Selected Abstracts of Thermal Spray Literature

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Application

Dies

The Plasma Spraying of Dies for Fan-Pulley in Truck. The failure mechanism of drawing die for the fan-pulley in a truck was analyzed and a method of strengthening by plasma spraying of Ni-16Cr-15Fe-4.5Si-3.5B-0.8C was studied. The results show that the surface microstructure and the component of the die are changed after plasma spraying. The coating raises the wear resistance of the die greatly, the service life of the die is ten times longer than that of ones without coating and the pulley made by the plasma sprayed die has a bright and clean surface without drawing-burr.

X.H. Jie and S.R. Chen. Cited: *Heat Treatment of Metals (China)* (9), Sept 1992, 29-31 [in Chinese]. ISSN: 0254-6051. PHOTOCOPY ORDER NUMBER: 199304-58-0375.

General Review of Processes

Coatings for High Temperature Materials. High-temperature coatings have become the prime requirement for many components operating at high temperatures in several important installations, for example, gas turbine components. There are several coating techniques, based on chemical or physical deposition. An attempt has been made to describe the principles of various techniques with their advantages, limitations, and important structural characteristics. Examples of where these coatings may be suitable are also given.

A.S. Khanna. Cited: *Transactions of the Metal Finishers' Association of India*, *1* (4), Oct-Dec 1992, 35-44. [in English]. PHOTOCOPY ORDER NUMBER: 199304-58-0398.

Japanese Review

Status of Thermal Spray Technology in Japan. The present status and prospects for future progress of the thermal spraying business and technology in Japan are summarized. Organizations that have supported thermal spraying business and technology consist of coating contract shops, producers and suppliers of spray equipment and consumables, and large companies that have been using thermal spray technology in their production lines. Moreover, outside, noncommercial organizations such as universities, government, local industrial institutes, and academic societies for thermal spraying are reviewed. In terms of thermal spraying equipment, in particular, the installation of atmosphere-controlled plasma spray and high-velocity oxygen/fuel spray (HVOF) are investigated. Typical examples include industrial applications that are performed mainly by coating contract shops and large companies. In emerging spraying process technologies, synthesis of new materials using atmospheric plasma spray and atmosphere-controlled plasma spray, laser-assisted spraying, and new plasma torches are presented. The automotive, aerospace, steel-rolling, and Al-rolling industries make use of this technology. A series of cermet sprayed coatings are discussed.

K. Tani and H. Nakahira. Cited: *Journal of Thermal Spray Technology*, *1*, (4), Dec 1992, 333-340 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-58-0600.

Maintenance Repair

Flame Spray Coatings Help Decrease Maintenance Costs. The applications of flame spray coating with corrosion- and abrasion-resistant powders are described which include coating of mild steel rolls (14 ft long × 11 in. in diameter) for a paper mill to improve corrosion resistance, and filter panels in an Al mill. A frequent application involves rebuilding of shafts for pumps, fans, and various machinery with spray coatings up to 0.01 in. Wear resistance of flame spray coating apparently outlasts Cr plate.

Cited: *Welding Journal*, *71* (11), Nov 1992, 54-55 [in English]. ISSN: 0043-2296. PHOTOCOPY ORDER NUMBER: 199304-58-0523.

Thermal Spraying Makes the Grade as a Repair Process. The usefulness of flame spray technique for repair and maintenance of a variety of machine parts, castings and sheet metal products is discussed. Advantages include: easy automation of the process, choice of a wide range of materials from alloys to ceramics for coating, and elimination of stress on the coated base metal. The technique is not suitable for nitrided steel base materials or areas subject to shear load in service. Sprayed materials discussed include: stainless, Al bronze, Ni-base superalloys, Cu, brass, and Al.

M.L. Thorpe. Cited: *g Journal*, *71* (11), Nov 1992, 45-48 [in English]. ISSN: 0043-2296. PHOTOCOPY ORDER NUMBER: 199304-58-0522.

Thermal Barrier

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

W. Lih, E. Chang, C.H. Chao, and M.L. Tsai. Cited: *Oxidation of Metals*, *38*, (1-2), Aug 1992, 99-124 [in English]. ISSN: 0030-770X. PHOTOCOPY ORDER NUMBER: 199305-57-0581.

