Selected Abstracts of Thermal Spray Literature

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Applications

Biomaterials

Mixed-Mode Fracture Characterization of Hydroxylapatite/Titanium Alloy Interface. Cantilever beam and four-point bend specimen geometries were used to experimentally determine the critical energy release rates for a plasma sprayed hydroxylapatite (HA)/Ti alloy interface. A locus of energy release rates as a function of crack tip phase angle was determined where a 0° phase angle represented a tensile opening (mode I) loading and a 90° phase angle represented in-plane shear (mode II) loading. Energy release rates were found to increase substantially with an increase in phase angle An energy release rate of 0.108 N/mm was determined for a phase angle of 0° (mode I). Energy release rates of 0.221, 0.686, and 1.212 N/mm were determined for phase angles of 66°, 69°, and 72°, respectively. The experimental data were matched to a phenomenological model for which crack propagation depended on mode I loading alone, indicating that crack propagation at the HA/Ti alloy interface is dominated by the mode I loading component. Therefore, regions of HA-coated implants that experience compressive or shear loading across the HA/Ti alloy interface may be much less likely to debond than regions that experience tensile loading

K.A Mann, A.A. Edidin, R.K. Kinoshita, and M.T. Manley. Cited *J Appl. Biomater.*, Vol 5 (No. 4), 1994, p 285-291 [in English]. ISSN: 1045-4861. PHOTOCOPY ORDER NUMBER: 199507-E7-C-0148.

Low-Friction Coatings

Low Friction Coatings for Diesel Engines. The protection of engine parts by coating techniques usually aims at increased lifetime, reduced friction, wear losses, and thus improved overall efficiency. Besides environmental limitations (emissions, fuel consumption) the service conditions in diesel engines usually require multifunctional surfaces. These surfaces have to withstand wear, corrosion, oxidation, and thermal attack. In order to find solutions adapted to specific loads, it is necessary, however, to investigate the complete tribological system consisting of both friction patterns, surrounding environment and intermediate layers, and media, respectively. In general, different methods are available to realize a good friction behavior based either on suitable material combinations or adding separating and lubricating fluids, pastes, or gases. The thermal spraying technology offers many solutions in this area because tailor-made surface structures combined with additional properties can be easily realized. The use of Al_2O_3, Cr_2O_3, Cr_3C_2, and NiCrBSi coatings are discussed.

E. Lugscheider, R. Limbach, and P. Jokiel. Cited: Conf.: 26th Int. Symp. Automotive Technology and Automation, *New and Alternative Materials for the Automotive Industries* (Aachen, Germany), 13-17 Sept 1993, Automotive Automation Ltd., 1993, p 493-499 [in English]. PHOTOCOPY ORDER NUMBER: 199506-57-0781.

Magnetostrictive

Magnetostrictive Damping to Reduce Noise and Vibrations. The magnetomechanical damping capacity of cast and thermally sprayed Fe-Cr based alloys (Fe-16Cr, Fe-16Cr-2Al) has been investigated using free and forced vibration techniques. The coatings were deposited using a vacuum plasma spraying method and the cast alloys were prepared in a high frequency furnace under an argon atmosphere. Three laboratory devices including a torsion pendulum, a resonant bar, and a cantilever were used to cover a wide range of frequencies and amplitudes varying between $f = 1$ Hz and 10 kHz, and $\varepsilon = 10^{-6}$ and 10^{-3}. The damping capacity of the plasma sprayed coatings was found to be comparable to that of cast alloys. Appropriate heat treatments improved the damping capacity of both coatings and cast alloys by several times. The variation of the loss factor as function of the vibration amplitude showed a maximum, but versus frequency exhibited a slightly monotonous character. The magnetic domains were observed using the magneto-optical Kerr effect, and their modification under heat treatments was associated with different values of the damping capacities.

A. Karimi and J.L. Martin. Cited: *Materials for Smart Systems*, Conf. (Boston, MA), 28-30 Nov 1994, Materials Research Society, 1995, p 353-358 [in English]. ISSN: 1-55899-261-8. PHOTOCOPY ORDER NUMBER: 199507-31-2393.

