (In English, p E147-E150). PHOTOCOPY ORDER NUMBER: 199212-57-1709.

Bond Coats for TBCs

Performance Improving Mechanisms of Zirconia/Pack-Aluminized MCrAlY Thermal Barrier Coatings. II. Performance Improving Mechanisms. The proposed performance improving mechanisms, which include the oxidation rate of the bond coat, bond coat oxide phase, surface roughness of the bond coat and the formation mechanisms of aluminide layer on the bond coat, were correlated with the results of thermal cyclic tests and fractographic investigations. It was concluded that the capability of performance improvement on thermal barrier coatings (TBCs) was directly responsed by the capability of decrease in oxidation rate of the bond coat. A relatively high-Al activity Al inward diffusion controlled pack-cementation process occurred on the aluminized CoCrAlY bond coat but a relatively low-Al activity Ni outward diffusion dominated process occurred on aluminized CoNiCrAlY and CoCrAlY bond coats. The characteristics of Ni-outward forming aluminide layer resulted in the flattened surface of the aluminized NiCrAlY bond coat and hence the incapability of performance improvement on TBCs. Co-29Cr-6Al-1Y, Ni-22Cr-10Al-1Y and Co-32Ni-21Cr-8Al-0.5V are discussed as bond coats on MAR-M247.

B.-C. Wu, J.D. Chan, E. Chang. Cited: *MRL Bulletin of Research and Development*, *6*(1), 1992, 81-92 [in English]. PHOTOCOPY ORDER NUMBER: 199212-58-1569.

Performance Improving Mechanisms of Zirconia/Pack-Aluminized MCrAlY Thermal Barrier Coatings. I. Performance of TBCs Specimens. The effects of a 980 °C, 4 h pack aluminizing treatment on thermal barrier coating (TBC) specimens with various bond coat, Co-29Cr-6Al-1Y, Co-32Ni-21Cr-8Al-0.5Y and Ni-22Cr-10Al-1Y were evaluated by thermal cyclic tests within temperature range from 1050-1200 °C to elucidate the performance improving mechanisms of TBCs. Microstructures of as-aluminized bond coat and results of thermal cyclic tests were investigated and discussed. Experimental results showed that the performance of TBCs at all testing temperatures can be remarkably improved after CoCrAlY bond coat was aluminized. However, the performance improvement on specimens with CoNiCrAlY bond coat was effective only at testing temperatures >1075 °C, and the applied aluminizing treatment was incapable of improving the performance of TBCs specimens with NiCrAlY bond coat due to poor bonding strength between zirconia top coat and aluminized NiCrAlY bond coat. MAR-M247 is used as a substrate.

B.-C. Wu, A.Y.M. Peng, C.S. Lin, E. Chang. Cited: *MRL Bulletin of Research and Development*, *6*(1), 1992, 71-80 [in English]. PHOTOCOPY ORDER NUMBER: 199212-58-1568.

Book

Operator Qualification

Guide for Thermal-Spray Operator Qualification.

Report No.: ANSI/AWS, American Welding Society, 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199212-72-0509.

Composites

Co-Deposition

Microstructure, Excess Solid Solubility, and Elevated-Temperature Mechanical Behavior of Spray-Atomized and Codeposited Al-Ti-SiC_p. The microstructure, thermal stability, and elevated temperature mechanical behavior of Al-Ti-SiC_p metal matrix composites (MMCs) processed by spray atomization and codeposition were investigated. The evolution of the microstructure of the spray-deposited material before and after thermal annealing was studied using X-ray diffractometry, transmission electron microscopy (TEM), scanning electron microscopy (SEM), and optical microscopy. The thermal stability of the spray-deposited materials was determined by monitoring the changes in hardness after isochronal thermal anneals at various temperatures. The results of X-ray and microanalysis studies revealed the presence of a supersaturated solid solution of Ti in αAl in the spray-atomized and codeposited material, with Ti concentrations in the 0.8-1.1 wt.% range. The formation of an extended solid solution was discussed in light of the cooling rates present during atomization and, subsequently, during deposition. Regarding mechanical behavior, the present results suggest that the as-spray deposited and hot-extruded Al-Ti matrix is thermally stable up to a temperature of 400 deg C and that the excess solid solubility of Ti in alpha Al, resulting from the rapid quench during processing, is maintained up to a temperature of 300 °C. The elevated-temperature mechanical properties of the hot extruded spray-deposited materials were studied following a 100 h exposure at 250, 350, and 450 °C; the room-temperature mechanical properties were also determined. Results show that the elevated-temperature yield strength of the spray-deposited and extruded materials compared favorably to those of the ingot material, but were inferior to those of mechanically alloyed Al-Ti materials. In addition, TEM studies showed no evidence of interfacial reactions at the Al—Ti/SiC sub p interface.