Composites

Spray Infiltration

Some Concepts for Fabrication Processing of MMCs in Liquid State. Metals matrix composites (MMC) can be split into two classes: those containing fibers (MMCf) and those containing particulates (MMCp). Because they are very difficult to fabricate, MMC fibers are usually very expensive. Some of them reach $1000/lb. There are at least two main reasons for this high price: the small market size; most of the applications being military; and very expensive fabrication processes because fibers are difficult to wet by the liquid metal. On the other hand, MMCs reinforced by particulates are less expensive because: particulates are inexpensive (~$20.00/lb or less) and fabrication processes are easier. Because they are relatively less expensive, easier to fabricate and they have interesting mechanical and physical properties, MMCp are more used. This review excluded secondary processes, focusing only on primary processes such as foundries, spray, infiltration, etc. for which no ulterior processes are needed prior to using the piece. Consequently, machining, secondary forging, extrusion, etc. are not discussed. Only Al matrix composites are discussed, excluding other types of metal matrices such as Cu, steel, etc. MMCp can be formed by powder metallurgy, from liquid state, in mushy state or in solid phase. This brief review deals only with incorporation of particulates in liquid. Forming in solid state is not dealt with. In all cases, it has to be remembered that the principal criterion for judging process is the cost. Most of the processes described are from patents; some are already at the industrial stage.

J. Masounave and F. Marchand. Cited: Conference: Advances in Production and Fabrication of Light Metals and Metal Matrix Composites, Edmonton, Alberta, Canada, 23-27 Aug. 1992, Canadian Institute of Mining, Metallurgy and Petroleum, Xerox Tower, 1210-3400 de Maisonneuve Blvd. W., Montreal, Quebec H3Z 3B8, Canada, 1992, 521-530 [in English]. PHOTOCOPY ORDER NUMBER: 199304-62-0632.

Materials

Composition of Carbides

Influence of Carbide Powder Composition on Properties of Air Plasma Sprayed Coatings. Carbide spraying powders are a very important class of powders for various thermal spray processes and are mainly used for wear protection. The present paper deals with the alterations in chemical composition and phase structure of carbide powders during air plasma spraying. Carbides of tungsten and titanium and mixed carbides of these, were sprayed as unblended powders and also as powders blended with an Fe/Cr powder. The results of X-ray and chemical analyses, as well as an adhesive wear test show the advantages of the cubic titanium carbide based powders in comparison with the hexagonal tungsten carbides based ones. A method of protection against decarburization, making use of thin carbon coatings, was developed and investigated with a WC-6Co spraying powder as the most sensitive system.

L.-M. Berger, B. Schultrich, H. Preiss, and A. Oswald. Cited: Conference: Advances in Powder Metallurgy & Particulate Materials—1992. Vol 8, Properties of Emerging P/M Materials, San Francisco, California, USA, 21-26 June 1992; Metal Powder Industries Federation, 1992, 307-318 [in English]. PHOTOCOPY ORDER NUMBER: 199305-57-0568.

Magnesia Powders

Flame Spraying Properties of MgO Bearing Materials. Effect of additives on meltability of MgO bearing materials for flame spraying on MgO-Cr_2O_3 refractory brick was studied under the condition of LPG 15 Nm^3/h, O_2 75 Nm^3/h and powder feeding speed of maximum 30 kg/h. It was revealed that addition of L.D. converter slag or alumina increased flame spraying property of MgO material. Periclase, hercynite, monticellite, spinel and olivine were detected as mineral phase of flame sprayed layers through X-ray powder diffraction analysis.

I.S. Kim, G.G. Hong, and N.H. Park. Cited: *Technical Research Report, 6* (3), Sept 1992, 453-458 [in Korean]. PHOTOCOPY ORDER NUMBER: 199304-45-0357.

Nickel-Base Coatings

Comparison of Superalloy Coatings Sprayed With Plasma and HVOF. The relatively new HVOF (high velocity oxygen fuel) spray technique offers interesting possibilities, e.g. very dense and low oxide content corrosion-resistant coatings can be produced. This report compares plasma and HVOF sprayed coatings of the superalloys Anval 625 and Anval 718. Coating properties are evaluated with respect to: porosity, hardness, oxide content, bond strength, unmelted particles, corrosion properties. All powders used were produced by gas atomization to homogeneous, spherical particles. The size ranges were 16-44 μm for HVOF, 44-88 and 16-05 μm for plasma spraying. Coatings produced from the two different plasma powders were compared in order to illustrate the effect of the width of the size range.

