JTTEE5 17:454–455
DOI: 10.1007/s11666-008-9233-x
1059-9630/$19.00 © ASM International

Meet Our New Colleagues

This column presents selected thermal spray research from graduating Ph.D. students as a way of introducing these researchers to the larger thermal spray community and helping them to apply their skills to existing needs. Recently graduated and soon-to-graduate (within 6 months) students are encouraged to submit a short description (1-2 pages) of the research they performed during their studies to Kendall Hollis, *JTST* Associate Editor at: Los Alamos National Laboratory, P.O. Box 1663, MS G-770, Los Alamos, NM 87544; e-mail: kjhollis@lanl.gov. With agreement of the student's thesis advisor, selected submissions will be published in the upcoming issues of *JTST*.

Elucidation of Deposition Mechanisms of Cold-Gas-Dynamic-Sprayed MCrAlY Coatings Focused on Nano-Structure

- -

Yuji ICHIKAWA, Ph.D., Assistant Professor, Fracture and Reliability Research Institute, Graduate School of Engineering, Tohoku University, 6-6-11-720, Aoba, Aramaki, Aoba-ku, Sendai, 980-8579, Japan. E-mail: ichikawa@rift.mech.tohoku.ac.jp.

- -

Yuji Ichikawa

Papers and Conference Proceedings

- K. Ogawa, Y. Ichikawa, M. Tanno, T. Shoji, O.P. Solonenko, A.N. Cherepanov, V.A. Poluboyarov, and A.R. Lapin, Application of Mechanical Grinding and Refractory Ultrafine Powders for Thermal Sprayed Thermal Barrier Coatings, *Proceedings of Surface Modification Technologies XVIII*, 2004, p 45-51
- Y. Ichikawa, K. Ogawa, T. Shoji, and O.P. Solonenko, Development of Highly Molten Chloride Corrosion Resistant Coatings Assisted by Mechano-Chemical Reaction, *Proceedings of International Thermal Spray Conference & Exposition*, 2005, CD-ROM
- Y. Ichikawa, K. Ogawa, M. Nivard, L. Berthe, M. Boustie, M. Ducos, S. Barradas, and M. Jeandin, Adhesion Study of Cold-Sprayed CoNiCrAlY + Mo Coatings of Inconel 625 Using the Laser Shock Adhesion Test (LASAT), *Mater. Sci. Forum*, 2007, **539-543**, p 1086-1091
- Y. Ichikawa, S. Barradas, F. Borit, V. Guipont, M. Jeandin, M. Nivard, L. Berthe, K. Ogawa, and T. Shoji, Evaluation of Adhesive Strength of Thermal-Sprayed Hydroxyapatite Coatings Using the Laser Shock Adhesion Test (LASAT), *Mater. Trans.*, 2007, **48**, p 793-798
- Y. Ichikawa, T. Miyazaki, K. Ogawa, T. Shoji, and M. Jeandin, Deposition Mechanism of Cold Sprayed MCrAlY Coatings Focused on Nanostructure, *Proceedings of International Thermal Spray Conference & Exposition*, 2008, CD-ROM

Background

I obtained my Ph.D. degree in March 2007 from Tohoku University in Japan and am currently working as an assistant professor at Tohoku University. The title of my thesis is "Elucidation of Deposition Mechanisms of Cold-Gas-Dynamic-Sprayed MCrAlY Coatings Focused on Nano-Structure." In my thesis I discuss the deposition mechanism of a cold-sprayed MCrAlY coating. Our approach to revealing cold spray deposition mechanisms is cross-sectional observation of individual particles.

Experiment

CoNiCrAlY (SULZER METCO AMDRY 9951), one of the typical MCrAlY materials, was used as a spraying material and the Ni-base superalloy Inconel 625 was used as the substrate. The MCrAlY powder was sprayed by using the cold-spray facility (CGT KINETIKS 3000) in the Centre des Materiaux, Ecole des Mines de Paris, France.

Our goal is to understand individual particle deformation behavior; therefore, we need cross-sectional observations of deposited particles. The focused ion beam (FIB) technique is a powerful micromachining tool for obtaining cross sections of deposited particles. First, we made individual splat specimens by using a low powder feed rate and high traverse speed (Fig. 1a). Subsequently, individual particles were cut with the FIB (Fig. 1b). To discuss the deposition tendency, the cross section of the interface between the deposited particle and the substrate was observed and the dimensions of the particles were measured. The dimension parameters such as the width (W), height (H), and incursion depth (D) of the substrate are shown in Fig. 2. An example of particle observation is shown in Fig. 3.