M. Gupta, F.A. Mohamed, E.J. Lavernia, J. Juarez-Islas, and W.E. Frazier. Cited: *Metallurgical Transactions B*, *23B*(6), 1992, 719-736 [in English]. PHOTOCOPY ORDER NUMBER: 199212-31-3849.

Environmental Specifications

New Laws Point to Powder. The surface coating industry emits 250 000 t of solvents/year in the UK. Powder coating has long been recognized as an efficient, cost effective way of coating metal. Now, with the new environmental legislation in the UK and a number of new applications opening up for metallic powder coating, the switch from liquid to powder finishing seems more and more attractive.

B. Russell. Cited: *Sheet Metal Industries*, *69*(2), 1992, 24, 26 [in English]. PHOTOCOPY ORDER NUMBER: 199211-58-1531.

Feedstock

CrAlMo Powders

Plasma Spraying of Coatings for Application With "LOW-NO_x" Firing Techniques. Details are given of the LOW-NO_x coatings (CrAlMo, CrNi and CrAl), substrate materials (e.g. 310, 15Mo3 and 10CrMo9 10), and the plasma spray process using a compressed air knife. The phenomenon of layer separation which has an unfavourable effect on the mechanical and anti-corrosion properties and how it can be avoided, using a compressed air knife, is discussed. Details are given of the adhesive strength of specimens having an adhesive layer of 95% Ni and 5% Al and of the tension appliance used to measure it. Optimum adhesive strength of the coatings materials (50Cr-50Ni and Fe-24Cr-8Al) can be achieved by intensive cooling during spraying and the prevention of concentrated vapour condensates. The plasma sprayed coatings of these materials can resist rapidly imposed plastic strain of <0.5%. The resistance to greater plastic deformation or the avoidance of embrittlement can be attained by spraying under vacuum.

J.M. Houben and G. van Liempd. Cited: Original Title: Plasmaspuiten van Cleklagen Voor Toepassing bij "LOW-NO_x" Stooktechnieken. *Materialen*, (2), 1992, 23-27. [in Dutch]. PHOTOCOPY ORDER NUMBER: 199210-58-1324.

String Morphology

String Materials Are a Reserve for Efficient Spraying. Alternatives to powders for spraying are considered. In view of the impossibility of making wire out of many high-melting metals, oxides and cemented carbides, the use of string made from powder mixtures with an organic binder has been investigated. The following techniques of using such materials and a twin-jet plasma gun were studied: spraying coatings from fine materials that are not free-flowing; spraying coatings from undispersed powders of a wide particle-size range; and spraying of fine powders several microns in size. Strings were made by extrusion. Coatings obtained from various strings under different spraying conditions were investigated and promising results are discussed.

Zh.Zh. Zheenbaev, M.A. Samsonov. Cited: *Tekhnicheskikh*, (5), 1990, 89-93 [in Russian]. PHOTOCOPY ORDER NUMBER: 199211-58-1469.

Mechanical Properties

Fatigue

Fatigue Strength of Sprayed Specimen—Study on Flame Spraying. I. Various methods of surface treatment have been performed for improving the properties of metals and alloys. Among these surface treatments, the flame sprayed coating technique is selected, since this technique is expected to be one of the effective methods for surface treatment. The flame spraying used has low cost equipment and easy maintenance, and can be adopted in various places and forms. The fatigue strength of the high strength steel (HT 60) is examined by the sprayed specimens with four kinds of thermal spray materials [Zn, Al, ceramics and metallizing alloy ($Ni_{90}Al_5Mo_5$)]. The results are as follows. The surfaces of the turning and blasted specimens have a little higher hardness due to the work hardening effect. The fatigue limit of the rotate-bending fatigue test is the same as that of the blasted specimen, and it has no relation to the blasted specimen and the kinds of spray material, except the metallizing alloy material. The microstructure of the base metal near the sprayed coating is the mixture of ferrite and pearlite. The micrography of the fatigue fracture surface shows mainly dimple and quasi-striation pattern.