P.E. Arvidsson. Cited: *Powder Metallurgy International, 24* (3), June 1992, 176-179. [in English]. ISSN: 0048-5012. PHOTOCOPY ORDER NUMBER: 199304-58-0403.

Resins

Flame Spraying of Resins Without Pretreatment of Substrates. Up to now, spraying of resins without preheating of substrates was not possible. Large-sized objects and materials which are weak in heating, such as concretes and woods, could not be applied for spraying of resins. Therefore, improvement of flame spraying apparatus and spraying techniques were estimated. Main results were as follows: (1) Adhesion of spraying of resins between substrates and coatings are not anchor-effect. (2) By improving flame spraying apparatus and applying proper spraying conditions, resin spraying without preheating of substrates is possible. (3) Materials such as metals (e.g. carbon steels and Al), concretes, stones, and woods can be applied by flame spraying of resins. (4) Adhesion strengths of polyethylene coatings were ~6 mPa, and nylon coatings were ~30 mPa. (5) Spraying of fluorocarbon resins became possible by using this flame spraying apparatus and applying proper spraying conditions. Heat balance is especially important to obtain good coatings.

H. Noji, N. Hara, T. Tsutsumoto, and T. Sera. Cited: *Hiroshima Kenritsu Seibu Kogyo Gijutsu Senta Hokoku* (Bulletin of the Industrial Research Institute, Hiroshima Prefecture, West), (35), Oct 1992, 46-49 [in Japanese]. ISSN: 0915-194X. PHOTOCOPY ORDER NUMBER: 199305-57-0567.

Mechanical Properties

Fatigue

Fatigue Crack Growth Behavior of Alumina Plasma-Sprayed Stainless Steel. To clarify the effect of plasma spraying on cyclic fatigue crack growth behavior, the single edge notched (SEN) specimen of SUS 316 stainless steel with plasma-sprayed alumina deposit on one side has been fatigued. Fatigue tests were conducted in push-pull loading with a servoelectro hydraulic fatigue testing machine at a stress ratio of $R = -1$ and a frequency of 30 Hz. Microscopic examination of the front rim contour of growing cracks demonstrated that at the stress amplitude of 46 MPa fatigue cracks fairly delayed on the alumina plasma-sprayed one. However, the plasma spraying had no effect on crack growth behavior at 130 MPa. It was concluded that the retardation of crack growth on the sprayed surface side was closely connected with the grit blasting which was carried out prior to plasma spraying and depended on cyclic stress amplitudes. Fatigue cracks in the alumina deposit were observed to develop linking those microcracks which were formed in grains and on grain boundaries near the tip of a main crack under cyclic loading. Fracture surface of the alumina deposit was characterized by the mixed brittle mode of transgranular and intergranular fracture. In addition, microstructure of the alumina deposit was examined by X-ray and transmission electron microscope techniques. It was found that the plasma-sprayed alumina deposit was composed of the η-phase which often contained small α-phase grains and a number of pores were included in some grains. These pores have been mostly observed with microcracks which were formed around a main crack.

M. Sugano, T. Satake, H. Kisuki, S. Tsukamoto, and T. Takahashi. Cited: *Nippon Seramikkusu Kyokai Gakujutsu Ronbunshi* (Journal of the Ceramic Society of Japan), *100* (11), Nov 1992, 1309-1315 [in Japanese]. ISSN: 0914-5400. PHOTOCOPY ORDER NUMBER: 199305-57-0556.

Models

Splat Formation

Flattening and Solidification of Thermally Sprayed Particles. Molybdenum particles were plasma sprayed on Cu, zirconia, and glass substrates. The impact of the molten particles was monitored using a fast two-color optical fiber pyrometer focused on a small spot on the substrate surface. The apparent duration of the flattening process and the cooling speed, both determined from the pyrometer signals, were found to depend on the substrate conditions and to vary with coating thickness. The substrate material and its roughness were also found to influence the texture in the sprayed coatings. Furthermore, a transient thermal flow numerical model was used to compute reliable thermal histories of the impinging particles and the underlying lamellae, the interfacial thermal resistance being determined by comparison of experimental thermograms with computed ones.

C. Moreau, P. Cielo, and M. Lamontagne. Cited: *Journal of Thermal Spray Technology, 1*, (4), Dec 1992, 317-324. [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-58-0598.

