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Selected Abstracts of Thermal Spray Literature

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Applications

Aerospace

Blade failure in second stage turbine. The present paper reports the investigation of a sudden blade fracture leading to a fatal engine failure. The blade sample was subjected to a series of examinations, including visual examination and photographic documentation, optical microscopy, scanning electron microscopy (SEM), using both energy dispersive spectroscopy (EDS) and x-ray mapping. Analysis of all elements show that loss of aluminum from coating due to oxidation and coating phases changing; decreasing of alloy ductility and toughness due to carbides precipitation in grain boundaries; degradation of the alloy δ' & δ^1 phase (aging and coarsening) and micro cavities. These were found on fracture surfaces which served as an origin of creeping failure mechanism and are the most important factor for failure of this blade.

K. Mohammadi and A.K. Haghi, University of Guilan, Rasht, Iran. Cited: *Key Eng. Mater.,* p 393-396. ISSN 1013-9826.

Characterization of HVOF sprayed NiCrAlY-0-4wt.%CeO_2 coatings on superalloys. In the present work, metallurgical and mechanical properties of high velocity oxy fuel thermal sprayed NICrAlY-0-4wt.%CeO_2 coatings on NI and Fe based superalloys have been investigated. The microstructural morphologies, composition, and phases of the coatings were characterised using the techniques such as optical microscopy, field emission scanning electron microscopy/energy dispersive spectroscopy and x-ray diffraction. The mechanical properties of coatings such as microhardness and adhesion strength were measured. The coatings exhibited characteristic splat like, layered morphologies due to the deposition and resolidification of successive molten or semimolten powder particles. The coatings contained less than 1-4% porosity and showed the measured hardness values in the range of 649-753 HV. Average bond strength of the coating was found to be 45 MPa. The observed higher values of microhardness of the coated samples might be attributed to the addition of small amount of rare earth oxide CeO_2 in the coatings.

R.A. Mahesh, R. Jayaganthan, and S. Prakash, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, India. Cited: *Surf. Eng.,* 2008, Sept, **24**(5), p 366-373. ISSN 0267-0844.

Hard chromium substitution using HVOF coatings. Electroplated hard chromium coatings have long been used to improve the wear and/or corrosion resistance of components. However, concerns over the health problems associated with hexavalent chromium solutions have led to increasing regulation of this process route. One promising substitute for hard chromium is 'cermet' layers (e.g. Cr_3C_2-NiCr and WC-CoCr) which may be deposited by the high velocity oxyfuel process. High velocity oxyfuel coatings were characterized by microscopy, x-ray spectroscopy, density and a microabrasive wear test. The WC-CoCr coating provided the best overall performance and is an excellent candidate for hard chromium substitution.

L.C. Casteletti, R. Nucci, A.L. Neto, E.A.B. Arnoni, and G.E. Totten, Portland State University, Portland, OR 97207. Cited: *Int. Heat Treat. Surf. Eng.,* 2008, March, **2**(1), p 27-31. ISSN 1749-5148.

Ultra-high temperature ceramic coatings. Multilayer ceramic coatings appear to offer the best oxidation protection for carbon-carbon composites that make up the structure of future hypersonic space vehicles.

E.L. Corral, University of Arizona, Department of Materials Science and Engineering, Tucson, AZ 85721. Cited: *Adv. Mater. Processes,* 2008, Oct, **166**(10), p 30-32. ISSN 0882-7958.

Architecture

Gold spray: A solution for architectural glass. Low-pressure cold spray is an out-standing alternative solution to silver frit screen printing to produce bus bars in heated and photovoltaic glass. Simplicity and reliability are two of the advantages of low-pressure cold spray, which will facilitate the widespread implementation of functional and environmentally friendly glass technologies in the marketplace.

J. Villafuerte, Research and Development, CenterLine (Windsor) Ltd., Windsor, ON, Canada. Cited: *Weld. J. (Miami, Fla),* 2008, Aug, **87**(8), p 40-42. ISSN 0043-2296.

Automotive

Optimization of an irreversible diesel cycle: Experimental results of a ceramic coated indirect-injection supercharged diesel engine. In this work, an irreversible dual cycle analysis has been performed for enhancing the characteristics of a low heat rejection (LHR) supercharged single-cylinder indirect-injection (IDI) diesel engine. A relation which gives the maximum power (MP) and the corresponding efficiency has been derived analytically. Optimization of the diesel cycle has been performed for power and thermal efficiency with respect to the pressure ratio and temperature ratio. Optimum values of the pressure ratio and cutoff ratio of the diesel cycle, depending on the temperature ratios, have been derived analytically and compared to the results of an experimental study of the LHR engine, whose optimum performance was obtained by increasing the temperature in the combustion chamber. Effects of a ceramic coating on performance and exhaust emissions in the LHR engine have been compared to those obtained from the standard (STD) diesel engine based on the comparison of the STD and the LHR engines for identical airflow and brake mean effective pressure. Intake pressure was adjusted to give the same air consumption as the corresponding STD engine for the same brake mean effective pressure (BMEP) and engine speed to avoid a reduction in the volumetric efficiency of the LHR engine. In comparison to the STD engine, satisfactory performance was obtained with the LHR engine. Specific fuel consumption was decreased up to 4.5%, and brake efficiency was increased by 1.5%. NOx emissions were increased by 12% because of the higher flame temperature in the LHR engine.

A. Parlak, H. Yasar, H.S. Soyhan, and C. Deniz, Technical Education Faculty, Sakarya University, Esentepe 54187, Sakarya, Turkey. Cited: *Energy Fuels,* 2008, May/June, **2**(3), p 1930-1935. ISSN 0887-0624.

Biomaterials and Bioactive Materials

Anti-bacterial and cytotoxic properties of plasma sprayed silver-containing HA coatings. Silver-containing hydroxyapatite (HA) coatings have been prepared on titanium substrate by vacuum plasma spraying (VPS) method and anti-bacterial properties of the coatings were examined. Three types of bacteria stains, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, were employed in this test. The results showed that the silver-containing HA coatings exhibited significant anti-bacterial effects against the three bacteria with anti-bacterial ratios higher than 95%. The release of silver ions in the physiological environment ensured excellent anti-bacterial properties of the silver-containing HA coatings. International standard ISO 10993-12 was adopted for cytotoxicity evaluation using fibroblast cell line L929, and it was found that the cytotoxicity for the coatings ranked 0 that showed no cytotoxicity for the coatings. Hemolysis test was processed according to ASTM F 756 standard with anti-coagulated rabbit blood, and the hemolysis ratios of the coatings were below 0.4%, indicating of non-hemolysis for the coatings.

Y. Chen, X. Zheng, Y. Xie, C. Ding, H. Ruan, and C. Fan, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China. Cited: *J. Mater. Sci.: Mater. Med.,* 2008, Dec, **19**(12), p 3603-3609. ISSN 0957-4530.

Options for acetabular fixation surfaces. Aseptic loosening is the most common cause for revision total hip arthroplasty (THA). Due to poor long-term results with cemented acetabular components, cementless implants that rely on biologic fixation became popular in the United States for both primary and revision procedures in the early 1980s. Cementless acetabular components used in THA have been reported to have superior radiographic performance compared with cemented fixation, although the optimal method of acetabular fixation remains controversial. Cementless acetabular components require initial implant stability to allow for bone ingrowth and remodeling into the acetabular shell, providing long-term durability of the prosthesis. Many improved implant materials are available to facilitate bone growth and remodeling, including the 3 most common surface treatments; fibermesh, sintered beads, and plasma spray coatings. Recently added to these are porous metal surfaces, which have increased porosity and optimal pore sizes when compared with titanium fibermesh. The most studied of these materials is the titanium fibermesh fixation surface, which has demonstrated a mechanical failure rate of 1% at 10 to 15 years. This technology utilizes the diffusion bonding process to attach fiber metal pads to a titanium substrate using heat and pressure. The sintered bead fixation surface offers a porous coating of various sizes of spherical beads, achieved by the sintering process, and has been shown to provide long-term fixation. While there are less

long-term published data regarding the titanium plasma spray surface, its early results have provided evidence of its durability, even in the face of significant osteolysis. The most recently added alternative fixation surface is porous tantalum metal, which offers potentially greater bone ingrowth and bone graft incorporation due to its high porosity (80%) and low modulus of elasticity (3 MPa). Porous tantalum implants have shown early favorable clinical results and have been reported to have excellent bone graft incorporation of the acetabular component based on serial radiograph data at a minimum 1-year follow-up. Titanium is a porous metal, which has emerged as a promising new surface technology for acetabular shells. While no clinical data are yet available, basic science research has demonstrated enhanced bone ingrowth and mechanical strength.

A.K. Klika, T.G. Murray, H. Darwiche, and W.K. Barsoum, Department of Orthopaedic Surgery, Cleveland Clinic, Cleveland, OH 44195. Cited: *J. Long Term Eff. Med. Implants,* 2007, **17**(3), p 187-192. ISSN 1050-6934.

Preparation and antibacterial effect of plasma sprayed wollastonite coatings loading silver. In this work, the plasma sprayed wollastonite coating was soaked in 5 wt.% $AgNO_3$ solution at room temperature to load silver for improving its antibacterial effect. The surface characteristics of the silver-loaded coating were investigated by SEM, EDS and XRD. The release rate of silver from the coating was measured by ICP-OES in deionized water. The osteotoxicity of the silver-loaded coating was evaluated by in vitro cell culturing test. The antibacterial activity against *Staphylococcus aureus* was examined by Zone of Inhibition test. The results showed that the loaded silver reacted with the wollastonite coating to form silver silicate, which ensured a sustained release of silver in deionized water for as long as 50 days. The antibacterial activity and cell culturing tests confirmed that the silver released from silver-loaded wollastonite coating had strong inhibition against the growth of *S. aureus*, while they did not exhibit any adverse effects on the osteoblasts proliferation.

B. Li, X. Liu, C. Cao, F. Meng, Y. Dong, T. Cui, and C. Ding, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China. Cited: *Appl. Surf. Sci.,* 2008, Nov, **255**(2), p 452-454. ISSN 0169-4332.

Surface modification of titanium by nano-TiO_2HA bioceramic coating. A nano-TiO_2 hydroxyapatite composite bioceramic coating was developed and applied to the surfaces of pure titanium discs by the sol-gel method. A TiO_2 anatase bioceramic coating was utilized in the inner layer, which could adhere tightly to the titanium substrate. A porous hydroxyapatite (HA) bioceramic coating was utilized in the outer layer, which has higher solubility and better short-term bioactivity. Conventional HA coatings and commercially pure titanium were used as controls. X-ray diffraction (XRD) and scanning electron microscopy (SEM) were employed to characterize the crystallization, surface morphology, and thickness of the coatings. The bioactivities of the coatings were evaluated by in vitro osteoblast cultures. Results showed that the nano-TiO_2HA composite bioceramic coating exhibited good crystallization and homogeneous, nano-scale surface morphology. In addition, the nano-TiO_2HA coating adhered tightly to the substrate, and the in vitro osteoblast cultures exhibited satisfactory bioactivity.

G. He, J. Hu, S.C. Wei, J.H. Li, X.H. Liang, and E. Luo, State Key Laboratory of Oral Disease, Sichuan University, Chengdu 610044, China. Cited: *Appl. Surf. Sci.,* 2008, Nov 15, **255**(2), p 442-445. ISSN 0169-4332.

Energy

Coal-fired power materials. Advances in materials technology have paved the way for building coal-fired power plants with much higher efficiencies. For instance, there are now projects, sponsored by the US Department of Energy and the Ohio Coal Development Office, on 1400 °F/5000 psi designs, and similar projects are being undertaken in Europe. Such designs increase efficiency from the current 35-46%. There have been efforts also to improve headers in coal-fired power plants. In headers, the preferred material include ferritic and martensitic steels such they have lower coefficient of thermal expansion and higher thermal conductivity. In tubing applications, a newer material and better than auestenitic steel, nickel-base alloys are preferred since they provide more creep-resistance. There are also advances alloys for 760°; applications, such as nickel-base alloy Haynes 230, Inco 740, and CCA 617.

V. Viswanathan, R. Purgert, and P. Rawls, Electric Power Research Institute, Palo Alto, CA 94304. Cited: *Adv. Mater. Processes,* 2008, Aug, **166**(8), p 47-49. ISSN 0882-7958.

Graded Ni-YSZ anode coatings for solid oxide fuel cell prepared by EB-PVD. In order to reduce concentration polarization from the solid oxide fuel cell (SOFC) anode and the internal stress originating from the thermal expansion mismatch between the anode and electrolyte, a NiO-YSZ coating with a graded composition distribution was prepared by electron beam physical vapor deposition (EB-PVD) through adjusting the electron beam currents. Then the graded Ni-YSZ coating was obtained after a reduction treatment from this NiO-YSZ coating. A graded distribution in contents of both nickel and zirconium was found in this Ni-YSZ coating from the electron probe microanalysis (EPMA) result. Scanning electron microscopy (SEM) observation exhibited a continuous variation in porosity and pore diameter along the direction across the coating thickness. In this coating, a high porosity of up to 43% and an average pore diameter of about 1 μm were obtained in the part close to the substrate, while a low porosity of 10% and mean pore diameters of about tens of nanometres were achieved in the part close to the coating surface. This pore structure not only could decrease the concentration polarization, but also facilitate the following preparation of dense electrolyte films.

B. Meng, Y. Sun, X.D. He, and M.W. Li, Center for Composite Materials, Harbin Institute of Technology, Harbin 150080, China. Cited: *Mater. Sci. Technol.,* **24**(8), p 997-1001. ISSN 0267-0836.