H. Yara and D. Fujiki. Cited: *Quarterly Journal of the Japan Welding Society, 10*(2), 1992, 79-83 [in Japanese]. PHOTOCOPY ORDER NUMBER: 199212-57-1507.

Metallography

Preparation of VPS and PVD Coatings for Metallographic and TEM Investigations. The aim is to give some advice for the faultless metallographic preparation of vacuum plasma sprayed coatings. Several coating/substrate combinations using metals, alloys and ceramics were investigated to derive some general rules. The second part deals with a preparation technique for cross-sections of physical vapour deposition coatings. This technique was optimized for titanium nitride and Ti(C,N) coatings on hardmetals which were examined in an analytical transmission electron microscope.

G. Block, D. Hirschfield, I.-M Lichtenauer, and A. Pohl. Cited: Conference: Progress in Materials Analysis, Vol 5, 1991, *Mikrochimica Acta, 107*(3-6), 1992, 279-282 [in English]. PHOTOCOPY ORDER NUMBER: 199212-21-0353.

Method for Micrographic Examination of Plasma Coatings. Artem has developed a technique to examine a plasma spray coating composed primarily of yttrium zirconia. In order not to alter the structure of the coating specifically when the sample is cut and prepared, the sample is mounted under pressure in a liquid environment.

P. Villard. Cited: Original Title: Methode d'Examen Micrographique de Revetement Plasma. *Galvano-Organo-Traitements de Surface*, (624), 1992, 247-248 [in French]. PHOTOCOPY ORDER NUMBER: 199210-57-1305.

Modeling

In-Flight Properties

A Prediction Model to Assist Plasma and HVOF Spraying. A theoretical prediction model is developed to estimate the in-flight velocity, temperature and size of a particle during plasma and HVOF spraying. The salient features of this model are outlined and the model predictions are examined through some example calculations performed under typical spraying conditions. Comparison with experimental data reveals that the present method enables accurate predictions. The principal advantages and shortcomings of the plasma and HVOF systems are also discussed based on the model estimates. Shown is spraying alumina, yttria-stabilized zirconia, WC—12Co and Ni.

S.V. Joshi. Cited: *Materials Letters, 14*(1), 1992, 31-36 [in English]. PHOTOCOPY ORDER NUMBER: 199211-57-1487.

Residual Stress

The Effect of Substrate Temperature and Thickness on Residual Stresses in Plasma Sprayed Deposits. Residual stresses have been studied experimentally by continuously monitoring type curvature of the substrate/deposit couple during spraying, using a video recording system. Data obtained in this way have been compared with predictions from a numerical model describing the heat flow and thermal contraction effects involved. This comparison facilitated evaluation of the boundary conditions for the model. Information is presented for spraying of Ti, alumina and a FeCrAlY alloy onto metallic substrates. It is shown for the Ti deposition (on a substrate of higher expansivity) that raising the substrate temperature during spraying makes the final residual stress more compressive, as a result of the increased contribution from differential thermal contraction and a reduced quenching stress (which is always tensile in the coating). The effect of changing from a thin to a thick substrate was studied for deposition of FeCrAlY and alumina. For the FeCrAlY, the main effect of a thicker substrate was to reduce the through-thickness stress gradient in the coating. This occurs because the creation of curvature during spraying allows relaxation of the stresses in the parts of the coating nearer the interface. For the alumina, in which the stresses are in any event much lower, the main effect was to make the coating stresses more tensile, as a result of lower substrate temperatures and hence less differential thermal contraction after spraying.

S.C. Gill and T.W. Clyne. Cited: Conference: *Euromat 91. Vol. 1., Advanced Processing*, 1992, 289-297 [in English]. PHOTOCOPY ORDER NUMBER: 199211-58-1475.

News

New Center

Surface Technology: Pro-Long Life—Contra-Wear. Preussag AG has created a Center for Modern Surface Technology. This center offers treatments for problems on surfaces concerning wear, corrosion, friction, thermal, electrical and optical effects. It has facilities for applying thick coatings by arc, wire flame, powder flame, high velocity flame, plasma and vacuum plasma sprays. For laser treatment, a 10 kW CO_2 laser is available. Thin coatings can be deposited by PVD. Grinding facilities can accommodate parts up to 5000 mm long and 630 mm in diameter. Nickel and Cr coatings are discussed. Salzgitter Oberflachentechnik GmbH has tested the system thoroughly, and provided all initial data on performance for this report.