Offshore Infrastructure

Performance History of Thermal-Sprayed Aluminum Coatings in Offshore Service. In 1984, the Hutton TLP was installed with a sealed thermal sprayed aluminum (TSA) coating. After eight years of service, the TSA coating on the production risers and tethers was still in good condition. The condition in the splash zone was indistinguishable from other inspected components. However, there were notable differences between the production risers and the tethers. The tethers, having a vinyl sealer, showed a blistered surface, while the risers, with a silicone sealer, did not show any blistering. No corrosion has been observed underneath any of the blisters. The importance of adequate sealers in connection with blistering has been documented by testing. The excellent performance of TSA coating in the splash zone is further documented by field studies published in the last few years

K.P. Fischer, W.H. Thomason, T. Rosbrook, and J. Murali. Cited: *Mater. Perform.*, Vol 34 (No 4), April 1995, p 27-35 [in English]. ISSN-0094-1492. PHOTOCOPY ORDER NUMBER· 199506-35-0851.

Book

Thermal Spray Coatings

Science and Engineering of Thermal Spray Coatings.

I. Pawlowski. John Wiley & Sons, 1994 [in English]. ISSN: 0471952532. PHOTOCOPY ORDER NUMBER: 199507-72-0254.

Manufacturing

Flame Sprayed Ceramic Shells

Production and Evaluation of Flame Sprayed Ceramic Shells. The work describes a very simple method to produce ceramic tubes by using oxyacetylene flame spraying Ceramic (Al_2O_3 and Al_2O_3/TiO_2) fine powders are warmed up in oxyacetylene flame and sprayed onto a substrate. The properties of so-formed free-standing bodies depend upon the interactions between individual lamellae and between lamellae and substrate. The porosity and mechanical properties are evaluated as a function of spraying parameters The tubes present low strength, low internal roughness, and high open porosity. The results were associated with the ceramic powders, sintering temperature, and the rotating speed of the substrate.

R.S. Lima and C.P. Bergmann. Cited· *Ind. Ceram. (Italy)*, Vol 14 (No. 4), 1994, p 159-162 [in English]. ISSN-1121-7588. PHOTOCOPY ORDER NUMBER 199508-E7-C-0169.

Machinability of Sprayed Coatings

Machinability of Sprayed Coatings of 13Cr Stainless Steel, Eutectoid Steel and Aluminum Bronze. Machinability of overlay coatings that are cut with an engine lathe is investigated. Five kinds of thermal spray materials are used: 13% Cr stainless steels made in the United States and in Japan, eutectoid steel made in the United States, and aluminum bronzes made in the United States and in Japan. The materials made in the United States are thermal sprayed with wire flame spraying equipment, and those made in Japan are sprayed with arc spraying one on the 29 mm diam mild steel bar for ~2.5 mm in thickness. The cutting conditions are as follows: WC type carbide cutting tool, negative back rake angle, 10, 25, and 40 m/min for cutting speed, 0.1 mm/rev for feed, 0.1, 0.25, and 0.5 mm for depth of cut. Results obtained are as follows: (1) The radial cutting forces are greater than the tangential forces because of the negative back rake angle. (2) Flame sprayed coatings of the 13Cr stainless steel made in the United States had poor machinability region when the cutting speed was faster than 25 m/min and the depth of cut was thicker than 0.25 mm; however, arc sprayed coatings of similar material made in Japan could be cut without any problem in spite of being harder than the ones made in the United States. (3) Flame sprayed eutectoid steel coatings could be cut in almost the same cutting conditions, though they had a similar hardness value to that of the flame sprayed 13Cr stainless steel made in the United States. (4) Sprayed aluminum bronze coatings showed good machinability in all cutting conditions. (5) Because of the layered structure containing pores, the surface roughness of the sprayed coatings after cutting is greater than that of the theoretical value of cutting surface, especially in the cases of 13Cr stainless steel and eutectoid steel.

S. Itomura, W. Oshikawa, J. Yamaguchi, G. Ueno, and T. Fukushima. Cited: *Ryukyu Daigaku Kogakubu Kiyo (Bull. Fac. Eng. Ruykyus)*, Vol 49, March 1995, p 1-9 [in Japanese]. ISSN: 0389-102X. PHOTOCOPY ORDER NUMBER 199509-58-1006.

Materials

NiCrAlY Phase Stability

Phase Stability of NiCrAlY Powders for Plasma Sprayed Coatings. Phase transformations of additional material used for plasma spraying based on the Ni-Cr-Al-Y system are investigated Three powder samples have been studied up to 1100 °C by DTA and x-ray diffraction measurement, respectively The view on recorded transitions is also given. It is shown that several transformations should influence the resulting thermal properties and lifetime of plasma sprayed coatings.

