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Selected Abstracts of Thermal Spray Literature

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Applications

Aerospace

Evolution of surface deposits on a high-pressure turbine blade—Part I: Physical characteristics. Turbine blade coupons with three different surface treatments were exposed to deposition conditions in an accelerated deposition facility. The facility simulates the flow conditions at the inlet to a first-stage high-pressure turbine ($T = 1150$ °C, $M = 0.31$). The combustor exit flow is seeded with dust particulate that would typically be ingested by a large utility power plant. The three coupon surface treatments included: bare polished metal, polished thermal barrier coating with bondcoat, and unpolished oxidation-resistant bondcoat. Each coupon was subjected to four successive 2 h deposition tests. The particulate loading was scaled to simulate 0.02 parts per million weight (ppmw) of particulate over 3 months of continuous gas turbine operation for each 2 h laboratory simulation (for a cumulative 1 year of operation). Three-dimensional maps of the deposit roughened surfaces were created between each test, representing a total of four measurements evenly spaced through the lifecycle of a turbine blade surface. From these measurements the surface topology and roughness statistics were determined. Despite the different surface treatments, all three surfaces exhibited similar nonmonotonic changes in roughness with repeated exposure. In each case, an initial buildup of isolated roughness peaks was followed by a period when valleys between peaks were filled with subsequent deposition. This trend is well documented using the average forward facing roughness angle in combination with the average roughness height as characteristic roughness metrics. Deposition-related mechanisms leading to spallation of the thermal barrier coated coupons are identified and documented.

J.E. Wammack, J. Crosby, D. Fletcher, J.P. Bons, and T.H. Fletcher, Department of Mechanical Engineering, Brigham Young University, Provo, UT 84602. Cited: *J. Turbomachinery*, 2008, April, **130**(2). ISSN 0889-504X.

Evolution of surface deposits on a high-pressure turbine blade—Part II: Convective heat transfer. A thermal barrier coating (TBC) coated turbine blade coupon was exposed to successive deposition in an accelerated deposition facility simulating flow conditions at the inlet to a first-stage high-pressure turbine ($T = 1150$ °C, $M = 0.31$). The combustor exit flow was seeded with dust particulate that would typically be ingested by a large utility power plant. The turbine coupon was subjected to four successive 2 h deposition tests. The particulate loading was scaled to simulate 0.02 parts per million weight (ppmw) of particulate over 3 months of continuous gas turbine operation for each 2 h laboratory simulation (for a cumulative 1 year of operation). Three-dimensional maps of the deposit-roughened surfaces were created between each test, representing a total of four measurements evenly spaced through the life cycle of a turbine blade surface. From these measurements, scaled models were produced for testing in a low-speed wind tunnel with a turbulent, zero-pressure gradient boundary layer at $Re = 750{,}000$. The average surface heat-transfer coefficient was measured using a transient surface temperature-measurement technique. Stanton number (St) increases initially with deposition burr then levels off as the surface becomes less peaked. Subsequent deposition exposure then produces a second increase in St. Surface maps of St highlight the local influence of deposit peaks with regard to heat transfer.

J.P. Bons, J.E. Wammack, J. Crosby, D. Fletcher, and T.H. Fletcher, Department of Mechanical Engineering, Brigham Young University, Provo, UT 84602. Cited: *J. Turbomachinery*, 2008, April, **130**(2). ISSN 0889-504X.

The repair of magnesium rotorcraft components by cold spray. The U.S. Army and Navy have experienced significant corrosion problems with magnesium alloys that are used to fabricate aircraft components. The most severe of these are associated with large and expensive transmission and gearbox housings for rotorcraft, which have to be removed prematurely because of corrosion, adversely affecting fleet readiness and safety. Many of the parts cannot be reclaimed because there is not an existing technology that can restore them adequately for service. The replacement of these parts is very expensive ranging in the millions of dollars every year. One common repair technique, used for some of those parts that can be salvaged, involves the use of aluminum shims, which are adhesively bonded over areas where the corrosion has been ground down and dimensional restoration is required. The U.S. Army Research Laboratory (ARL) Center for Cold Spray has developed a cold spray process to reclaim magnesium components that shows significant improvement over existing methods and is in the process of qualification for use on rotorcraft. The cold spray repair has been shown to have superior performance in the tests conducted to date, is inexpensive, can be incorporated into production, and has been modified for field repair, making it a feasible alternative over competing technologies. The work presented in this chapter represents the first 2 years of a 3-year effort, which will result in the establishment of a demonstration cold spray facility at the Naval Air Depot at Cherry Point, NC (NADEP-CP) where the overhaul and repair of Navy rotorcraft is accomplished. The program involved the participation of all branches of the U.S. Department of Defense, major U.S. helicopter companies, academia, and international participation.

Cited: *J. Fail. Anal. Prevent.*, 2008, April, **8**(2), p 164-175. ISSN 1547-7029.

Architecture

Cold spraying: The future for architectural applications? The development in glass-forming technology, such as cold spray technology, insulating glazing, and sophisticated thin-film deposition technique, has helped to fabricate modern glass for architectural applications. Cold spray is a solid-state spraying process that converts kinetic energy of supersonically accelerated solid particles into interfacial heat upon impact with the substrate. The cold spraying process provides heat to pressurized air or nitrogen and directs to a convergent-divergent nozzle. It has the capability to produce thick coatings, which show extremely low porosity with avoidance of oxidation, phase transformations, and tensile residual stresses for selection of metals, cements, and other material combinations. Thin-film deposition technology allows the deposition of materials that provide electrical conductivity and thermal properties to the glass.

J. Villafuerte, Research and Development, CenterLine, Windsor, Canada. Cited: *Glass Int.*, 2008, June, **31**(5), p 50-52. ISSN 0143-7836.

Biomaterials and Bioactive Materials

Bacteria killer. The U.S. Environmental Protection Agency (EPA) has approved the legal association of copper in hospitals, which is effective in killing Methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria, which is one of the most virulent strains of antibiotic-resistant bacteria and common cause of hospital- and community-acquired infections. Copper's antimicrobial properties will be best used in applications where the surface is frequently touched, and areas where disease-causing bacteria live. Copper's antimicrobial properties go beyond a surface coating and provided the surface is clean, copper will continue to kill bacteria after wear and abrasion. EPA's registration is based on a result of the tests and includes more than 300 copper alloys.

Cited: *Eng. Cast. Solutions*, 2008, May/June, **10**(3), p 32-33. ISSN 1523-4371.

Bone ingrowth into a porous-coated implant predicted by a mechano-regulatory tissue differentiation algorithm. Bone ingrowth into a porous surface is one of the primary methods for fixation of orthopedic implants. Improved understanding of bone formation and fixation of these devices should improve their performance and longevity. In this study predictions of bone ingrowth into an implant porous coating were investigated using mechanoregulatory models. The mechanoregulatory tissue differentiation algorithm proposed by Lacroix et al., and a modified version that enforces a tissue differentiation pathway by transitioning from differentiation to bone adaptation were investigated. The modified algorithm resulted in nearly the same behavior as the original algorithm when applied to a fracture-healing model. The algorithms were further compared using micromechanical finite element model of a beaded porous scaffold. Predictions of bone and fibrous tissue formation were compared between the two algorithms and to clinically observed phenomena. Under loading conditions corresponding to a press-fit hip stem, the modified algorithm predicted bone ingrowth into approximately 25% of the pore space, which is similar to that reported in experimental studies, while the original algorithm was unstable. When micromotion at the bone-implant interface was simulated, 20 μm of transverse displacement resulted in soft tissue formation at the bone-implant interface and minimal bone ingrowth. In contrast, 10 and 5 μm of micromotion resulted in bone filling 40% of the pore space and a stable interface, again consistent with clinical and experimental observations.

X. Liu and G.L. Niebur, Department of Aerospace and Mechanical Engineering, 376 Fitzpatrick Hall, University of Notre Dame, Notre Dame, IN 46556. Cited: *Biomech. Model. Mechanobiol.*, 2008, Aug, **7**(4), p 335-344. ISSN 1617-7959.

