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Discrete element method simulations of mechanical plating of composite coatings on aluminum substrates

Renata Khasenova[1,*], Sergey Komarov[1], Shingo Ishihara[2], Junya Kano[2], V.Yu. Zadorozhnyy[3]

[1]Graduate School of Environmental Studies, Tohoku University, 6-6-02 Aza-Aoba, Aramaki, Aoba-ku, Sendai, Japan, 980-8579

[2]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, 2-1-1, Katahira, Aoba-ku, Sendai, Japan 980-8577,

[3]National University of Science and Technology "MISIS", Moscow 119049, Russia

[*]Corresponding author

E-mail address khasenova.renata.sagidullaevna.t3@dc.tohoku.ac.jp (R.S. Khasenova)

Abstract

Mechanical plating deposits coatings by cold welding fine particles to a workpiece through ball or shot impact treatment, for example in ball mills. This process offers flexibility in selecting material systems because the formation of coatings occurs in the solid state at near room temperature and ambient pressure. However, parametric optimization of the process remains a challenge since many parameters affect the process efficiency. The goal of this study was to numerically investigate the behavior of the balls and a substrate sample in a planetary ball mill and thus to elucidate the mechanisms involved in this mechanical plating treatment. An aluminum substrate with aluminum-carbon nanotube coating system that was previously investigated experimentally was simulated. A discrete element method model was proposed to perform numerical simulations to predict the energy, frequency, and angle of ball-to-substrate collisions. Measurements were also conducted to determine the friction coefficient necessary for the simulation. The results revealed that small balls caused more frequent and mild collisions with the substrate predominantly in the tangential direction. These collisions are assumed to be the primary contributor to the coating formation. Collisions between large balls and the substrate