Selected Abstracts of Thermal Spray Literature

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Analysis

XRD and SEM of Mo

Synthesis Analysis of Thin Films by XRD and SEM. This is a report of an investigation by XRD and SEM of thin coatings such as are applied by plasma spray methods for improving properties, such as are wanted in electronic devices, and for increasing durability in service. Samples were studied that had been coated under controlled conditions: physical vapor deposits (PVD) of titanium nitride on steel plate and plasma spray coatings of molybdenum on steel plate. X-ray determinations were made of X-ray lattice constants, crystallite size, lattice strain, orientation and residual stress, before and after strain was applied to the specimens.

G. Fujinawa and S. Tobe, Cited: Conf: *Advances in X-Ray Analysis*, Vol. 35A, (Hilo and Honolulu, Hawaii), 7-16 Aug 1991, Plenum Publishing Corp., 1992, p 197-203 [in English]. PHOTOCOPY ORDER NUMBER: 199411-57-1312.

Application

Biomaterials

Surface Reactivity and Biocompatibility of Bulk Glass and Glass Coatings. Following a comparison of conventional and biofunctional glasses, the bioactivity of glass was examined associated with a hydrolytic degradation process and the development of a hydroxyapatite calcium phosphate film at the glass/bone tissue interface. The main compositions of bioactive glasses are reported. Experiments in the field of reactivity and biocompatibility of these glasses are described. A "biovetro" has been developed exhibiting good osteoconductive properties, and its possible application as coatings with the same features deposited by plasma spray onto metal substrates have been evaluated.

B. Locardi, Cited: Conf: *Bioceramics and the Human Body* (Faenza, Italy), 2-5 Apr 1991, Elsevier Applied Science, 1992, p 148-155 [in English]. PHOTOCOPY ORDER NUMBER: 199410-57-1252.

Cytoxicity Investigations of Plasma Sprayed Calcium Phosphate Coatings. One potential alternative material to replace hydroxyapatite (HAp) as a coating material for plasma-sprayed coatings on implants for hip replacement is fluorapatite (FAp). FAp has advantages over HAp regarding the capability of being chemically stable during the coating process. This leads to surface coatings containing high apatite rates with a mechanical stability (bond strength, microhardness) comparable to HAp. From the technical point of view, the production of FAp coatings is well investigated, although studies on biocompatibility of FAp coatings are fewer. This paper reports the production of HAp and FAp coatings with varying solubilities by plasma spraying (on Ti-6Al-4V plates) and their in vitro cytotoxicity. Varying solubilities were realized by using modified plasma-spray parameters in common with suitable apatite powders with different crystallinities. Coating solubilities were evaluated by immersing the plasma-sprayed coatings in deionized water and electrolyte solution. Afterwards, cytotoxicity tests were performed using a modified half-slide technique. Cell attachment and cell morphology were evaluated. Neither HAp nor HAp coatings exhibited cytoxic influence on cells in culture. Results suggest that HAp coatings stimulate cell growth and FAp coatings do not. This could be explained by a neagative effect on cell growth of the dissolved fluoride ions.

E. Lugscheider, M. Knepper, B. Heimberg, A. Dekker, C.J. Kirkpatrick, Cited: *J. Mater. Sci.: Mater. Med.*, Vol 5 (No. 6-7), June-July 1994, p 371-375 [in English]. ISSN: 0957-4530. PHOTOCOPY ORDER NUMBER: 199410-57-1238.

Evaluation of Different Preparations of Plasma-Spray Hydroxyapatite Coating on Titanium Alloy and Duplex Stainless Steel in the Rabbit. Many variables are involved in hydroxyapatite coating of metals by plasma-spray techniques. The authors have investigated the biological response to some of the most relevant variables in a controlled in vivo trial. The bone response in the rabbit toward hydroxyapatite coated cylinders was studied keeping the following variables fixed: (a) crystallinity of coating (>90% and between 70 and 60%); (b) thickness of coating (50 and 100 μm); (c) metallic substrate (Ti alloy Ti-6Al-4V and duplex stainless steel 305). Analysis of the results highlight the importance of defining the crystallinity of the coating to forecast its in vivo behavior: highly crystalline coating is more stable in time but can give rise to fragmented bulky particles; a less crystalline coating is subject to slow degradation in the long term but facilitates its substitution by newly formed bone. Furthermore, it has been found that no relevant differences can be ascribed to a variation in coating thickness between 50 and 100 μm. It has also been observed that there are no differences when duplex stainless steel is used instead of Ti alloy as metallic substrate, confirming that bone responds primarily to the coating.

P. Leali Tranquilli, A. Merolli, and O. Palmacci, Cited: *J. Mater. Sci.: Mater. Med.*, Vol 5 (No. 6-7), June-July 1994, p 345-349 [in English]. ISSN: 0957-4530. PHOTOCOPY ORDER NUMBER: 199410-57-1236.

Biological Effects of Aluminium Diffusion From Plasma-Sprayed Alumina Coatings. Plasma-sprayed alumina (Al_2O_3) coatings on metal stems of hip prostheses are used to favor bone apposition on the stem without fibrous interposition. We tested both in vitro and in vivo in rabbits, alumina coatings in order to evaluate the biological effect of this material on bone. Mice Fibroblasts were grown on Al_2O_3-coated stainless steel discs and time course of Al concentration was recorded in two phosphate and citrate buffers (pH4 and 7) bathing the alumina coated discs. Alumina-coated cylinders were implanted into femur condyles of ten rabbits for periods of time from 1-6 months. Then, they were histologically analyzed using light and scanning electron microscopy, and X-ray microanalysis. Cell proliferation was not affected on alumina coatings compared to controls. In pH 4 buffer, Al was released from the coatings. From a period of implantation of 4-6 months an increasing demineralization process took place in the bone at the coating contact. Aurine staining showed the presence of Al at the interface between the non-mineralized and the mineralized bone. These results suggest the Al is released from alumina coatings and leads to bone demineralization at the coating contact.

P. Frayssinet, F. Tourenne, N. Rouquet, G Bonel, and P. Conte, Cited: *J. Mater. Sci.: Mater. Med.*, Vol 5 (No. 6-7), June-July 1994, p 491-494 [in English]. ISSN: 0957-4530. PHOTOCOPY ORDER NUMBER: 199410-34-0670.

Bone Ingrowth Analysis and Interface Evaluation on Hydroxyapatite Coated vs. Uncoated Titanium Porous Bone Implants. Fourteen Ti porous-coated implants with a cylindrical shape (length 22 mm and diameter 5 ±3 mm) were prepared. Bead size was 250-350 μm. Seven implants were plasma-sprayed with hydroxyapatite and the other seven remained uncoated. Implants, both hydroxyapatite-coated and uncoated, were randomly selected and press fitted longitudinally into the proximal femoral cancellous bone bilaterally in seven dogs. After 12 weeks, the dogs were euthanized and push-out and histomorphometric backscattered electron microscopy studies were carried out. No statistical differences in the mechanical tests were observed. Comparing hydroxyapatite-coated vs. uncoated implants, the histomorphometric results showed statistical significance in the percentage of bone ($p = 0.01$); and in bone index, ratio between bone ingrowth and bone ongrowth ($p = 0.01$). The size of the bone implant interface was smaller in the hydroxyapatite-coated implants than in the uncoated ($p = 0.29$). Beneficial effects of hydroxyapatite applied to spherical bead Ti porous coatings were demonstrated. These morphological and histomorphometric results support the concepts involved with the use of hydroxyapatite as a coating for uncemented porous prosthetic devices.

A. Moroni, V.L. Caja, C. Sabato, E.L. Egger, F Gottsauner-Wolf, and E.Y.S. Chao, Cited: *J. Mater. Sci.: Mater. Med.*, Vol 5 (No. 6-7), June-July 1994, p 411-416 [in English]. ISSN: 0957-4530. PHOTOCOPY ORDER NUMBER: 199410-34-0669.

Tensile and Torsional Shear Strength of the Bone Implant Interface of Titanium Implants in the Rabbit. The effect of three different Ti plasma flame spray coatings on the tensile strength and the effect of macrostructures on the torsional shear strength of the bone implant interface was studied. Titanium cylinders, of 8 mm length and 4 mm diameter, were implanted into distal rabbit femurs. For tensile testing, two porous Ti plasma flame spray coatings, Plasmapore, fine-grain Plasmapore, one dense, unporous coating, Plasmapore fine on cylinders with axial grooves, and corundum blasted specimens as control group were used. For torsional loading smooth, and macrostructured cylinders with axial grooves, both with Plasmapore fine-coating, were used. After 168 days the implant-bone interface was biomechanically tested. A tensile test and a torsional shear test was performed. The results indicated that the Ti plasma flame spray coating did not differ in their tensile interface strength, but yielded a stronger interface as sandblasted surfaces and that the macrostructures did not influence the torsional shear strength.