Vacuum plasma sprayed silicon coatings for biomedical application. Silicon coating was deposited on titanium alloy substrates by vacuum plasma spraying technology. The morphologies and phase composition of the coatings were analyzed by field-emission scanning electron microscopy and x-ray diffraction. The thermal expansion coefficient of silicon coating was measured to be about 3.70×10^{-6} K^{-1}. The bond strength of coating was approximately 20.6 MPa. The density, open porosity, roughness, and Young's modulus of silicon coating were also measured. The as-sprayed silicon coating was treated by deionized water at 60, 80, and 100 °C for a period of time and soaked in simulated body fluids to evaluate its bioactivity. The results showed that the water-treated coating could induce apatite to precipitate on its surface in simulated body fluid, indicating that the bioactivity of silicon coating was improved. The increase of temperature and duration of water treatment had a positive effect on the bioactivity of silicon coatings.

Y. Niu, X. Liu, and C. Ding, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai, 200050, China. Cited: *Mater. Sci. Eng. C*, 2008, Aug 1, **28**(7), p 1132-1137. ISSN 0928-4931.

Environmental

Development of thermal sprayed layers for high temperature areas in waste incineration plants. Corrosion and wear in the hot gas area of thermal energy plants are severe problems, which often cause premature damage of components. In general, the most components of plants are made of materials, which are not stable under corrosive conditions. For corrosion protection (and also wear protection) and lifetime extension of these components, coatings with more resistant materials are applied. Because of the high concentration of corrosive species and the alternating composition of the atmosphere near to the components, the waste incineration plant is the "worst case" of high-temperature corrosion. Nowadays, the most usual coating process to protect pipes in the waste incineration plants is cladding. In the last few years, alternative processes are under investigation because cladding is very cost intensive. The specific costs of thermal spraying are much lower than those of cladding. In addition, the coating by thermal spraying reduces the risk of the dilution of substrate and coating material, different materials can be combined (e.g., metal alloys, ceramics) and the thickness of the layer for an acceptable resistance according to corrosion and wear can be drastically reduced. Thermal spraying has the potential to create cost-efficient coatings to protect components in the critical zones of incineration plants. For many years, ATZ Entwicklungszentrum has been involved in the development and/or advancement of materials, technologies, and applications of thermal spraying for corrosion and/or wear protection in thermal energy plants. The main focuses of the investigations are layers for components in high-temperature areas of waste incineration plants. On the basis of the present results, different coatings (metal alloys, ceramics) and different spray technologies (e.g., HVOF, APS) have been tested by different strategies (corrosion tests under laboratory scale, air-cooled material probes inside the hot gas area of an incineration plant and coated pipes in operation as part of the superheater of incineration plants). This paper gives an overview about the current results of these corrosion tests, in which the focus are the investigations with material probes. First results showed that with the combination of different thermal sprayed layers, significant corrosion protection can be achieved.

D. Bendix, G. Tegeder, P. Crimmann, J. Metschke, and M. Faulstich, ATZ Entwicklungszentrum 92237 Sulzbach-Rosenberg, Germany. Cited: *Mater. Corros.*, 2008, May, **59**(5), p 389-392. ISSN 0947-5117.

Preparation and characterization of metallic membrane using wire arc spraying. Metallic membranes can be prepared by various techniques. This work introduces a novel method for the preparation of metallic membranes using wire arc spraying. The formed metallic membranes were characterized by metallographic techniques such as microscopy image analysis. The distance between gun and the substrate surface, which is called spray distance or gun distance, was selected as the variable of metal spraying. The effects of gun distance on coating properties and membrane performance were investigated. The metallographic and performance data showed that the range of 35 to 40 cm is the optimum gun distance for spraying. Ion rejection capability of the prepared membrane was tested using saline water as the feed. Moreover the filtration capability of the prepared membranes for blue indigo dye particles was investigated. Energy-dispersive x-ray (EDX) analysis and SEM technique were used for the investigation of filtration mechanism. The results indicate that the prepared stainless steel membrane is able to efficiently remove particles from water.

S.S. Madaeni, M.E. Aalami-Aleagha, and P. Daraei, Membrane Research Center, Department of Chemical Engineering, Razi University, Kermanshah, 67149, Iran. Cited: *J. Membrane Sci.*, 2008, July 15, **320**(1-2), p 541-548. ISSN 0376-7388.

Functional

Cold spray electroding of piezoelectric ceramic. Lead zirconate titanate (PZT) is a piezoelectric material that is used in a wide range of applications from small actuators for the precise movement of lenses and mirrors to ultrasonic generators for the industrial mixing and emulsification of liquids. Conventional bonding of PZT involves the use of adhesives that dampen the movement of the element. This paper is a summary of recent work on an alternative approach to coating two opposing surfaces of PZT specimens with a high conductivity metal, i.e., electroding the ceramic, using cold spray technology. Cold spray aluminum coatings and duplex aluminum/copper coatings exhibited low porosity and good bonding with the PZT substrate. The coated substrates could then be directly soldered.

P.C. King, S.H. Zahiri, M. Jahedi, and J. Friend, CSIRO Manufacturing and Materials Technology, Clayton, VIC 3168, Australia. Cited: *Mater. Forum*, 2007, **31,** p 116-119. ISSN 0883-2900.

Effects of the nickel-coated ferritic stainless steel for solid-oxide fuel cells interconnects. In this study, a protective nickel layer was prepared on the SUS430 alloy substrate by the atmospheric plasma spraying technology (APS). Oxidation kinetics, area specific resistance (ASR), and interfacial microstructure of the SUS430 alloy with nickel layers as well as its elemental composition were studied under the flowing humidified hydrogen atmosphere at 800 °C to evaluate the effectiveness of the protective nickel layer. The current collector between the interconnect and the anode was optimized in this paper. Results showed that the oxide growth rate constant of the SUS430 alloy with the APS nickel layer was 1.99×10^{-14} g^2/cm^4 s, which was only 1/50 that of the alloy without a protective layer. The ASR of the SUS430 alloy with the APS nickel layer was 12 $\Omega \cdot cm^2$ after being oxidized under the simulated SOFC anode operating atmosphere at 800 °C for 250 h. With the optimized structure of current collector, the contact ASR between the nickel-coated interconnect and the Ni-YSZ anode was only 3 $\Omega \cdot cm^2$ after being oxidized at 800 °C for 100 h.

C. Fu, K. Sun, X. Chen, N. Zhang, and D. Zhou, Department of Applied Chemistry, Harbin Institute of Technology, Zip Code 150001 Harbin, China. Cited: *Corros. Sci.*, 2008, July, **50**(7), p 1926-1931. ISSN 0010-938X.

Material parameter measurements for microwave antireflection coating development. The main steps for characterization and measurement of microwave absorbent materials in the 1 to 10 GHz range are introduced. The coaxial reflection-transmission type of material parameter measurement is analyzed in detail, and the main measurement error is corrected. The microscopic material particle parameter measurement concept is also presented using different mixing rule laws to determine the material parameters of the single particles from the macroscopic parameters. Two-dimensional FDTD simulations have been used to model the behavior of mixed electric and magnetic type of material.

L. Nagy, Department of Broadband Infocommunications and Electromagnetic Theory, Budapest University of Technology and Economics, 1111 Budapest, Hungary. Cited: *Active and Passive Electronic Components*, 2008. ISSN 0882-7516.

Metallization of ceramics is pushing the boundaries of engineering materials. Some of the significant challenges that are being faced by manufacturers in designing and manufacturer of ceramic components in many applications are discussed. Joining ceramic to metal in order to create the finish part is one of the biggest challenge because of the inherent thermal differences in the thermal expansion coefficient of the two types of materials. Another challenge is to develop a design and a manufacturing process to produce a robust, high-integrity vacuum seal with a leak rate of 10 to 8 mbar 1/s across a component with a 200 mm diameter. Manufacturers metallized ceramic components for vacuum electronic devices (VEDs) that are used in continuous wave and pulsed radar systems. The manufacturers faced challenges in pushing the performance envelope of the materials to meet the demand for higher frequencies.

Cited: *Weld. Des. Fabricat.*, 2007, Oct 19, **80**(10). ISSN 0043-2253.