M. Cepera and J. Zeman. Cited: *Mater Sci. Forum,* Conf. 3rd European Powder Diffraction Conf. (EPDIC 3) (Vienna), 25-28 Sept 1993, Trans Tech Publications, 1994, p 166-169 (Part 2), p 373-378 [in English]. ISSN 0255-5476 PHOTOCOPY ORDER NUMBER: 199506-57-0738.

Microstructure

Phase Structure

Formation and Properties of Iron Base Amorphous Coatings by Low Pressure Plasma Spraying. Fe-10Cr-10Mo alloys containing a large amount of carbon and/or boron were plasma sprayed under reduced pressure. All the sprayed coatings on SS400 are perfectly amorphous and show a very high hardness of 800 to 900 DPN. The amorphous coatings crystallize at 773 K or above. The crystallization temperature shifts higher with increasing boron content of the alloy. Very fine carbide, borocarbide, or boride precipitates in the matrix of ferrite after crystallization bring about an extremely high hardness of 1400 DPN. The coatings containing high carbon keep very high hardness (>1000 DPN) even after tempering at high temperatures of 1073 and 1173 K The anodic polarization behavior of the as-sprayed amorphous coatings exhibits the activation-passivation transition in 1 *N* H_2SO_4 solution at 303 K. The active and passive current densities of the coatings increase with increasing boron content of the alloy The corrosion resistance of the coating containing no boron is superior to SUS316L stainless steel coating.

K Kishitake, H. Era, and F. Otsubo Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spray. Soc.),* Vol 32 (No. 1), Jan 1995, p 28-34 [in Japanese]. ISSN. 0916-6076. PHOTOCOPY ORDER NUMBER 199509-58-0982.

TaC Coatings

Microstructure of Plasma-Sprayed TaC Coatings. Tantalum carbide coatings were plasma sprayed in a controlled argon atmosphere. The microstructure of the coatings was determined by scanning electron microscopy and transmission electron microscopy. All the lamellae in the coating are formed by a mosaic of columnar grains normal to the interface, perfectly polygonized and jointed This microstructure can be explained by a crystal growth mechanism in the solid phase (a grain-growth mechanism) starting immediately after the solidification of the first lamella

L. Trignan-Piot, M. Berardo, A. Charai, J. Gastaldi, and S Giorgio. Cited: *Thin Solid Films,* Vol 248 (No. 1), 1 Aug 1994, p 12-17 [in English]. ISSN: 0040-6090. PHOTOCOPY ORDER NUMBER· 199508-12-0924.

Patent

Brazing Material

Corrosion-Resistant and Brazeable Aluminum Material and a Method of Producing Same. A corrosion-resistant and brazable aluminum material has an aluminum core, and a thermally sprayed layer formed on the core is composed of a brazing metal intermingled with zinc or its alloy. The brazing metal may be a mixture of aluminum and silicon, an Al-Si alloy, a blend of the mixture with the alloy, or silicon. The brazable aluminum material may be produced by blending a first powder of the brazing metal with a second powder of a corrosion-resistant substance including zinc so as to prepare a powder mixture, and then thermally spraying the powder mixture onto the aluminum core.

T. Kanal, M. Furuta, M. Kojima, and M. Ueda. European Patent: EP0605323, 28 Dec 1993 [in English]. PHOTOCOPY ORDER NUMBER: 199508-55-0989.

Coating on Appliances

Process and Equipment for Coating the Metallic Body of a Domestic or Cooking Utensil, as well as for Using the Atmospheric Oxidation of the Surface of a Metallic Body. [Original title: Verfahren und Vorrichtung zum Beschichten eines metallischen Korpers eines Haus-oder Kuchenerates sowie Verwendung des atmospharischen Oxidierens einer Oberflache eines metallischen Korpers.] A process and the equipment used to coat the metallic body (e.g., of Al-Mg alloy) of a domestic or cooking utensil, e.g., a frying pan, are described. A hard material coating is produced by thermal spraying, and an adherent coating is applied to the hard material coating thereafter In addition, a further layer is provided between the hard material coating and one surface of the body, and this is produced as a dense oxidic layer by oxidizing the metal forming the body.