Protective coatings for very high temperature reactor applications. The future very high temperature reactors (VHTR) are nuclear systems that shall operate at a maximum temperature of about 950 °C. Primary circuit materials thus require good creep and corrosion resistance on very long time. Use of high-strength alloys with protective coatings could significantly improve the service life of high temperature reactor components. However, coating systems are mainly designed for shorter term purposes, often under extremely aggressive atmospheres, that cannot be extrapolated to the VHTR environment. We present our first investigations on the environmental resistance of Alloy 800H coated with two different protective systems under VHTR representative conditions: NiAl(Pt)ZEBPVD ZrO_2(Y) and NiCrAl(Y)CVD ZrO_2(Y). Isothermal exposures were carried out up to 1000 h at 950 °C in impure helium. This specific atmosphere was shown to induce formation of a surface oxide scale together with carburization of the bare Alloy 800H. After high temperature exposure to impure helium, the microstructure of the coated specimens has changed due to both thermal ageing and corrosion. Performances of the two coating systems are compared regarding the VHTR application.

C. Cabet, F. Thieblemont, and C. Guerre, Service de la Corrosion et du Comportement des Materiaux dans leur Environnement, DEN/DANS/DPC, CEA Saclay, 91191, Gifsur, Yvette, France. Cited: *Mater. Corros.,* 2008, July, **59**(7), p 591-597. ISSN 0947-5117.

Thermal Barrier Coatings

A software tool for lifetime prediction of thermal barrier coating systems. Thermal barrier coatings (TBCs) are widely used to extend the lifetime of key components within gas turbines, and so the ability to predict the lifetime of TBCs is a high priority for gas turbine users. A complete model of TBC failure requires characterization of the coating system, identification of the main failure mechanisms, quantitative description of stress evolution in the key areas within the coating system and robust failure criteria for each failure mechanism. Thus lifetime prediction invariably requires a massive effort both in terms of determining the appropriate input parameters for the model and in computing the solution. In order to reduce the need for extensive calculation, a software tool has been developed that interpolates the key stresses for each failure mechanism from a matrix of previously calculated values. The matrix of values is generated using a recently developed finite element (FE) model of TBC lifetime of an IN738/MCrAlY/EB-PVD YSZ system. The stress distribution predicted by this model is dependent on exposure time and temperature as well as the morphology of the bond coat/ceramic interface and requires FE calculation for each specific set of conditions. The software tool interpolates the FE results with respect to time, temperature and a geometric parameter to predict key stresses that drive failure, and coating system lifetime. This paper describes the principles behind the development of the algorithms implemented in the software tool. Validation of the approach is in progress through comparison of predictions with non-destructive measurements on the coating system.

E.P. Busso, H.E. Evans, L. Wright, L.N. Mccartney, J. Nunn, and S. Osgerby, Centre des Materiaux, Mines Paris, UMR CNRS 7633, 91003 Evry, France. Cited: *Mater. Corros.,* 2008, July, **59**(7), p 556-565. ISSN 0947-5117.

Analysis of crack nets development in thermal barrier coatings. After a relatively short time in service, components with thermal barrier coatings (TBCs) protection typically develop a system of cracks that propagate from the coated surface toward the interface. Usually these cracks propagate across the thickness of the protective coating and branch along the interface between the coating and the bank metal. The presence of these crack nets is a concern for the durability of the components with TBCs. In the study of thin TBCs by Rubinstein and Tang (Int. J. Solids Struct. 42:5831-5847, 2005), it was found that in a number of cases, these components may still serve for a long time because of crack growth resistance development for cracks growing along the interface, which was found to be the most stable crack path under thermal loading conditions. One of the aims of this study is to determine whether similar fracture resistance is typical for thick TBC coatings as well. The emphases of the analysis presented here are on cases when the coating thickness is comparable to the thickness of the bank material, and on the effect of heat conduction changes due to branching of the developing cracks in a direction parallel to or along the interface. These items were not addressed in sufficient detail in the previous investigations.

A.A. Rubinstein and Y. Tang, Microstrength, Inc., Metairie, LA 70009-6234. Cited: *Int. J. Fract.,* **151**(1), p 57-79. ISSN 0376-9429.

Chemical aspects of plasma spraying of zirconia-based thermal barrier coatings. Zirconia-based thermal barrier coatings (TBCs) of nominal chemical composition 8 wt.% Y_2O_3-ZrO_2 and 25.5 wt.% CeO_2-2.5Y_2O_3-ZrO_2 were prepared by atmospheric plasma spray and low-pressure plasma spray by selecting different deposition parameters. The surface chemical composition has been investigated by x-ray photoelectron spectroscopy in order to study the variation of surface chemical composition induced by the plasma-spraying process as a function of deposition parameters. The results reveal the occurrence of chemical-physical reactions such as stabilizing oxide depletion and enrichment, reduction to lower valence states, impurity segregation phenomena and the formation of new species. The chemical information was confirmed by differential thermal analysis measurements, which indicates that chemical aspects in plasma spraying are relevant and should be considered in designing reliable TBCs for maximum performance in aerospace applications.

G.M. Ingo and T. De Caro, Istituto per lo Studio dei Materiali Nanostrutturati-Consiglio Nazionale delle Ricerche, 00016 Monterotondo Stazione, Rome, Italy. Cited: *Acta Mater.,* 2008, Oct, **56**(18), p 5177-5187. ISSN 1359-6454.

Dynamics of kink band formation in columnar thermal barrier oxides. The dynamics of kink band formation in columnar yttria-stabilized zirconia (YSZ) have been investigated via dynamic finite element modeling. A microstructure-based constitutive law models each column as a low-porosity solid and the intercolumnar zones as a high-porosity elastic-plastic foam. In the simulations, a rigid particle impacts a YSZ coating at fixed velocity. At the lowest velocities, kink bands develop having the characteristic location, orientation, and width established in previous quasi-static assessments. However, with increasing impact velocity and/or decreasing YSZ yield strength, kink bands are observed to form at increasingly shallower declinations. Thus a yield-strength-dependent velocity threshold exists, above which kink bands become non-penetrating. Kink band suppression is attributed to inertial stabilization of the columns against buckling. Further interrogation reveals that, for a given particle and YSZ yield strength, there exists a critical coating thickness above which kink-band-induced spallation cannot occur, regardless of impact velocity.

M.W. Crowell, J. Wang, R.M. Mcmeeking, and A.G. Evans, Materials Department, University of California, Santa Barbara, CA 93106-5050. Cited: *Acta Mater.,* 2008, Oct, **56**(16), p 4150-4159. ISSN 1359-6454.

Effect of bond coat surface roughness on oxidation behaviour of air plasma sprayed thermal barrier coatings. Two layered thermal barrier coatings (TBCs) with different bond coat surface roughnesses were produced by air plasma spraying. Isothermal oxidation test was carried out to evaluate the durability and oxidation behavior of these systems. The results show that the roughness of bond coat significantly affects the lifetime of TBCs. With the increase in bond coat roughness, the lifetime decreases exponentially. The durability is enhanced by surface grinding treatments that decrease diffusion paths on the surface of the bond coat and diminish Al depletion rate. The shape and path of cracks at failure are also affected by the bond coat surface roughness.

C. Che, G.Q. Wu, H.Y. Qi, Z. Huang, and X.G. Yang, School of Materials Science and Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100083, China. Cited: *Surf. Eng.,* 2008, July, **24**(4), p 276-279. ISSN 0267-0844.

Effect of diffusion barrier on the high-temperature oxidation behavior of thermal barrier coatings. A selective oxidation technique has been applied to form a diffusion barrier on the Ni-based superalloy substrate by heating the substrate with electron beam of the electron beam-physical vapor deposition (EB-PVD) facility. The interdiffusion behavior, cross-sectional morphology, isothermal and cyclic oxidations were studied for thermal barrier coatings (TBCs) with and without diffusion barrier. Under an oxygen partial pressure of about 2.5^{10}-5 kPa and after heating for 30 min, the alloying elements of substrate were selectively oxidized and a thin layer of diffusion barrier with a thickness of 500 nm was formed on the substrate, and the diffusion barrier was composed of mainly α;-Al_2O_3, NiO and Cr_2O_3. Different alloying elements had different diffusion behaviors, it was observed that Al and Cr diffused inwards from the bond coat to the substrate, and Ti, Mo and W diffused outwards from the substrate to the bond coat. It was also observed that the lifetime of TBC with diffusion barrier could be partially improved, though the experimental results received from isothermal oxidation and cyclic tests are not extremely obvious.

Z. Xu, R. Mu, L. He, and X. Cao, CAS Key Laboratory of Rare Earths on Advanced Materials and Valuable Utilization of Resources, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Changchun 130022, China. Cited: *J. Alloys Compd.,* 2008, Oct 20, **466**(1-2), p 471-478. ISSN 0925-8388.

Effect of platinum on the durability of thermal barrier systems with a γ; + γ; prime bond coat. The effect of the Pt content on the durability of thermal barrier coatings (TBCs) with a Pt-enriched γ; γ; prime bond coat was investigated. It was found that the TBCs with a higher Pt content exhibit a significantly longer isothermal life than those with a lower Pt content. The subsequent analysis indicated that the Pt content has only a negligible effect both on the stresses in the thermally-grown oxide (TGO) and the elastic properties of the bond coat, but has a significant effect on the interfacial chemistry. During oxidation, impurities such as S, C and refractory elements segregating to the interface would degrade the TGO adherence to the bond coat. However, a higher content of Pt can inhibit this segregation, and thus improve the TBCs life.

X. Zhao and P. Xiao, Materials Science Centre, School of Materials, University of Manchester, Manchester, M1 7HS, UK. Cited: *Thin Solid Films,* 2008, Nov 28, **517**(2), p 828-834. ISSN 0040-6090.

Interfacial fracture characteristic and crack propagation of thermal barrier coatings under tensile conditions at elevated temperatures. Thermal barrier coatings (TBCs) have been extensively used in aircraft engines for improved durability and performance for more than fifteen years. In this paper, thermal barrier coating system with plasma sprayed zirconia bonded by a MCrAlY layer to SUS304 stainless steel substrate was performed under tensile tests at 1000 °C. The crack nucleation, propagation behavior of the ceramic coatings in as received and oxidized conditions were observed by high-performance camera and discussed in detail. The relationship of the transverse crack numbers in the ceramic coating and tensile strain was recorded and used to describe crack propagation mechanism of thermal barrier coatings. It was found that the fracture/spallation locations of air plasma sprayed (APS) thermal barrier coating system mainly located within the ceramic coating close to the bond coat interface by scanning electron microscope (SEM) and energy dispersive x-ray (EDX). The energy release rate and interface fracture toughness of APS TBCs system were evaluated by the aid of Suo-Hutchinson model. The calculations revealed that the energy release rate and fracture toughness ranged, respectively, from 22.15 J m^{-2} to 37.8 J m^{-2} and from 0.9 MPa $m^{1/2}$ to 1.5 MPa $m^{1/2}$. The results agree well with other experimental results.

W.G. Mao, C.Y. Dai, L. Yang, and Y.C. Zhou, Faculty of Materials, Optoelectronics and Physics, Xiangtan University, Hunan 411105, China. Cited: *Int. J. Fract.,* **151**(2), p 107-120. ISSN 0376-9429.

Investigation on the oxidation behavior of gamma titanium aluminides coated with thermal barrier coatings. In the present study, the applicability of thermal barrier coatings (TBCs) on δ;-TiAl alloys was investigated. Two alloys with the chemical compositions of Ti-45Al-8Nb-0.2B-0.15C and Ti-45A1-1Cr-6Nb-0.4W-0.2B-0.5C-0.2Si were used. Before TBC deposition, the specimens were pre-oxidized in laboratory air or low partial pressure oxygen atmosphere. Yttria partially stabilised zirconia top coats were then deposited using electron-beam physical vapor deposition (EB-PVD). The oxidation behaviour of the δ;-TiAl specimens with TBC was studied by cyclic oxidation testing in air at 850 and 900 °C. Post-oxidation analysis of the coating systems was performed using scanning electron microscopy with energy-dispersive x-ray spectroscopy (EDS). No spallation of the TBC was observed for pre-oxidized specimens of both alloys when exposed to air at 850 °C for 1100 cycles of 1 h dwell time at high temperature. SEM micrographs of the thermally grown oxide scale revealed outer mixed $TiO_2Al_2O_3$ protrusions with a columnar structure. The protrusions contained small particles of zirconia and a low amount of about 0.5 at.% zirconium was measured by EDS analysis throughout this outer oxide mixture. The TBCs exhibited excellent adherence on the oxide scale. Intercolumnar gaps and pores in the root area of the TBC were filled with titania and alumina. Below the outer columnar oxide scale, a broad porous zone of predominant titania was observed. The transition region between the oxide scale and substrate consisted of a discontinuous nitride layer intermixed with alumina particles and intermetallic phases rich in niobium formed at the nitride layer/substrate interface. When thermally cycled at 900 °C, the oxide scales on the alloy Ti-45Al-8Nb-0.2B-0.15C pre-oxidized in low partial pressure oxygen spalled off after 540 cycles. For the sample with TBC, spallation was observed after 810 cycles. Failure occurred in the thermally grown oxide near the oxide/nitride layer interface. Microstructural examinations revealed again oxide scales with columnar structure beneath the zirconia top coat and good adherence of the TBC on the thermally grown oxides formed at 900 °C.