Optimization

Design of Experiments

Plasma Sprayed Alumina-Titania Coatings. This paper presents an experimental study of the air plasma spraying (APS) of alumina-titania powder onto 6061 Al substrates using Ar H working gases. This powder system is being used in the fabrication of heater tubes that emulate nuclear fuel tubes for use in thermal-hydraulic testing. Experiments were conducted using a Taguchi fractional-factorial design parametric study. Operating parameters were varied around the typical spray parameters in a systematic design of experiments to display the range of plasma processing conditions and their effect on the resultant coatings. The coatings were characterized by hardness and electrical tests, surface profilometry, image analysis, optical metallography, and X-ray diffraction. Coating qualities are discussed with respect to dielectric strength, hardness, porosity, surface roughness, deposition efficiency, and microstructure. Attempts are made to correlate the features of the coatings with the changes in operating parameters.

T.J. Steeper, A.J. Rotolico, J.E. Nerz, D.J. Varacalle Jr., and G.C. Wilson. Cited: Conference: Better Ceramics Through Chemistry V, San Francisco, California, USA, 27 Apr-1 May 1992, Materials Research Society, 9800 McKnight Rd., Pittsburgh, Pennsylvania 15237, USA, 1992, 485-492 [in English]. PHOTOCOPY ORDER NUMBER: 199305-57-0548.

Response Surface

Response Surface Methodology for Optimization of Plasma Spraying. Response surface methodology was used to describe empirical relationships among three principal independent variables that control the plasma spraying process. The torch-substrate distance, the amount of hydrogen in the primary gas (argon), and the powder feed rate were studied. A number of dependent variables (responses) were determined, including the deposited layer roughness, density, hardness, chemical composition, and erosion rate. The technique facilitates mapping of responses within a limited experimental region without much prior knowledge of the process mechanisms. The maps allow process optimization and selection of operating conditions to achieve the desired specifications of the plasma-sprayed coating. To illustrate the approach, a simple system of WC-12% Co was deposited on a mild-steel substrate. The resulting response surfaces were used to define optimum, or "robust", deposition parameters.

T. Troczynski and M. Plamondon. Cited: *Journal of Thermal Spray Technology, 1*, (4), Dec 1992, 293-300 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-62-0761.

Patent

Abradable Powders

Thermal Spray Powder. A thermal spray powder is comprised of a matrix-forming component, a solid lubricant and a plastic. The production thereof is presented. An abradable material which comprises a substantially continuous matrix, the matrix being formed of a material selected from metals, metal alloys and ceramics, solid lubricant inclusions dispersed throughout the matrix, and plastic inclusions dispersed throughout the matrix; and the production thereof are presented.

S. Rangaswamy and R.A. Miller. Cited: Patent No. EP0487273, European Patent, 15 Nov 1991, 27 May 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199304-54-0327.

Agglomerated Powders

Thermal Spray Powders, Their Production and Their Use. A method of forming a binder-free agglomerated powder comprises: placing first and second materials in a drum of a mechanical agglomerator, the drum having a continuous curved inner wall and the mechanical agglomerator having impact means disposed in the drum adjacent to the drum inner wall and means for providing relative movement between the impact means and the drum inner wall; processing the first and second materials in the mechanical agglomerator by centrifugally forcing the first and second materials between the impact means the drum inner wall; processing the first and second materials in the mechanical agglomerator by centrifugally forcing the first and second materials to agglomerate to form agglomerated particles which are composites of the first and second materials; and classifying the agglomerated particles to form a thermal spray powder fraction. A thermal spray powder comprises mechanically agglomerated particles having a first component and a second component, in which substantially all of the particles range in size from ~0.5 to 177 μm and the powder has an average particle size of from ~44 to 150 μm. A method of forming a thermal spray coating, which comprises providing a thermal spray powder fabricated by mechanical agglomeration in a drum having an impact member; and thermal spraying the powder onto a target to form a coating.

S. Rangaswamy, and R.A. Miller. Cited: Patent No. EP0487272, European Patent 15 Nov 1991, 27 May 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199304-54-0326.

Enhanced Adhesion

Substrate of Improved Melt Sprayed Surface Morphology. A metal surface is now described having enhanced adhesion of subsequently applied coatings. The substrate metal of the article, such as a valve metal as represented by Ti, is provided with a highly desirable surface characteristic for subsequent coating application. This can be achieved by a plasma sprayed coating of well-defined surface morphology, the plasma spraying being with one or more metals usually valve metals. The metal of the coating may be the same or different from the metal of the substrate. Subsequently applied coatings, by penetrating into the coating of well-defined surface morphology, and desirably locked onto the resulting metal article provide enhanced lifetime even in rugged commercial environments.