W. Heinzel and T F Weber. European Patent: EP0567822, 8 April 1993 [in German]. PHOTOCOPY ORDER NUMBER: 199508-57-0979

Silicide Coating for Molten Metals

Silicide Coating Having Good Resistance to Molten Metals. Silicides of refractory metals such as chromium, molybdenum, tantalum, niobium, tungsten, zirconium, titanium, and vanadium, preferably $CrSi_2$ and $MoSi_2$, are materials that are resistant to attack by molten metals, such as zinc, and can provide coatings for various articles. The coated materials may be formed by a thermal spraying method.

J.C. Wood and S. Katoh. European Patent: EP0603797, 20 Dec 1993 [in English]. PHOTOCOPY ORDER NUMBER: 199508-57-0941.

Sliding Bearing

Sliding Bearing with a Bearing Cup. A sliding bearing with a bearing cup comprises a supporting element, a bonding layer, and a cover layer of babbitt metal. The layers are formed either by a wire flame spraying process or by the spraying on of powder and heat treatment The bonding layer, which may comprise NiAl 80/20 or AlSi 12, is open-cell porous, as is the cover layer at least on its surface contiguous with the bonding layer, and the cover layer has a decreasing porosity in a direction toward the bearing surface.

B. Negwer. UK Patent: GB2273750, 16 Dec 1993 [in English]. PHOTOCOPY ORDER NUMBER: 199508-61-0706.

Processing

Energy Reduction

Reduction of Energy Consumption and Resources in Thermal Spray Process. A review covers thermal spray processes including plasma, high-velocity oxygen fuel (HVOF), and arc thermal spray system with an emphasis on improvement in efficiency. It examines opportunities in savings in energy and material; they include power supply, fuel control, powder feed, cooling system, feed wire size, procedures, and other operating parameters. Several examples are discussed for the improvement of the overall efficiency.

M. Nakagawa and M. Sasaki. Cited: *Hyomen Gijutsu (J. Surf. Finish. Soc. Jpn.),* Vol 46 (No. 2), 1995, p 124-131 [in Japanese]. ISSN: 0915-1869. PHOTOCOPY ORDER NUMBER: 199508-58-0862.

Hard Soldering

Hard Soldering with X5CrNi18 10 of NiCr20TiAl with Atmospheric Plasma Spray Solder L-Ni2. [Original Title: Hardsolderen van X5CrNi18 10 en NiCr20TiAl met atmosferich plsmagespoten soldeer L-Ni2.] This paper describes a hybrid type of technology, developed for hard soldering NiCr20TiAl. The mechanism of using X5CrNi18 10 for this is explained and involves temperatures of 500 to 700 °C. A variety of spray powders can be used, and the use of L-Ni2 is described, with its general structure. The hard soldering of cylindrical test pieces is explained and also the structure of the actual joining solder. That of some similar materials is also outlined. Quality controls established for the process are given, with tests and notes on complicated shapes. The process gives important new advantages.

B. Wielage and J. Drozak. Cited: *Roestvast Staal,* Vol 10 (No. 2), March 1994, p 11-19 [in Dutch]. ISSN: 0169-3328. PHOTOCOPY ORDER NUMBER: 199507-55-0913.

HVOF

Characterisation of Cr_3C_2-NiCr Cermet Powder for High Velocity Oxyfuel Spraying. The structural characteristics of a commercial high-velocity oxyfuel thermal spraying powder containing chromium carbides and a Ni-Cr metallic matrix have been determined using a variety of experimental techniques including x-ray diffraction, SEM, and electron probe microanalysis. The powders were prepared in such a way that a liquid phase was formed. In some cases the liquid phase surrounded the original carbides, but in other cases the liquid did not surround the carbide particles, giving rise to a mixture of both spherical and irregular granules. Apart from the original Cr_3C_2, secondary Cr_3C_2 has been found together with Cr_7C_3 and $Cr_{23}C_6$ with some nickel replacement for chromium in these carbides. The results have been interpreted in relation to the C-Cr equilibrium diagram with appropriate modifications for the presence of Ni.

J.M Guilemany, J. Nutting, and N. Llorca-Isern. *Powder Metall.,* Vol 37 (No. 4), 1994, p 289-292 [in English]. ISSN: 0032-5899. PHOTOCOPY ORDER NUMBER: 199507-62-9872.