L. Pr ster, Ch Voigt, G. Fuhrmann, U.M. Gross, Cited: *J. Mater. Sci.: Mater. Med.*, Vol 5 (No. 6-7), June-July 1994, p 314-319 [in English]. ISSN: 0957-4530 PHOTOCOPY ORDER NUMBER: 199410-58-1075.

Stability of 3 Plasma-Sprayed Coated Ti-6Al-4V Under Cyclic Bending in Simulated Physiological Solutions. The aim of this research was to study the stability of plasma-sprayed coated metal systems and to evaluate their susceptibility to the occurrence of corrosion fatigue. Hydroxylapatite plasma-sprayed coated samples of Ti-6Al-4V were studied under cyclic bending. During fatigue testing samples were immersed in a simulated physiological solution and mechanical and electrochemical degradation were monitored. Applied loads were intended to crack the ceramic coating and not the metal substrate. Electrochemical impedance spectroscopy was used to further characterize the electrochemical behavior. No increase in tendency to corrode was detected in open-circuit corrosion fatigue testing. It appears as if the coating cracking does not increase metal substrate corrosion susceptibility. The coating integrity has been seriously affected, with marked decrease in thickness, due to the synergistic effect of load and presence of simulated body fluids environment. Impedance results, however, show a general tendency to an increase in corrosion kinetics after corrosion fatigue testing.

R.L. Reis, F.J. Monteiro, and G.W. Hastings, Cited: *J. Mater. Sci.: Mater. Med.*, Vol 5 (No. 6-7), June-July 1994, p 457-462 [in English]. ISSN: 0957-4530. PHOTOCOPY ORDER NUMBER: 199410-35-2263.

Cryopump Components

Materials Selection, Qualification and Manufacturing of the In-Vessel Divertor Cryopump for Jet. This paper reports on the materials selection based on measurements of properties at cryogenic and elevated temperatures and the development of an optimised thermal treatment combining solution heat treatment, brazing and precipitation hardening. It also reports on the successful development of various manufacturing technologies which have been employed including (a) techniques for brazing of the chosen copper alloy onto inconel and stainless steel, (b) surface blackening of the Cu alloy with plasma sprayed ceramic coatings that are vacuum compatible and able to withstand temperatures between 70-1135K and (c) plasma spray deposition of Cu onto stainless steel in order to produce an anisotropic composite material with improved thermal conductivity, high strength and high electrical resistivity for use at temperatures between 70-650K.

S. Papastergiou, W. Obert, and E. Thompson, Cited: Conf: *Advances in Cryogenic Engineering Materials. Vol 40B* (Albuquerque, New Mexico), 12-16 July 1993, Plenum Publishing Corp., 1994, p 1429-1436 [in English]. PHOTOCOPY ORDER NUMBER: 199410-55-1582.

Heat Transfer in Boilers

Plasma Spray Produced Coatings for Boiling Heat Transfer Enhancement. Efficiency of plasma sprayed porous coatings by the enhancement of heat transfer for boiling freon F-113 and its influence on nucleate boiling burnout and hysteresis phenomena were investigated. Copper, aluminium and bronze coatings were sprayed in air by means of low-temperature plasma jet. After heat transfer experiments, porous coating thickness, porosity and mean pore radius were measured. The influence of these parameters on heat transfer processes for boiling freon F-113 is analyzed on the basis of a theoretical model and experimental data. It is shown that the optimum values form the viewpoint of heat transfer intensification exist for these three parameters. At the same time the optimum of each parameter depends on two other parameters and heat flux density.

J. Tehver and H Sui, Cited: *Int. J. Mater. Prod. Technol.*, Vol 8 (No. 2-4), 1993, p 325-331 [in English]. ISSN: 0268-1900. PHOTOCOPY ORDER NUMBER: 199410-58-1108.

Injection Molding

Cheaper Route to SRIM Parts. A simple solution to making cost-effective complex preforms for the structural reaction injection moulding (SRIM) process is offered by Dow Chemical Co. The method involves blowing a resin powder through a ring of flame in a commercial thermal spray gun. The powder binder melts and is directed onto a fibre reinforcement where the polymer solidifies on contact and binds the fibres together. The fibres are fed through a chopper gun and deposited with the binder onto a screen in the shape of the part. A vacuum is applied to the back of the screen by a blower to hold the fibres in place.

Cited: *Reinf. Plast.*, Vol 38 (No. 10), Oct 1994, p 17 [in English]. ISSN: 0034-3617. PHOTOCOPY ORDER NUMBER: 199410-D3-0134.

Sink Rolls in Hot-dip Galvanizing

Durability of Sprayed WC/Co Coatings in Aluminum-Added Zinc Bath. In order to develop protective coatings for sink rolls used in continuous hot-dip galvanizing, the sprayed WC/Co cermet coating was formed on a mild steel by the high velocity oxygen fuel spraying process and its durability in the molten zinc bath (753 K) containing 0-3 mass% Al has been investigated on the basis of the constitutional change measured by SEM and EDS. The following results were obtained: (1) During immersion periods, Al was enriched in the Zn-Al solution close to the sprayed coating surface and Al-rich phase was deposited on the sprayed coating surface. (2) Under the sprayed coating surface, the diffusion layer, where Zn was rich and cobalt was poor, was built up. As Al concentration in the molten Zn bath was increased, the thickness of the diffusion layer was decreased and the durability of the sprayed coating could be kept for longer times. (3) It is presumably a reason for such improvement of the durability that the Al-rich phase acts as a diffusion barrier against Zn and Co at the interface of molten Zn/sprayed coating and consequently suppresses the growth of the diffusion layer.

K. Tani, T. Tomita, Y. Kobayashi, Y. Takatani, and Y. Harada, Cited: *ISIJ Int.*, Vol 34 (No. 10), Oct 1994, p 822-828 [in English] ISSN: 0915-1559. PHOTOCOPY ORDER NUMBER: 199411-57-1364.

TBCs

Plasma Sprayed Thermal Barrier Coatings for Industrial Gas Turbines. Morphology, Processing and Properties. Thermal barrier coatings out of fully or partially stabilized zirconia offer a unique chance in gas turbines to increase the gas inlet temperature significantly while keeping the temperature of the structural material of the component within conventional limits. For large land based industrial or utility gas turbines, for example, coating life between 25 000 and 30 000 h is a minimum requirement. Premature failure of a coating by e.g. local spalling causes local overheating of the component with the consequence of its total destruction or even more expensive secondary damages. Life limiting is the corrosion rate at the ceramic-metal interface and the behavior of the coated system under transient operating conditions, where multiaxial strain and stress distributions are generated. Sufficient strain tolerance of teh coating both under tensile as well as compressive conditions is required. The properties of thermal barrier coating systems depend strongly on the structure and phase composition of the coating layers and the morphology of and the adhesion at the ceramic-metal interface. They have to be controlled by the process itself, the process parameters and the characteristics of the applied materials (e.g. chemical composition, processing, morphology, particle size and size distribution). It will be reviewed, how properties and structures of coating systems correlate and how structures can be modified by careful control of the process parameters.

H W. Grunling and W. Mannsmann, Cited: Conf· Euromat 93: The 3rd European Conference on Advanced Materials and Processes, Vol. II (Paris, France), 8-10 June 1993, *J. Phys.*, Vol IV Nov 1993, p 3 [in English]. PHOTOCOPY ORDER NUMBER: 199412-57-1447.

Thermonuclear Devices

Protective Coatings for Plasma Facing Components in Thermonuclear Reactors. The plasma facing components (PFC) in future thermonuclear confinement experiments have to withstand high stationary heat loads during normal operation and severe thermal shocks during off-normal conditions (so-called disruptions). In these transient events on the first wall energy depositions up to 2 MJm^{-2} can occur with pulse durations in the order of 1 ms. To improve the performance of the plasma and to protect it against high-Z impurities from metallic structures boron carbide coatings have been used successfully in different fusion experiments. Thick coatings of this material have been prepared by plasma spraying, a technique which also offers potential for in situ repair of damaged coatings inside the torus. Coatings with thicknesses of several hundred microns on different substrates (graphites, carbon fiber composites, stainless steel, refractory metals) have been tested in high heat flux test facilities at heat loads simulating the normal operation and disruption conditions. In addition a limited number of coated tiles have been installed in fusion relevant tokamak experiments such as TEXTOR, JET or JT-60U.

J. Linke, M. Akiba, T. Ando, J.P. Coad, S. Deschka, and E. Wallura, Cited: Conf: *13th International Plansee Seminar '93. Vol. 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, Plansee Metall AG, 1993, p 112-128 [in English]. PHOTOCOPY ORDER NUMBER· 199411-57-1338.