Performance of tubular solid oxide fuel cell assembled with plasma sprayed Sc_2O_3-ZrO_2 electrolyte. Ni-Al_2O_3 cermet supported tubular solid-oxide fuel cell (SOFC) was fabricated by thermal spraying. The anode, electrolyte, and cathode were deposited by plasma spraying, and the Ni-Al_2O_3 cermet support was deposited by flame spraying to aim at reducing manufacturing cost. The test cell was assembled employing scandia-stabilized zirconia (ScSZ) and yttria-stabilized zirconia (YSZ) deposits as the electrolyte and influence of electrolytic ohmic polarization on performance of the cell was investigated. The results showed that the maximum output power density increased through reducing the electrolyte thickness and increasing the electrical conductivity of electrolyte. The maximum output power density reached 0.89 W/cm^2 with ScSZ electrolyte of 40 μm thick at 1000 °C in comparison of 0.76 W/cm^2 obtained with YSZ electrolyte. The present results clearly revealed that the controlling polarization was electrode polarization for the plasma sprayed single cell assembled with a thin APS ScSZ electrolyte of 40 μm thick. This fact indicates that the design and preparation of effective electrode in the SOFC assembled using thin electrolyte are more important to improve cell performance.

C.-J. Li, C.-X. Li, H.-G. Long, Y.-Z. Xing, and G.-J. Yang, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China. Cited: *Solid State Ionics*, 2008, Sept 30, **179**(27-32), p 1575-1578. ISSN 0167-2738.

Thermal Barrier Coatings

Mechanisms of cracking and delamination within thick thermal barrier systems in aeroengines subject to calcium-magnesium-aluminosilicate (CMAS) penetration. An analysis has been conducted that characterizes the susceptibility to delamination of thermal barrier coated (TBC) hot-section aeroturbine components when penetrated by calcium-magnesium-aluminosilicate (CMAS). The assessment has been conducted on stationary components (especially shrouds) with relatively thick TBCs after removal from aeroengines. In those segments that experience the highest temperatures, the CMAS melts, penetrates to a depth about half the coating thickness, and infiltrates all open areas. Therein the TBC develops channel cracks and subsurface delaminations, as well as spalls. Estimates of the residual stress gradients made on cross sections (by using the Raman peak shift) indicate tension at the surface, becoming compressive below. By invoking mechanics relevant to the thermoelastic stresses upon cooling, as well as the propagation of channel cracks and delaminations, a scenario has been presented that rationalizes these experimental findings. Self-consistent estimates of the stress and temperature gradients are presented as well as predictions of channel cracking and delamination upon cooling.

S. Kramer, S. Faulhaber, M. Chambers, D.R. Clarke, C.G. Levi, J.W. Hutchinson, and A.G. Evans, Materials Department, University of California, Santa Barbara, CA 93106-5050. Cited: *Mater. Sci. Eng. A*, 2008, Aug 25, **490**(1-2), p 26-35. ISSN 0921-5093.

The retention of thermal barrier coating systems on single-crystal superalloys: Effects of substrate composition. The retention during thermal cycling of three types of thermal barrier coating (TBC) systems by a number of different nickel-base single-crystal superalloy substrates is examined. It is demonstrated conclusively that TBC compatibility depends on substrate composition; this result implies that considerable chemical effects are at play. The influence of substrate composition on TBC spallation life is at least as strong as that induced by altering the bond coat (platinum-diffused, inward/outward platinum aluminides). A significant improvement was nonetheless displayed by the so-called platinum-diffused bond coat compared to conventional platinum aluminide systems. The results can be explained only if the fracture toughness parameters controlling decohesion—e.g., the fracture toughness of the thermally grown oxide and the fracture toughnesses of the interfaces bounding it—are influenced strongly by small changes in composition arising from interdiffusion with the bond coat and underlying substrate, such that they are degraded during thermal cycling. As the sulfur content in the substrates was nearly constant at 2 to 3 ppm, other elements must represent the cause of the differences observed.

R.T. Wu, K. Kawagishi, H. Harada, and R.C. Reed, Department of Materials, Imperial College London, London, SW7 2BP, United Kingdom. Cited: *Acta Mater.*, 2008, Aug, **56**(14), p 3622-3629. ISSN 1359-6454.

Thermal expansion behavior and high-temperature transport properties of $Sr_3YCo_{4-x}Fe_xO_{10.5+y}$, $x = 0.0, 1.0, 2.0,$ and 3.0. High-temperature x-ray diffraction revealed peculiarities of thermal expansion of $Sr_3YCo_4O_{10.5}$ with tetragonal 314-structure such as anisotropy of the lattice expansion (thermal expansion coefficient of the a-parameter $TEC_{av}(a) = 18.6$ ppm K^{-1}, $TEC(c) = 25.6$ ppm K^{-1}) and two intermediate regions with different TEC anisotropy: $TEC(c)/TEC(a) = 1.98$ at 298 to 773 K and 0.96 at 773 to 1173 K. Replacement of Co by Fe in $Sr_3YCo_{4-x}Fe_xO_{10.5+y}$ leads to decreasing of TEC at T less than or equal 673 K to 16.6 ppm K^{-1} for $x = 1.0$ and 14.6 ppm K^{-1} for $x = 3.0$. At $T > 673$ K increase of TEC up to $\sim$20 ppm K^{-1} due to the oxygen loss from the crystal structure is observed. $Sr_3YCo_{4-x}Fe_xO_{10.5+y}$ compounds show high electrical conductivity values at 1173 K up to $\sim$200 S/cm for $Sr_3YCo_4O_{10.5}$. A decrease in conductivity at high temperature is observed with increasing the Fe content.

S.Y. Istomin, O.A. Drozhzhin, P.S. Napolsky, S.N. Putilin, A.A. Gippius, and E.V. Antipov, Department of Chemistry, Moscow State University, 119992 Moscow, Russian Federation. Cited: *Solid State Ionics*, 2008, Sept 15, **179**(21-26), p 1054-1057. ISSN 0167-2738.

Diagnostics and Control

Size and velocity measurements in sprays and particle-producing flame sprays. The liquid flame spray technique for nanoparticle production was investigated by in situ droplet and particle diagnostics with and without spray combustion in the presence or absence of zirconia particle precursor. In particular, the effect of atomization gas flow and liquid feed rates on spray characteristics and particle morphology was studied. Droplet size distributions were determined from submicron to supermicron range using phase Doppler anemometry (PDA, droplets 1 m), scanning mobility particle sizer (droplets 1 m), and electrical low-pressure impactor (whole droplet size range). The number mean droplet diameters were submicron, while the mass mean diameters were in the supermicron range. During spray combustion, droplet size distributions measured by PDA were affected by fast droplet evaporation and combustion such that an increasing atomization gas flow rate led to decreasing Sauter mean diameters. Average downstream gas velocities estimated by PDA decreased for increasing liquid feed and constant atomization gas flow. Also, particle production, that is, precursor feed to the flame, reduced the gas velocities. Zirconia product composition and morphology were determined by transmission electron microscopy and x-ray diffraction. High atomization gas flow rates resulted in complete precursor evaporation and produced zirconia particles of uniform size and shape.

H. Keskinen, M. Aromaa, M.C. Heine, and J.M. Makela, Particle Technology Laboratory, Institute of Process Engineering, Department of Mechanical and Process Engineering, 8092 Zurich, Switzerland. Cited: *Atom. Spray.*, 2008, **18**(7), p 619-644. ISSN 1044-5110.

Environmental and Management

Development of high-quality thermal spraying process by shielding control. The shielding-controlled plasma spraying process was investigated to improve corrosion resistance of metal surfaces. In this process, a shielding nozzle that covered only spraying area was attached in front of the tip of a commercial plasma spray gun nozzle, and the environment surrounding the plasma jet was controlled by nitrogen flow. When the oxygen concentration in the shielding nozzle was maintained at 0 to 5%, the metal oxide contents in CoNiCrAlY coating and the porosity of the coating reduced to 0 to 2 and 0 to 3% at optimal spray particle size, respectively. The corrosion potential in an acid solution including chloride ions was almost constant for 1000 h for CoNiCrAlY coating deposited by shielding-controlled plasma spraying. On the other hand, those obtained by atmospheric plasma spraying process decreased in the corrosion potential largely after 10 h. Thus, it can be concluded that the shielding-controlled plasma spraying process improves the corrosion resistance of the metal.