Liquid-Manganese Sintering

Liquid-Manganese Sintering of Plasma-Sprayed Zirconia-Yttria Coatings. The penetration phenomena of liquid manganese into a porous ZrO_2-8 wt% Y_2O_3 coating, plasma sprayed on a JIS SS400 steel substrate was studied by heating at 1573 K in vacuum, and the possibility of improving the mechanical properties of the coating by heat treatment with liquid manganese was examined. It was found that liquid manganese rapidly penetrated the coating and formed an interface between the coating and the substrate. Densification of the coating occurred when ZrO_2 particles were sintered with liquid manganese that penetrated the porous ZrO_2 coating. It was revealed that the dense coating was free of porosities and that its hardness increased greatly after heat treatment with manganese, compared with an as-sprayed ZrO_2 coating. Moreover, the modulus of elasticity and the fracture toughness of the coating reached the same levels as those of sintered partially stabilized ZrO_2 (Y_2O_3).

A. Ohmori, Z. Zhou, and K Inoue. Cited: *Thin Solid Films*, Vol 251 (No. 2), 1 Nov 1994, p 141-146 [in English] ISSN: 0040-6090 PHOTOCOPY ORDER NUMBER: 199507-57-0924.

Nanostructured Materials

Chemical Processing and Applications for Nanostructured Materials. This paper presents an overview of recent research performed at Rutgers University and the University of Connecticut on the synthesis and processing of nanostructured materials. Highlights of this collaborative research program include: synthesis of carbide strengthened steel and hard cermet powders from aqueous solution precursors, synthesis of ceramic powders, and ceramic matrix composites from metalorganic precursors, densification of powder compacts by liquid phase sintering, formation of high-quality coatings by thermal spraying, and demonstration of superior hardness and wear resistance in bulk materials and coatings.

B.H. Kear and P.R. Strutt. Conf.: 2nd Int. Conf. Nanostructured Materials (Stuttgart, Germany), 3-7 Oct 1994. Cited: *Nanostructured Mater.*, Vol 6 (No 1-4), 1995, p 227-236 [in English]. ISSN: 0965-9773. PHOTOCOPY ORDER NUMBER: 199509-54-0858.

Reactive Plasma Spray Forming

Reactive Plasma Spray Forming of Nitride/Nitrogen Composite Materials. Reactive plasma spray processing has been investigated as a method for producing titanium nitride composites, nitrogen-strengthened steels, and a nitrided ceramic Al_2O_3/SiAlON. Results indicate that plasma spraying in controlled atmospheres can produce such materials either as coatings or structural components Conventional plasma spray coating systems, normally used in low-pressure plasma spraying, have been modified to reactively spray titanium, high-E steel alloys such as P-900 and alumina powders.

R. Knight and R.W Smith Cited: *11th Int Symposium on Plasma Chemistry*, (Loughborough, Leicestershire, UK), 22-27 Aug 1993, Vol 1, International Union of Pure and Applied Chemistry, 1993, p 139-144 [in English]. ISSN: 0-9522149-1-1. PHOTOCOPY ORDER NUMBER: 199507-E2-D-0208

Supersonic Jets

Use of Supersonic Jets in the Gas-Thermic Spraying Technology. Various ways of development of the supersonic spraying techniques are presented. An increase in kinetic energy of the sprayed particles leads to an increase in the coating density (up to 97 to 99.5%) and the adhesion strength with a base metal. The installations are created, and the special powders are developed similar to tungsten-cobalt hard alloys, nickel and cobalt alloys, bronze, aluminum and chromium oxides, chromium carbide and nichrome mixture, aluminum alloy, and polyester. The positive results are obtained in practice by supersonic spraying the above materials

Yu S. Borisov and S.V. Petrov. Cited: *Avtom. Svarka*, Vol 1, Jan 1995, p 41-44 [in Russian]. ISSN-0005-111X. PHOTOCOPY ORDER NUMBER: 199508-57-0969.