Cited: Original Title: Oberflachentechnik: Pro Lebensdauer—Contra Verschleiss., *Verein Deutscher Ingenieure Zeitschrift, 134*(1), 1992, 14-18 [in German]. PHOTOCOPY ORDER NUMBER: 199210-58-1371.

Patent

Arc Spraying

Arc Sprayed Continuously Reinforced Aluminum Base Composites and Method. A metal matrix composite is produced by rapidly solidifying an Al-base alloy directly 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. Cited: Patent No. US5130209, 1991, 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199211-62-1333.

Boride Powder

Thermal Spray Material and Its Coated Article Excellent in High-Temperature Wear Resistance and Build-Up Resistance. A thermal spray material which is a composite powder or a blended powder containing metal boride particles and alloy particles is disclosed wherein: the metal boride particles constitute 5-50 vol.% of the thermal spray material, and each of the alloy particles contains 5-40 wt.% advantageously 15-40 wt.%, of Cr, 5-20 wt.% of Al, and the balance of at least one of Ni, cobalt and Fe, and incidental impurities.

Y. Iwasaki, J. Oohori, N. Sato, N. Kawamura, and K. Kiyoshi. Cited: European Patent No. EP0440437, *Auszuge aus den Europaischen Patentanmeldungen, Teil I 7*(32), 1991, 3000 [in English]. PHOTOCOPY ORDER NUMBER: 199212-58-1620.

Electric Connectors

Electric Connectors Formed of Aluminium Spray Coated With Copper. A bimetallic electric connector for Cu to Al joints is made by first forming a bulk component of Al (typically a stock Al connector) and then coating an appropriate part of its surface with Cu or a conductive Cu alloy (such as brass) by a thermal spray coating technique, such as plasma spraying or gas-wire metallizing. The coating may be porous, in which case the use of a pore sealant, e.g. an air-drying glyceride resin, is recommended and this may also form a corrosion-resistant layer over the edge of the Cu (or Cu alloy) coating. Suitable coating and sealing techniques are commercially available. The technique is less expensive than conventional friction welding, and offers additional design flexibility. The connector illustrated comprises an Al tube flattened at one end to form a palm through which are formed holes, the entire surface area to the left being coated with Cu.

G.J. Davidson. Cited: Patent No. GB2252569, U.K., 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199212-63-0771.

Zinc Coating

Method of Producing Aluminum Tube Covered With Zinc. A method of producing an Al tube covered by a layer of Zn using a continuous cold forming machine which includes the steps of: providing an extrusion die having a heating device and an inert gas-blowing tube to the cold forming machine, introducing an Al prime wire to the cold forming machine, extruding the prime wire through the extrusion die to form an Al tube while heating the die to a high temperature and blowing an inert gas across the die toward the tube to provide a high-temperature, non-oxidized Al tube, and flame spraying Zn powder onto the outer non-oxidized surface of the tube to cover the surface and provide an anticorrosive layer of Zn on the Al tube.

T. Matsuoka, Cited: Patent No. US5133126, USA 1991, 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199211-61-0892.

Processes

D-Gun

A New Detonation Cannon: the Super D-Gun of Union Carbide. Union Carbide Coating Service Ltd. specializes in surface coatings to increase wear and erosion resistance. A new cannon has been developed with a high gas pressure. This cannon fires material at high speeds, creating a better coating adherence to the substrate, better fracture resistance, improved resilience, erosion and impact resistance, and better surface finishes. Stress-strain data are given for coated and uncoated Ti-6Al-4V, Al 7075 and, 4340 steel.

Cited: Original Title: Un Nouveau Canon a Detonation: le Super D-Gun d'Union Carbide, *Industrie Cfe*, (4), 1990, 34-38 [in French]. PHOTOCOPY ORDER NUMBER: 199211-58-1419.