R. Braun, M. Frohlich, A. Ebach-Stahl, and C. Leyens, DLR, German Aerospace Center, Institute of Materials Research, D-51170 Koln, Germany. Cited: *Mater. Corros.,* 2008, July, **59**(7), p 539-546. ISSN 0947-5117.

Microstructural and acoustic damage analysis and finite element stress simulation of air plasma-sprayed thermal barrier coatings under thermal cycling. Degradation evolution and failure mechanisms of air plasma-sprayed thermal barrier coatings during thermal cycling were investigated using microstructural and acoustic emission analysis. The microcrack evolution observed suggests that the life-time is governed by the kinetics of crack formation, growth and linking of individual cracks. The damage in the thermal barrier coatings mainly occurs during cooling due to thermal-expansion mismatch stresses at the metalceramic interface. The effect of the minimum cycling temperature on the lifetime was found to be much more pronounced than that of a variation in cooling rate. Experimental results were supported by finite element modeling of the stress distribution at the metal-ceramic interface during cooling at different rates.

O. Trunova, P. Bednarz, R. Herzog, T. Beck, and L. Singheiser, Forschungszentrum Julich GmbH, Institute of Energy Research-2, D-52425,

Julien, Germany. Cited: *Int. J. Mater. Res.,* **99**(10), p 1129-1135. ISSN 1862-5282.

Microstructure-thermal conductivity relationships for plasma-sprayed yttria-stabilized zirconia coatings. The microstructures of plasma-sprayed yttria-stabilized zirconia (YSZ) coatings are complex, contributing to challenges in establishing microstructure-thermal conductivity relationships. Furthermore, the dynamic evolution of microstructure and properties during service offers a significant challenge in defining design strategies and extended coating performance. In this paper, the relationship between microstructure and thermal conductivity is investigated for three sets of plasma-sprayed YSZ coating systems prepared using different morphology powders, different particle size distributions, and controlled modification of particle states through plasma torch parameters. Both ambient and temperature-dependent thermal conductivity were conducted in the as-sprayed and thermally aged states. The results suggest that a range of thermal conductivities can be achieved from the coatings, offering potential for microstructural tailoring for desired performance. The results also demonstrate that different as-deposited microstructures display varying propensity for sintering and these attributes need to be considered in the design and manufacturing cycle. This expansive study of a range of coatings has also allowed synthesis of the results through thermal conductivity-porosity maps and has allowed elucidation of the contributing microstructural components for both the ambient and high-temperature thermal conductivity. Considering that the operating thermal transport mechanisms are different at these two temperature extremes, such mapping strategies are of value to both science and technology.

W. Chi, S. Sampath, and H. Wang, Center for Thermal Spray Research, State University of New York, Stony Brook, NY 11794-2275. Cited: *J. Am. Ceram. Soc.,* 2008, Aug, **91**(8), p 2636-2645. ISSN 0002-7820.

The role that bond coat depletion of aluminum has on the lifetime of APS-TBC under oxidizing conditions. Bond coat oxidation as well as bond coat depletion of Al are still believed to be a major degradation mechanism with respect to the lifetime of thermal barrier coating (TBC) systems. In this study the top coat lifetime is described as being limited by both bond coat depletion of Al and mechanical failure of the top coat. The empirical results are introduced by considering three spallation cases, namely, Al depletion failure, thermal fatigue failure, and thermal aging failure. Al depletion failure occurs when the Al content within the bond coat reaches a critical value. In this paper bond coat depletion of Al is modeled by considering the diffusion of Al into both the thermally grown oxide (TGO) and substrate. The diffusion model results are compared to Al concentration profiles measured with an electron beam microprobe. These measured results are from oxidized air plasma sprayed TBC systems (APS-TBC) with vacuum plasma sprayed (VPS) bond coats for exposures up to 5000 h in the temperature range of 950-1100 °C. This paper focuses on the Al depletion failure and how it relates to top coat spallation.

D. Renusch, M. Schorr, and M. Schutze, Karl-Winnacker-Institut, DECHEMA e.V., D-60486 Frankfurt am Main, Germany. Cited: *Mater. Corros.,* 2008, July, **59**(7), p 547-555. ISSN 0947-5117.

Thermal fatigue of thermal barrier coatings by atmospheric plasma spraying. Turbine vanes and blades are the most intensively loaded elements in that they are subjected to a large variety of mechanical and high temperature loads. The thermal barrier coatings (TBCs) are widely used on different hot components of gas turbines, as blades and vanes, for both, power engineering as well as aeronautical applications. Currently, two methods are used for depositing TBCs on substrate, which are plasma spray (PS) and electron beam-physical vapor deposition (EB-PVD). A typical TBCs system consists of two thin coatings, including a ceramic coating and a metallic bond coat. Despite considerable efforts, the highly desirable prediction of their life time is still a demanding task. The PS coating was focused on in this work. Firstly, the TBCs systems are multilayer material systems. The material properties are not easily determined, such as Young's modulus of the top-coating of TBCs. Using the resonant frequency and the composite beam theory, the Young's modulus of APS TBCs was gotten under from room temperature to 1150 °C. Then using a commercial finite-element program, the model geometry is that of a cylinder specimen. The interface region between bond coat and top coating is modeled and meshed with a sinusoidal geometry. The temperature was designed and cycled over a range from room temperature to 1050 °C. The force-air-cooling was designed to form temperature gradient across the thickness of TBCs. Finally, the fatigue life of TBCs was predicated. The maximum relative error is 20.1%.

H. Qi, H. Ma, X. Li, X. Yang, and D. Shi, School of Jet Propulsion, BeiHang University, Beijing 100083, China. Cited: *Key Eng. Mater.,* **385-387,** p 405-408. ISSN 1013-9826.

Diagnostics and Control

Off-line development of robot motion programs. A coating program is developed using Microsoft™ Excel™ to define a path for the coating of fixed, tubular parts with robot motion along the axis of the parts that are rotated during the thermal spray coating operations. The program development has given key considerations to define the velocity profile along the path and has illustrated the efficiency of the standard Excel™ tools on a conical shaped part. The key factors have included the normal distribution of the thermal spray deposit along with that of the Microsoft™ Excel™ tools. The technique has enabled the offline evaluation of the robot coating programs, facilitated an insight into the coating operations, and has presented the opportunity to optimize these operations. The chart tools from Microsoft™ Excel™ allows for visual feedback to the programmer.

D.R. Moody, Plasma Powders and Systems, Inc., Marlboro, NJ. Cited: *Weld. J. (Miami, Fla),* 2008, Aug, **87**(8), p 44-47. ISSN 0043-2296.

Process maps for plasma spraying of yttria-stabilized zirconia: An integrated approach to design, optimization and reliability. Plasma-sprayed yttria-stabilized zirconia (YSZ) continues to play an important role in enhancing performance of both propulsion and land-based gas turbine engines. Tailoring the microstructure and properties of these thermal barrier coatings towards achieving both prime reliance and manufacturing reproducibility is a complex task due to the multitude of interrelated parameters that influence the plasma spray process and the deposit formation dynamics. In this article, we report on a study that connects thermal spray coatings through process science and materials science utilizing the concept of process maps. Process maps are representations of interrelationships among control parameters and measured responses. First-order process maps have been established for three YSZ powder morphologies, linking the plasma forming torch parameters to the particle state (responses) through a design of experiments approach and in-flight diagnostics. Refinements to representation of the raw particle characteristics are proposed through the use of group parameters (melting index and kinetic energy) from the experimental results. First-order process maps have been used for process parameterization and feedback control. Correlating the first-order responses with coating properties allows representation of coating properties in the form of second-order process maps and enables identification of process windows. As will be demonstrated in this paper, these advances provide a platform with which to construct comprehensive process-microstructure-property relationships with implications for coating design, process efficiency and full-field assessment of manufacturing reliability.

A. Vaidya, V. Srinivasan, T. Streibl, M. Friis, W. Chi, and S. Sampath, Center for Thermal Spray Research, State University of New York, Stony Brook, NY 11794-2275. Cited: *Mater. Sci. Eng. A,* 2008, Dec 15, **497**(1-2), p 239-253. ISSN 0921-5093.

Thermal spray cooling using cryogenic nitrogen. Air Product has developed an automated thermal cooling system as a better solution to meet the challenges requiring maintenance of the part temperature during thermal spray coating applications that are arising from the need of the faster and more heat-intensive processes for the cooling systems. The advanced cooling system helps the users maintain part temperature between ±20 °F using cryogenic, inert nitrogen vapor (−320 °F) while eliminating the inefficiencies and also offering a variety of system designs for application-specific use. High-velocity oxygen fuel (HVOF) thermal spray and plasma thermal spray are the two heat intensive process that the technology uses for coating parts, such as landing gear, bearing races, valves, and turbine components with wear, corrosion, and heat-shielding materials. A very high-purity carbon dioxide (CO_2) enables a constrained heat removal rate.

Anon, Cited: *Weld. J. (Miami, Fla),* 2008, Aug, **87**(8), p 26-29. ISSN 0043-2296.

Thermal spray techniques for deep bore applications. High-velocity oxygen fuel (HVOF) thermal spray combined with an off-angle technique is playing an effective role to apply the high-structure coatings, especially to tubes for deep bore applications. The off-angle HVOF technique responses directly to meet the challenges for the companies to achieve the correct balance between coating quality and cost and also has eliminated the application limitations with the thermal spray coating as a line-of-sight process. The technique effectively works to consistently maintain a proper thickness and structure on virtually all surfaces that leads to improved life expectancy of the components. The technique also significantly solves the problems of processors' limited ability to coat inside diameters greater in length than the size of the ID. Standard measured responses for the coatings, such as microhardness and Almen deflection have indicated beneficial aspects of the extreme off-angle HVOF WC/CoCr coatings over 90° coatings in several significant ways.

M. Froning, P.F. Ruggiero, and R. Bajan, BASF Catalysts LLC, Surface Technologies, East Windsor, CT. Cited: *Weld. J. (Miami, Fla),* 2008, Aug, **87**(8), p 34-35. ISSN 0043-2296.

Measurement Methods

On cracks and delaminations of thermal barrier coatings due to indentation testing: Experimental investigations. Rockwell indentation testing as a method of establishing the interfacial fracture toughness of thermal barrier coatings is investigated. To this end, indentation tests have been systematically performed on coatings with yttria-stabilized zirconia top coat deposited by

electron beam physical vapor deposition. Specimens in "as-coated" condition and after heat treatment in air have been studied. Unexpectedly, indentation of the heat-treated samples resulted in smaller delaminations than the as-coated samples, suggesting an increase in fracture toughness for coatings subjected to elevated temperatures. Careful image analyses of the cross-section of the indented area show that the ceramic top coat undergoes a complex damage evolution during indentation that is altered by thermal treatment. The consequences of this are discussed and we note that care must be taken when evaluating fracture parameters for multilayered structures based on indentation testing.

J. Yan, T. Leist, M. Bartsch, and A.M. Karlsson, Department of Mechanical Engineering, University of Delaware, Newark, DE 19716. Cited: *Acta Mater.,* 2008, Sept, **56**(15), p 4080-4090. ISSN 1359-6454.

Microstructure

An investigation of the effect of processing conditions on the microstructure of vacuum plasma-sprayed Ti-Zr-Ni quasicrystal coatings. $Ti_{41.5}Zr_{41.5}Ni_{17}$ (at.%) powders from two batches having different size fractions have been vacuum plasma sprayed to form coatings using different sets of spray parameters. The powders are composed mainly of the HCP alpha and Laves phases which transform to i-phase owing to rapid quenching during plasma spraying. The coatings are examined using image analysis, hardness tester, XRD, SEM, and TEM. TEM studies revealed that the coating has a microstructure constituted by extremely fine grains. It has been observed that the polycrystalline to i-phase transformation occurs in both coatings irrespective of the differences in starting powder size and other spray parameters.

P.P. Bandyopadhyay and Siegmann, Department of Mechanical Engineering, IIT Kharagpur, Kharagpur 721302, India. Cited: *J. Coat. Technol. Res.,* 2008, Sept, **5**(3), p 379-383. ISSN 1547-0091.

Characterization of microstructure and surface properties of hybrid coatings of WC-CoCr prepared by laser heat treatment and high velocity oxygen fuel spraying. The microstructure and microhardness of high velocity oxygen fuel-sprayed WC-CoCr coatings were comparatively studied both before and after laser heat treatment of the coatings. Optical microscopy, scanning electron microscopy, x-ray diffraction and microhardness testing were applied to investigate the microstructure, phase composition, porosity and microhardness. The results indicate that WC is still present, and W_2C has appeared, while neither cobalt nor σ;-CrCo is detectable. Co_4W_2C has appeared in the high velocity oxygen fuel-sprayed coating after laser heat treatment as compared to the coating before laser treatment. The relative content of the W_2C has not increased with laser treatment, but the laser treatment has essentially eliminated the porosity almost entirely, providing a more homogeneous and densified microstructure. The laser heat treatment has effected the formation of a denser compact coating on the substrate. After laser heat treatment, the thickness of the coating has decreased from 300 to 225 μm. This corresponds to an average porosity in the high velocity oxygen fuel-sprayed coating that is approximately five times greater than that in the subsequently laser heat-treated coating. The laser treatment has also resulted in an increased hardness of the coating near the surface, where the average value increased from $Hv_{0.2}$ = 1262.4 in the coating before laser heat treatment to $Hv_{0.2}$ = 1818.7 after laser heat treatment.