Composites

Plasma Spray Atomization

Al-Li/SiCp Composites and Ti-Al Alloy Powders and Coatings Prepared by a Plasma Spray Atomization (PSA) Technique. There has been increasing use of Al-Li alloys in the aerospace industry, due mainly to the low density and high elastic modulus of this material. However, the problem of low ductility and fracture toughness of this material has limited its present application to only weight- and stiffness-critical components. Development of Al-Li/ceramic composites is currently being investigated to enhance the service capabilities of this material. The Ti-Al alloy is also of interest to aerospace-type applications, engine components in particular, due to its attractive high-temperature properties. Preparation of fine powders by plasma melting of composite feedstock and coatings on copper formed by plasma spraying was carried out to examine the effect of spray parameters on the microstructure and properties of these materials. Characterization of the powders and coatings was performed using the scanning electron microscope and image

analyzer. Examination of the plasma-sprayed powders and coatings has shown that in the Al-Li (8000)/SiC composite there is melting of both materials to form a single composite particle. The SiC reinforcement was in the submicron range and contributed to additional strengthening of the composite body, which was formed by a cold isostatic press and consolidated by hot extrusion or hot forging processes. The plasma-sprayed Ti-Al (Ti-36Al-0.14Fe-0.041O) powder showed four categories of microstructures: featureless, dendritic, cellular, and martensite-like.

K.A Khor, F.Y.C. Boey, Y. Murakoshi, and T. Sano, Cited: *J. Therm. Spray Technol.*, Vol 3 (No. 2), June 1994, p 162-168 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199412-54-1162.

Polymer Matrix Coatings

Production of Polymer Matrix Composite Coatings by Thermal Spraying. The production of ceramic-polymer and metal-polymer matrix composite coatings by plasma spray deposition has been studied The work involves the co-deposition of alumina, magnesium hydroxide, silica and stainless steel with nylon (Rilsan ES) by simultaneous powder injection into the plasma jet. The results show that the dense deposits with sound bonding between the filler particles and the matrix can be produced. The deposition efficiency of the filler decreases with increasing particle size and density due to particle rebound from the underlying coating layers and substrate during spraying. No significant deterioration in coating-substrate adhesion of the composite coatings relative to the equivalent pure nylon was found owing to the formation of a denuded interfacial layer and the enhanced integrity of the deposit The composite coatings showed major improvements in abrasive and adhesive wear resistance due to particle-strengthening and reduced contact between nylon and the counterface at the sliding interface

Y. Bao, D.T. Gawne, D. Vesely, and M.J Bevis, Cited: *Trans. Inst. Met. Finish.*, Vol 72 (No. 3), 1994, p 110-113 [in English]. ISSN: 0020-2967. PHOTOCOPY ORDER NUMBER: 199412-E7-D-0269.

Corrosion

Al-based Coatings

The Corrosion Protection of Weldable 7xxx Aluminium Alloys by Aluminium Based Arc Spray Coatings. The weldable 7xxx series Al alloys have been used extensively during the last two decades for transport applications, storage vessels and military equipment. Service performance however may be reduced by exfoliation corrosion of stress corrosion. An approach for the simultaneous prevention of both exfoliation and weld toe cracking is that of applying by thermal spraying a sacrificial metal coating adjacent to the susceptible regions of the structure. Previous work by the authors has identified the local environmental conditions and the electrochemical conditions providing immunity to exfoliation and weld toe cracking. Immunity is guaranteed for pH's where Al based alloys are stable with respect to exfoliation and weld toe cracking if the electrochemical potentials remain respectively < -975 mv, and within the range -1200 to -1130 mv on the saturated calomel electrode. This paper considers how these, and adhesion, requirements have been met by selection of the metal spray wire composition and arc spray process parameters.

S.S. Birley, W. Hepples, N.J.H. Holroyd, Cited: Conf: *Third International Conference on Aluminium Alloys: Their Physical and Mechanical Properties*, Vol. 2 (Trondheim, Norway), 22-26 June 1992, Sintef Metallurgy, 1992, p 497-502 [in English]. PHOTOCOPY ORDER NUMBER: 199411-35-2388.

High Temperature Application

The Yttrium Effect on the Corrosion Resistance of CO_2-Laser Processed MCrAlY Coatings. To improve the corrosion resistance and to study the effect of yttrium in the behavior of coatings produced by thermal spraying MCrAlY (M=Ni, Co) powders on AISI 304 substrate, CO_2 processing was conducted. Three methods were used: (1) a combination of gas flame and plasma spraying in air followed by laser glazing in argon, (2) low-pressure plasma spraying (LPPS) and laser glazing in Ar, and (3) LPPS and laser-gas (O_2) alloying. Laser glazing in Ar of the MCrAlY coatings sprayed in air promoted formation of weakly adherent agglomerates of Al-Y oxides and an alumina-chromia solid solution. Glazing in Ar atmosphere of LPPS CoNiCrAlY and NiCrAlY coatings caused the formation of nickel aluminides besides the formation of Y-Al compounds. Gas (O_2)-alloying of these coatings produces continuous and adherent (yttrium-containing) alumina and chromia layers. The effect of Y on the characteristics of the oxides formed in the coatings during laser glazing, laser-gas alloying, and high-temperature oxidation is discussed. This work also investigated the oxidation resistance of the laser-processed MCrAlY coatings in air and in the presence of 85 mol/o V_2O_2-Na_2SO_4 fused salt at 900 °C.

Y. Longa and M. Takemoto, Cited: *Oxid. Met.*, Vol 41 (No. 5-6), June 1994, p 301-321 [in English]. ISSN: 0030-770X. PHOTOCOPY ORDER NUMBER: 199410-58-1088.

Data Base

Ceramics Research in Canada

University Research in Ceramics in Canada. A summary is given of major research groups in ceramics and related materials in universities in Canada. For example, at the University of British Columbia current activities include the thermal spraying of ceramic coatings and thermal forming of ceramics such as Al_2O_3, Cr_2O_3, ZrO_2, WC/Co, TiC, and TiB_2. Work is also carried out on the post-deposition modification of thermally formed ceramics, the mechanical properties and nondestructive evaluation of thermally sprayed coatings, and on the mechanical properties of biomaterials. A telephone number for the person noted with each research group and an address for mail contact are provided.

M. Sayer, Cited: *Can. Ceram. Q.*, Vol 63 (No. 3), Aug 1994, p 174-178 [in English]. ISSN: 0831-2974. PHOTOCOPY ORDER NUMBER: 199410-C9-0023.

Feedstock

Borides and Aluminides

Some Properties of New Composite Powders Containing Boride and Aluminide Phases for Thermal Spraying Processes. The article presents some properties of new powders for thermal spraying processes. The matherial and technological conception of obtaining some borides powders: B_4C-CrB, CrB_2, TiB_2 and FeB was characterized. The powders in question were obtained by the self-propagation high-temperature synthesis and the activated reaction diffusion. The self-decomposition powders of Fe-Cr-Al-C alloys were obtained from the chemical compositions containing the primary carbides Al_4C_3 and (Fe-Me-Al), $FeAl_2$ phases. The powders were subjected to the X-ray analysis to determine the chemical compositions. The powder morphology and their grain size were controlled by the chemical composition of the alloys, the melting temperature and the cooling conditions. Some Ni-Al powders covered with the Ni chemically show the egzothermal properties. Chosen parameters of the plasma spraying of some powders were presented. Chosen functional qualities of the composite powder were determined for wear and oxidation resistance conditions.

B. Formanek, B. Binczyk, L. Swadzba, and S. Stolarz, Cited: Conf: *13th International Plansee Seminar '93. Vol. 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, Plansee Metall AG, 1993, p 408-423 [in English]. PHOTOCOPY ORDER NUMBER: 199411-57-1351.

Feeding Stability

Characteristics and Stability of Feeding Powders for Thermal Spraying by Plasma Arc. The apparent density and the flow factor of powders used for thermal spraying by plasma arc were investigated. The powders investigated were: WC+Co, ZrO_2, ZrO_2 + MgO, ZrO_2 +Y_2O_3 , NiCrAlY, NiAl, CoNiCrAlTa, NiCr, NiCrBSi, and CuSn10. Besides this the stability of feeding powders to the plasma beam was tested on the feeding equipment P30 and TWIN 10C of the Plasma-Technik Company. The results of the investigations are presented and discussed.

V. Palka, M. Brezovsky, M. Lickova, Cited: *Zvaranie*, Vol 42 (No. 1), 14-16 Jan 1993 [in Slovak]. ISSN: 0044-5525. PHOTOCOPY ORDER NUMBER: 199411-58-1163.