L.M. Emes, R.C. Carlson, and K.L. Hardee. Cited: Patent No. EP0493326, European Patent, 20 Dec 1991, 1 July 1992 [in English]. PHOTOCOPY ORDER NUMBER: 199304-58-0518.

Wire Arc Spray

Depositing Metal Onto a Surface. In order to deposit metal onto a surface such as a cylindrical surface, an arc spraying method is used with a consumable electrode, a non-consumable electrode and a jet of atomizing gas blown through the arc in a radial direction to propel the molten metal of the consumable electrode from the arc to the cylinder wall. The non-consumable electrode and the atomizing gas jet both rotate about the cylinder axis so that the entire surface can be covered. The supply for the consumable electrode will normally come from a reel which can be stationary such that the consumable electrode does not rotate about its own axis.

A.R.E. Singer, G.I. Davies, and A.D. Roche. Cited: Patent No. EP0459995, European Patent 12 Jan 1990, *Auszuge aus den Europaischen Patentanmeldungen, Teil I 7* (50), 11 Dec 1991, 4639. [in English]. PHOTOCOPY ORDER NUMBER: 199304-58-0483.

Processes

Control of Parameters

High-Speed Temperature Measurement for On-Line Process Control and Quality Assurance During Plasma Spraying. I. Identification of Important Process Parameters—Measurement Principle and Potential as an Industrial Process Control Instrument. Thermal spraying, especially plasma spraying, today is a standard method for the production of functional coating on technical surfaces. A wide variety of metal, ceramic and organic powders can be sprayed on just as wide a variety of materials. The thermal spraying technique has become a standard coating method, is reliable and manifold in operation. High melting ceramics such as aluminum or zirconium oxides, as well as low melting materials like Al- or Ni-base alloys, are manufactured by plasma spraying. The thermal energy deposited in the substrate and coating has an important influence on the formation of the microstructure within the temperature-loaded parts of the substrate, the coating itself and on the interface. Residual stresses depend on the temperatures and gradients during spraying. The thermal shock resistance of coatings is related to these internal stresses and to the lifetime of coating systems and coated components. It is a very important property, which therefore must be properly controlled by temperature adjustment during spraying. The present study deals with surface temperature measurements and on-line process control during plasma spraying by high-speed pyrometry. The investigations show how the temperature measurement of the particles just hitting the surface is carried out. In situ measurements of surface temperature variations are used as an industrial process control instrument. Incorrect settings and changes in the spraying conditions can be detected on-line and therefore this test method can be used for control of the spraying process and the related coating quality.

H.-J. Solter, U. Muller, and E. Lugscheider. Cited: *Powder Metallurgy International, 24* (3), June 1992, 169-175 [in English]. ISSN: 0048-5012. PHOTOCOPY ORDER NUMBER: 199304-57-0476.

Copper Coatings

Study of Formation of Macro- and Micro-Structures in Gaso-Thermal Coating Particles. A method for controlling the structure of gaso-thermal Cu coatings was developed. The tests were made with Ni wire or powder and a rotary crystallizer, over a range of speeds of rotation, angle of impact and spraying distance. The particles were classified into four types, depending on the method of formation and the method of cooling. The fractional distribution of the particles after impact had a bimodal form, corresponding to predominantly round or disc-like particles. The latter were formed at high rates of cooling and could be amorphous. Small angles of impact increased the formation of disc-like particles.

V.V. Kudinov, V.I. Kalita, and O.B. Kopteva. Cited: *Fizika i Khimiya Obrabotki Materialov* (4), July-Aug 1992, 88-92 [in Russian]. ISSN: 0015-3214. PHOTOCOPY ORDER NUMBER: 199304-58-0385.

Hypervelocity Impact

Hypervelocity Impact Fusion—a Technical Note. A very simple outline of the engineering theory for the implementation of hypervelocity oxygen fuel (HVOF) and hypervelocity air fuel (HVAF) processes is presented. Several calculations show that a condition can be reached where the impact energy of these processes can be optimized to produce a new class of coatings termed "hypervelocity impact fusion" coatings. The microstructures of these coatings exhibit minimum oxidation and very good bonding to the substrate. A Cr_3C-25NiCr cemented-carbide coating and an Inconel 625 coating are discussed.