S.-H. Zhang, T.-Y. Cho, J.-H. Yoon, W. Fang, K.-O. Song, M.-X. Li, Y.-K. Joo, and C.G. Lee, School of Nano and Advanced Materials Engineering, Changwon National University, Gyeongnam, 641-773 South Korea. Cited: *Mater. Charact.,* 2008, Oct, **59**(10), p 1412-1418. ISSN 1044-5803.

Microstructural evolution of the NiCrAlY/CrON duplex coating system and its influence on mechanical properties. The microstructural evolution of the NiCrAlY/CrON system during vacuum heat treatment and thermal exposure was investigated by scanning electron microscopy (SEM), x-ray diffraction (XRD) and transmission electron microscopy (TEM). The elastic modulus and residual stress of the coating system were measured by nanoindentation and photo-stimulated luminescence spectrum (PSLS) methods, respectively. It was shown that the series reaction of $\beta \rightarrow \gamma' \rightarrow \gamma$; took place in the NiCrAlY coating, which contributed to a decrease in the Young's modulus. The replacement of Cr_2/O_3 by Al_2O_3 during thermal exposure resulted in an increase of the Young's modulus of the barrier layer. A change in the residual stress in the barrier layer was due to a combination of thermal and growth stresses.

W.Z. Li, Q.M. Wang, Z.B. Bao, Y. Yao, J. Gong, C. Sun, and X. Jiang, State Key Lab for Corrosion and Protection, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China. Cited: *Mater. Sci. Eng. A,* 2008, Dec 20, **498**(1-2), p 487-494. ISSN 0921-5093.

Microstructural investigation of walking parts of military tanks coated with arc spraying. The walking parts of military tanks coated with Arc spraying was investigated. Pallet directions were located inside the carrying wheel in running part of military tanks. Pallet direction forks were produced from AISI 4140 steel. Worn side surfaces of direction forks were repaired by means of filet welding to get the initial form of them. Side surfaces of pellet direction forks work during working were coated by flame wire spraying method. Mo wire was used for lining of carrying wheels with 40 m/min coating rate, and then process were performed with steel coating wire called Met-Colloy 2 up to 3.5 mm coating thickness were reached. Pin-on-disc was used to test the friction and wear properties of sliding contact of braking pads. Repair and maintenance of worn pallet direction forks by fillets welding is being seen viable, and also it will be more economical in future by developing more modern joining technologies.

U. Ozsarac, S. Aslanlar, and E. Ilhan, Sakarya University, Applied Sciences Faculty, Esentepe Campus, 54187, Sakarya, Turkey. Cited: *Adv. Eng. Mater.,* 2008, July, **10**(7), p 678-685. ISSN 1438-1656.

Microstructure and mechanical properties of thermal sprayed nanostructured Cr_3C_2-Ni20Cr coatings. Cr_3C_2-Ni20Cr coatings have been used for corrosion and wear resistant applications. However, one of the shortcomings of these coatings is its low hardness, and consequent low wear resistance, for long term high temperature applications. Nanostructured coatings of many materials have exhibited higher hardness and strength compared with conventional coatings of the same material. Consequently, nanostructured coatings of other materials, including Cr_3C_2-Ni20Cr have been attempted to enhance overall performance. In this study the effects of high energy milling parameters on Cr_3C_2-25(Ni20Cr) powder characteristics as well as the microstructure and mechanical properties of nanostructured Cr_3C_2-25 (Ni20Cr) coatings formed by high velocity oxygen fuel (HVOF) spraying have been evaluated. The average particle size and crystallite size of milled Cr_3C_2-25-25 (Ni20Cr) powders decreased with increase in milling time and this decrease was more pronounced in nitrogen compared to that in hexane. This difference has been attributed to a cushioning effect in the latter medium. The coatings prepared with milled Cr_3C_2-25 (Ni20Cr) powders had a more uniform microstructure, were harder and had higher relative fracture toughness compared with coatings prepared with as-received powders.

C.A. Da Cunha, N.B. De Lima, J.R. Martinelli, A.H.D.A. Bressiani, A.G.F. Padial, and L.V. Ramanathan, Instituto de Pesquisas Energeticas e Nucleares – IPEN, 05508-000, Sao Paulo – SP, Brazil. Cited: *Mater. Res.,* **11**(2), p 137-143. ISSN 1516-1439.

Microstructure and microhardness of cold-sprayed CuNiIn coating. In this study, the emerging cold spraying technique was used to deposit the CuNiIn coating. The microstructure of cold sprayed Cu36Ni5In coating was examined by optical microscope, scanning electron microscope and x-ray diffraction. It was found that a very dense Cu36Ni5In coating was deposited under certain spray condition. The impact melting at the localized interfaces of the deposited particles was observed and agreed with the theoretical analysis. The coating microhardness was about 240 $Hv_{0.2}$.

W.-Y. Li, H. Liao, J. Li, and C. Coddet, Shaanxi Key Laboratory of Friction Welding Technologies, School of Materials Science and Engineering, Northwestern Polytechnical University, Xi'an 710072, China. Cited: *Adv. Eng. Mater.,* 2008, Aug, **10**(8), p 746-749. ISSN 1438-1656.

Processing-structure-property correlation and decarburization phenomenon in detonation sprayed WC-12Co coatings. In this paper, we demonstrate how the microstructure evolution in terms of nature/extent of decomposition of WC as well as properties of WC-12wt.% Co coatings is critically dependent on variation of oxygen-fuel (OF) ratio. The coating deposition was carried out over a wide range of OF ratios using a detonation spray technique, and particle velocity was measured using a high-speed particle diagnostics system. The presence of free W and increased W_2C phase is observed under deposition at higher OF ratios of 1.5 or 2.0, and this has been confirmed using XRD, EBSD and SEM-EDS elemental mapping. In order to obtain representative hardness and modulus of the as-deposited coatings, careful measurements and analysis of indentation response (cross-section and surface) were carried out using nanoindentation and Vickers hardness testers. Based on our experimental results, a major emphasis has been put forward to establish a processing-structure-property correlation for detonation sprayed WC-12Co coatings.

P. Suresh Babu, B. Basu, and G. Sundararajan, Department of Materials and Metallurgical Engineering, Indian Institute of Technology Kanpur, Uttar Pradesh, India. Cited: *Acta Mater.,* 2008, Oct, **56**(18), p 5012-5026. ISSN 1359-6454.

Structure formation during gas-detonation spraying of coatings from composite powders $TiAl_3$ and Ni_3Al. This paper considers the mechanisms of structure formation during gas detonation spraying of coatings of $TiAl_3$ and Ni_3Al intermetallic compounds produced under equilibrium and nonequilibrium synthesis conditions. The coating sprayed from $TiAl_3$ has the same phase composition as the initial powder, regardless of the synthesis conditions. During spraying of Ni_3Al, the structure of the coating also does not depend on the synthesis conditions and consists of two phases—Ni_3Al, and NiAl, with the crystal structure varying along the coating thickness. Comparative impact abrasion tests of the coatings showed advantages of $TiAl_3$ coatings over coatings based on Ni_3Al and titanium diboride.

V.Y. Filimonov, V.I. Yakovlev, M.A. Korchagin, M.V. Loginova, A.S. Semenchina, and A.V. Afanas'ev, Polzunov Altai State Technical University, Barnaul 656038.

Cited: *Combust. Explos. Shock Waves,* 2008, Sept, p 591-596. ISSN 0010-5082.

Thermal stability of nanostructured NiCrC coating prepared by HVAF spraying of cryomilled powders. Thermal stability of nanostructured NiCrC coating prepared by high velocity air-fuel (HVAF) spraying of cryomilled feedstock powders was investigated. Transmission electron microscopy (TEM), differential scanning calorimetry (DSC), and x-ray diffraction (XRD) were utilized for characteristic analysis. Recrystallization and normal grain growth occur when isothermal treatment is performed at 923 K (0.55 T_M) for up to 100 h, and the average grain size increases from initial 41 nm for as-deposited state to around 100 nm for nearly equilibrium state. Isochronal treatment at 823 and 1023 K was also conducted for comparison. Accordingly, for 0.49 to 0.61 T/T_M, the time exponent n deduced from $D^1n - D_0 > 1n = kt$ increases from 0.15 to 0.30. The observed high thermal stability is attributed primarily to a Zener pinning mechanism arising from the fine Cr_2/O_3 dispersions and the solute drag effect as well.

H. Cui, K. Tao, X. Zhou, and J. Zhang, State Key Laboratory for Advanced Metals and Materials, University of Science and Technology Beijing, Beijing 100083, China. Cited: *Rare Met.,* 2008, April, **27**(4), p 418-424. ISSN 1001-0521.

Thermal stability of phases in a NiCoCrA1Y coating alloy. The temperature dependence of the thermal stability in a NiCoCrAlY coating alloy was examined by experimental observation and thermodynamic modeling in the 400-1200 °C temperature range. The results indicated that the thermal stabilities of primary β-NiAl, β-NiAl α-Cr eutectic, and γ-Ni were slightly temperature dependent, but those of γ-Ni_3Al, σ-(Cr,Co,Ni), and α-Cr were strongly temperature dependent in the annealed NiCoCrAlY specimens. The temperature dependence of the thermal stabilities among γ-Ni_3Al; σ-(Cr,Co,Ni), and α-Cr might be ascribed to the $\sigma \rightarrow \alpha$; transformation at ~1100 °C and the $\gamma' \rightarrow \gamma$; transformation at ~800 °C. Further, using Thermocalc associated with TTNi7 database, thermodynamic equilibria were calculated. The modeling results were compared with the experimental results and found to be in reasonable agreement with the experimental observations of β;-NiAl, δ;-(Cr,Co,Ni), and γ′-Ni_3Al. Some deviations observed are discussed in the light of both limited availability of thermodynamic data and experimental problems.

J.J. Liang, H. We, G.C. Hou, Q. Zheng, X.F. Sun, H.R. Guan, and Z.Q. Hu, Superalloys Division, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China. Cited: *J. Mater. Res.,* 2008, Aug, **23**(8), p 2264-2274. ISSN 0884-2914.

Thermophysical, mechanical and microstructural characterization of aged free-standing plasma-sprayed zirconia coatings. The effect of porosity on the thermal diffusivity and elastic modulus has been studied on artificially aged, free-standing thermal barrier coatings (TBCs) produced by air plasma spray (APS). The activation energy of the sintering phenomenon was estimated from the variation in diffusivity with time and temperature. x-ray diffraction was used to evaluate the phase stability of 7 wt.% yttria partially stabilized zirconia (YPSZ) coatings. The thermal diffusivity and elastic modulus as measured by photothermal techniques and three-point bending, respectively, are reported as a function of the ageing time. Correlations between the thermal and mechanical parameters are investigated by suitable models based on the microstructural features revealed by electron microscopy. The reliability of porosity information provided by image analysis and used as input for the modeling is critically discussed.

F. Cernuschi, P.G. Bison, S. Marinetti, and P. Scardi, CESI RICERCA 20134, Milano, Italy. Cited: *Acta Mater.,* 2008, Oct, **56**(16), p 4477-4488. ISSN 1359-6454.

Modeling

Mechanical Modeling

Analysis of transient thermal stress in sandwich plate with functionally graded coatings. In this paper, the formulae of transient temperature field and transient thermal stress field in an infinite sandwich plate with double-sided functionally graded coatings (FGM coatings) under the convective boundary condition are derived via an asymptotic solution approach. The thermo-physical properties of the two symmetrical graded coatings are assumed to have distributions of power forms along the thickness direction of the plate. Numerical calculations of transient thermal stresses for a TiC-Al_2O_3 FGM coating/Al_2O_3 substrate/Al_2O_3-TiC FGM coating system under different Biot numbers in cold shock are performed in contrast to a sandwich plate with homogeneous coatings and a homogeneous plate. The effects of the thermo-physical property distributions of the FGM coatings on the thermal shock resistance of the plate are analyzed. And consequently some design rules for the sandwich plate with FGM coatings are put forward, which may be used to design FGM coated cutting tools with high thermal shock resistance.

J. Zhao, Y. Li, and X. Ai, School of Mechanical Engineering, Shandong University, Jinan 250061, China. Cited: *Thin Solid Films,* 2008, Sep 1, **516**(21), p 7581-7587. ISSN 0040-6090.

Analytical models of thermal-stress induced phenomena in isotropic multi-particle-matrix system. The paper presents four topics dealing with phenomena induced by elastic thermal stresses acting in an isotropic multi-particle-matrix system to represent a model system applicable to real multi-phase materials of a precipitation-matrix type. The isotropic multi-particle-matrix system consists of periodically distributed spherical particles in an infinite matrix to be imaginarily divided into cubic cells containing a central spherical particle. Formulae for the thermal stresses to be investigated within the cubic cell represents functions of the particle volume fraction v and the particle radius R. The thermal stresses originate during a cooling process as a consequence of the difference m-p in the thermal expansion coefficients m and p of the matrix and the particle, respectively. Additionally, such temperature range is considered within which the multi-particle-matrix system exhibits elastic deformations regarding the yield stress and the particle-matrix boundary adhesion strength. Analytical fracture mechanics to represent the first topic of this paper results from the determination of a curve integral of the thermal-stress induced elastic energy density. The curve elastic energy density results in the determination of the critical particle radii Rpc and Rmc as reasons of the crack initiation in the spherical particle and the matrix for m-p0 and m-p0, respectively. Consequently, the crack propagation to follow the crack initiation is a consequence of the particle radius RRqc (q = p, m). Finally, a shape of the crack in a plane perpendicular to the direction of the crack propagation in the particle (q = p) and the matrix (q = p) is described by the function fq related to the ideal-brittle components. With regard to the crack initiation, the analytical determination of the radius Rqc is considered for any multi-phase materials of a precipitation-matrix type. With regard to the crack propagation, the analytical determination of the function fq along with an analysis concerning the crack dimension and directions of the crack propagation is considered for ceramic multi-phase materials which are generally assumed to be ideal-brittle. The thermal stresses induce resistance against compressive or tensile mechanical loading for m-p0 or m-p0, respectively. The analytical determination of the resistance results from the elastic energy gradient to represent the second topic of this paper. Derived by two equivalent mathematical techniques, the gradient within the cubic cell is defined as a surface integral of the thermal-stress induced elastic energy density. Consequently the 'surface' elastic energy density results in the analytical determination of the system strengthening to represent the third topic of this paper. Representing the fourth topic of this paper, an analytical model of stresses originating in isotropic crystalline lattices are derived. The stresses in the lattices are a consequence of the presence of a central substitutive atom. Additionally, elastic energy, induced by the substitute atom and accumulated in the lattices, is also derived. Finally, readers can substitute numerical values of parameters of real multi-phase materials into the presented formulae.

