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ORIGINAL ARTICLE

Modelling of the ball burnishing process with a high-stiffness tool

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Abstract This paper deals with the problem of forming a surface roughness profile of a machined surface and a definition of the optimal depth of penetration in ball burnishing which would allow minimization of surface roughness. The assumptions, which have been numerically and experimentally verified, claim that maximum surface quality, i.e., minimum surface roughness, Ra, is achieved when the depth of ball penetration into the workpiece material is approximately equal to the maximum peak height, Rp. For the purpose of numerical simulations, a surface roughness model based on milling kinematics was used. Numerical simulations and the used roughness model support the claim that penetrating with a stiff tool up to the mean line of the roughness profile yields best surface quality. The authors maintain that ball penetrations, which exceed Rp, cannot significantly improve surface quality. Furthermore, the phenomenon of profile peak deformation is substantially clarified. The analysis of internal stresses within the workpiece after ball burnishing allowed a relationship to be established between internal stress distribution along the depth of the hardened layer and ball penetration depth.

Keywords Ball burnishing · FEM analysis · Surface roughness · Residual stresses

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1 Introduction

Ball burnishing is a cold finishing process in which a ball is rolled over the workpiece surface. Contact pressures cause plastic deformation of the workpiece surface layer. A plastic flow of surface roughness profile peaks takes place, thus filling the adjacent valleys. In this process, the rough surface texture is evened out and becomes smoother. The described method also contributes to formation of hard surface layers due to deformation strengthening. Under certain conditions, ball burnishing is a good alternative for processing and can be applied for the treatment of workpieces of different materials. Using ball burnishing as a final processing, operation allows certain workpiece surfaces to have improved wear resistance, corrosion resistance, fatigue, tensile strength, etc.

Many investigations of burnishing processes have been focused on the ball burnishing process, due to its advantages, such as flexibility, simplicity, cost-effectiveness, etc. Previous investigations have been mostly focused on the development of analytical and empirical regression models, as well as the application of optimization methods (response surface methodology, Taguchi method) and the application of artificial intelligence, the finite element method (FEM) and practical experiments.

Literature reviews show that many studies focus on the development of analytical models. Bouzid et al. [1] defined an analytical model to determine the roughness of burnished surfaces in relation to the feed rate, the depth of penetration and the roughness of the initial surface obtained by turning or grinding. The normal displacement has been calculated using the Hertz contact theory which supposes that the behaviour of the workpiece material is elastic. Bougharriou et al. [2] performed analytical modelling and FEM analysis to study burnishing on an AISI 1042 workpiece. The simulations were made to analyze the surface profile, the residual stresses and

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