The particle impact in the cold spraying process was not perfect in the perpendicular direction. This particle impinged from the upper right to lower left in the image. Consequently, the deformation of the left portion of the particle was larger than that of the right portion. The left portion shows good deposition; however, the right one does not. The reason for this difference is the difference in impact velocities between the sides. Therefore, to understand the

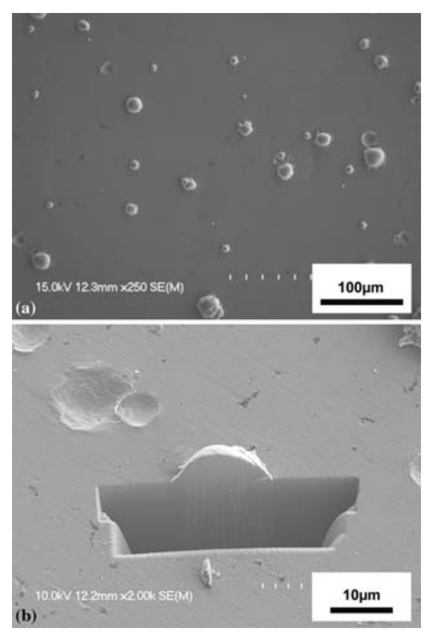

Fig. 1 Appearance of particles sparsely deposited on a substrate. (a) Overview and (b) Cross-sectional view of a deposited particle sectioned using the FIB technique

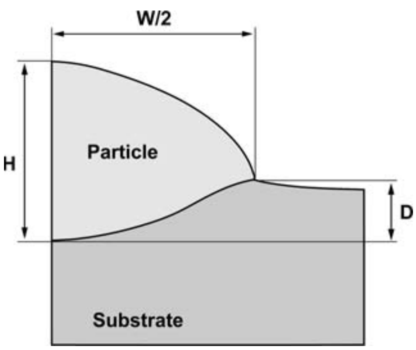

Fig. 2 Geometry of the deposited particle. *W*, width of the particle; *H*, height of the particle; and *D*, intrusion depth into the substrate

threshold condition of deposition, the differences in shape between the right and left portions of the particle were investigated.

The measurement results of the deposited particles are shown in Fig. 3 and summarized in Table 1. The measured dimensional ratios such as *D*/*W* and *D*/*H* are shown in Fig. 4(a) and (b), respectively. In these plots, the triangles indicate the rebounded particles, and the circles indicate the particles with good adhesion. In both plots, there is a threshold ratio between the deposited and rebounded particles. In other words, the deposited particles exhibit greater deformation.

The results of other investigations found that the deposition mechanism of the cold spray technique required the creation of nascent surfaces and high-pressure contact with high-velocity impingement and plastic deformation. In other words, it is necessary to create

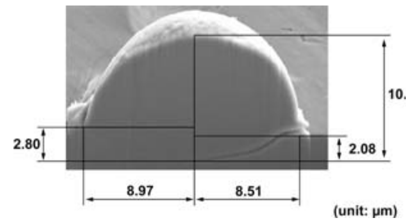

Fig. 3 Example measurement of a cold spray-deposited particle

Table 1 Measurement results of dimensional ratios of a cold spray-deposited particle.

	Deposited (left side)	Rebounded (right side)
D/*W*	0.624	0.488
D/*H*	0.262	0.195

nascent surfaces on the particles and substrates. The amount of the nascent surface is a key parameter for deposition, and it corresponds to the plastic deformation of the particles and substrate. Therefore, the deposition threshold is explained on the basis of critical plastic deformation. When the amount of plastic deformation exceeds the threshold condition, particle deposition is initiated. The mechanism of cold-spray deposition is fundamentally related to the plastic strain of the particle and substrate; therefore, we should focus on plastic strain to explain the cold spray adhesion mechanism.

Further experimental and theoretical work in determining the cold spray adhesion mechanism is needed. I am still interested in this area and continue to research this topic. My research will

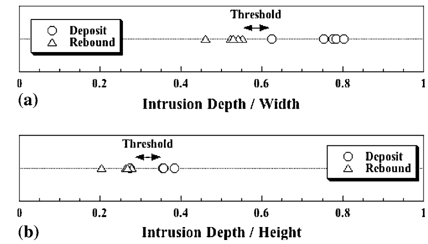

Fig. 4 Relationship between dimensional measurement results and particle adhesion condition. (a) Tendency of the intrusion depth to width ratio and (b) Tendency of the intrusion depth-to-height ratio vs. the deposition threshold obtained from observations

continue on the cold spray adhesion mechanism of a wide variety of materials by using the individual particle investigation approach.

Acknowledgments

T. Shoji and K. Ogawa, my supervisors in Tohoku University, gave me much advice and many opportunities to work on this topic. M. Jeandin and his group members, at C2P, Centre des Materiaux, Ecole des Mines de Paris, assisted me greatly. I would like to express my appreciation to them. This research work was partly supported by the 21st COE Program "The Exploration of the Frontiers of Mechanical Science Based on Nanotechnology" at Tohoku University and the Japan-France Integrated Action Program (SAKURA).