Laser Thermal Spraying

Friction and Wear Properties of Titanium Films Formed on Aluminium by Laser Thermal Spraying. The friction and wear behaviour of Ti coatings on 99.0% Al is examined under sliding conditions using a ball-on-disk tribometer. The coatings are formed by newly developed laser thermal spraying using Ti wire as the spraying material. The tribological characteristics of coatings are markedly influenced by the atmosphere used in the laser thermal spraying process and by the film thickness. This is because the main component of the coated film formed in Ar atmosphere is pure Ti, and that formed in nitrogen atmosphere is titanium nitride. It has been found that the Ti coating sprayed in a N atmosphere has a good bond strength and can provide a good wear-resistant surface.

M. Kaneta, K. Matsuda, J. Matsuda, and A. Utsumi. Cited: *Wear, 156*(1), 1992, 161-173 [in English]. PHOTOCOPY ORDER NUMBER: 199212-31-4005.

RF Spraying

Application of Radio Frequency Plasma Spraying to Fabrication of Intermetallic Matrix Composite Coatings. Ti_3Al intermetallic compound coating on carbon steel was fabricated just as sprayed conditions by rf plasma spraying without any after heat treatment. Mechanically alloyed Ti-Al powders, which were highly mixed and bonded using SUS304 as a ball mill pot, stainless steel as a grinding vial and steel as a ball pestle, were introduced to plasma spraying. DC plasma sprayings were also conducted under various combinations of working gases for comparison purposes. The results obtained are summarized as follows. Ti_3Al intermetallic coatings could not be obtained by the dc plasma spray process. The coatings obtained by dc plasma spraying had layer structures of different compositions. Too large acceleration by the dc plasma jet should be attributed to this coating structure. Ti_3Al intermetallic coatings were prepared by rf plasma spraying of MA powders without any after heat treatments. The feasibility of the combination process of mechanical alloying and rf plasma spraying to fabricate the intermetallic coatings was also discussed.

M. Fukumoto and M.I. Boulos. Cited: *Journal of the Japan Institute of Metals, 56*(6), 1992, 678-683 [in Japanese]. PHOTOCOPY ORDER NUMBER: 199211-58-1438.

Surface

Structural Examinations of Plasma Spray Coatings Fused by Electron Beam Treatment. The advantages and disadvantages of several methods for fusing thermal spray coatings are described. The results of electron beam fusing of plasma sprayed FeCrC-alloy coatings with and without additions of tungsten carbide on heat treatable steel (30CrMoV9) are demonstrated by means of hardness profiles and structural examinations. First results concerning the influence of electron beam treatment on the resistance to wear are presented.

B. Simmen, A. Oswald, and S. Keitel. Cited: Original Title: Untersuchungen zur Gefugeausbildung in Elektronenstrahlnachbehandelten Plasmaspritzschichten, Technische Hochschule Wismar Conference: 47th Hardening Conference, *Harterei-Technische Mitteilungen, 47*(3), 1992, 161-168 [in German]. PHOTOCOPY ORDER NUMBER: 199211-58-1462.

Ultrasound Treatment

Effect of Ultrasound Treatment on Mass Transfer Processes in Thermally Sprayed Coatings. Experiments were carried out on cylindrical specimens (10 mm in diameter, 10 mm high) of low-carbon steel St3, with a thermally sprayed coating of PNE-1 Ni powder applied to one end, to investigate the effect of ultrasonic impact treatment on the mass transfer in the surface layer of the substrate. It is found that the treatment stimulates diffusion processes and effectively improves the properties of the thermally sprayed coating. The results can be used for optimizing the treatment of the Ni/low-C steel system.

Yu.S. Borisov, A.G. Ilenko, G.I. Prokopenko, and A.L. Gaidarenko. Cited: *Metallofizika, 13*(2), 1991, 99-103 [in Russian]. PHOTOCOPY ORDER NUMBER: 199212-58-1567.

Variables for TBCs

Effect of Substrate Cooling on Properties of Ceramic Coatings. An overview covers the relationships between deposition temperature, microstructure and mechanical properties of ceramic coatings produced by plasma spraying of ceria- and yttria-partially stabilized zirconia and alumina on steel and Al substrates, respectively. The residual stresses of coatings are discussed along with the microstructural details of deposition in terms of microcracks, porosity and additional effects due to phase composition and valence state. The thermal shock resistance and adhesion of coatings are correlated to the deposition temperature.

C. Bartuli and S. Sturlese. Cited: *Rivista Italiana della Saldatura, 43*(6), 1991, 539-548 [in English]. PHOTOCOPY ORDER NUMBER: 199212-57-1599.