N. Sakakibara, Y. Manabe, Y. Hiromoto, and Y. Kobayashi, Nagasaki Research and Development Center, Mitsubishi Heavy Industries Ltd., Nagasaki 851 0392, Japan. Cited: *Sci. Technol. Weld. Join.*, 2008, July, **13**(4), p 344-348. ISSN 1362-1718.

Dust explosion protection using flameless venting. Development of a flameless venting technique has brought about an explosion-prevention technique, which is capable of minimizing or eliminate the occurrence of explosions and thus eliminate the damage that could occur due to an explosion. One of the important applications of this technique is the retrofitting of existing installations. The technique combines the technique of explosion venting and flame arresting and follow the principle behind that during the early stages of an explosion the explosion vent cover opens, and burnt and un-burnt dust and flame enter the flame arrestor element. The technique provides some advantages in terms of the flameless extinguishments, dust retention, elimination of the need for explosion vent ducts, and minimization of the vent relief area requirement for indoor venting. Limitations of the technique have forced to take some safety considerations, such as proximity of personnel, volume of the room, and possible toxic emissions.

J. Snoeys, Explosion Protection Technology, 2200 Herentals, Belgium. Cited: *Bulk Solids Handling*, 2007, June/July, **28**(4), p 253-257. ISSN 0173-9980.

New federal regulation affecting paint stripping activities and surface coating operations. The key concepts and requirements of Subpart HHHHHH were presented to provide affected sources with a basic understanding of the regulation. Subpart HHHHHH establishes emissions standards for area sources involved in the activities such as paint stripping operations. New regulations such as Subpart HHHHHH might mean capital expenditures to comply with the rule. In addition, training of current painters also requires time away from production and money. Hiring of only certified and trained painters could result in an increase in hourly wages, making the candidate hiring pool smaller and potentially affecting already-established operating budgets for a facility. A facility is essentially forced to comply or abandon the Subpart HHHHHH-regulated activities. The key to the evaluation is to be proactive, keeping in mind that some options such as requiring material suppliers to reformulate materials to provide new alternate compliant materials.

M. Wenclawiak, O'Brien and Gere, Atlanta, GA. Cited: *Met. Finish.*, 2008, April, **106**(4), p 49-56. ISSN 0026-0576.

Optimizing your spray booth performance. Ron Joseph, paint and coating consultant with Exponent, Inc., of Menlo Park, CA, expressed his views on the subject of spray booth performance optimization. Joseph talked about the exhaust airflow in a cross-draft spray booth and said that at a low air velocity the overspray settles on the spray booth floor and walls before it can reach the filters. A spray booth technology is also able to recirculate 90% of its air, yet is in compliance with OSHA/NFPA, while MNOSHA has stated that a company will also need to measure isocyanate levels to 10% of the PEL in the returned recirculated air. Joseph recommended Gardco and BYK-Gardner as an efficient supplier of plastics with different size markings to use as a gauge to measure dirt on a painted part. Joseph said that the book entitled "Standard for Spray Application Using Flammable or Combustible Materials," specifies design and installation of a spray booth so that it is not a fire hazard.

R. Joseph. Cited: *Met. Finish.*, 2008, May, **106**(5), p 48-49. ISSN 0026-0576.

Supporting the designer—New standards for thermal spraying. New standards for thermal spraying have been devised that have extensively supported the designers. Standards prepared for thermal spraying dealt with the terminology and spraying processes (EN 657), spraying equipment (EN 1395 Parts 1 to 7), spraying consumables (EN 1274 and EN ISO 14919), the spraying personnel with testing of the thermal sprayer (EN ISO 14918), and qualification of the responsible coordinator (EN 13214). The standardizing activities of the working group AGV 7, held by DIN-German Institute for Standardisation together with DVS shifted into the direction of supporting the designer. General recommendations and a necessary background knowledge to apply thermal spraying are summarized in the standard EN 14616 as Recommendations for Thermal Spraying. The standard EN ISO 2063 Metallic and Other Inorganic Coating—Zinc, Aluminum and Their Alloys gives references of constructive design in case applying thermal spraying for protection of steel structures.

W. Dien, Morlenbach. Cited: *Weld. Cut.*, 2008, **7**(3), p 144-145. ISSN 1612-3433.

Measurement Methods

Analytical and experimental elastoplastic spherical indentations of a layered half-space. This paper presents an analytical model for the elastoplastic spherical indentation of smooth coated spheres. In this model, only the coating deforms plastically, while the bulk materials remain elastic. This model takes into account the elastic properties of the spheres and the elastic then elastoplastic behavior of the coating. Two sets of interface conditions were investigated. In one, the coating is freely laid on its substrate; in the other the coating is bonded to it. The coating was modeled using a thin layer assumption. The model provides a prediction of the contact radius under load. A specifically designed experimental apparatus is then presented and experimental data are analyzed. Tests were carried out for silver, copper, aluminum, and zinc layers of thicknesses ranging from 20 to 500 μm. Spherical indenters radii were 0.5, 1, or 2.5 mm and the interfaces were free or bonded. Comparisons between analytical and experimental results showed a good agreement, even for experimental conditions beyond the thin layer assumption.

T. Da Silva Botelho, R. Progri, G. Inglebert, and F. Robbe-Valloire, LISMMA (Laboratoire d'Ingenierie des Systemes Mecaniques et des Materiaux), EA 2336, Institut Superieur de Mecanique de Paris, F-93407 Saint-Ouen Cedex, France. Cited: *Mech. Mater.*, 2007, Oct, **40**(10), p 771-779. ISSN 0167-6636.

Cyclic laboratory tests for evaluating coatings: A brief review of literature. A review of most widely used accelerated tests for protective coatings is presented. Cyclic tests have been developed by J.B. Harrison and his coworker who used a mixture of 0.25 wt% sodium chloride and 3.25 wt% ammonium sulfate as the electrolyte solution in the salt spray test that improved correlation with coatings exposed for 14 years in an industrial environment. Skerry and his coworkers added ultraviolet (UV)-moisture condensation exposure cycles to reflect the stresses and degradation that coatings are subjected to upon exterior application. NOR SOK M-501 is a standardized Norwegian test that is designed for the harsh offshore conditions of the North Sea, while M-501 is the most recognized global standard for offshore coatings and is the cyclic exposure to salt spray, drying, and UV/condensation.

T. Bos. Cited: *J. Protect. Coat. Linings*, 2008, June, **25**(6), p 73-79. ISSN 8755-1985.

Determination of the fatigue resistance of HVOF thermal spray WC-CoCr coatings by means of impact testing. Impact testing is an efficient experimental procedure that enables the determination of the fatigue resistance of mono- and multilayer coatings deposited on various substrates, which was not possible with the common testing methods previously available. In this paper an advanced impact tester, able to assess the fatigue failure resistance of coatings working under cyclic loading conditions, is presented. The fatigue failure of the tested coatings was determined by means of scanning electron, optical microscopy, and EDX analysis. The test results are recorded in diagrams containing the impact load versus the number of successive impacts that the examined coatings can withstand. From the experimental results it was concluded that a hard, wear-resistant HVOF thermal spray WC-CoCr coating deposited on P91 steel substrate presents a high fatigue resistance.

C. David, K. Anthymidis, P. Agrianidis, and D. Tsipas, Mechanical Engineering Department, Technical University of Serres, 62124 Serres, Greece. Cited: *J. Test. Eval.*, 2007, Nov, **35**(6), p 630-633. ISSN 0090-3973.

Fourier transform infrared (FTIR) spectroscopy for coating characterization and failure analysis. FTIR is a powerful analytical technique that can readily be applied to the analysis of coating systems. An FTIR spectrum contains a wealth of information about the basic functional chemical groups in a sample that can be used for identification and for evaluation of chemical changes that occur as a result of environmental exposure or other techniques such as energy-dispersive spectroscopy (EDS) or x-ray diffraction (XRD) may be necessary to confirm the identity of mineral pigments and more detailed structural information can be obtained using techniques such as gas chromatography-mass spectrometry (GC MS)-FTIR should be the technique of choice for the initial identification of resins and other organic additives in paint systems.

