FEM Analysis of the Plastic Deformation of the Regular Arched Asperities in the Two-stage Cold Metal Forming Processes

P. Kaldunski[1, a)], L. Kukielka[1, 2, b)], L. Bohdal[1, c)], J. Chodor[1, d)], K. Gotowala[1, e)], K. Kukielka[1, f)], A. Kulakowska[1, g)], R. Patyk[1, h)], M. Szczesniak[1, i)]

[1]Department of Mechanical Engineering, Koszalin University of Technology, Poland
[2]Department of Mechanical Engineering, Jacob of Paradies University, Gorzów Wielkopolski, Poland

[a)]Corresponding author: [a)]pawel.kaldunski@tu.koszalin.pl
[b)]leon.kukielka@tu.koszalin.pl
[c)]lukasz.bohdal@tu.koszalin.pl
[d)]jaroslaw.chodor@tu.koszalin.pl
[e)]katarzyna.gotowala@tu.koszalin.pl
[f)]krzysztof.kukielka@tu.koszalin.pl
[g)]agnieszka.kulakowska@tu.koszalin.pl
[h)]radoslaw.patyk@tu.koszalin.pl
[i)]michal.szczesniak@tu.koszalin.pl

Abstract. The paper presents the innovative process with possibility of predict the state of deformation and stresses in a two-stage metal forming process. In the first stage, regular surface roughness with arched outlines are embossed. In the second stage, these inequalities are flat burnished to obtain the required dimensions, roughness of the surface, and state of deformation and stresses in the surface layer of the workpiece. The process are considered as a geometrical and physical non-linear boundary and initial value problem, with unknown boundary conditions in the contact zone. The applications were developed in the Ansys/LS-Dyna system, which makes possible a complex time analysis of the states of displacements, strains and stresses, in the workpiece in the two-stage cold metal forming processes. Application of this method were showed for examples the modelling and the analysis of the regular asperities with arched outlines. In the simulations, the material as well as the geometrical parameters of surface asperities were changed. The simulation results were verified experimentally.

INTRODUCTION

The most important technological problems in the manufacturing and in the regeneration is the formation of the surface layer, characterized by assigned physical and stereometrical properties and precision of the part dimensions, that effects the target life and the reliability of the machined elements. Special attention should be paid to those machine elements which are costly to manufacture, or which have a bearing on machine reliability and environmental pollution, etc. Burnishing is a pro-ecological and cost-effective process used in the technological process of manufacturing machine parts as a final operation. The burnishing of machine parts has been known and used for a long time [1], but to predict and obtaining the assumed properties of the surface layer of the product is unresolved and very difficult. The basic problem of classical burnishing methods is to obtain a regular profile and the difficulty in completely smoothing asperities. The dimensions of the parts meet the requirements of the standard, while in the surface layer there are secondary grooves and fins.

The objective in this paper is to develop a numerical applications in ANSYS program, using APDL language (ANSYS Parametric Design Language) to predict the quality of the product after hybrid burnishing. It was assumed that part is prepared by embossing process and has determined geometrical structure with a arched outline inequality. Another objective is to determine the effect of the geometry of arched irregularities asperities (radius - R and height - H) after embossing on the states of displacement, strain and stress of the product after hybrid burnishing.

NUMERICAL RESULT AND EXPERIMENTAL VERIFICATION

In numerical simulations, the burnishing process took place in two stages. In the first stage, regular inequalities was created with an arched outline of geometry: R = 4 mm and H = 2, 3 and 4 mm (Fig 1). Then, the irregularities were crushed with a flat punch until it was completely smoothed. Obtained results of numerical calculations were verified experimentally. On the outer surface of the samples, on a special stand [2] (Fig. 2a), a roller with an arched outline of the active surface(Fig. 2b), regular irregularities were creased with the same geometry as in the numerical calculations (Fig. 2c). Then, in the same stand, the inequalities were crushed with a roller ring (Fig. 2d) until it was completely smoothed (Fig. 2e).

