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Puthumana, Govindan; Bissacco, Giuliano; Hansen, Hans Nørgaard

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The effect of TWD estimation error on the geometry of machined surfaces in micro-EDM milling

G.Puthumana[1], G. Bissacco[1], H. N. Hansen[1]

[1]Technical University of Denmark, Lyngby, Denmark

gput@mek.dtu.dk

Abstract

In micro EDM (electrical discharge machining) milling, tool electrode wear must be effectively compensated in order to achieve high accuracy of machined features [1]. Tool wear compensation in micro-EDM milling can be based on off-line techniques with limited accuracy such as estimation of the volumetric wear ratio and continuous compensation proportional to the in-plane displacements (anticipated wear compensation) or real time wear sensing [2]. Tool wear per discharge (TWD) is a parameter based on which a novel approach has been developed for tool wear compensation based on discharge counting and statistical characterization of the discharge population [3]. The TWD based approach permits the direct control of the position of the tool electrode front surface. However, TWD estimation errors will generate a self-amplifying error on the tool electrode axial depth during micro-EDM milling. Therefore, accuracy of the tool wear compensation method as well as the geometry of the machined feature depends on the variability of TWD during machining operation. This paper analyses the effect of errors on the estimation of TWD on geometry of the machined features, in the case of a typical slot machining process. The error propagation effect is demonstrated through a software simulation tool developed by the authors for determination of the correct TWD for subsequent use in compensation of electrode wear in EDM milling. The implemented model uses an initial arbitrary estimation of TWD and a single experiment with determination of number of discharges and removed electrode volume. The simulation tool developed is used to calculate the effects of errors in the initial estimation of TWD on the propagation effect of error on the depth of the cavity generated. Simulations were applied to EDM milling of a slot of 5000 µm length and 50 µm depth, with a segment length of 100 µm and layer thickness of 1 µm. Simulations have been performed for TWD estimation errors ranging from -15% to +15%, see Figure 1: a. In order to validate the results obtained using simulations, slot milling experiments were performed on a SARIX SX-200 micro-EDM machine. Tungsten carbide rod of Ø300 µm and Stavax steel blocks were used as the tool material and workpiece material respectively. The programming for machining along the segments and along each layer was done using G codes. The population of discharge current signals were characterized for

selection of the trigger level to count all the discharges contributing to the tool wear. Experiments were replicated five times to ensure the repeatability of the results. From the simulations, it is observed that the depth error due to TWD estimation error is magnified and transmitted in different progressions along the tool path. The simulation results show that a variation in TWD estimation error from +1% to +5%, the maximum error in the geometry of micro-EDM milled profile varied from +6.14% to +40.52%. It is observed that results of depth predicted using the simulation and the average depth obtained using experiments match thoroughly within an error of 5%, see Figure 1: b.

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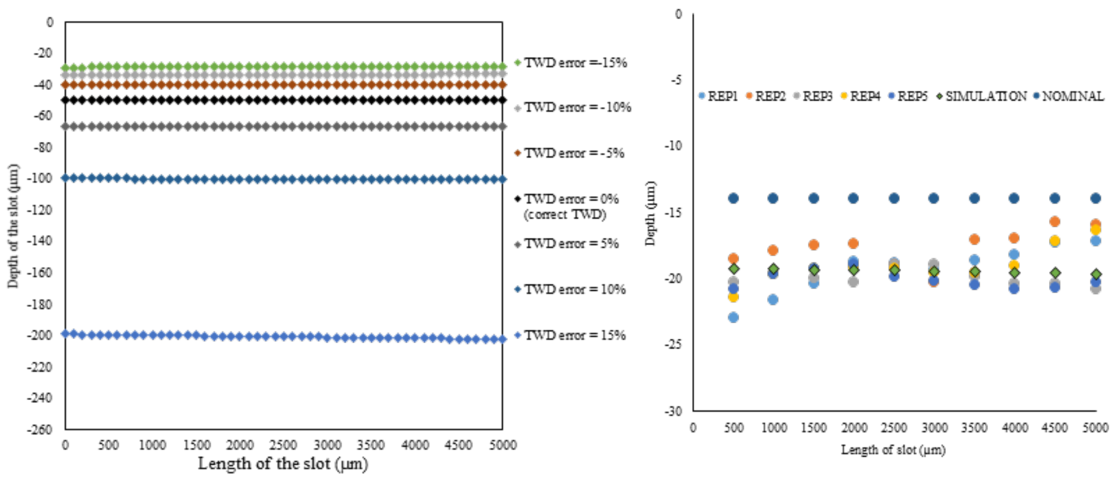

a. b.

Figure 1: a-b Results of a. depth of the slot predicted using simulation, b. experimental validation