M. Poliskie and J.O. Clevenger, Solyndra, Inc., Fremont, CA. Cited: *Met. Finish.*, 2008, May, **106**(5), p 44-47. ISSN 0026-0576.

Microstructure

Microstructure characterization of alloy 625 deposited on nickel foam using air plasma spraying. Microstructure characterization of alloy 625 deposited on nickel foam using air plasma spraying (APS) was reported. Nickel-base superalloys have a good combination of creep strength, yield strength, tensile strength, and high-service temperature, so these are used as skin materials. Coatings of alloys 625 were deposited on nickel foam substrate by APS with and without active cooling of the substrate during depositions. Optical microscopy and scanning electron microscopy (SEM) observation of unetched samples showed that the APS deposits consist of three different regions. The majority of the microstructure in both coatings consisted of face-centered cubic (fcc) Ni alloy phase, which appeared light in the micrographs, with a composition very close to that of initial powder as determined by energy-dispersive spectroscopy (EDS). The regions that appeared black in the micrographs, rounded shapes distributed through the structure and in thin layers along interface between splats, were identified as the remnant porosity.

F. Azarmi, J. Saaedi, T.W. Coyle, and J. Mostaghimi, Center for Advanced Coating Technologies, University of Toronto, Toronto, M5S 3G8. Cited: *Adv. Eng. Mater.*, 2008, May, **10**(5), p 459-465. ISSN 1438-1656.

Microstructure development of plasma sprayed yttria-stabilized zirconia and its effect on electrical conductivity. 4.5 mol% yttria-stabilized zirconia (YSZ) deposit was prepared by atmospheric plasma spraying (APS) using an agglomerate-sintered YSZ powder. Two samples were continuously deposited at two spray distances of 80 and 90 mm without intermittence during spraying. The measurement showed that the ionic conductivity of the YSZ deposit at 1000 °C significantly decreased from 0.06 to 0.033 S/cm with increasing spray distance from 80 to 90 mm. The deposit microstructure exhibited distinct interfaces between consecutive pass layers in the deposit sprayed at long spray distance. The decrease of ionic conductivity can be ascribed to change of the bonding ratio between consecutive passes resulting from decrease of deposition temperature with the increase of spray distance.

Y.-Z. Xing, C.-X. Li, C.-J. Li, H.-G. Long, and Y.-X. Xie, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China. Cited: *Solid State Ionics*, 2008, Sept 30, **179**(27-32), p 1483-1485. ISSN 0167-2738.

Microstructural investigation on bond coats in molybdenum and steel coatings for the renovation of mechanical pieces. Thermal spraying has been used in industry for many years to improve the properties of the surface of a workpiece, such as its mechanical and electrical properties and its wear resistance. Fabricating these high-quality coatings requires good cohesion of the deposited material and high adherence to the substrate. To improve adhesion of the coating to the substrate, the Company SNC ATRA (Algeria) uses molybdenum as the intermediate adhesion layer to restore the brace and bit. The purpose of this paper is to study the microstructure and morphology of the bond coat and coating using a flame-spray technique. Coatings have been characterized by scanning electron microscopy combined with traditional procedures of metallographic preparation. The results show that the substrate is thermally damaged when molybdenum is deposited as a bond coat, and that the bond coat is delaminated in its middle layer.

M.A. Bradai and A. Ati, Laboratory of Technology of Materials and Engineering of the Processes, Faculty of Science and Science Engineering, University of Bejaia, 06000, Algeria. Cited: *Canad. J. Phys.*, 2008, May, **86**(5), p 727-732. ISSN 0008-4204.

Microstructure and properties of thermal sprayed NiCrWRE coatings. The powders of NiCrW and NiCrWRE alloys were flame sprayed on a medium-carbon steel substrate by thermal spray welding. The microstructure and tribological behavior of coatings were studied experimentally by means of scanning electron microscopy (SEM), field emission gun scanning electron microscope (FEGSEM), and wear tests. The addition of CeO_2 modifies the coating morphology from a needlelike structure to a roughly cubic morphology; the refining and purifying effect of rare earth elements makes the microstructure more compact and finer. Analysis of the worn surfaces reveals that the coatings with CeO_2 addition show improved abrasive wear resistance over those without CeO_2. By adding CeO_2, the hardness of the coatings is significantly increased, and the wear resistance of the coatings is enhanced.

Z. Zhang, Z. Wang, and B. Liang, Mechanical Engineering Department, Lanzhou Polytechnic College, Lanzhou, 730050, China. Cited: *Rare Metals*, 2008, June, **27**(3), p 261-265. ISSN 1001-0521.

Microstructure and properties of TiC-Fe36Ni cermet coatings by reactive plasma spraying using sucrose as carbonaceous precursor. This study is aimed to introduce an innovative precursor pyrolysis process to prepare Ti-Fe-Ni-C compound powder and to discuss and evaluate the relationship between microstructure and properties of TiC-Fe36Ni cermet coatings in situ synthesized by reactive plasma spraying (RPS) of these compound powders. The main characteristic of the pyrolysis process is that sucrose ($C_{12}H_{22}O_{11}$) is used as a source of carbon as well as a binder to bind reactive constituent particles. The compound powder with high bonding strength can prevent the problem that reactive constituent particles are separated during spraying. The TiC-Fe36Ni cermet coatings present typical splatlike morphology of thermally sprayed coatings and consist of two different areas: one is a composite reinforcement area where spherical fine TiC particles (100-500 nm) homogeneously distribute within the Fe36Ni matrix; the other is an area of TiC accumulation. The surface hardness of the coatings reaches about 90 $\pm$ 2 (HR15N). The maximum and average microhardness values of the coatings are 1930 $HV_{0.2}$ (Vickers hardness) and 1640 $HV_{0.2}$, respectively. The average bonding strength of the coatings is about 62.3 MPa. The wear-resistance property of the coatings is much more than that of Ni60 alloys coatings.

J. Zhu, J. Huang, H. Wang, S. Zhang, H. Zhang, and X. Zhao, School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing, 100083, China. Cited: *Appl. Surf. Sci.*, 2008, Aug 15, **254**(20), p 6687-6692. ISSN 0169-4332.

Modeling

Mechanical Modeling

Evaluation of the interfacial strength of layered structures by indentation method. The delamination of thin coating films from substrates is a critical issue for the reliability of micro- and nanoelectronic devices. Indentation methods have the potential to measure interfacial strength in micro- and nanofilm thickness coating films. In this paper, indentation tests of layered structures are simulated using the damage-based cohesive zone model. When the delamination initiates, the indentation load and depth curve tend to deviate from the indentation load and depth curve for the perfectly bonded case. When the interface is stiffer than the coating film, a brittlelike delamination occurs on the interface; when the stiffness of the interface is smaller than that of the coating layer, a ductilelike delamination occurs on the interface. The ratio of shear moduli, μ_{int}/μ_{PI}, characterizes the delamination behavior on the interface during indentation tests. Focusing on the discontinuous point during the indentation tests and introducing the balance of energy before and after the onset of delamination, the evaluation method of the interfacial strength is proposed. The proposed method can be used to estimate the interfacial strength when the ratio of hardness and the yield stress of the coating, film is $3.5 \leq H_A/\sigma_y \leq 4.5$.

M. Qmiya, K. Kishimoto, and T. Nakano, Department of Mechanical Engineering, Faculty of Science and Technology, Keio University, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan. Cited: *J. Appl. Mech., Trans. ASME*, 2008, May, **75**(3), p 0310061-0310066. ISSN 0021-8936.