Properties

Corrosion Fatigue

Influence of Plasma-Sprayed Coating on Corrosion Fatigue Strength of 13Cr Stainless Steel. In order to clarify the influence of plasma-sprayed coating on the corrosion fatigue strength of 13Cr (SUS410J1) stainless steel, WC-Co, ZrO_2, Cr_3C_2, and Co-Cr-Ni-W were plasma sprayed on round bar fatigue test specimens of 13Cr stainless steel. The surface, the cross section of these coatings, and the interface between these coatings and base metal were examined by SEM and optical microscopy. Rotating corrosion fatigue tests of these coated specimens were conducted in 3% NaCl aqueous solution at a testing speed of 3600 rpm. The WC-Co and ZrO_2 coatings with low porosity improved corrosion fatigue strength at 10^7 cycles by ~70%. It might be concluded that the effective coating to improve corrosion fatigue strength should be of very low porosity and firmly adhesive to the base metal. On the other hand, no improvement of corrosion fatigue strength was observed by the Cr_3C_2 and Co-Cr-Ni-W coatings with relatively high porosity. In these specimens, corrosion fatigue cracks initiated from corrosion pits at the surface of the base metal and propagated predominantly through the intergranular path

R. Ebara, S. Shigemura, and T. Yamane. Cited: *J. Soc. Mater. Sci. Jpn.*, Vol 43 (No. 490), July 1994, p 881-887 [in Japanese]. ISSN: 0514-5163. PHOTOCOPY ORDER NUMBER: 199506-57-0732.

Corrosion Resistance

The Influence of CeO_2 on the Corrosion Resistance of Laser Remelted Alloy Spray Coatings on Steel. Thermal spraying, an important surface technique, has important economic consequences in the maintenance of equipment and the improvement of resistance to wear and corrosion of components. Results of the influence of a rare earth, specifically cerium, on the corrosion resistance of laser-remelted $M_{80}X_{20}$ spray coatings on 1020 steel are presented. The addition of rare earth (8% CeO_2) improves the corrosion resistance of the laser-remelted $M_{80}X_{20}$ alloy layer remarkably, resulting in an obvious decrease of the values of ip and i'p, and hence significant improvement of passivation. The addition of rare earth (8% CeO_2) lowers the corrosion rate (to approximately one-third of that without rare earth) of the laser-remelted $M_{80}X_{20}$ alloy coating and also changes the corrosion morphology.

Y Wang, Q. Zhang, M. Su, and Q.P. Zhong. Cited: *Scr. Metall Mater.*, Vol 32 (No 6), 15 March 1995, p 891-894 [in English]. ISSN 0956-716X. PHOTOCOPY ORDER NUMBER 199506-56-0417.

Improvement of Corrosion Fatigue Strength of High Strength Steel by Thermal-Sprayed (WC-Cr-Ni) Cermet Coating. In order to clarify the effect of thermal-sprayed (WC-Cr-Ni) cermet coating on the corrosion fatigue strength of high-strength SKD11 steel, rotating bending corrosion fatigue tests were conducted in a 2 mass% $ZnSO_4$ aqueous solution environment. It was found that the corrosion fatigue strength of the (WC-Cr-Ni) cermet thermal sprayed specimen with 100 μm thickness was 318.6 MPa at 2×10^7 cycles in 2 mass% $ZnSO_4$ aqueous solution and was ~3 times larger than that of the SKD11 base metal at the same number of cycles. The effective thickness of the (WC-Cr-Ni) cermet thermal sprayed coating to improve the corrosion fatigue strength of SKD11 steel was ~100 μm. The principal cause of improvement of the corrosion fatigue strength of steel by thermal sprayed (WC-Cr-Ni) cermet coating is the insulation of SKD11 steel surface from the permeation of $ZnSO_4$ aqueous solution. Impregnation of fluorine-contained resin into the thermal sprayed (WC-Cr-Ni) cermet was ineffective to improve the corrosion fatigue life of SKD11 steel at a high stress region. However, the corrosion fatigue strength at 2×10^7 cycles was improved by ~22%. In the high stress region of *S-N* curves, the insulation effect was not enough due to an exfoliation of fluorine-contained resin from the thermal sprayed (WC-Cr-Ni) cermet coating. Corrosion fatigue crack initiated at a corrosion pit in the SKD11 base metal surface and propagated through the transcrystalline path.

H. Nakahira, Y. Harada, K. Tani, R. Ebara, and Y. Yamada. Cited: *J. Soc. Mater. Sci. Jpn.*, Vol 43 (No 490), July 1994, p 888-894 [in Japanese]. ISSN: 0514-5163. PHOTOCOPY ORDER NUMBER: 199506-58-0638.