Mechanical Alloying

Mechanically Alloyed Intermetallic NiAl Powders for Thermally Sprayed Coatings. Nickel-aluminium alloy powder with the composition of the intermetallic compound NiAl ($Ni_{50}Al_{50}$ at.%) was prepared by mechanical alloying of mixtures of pure Ni and Al powders. The influence of the particle size of the starting Al powder on the characteristics of the synthesized powder was studied. Use of fine Al powder led to the formation of stable intermetallic compound powder with extremely fine particle size after 6 h of milling. The fineness and consequently reduced flow characteristics made this powder less suitable for thermal spray coating processes. With coarser Al powder the milling procedure had to be modified to avoid the adherence of the starting materials to the vial and milling media. After 6 h of milling the resulting powder had coarser particle size, good flowability and a composite microstructure consisting of separate small Al islands in Ni matrix. Mechanically alloyed powders were used as starting materials for thermally sprayed coatings prepared by either plasma spraying or detonation gun technique. Prepared coatings were characterized by microstructural studies and X-ray diffraction. Use of the fine intermetallic powder led to the formation of a metastable solid solution coating instead of intermetallic compound. Thermal spraying with the coarse composite powder led to the formation of intermetallic compound coating with characteristics typical of intermetallic material. On the basis of obtained results, the possibilities of utilizing the metastable character of mechanically alloyed powders (at intermediate milling stages) in the production of thermally sprayed intermetallic coatings are presented and discussed.

T J. Tiainen, J. Lagerbom, and V. Polvi, Cited: Conf: *13th International Plansee Seminar '93. Vol 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, Plansee Metall AG, 1993, p 386-396 [in English]. PHOTOCOPY ORDER NUMBER: 199411-58-1170.

Wear Materials

New Eutectic Powder Materials and Alloys and Procedures for Wear Resistant Coatings Deposition. A new approach concerning improvement of wear resistance of metallic structural materials, by the method of crystallization of melts, prepared of powder eutectic iron-based compositions (a Fe-Mn-C-B system), is proposed. Development of powder materials is based on the content of one or more elements in the mixture, that form eutectics with strengthening metal (in this case it is carbon or boron) as well as fusible metals with $T_{melt} \leq T_{eut}$ (e.g. Fe, manganese). The eutectic wear resistant powder coating is applied by overlaying and centrifugal bimetallization using heating by high frequency current (HFC), spraying by gas-thermal equipment (plasma, flame, impulse-plasma and some other methods of spraying) and also by electric spark alloying using eutectic alloy electrodes.

V.M. Golubets, Cited: *Int. J. Mater. Prod. Technol.*, Vol 8 (No. 2-4), 1993, p 200-203 [in English]. ISSN: 0268-1900. PHOTOCOPY ORDER NUMBER: 199410-57-1260.

Graded Coatings

TBC

Graded Thermal Barrier Coatings: Evaluation. "Dual graded" thermal barrier coatings have been developed in order to increase the coating life of conventional plasma ceramic thermal barrier coatings (NiCrAlY bond coat plus zirconia-based top coat). This coating consisted of plasma sprayed NiCrAlY bond coat, graded interlayer of NiCrAlY/ZrO_2-8Y_2O_3, and ZrO_2-Y_2O_3 top coats with a laser glazed surface layer on Inconel 718 substrate. These coatings had two gradients: an interlayer composition gradient and a density gradient at the surface of the top coat. These coatings were compared with conventional plasma sprayed coatings after cyclic thermal testing. The thermal fatigue life of the "dual graded" coatings was significantly greater than that of conventional coatings.

M.I. Mendelson, T.N. McKechnie, and L.B. Spiegel, Cited: Conf: 18th Annual Conference on Composites and Advanced Ceramic Materials A (Cocoa Beach, Florida), 9-14 January 1994, *Ceram. Eng. Sci. Proc.*, Vol 15 (No. 14), July-Aug 1994, p 555-562 [in English]. ISSN: 0196-6219. PHOTOCOPY ORDER NUMBER: 199410-57-1171.

Thermal Shock Resistance

Synthesis of Graded Thermal Resistance Coating. A graded coating consisting of NiCr and 24 wt.% MgO-stabilized ZrO_2 was deposited using plasma spraying. The design of the coating was described. The chemical composition, microstructure and thermal properties of the coating were determined. A thermal shock test of the coating with a O_2-C_2H_2 flame torch was conducted. The relationship between the microstructure and properties of the coating and its thermal shock characteristics was discussed. The results obtained indicated that the graded coating possesses high thermal expansion coefficient, low thermal conductivity and excellent thermal shock resistance. The experimental results coincided with the design for the graded thermal resistance coating.

C. Ding and M Chen, Cited: Conf: International Union of Materials Research Society-International Conference in Asia (Wuhan-Chongqing, China), 6-10 Sept 1993, *Chin. J. Mater. Res. 1994.5*, (supplement), May 1994, p 158-161 [in English]. ISSN: 1005-3093. PHOTOCOPY ORDER NUMBER: 199410-58-1067.

FGMs

Synthesis of Functionally Gradient Ni-Cr-Al/MgO-ZrO_2 Coating by Plasma Spray Technique. Functionally gradient coatings offer the possibility of tailoring properties between a substrate and a functional surface. A graded coating based on the system of Ni-Cr-Al/MgO-ZrO_2 was synthesized in a single-torch plasma spray reactor at atmospheric pressure. Monolithic coatings were first studied as a function of input powder compositions. X-ray analyses indicated that the compositions of the coatings agreed qualitatively with those of starting powders. A methodology for synthesis of graded coatings was presented. The graded coating consisted of a metallic NiCr-Al layer near the interface between the 4140 steel substrate and the coating, followed by a graded zone with ZrO_2 content increasing with thickness and a ceramic top coat of stabilized ZrO_2.

S. Eroglu, N.C. Birla, M. Demirci, and T. Baykara, Cited: Conf: *13th International Plansee Seminar '93. Vol. 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, Plansee Metall AG, 1993, p 363-372 [in English]. PHOTOCOPY ORDER NUMBER: 199411-57-1348.

Manufacturing

Ceramic Net Shapes

High Precision Ceramic Components. Net-shape ceramic components that are said to have precise internal dimensions and ultra-smooth surfaces are available from Technetics Corp. of DeLand, Florida, USA. According to the company, dimensional control as accurate as 25 μm (0.001 in.) is possible since plasma flame spraying is used to produce the components. Potential applications for the components are expected to be found in the electronics, aviation, medical and laser-based industries. Components can be produced from most liquid-phase, plasma-sprayable materials, including alumina, partially and fully stabilized zirconias, magnesium zirconate and magnesium alumina spinel.

Cited: *Adv. Ceram. Rep.*, Oct 1994, p 2 [in English]. ISSN: 0268-9847. PHOTOCOPY ORDER NUMBER: 199412-C7-0044.

Net-shape Production

Controlled Microstructure of Arc-Sprayed Metal Shells. Shells made of sprayed ferrous materials are feasible for prototype and limited production tooling. A systematic study of the microstructure of arc-sprayed ferrous structures is presented, demonstrating why these structures display a degree of mechanical anistropic behavior. The results of controlling oxide formation with inert atmomization gases are given, and methods for tailoring the composition and orientation of the lamellae through robotically controlled deposition are discussed. Plain carbon steel 1080, martensitic type 420 stainless steel, bronze, Invar are sprayed onto low carbon steel plate.

P.S. Fussell, H.O.K. Kirchner, F.B. Prinz, and L.E. Weiss, Cited: *J. Therm. Spray Technol.*, Vol 3 (No. 2), June 1994, p 148-161, [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199412-58-1336.

Microstructure

LPPS of Iron Based Alloys

Structures and Mechanical Properties of Rapidly Solidified Deposits of an Fe-1.5 Wt.%C-10.7 Wt.% Cr Alloy By Low Pressure Plasma Spraying. Powder of an Fe-1.50 wt.% C-10.7 wt.% Cr alloy was low pressure plasma sprayed onto substrates which were cooled to varying extents. When the maximum deposit temperature was below 773 K during spraying, the deposit was mainly composed of retained austenite supersaturated with the alloying elements. In a deposit which reached the maximum temperature of about 973 K, a large portion of the retained austenite decomposed to ferrite and fine carbide particles. Although the hardness of this deposit was high, its tensile strength, measured on tensile test pieces machined from the deposit which was separated from the substrate, was low because of weak adhesion at the boundaries between the flattened particles composing the deposit. In the case of maximum deposit temperature 1235-1357 K, the deposit consisted of the stable phases of ferrite and somewhat coarse carbide particles. The adhesion between the flattened particles was strong and the strength of the deposit was remarkably improved. This strengthening of adhesion was caused by enhanced diffusion of elements across the boundaries between the flattened particles when the sprayed droplets impinged onto the already-formed high temperature deposit.