Fundamental thermoelasticity equations for thermally induced flexural vibration problems for inhomogeneous plates and thermoelastic dynamical responses to a sinusoidally varying surface temperature. Equations of motion governing thermally induced vibration of plates with inhomogeneous material properties through the thickness direction are presented. Equations of motion for thermally induced flexural vibration for inhomogeneous rectangular plates in which the material properties are given in the form of a power of the thickness coordinate are derived from the aforementioned fundamental equations. An exact solution of the one-dimensional temperature change is presented for an inhomogeneous plate in which one surface is exposed to a sinusoidally varying temperature, and the other is kept at zero temperature change. The associated quasi-static and dynamic solutions pertinent to deflection and thermal stresses in the inhomogeneous rectangular plate are derived under the condition of simply supported edges. Numerical calculations are performed, and the effects of material inhomogeneity such as Young's modulus, coefficient of linear thermal expansion, and mass density, angular frequency in cyclic heating, and aspect ratio on the thermoelastic response of the rectangular plate are shown in graphical form. Comparing the dynamic solutions with quasi-static ones, the effect of inertia on the thermoelastic response of the inhomogeneous rectangular plate is evaluated.

R. Kawamura, Y. Tanigawa, S. Kusuki, and H. Hamamura, Department of Mechanical Engineering, Osaka Prefecture University, Osaka 599-8531, Japan. Cited: *J. Eng. Math.*, 2008, Aug, **61**(2-4), p 143-160. ISSN 0022-0833.

Numerical simulation of relation between interface topography and residual stress in thermal barrier coatings. With respect to thermal barrier coating, the analysis of interface cohesion and residual stress is important to the life of TBC from a mechanical viewpoint. Up to now, there is not a model of describing interface cohesion. In the paper, we give a simple model of computing residual stress and study the residual stress of TBC with ANSYS. The distribution of the residual stress in different interface topography and the relationship between the residual stress and the interface topography dimension are presented.

G.-F. Yao, H.-M. Ma, and L.-W. Zhang, College of Mechanical Science and Engineering, Nanling Campus, Jilin University, Changchun 130025, China. Cited: *Struct. Eng. Mech.*, 2008, July 10, **29**(4), p 423-431. ISSN 1225-4568.

Thermal stress in a nonhomogeneous curved beam. The thermoelastic stress field in a functionally graded curved beam, where the elastic stiffness varies in the radial direction, is considered. An analytical solution is obtained where the radial variation of the stiffness is represented by a fairly general form. The stress fields corresponding to two different cases for the elastic properties are examined: first, the elastic properties representing a coating on the outer surfaces of the curved beam; second, the elastic properties obtained from experimental data. The flexural stress in the curved beam is then compared with that of a solid ring. Finally, a relatively simple approximate solution is developed, and this is shown to be in good agreement with the analytical results.

M. Mohammadi and J.R. Dryden, Department of Mechanical and Materials Engineering, University of Western Ontario, London, ON N6A 5B8, Canada. Cited: *J. Therm. Stresses*, 2008, July, **31**(7), p 587-598. ISSN 0149-5739.

Young's modulus of low-pressure cold sprayed composites: An analysis based on a minimum contact area model. A theoretical and mathematical model based on minimum contact area (MCA) is developed to explain the bonding that takes place in the low-pressure gas dynamic spray (LPGDS) process. It is shown that by normalizing this MCA it is possible to compare the relative elastic modulus as a function of porosity. Theoretical predictions of relative elastic modulus are compared against results obtained through acoustic analysis, and it is found that the correlation between is dependent on the porosity. For low porosity, the experimental and theoretical results differ substantially, while for higher porosity there seems to be good agreement between the two. To explain this behavior, it is theorized that full adiabatic shear bands (ASB) are created between only some of the particles. The higher porosity causes higher strain in the samples and thus more local deformation of the particles. This, in turn, causes more actual ASB formation. Since the theoretical model assumes full ASB formation, only the higher porosities cause enough strain to have a comparable relative elastic modulus. For the lower porosities, the local strain is less, and some of the bonds will not achieve full ASB formation. For these cases, the relative elastic modulus will be lower than that predicted.

M. Lubrick, R.G. Maev, F. Severin, and V. Leshchynsky, University of Windsor, Windsor, ON, Canada. Cited: *J. Mater. Sci.*, 2008, July, **43**(14), p 4953-4961. ISSN 0022-2461.

Postprocessing

Application of the hot isostatic pressing process on a thermally sprayed coating layer on copper dies. Recent research has shown that copper-alloy dies sprayed with a protective steel layer can potentially replace steel dies in the pressure die casting process for the purpose of rapid heat extraction. The deposited layer is required to withstand abrasion, thermal shock, and cyclic loading, and be resistant to debonding from the copper/die substrate. This paper is concerned with an experimental investigation into the application of the HIP process to ascertain its effectiveness toward enhancing the bond strength, hardness, and densification of chrome steel coatings on a copper substrate. A particular focus of the paper is on the use of partial encapsulation coupled with the use of ceramic paper whose purpose is to transfer the loading pressure and prevent bonding between the die and the encapsulation container. It is shown in the paper that partial encapsulation is effective and can be used to HIP localized regions of a die. The ceramic paper was shown to be effective in transmitting loading and has the added advantage of providing relatively good surface finish compared with that obtained with ceramic powder. The results of the experimental trials show reduced porosity and increased bond strength with application of the HIP process. In addition, hardness values are shown to be reduced to levels typically found in traditional die-tool steels.

A.M. Kamara and K. Davey, School of Mechanical, Aerospace, and Civil Engineering, University of Manchester, Manchester M60 1QD, United Kingdom. Cited: *Proc. Inst. Mech. Eng., Part B: J. Eng. Manuf.*, 2008, **222**(5), p 567-579. ISSN 0954-4054.

Behavior modeling of laser micromachining in hybrid-layered manufacturing for components made of a material with a periodic microstructure. A heterogeneous material with a certain periodic microstructure may have specific properties, such as negative Poisson's ratio and zero thermal expansion coefficients, which can satisfy some requirement of high technology. However, currently research about how to fabricate such 3-D periodic microstructures is rarely reported in the published literature and only

some 2D fabrication procedures were developed. To fabricate such components, a hybrid-layered manufacturing process has been developed and applies spraying, engraving, and refinishing technologies, among which the engraving is the key technology for generating the voids of periodic microstructures with their required dimensions and accuracies. To implement such an accurate engraving, it is important to study its engraving behavior. This paper establishes a behavior model of the engraving operation and performs its behavior simulation, thus providing a reliable basis for future practical manufacturing.

F. Wang, K.-Z. Chen, and X.-A. Feng, Department of Mechanical Engineering, University of Hong Kong, Hong Kong, Hong Kong. Cited: *Int. J. Adv. Manuf. Technol.*, 2008, July, **38**(1-2), p 85-92. ISSN 0268-3768.

Microwave sintering of plasma sprayed yttria-stabilized zirconia electrolyte coating. In this work, microwave (MW) was used to sinter atmospheric plasma sprayed 8 mol% yttria-stabilized zirconia (YSZ) electrolytes coatings. Three types of coatings were studied: pure YSZ coating, 5 wt% $BaTiO_3$-filled YSZ coating and 10 wt% $BaTiO_3$-filled YSZ coating. Microstructures and ionic conductivities of as-sprayed and MW-sintered coatings were characterized. The results indicated that that the pure YSZ coating can hardly be sintered by the MW sintering and it can only be heated up to 900 °C. For two composite coatings, $BaTiO_3$ particles distributed in the composite coating act as a good MW susceptor and thereby, a good heat source for sintering YSZ matrix. After a MW sintering at 1450 °C for about 30 min, an obvious structural modification was noticed: the lamellar and columnar crystal features of as-sprayed plasma sprayed YSZ coatings were modified to equiaxe crystal in the sintered coatings. Ionic conductivity of sintered 5 wt% $BaTiO_3$-filled YSZ composite coatings were elevated to about twice of as-sprayed coating. A further increase of $BaTiO_3$ content to 10 wt% in the composite coating enhanced the sintering efficiency; however, the ionic conductivity of composite coatings was decreased.

C. Zhang, G. Zhang, S. Leparoux, H. Liao, C.-X. Li, C.-J. Li, and C. Coddet, LERMPS, Universite de Technologie de Belfort-Montbeliard, 90010 Belfort, France. Cited: *J. Europ. Ceram. Soc.*, 2008, Sept, **28**(13), p 2529-2538. ISSN 0955-2219.