L. Ceniga, Institute of Materials Research, Slovak Academy of Sciences, 040 01 Kosice, Slovakia. Cited: *J. Therm. Stresses,* 2008, Sept, **31**(9), p 862-891. ISSN 0149-5739.

Axisymmetric frictionless contact problem of a functionally graded coating with exponentially varying modulus. This paper is concerned with the problem of a functionally graded coated half-space indented by an axisymmetric smooth rigid punch. The shear modulus of the graded coating is assumed to be an exponential function and the Poisson's ratio is a constant. With the use of Hankel integral transform technique, the axisymmetric frictionless contact problem is reduced to a Cauchy singular integral equation. The contact pressure, contact radius and penetration depth are calculated for various indenters by solving the equations numerically. The results show that these quantities are greatly affected by the gradient of the coating.

T.J. Liu and Y.S. Wang, Institute of Engineering Mechanics, Beijing Jiaotong University, Beijing 100044, China. Cited: *Acta Mech.,* 2008, Aug, **199**(1-4), p 151-165. ISSN 0001-5970.

Dynamic crack-tip stress and displacement fields under thermomechanical loading in functionally graded materials. Thermomechanical stress and displacement fields for a propagating crack in functionally graded materials (FGMs) are developed using displacement potentials and asymptotic analysis. The shear modulus, mass density, and coefficient of thermal expansion of the FGMs are assumed to vary exponentially along the gradation direction. Temperature and heat flux distribution fields are also derived for an exponential variation of thermal conductivity. The mode mixity due to mixed-mode loading conditions around the crack tip is accommodated in the analysis through the superposition of opening and shear modes. Using the asymptotic stress fields, the contours of isochromatics (contours of constant maximum shear stress) are developed and the results are discussed for various crack-tip thermomechanical loading conditions.

K.H. Lee, V.B. Chalivendra, and A. Shukla, Dynamic Photomechanics Laboratory, University of Rhode Island, Kingston, RI 02881. Cited: *J. Appl. Mech., Trans. ASME,* 2008, Sept, **75**(5), p 0511011-0511017. ISSN 0021-8936.

Mesomechanics of multiple cracking of brittle coatings in a loaded solid. The paper deals with an analysis of two kinds of multiple cracking in a loaded solid with a brittle coating. First is the front-wise development of opening mode cracks, while the second is the formation of a system of sliding mode cracks along conjugate directions of maximum tangential stresses τ_{max}.

The mesomechanics of each kind of multiple cracking is discussed. The conditions which provide an increase in both the strength and the ductility of a loaded solid experiencing multiple cracking are formulated; the essence of the model is the growth of cracks in the sliding mode along conjugate directions of maximum tangential stresses.

V.E. Panin, R.V. Goldstein, and S.V. Panin, Institute of Strength Physics and Materials Science, Siberian Branch, Russian Academy of Sciences, 634021, Tomsk Russian Federation. Cited: *Int. J. Fract.,* 2008, March, **150**(1-2), p 37-53. ISSN 0376-9429.

Mixed-mode fracture analysis of orthotropic functionally graded material coatings using analytical and computational methods. This article presents analytical and computational methods for mixed-mode fracture analysis of an orthotropic functionally graded material (FGM) coating-bond coat-substrate structure. The analytical solution is developed by considering an embedded crack in the orthotropic FGM coating. The embedded crack is assumed to be loaded through arbitrary self-equilibrating mixed-mode tractions that are applied to its surfaces. Governing partial differential equations for each of the layers in the trilayer structure are derived in terms of the effective parameters of plane orthotropic elasticity. The problem is then reduced to a system of two singular integral equations, which is solved numerically to evaluate the mixed-mode crack tip parameters. The computational approach is based on the finite element method and is developed by applying the displacement correlation technique. The use of two separate methods in the analyses allowed direct comparisons of the results obtained for an embedded crack in the orthotropic FGM coating, leading to a highly accurate numerical predictive capability. The finite element based approach is used to generate further numerical results by considering periodic cracking in the orthotropic FGM coating. Parametric analyses presented in this article illustrate the influences of the material nonhomogeneity and orthotropy constants, the bond coat thickness, and the crack periodicity on the mixed-mode stress intensity factors and the energy release rate.

S. Dag and A.A. Ilhan, Department of Mechanical Engineering, Middle East Technical University, Ankara 06531, Turkey. Cited: *J. Appl. Mech., Trans. ASME,* 2008, Sept, **75**(5), p 0511041-0511049. ISSN 0021-8936.

Non-local modeling of thermal shock damage in refractory materials. A non-local damage framework has been coupled with heat transport to model transient thermo-mechanical damage (in particular thermal shock) in refractory materials. The non-locality, to be dealt with to obtain an adequate problem formulation, is introduced by terms accounting for micro-structural strain gradients induced by transient temperature gradients. The parameters figuring in the evolution law for elasticity-based damage are temperature dependent. Damage due to isotropic thermal expansion has been accounted for by proposing a new evolution law. A single variable for the total damage is obtained by combining both damage mechanisms. The influence of non-locality and transient temperature gradients within non-locality is investigated in numerical examples. The phenomenological relevance of the framework is verified by modeling of experiments, which simulate thermal shock under process conditions.

F. Damhof, W.A.M. Brekelmans, and M.G.D. Geers, Corus Research Development and Technology, 1970CA Ijmuiden, Netherlands. Cited: *Eng. Fract. Mech.,* 2008, Nov, **75**(16), p 4706-4720. ISSN 0013-7944.

Spherical indentation of a finite poroelastic coating. Indentation testing of a finite poroelastic layer is considered. Finite element modeling was used to investigate spherical contact creep tests, with emphasis on the influence of layer thickness and of finite rise time on the time-dependent deformation. Thin layers are stiffened by the substrate constraint even at very small relative indenter penetrations and reach steady state more quickly than thick layers. The degree of consolidation following loading is affected by the interaction of layer thickness and rise time and cannot be predicted from either alone. These results provide guidance for micro- and nanoindentation testings of hydrogel coatings for biomedical applications.

M. Galli and M.L. Oyen, Engineering Department, Cambridge University, Cambridge CB2 1PZ, UK. Cited: *Appl. Phys. Lett.,* 2008, **93**(3), ISSN 0003-6951.

Stochastic analysis of a thermoelastic problem in functionally graded plates with uncertain material properties. The statistics (i.e., mean and variance) of temperature and thermal stress are analytically obtained in functionally graded material (FGM) plates with uncertainties in the thermal conductivity and coefficient of linear thermal expansion. These FGM plates are assumed to have arbitrary nonhomogeneous thermal and mechanical properties through the entire thickness of plate and are subjected to deterministic convective heating. The stochastic temperature and thermal stress fields are analysed by assuming the FGM plate is multilayered with distinct, random thermal conductivity and coefficient of linear thermal expansion in each layer. Vodicka's method, which is a type of integral transform method, and a perturbation method are employed to obtain the analytical solutions for the statistics. The autocorrelation coefficients of each random property and cross-correlation coefficients between different random properties are expressed in exponential function forms as a non-homogeneous Markov random field of discrete space. Numerical calculations are performed for FGM plates composed of partially stabilized zirconia (PSZ) and austenitic stainless steel (SUS304), which have the largest dispersion of the random properties at the place where the volume fractions of the two constituent materials are both 0.5. The effects of the spatial change in material composition, thermal boundary condition and correlation coefficients on the standard deviations of the temperature and thermal stress are discussed.

R. Chiba and Y. Sugano, Department of Mechanical System Engineering, Yamagata University, Yonezawa 9928510, Japan. Cited: *Arch. Appl. Mech.,* 2008, Oct, **78**(10), p 749-764. ISSN 0939-1533.

Theoretical modeling and experimental validation of thermal response of metal-ceramic functionally graded beams. A third-order zigzag theory based finite element model in conjunction with the modified rule of mixtures and Wakashima-Tsukamoto model for estimating effective modulus of elasticity and coefficient of thermal expansion, respectively, is presented for layered functionally graded beams under thermal loading. The model is validated through experiments with two systems, Al/SiC and Ni/Al_2O_3, fabricated using powder metallurgy and thermal spraying techniques, respectively. The predicted thermal deflections for simply supported and cantilever FGM beams are found to be in good agreement with the experimental values for both systems. For nonlinear variation of FGM composition across the thickness, two models for thickness discretization with equal thickness and equal change in volume fraction, respectively, are evaluated in terms of magnitude of axial stress and its jump at the interfaces. The effect of inhomogeneity parameter and number of layers in the FGM on the reduction of thermal stress and its jump at the interfaces is investigated.

S. Kapuria, M. Bhattacharyya, and A.N. Kumar, Department of Applied Mechanics, I.I.T. Delhi, New Delhi, India. Cited: *J. Therm. Stresses,* 2008, Aug, **31**(8), p 759-787. ISSN 0149-5739.

Thermal stresses in model materials. The paper deals with analytical models of elastic thermal stresses in isotropic continuum represented by periodically distributed spherical particles in an infinite matrix imaginarily divided into identical cells with dimensions equal to inter-particle distance, containing a central spherical particle with or without a spherical envelope on the particle surface. As a model system regarding the analytical modeling, the multi-particle-(envelope)-matrix system is applicable to four types of real composite materials. Investigated within the cell, thermal stresses originate during a cooling process as a consequence of the difference in thermal expansion coefficients of phases represented by the matrix, envelope and particle. Derived by three different mathematical techniques, and considering the Castigliano's theorem, the analytical models are functions of the inter-particle distance d, the particle volume fraction v, the particle and envelope radii, R_1 and $R_2 > R_1$, respectively. Finally, an analytical-(experimental)-computational methods of the lifetime prediction for composite material is presented.

L. Ceniga, Institute of Materials Research, Slovak Academy of Sciences, Kosice 040 01, Slovakia. Cited: *J. Therm. Stresses,* 2008, Aug, **31**(8), p 728-758. ISSN 0149-5739.

Process Modeling

A unified model for the cohesive enthalpy, critical temperature, surface tension and volume thermal expansion coefficient of liquid metals of bcc, fcc and hcp crystals. First the cohesive enthalpy of pure liquid metals is modeled, based on experimental critical temperatures of alkali metals. The cohesive enthalpies are scaled to the melting points of pure metals. The temperature coefficient of cohesive enthalpy is the heat capacity of the liquid metal. The surface tension and its temperature coefficient for pure liquid metals are modeled through the excess surface enthalpy, excess surface entropy and molar surface area supposing that the outer two surface layers of liquid metals are similar to the {1 1 1} plane of fcc crystals. The volumetric thermal expansion coefficient of liquid metals is scaled to the ratio of the heat capacity and cohesion enthalpy. From known values of melting point, heat capacity and molar volume the following calculated properties of liquid metals are tabulated: (i) cohesive enthalpy at melting point, (ii) cohesive energy of the solid metal at 0 K, (iii) critical temperature, (iv) surface tension at melting point, (v) volume thermal expansion coefficient, and (vi) temperature coefficient of surface tension. The present models are valid only for liquid metals of bcc, fcc or hcp crystals as only their structure and nature of bonding are similar enough to be treated together.

G. Kaptay, Institute of Nanotechnology, Bay Foundation of Applied Research, University of Miskolc, 3515 Miskolc, Egyetemvaros, Hungary. Cited: *Mater. Sci. Eng. A,* 2008, Nov, **495**(1-2), p 19-26. ISSN 0921-5093.

Computational simulation on performance enhancement of cold gas dynamic spray processes with electrostatic assist. A real-time computational simulation on the entire cold spray process is carried out by the integrated model of compressible flow field, splat formation model, and coating formation model, in order to provide the fundamental data for the advanced high performance cold gas dynamic spray process with electrostatic acceleration. In this computation, viscous drag force, flow acceleration added mass, gravity, Basset history force, Saffman lift force, Brownian motion,

thermophoresis, and electrostatic force are all considered in the particle equation of motion for the more realistic prediction of in-flight nano/microparticle characteristics with electrostatic force and also for the detailed analysis of particle-shock-wave-substrate interaction. Computational results show that electrostatic acceleration can broaden the smallest size of applicable particle diameter for successful adhesion; as a result, wider coating can be realized. The utilization of electrostatic acceleration enhances the performance of cold dynamic spray process even under the presence of unavoidable shock wave.

H. Takana, K. Ogawa, T. Shoji, and H. Nishiyama, Institute of Fluid Science, Tohoku University, Aoba-ku, Sendai, Miyagi 980-8577, Japan. Cited: *J. Fluids Eng., Trans. ASME,* 2008, Aug, **130**(8), p 0817011-0817017. ISSN 0098-2202.