Corrosion Resistance of Plasma Protective Coatings in Fusible Fluoroplastics. Studies have been performed on 38KhA, 38Kh2MYuA, 12Kh18N10T, and Kh12M specimens coated with a PN85Yu15 (Ni-Al) powder at 653 and 753 K within 30 h. The coatings are heat-resistant strong composites based on NiAl and Ni_3Al intermetallics compounds. The corrosion resistance of coated steels is 5 to 20 times better. Coating reduces the labor intensity of manufacturing elements used for fluoroplastic reprocessing and makes it possible to give up a nickel alloy (KhN77TYuR) that is difficult-to-obtain.

V.P. Valuev, A A. Ivanov, Yu.P. Lozhechko, B.V. Revnov, and V A. Berezin. Cited: *Zashch. Pokrytiya Met.*, Vol 26, 1992, p 79-81 [in Russian] PHOTOCOPY ORDER NUMBER: 199506-58-0622.

Failure Mechanisms TBC

Failure Mechanisms of a Zirconia-8 wt.% Yttria Thermal Barrier Coating. Isothermal and cyclic heat treatments of a plasma sprayed zirconia-8 wt% yttria thermal barrier coating on a nickel superalloy Inconel 600 substrate highlighted coating failure mechanisms. A reaction layer formed at the bond coat/ceramic interface, and failure of the coating initiated in the reaction layer due to opening thermal expansion mismatch stresses associated with a nonplanar interface. Crack propagation occurred in the ceramic in all cases, due to the high fracture energy of the interface. The relatively low fracture energy of the coating, in planes parallel to the interface, is the ultimate factor limiting coating lifetime.

A.H. Barlett and R. Dal Maschio. Cited: *J. Am. Ceram. Soc.*, Vol 78 (No. 4), April 1995, p 1018-1024 [in English]. ISSN: 0002-7820 PHOTOCOPY ORDER NUMBER: 199506-57-0717.

Residual

Characterization of Flame-Sprayed and Plasma-Sprayed Pure Metallic and Alloyed Coatings. The composition, structure, and properties of thermally sprayed coatings were investigated by a number of methods, including x-ray diffraction, x-ray spectroscopy, and scanning electron microscopy. The Vickers hardness and porosity were also investigated. The coatings were plasma sprayed pure molybdenum and flame sprayed copper and nickel alloys. It was found that the alloyed coatings had a different chemical composition than the powders they had been produced from. In addition, all the coatings exhibited a fiber texture that complicated the x-ray method for estimation of residual stresses. However, for the pure molybdenum coating, it was possible to evaluate this parameter, taking into account the effects of the measured porosity and crystallographic anisotropy on the Young's modulus and Poisson's ratio.

I. Iordanova, K.S. Forcey, B. Gergov, and V. Bojinov. Cited: *Surf. Coat. Technol.*, Vol 72 (No. 1-2), 1 May 1995, p 23-29 [in English]. ISSN: 0257-8972. PHOTOCOPY ORDER NUMBER: 199507-58-0719.

Review

The Future of Thermal Spray Technology. A review of thermal spray processes is presented. Although dating back more than 100 years, thermal spray processes are not well understood and, as a consequence, are often overlooked. Education, skills training, and standards are needed if the industry is to grow. Thermal spray technologies discussed include flame, high-velocity oxyfuel, wire arc, and plasma. Applications and growth areas are discussed in aerospace and automotive, as well as other areas, but education to provide trained operators is seen as a major obstacle to use of these technologies. Applicable standards are listed, but to ensure high-quality coatings the standards must be incorporated into a system.

R.W. Smith and R.D Fast. Cited: *Weld. J.*, Vol 73 (No. 7), July 1994, p 43-50 [in English]. ISSN: 0043-2296. PHOTOCOPY ORDER NUMBER: 199507-57-0840.

Coating Technology for Gas

Current Status of Coating Technology for Gas Turbines and Development of Coating Design System. Current status of the coating technology for gas turbines, such as a high-temperature protective coating and a thermal barrier coating on nickel-base superalloys, is investigated by examining the coating processes and materials. As a result, it is thought that multilayered coatings each with different faculties become the future trend for high-performance gas turbines. Also, a coating design is necessary for developing the multilayered coatings. For that reason, a computer-aided interactive system has been developed that enables convenient analysis of the thermal stress for multilayered coatings including functionally graded materials. The thermal stresses are calculated by the analytical method based on strain suppression and beam theory The analysis can be easily conducted by the selection of menus and the data input acceding to a few commands.