Morphologies and nonlinear scaling of laser damage on glass surfaces by tightly focused femtosecond pulses. We examine the relationship between pulse energy and the morphology of damage by a femtosecond pulsed laser, tightly focused onto the back surface of glass. For fluences up to three times that of threshold, an unexpected discontinuity in the scaling of damage size is caused by ejection of rings of material surrounding central damage that appear above a sharp threshold fluence. A mechanism for the production of these structures via thermal expansion and shockwave generation is proposed.

J.F. Herbstman, A.J. Hunt, and S.M. Yalisove, Department of Biomedical Engineering, University of Michigan, Ann Arbor, MI 48109. Cited: *Appl. Phys. Lett.*, 2008, **93**(1), ISSN 0003-6951.

Processing

Innovative fabrication of porous titanium coating on titanium by cold spraying and vacuum sintering. A porous titanium coating on titanium is fabricated by cold spraying "Mg + Ti" powders followed by vacuum sintering. The porous coating is interconnected, possesses the porosity of 48.6% with pore sizes in the range of 70 to 150 μm and firmly bonds to titanium substrate with a bond strength higher than 42 MPa. The bending Young's modulus and bending strength of the porous coating are 14.47 ± 1.21 GPa and 106.93 ± 10.79 MPa, respectively. The compressive Young's modulus and compressive yield strength of the porous coating are 3.99 ± 0.12 GPa and 178.66 ± 13.20 MPa, respectively. The porous titanium coating has sufficient strength and matched Young's modulus with natural bone for clinical use under load-bearing conditions.

J. Sun, Y. Han, and K. Cui, State-key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an, 710049, China. Cited: *Mater. Lett.*, 2008, Aug 15, **62**(21-22), p 3623-3625. ISSN 0167-577X.

The solution precursor plasma spray processing of nanomaterials. Solution precursor plasma spray (SPPS) synthesis is a simple, single-step, and rapid technique for synthesizing nanoceramic materials from solution precursors. This innovative method uses molecularly mixed precursors as liquids, avoiding a separate processing method for the preparation of powders and enabling the synthesis of a wide range of metal oxide powders and coatings. Also, this technique is considered to be promising for the formation of nonequilibrium phases in multicomponent oxide systems. This short review provides an insight into the important aspects of SPPS, the properties obtained compared to conventional plasma spray and the potential applications of the SPPS process.

E. Brinley, K.S. Babu, and S. Seal, Surface Engineering and Nanotechnology Facility, Advanced Materials Processing and Analysis Center, University of Central Florida, Orlando, FL. Cited: *JOM*, 2007, July, **59**(7), p 54-59. ISSN 1047-4838.

What in the world of standards is new for surface preparation? Some of the significant contributions of several standards organizations in formulating and implementing standards for the surface preparation industry are discussed. The International Organization for Standardization (ISO), the European Standards Committee (CEN), the Society for Protective Coatings (SSPC), NACE International, and ASTM International, are some of the major international standards organizations that are involved in formulating, implementing, and updating standards for the global surface preparation sector. Standards are drafted by technical committees, comprising national delegations of experts, selected by the national standards organizations within the ISO and CEN. The two standards organizations cooperate and coordinate with each other to make the most effective use of available resources and avoid conventional efforts at developing standards for the surface preparation sector.

B. Goldie. Cited: *J. Prot. Coat. Linings*, 2008, June, **25**(6), p 66-67. ISSN 8755-1985.

Properties

Corrosion

Ability of metallic coatings to protect low-carbon steels from aqueous corrosion. In the present work, strips of steel St-37 were coated with zinc (Zn) using wire flame spraying and with tin (Sn) using plasma spraying. Their corrosion behavior was examined by exposure in a salt-spray chamber. The exposure time ranged from 24 h up to 18 days. The as-corroded samples were studied by optical microscopy, scanning electron microscopy, and x-ray diffraction, and in the case of zinc coatings, the weight of the corrosion products was also measured. From this research, it was deduced that zinc coatings corrode uniformly and pits are also formed. A layer of different zinc compounds including zinc oxide and hydroxides, hydrated zinc chlorides, and hydroxides covers the coating, which has an inhibiting effect on corrosion. However, hot dip galvanized coatings seem to be more resistant probably due to the presence of Fe-Zn phases. Regarding the tin coatings, Sn and Fe oxides and chlorides were detected on the coating surface along with the formation of large cavities. A possible mechanism of internal oxidation (intergranular corrosion) was used to explain these observations. Their performance seems also inferior to that of the hot dip galvanized coatings.

G. Vourlias, N. Pistofidis, and G. Stergioudis, Physics Department, Aristotle University of Thessaloniki, 54 124 Thessaloniki, Greece. Cited: *Corros. Eng. Sci. Technol.*, 2008, June, **43**(2), p 163-172. ISSN 1478-422X.

Electrochemical impedance spectroscopy of sealed air plasma sprayed TiO_2 coating in seawater. Air plasma sprayed (APS) TiO_2 coating and sealed APS-TiO_2 coating were studied by electrochemical impedance spectroscopy (EIS). The experimental results revealed that corrosion potentials (E_{corr}) of the sealed APS-TiO_2 coating are generally more positive, and the R_p resistance is almost one order of magnitude larger than for the unsealed APS-TiO_2 coating. The microstructure and composition of APS-TiO_2 coating have been characterized by SEM and XRD, respectively. The mechanism responsible for the significant improvement in the corrosion resistance of the sealed APS-TiO_2 coating is investigated in detail.

Y. Fana, Y. Yin, S. Cheng, X. Chang, and W. Zhang, Institute of Material Science and Engineering, Ocean University of China, Qingdao 266100, China. Cited: *InterCeram: Int. Ceram. Rev.*, 2008, May, **57**(3), p 170-175. ISSN 0020-5214.

Evaluation of hot corrosion behavior of HVOF sprayed NiCrAl coating on superalloys at 900 °C. In the present investigation, NiCrAl coating was deposited on Ni- and Fe-base superalloy substrates by using high-velocity oxyfuel (HVOF) process to study the hot corrosion behavior in molten salt (Na_2SO_4-60% V_2O_5) environment at 900 °C under cyclic conditions. The mass gain measurements were performed after each cycle to establish the kinetics of corrosion using thermogravimetric technique. X-ray diffraction (XRD), scanning electron microscopy/energy dispersive spectroscopic analysis (SEM/EDS), and x-ray mapping techniques were used to analyze the corrosion products. The bare superalloys experienced higher weight gain. The NiCrAl-coated Superni 750 alloy (SN 750) provided a better protection among the coated superalloys investigated. The formation of oxides and spinels of nickel, chromium, and aluminum may be contributing better resistance to hot corrosion.

R.A. Mahesh, R. Jayaganthan, and S. Prakash, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttarakhand, India. Cited: *Mater. Chem. Phys.*, 2008, Oct 15, **111** (2-3), p 524-533. ISSN 0254-0584.

Hot corrosion behavior of detonation gun sprayed Cr_3C_2-NiCr coatings on Ni- and Fe-base superalloys in Na_2SO_4-60% V_2O_5 environment at 900 °C. The present work investigates the hot corrosion resistance of detonation gun sprayed (D-gun) Cr_3C_2-NiCr coatings on Superni 75, Superni 718, and Superfer 800 H superalloys. The deposited coatings on these superalloy substrates exhibit nearly uniform, adherent, and dense microstructure with

porosity less than 0.8%. Thermogravimetry technique is used to study the high-temperature hot corrosion behavior of bare and Cr_3C_2-NiCr coated superalloys in molten salt environment (Na_2SO_4-60% V_2O_5) at high-temperature 900 °C for 100 cycles. The corrosion products of the detonation gun sprayed Cr_3C_2-NiCr coatings on superalloys are analyzed by using XRD, SEM, and FE-SEM/EDAX to reveal their microstructural and compositional features for elucidating the corrosion mechanisms. It is shown that the Cr_3C_2-NiCr coatings on Ni- and Fe-base superalloy substrates are found to be very effective in decreasing the corrosion rate in the given molten salt environment at 900 °C. Particularly, the coating deposited on Superfer 800 H showed a better hot corrosion protection compared to Superni 75 and Superni 718. The coatings serve as an effective diffusion barrier to preclude the diffusion of oxygen from the environment into the substrate superalloys. It is concluded that the hot corrosion resistance of the D-gun sprayed Cr_3C_2-NiCr coating is due to the formation of desirable microstructural features such as very low porosity, uniform fine grains, and the flat splat structures in the coating.