Dense particulate flow in a cold gas dynamic spray system. The effect of particle-gas and particle-particle interactions in a cold spray process is studied when the particle loading is high. To examine the effect of the presence of a dense particulate flow on the supersonic gas, an Eulerian-Eulerian approach is used. It is found that when the volume fraction of the injected particles is increased, the turbulence of the gas phase will be augmented by the motion of particles and consequently, the shape, the strength, and the location of the compression and expansion waves will be altered. Shock particle interactions are demonstrated for various volume fractions. Another important parameter, which will affect the spraying deposition efficiency, is the substrate stand-off distance. It is found that the stagnation pressure alternates for different stand-off distances because of the formation of compression and expansion waves outside the nozzle exit. The particle normal velocity on impact is a strong function of the stagnation pressure on the -substrate as particles must pierce through the bow shock formed on that region. The effect of the particle size and number density are also studied for different loading conditions. It is found that small and large particles behave differently as they pass through shock diamonds and the bow shock, i.e., in the case of very small particles, as the loading increases, the impact velocity increases, while, for the large particles, the trend is reversed.

B. Samareh and A. Dolatabadi, Department of Mechanical and Industrial Engineering, Concordia University, Montreal, QC, H3G 1M8, Canada. Cited: *J. Fluids Eng., Trans. ASME,* 2008, Aug, **130**(8), p 0817021-08170211. ISSN 0098-2202.

General aspects of interface bonding in kinetic sprayed coatings. In this study, different engineering materials are classified into four impact cases according to their physical and mechanical properties, i.e., soft/soft, hard/hard, soft/hard, and hard/soft (particle/substrate). Based on finite-element modeling, impact behaviors of the four cases were numerically analyzed. For soft/soft and hard/hard cases, the size variation of the thermal boost-up zone (TBZ), accompanied with the different aspects of adiabatic shear instability, was numerically estimated and is theoretically discussed. Meanwhile, for soft/hard and hard/soft cases, the specific aspect of shear instability, which has a very high heat-up rate, is always observed on the relatively soft impact counterpart where a thin molten layer is expected as well. Based on these phenomenological characteristics, bonding aspects are characterized, and a database for numerically estimated critical velocities of different particle/substrate combinations was developed for kinetic spraying process.

G. Bae, Y. Xiong, S. Kumar, K. Kang, and C. Lee, Kinetic Spray Coating Lab (NRL), Division of Materials Science and Engineering, Hanyang University, Seoul 133-791, South Korea. Cited: *Acta Mater.,* 2008, Oct, **56**(17), p 4858-4868. ISSN 1359-6454.

Numerical modelling of sequential droplet impingements. During the process of thermal spray coating, molten powders are sprayed and deposited on substrates to generate protective coatings. It is essential to have a clear understanding of the physics of droplet impingement on the surface of substrates for better control of the generation of splats and the structure of coating. A numerical model is developed in this paper to simulate the dynamics of transient flow during the impingement process, including spreading, break-up, air entrapment and solidification. The computation is achieved using the technique of volume of fluid surface tracking within a fixed Eulerian structured mesh. The three-dimensional simulation is able to accurately give a demonstration of dynamic flow patterns such as the generation of fingers, satellite droplets and pores during impingement. The numerical model is validated with experimental data from the tin droplet measurement and excellent agreement is found between the simulation and the experiment.

S. Kamnis, S. Gu, T.J. Lu, and C. Chen, School of Engineering Science, University of Southampton, Highfield, Southampton SO17 1BJ, UK. Cited: *J. Phys. D: Appl. Phys.,* 2008, Aug 21, **41**(16). ISSN 0022-3727.

Study of flying particles in plasma spraying. In this article, the trajectories of ceramic and metal particles in plasma spray are calculated by solving related momentum and energy equations. Meanwhile, the spatial distributions, temperatures, velocities, as well as diameters of the particles are measured by employing an online, in-flight particle sensor (DPV2000). The experimental and computational results are in good agreement. It has been found that the particle flying trajectories are dependent on material types and particle diameters, and in a plane vertical to the spraying axis, there is a certain corresponding relationship between the particle diameter and the particle velocity, as well as particle temperature.

F. Qunbo, W. Fuchi, and W. Lu, Beijing Institute of Technology, Beijing 100081, China. Cited: *J. Mater. Eng. Perform.,* 2008, Oct, **17**(5), p 621-626. ISSN 1059-9495.

Study of the porosity in plasma-sprayed alumina through an innovative three-dimensional simulation of the coating buildup. Porosity is a key feature of a thermally sprayed coating microstructure. Within ceramic coatings, porosity is made of pores and cracks of various shapes, dimensions, and orientations. Cracks can be intralamellar or interlamellar due to the buildup of the coating, which leads to piled-up lamellae from impinging and the additional rapid solidification of liquid droplets. Pores are interconnected with cracks, which results in a three-dimensional (3-D) porosity network. Direct observation of this network is an intricate task and current attempts remain somewhat limited. A 3-D simulation of this network was, therefore, developed in this work, based on a stochastic approach to the building up of simulated lamellae in the sprayed microstructure. A library of mathematical objects was achieved from morphological measurements, using confocal microscopy of actual isolated flattened lamellae, i.e., 'splats' and scanning electron microscopy (SEM). This stochastic approach to the simulation of hundreds of lamellae also involves the random distribution of cracks and pores. Simulation fit parameters were selected according to the overall characteristics of porosity (i.e., content, orientation, size, etc.) that were determined from the thorough quantitative image analysis (QIA) of cross-sectioned plasma-sprayed alumina coatings. Two plasma modes that varied the atmosphere in a controlled-atmosphere plasma spraying (CAPS) chamber were applied, to produce the microstructures of two different alumina coatings. The 3-D random modeling tool allowed the processing of a volume of digital material through a 3-D simulated binary image of a two-phased composite material. Using one 3-D image result of the simulation, finite element (FE) calculations were performed, in order to study the overall dielectric properties of a plasma-sprayed alumina as a function of porosity. The influence of anisotropy is discussed, in particular, and both analytical and numerical predicted values were compared to experimental ones. The presence of the defects related to both digital coatings is also discussed.

S. Beauvais, V. Guipont, M. Jeandin, D. Jeulin, A. Robisson, and R. Saenger, Mines ParisTech, Centre des Materiaux/UMR CNRS 7633, Competence Center for Spray Processing-C2P, Evry Cedex F-910003, France. Cited: *Metall. Mater. Trans. A: Phys. Metall. Mater. Sci.,* 2008, Nov, **39**(11), p 2711-2724. ISSN 1073-5623.

Postprocessing

Effect of a novel sequential motion compaction process on the densification of multi-layer spray deposited 7090SiCp composite. In the present study, a large dimension Al-10.15Zn-3.6Mg-1.8Cu-0.15Ni-0.3ZrSiCp composite was synthesized by the multi-layer spray deposition process, then densities by a novel sequential motion compaction technique. The microstructures and mechanical properties of the multi-layer spray-deposited Al-10.15Zn-3.6Mg-1.8Cu-0.15Ni-0.3ZrSiCp composite were studied by optical microscopy, scanning electron microscopy, and tensile tests before and after densities. The experimental results showed that sequential motion compaction technique can be used to fully density sample with large dimensions and difficult to further processing by the traditional techniques. This technique can greatly improve the microstructures and mechanical properties of the composite. The pores in the composite are elongated and closed through model pressing at the jointed effect of huge hydrostatic pressure and shearing stress. After pressed, SiC particles in the composite were broken and redistributed. Compared with the as-spray-deposited composite, the tensile properties of compaction processed composite have a great improvement not only in transverse direction but also in longitudinal direction. When the thickness reduction is about 40%, relative densities approach the theoretical density, and the actual relative density is 91.76%. The relative theoretical density is 93%.

Y.P. Sun, H.G. Yan, Z.H. Chen, D. Chen, and G. Chen, School of Materials Science and Engineering, Hunan University, Changsha 410082, China. Cited: *J. Mater. Sci.,* 2008, Sept, **43**(18), p 6200-6205. ISSN 0022-2461.

Effect of post-deposition heat treatment on mechanical properties of thermally sprayed hydroxyapatite coating. This paper mainly deals with the inner microstructure and mechanical performance of plasma sprayed hydroxyapatite (HA) coatings before and after heat treatment. The electron probe microanalyser shows that some regions with different contrasts exist in the as-sprayed coatings. Under the back scattering electron (BSE) model, the origin particles of HA are well melted, and there are the more inhomogeneities in the as-sprayed coatings. Heat treatment can eliminate the regions with different contrasts and improve the crystallinity of the coatings. Some coatings were immersed into 50 mL deionised water under constant 37 °C condition for 20 days. After the immersion in the deionized water, new layers with dot like precipitates formed on the surface of the as-sprayed coatings and the inhomogeneities were eliminated. For as-sprayed coatings, the amount of precipitates on the surface of low crystalline coatings is larger than that of high

crystalline coatings. For post-heat treated coatings, there are no other phases but β;-Ca_2/P_2O_7 precipitates along the cracks paths. The shear strength of as-sprayed coatings of low crystallinity is higher than that of high crystalline coatings. In this paper, post-heat treatment can improve the shear strength of coarse coatings but decrease that of fine coatings.

G.Y. Xiao, Y.P. Lu, R.F. Zhu, S.T. Li, and A.J. Wang, School of Materials Science and Engineering, Shandong University, Jinan 250061, China. Cited: *Surf. Eng.,* 2008, July, **24**(4), p 307-312. ISSN 0267-0844.

Laser treatment of HVOF coating: Modeling and measurement of residual stress in coating. High-velocity oxy-fuel (HVOF) coating of diamalloy 1005 (similar to Inconel 625 alloy) onto the Ti-6Al-4V alloy is considered and laser-controlled melting of the coating is examined. The residual stress developed after the laser treatment process is modeled using the finite element method (FEM). The experiment is conducted to melt the coating using a laser beam. The residual stress measurement in the coating after the laser treatment process is realized using the XRD technique. The morphological and metallurgical changes in the coating are examined using scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). It is found that the residual stress reduces at the coating-base material interface and the residual stress predicted agrees with the XRD measurements. A compact and crack-free coating is resulted after the laser treatment process.

A.F.M. Arif and B.S. Yilbas, Mechanical Engineering Department, KFUPM, Box 1913, Dhahran 31261, Saudi Arabia. Cited: *J. Mater. Eng. Perform.,* 2008, Oct, **17**(5), p 644-650. ISSN 1059-9495.

Microstructural features and mechanical properties induced by the spray forming and cold rolling of the Cu-13.5 wt.% Sn alloy. Copper alloys with high strength and high conductivity are an important functional material with full of potential applications. In the present investigation, a bronze with higher tin content (Cu-13.5 wt.% Sn) was prepared successfully by spray forming, the feasibility of cold rolling this alloy was investigated, and the cold rolling characteristics of this alloy have also been discussed. The results indicate that the spray-formed Cu-13.5 wt.% Sn alloy, compared with the as-cast ingot, shows a quite fine and homogeneous single-phase structure, and, therefore shows an excellent workability. It can be cold-rolled with nearly 15% reduction in the thickness per pass and the total reduction can reach 80%. The classical border between the wrought and cast alloys is shifted to considerably higher tin contents by spray forming. After proper thermo-mechanical treatment, spray-formed Cu-13.5 wt.% Sn alloy exhibits excellent comprehensive mechanical properties. Particularly, it shows a low elastic modulus (~88 GPa) and a high flow stress (>800 MPa) after cold forming. This combination of properties is unique in the domain of metallic materials and could open new possibilities in spring technology field.

X. Wang, J. Zhao, J. He, and J. Wang, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China. Cited: *J. Mater. Sci. Technol.,* 2008, Sept, **24**(5), p 803-808. ISSN 1005-0302.

Tailored surfaces by means of thermal spraying and post-treatment. A brief overview of existing methods of post-treatment of thermally sprayed coatings is given and the influence of mechanical and chemical as well as high-energy beam post-treatment methods on the coating microstructure formation and some exploitation properties is described. As a special example, the modification of thermally sprayed coatings on magnesium alloys using electron and laser beams and high-density irradiation of an infra-red beamer for the improvement of wear and corrosion resistance is presented.

B. Wielage, T. Grund, H. Pokhmurska, C. Rupprecht, and T. Lampke, Chemnitz University of Technology, Institute of Composite Materials and Surface Technology, D-09107 Chemnitz, Germany. Cited: *Key Eng. Mater.,* **384**, p 99-116. ISSN 1013-9826.

Powder

Development of spherical magnetic abrasive made by plasma spray. Magnetic abrasive used for the internal finishing of capillary tubes, which prevents accumulation of contamination and erratic flow of the conveyed fluid, is a composite particle, consisting of iron and Al_2O_3 abrasive grains. The irregularity of the magnetic abrasive shape, due to the mechanical crushing process, causes nonuniform depth of cut of the abrasive and restricts the improvement of the finished surface quality. This has resulted in a narrow range of finishing performance. Moreover, the irregularity of the magnetic abrasive shape brings about difficulty in merely introducing it into capillary tubes. To break through these difficulties, this research proposes to develop a spherical iron-based magnetic abrasive, which carries Al_2O_3 grains on the surface, made by plasma spray. First, this paper examines the feasibility of the plasma spray to make the existing magnetic abrasive more spherical, and suggests the conditions needed to produce the spherical magnetic abrasive. Second, it studies the development of the new spherical magnetic abrasive made of separate particles: iron particles and Al_2O_3 abrasive grains, which carries the nonferrous abrasive on the outer surface alone. Their finishing performance, evaluated through the experiments using SUS304 stainless steel tubes, shows their applicability to magnetic abrasive finishing.