J.A. Browning. Cited: *Journal of Thermal Spray Technology, 1* (4), Dec 1992, 289-292 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-62-0760.

RF Plasma Spraying

Intermetallic Matrix Composite Coatings by Means of RF Plasma Spraying. High performance Ti_3Al intermetallic compound coatings, as the hard facing to the normal mild steel substrates, were fabricated by means of rf plasma spraying of pre-mixed Ti/Al composite powders sprayed without any after-heat-treatment. For this purpose, mechanical alloying (MA) method was introduced to get the pre-mixed powders of Ti/Al system. DC plasma sprayings were also conducted under the various combinations of working gases for the comparison purpose. To fabricate the intermetallic matrix composite coatings, MA pre-composite powder of $Ti/Al/Si_3N_4$ system was prepared and plasma sprayed. The technical feasibility of the combined processes of mechanical alloying and rf plasma spraying was also discussed.

M. Fukumoto and M.I. Boulos. Cited: Conference: Heat & Surface '92, Kyoto, Japan, 17-20 Nov 1992, Japan Technical Information Service, Tokyo, Japan, 1992, 491-494 [in English]. PHOTOCOPY ORDER NUMBER: 199305-58-0534.

Water-Stabilized Plasma

Study of Phase Changes in Plasma Sprayed Deposits. The formation of a plasma-sprayed coating that exhibits predictable properties requires the control of many process variables. The phase changes that take place during plasma spraying are significant material variables that should be controlled. Several different materials were deposited in air with a water-stabilized plasma torch (model PAL 160). Usually, air was used as a carrier gas for the powder; however, argon was also used for some coatings. The injected powders (NiAl, Ni, $ZrSiO_4$-base, Al_2O_3-base, etc.) and the coatings were studied for structure, particle size, microhardness, and chemical and phase composition. Phase changes induced by the different cooling rates of molten particles after their impact on a substrate are illustrated for $ZrSiO_4$. It has also been found that the oxidizing power of the water-stabilized torch is less than previously believed. For example, coatings produced with nickel powder injected with Ar as the carrier gas exhibited almost no oxides. Significant element redistribution during plasma spraying was demonstrated with a two-phase NiAl feed and stock powder. The coating exhibited almost all the phases that are present in the binary NiAl alloy, envelopes of oxides, and traces of amorphous phase.

P. Chraska, J. Dubsky, B. Kolman, J. Forman, J. Ilavsky. Cited: *Journal of Thermal Spray Technology, 1,* (4), Dec 1992, 301-306 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-58-0597.

Processing

Combustion Synthesis

Elemental Powder Processing of Iron Aluminides. A review is presented of the fabrication and properties of alloys based on the intermetallic compound Fe_3Al using combustion synthesis of elemental iron and aluminum powder mixtures. The synthesis mechanism involves initial compound formation in the solid state, followed by the appearance of an Al-rich liquid at the site of Al particles as the exothermic reaction proceeds, Fe dissolution accompanied by outward spreading of the liquid, and subsequent precipitation of the Fe-rich compound. Fully dense material with a fine, highly stable grain size can be formed by application of pressure during or subsequent to compound synthesis. The yield strength of combustion synthesized material is approximately twice that of conventional powder metallurgy material, while it retained ~5% room temperature tensile ductility. Recent applications of the combustion synthesis process include formation of Fe_3Al coatings on carbon steel, and joining Fe_3Al components.

R.N. Wright and B.H. Rabin. Cited: Conference: Advances in Powder Metallurgy & Particulate Materials—1992, Vol 9, Particulate Materials and Processes, San Francisco, California, USA, 21-26 June 1992, Metal Powder Industries Federation, 105 College Rd. East, Princeton, New Jersey 08540-6692, USA, 1992, 283-294 [in English]. PHOTOCOPY ORDER NUMBER: 199305-54-0520.