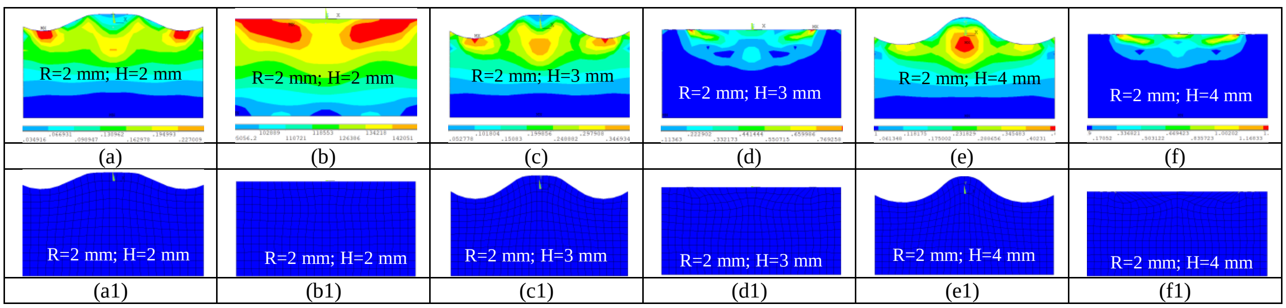

FIGURE 1. Profile of regular roughness surface after embossing and maps of reduced strain in arched asperities (a), (c), (e) and after smoothing (b), (d), (f) and deformation of the finite element grid (a1)-(f1) obtained in the numerical simulation

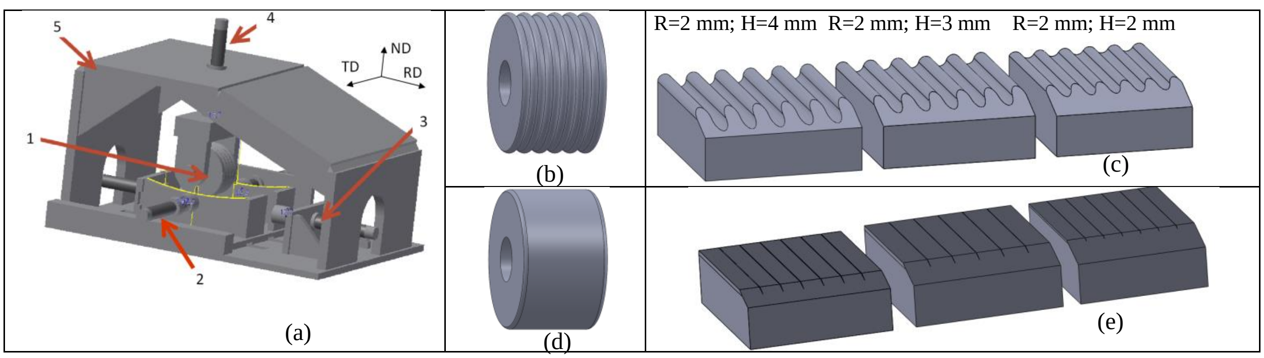

FIGURE 2. Devices (a) for forming regular asperities on the surface of a sample intended for testing the burnishing process; roller with arched profile (b); Steel sample with arched profile after embossing (c); Smooth roller (d); sample after burnishing (e): 1 - embossing or burnishing roller; 2 - horizontal screw for positioning the sample in the direction of TD; 3 - horizontal screw for moving the sample in the direction of RD; 4 - vertical screw for moving the roller in the direction of ND; 5 - frame

Numerical simulations of the burnishing process confirmed the ability to control the quality of the surface, the distribution of strains and stresses. Numerical algorithms facilitate a better understanding of phenomena occurring in the contact zones and deformations, and thus can be the basis for the development of guidelines for the selection of geometrical parameters of arched asperities and burnishing process, taking into account the required technological quality of the product.

REFERENCES

1. W. Przybylski, *Technologia obróbki nagniataniem*, WNT, Warszawa, 1987.
2. L. Kukielka, R. Patyk, S. Patyk, A. Kulakowska, M. Szczesniak, Patent No. PL410198 (23 May 2016)