H. Yamaguchi and K. Hanada, Department of Mechanical and Aerospace Engineering, University of Florida, 226 MAE-B, Gainesville, FL 32611. Cited: *J. Manuf. Sci. Eng., Trans. ASME,* 2008, June, **130**(3), p 0311071-0311079. ISSN 1087-1357.

Nano-sized hydroxyapatite powders prepared by flame spray pyrolysis. Nano-sized hydroxyapatite (HAp) powders with high crystallinity and appropriate stoichiometry were prepared by high-temperature flame spray pyrolysis process from the spray solutions with polyethylene glycol (PEG). The mean sizes of the HAp powders obtained from the spray solutions with PEG were changed from several tens to several hundreds nanometers according to the concentrations of PEG added to the spray solutions at a post-treatment temperature of 800 °C. In the TEM-EDX spectrum, the composition ratio of calcium and phosphorous components was 1.69. The HAp powders post-treated at a low temperature of 400 °C had fiber-like morphology. On the other hand, the post-treated HAp powders at temperatures of 600 and 1000 °C had each rod-like morphology with low aspect ratio and spherical-like morphology. The mean sizes of the HAp powders post-treated at temperatures of 600 and 1000 °C were each 32 and 213 nm.

J.S. Cho and Y.C. Kang, Department of Chemical Engineering, Konkuk University, Seoul 143-701, South Korea. Cited: *J. Alloys Compd.,* 2008, Sept 22, **464**(1-2), p 282-287. ISSN 0925-8388.

Synthesis of hollow titania powder by the hydrothermal method. A layer-by-layer method is used to coat titania on spherical polystyrene (PS) powders in an aqueous solution. To increase surface charge density, a negatively charged PS powder is sequentially adsorbed by a cationic polyethylenimine (PEI)/anionic ammonium salt of poly(acrylic acid)/cationic PEI polyelectrolytes. A precursor of a negatively charged titanium bis-ammonium lactate dihydroxide (TALH) is then precipitated onto the above positively charged PS. Repeating the coating processes of TALH/PEI in an aqueous solution, a uniform, multilayer TALH/PEI coating on PS powder is formed. A crystalline, spherical, hollow titania powder is then obtained by hydrothermal treatment of the above powder in an aqueous solution at temperatures higher than 350 °C.

C.-J. Chung and J.-H. Jean, Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan. Cited: *J. Am. Ceram. Soc.,* 2008, Sept **91**(9), p 3074-3077. ISSN 0002-7820.

WC-Co-composite powders via hydrothermal reduction of Co_3O_4-suspensions. Due to the strong influence of the cobalt distribution in the green powder compact on the quality of the sintered hard metal alloy, intensive powder milling and a balanced ratio of WC to Co powder particle size are usually required to achieve uniform carbide-microstructures. In the past many attempts have been made to reduce or avoid powder milling and to improve the quality of the powder mixture by chemical means. The research described below focused on a new route to carbide coating comprising oxide-pressure-precipitation of submicron to nano-sized Co_3O_4-suspensions from cobalt solutions, mixing with WC-suspensions and subsequent hydrothermal reduction of those suspensions in hydrogen atmosphere. The effects of WC addition and catalyst addition on the progress of cobalt oxide reduction are discussed. The resulting cobalt and composite powders were characterized via powder diffraction, SEM and TEM imaging. Sintering tests confirmed the uniform Co distribution.

C. Adorjan, A. Bock, S. Myllymaki, W.-D. Schubert, and K. Kontturi, Vienna University of Technology, Institute of Chemical Technologies and Analytics, A-1060 Vienna, Austria. Cited: *Int. J. Refract. Met. Hard Mater.,* 2008, Nov, **26**(6), p 569-574. ISSN 0263-4368.

Properties

Adhesion

Experimental study on the adhesion properties of Zn-Al metal spray method for steel structures. Examination about sticking intensity security way of normal temperature metal spraying covering is required compulsorily accordingly with quantitative assessment about steel plate's surface roughness to secure adhesive power of steel materials and metal membrane stably at application of way method of construction by normal temperature metal spraying. In case of metal spraying, Sticking strength of metal spraying way finish is influenced greatly, and it is judged that is desirable that manages SmRz by 6 lows to secure more than sticking intensity 20 kgf/cm^2 by SmRz that evaluate that is rough of nature surface. The purpose of this study was to analyze an adhesion strength of metal spraying finish layer with the surface conditions of steel plate. For the purpose the experimental factors such as anticorrosive finish method and surface treatment method were selected.

J. Jin and H. Lee, School of Architecture and Environmental Engineering, Hanyang University, Ansan 425-791, South Korea. Cited: *Key Eng. Mater.,* **385-387**, p 613-616. ISSN 1013-9826.

On the evaluation of the adhesion of electroplated Ni coatings upon steel substrate with extended microbridge technique. The interfacial adhesion of electroplated Ni coatings on steel substrate was assessed using an extended microbridge technique (eMBT), and the fracture path of

interfacial cracks was examined through cross-sectional high-resolution SEM observation in loading condition. The results indicated that the magnitude of interfacial toughness increased ten to hundred times as the cleaning time of substrate surface was prolonged in a limited duration. The cross-sectional SEM examination revealed that the weak interface fracture was related to brittle mechanism, whereas the strong interface was a reflection of ductile one. In case of the duration time of substrate pre-cleaning, which was commonly adopted in applications of electroplate engineering, the over-erosion of substrate surface appeared and the steel surface became rough. In this case, the mechanical stick force, in addition to the physical bonding force across the interface, was observed to play a crucial role in the coatings integrity and bonding reliability.

X. Zhang and K. Xu, State-Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an 710049, China. Cited: *Mater. Sci. Eng. A,* 2008, Oct 25, **494**(1-2), p 122-126. ISSN 0921-5093.

Corrosion

Behavior of NiAl APS-coatings in chlorine-containing atmospheres. Due to their thermal expansion coefficient being close to those of ferritic steels, NiAl atmospheric plasma spraying (APS)-coatings have been chosen to be tested in chloridizing atmosphere. A new type of quasi-stability diagram which couples thermodynamic and kinetic approaches was developed to define the stability domains of the pure metals aluminum and nickel in dynamic chlorine- and oxygen-containing atmospheres. NiAl APS-coatings (300 μm) with low porosity on steels were applied and tested in an atmosphere containing 0.2 v/o chlorine and 3 ppm oxygen. After 280 h of exposure one quarter of the outer coating was transformed into a protective alumina layer. Much nickel depletion, due to the evaporation of nickel chlorides, was observed.

H. Latreche, S. Doublet, G. Tegeder, G. Wolf, P. Masset, T. Weber, and M. Schutze, Karl-Winnacker-Institut, Dechema e.V., 60486 Frankfurt am Main, Germany. Cited: *Mater. Corros.,* 2008, July, **59**(7), p 573-583. ISSN 0947-5117.

Electrochemical comparison between corrosion resistance of some thermally sprayed coatings. Electrochemical polarisation and impedance spectroscopy tests in 0.1 M HCl and 0.1 M H_2/SO_4 solutions were performed on HVOF-sprayed cermet coatings (WC-17% Co, WC-10% Co-4% Cr) and Atmospheric Plasma-Sprayed (APS) ceramics (Al_2O_3, A_2/ O_3-13 wt.%TiO_2>, Cr_2 O_3) with APS bond coat (Ni-Co-Cr-Al-Y). Reference tests were also performed on hard chrome electroplating. Plasma-sprayed coatings offer limited substrate protection owing to interconnected porosity, although the bond coat promotes some forms of passivation in H_2/SO_4 HVOF-sprayed cermets possess good corrosion resistance in both environments. Chrome electroplating shows comparatively better corrosion resistance in H_2/SO_4 but worse in HCl.

G. Bolelli, V. Cannillo, R. Giovanardi, and L. Lusvarghi, Dipartimento di Ingegneria dei Materiali e dell'Ambiente, Universita di Modena e Reggio Emilia, 41100 Modena, Italy. Cited: *Int. J. Surf. Sci. Eng.,* **2**(3-4), p 222-239. ISSN 1749-785X.

Influence of long-term aqueous exposure on surface properties of plasma sprayed oxides Al_2O_3, TiO_2 and their mixture Al_2 O_3-13TiO_2. The surface properties of plasma sprayed Al_2O_3- and TiO_2-based coating materials were characterized in order to investigate the influence of surface strain and phase inhomogenity. The materials were water exposed up to 8 months. The bulk crystallographic structure, dissolution behaviour, effective charge (zeta potential, isoelectric point), surface compositions and oxidation states were determined. In addition, the properties of the aging solutions, such as conductivity, supernatant pH (point of zero charge), and redox potential, were monitored during aging. It was shown that the materials were stable under aging conditions, but that considerable surface rearrangements, such as dissolution-reprecipitation and surface site redistributions may occur. However, overall only minor changes in surface properties results from this restructuring process.

M. Harju, M. Jarn, P. Dahlsten, J.B. Rosenholm, and T. Mantyla, Department of Materials Science, Tampere University of Technology, 33101 Tampere, Finland. Cited: *Appl. Surf. Sci.,* 2008, Sept 15, **254**(22), p 7272-7279. ISSN 0169-4332.

Mechanical

Cracking analysis of HVOF coatings under Vickers indentation. The fracture strength of five HVOF coatings, which are made of hard metals, Tribaloy alloy, and superalloys, respectively, coated on 1018 low carbon steel substrate, is studied under Vickers indentation, associated with FEA stress computation. The cross sections of the coating specimens are examined on a Hitachi Model S-570 scanning electron microscope (SEM), which investigates the quality and measures the geometry of the coatings. The mechanical properties of the coatings and the substrate are determined in the cross sections using the nano-indentation technique. The cracking behavior of the coatings under different indentation loads is investigated using a Vickers hardness tester. Three-dimensional finite element analysis (FEA) simulation of the Vickers indentation test is conducted to determine the stress fields in the coating/substrate systems in order to understand the fracture mechanisms of the coatings under the indentation loads using the ABAQUS software package. The FEA stress results are in good agreement with the experimental observation of Vickers indentation.

A.P. Buang, R. Liu, X.J. Wu, and M.X. Yao, Department of Mechanical and Aerospace Engineering, Carleton University, Ottawa, ON, K1S 5B6, Canada. Cited: *J. Coat. Technol. Res.,* 2008, Dec, **5**(4), p 513-534. ISSN 1547-0091.

Tribological

Abrasive wear behavior of continuously compacted thermal-sprayed Ni base alloy powder coatings in different conditions. In this paper, the influence of densification and post-spray heat treatment on the microstructure, porosity, micro-hardness and two-body abrasive wear behaviour of Ni-Cr-B-Si (EWAC 1004EN) coatings has been investigated. Coatings were deposited by using flame spraying torch. The post-spray heat treatment of the coatings was done using muffle furnace at 500 °C for 1 h. Wear behavior of the coatings was evaluated using pin-on-disk wear system against 220 abrasive grade SiC abrasive medium at 0.5, 1 and 1.5 kg normal loads. Results showed an increase in micro-hardness and wear resistance of densified and non-densified coatings after heat treatment.

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Comparison of deposits of wires applied by welding, thermal spraying, and spray and fuse. A study has evaluated the mechanical properties of deposits of the wires applied by the process including welding, thermal spraying, and spray and fuse technology and the aim of the study is to provide increased wear and corrosion resistance for severe wear applications. The study has prepared the sample testing following deposition techniques including Gas Metal Arc Welding, Wire Arc Spray, and Spray and fuse as each depositions process consists of its unique advantages and limitations. The researchers has examined the wear properties for the materials, such as PMet 273, FeCrBSi amorphous alloy, PMET 860BC, Alloy 625 with boron carbide, and PolyTung NiCrBWC. All these materials effectively works high-wear applications in welded, and sprayed form and are manufactured using a special cored wire technology. The evaluation has focused on the Metallography (photomicrographs at 200 X), Microhardness-Vickers (ASTM E384), and abrasion test (ASTM G65, 6000 cycles) of these materials.

R.H. Unger, R.D. Cook, and W.C. Mosier, Polymet Corp., Cincinnati, OH. Cited: *Weld. J. (Miami, Fla),* 2008, Aug, **87**(8), p 50-53. ISSN 0043-2296.

Dependence of sliding wear resistance and microhardness of al-spray coating layers on substrate conditions using high-velocity oxygen fuel (HVOF). Thermally sprayed coatings based on hard carbides embedded in a metallic matrix are considered as an important option to replace galvanic chromium deposits on many industrial components. Such components are often sprayed using the high-velocity oxygen-fuel (HVOF) spray systems. This technique is increasingly being used in industrial applications where high wear and corrosion resistance are needed. In this work, coatings of oxide ceramics were deposited on aluminum substrate using the flame spray process (i.e., HVOF). Employing uniform design experiments, the dry wear resistance and microhardness of the coatings were systematically investigated. The dry wear resistance was measured under dry sliding conditions against constant counter weight of 2000 g on a ball-on-disc arrangement, which was specially designed, built, and calibrated to standards before being used in tests. Spraying deposition time was varied in order to get coating layers with different thickness. The substrate surface roughness was varied as well as its initial temperature before coating. The results showed great impact of substrate surface roughness as well as its preheating temperature on the characteristics of the deposited coating layers. The wear resistance appeared to be critically improved by increasing the surface roughness of the aluminum substrate above a certain value (0.52 m). However, optimum values of the substrate conditions were obtained.