K. Murakami, Y. Fujii, H. Matsumoto, T. Irisawa, T. Okamoto, T. Kawai, J. Imazu, K. Niihara, and Y. Miyamoto, Cited: *Mater. Sci. Eng. A*, Vol 186 (No. 1-2), 15 Oct 1994, p 105-112 [in English]. ISSN: 0921-5093. PHOTOCOPY ORDER NUMBER: 199412-54-1140.

LPPS of MCrAlY

Microstructural Evolution of an Overlay Coating on a Single-Crystal Nickel-Base Superalloy. High-temperature overlay coatings of the MCrAlY type (where M is Ni, Co, or Ni + Co) formed via physical vapor deposition or plasma spray methods are finding increasing use in turbine blade applications because of their high-temperature oxidation and sulfidation resistance. Their mechanical behavior and resistance to environmental degradation have been extensively characterized, however, little attention has been paid either to the coating microstructure on a fine scale or to the evolution of the microstructure from the as-coated condition through to the substrate heat treatment and subsequent thermal exposure. This communication reports on a transmission electron microscopy (TEM) and scanning electron microscopy (SEM) based microstructural study of a low-pressure plasma-sprayed (LPPS) CoNiCrAlY coating on a single-crystal Ni-base superalloy substrate. The microstructure of the coating was characterized after each of the following stages of treatment: plasma spraying, a diffusion heat treatment of 1 h at 1100 °C, and 140 h thermal exposures in laboratory air at temperatures of 850 and 1100 °C.

T.C. Totemeier, W.F. Gale, J.E. King, Cited: *Metall. Mater. Trans. A*, Vol 25A (No. 12), Dec 1994, p 2837-2840 [in English] PHOTOCOPY ORDER NUMBER: 199411-58-1186.

Wear Resistance

Effect of Rare Earth Elements on Microstructure and Wear Resistance of Laser Remelted Iron Alloy Coatings Containing Metalloids. The microstructure, hardness, and wear resistance of thermal sprayed and laser remelted $M_{80}S_{20}$ and $M_{80}M_{20}$-$8CeO_2$ self-fluxing alloy coatings (where M signifies a metallic content, predominantly Fe, and S represents a metalloid content specifically boron, silicon, and carbon on steel (1020) were investigated using SEM, an electron microprobe, a microhardness tester, and an Amsler wear testing machine. The results showed that the rare earth element can significantly improve the surface quality, microstructure, and wear resistance of laser remelted coatings.

Y. Wang, J.-J. Liu, and Z.-H. Yu, Cited: *Surf. Eng.*, Vol 9 (No. 2), 1993, p 151-155 [in English]. ISSN: 0267-0844. PHOTOCOPY ORDER NUMBER: 199411-58-1168.

Zirconia TBCs

Microstructure of Yttria Stabilized Zirconia-Hafnia Plasma Sprayed Thermal Barrier Coatings. Hafnia is an attractive candidate to build reliable and durable thermal barrier systems, due to its similarity to zirconia and its elevated structural transformation temperatures. Structural investigations of various plasma sprayed coatings on nickel alloy substrates composed of ZrO_2 +x mole% HfO_2 (x=0, 25, 50 and 100), partially stabilized by 4.53 mole% yttria are reported. X-ray diffraction studies and TEM investigations show that, a metastable, non-transformable, high yttrium content, t' phase is the only phase observed on the as-sprayed samples. Such results had not yet been related in the literature.

H. Ibegazene, S. Alperine, and C. Diot, Cited: Conf: Euromat 93: The 3rd European Conference on Advanced Materials and Processes, Vol II (Paris, France), 8-10 June 1993, *J. Phys.*, Vol IV, Nov 1993, p 3, [in English]. PHOTOCOPY ORDER NUMBER: 199412-57-1452.

Patent

TiN Coating

Wear Resistant Titanium Nitride Coating and Methods of Application. Surfaces subject to wear and corrosion can have their service life increased by being coated with a composite coating applied by the electric arc thermal spray process using at least one titanium feed wire, optionally prenitrided, a second wire of a different metal, metal alloy ceramic or intermetallic compound and nitrogen in the arc spray gun.

Z. Zurecki, E.A. Hayduk Jr, J.G. North, R.B Swan, and K.R. Berger, Cited: Patent: EP0522438 (European Patent), 2 July 1992, 13 Jan 1993 [in English]. PHOTOCOPY ORDER NUMBER: 199410-57-1283.

Post-processing

HIP of Zirconia TBCs

Quality Upgrading of Plasma-Sprayed Thermal Barrier Ceramic Coatings by Hot Isostatic Pressing. Plasma-sprayed ZrO_2 coating subjected to hot isostatic pressing (HIP) is more compact and more homogeneous, having better performance and greater adhesion strength with the steel substrate (a plain carbon steel containing 0.45%C). The pores can be easily closed up and less cracks developed if the ZrO_2 coating is doped with appropriate amount of SiO_2. After HIP treatment, the bonding between ceramic layer and adhesion layer is of mixed mechanical and metallurgical nature. The bonding between the adhesion layer and the steel substrate is of pure metallurgical nature. Fe-Al-C intermetallics containing nickel were found at the interface which consisted of two sub-layers: the Ni containing Fe-Al-C intermetallics and the decarburized (ferrite) sub-layers.

H.C. Chen, Z.Y. Liu, Y.Z. Zhuang, and L.K. Xu, Cited: *Chin. J. Mech. Eng.* (Engl. Ed.), Vol 5 (No. 3), Sept 1992, p 183-188 [in English]. ISSN: 1000-9345. PHOTOCOPY ORDER NUMBER: 199412-57-1571.

Laser Remelting

Laser Remelting of HVOF Coatings. The hard metals Cr_3C_2-Ni and WC-Co were sprayed on different substrate materials using the HVOF process. Surface hardness and mechanical and thermal properties of the composite material can be controlled by varying the HVOF process parameters, e.g. oxygen/fuel gas mixture, spraying distance and powder feed rate. After this, the thermal spray coatings are subjected to a thermal secondary treatment using a CO_2 higher-power laser. The following secondary treatments were examined: partial melt-down of spray coating and melt-down of spray coating. The first results were summarized.

R. P tzl, Cited: Conf: *Second ASM Heat Treatment and Surface Engineering Conference in Europe. II* (Dortmund, Germany), 1-3 June 1993, Mater. Sci. Forum, 1994, p 163-165, 595-601 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199410-57-1203.

Process

D-gun of Alumina

Properties of Alumina-Based Coatings Deposited by Plasma Spray and Detonation Gun Spray Processes. Alumina, Al_2O_3 + 3-40 wt.% TiO_2, and Al_2O_3 + 40 wt.% ZrO_2 coatings were deposited onto low carbon steel substrates by atmospheric plasma spraying (APS) and detonation gun spraying (DGS). The coatings were evaluated by optical microscopy, microhardness measurements, and X-ray diffraction. Wear resistance of the coatings was evaluated by rubber wheel sand abrasion and particle erosion test methods. Detonation gun-sprayed coatings exhibited more homogeneous microstructures and somewhat higher microhardness than corresponding plasma-sprayed coatings. Small additions of TiO_2 (3 wt.%) improved both the abrasion and erosion wear resistance, whereas 40 wt.% TiO_2 coatings exhibited the best abrasion wear resistance of both APS and DGS coatings, but the erosion wear resistance of these coatings was lower than that of the Al_2O_3 and Al_2O_3 + 3 wt.% TiO_2 coatings. The best abrasion wear resistance of the coatings studied was obtained with DGS Al_2O_3 + 40 wt.% ZrO_2 and Al_2O_3 + 3-40 wt.% TiO_2 coatings. These coatings exhibited lower wear rates than bulk Al_2O_3. The best erosion wear resistance was obtained with the DGS Al_2O_3 + 3 wt.% TiO_2 coating; however, it exhibited a higher wear rate than bulk Al_2O_3. In general, detonation gun-sprayed coatings showed significantly enhanced abrasion and erosion wear resistance than the corresponding plasma-sprayed coatings.

K. Niemi, P. Vuoristo, and T. Mantyla, Cited: *J. Therm. Spray Technol.*, Vol 3 (No. 2), June 1994, p 199-203 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199412-57-1577.

Diamond like Coatings

Diamond Film Coating on Cemented Carbide. Diamond film coating on the cemented carbide cutting tool without graphite or amorphous carbon was preformed by the H_2-$O_2C_2H_2$ flame. The film was analysed by using scanning electron microscopy, Raman spectroscopy and X-ray photoelectron spectroscopy. The function of hydrogen in this process was etching non-diamond carbon atoms as well as stabilizing diamond carbon atoms in the depositing tag. Therefore, the quality of dimaond film coating on the cemented carbide cutting tool was improved by hydrogen. The diamond film can be deposited on all the surface or every cutting edge surface of the insert by moving the cemented carbide substrate in the flame. It has shown good results by cutting test which is using the diamond film coating cemented carbide insert for cutting the material of Al-8% Si alloy.