Y. Itoh. Cited: *Nippon Yosha Kyokai Shi (J. Jpn. Therm. Spraying Soc.)*, Vol 32 (No. 1), Jan 1995, p 44-51 [in Japanese]. ISSN: 0916-6076. PHOTOCOPY ORDER NUMBER: 199509-57-1098.

Testing

Hardness

Simulation of Hardness Testing on Plasma-Sprayed Coatings. A plasma sprayed thermal barrier coating consisting of a NiCoCrAlY bond coat and cerium-stabilized zirconia ceramic coating was heat treated at 400 °C for 1000 h. Microhardness measurements were used to evaluate microstructural variations throughout the coating. One hundred and twenty measurements were performed at both the bond coat and ceramic coating positions within the thermal barrier coating system Both data sets were analyzed to assess whether they could be described as Gaussian (i.e., "normal") or Weibull distributions. The influence of the sample size, that is, the number of microhardness tests for a group, on the mean hardness value was also evaluated by a Monte Carlo simulation procedure. The mean value, the standard deviation, the coefficient of variation, and the Weibull modulus for the subsets of data were calculated to assess these effects. The confidence for the mean value was also considered. The results indicated that the reliability of the microhardness test improved as the sample size increased. At least 20 measurements were needed to distinguish differences in microhardness between the bond coat and the ceramic coating at a 95% confidence level.

C.-K. Lin, C.-C. Lin, and C.C. Berndt. Cited: *J. Am. Ceram. Soc.*, Vol 78 (No. 5), May 1995, p 1406-1410 [in English]. ISSN: 0002-7820. PHOTOCOPY ORDER NUMBER: 199508-57-1062.

Statistical Analysis of Microhardness

Statistical Analysis of Microhardness Variations in Thermal Spray Coatings. A thermal barrier coating system consisting of a NiCoCrAlY bond coat and cerium-stabilized zirconia ceramic coating was sprayed onto a metallic substrate. Aging at 400 and 800 °C for 100, 500, and 1000 h was performed. Microhardness measurements of as-sprayed and heat-treated samples were used to evaluate microstructural variations throughout the thermally sprayed coating after different aging conditions. Forty readings were taken at both the bond coat and ceramic coating positions within the thermal barrier coating (TBC) system and adjusted by subtracting the two largest and two smallest readings. Both data sets were statistically analyzed to assess whether they belonged to Weibull or Gaussian (or "normal") distributions. This study has established that the homogeneity of coatings, at least as measured by a microhardness test, varies during service and thus may influence the lifetime.

C.K. Lin and C.C. Berndt. Cited: *J. Mater. Sci.*, Vol 30 (No. 1), Jan 1995, p 111-117 [in English]. ISSN: 0022-2461. PHOTOCOPY ORDER NUMBER: 199509-31-2886.

Superplasticity

Superplasticity of FeNiBSi Alloy Coating. The compressive superplastic tests at constant temperature were carried out on flame sprayed FeNiBSi alloy coating on GCr15 steel. The relationship of superplastic deformation between the coating and the substrate was investigated. After deformed superplastically, the internal cavities in the FeNiBSi alloy coating may disappear, and the bonding interface between the coating and the substrate may be metallurgically welded.

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Ultrasonic Evaluation of FGM

Ultrasonic Evaluation on Thermal Shock Damaged FGM Coatings. With regard to development and utilization of functionally gradient materials (FGM), nondestructive evaluation techniques are considered to play important roles. For example, it is necessary to measure elastic constants in their developing stage and evaluate an internal discontinuity or material deterioration to ensure the material soundness of actual FGMs. On the other hand, many FGMs are tested with CO_2 laser thermal shock test method to investigate the thermal shock resistance and the mechanisms of materials deterioration. Therefore, CO_2 laser thermal shock test is performed on the plasma sprayed FGM coatings (consisting of NiCrAlY and 8YSZ) on SUS304 substrate, and their damaged parts with ultrasonic immersion technique are evaluated. As shown by this experiment, useful information on the material deterioration can be provided by ultrasonic immersion technique.

M. Shimada, T. Yoshi, S. Akiyama, and T. Fukushima. Cited: *Hihakai Kensa (J. NDI)*, Vol 43 (No. 4), April 1994, p 230-235 [in Japanese]. ISSN: 0367-5866. PHOTOCOPY ORDER NUMBER: 199508-58-0858.