Review

General

Thermal Spraying—An Overview on Processes, Materials and Applications. Within surface technologies, thermal spraying is one of the most important techniques for depositing functional coatings. Coatings for various applications can be produced using a variety of coating techniques and coating materials. Saving energy and saving rare and expensive raw materials are additional important consequences of thermal spray technology. The technology is an important surfacing method used to enhance the performance of materials of a diverse range of applications in new parts production, maintenance and repair in every engineering field and, nowadays, life as well. Shown are Ti, fiber/plastic camshaft and implants.

E. Lugscheider and P. Jokiel. Cited: *Euromat 91. Vol 1. Advanced Processing*, 1992, 281-288 [in English]. PHOTOCOPY ORDER NUMBER: 199211-57-1431.

Spray Forming

Billets

Equipment and Safety for the Design, Engineering and Construction of Spray Deposition Plants. Mannesmann Demag Huttentechnik constructs complete spray deposition plants for the production of billets, tubes and falt products of different materials such as high alloy steels, Ni-base alloys, Al, Cu and MMC. A billet spray deposition plant is described in detail. The description of the main plant unit, the spray chamber, includes all important construction elements for the spray deposition work, e.g. spray chamber design, the rotating, lifting and lowering equipment, centering system, extracting system, etc. Safety features when spraying reactive materials are discussed. An outlook to the newest plant development presents continuously horizontal working spray deposition plants for the production of, e.g. billets. The all-embracing instrumentation and control technique is described. The presented general equipment concept is divided into main and subsidiary units. The secondary units consist of the gas cleaning system, an optional gas recycling system and an overspray recycling system.

R. Fuchs, F. Keutgen, U. Urlau, and D. Zebrowski. Cited: *Powder Metallurgy Science & Technology*, *3*(1), 1991, 23-34 [in English]. PHOTOCOPY ORDER NUMBER: 199211-62-1282.

Functionally Gradient

Developing Fabrication Process of a Large-Size FGM by Using LPPS. Fabrication process of a large-sized functionally gradient material (ZrO_2-8 wt.% Y_2O_3Ni-20 wt.% Cr) by using low pressure plasma spraying (LPPS) was developed. The problem for the enlargement is the thermal distortion of substrates (e.g. SUS304) which occurs during pre-heating and spraying. To solve this problem, it is necessary to make clear the effect of substrate temperature on the distortion. Under the optimum condition, such as maximum temperature < 600 °C and temperature distribution < 80 °C of substrate during pre-heating, distortion was successfully minimized.

H. Hamatani, N. Shimada, Y. Ichiyama, S. Kitaguchi, and T. Saito. Cited: *Journal of the Japan Society of Powder and Powder Metallurgy*, *39*(4), 1992, 299-302 [in Japanese]. PHOTOCOPY ORDER NUMBER: 199211-57-1402.

Surface Finishing

Surface Press Polishing of Plasma-Sprayed Metal Coatings. Plasma-coated surfaces generally have to be machined to satisfy the quality requirements for further processing. In addition to turning and grinding, press polishing is gaining increasing importance in this respect. It is based on the principle of levelling the surface without removing material. In this way the microhardness is increased and corrosion resistance improved. Iron, Ni, Ni-alloy and Al-alloy coatings on steel are discussed.

K.-H. Frackowiak and A. Oswald. Cited: Original Title: Oberflachenfeinwalzen Plasmagespritzter Metallschichten, *Schweissen und Schneiden*, *44*(6), 1992, 331-333 [in German] ([In English p. E119-E120). PHOTOCOPY ORDER NUMBER: 199212-58-1578.

Surface Preparation

Waterjet Strips Tenacious Coatings. The waterjet is being used to remove tough thermal-sprayed coatings of various alloys, carbides, and ceramics from aircraft-turbine components prior to resurfacing. Waterjets can provide considerable time savings over such traditional removal methods as machining, grinding, hand scraping, dipping in acid or other chemical baths, or grit blasting. Since the waterjet can be directed to a high degree of precision, coatings can be removed selectively in areas difficult to access normally—and without masking as is required with chemical-removal methods. Examples are given of the removal of a number of coatings including: 95Ni-5Al bond coat; zirconia thermal-barrier coating; chromium- and tungsten carbide wear-resistant coatings; arc sprayed Al and Ti/Cr/Ni; plasma-sprayed Ti alloy, Ni-Al, and chromium carbide/Nichrome; and high-velocity oxyfuel-applied Al and Al—polyester.