H.-y Lai and Z. Guo, S.Yin, Cited: Conf: *13th International Plansee Seminar '93. Vol. 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, Plansee Metall AG, 1993, p 282-286 [in English]. PHOTOCOPY ORDER NUMBER: 199411-53-0510.

Adherent Diamond Coatings on WC-Co Substrates Using a Modified Flame Technique. Diamond coatings on WC-Co substrates have been grown using the conventional O_2/C_2H_2 combustion flame and a modified flame technique. These deposits were characterized by SEM and Raman spectroscopy and their adhesion was evaluated using a scratch test. The modified technique yielded coatings which were relatively more uniform in morphology and superior in adherence. Diamond coatings deposited via the conventional process peeled off the WC-Co substrates at a critical load (L_c) around 2N, while the modified technique produced coatings with critical loads L_c in 52-57 N range.

S.P.S. Arya and V.K. Sarin, Cited: *13th International Plansee Seminar '93, Vol 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, p 101-111, Plansee Metall AG, 1993 [in English]. PHOTOCOPY ORDER NUMBER: 199411-E7-C-0254.

Flame Spraying

The Effect of Oxyacetylene Flame Powder Spray Weld and Post-Weld Heat Treatment on Structure and Hardness of Base Material and Alloy Layer. Experiments were conducted to determine the effect of oxyacetylene flame powder spray coating on the hardness and structure of the base material and the effect of heat treatment of the spray coated specimen on the structure and hardness of both the coating and the base material. Samples of 40CrNiMo steel were coated using the Ni-base alloy powder Ni45. Microstructures were analyzed using optical microscopy and X-ray diffraction. Hardness was measured using a Rockwell and Vickers multipurpose hardness test. It was shown that the spray coating process resulted in formation of a mixed structure, grain growth and decreased hardness in the base material. Heat treatment of the coated specimen restored the original hardness and structure to the base material without adversely affecting the structure or hardness of the coating.

Z. Guanjun, Cited: Conf: *9th International Congress on Heat Treatment and Surface Engineering and 5th French Open International Conference on Heat Treatment* (Nice-Acropolis, France), 26-28 Sept. 1994, PYC Edition, Vol 5, 1994, p 147-156 [in English]. ISSN: 2 85330-133-8. PHOTOCOPY ORDER NUMBER: 199412-58-1267.

Flame Spraying of Tin

Combined Thermal and Electrochemical Processes for Tinning and Lead Coating. Original Title: [Kombination von Thermischen und Elektrochemischen Verfahren beim Verzinnen und Verbleien.] The adhesion and solderability of electrodeposited tin and lead coatings on small parts, e.g. screws, are often reduced by the diffusion of metals such as zinc into the coatings from the substrate. Such diffusion can be restricted by using a tin interlayer applied, for example by flame-spraying. In contrast to hot-dip tinning, flame-spraying of tin, Sn-Pb alloy or Pb uses additions which can include fluxes and powdered metal of the same composition as the substrate. One of the most attractive features of the flame-spraying process for Sn is the formation of a diffusion layer at the substrate-coating interface which provides improved adhesion. Limitations of this lie in its modest thickness and poor coverage at the edges. Such disadvantages can be largely overcome by subsequent electro-tinning of the work.

M. Heck, Cited: *Galvanotechnik*, Vol 83 (No. 10), Oct 1992, p 3368-3370 [in German]. ISSN: 0016-4232. PHOTOCOPY ORDER NUMBER: 199411-58-1136.

HVOF

High-Velocity Oxy-Fuel Spraying. High-velocity oxygen-fuel (HVOF) processes as variants in thermal spray technology are increasingly used for industrial applications. In the thermal spray sector they represent a recent but significant development. The objective is to give broad overall view on how this thermal spray variant basically works, and where it can be applied to successfully benefit from the advantages achieved with functional protective coatings. Reference is made to economic significance, typical examples, new developments and the future prospects of this process.

Th. F. Weber, Cited: Conf: *Second ASM Heat Treatment and Surface Engineering Conference in Europe. II* (Dortmund, Germany), 1-3 June 1993, Mater. Sci. Forum, 1994, p 163-165, 573-578 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199410-57-1200.

Laser Cladding

Residual Stresses in Laser Treated Surfaces. Residual stresses were measured by the X-ray method in different laser treated surfaces. Additionally, the influence of heat treatments on the residual stress state was evaluated. Laser remelting of a 12% chromium-steel (e.g. $X_{22}CrMoV_{12}$ 1) with short and long interaction times resulted in tensile and compressive residual stresses, respectively. While the formation of compressive stresses was related in a straightforward manner to the phase transformations induced by the temperature/time cycle, a combination of insufficient strain accommodation at high temperature and subcritical thickness of the remelted layer was thought to be responsible for the absence of compressive stresses in the case of short interaction times. In laser cladding of Stellite 6 on (carbon) steel high tensile residual stresses were produced. By annealing subsequent to laser treatment, compressive residual stresses were induced in the surface provided the thermal expansion coefficient of the coating was smaller than that of the substrate. In the opposite case, i.e. thermal expansion coefficient of the coating higher than that of the substrate, stress relief only was possible by bending of the specimen. Laser cladding of an Fe/Cr-powder on C steel resulted in high residual tensile surface stresses. A subsequent aging treatment leads to the formation of the sigma -phase and to compressive residual stresses in the Fe-44 Cr layer.

M. Roth, Cited: Conf: *Residual Stresses III: Science and Technology, Vol 2* (Tokushima, Japan), 23-26 July 1991, Elsevier Science Publishers Ltd., 1992, p 845-851 [in English]. ISSN: 1-85166-858-6. PHOTOCOPY ORDER NUMBER: 199411-31-4189.

LPPS of Ceramic

Effect of LPPS Spray Parameters on the Structure of Ceramic Coatings. The structure of low-pressure plasma sprayed ceramic coatings on a molybdenum substrate depends on the spray parameters. Porosity decreases with decreasing chamber pressure for all mullite and alumina coatings investigated, whereas the number of cracks decreases for the mullite-type coatings and increases for the alumina-type coatings. The structure of the coatings was analyzed by X-ray diffraction and revealed that the phase content was independent of the chamber pressure. The results indicate that the lowest thermal mismatch exists between the mullite/glass coating and the Mo substrate.

J. Disam, K. Luebbers, U. Neudert, and A. Sickinger, Cited: *J. Therm. Spray Technol.*, Vol 3 (No. 2), June 1994, p 142-147 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199412-57-1576.

Manganese Penetration and Densification

Liquid Manganese Penetration and Reaction Treatment of Plasma-Sprayed Al_2O_3 Coating. The penetration phenomena of liquid Mn to porous Al_2O_3 coating plasma-sprayed on SS400 steel substrate was studied by heating at 1573 K in vacuum atmosphere. Moreover, the possibility of improving the Al_2O_3 coating properties was examined. The formation of $MnAl_2O_4$ was clearly recognized in the connected porosity of Al_2O_3 coating penetrated with liquid Mn. It was revealed that the hardness and the fracture stress of the composite coating consisted of Al_2O_3 and $MnAl_2O_4$ without porosities after heat-treatment with Mn increased greatly compared with as-sprayed Al_2O_3 coating.

A. Ohmori, Z. Zhou, and K. Inoue, Cited: *ISIJ Int.*, Vol 33 (No. 9), 1993, p 989-995 [in English]. ISSN: 0915-1559. PHOTOCOPY ORDER NUMBER: 199410-57-1184.

Plasma-Powder Surfacing

High Performance Plasma-Powder Weld Surfacing)Increase in Efficiency and In the Service Life of Components Subject to Wear and Corrosion. A version of the plasma-powder weld surfacing method optimized for performance is described. The technique is compared with the usual plasma cladding methods, which are also briefly discussed. Surface welding test concluded with the newly developed torch on a continuous casting guide roller under realistic conditions verifies the high efficiency and stability of the system.

B. Bouaifi, T. Plegge, D. Dommer, F. Hettiger, and H. Hallen, Cited: *Schweissen Schneiden 12/92*, Dec 1992, E220-E222 [in English and German]. ISSN: 0036-7184. PHOTOCOPY ORDER NUMBER: 199410-58-1028.

Super Jet System

Ceramic, Hard Metallic and Metallic Coatings Produced by High Speed Flame Spraying. The OSU super jet system (SJS) is a high speed flame spray system. It can operate with acetylene, hydrogen, propane and other liquid gases. A special system makes it possible to regulate the flame temperature, the gas speed and the chemical composition of the combustion atmosphere largely independent with each other. Therefore, the super jet system is able to produce metallic, hard metallic and ceramic coatings of high quality, as a table shows it. The existence of an optimal powder transport rate is being deduced from the knowledge about the physical mechanism of the heating and the acceleration of powder particles in the hot gas flow. The adhesion rate is used as an example for demonstrating how to optimize the transport rate and for showing that this method can also be used in order to optimize the burner regulation. The adhesion rate and the spraying capacity from the SJS are compared with those of plasma spraying plants.

