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Using a high-stiffness burnishing tool for increased dimensional and geometrical accuracies of openings

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ABSTRACT

The paper investigates ball burnishing of openings. A special high-stiffness tool was designed for the purpose of experimentation, allowing the burnishing of 40–120 mm openings. Experiments were performed with aluminium alloy EN AW-6082 (AlMgSi1). The primary goal was to achieve dimensional and geometrical accuracy of the openings. Using a specially designed stiff tool, the openings were widened by 0.06 mm on average, while the roundness and cylindricity errors were drastically reduced, especially at greater ball penetration depths. In addition, the surface roughness was improved by 35%. FEM analysis was conducted to determine the stress field distribution in the workpiece, as well as to approximate the residual stresses after the ball burnishing. Considering the experimental results, further investigation should be directed towards the achievement of high dimensional and geometrical accuracies, as well as increased process productivity.

1. Introduction

To provide the best performance and required product lifetime, it is necessary to satisfy numerous prerequisites, such as dimensional accuracy, geometrical accuracy, and surface finish. The surface finish is vital to the functional characteristics of surfaces, such as wear resistance, corrosion resistance, fatigue strength and losses due to friction. The most popular machining technologies – precision turning, reaming, milling, and even grinding – cannot always satisfy the required high surface quality. An improvement of surface finish can be achieved by treatments such as honing, lapping, super finishing and burnishing [1,2].

Ball burnishing is a finishing process in which a ball is rolled over the workpiece surface, which results in Hertzian contact pressures. These contact pressures exceed that of the yield, which causes plastic deformation of the workpiece surface layer. A plastic flow of the surface roughness profile peaks takes place, thus filling the adjacent valleys. By this process, the rough surface texture is evened out and the surface becomes smoother. The described method also contributes to the formation of hard surface layers due to deformation strengthening. The workpiece surface layers that undergo plastic deformation acquire special characteristics, while, due to previous machining processes, the residual surface stresses become transformed into compression stresses. The penetration depth of these compression stresses and the thickness of the strengthened surface layer depend on the workpiece material and applied loads. The compression stresses decrease towards the centre of the workpiece, and the depth of penetration depends on the workpiece material and applied load [3,4].

The burnishing process can be applied to workpieces of various materials, such as steels [5–9], aluminium alloys [10–18], titanium alloys [19,20], magnesium–calcium alloys [21], and brass alloys [22,23]. Additionally, it is possible to burnish workpieces of various geometries.

Many investigations of burnishing processes were focused on the ball burnishing process, due to its advantages, such as flexibility, low price, simple machining, etc.

El-Axir [16] studied the relationships between the fatigue life, the residual stress, and the ball burnishing process parameters. The experimental work was focused on establishing the effect of burnishing parameters (burnishing speed, force, and feed) on the residual stress and fatigue life of aluminium alloy 6061-T6. The residual stress distribution in the surface region due to ball burnishing was determined using a deflection-etching technique. Bougharriou et al. [8] performed an analytical study and finite element (FE) modelling to provide a fundamental understanding of burnishing on an AISI 1042 workpiece. The simulations were devoted to the study of the surface profile, the residual stresses

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