J.A. Vaccari. Cited: *American Machinist*, *136*(4), 1992, 46-47 [in English]. PHOTOCOPY ORDER NUMBER: 199211-58-1488.

Wear

Alumina/Titania

Wear of Plasma-Sprayed Alumina—Titania Coatings. Plasma-sprayed alumina-titania coatings are being increasingly employed as wear-control deposits. The combination of the two component oxides appears to impart the desirable properties of hardness/wear resistance and lubricity. The means through which powder characteristics and plasma spray processing influence the wear behavior of such coatings were studied. Plasma-sprayed coatings of alumina, alumina-3, 13 and 40 wt.% titania fused and alumina-13 and 40 wt.% titania composite, and nominally pure titania, were tested in an oil-alumina abrasive slurry against cast iron. Wear rates vs. spray distance were compared in an effort to determine the degree of spray-process-sensitivity for the various coatings. Wear behavior of the coatings obtained from the composite and the fused powder were comparable, with the fused-powder-based coating generally indicating a lower rate of wear. Of central importance, however, was the fact that the behavior of the coatings from the fused powder was substantially more "process variation forgiving" than were those based on the composite powder. In other words, the wear behavior for the fused powder coating showed a small spray distance effect, while the coatings based on the composite powder displayed very strong dependencies of wear rate on spray distance. This effect has important industrial implications.

R.A. Zatorski and H. Herman. Cited: Conference: *High Performance Ceramic Films and Coatings*, 1991, 591-601 [in English]. PHOTOCOPY ORDER NUMBER: 199211-31-3420.

Alumina Coatings

Study of Properties of Ceramic (Al_2O_3-Based) Plasma Sprayed Coatings. The effect of plasma spraying equipment and technology used on the mechanism of coating formation is studied. The study of welding parameters on adherence of coating on Al_2O_3 basis sprayed on low-carbon steel is presented. The effect of torch-substrate distance on the coating properties is given.

E. Grutka, D. Jankura, D. Kniewald. Cited: *Zvaranie*, *41*(5), 1992, 97-101 [in Czech]. PHOTOCOPY ORDER NUMBER: 199211-55-1773.

Fracture Mechanics

A Fracture Model for Wear Mechanism in Plasma Sprayed Ceramic Coating Materials. Wear resistant WC and Cr_2O_3 coatings were applied on to stainless steel ring surfaces by the plasma spray technique. Wear tests were conducted employing conforming and non-conforming block-on-ring arrangements in which coated rings slid against 45 mild steel or stainless steel. The worn surfaces and cross-section surfaces of the coatings and steel were examined using scanning electron microscopy. The wear rates of the coatings were measured and the results showed that the wear rates were related to the normal load by an exponent of 2/3. The mechanisms of the coating material removal during wear were examined. The hard particles fractured from the coating surface were trapped in the interfacial layer on the steel surface. These impregnated particles acted like moving indenters, and caused median fractures on the coating surfaces and fractures between layers in the coatings (lateral fracture). The extension of the median crack was found to be the controlling factor. A model based on the median fracture extension mechanism was set up and it was found that the model agreed well with the experimental results. The difference of wear mechanisms between ceramic coating materials and bulk ceramics was also discussed.

Z. Tong, C. Ding, and D. Yan. Cited: *Wear*, *155*(2), 1992, 309-316 [in English]. PHOTOCOPY ORDER NUMBER: 199212-31-3731.

WC Characterization

Characterization of Tungsten Carbide Coatings as a Function of Powder Manufacturing and Deposition Technologies. The starting powder and deposition process are examined relative to their effect on the resulting coating. Three different types of tungsten carbide-cobalt powders were deposited using both high velocity oxygen-fuel (HVOF) and high energy plasma (HEP) thermal spray techniques. The coatings were subjected to various wear tests which included abrasive wear, room temperature particle erosion and ring-on-block wear. Optical microscopy, X-ray diffraction, chemical analysis and differential thermal analysis (DTA) were used to relate the coating's properties to their wear performance.

J. Nerz, B. Kushner, and A. Rotolico. Cited: Conference: High Performance Ceramic Films and Coatings, 1991, 27-36 [in English]. PHOTOCOPY ORDER NUMBER: 199211-57-1358.