Properties

Thermal Transport Review

Thermal Transport Properties of Thermally Sprayed Coatings. The thermophysical properties of thermally sprayed metallic and ceramic materials are reviewed. The properties discussed are the temperature dependent thermal conductivity, diffusivity, specific heat, specific mass, and emissivity which are prerequisites to solve the differential heat conduction equation with its related boundary conditions. These coefficients are evaluated for ceramics such as ZrO_2 stabilized with various oxides (Y_2O_3, CaO, MgO, SiO_2, SrO_2), Al_2O_3, and Cr_2O_3; metals such as Mo; alloys such as Ni-Cr, Ni-Al, Ni-Cr-Al, Ni-Cr-Al-Y, Ni-Co-Cr-Al-Y; and, finally, the cermets Mo-ZrO_2 and Ni-Al-ZrO_2. A thermal contact resistance between ceramic coating (ZrO_2) and metallic bond layer (Mo or Ni-Al) is also estimated. These thermophysical coefficients are correlated with some characteristics of the materials used for thermal spraying, with the operating conditions of coatings' deposition process and with the microstructure of the sprayed material as well as other related properties. The fundamentals of the heat conduction process, and the methods used for the thermophysical properties investigations are briefly discussed. Finally, a few examples of the heat conduction equation solution, describing typical technological applications of thermally sprayed coatings, are given. Nickel-base alloys are coated.

L. Pawlowski and P. Fauchais. Cited: *International Materials Reviews, 37* (6), 1992, 271-289. [in English]. ISSN: 0950-6608. PHOTOCOPY ORDER NUMBER: 199304-58-0493.

Testing

Holographic Thermal Stress

Use of Thermal Stressing Technique in Holographic Detection of Coating Flaws. The use of the holographic thermal-stressing technique to detect the bonding flaws in arc- and flame-sprayed coatings (i.e. Al or stainless steel on low-carbon steel) is presented. Test results in several specimens have been shown. The location and shape of flaws detected are found closely related to the artificial ones. The thermal-stressing technique can be a useful method in flaw detection of arc- and flame-sprayed coatings. The employment of fringe control makes it more effective. The smallest area of the flaw detected is 3 x 5 mm. With the thermoplastic recording and vision system, the flaw can be visualized and evaluated in a few minutes.

T.Y. Chen and W.R. Chang. Cited: *Experimental Techniques 17,* (1), Jan-Feb 1993, 30-32 [in English]. ISSN: 0732-8818. PHOTOCOPY ORDER NUMBER: 199305-22-0341.

Residual Stresses

Significance of Quenching Stress in the Cohesion and Adhesion of Thermally Sprayed Coatings. In thermal spraying, molten particles strike a solid surface, where they are flattened and quenched within a very short time. Considerable in-plane tensile stress on the order of 100 MPa can develop within each splat during quenching after solidification because thermal contraction of the particle is constrained by the underlying solid. Ni-20Cr alloy and alumina powders have been plasma sprayed in air onto steel substrates that were maintained at ~473 K. The influence of spraying conditions such as spray distance on the magnitude of the quenching stress has been studied by measuring the curvature of the substrate during spraying. Mechanical properties such as Young's modulus and bend strength, of the deposited coatings have also been measured. A strong correlation was found between the quenching stress and the strength of Ni-20Cr coatings, which suggests that the strength of interlamellar bonding limits the quenching stress at such temperature.

S. Kuroda, T. Fukushima, and S. Kitahara. Cited: Conference: ITSC '92, Orlando, Florida, USA, June 1992; *Journal of Thermal Spray Technology, 1,* (4), Dec 1992, 325-332 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-58-0599.

Wear

WC-Co

Structure/Property Relationships in Sintered and Thermally Sprayed WC-Co. Thermally sprayed WC-Co is widely used as a wear-resistant coating for a variety of applications. Although it is well established that thermal spray processes significantly affect chemistry, microstructure, and the phase distribution of WC-Co coatings, little is known about how these changes influence wear resistance. The microstructure and wear behavior of sintered and thermally sprayed WC-Co materials are examined. Powders of WC-12 wt.% Co and WC-17 wt.% Co were pressed and sintered, as well as thermally sprayed by high-velocity oxy-fuel (HVOF), air plasma spray (APS), and vacuum plasma spray (VPS) techniques. Results indicated considerable differences in the resulting microstructures, mechanical properties, and wear resistance. The thermally sprayed coatings showed anisotropic fracture toughness, whereas the sintered materials did not. It was also shown that a combined mechanical property/microstructure parameter, based on considerations of indentation fracture mechanisms, can be used in most cases to describe abrasive and erosive wear resistance of thermally sprayed WC-Co materials. The given relationship provides a means for assessing wear resistance of WC-Co coatings intended for industrial applications requiring abrasion and/or erosion resistance.

S.F. Wayne and S. Sampath. Cited: *Journal of Thermal Spray Technology, 1,* (4), Dec 1992, 307-316 [in English]. ISSN: 1059-9630. PHOTOCOPY ORDER NUMBER: 199305-62-0762.