G. Matth us and W. Rother, Cited: Conf: *Second ASM Heat Treatment and Surface Engineering Conference in Europe. II* (Dortmund, Germany), 1-3 June 1993, Mater. Sci. Forum, 1994, p 163-165, 579-585 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199410-57-1201.

Processing

Microatomization

Reduction of Powder Particle Size and Simultaneous Spheroidization of High Melting Point Materials Using a Plasma Process. Original Title: [Reduzierung der Korngro e und gleichzeitige Spharoidisierung von Hochschmelzenden Pulverwerkstoffen unter Einsatz eines Plasmaprozesses.]. One of the most important facts concerning the quality of a sprayed coating is the selection of the starting powder. Among the great number of properties of powders, the average particle size is gaining in attention. The use of a plasma process offers new possibilities in the production of fine spherical powders. This paper deals with a feasibility study of the microatomisation of Al_2O_3-TiO_2, WC-Co and NiCoCrAl which had an average particle size finer than 106 μm. It was shown that this process is very useful to reduce the average particle size lower than 20 μm and spheroidize it in one single step

E. Lugscheider, A.R. Nicoll, M. Loch, and M. Nigbur, Cited: Conf: *13th International Plansee Seminar '93. Vol. 3: Coating Technology* (Reutte, Tirol, Austria), 24-28 May 1993, Plansee Metall AG, 1993, p 333-344 [in German]. PHOTOCOPY ORDER NUMBER: 199411-57-1347.

Spray Fusing of Intermetallics

Coatings of Aluminide Intermetallic Compounds on Steel Utilizing a Hybrid Technique of Spraying and IR-Laser Fusion. Titanium aluminide coatings were produced using a hybrid technique of arc-spraying followed by IR-laser fusion in an argon atmosphere. A Ti coating free of oxides was deposited onto a low-alloy steel by dc-arc spraying in Ar. Optimal laser irradiation conditions and the amount of preplaced aluminium powder on the sprayed Ti were determined to obtain a composite coating of $TiAl_3$ +Al of 150 μm thickness. Metallurgical and mechanical properties were examined using acoustic emission. The oxidation resistance of the coating was excellent up to 1173 K because of a protective alumina layer. Growth of the $TiAl_3$ interlayer by diffusion of Al into Ti improved the corrosion resistance. The intermetallic coating showed microcracking at ambient temperature, but possessed capability for filling and healing of cracks with alumina and titanium nitride during high temperature exposures. However, at temperatures >1200 K, the oxidation performance decreased by diffusion of iron into the coating.

Y. Longa, M. Shinya, and M. Takemoto, Cited: Conf: *Surface Modification Technologies VII* (Niigata, Japan), 31 Oct-2 Nov 1993, Institute of Materials, 1994, p 977-992 [in English]. ISSN: 0 901716 60 X. PHOTOCOPY ORDER NUMBER: 199410-58-1040.

Ultrasonic Densification

Effect of Ultrasonic Exposure on Composite Layer Properties. The structure and properties are investigated of gas thermal coatings of a powder alloy of the nickel- chromium-boron-silicium system sprayed on the steel 45 substrate by the gas plasma method and then fused by conventional and ultrasonic techniques. The latter is shown to influence the formation of coatings, to reduce their porosity, to vary their stressed state, to increase the strength and eventually the service life and durability of coated parts.

V.P. Bezborodov, E.A. Kovalevskii, and V.A. Klimenov, Cited: *Probl. Mashinostr. Nadezhn. Mash.* (No. 1), Jan-Feb 1994, p 81-83 [in Russian] ISSN: 0235-7119. PHOTOCOPY ORDER NUMBER: 199410-57-1222.

Properties

Corrosion of Alumina in Acid

The Electrochemical Behavior of Steel Coated With Plasma Sprayed Coatings. This study is dualistic in nature. First it concentrates on the corrosion resistance of some steels (316L and $Fe_{37}D$) coated with plasma sprayed aluminium oxide coatings in 30% sulfuric acid media Electrochemical methods were used to characterize the corrosion behavior of each steel with and without plasma sprayed Al oxide coating. Long term-corrosion monitoring was carried out to evaluate the long-term corrosion behavior. Plasma sprayed coatings did not completely inhibit corrosion but they did reduce the corrosion rate. The second part of this study discusses the reliabiltiy of electrochemical impedance spectroscopy and conventional electrochemical techniques for the characterization of ceramic coatings. Due to the complicated interaction of the metallic substrate and the ceramic coating the electrochemical response of the system is seldom definite. Very complicated mass transport processes within the pores of the coating meant that extreme care should be taken when using electrochemical impedance spectroscopy and other electrochemical techniques.

O. Forsen, J. Aromaa, J.-J. Kukkonen, and M. Tavi, Cited: Conf: *Electrochemical Methods in Corrosion Research IV* (Espoo, Finland), 1-4 July 1991, Mater Sci. Forum, Vol 111-112, 1992, p 245-255 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199411-35-2477.

Residual Stresses

Residual Stresses on Plasma Spraying Coatings Influence on HIP and Laser Treatments. Different coatings (Al_2O_3, Cr_2O_3, ZrO_2, NiAl) were made by atmospheric plasma spraying, in some cases under different experimental parameters, in order to obtain several microstructures and porosity rates. Elastic constants determinations were performed using a four points bending apparatus. Residual stresses profiles were estimated on surface and in-depth of some coatings. A complementary analysis was carried out on Al_2O_3 and Cr_2O_3 coated specimens, having suffered post-spraying treatment by hot isostatic pressing (HIP) or by LASER superficial remelting. The results were discussed in the light of coatings microstructure properties. Substrate materials were steel and Al.

J. Pina, V. Costa, A. Dias, M Zaouali, and J.L. Lebrun, Cited: Conf: *Residual Stresses III: Science and Technology, Vol 1* (Tokushima, Japan), 23-26 July 1991, p 686-691, Elsevier Science Publishers Ltd, 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199412-C1-C-2803.

PTA Surfacing

Plasma Transferred Arc Weld Surfacing. A resistance heating technique for raising the temperature of wire being fed into the weld pool during twin hot wire plasma transferred arc weld surfacing is described. The resistance heating technique is applied to the filler wires in order to increase deposition rates while maintaining high quality deposits with low dilution levels. Initial results obtained using filer wire materials NIFD (WC), TG40 (cobalt alloy) and Inconel 625 deposited on low alloy steel showed increases in deposition rate.

G.D. Sexton and R.P. Walduck, Cited: Conf: *Eurojoin 2: Second European Conference and Joining Technology* (Florence, Italy), 16-18 May 1994, Istituto Italiano della Saldatura, Vol 15, 1994, p 545-554. [in English]. PHOTOCOPY ORDER NUMBER: 199412-58-1273.

Hardfacing by Means of the PTA Process With Powder. The principles and applications of the plasma transferred arc coating process are described. Coating materials covered include nickel-, cobalt- and iron-base alloys (HMSP 1550, HMSP 520, HMSP 2537, HMSP 2540, P30, HMSP 3560) and tungsten carbide (HMSP 4370). Components coated using these materials that are illustrated include engine valves, extrusion screws for plastic injection molding, continuous casting rolls and ball valves for the chemical industry. Other examples of applications not shown are forging tools, internal coating of pipes to the petrochemical industry, extrusion dies for forming of metal rods and dredger tooth.

C. Vanmann, H. Hallen, and M Bonacini, Cited: Conf: *Eurojoin 2: Second European Conference and Joining Technology* (Florence, Italy), 16-18 May 1994, Istituto Italiano della Saldatura, Vol 15, 1994, p 85-95 [in English]. PHOTOCOPY ORDER NUMBER 199412-58-1271

Review

General

Preparation of Coatings by Thermal Spraying Techniques and Their Application in Primary Production and Renovations. The technology of coating fabrication by the thermal spraying techniques is discussed. Qualitative difference among the preparation of coatings and layers by the surfacing, thermal spraying and two-stage spraying are covered. The consumables used and the properties of thermally sprayed coatings used in primary production and renovations are described.

O. Ambroz, Cited: *Zvaranie*, Vol 42 (No. 7), July 1993, p 152-155, [in Czech]. PHOTOCOPY ORDER NUMBER: 199411-58-1153.

Thermal Spraying

Thermal Spraying. Thermal spraying has grown into a well introduced industrial technology. Due to continuously increasing cost of materials as well as greater material requirements thermal spraying has gained more and more importance during the last two decades. Developments in thermal spraying as well as advances in powder and wire production have resulted in coatings with excellent properties under service conditions, thus enlarging the field of application. Moreover, much research work has shown that thermal spraying provides progress in both development of materials and modern coating technology.