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Fretting wear behavior of conventional and nanostructured Al_2O_3 </-1 wt.%TiO_2 coatings fabricated by plasma spray. The fretting wear behavior of conventional and nanostructured Al_2O_3-13 wt% TiO_2 coatings fabricated by plasma spray was studied in this paper. The conventional coatings were deposited with commercial Metco 130 feedstock, and the nanostructured coatings were deposited with agglomerated feedstock with nanostructure. There were typical lamellar structures existing in conventional coating, however, those were not obviously observed in nanostructured coating. Amorphous phases, nanosized grains and some submicron grains existed in nanostructured coating. In fretting wear tests, the coatings wear against 52100 steel ball. In all of three conditions tests, the fretting maintained in gross slip regime for both nanostructured and conventional coatings. The coefficient of friction (COF) ranged from 0.7 to 0.9 in the fretting wear test. There was a transfer iron oxide layer formed on the worn coating surface.

Fretting cracks propagate along the splat boundary in conventional coatings but propagate at random in nanostructured coatings. Test results showed that nanostructured coatings exhibited much better fretting wear resistance than conventional coating. The improved fretting wear resistance of nanostructured coatings was attributed to the nanosized grains, reduced lamellar structures and amorphous phases.

W. Tian, Y. Wang, and Y. Yang, Nano Surface Engineering Laboratory, Department of Materials Science, Harbin Institute of Technology, Harbin, 150001, China. Cited: *Wear,* 2008, Nov 26, **265**(11-12), p 1700-1707. ISSN 0043-1648.

Friction and wear behavior of laser cladding Ni/hBN self-lubricating composite coating. Ni/hBN coating was successfully prepared on 1Cr18Ni9Ti stainless steel substrate by means of laser cladding. The microhardness profile of the composite coating along the depth direction was measured, while its cross-sectional microstructures and phase compositions were analyzed by means of scanning electron microscopy and x-ray diffraction. Moreover, the friction and wear behavior of the composite coatings sliding against Si_3/N_4 from ambient to 800 °C was evaluated using a ball-on-disc friction and wear tester, and the worn surface morphologies of the composite coatings and counterpart ceramic balls were observed using a scanning electron microscope. At the same time, the worn surfaces of the ceramic balls were also analyzed using a 3D non-contact surface mapping profiler as well. It was found that the laser cladding Ni/hBN coating on the stainless steel substrate had high microhardness and good friction-reducing and antiwear abilities at elevated temperatures up to 800 °C. The composite coating registered slightly increased friction coefficient and wear rate as the temperature rose from ambient to 100 °C; then the friction coefficient and wear rate decreased with increasing temperature up to 800 °C (with the slight increase in the wear rate at 700 °C and 800 °C to be an exception). The laser cladding Ni/hBN coating was dominated by mixed adhesion and abrasive wear as it slid against the ceramic ball below 300 °C. With further increase in the test temperature up to 400 °C and above, it was characterized by mild adhesion wear and plastic deformation. Since the laser cladding Ni/hBN coating registered an increased wear rate at temperatures of 600 °C and above, it was not suggested to be used for wear prevention and protection of the stainless steel at elevated temperature above 800 °C.

S. Zhang, J. Zhou, B. Guo, H. Zhou, Y. Pu, and J. Chen, State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, China. Cited: *Mater. Sci. Eng. A,* 2008, Sept 15, **491**(1-2), p 47-54. ISSN 0921-5093.

Near-net-shape and dense wear resistant thermally sprayed coatings. Deep drawing of high strength steels imposes high tribological requirements on forming tools. Thermal spraying is regarded as a promising technology to improve the tool's performance and the service life of the forming tool, as long as ambitious demands of the coating process are matched. In order to qualify a thermal spraying process for a surface technology in deep drawing it is crucial that the coating obtains an extremely dense structure and a smooth, near-net-shape surface. The study presented considers two different approaches to achieve those goals. The application of fine-scaled powders (≤10 μm) spraying through HVOF technique offers the opportunity to deposit dense coatings with very smooth surfaces. In contrast, it is also feasible to achieve very smooth and dense coatings by combining conventional powders with a subsequently densification procedure.

W. Tillmann, E. Vogli, I. Baumann, and B. Krebs, Institute of Materials Engineering, Technical University of Dortmund, 44227 Dortmund, Germany. Cited: *Key Eng. Mater.,* **384**, p 117-123. ISSN 1013-9826.

Properties of Al_2/O_3-40 wt.% ZrO_2 composite coatings from ultra-fine feedstocks by atmospheric plasma spraying. In the present study, both ultra-fine and coarse Al_2-40 wt.% ZrO_2 grains were used as the starting materials to prepare ultra-fine structured and micro-structured Al_2O_3-40 wt.% ZrO_2 composite coatings (coded as NZTA coating and MZTA coating, respectively) by atmospheric plasma spraying. The ultra-fine Al_2O_3-40 wt.% ZrO_2 feedstocks for spraying were prepared by means of crushing sintered, starting from commercially availed powders of ultra-fine Al_2O_3 and ZrO_2. The microstructures and phase compositions of the crushing sintered powders and the corresponding composites coatings were investigated by means of scanning electron microscopy (SEM) and x-ray diffraction (XRD). The friction and wear behaviors of the composites coatings sliding against stainless-steel under dry friction conditions and at room temperature were investigated using an optimol SRV oscillating friction and wear tester. The wear mechanisms of the coatings were discussed based on the SEM observation of the worn surface morphologies and wear debris, and the elemental composition analysis of the wear debris by energy dispersive x-ray analysis as well. Results showed that aside from the typical splat lamellae, equiaxle grains were also observed in the Al_2O_3-40 wt.% ZrO_2 composite coating made from the corresponding ultra-fine crushing sintered powders. The NZTA coatings had higher microhardness and better wear resistance than that of the MZTA coatings, which could be largely attributed to the better inter-splats bonding of the former. And the stainless-steel counterpart matched with the NZTA coatings had a smaller wear rate as well. Moreover, the two types of composites coatings were dominated by spalling and fracture as sliding against the stainless-steel counterpart, and the MZTA coatings experienced more severe worn surface damage at a larger load than the NZTA coatings tested under the same conditions, well corresponding to the difference in the wear resistance of the two types of composite coatings.

X. Zhao, Y. An, J. Chen, H. Zhou, and B. Yin, State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, China. Cited: *Wear,* 2008, Nov 26, **265**(11-12), p 1642-1648. ISSN 0043-1648.

Rolling contact fatigue behavior of plasma-sprayed CrC-NiCr cermet coatings. The aim of the present study was to address the fatigue behavior and failure mechanisms of plasma-sprayed CrC-NiCr cermet coatings in rolling contact. Rolling contact fatigue (RCF) tests were conducted for the coatings under two different tribological conditions of contact stress at room temperature. For all tests, the thicknesses of the coatings were controlled to be about 100 ≤μm. At a given contact stress, 13 rolling contact tests were performed to obtain the statistical result. The Weibull distribution plots of fatigue life data of the coating specimens were obtained. Experimental results showed that the life parameters, such as the characteristic life, decreased with increasing the contact stress. Moreover, the RCF life data of the coatings tested at higher contact stress exhibited higher scattering. Worn surface observations of the failed coating specimens showed that the failure modes of coatings could be classified into four main categories, i.e., surface abrasion, spalling, delamination within the coating and at the coating/substrate interface. When the contact stress was low, most of the coating specimens failed due to the delamination within the coating. However, the interfacial delamination was the main failure mode of the coatings at high contact stress. The failure mechanisms of the coatings were associated with the microstructure and the bonding strength of the coatings, the depths of the orthogonal shear stress and the maximum shear stress.

X.C. Zhang, B.S. Xu, F.Z. Xuan, S.T. Tu, H.D. Wang, and Y.X. Wu, Shanghai Key Laboratory of Materials Laser Processing and Modification, Shanghai Jiao Tong University, Shanghai 200030, China. Cited: *Wear,* 2008, Nov 26, **265**(11-12), p 1875-1883. ISSN 0043-1648.

Tribological behavior of NiCr-base blended and nanostructured composite APS coatings by rig test. In the present paper, a nanostructured composite powder containing nano-sized Cr_2O_3 (≤100 nm) is manufactured by spray drying and heat treatment. By wear and rig test at room temperature (RT), 200 °C, and 350 °C, respectively, the mechanical and tribological properties of atmospheric plasma spray (APS) blended (PS304) and composite coatings with same composition (60NiCr-20Cr_2O_3-10Ag-10BaF_2/CaF_2, wt.%) are compared. The results show that uniform microstructure of the composite coating could be obtained by eliminating the difference in physical and thermophysical properties of components in feedstock, which leads to the non-uniformity of blended coating due to their different in-flight trajectories of components in APS process. Therefore, the excellent wear resistance of composite coating benefits from its uniform and fine microstructure. Also, the wide and uniform distribution of plastic Ag lubricant could result in the formation of surface localized tribofilm as lubricant film to protect the coating from fracture and spallation.

J. Cho, Y. Xiong, J. Kim, C. Lee, and S. Hwang, Kinetic Spray Coating Laboratory (NRL), Division of Materials Science and Engineering, College of Engineering, Seoul 133-791, South Korea. Cited: *Wear,* 2008, Nov 26, **265**(11-12), p 1565-1571. ISSN 0043-1648.

Review

Smart self-repairing protective coatings. Nanocontainers with a shell possessing controlled release properties can be used to fabricate a new family of active coatings that can respond quickly to changes in the coating environment or the coating's integrity. The release of corrosion inhibitors encapsulated within nanocontainers is triggered by the corrosion process, which prevents the spontaneous leakage of the corrosion inhibitor out of the coating. Moreover, if different types of nanocontainers loaded with the corresponding active agents are incorporated simultaneously into a coating matrix, the coating can act in several different ways (e.g. antibacterial, anticorrosion and antistatic). This review presents methods for the fabrication of such nanocontainers, how they can encapsulate active material, and their permeability properties.

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The emergence of cold spray as a tool for surface modification. Cold spray is an emerging coating technology that allows hardness, corrosion and wear resistance, as well as thermal and electrical properties of surfaces to be optimised. The advantages of cold spray over thermal spray are discussed, with emphasis on a new cold spray variant called Kinetic Metallization. The influence of gas dynamics on surface adhesion are examined. Examples from

the literature and from the present work of corrosion and wear resistance, bond strength and cohesive strength of cold spray coatings are reviewed.

K. Spencer and M.X. Zhang, Division of Materials, School of Engineering, University of Queensland, Brisbane, QLD 4072, Australia. Cited: *Key Eng. Mater.,* **384**, p 61-74. ISSN 1013-9826.

Thermal and cold spray: Recent developments. Thermal spraying consists in a technology aiming at producing coatings whose thicknesses range from 10 μm to a few millimeters onto mechanical components to confer them specific and unique functional properties, such as wear and corrosion resistances, friction coefficient adaptation, thermal and electrical insulation, biocompatibility, repair, etc., among the principals. Thermal spraying consists in injecting in a viscous enthalpic jet (animated by a momentum) powder with particles which average size ranges from 0.01 to 100 μm. These particles are melted and simultaneously accelerated towards the surface of the part to be covered. They form, after impact, spreading and solidification, near-circular lamellae the stacking of which form the coating. Due to the versatility of the available processes exhibiting a wide range of enthalpic and momentum contents, virtually any kind of material exhibiting congruent melting behavior can be processed, from alloys and ceramics to polymers, ever since its melting temperature differs from its vaporization or decomposition temperature by at least 300 K and that it can be processed previously under the form of powder particles or wires. Thermal spray techniques offer the unique capability to manufacture a large variety of coatings on components of a large variety and geometry. However, thermal spraying constitutes a special process for which the coating service properties derive mostly from the structure and indirectly from the selection of the operating parameters. Very significant improvements over the past years permitted to diagnose the in-flight particle characteristics, mostly in terms of velocity and temperature. Recently, these new capabilities have made possible the development of on-line process controls. This should participate to a drastic increase in coating reliability. In conventional thermal spraying processes, a pulverulent feedstock (i.e., powder particles) is injected within the plasma jet via a carrier gas. This approach does not permit to process small diameter particles; i.e., nano-sized particles, which could permit to form finely grained coatings. Replacing gas by liquid to carry particles offer the unique possibility to process nano-sized particles. Cold gas spraying may appear as an alternative process to reach the same goal. Indeed, thermal spray processes experienced very significant developments over the past years, opening new doors to manufacture coatings with a high reliability and superior properties. This paper intend at presenting some of those developments.

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Thermal spraying of wear and corrosion resistant surfaces. Thermal spraying is one of the most variable and diverse surface coating techniques concerning materials to be processed as well as possible geometries to be coated. The group of thermal spray processes covers a large parameter field to combine nearly each coating with each base material. Thermally sprayed coatings can be applied very evenly and therefore allow to be applied on final-shaped components. Otherwise, if further treatment or finishing is necessary, thermal spray coatings can be processed by grinding or even milling. Masking during the coating process permits the selective coating of specific surface parts or the application of required geometrically structures, e. q. conductor structures. The main application field of thermal spray coatings is the (combined) wear and corrosion protection of selected component parts.

B. Wielage, T. Lampke, and T. Grund, Chemnitz University of Technology, Institute of Composite Materials and Surface Technology, D-09107 Chemnitz, Germany. Cited: *Key Eng. Mater.,* **384**, p 75-98. ISSN 1013-9826.