S. Kamal, R. Jayaganthan, S. Prakash, and S. Kumar, Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Roorkee, Roorkee, 247667, India. Cited: *J. Alloys Compd.*, 2008, Sept 8, **463**(1-2), p 358-372. ISSN 0925-8388.

State-of-the-art of thermal spray coatings for corrosion protection. Thermal spray coatings are widely used in marine structures including offshore pipelines without external cathodic protection (CP). Al, Zn, and Zn-Al thermal-spray coatings protect steel by acting both as barrier coatings and as sacrificial anodes at local defects where corrosion would otherwise occur. Zn provides better galvanic protection, whereas Al is better as a less-reactive barrier layer. Zn-Al alloys appear to combine the protective properties of both Zn and Al. Although further research is required to specify the optimal alloy compositions for specific applications, 85%Zn-15%Al alloy is widely used. The best long-term protection is provided by suitably primed, sealed, and painted thermal spray coatings. Thermal spray coatings of acceptable structures and properties can be produced by flame spraying (wire or powder), arc spraying or plasma processing. However, because of economical reasons low melting point metals and their alloys are sprayed either by arc or flame. Surface preparation is considered to be a key factor in the production of uniform high-quality coatings with maximum bond strength. Also of equal importance are the control of process facilities, equipment selection, and quality of consumable material for applying thermal spray coatings. Well-bonded, relatively dense, sealed coatings have the ability to provide effective long-term corrosion protection (10-20 years), with minimum periodic maintenance. Standards for evaluating thermal spray coatings have recently been developed.

S. Papavinasam, M. Attard, B. Arseneult, and R.W. Revie, CANMET Materials Technology Laboratory, Natural Resources Canada, Ottawa, ON K1A 0G1, Canada. Cited: *Corros. Rev.*, 2008, **26**(2-3), p 105-146. ISSN 0334-6005.

Magnetic

Microstructure and magnetic properties of FeSiBNbCu-Al cold spray coatings. In this paper, the FeSiBNbCu and FeSiBNbCu-Al coatings were synthesized using cold spray technique in order to produce ferromagnetic materials. Ultrafine grain coatings are obtained using FINEMET nanostructured powders mixed with aluminum. Various percentages of aluminum characterized by its low hardness were taken in account. The obtaining coatings were formed of aluminum matrix and randomly distribution of FINEMET particles. Indeed, magnetic measurements revealed a soft magnetic character for all the powders and the coatings. Al content of 25% was considered as ideal to produce a homogenous coating with good soft magnetic properties.

M. Cherigui, W. Li, R. Hamzaoui, V. Ji, N. Fenineche, and C. Coddet, LERMPS-UTBM, Site de Sevenans, 90010 Belfort Cedex, France. Cited: *EPJ Appl. Phys.*, 2008, July, **43**(1), p 79-86. ISSN 1286-0042.

Oxidation

Effect of surface preparation on the durability of NiCoCrAlY coatings for oxidation protection and bond coats for thermal barrier coatings. A principal concern with alumina-forming coatings for high-temperature oxidation protection and bond coats (BCs) for ceramic thermal barrier coatings (TBCs) used in gas turbines is the spalling of the alumina scales during service. This paper describes the effects of BC surface preparation on the durability of NiCoCrAlY coatings exposed under thermal cycling conditions. State-of-the-art TBC systems deposited by electron beam physical vapor deposition (EB-PVD) with NiCoCrAlY overlay BCs were found to fail as the result of defects that included transient oxides, defects in the BC surface, defects in the as-deposited microstructure of the TBC, and excessive oxidation of reactive element additions. In some instances, the TBC life was greatly extended by surface treatments, such as fine polishing. The oxidation behavior of NiCoCrAlY coatings, absent a TBC, was found to be sensitive to Y content and to surface preparation. This paper describes how a variety of surface treatments affected coating lives and failure mechanisms.

E.M.M. Jackson, N.M. Yanar, M.C. Maris-Jakubowski, K. Onal-Hance, G.H. Meier, and F.S. Pettit, Department of Materials Science and Engineering, University of Pittsburgh, Pittsburgh, PA 15261. Cited: *Mater. Corros.*, 2008, June, **59**(6), p 494-500. ISSN 0947-5117.

HVOF coatings for steam oxidation protection. In the context of the European project "Coatings for Supercritical Steam Cycles" (SUPERCOAT), the use of steam oxidation resistant coatings on currently available ferritic materials with high creep strength but poor oxidation resistance was investigated to allow increase in the operating temperature of steam power plants from 550 to 650 °C. Among the explored coating techniques for this application, chosen on the basis of being potentially appropriate for coating steam turbine components, high-velocity oxyfuel (HVOF) thermal spray has resulted in one of the most successful techniques. Different alloyed materials such as FeCrAl, NiCrSiFeB, FeAl, NiCr, and FeCr have been deposited, optimized and tested under flowing steam at 650 °C. Characterization of as-deposited and tested samples by metallography, SEM-EDS, and XRD was carried out. Some of these coatings form protective pure chromium or aluminum oxides exhibiting excellent behavior for at least 15000 h of exposure, whereas others form less stable complex mixed oxides that nevertheless grow at considerably slower rates than the oxides formed on uncoated P92 (9 wt% Cr ferritic steel).

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Identification of degradation mechanisms in coatings for supercritical steam applications. The development and qualification of coatings for materials used in modern steam power plants stems from the increased demand for higher efficiency, and hence higher operating temperatures. Within the EU funded project 'SUPERCOAT, several coatings, both overlay and diffusion type, were investigated. Seven different coatings are presented in this work. They included two commercially available HVOF coatings (Ni-20Cr and Ni-50Cr), an aluminum-based slurry coating (IPCOTE), together with two further variations of this slurry coating containing sputter-coated interlayers. An overlay slurry coating consisting of silica particles embedded in a matrix of alumina and chromia was also examined. The final coating to be investigated was a pack-aluminized sample of P92. All the coating systems examined showed superior oxidation resistance compared to the 9%Cr steel substrate (P91 or P92) in extended exposures to a steam environment at 650 °C. However, in-service component lifetime will be limited by degradation of the coating; therefore, it is essential that the mechanisms controlling this behavior are understood. This paper reviews several degradation mechanisms that have been observed during long-term exposure of these coatings. The mechanisms that have been observed include depletion of active alloying elements, diffusion of aluminum into the substrate from the coating, formation of Kirkendall porosity, and mechanical failure of the coatings. Examples of each of these mechanisms are presented. Possible processing routes to avoid these degradation mechanisms are also discussed.

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Tribological

Influence of CrC addition in Ni-Cr-Si-B flame sprayed coatings on microstructure, microhardness, and wear behavior. In the present paper the influence of the addition of chromium carbide (CrC) particles on the microstructure, microhardness and abrasive wear behavior of flame sprayed Ni-Cr-Si-B coatings deposited on low-carbon steel substrate has been reported. Wear behavior of the coatings was evaluated with a pin-on-block wear system against SiC abrasive medium (120 and 600 grades) over a range of normal load (5-20 N). It was observed that the wear behavior is governed by the material-related parameters (microstructure, microhardness of coating) and test parameters (abrasive grit size and normal load). The addition of CrC reduces the wear rate three to eightfold. Wear resistance was greater against coarse abrasives at high loads than against fine abrasives. Heat treatment of both unmodified (1004) and modified powder (1004-10%CrC, 1004-20%CrC) coatings deteriorated the abrasive wear resistance. SEM study of wear surfaces showed that wear of the coatings largely takes place by groove formation, plowing, and scoring. Electron probe microanalysis (EPMA) of the coating was carried out for composition and phase analysis.

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