H.-D. Steffens, M. Gramlich, and K. Nassenstein, Cited: Conf: *Second ASM Heat Treatment and Surface Engineering Conference in Europe. II* (Dortmund, Germany), 1-3 June 1993, Mater. Sci. Forum, 1994, p 163-165, 559-571 [in English]. ISSN: 0255-5476. PHOTOCOPY ORDER NUMBER: 199410-57-1199.

Test

Fatigue Resistance

Fatigue Resistance of a Medium Carbon Steel With a Wear Resistant Thermal Spray Coating. The fatigue behavior of a nickel-chromium-base powder flame-spray coating on a 0.4% C steel is investigated. Fatigue tests were carried out using mild hour-glass profile specimens. Cracks were detected and measured using plastic replicas and an image analysis system. Coated specimens showed a slightly lower fatigue endurance than plain specimens under torsion loading, while the opposite was observed for push-pull loading. Microcracks in coated specimens invariably form at pores. Contrary to the usual case of stage I shear growth for a plain 0.4% carbon steel in tension or torsion loading, the coated specimens show initial crack growth from pores along directions perpendicular to the maximum tensile stress. The crucial behavior of short cracks, and their growth rates, relative to the thickness of the coating, are discussed in some detail.

A.A. Rakitsky, E.R. De Los Rios, K.J. Miller, Cited: *Fatigue Fract. Eng. Mater. Struct.*, Vol 17 (No. 5), May 1994, p 563-570 [in English]. ISSN: 8756-758X. PHOTOCOPY ORDER NUMBER: 199410-58-1077.

Scratch Method

Surface Mechanical Strength Assessment of Various Spray Coatings on Cylindrical Substrates. Scratch testing is presented as evidence of the mechanical strength (adhesion and cohesion) of various spray coatings (detonation gun and plasma spraying) on cylindrical substrates from industrial suppliers Applied to medium thick (~20 μm) and thick (100 μm or more), rough and porous brittle coatings, scratch testing is presented as part of a general procedure including single and multi-pass operation at constant loads. The observed damage is essentially cohesive and acoustic emission becomes an indicator of chipping rather than spalling damage. Coating perforation can be reliably and reproducibly identified by means of on-line friction force monitoring which may also yield information about ploughing and prow formation in multi-pass operation. The critical load for the onset of through-thickness cracking is found to be inadequate for reliable quality ranking.

J. von Stebut, Cited: *Surf. Coat. Technol. 68/69*, Dec 1994, p 591-597 [in English]. ISSN: 0257-8972. PHOTOCOPY ORDER NUMBER: 199412-57-1532.

Thermal Cycling

On Fracture Conditions for Thermal Sprayed Heat-Protective Coatings Under Thermal Cycling. The paper presents the results of thermal

cyclic testing of thermal sprayed heat-protective coatings composed of two layers: the lower metallic one on the basis of CoCrAlY alloy and the upper ceramic layer on the basis of zirconium dioxide. For ZrO, partial stabilization the following additives are used: 30% CeO and 8% YaO. Conditions of crack propagation at the metal-ceramics interface are considered depending on the thickness of the ceramic layer. Conclusions are made on the expediency of creating the metal-ceramics interface with a nonuniform adhesive bond which would include the areas of higher resistance to fracture evolution.

G.E. Brailovskii, B.A. Lyashenko, Yu S. Borisov, and O.E. Karasevich, Cited: *Probl. Prochn.*, (No. 2), Feb 1994, p 44-47 [in Russian]. ISSN: 0556-171X. PHOTOCOPY ORDER NUMBER: 199411-31-4140.

Wear

Erosion of Composite Coatings

Erosion Resistance and Adhesion of Composite Metal/Ceramic Coatings Produced by Plasma Spraying. Ceramic coatings can exhibit greater erosion resistance than most metallic coatings. Such coatings are conveniently produced by thermal spraying. Unfortunately, thermally sprayed ceramic coatings often exhibit poor adhesion, partly as a consequence of the development of residual stresses during spraying and subsequent cooling. Composite coatings have been studied using aluminium/alumina deposit on mild steel substrates. The incorporation of ceramics within a ductile matrix has potential for sharply reducing the erosive wear at high erodent impact angles, while retaining the good erosion resistance of ceramics at low angles. It is shown that the proportion of metal and ceramic at the free surface can be specified so as to optimise the erosion resistance. Experiments have also been carried out on the resistance of the coatings to debonding during four-point bending of the coated substrate. Progress is being made towards the tailoring of composition profiles in graded coatings so as to optimize the combination of erosion resistance and adhesion.

D.A J. Ramm, I.M. Hutchings, and T.W. Clyne, Cited: Conf: Euromat 93: The 3rd European Conference on Advanced Materials and Processes, Vol. II, (Paris, France), 8-10 June 1993, *J. Phys.*, Vol IV, Nov 1993, p 3 [in English]. PHOTOCOPY ORDER NUMBER: 199412-57-1448.

High-Nitrogen-Bearing Steels

Plasma Spraying of High-Nitrogen-Bearing Steels for Wear-Resistant Coatings and Structural Applications. Thermally sprayed coatings of high-nitrogen-bearing steel for corrosion resistance and wear applications were investigated. High-nitrogen steels represent a new class of engineering materials. Additions of nitrogen enhance the strength, corrosion resistance, and hardness of austenitic stainless steels without sacrificing low-temperature ductility and fracture toughness. In addition, the precipitation of nitrides at the grain boundaries is slower compared to that of ferrous carbides, thus increasing the elevated-temperature use of the steels. The objective was to take advantage of these properties and produce high-nitrogen steels via plasma spraying. An Fe-18Cr-18Mn steel with 0.61 wt.% N was air and vacuum plasma sprayed over 4340 steel and Al substrates Plasma spraying was conducted with Ar/H_2, Ar/He, and Ar/N_2 plasma gases in air, vacuum, and nitrogen atmospheres. It was found that the N atmosphere increased the N and nitride content of the coatings and improves wear and corrosion properties. The sprayed coatings were characterized for N and O content, porosity, hardness, and wear resistance.

S. Khatri, R. Smith, P. Jokiel, E. Lugscheider, and M. Bohley, Cited: *J. Mater. Eng. Perform.*, Vol 3 (No. 4), Aug. 1994, p 476-483 [in English]. ISSN: 1059-9495. PHOTOCOPY ORDER NUMBER: 199412-58-1229.

WC-Co Coatings

Wear and Erosion Behavior of Plasma-Sprayed WC-Co Coatings. Wear mechanisms of air plasma-sprayed WC-12% Co coatings on low carbon steel were studied by using a dry sand rubber wheel (DSRW) abrasive, ring-on-square adhesive wear, and alumina particle erosion tests. Coating properties such as intersplat cohesive strength, porosity, surface roughness, hardness, and retained carbide and microstructures were characterized to assess their relationship on wear performance. Porosity, hardness, surface roughness, and retained carbide of the coatings are not the principal factors affecting wear performance. Intersplat cohesive strength of coatings, measured by a simple bonding test, is the most significant factor that relates to the wear rate of thermal spray coatings.

H.J. Kim, Y.G. Kweon, and R.W. Chang. Cited: *J. Therm. Spray Technol.*, Vol 3 (No. 2), June 1994, p 169-178 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199412-58-1337.

Wear Behavior of Thermally Sprayed Tungsten Carbide-Cobalt Coatings. Two types of wear test, dry sliding and erosion, were carried out on thermally sprayed tungsten carbide—cobalt coatings. Two different grades of coating from powders with similar cobalt content were prepared; coating I mainly consisted of WC while coating II contained substantial decomposed phases including W_2C and tungsten. In sliding wear against mild steel, weight losses of the WC-Co coatings were very small while adhesion of steel to the coatings was observed. For sliding wear against sintered alumina, wear loss significantly increased with increasing contact pressure. Plastic cutting was observed for the smaller contact pressures and more severe material removal by delamination was observed for the greater contact pressures. In erosion tests with alumina grit, plastic cutting or grooving was predominant for the lower impact angle The perpendicular impact yielded greater wear loss and the wear surface morphology suggested possible brittle fracture as well as plastic cutting. These wear characteristics were essentially identical for both coatings, but coating I with smaller WC grains and less decomposed phases exhibited better wear resistance, regardless of test conditions.

T. Senda and A. Ohmori, Cited: *J. High Temp. Soc. Jpn.*, Vol 19, (Suppl.), Dec 1993, p 325-334 [in Japanese] ISSN: 0387-1096. PHOTOCOPY ORDER NUMBER: 199410-22-1098.

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