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Original Research Article

Numerical and experimental analysis of a cross wedge rolling process for producing ball studs

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ABSTRACT

The paper reports the results of theoretical and experimental tests of a forming process for producing ball studs which are widely used in the automotive industry. It is proposed that semi-finished ball studs are produced by cross wedge rolling in a double configuration. The theoretical analysis was performed by numerical techniques based on the finite element method. Numerical computations were made using the simulation software DEFORM v 11.0. During the simulations, the accuracy of the adopted tool design was verified, and optimal parameters of the process along with the effect of selected parameters of the process and the quality of produced parts were determined. The proposed rolling process was verified under laboratory conditions using a flat-wedge forging machine available at the Lublin University of Technology. The experimental findings show a high agreement with the numerical results, in terms of both quality and quantity. The results confirm that ball studs can be produced by the proposed cross wedge rolling technique.

1. Introduction

Ball studs make part of ball-and-socket joints which are used, among others, to join rigid suspension elements or elements of the steering system [1,2]. Fig. 1 shows the application of a ball stud in the ball-and-socket joint as well as the dimensions of the ball stud investigated in this paper. Ball studs can be produced by flashless cold forging. This process is, however, little effective due to high consumption of energy caused by low plasticity of material and the necessity of performing the process in several stages (Fig. 2) [3,4]. An additional problem in cold forging is heavy wear of forging dies [5,6]. Regarding the forging process for the ball stud, the design of which is shown in Fig. 1, it is necessary to use tools with a more complex design than is the case with the forging process for producing the ball stud shown in Fig. 2. A schematic design of a forging process for producing a ball stud with necking is shown in Fig. 3. Compared to rolling processes, the forging technique for ball studs has the following advantages: a simple design of the process, a higher availability of forging machines and less complicated tool geometry [7–9].

An alternative method for producing ball studs is cross wedge rolling (CWR). In this process parts are formed by wedge-shaped tools [12]. The tools are mounted on the wedges or on flat or concave rolling mill plates. In contrast to forging, CWR is characterized by reduced energy consumption [13,14]. Its rolling efficiency can be additionally increased by running

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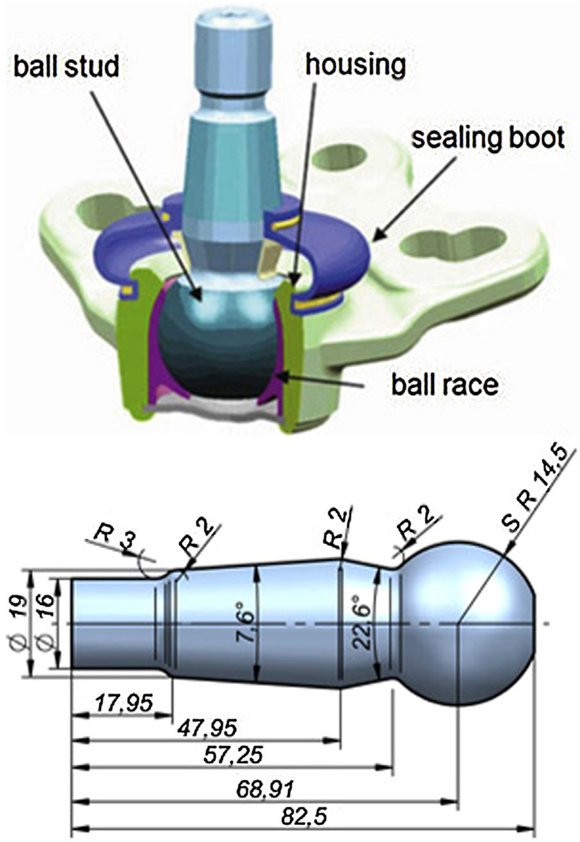

Fig. 1 – Schematic design of a ball stud and its dimensions [10].

the forming process for ball studs in a double configuration. A particularly interesting variant of CWR is multi-wedge cross rolling (MCWR) which is currently used for forming elongated parts such as car axles [15]. The use of multi-wedge tools for forming short parts such as ball studs makes it possible to produce more parts simultaneously. The production of parts in a double configuration is also vital given the design of both the wedge tool and the rolling process itself. Asymmetrical parts are formed in a double configuration [12,16]. During the forming of asymmetrical parts, there occur unbalanced axial loads and strains are located in a non-uniform manner, which can lead to a series of undesired phenomena [17,18]. Failure modes which may occur during the forming of asymmetrical parts include the loss of position stability of the workpiece relative to the tool, formation of helical grooves on the workpiece surface, and overlap.

2. Methods and procedures

This paper reports the results of a study on a cross wedge rolling process for producing a ball stud in a double configuration. The process was performed using tools described by the forming angle $\alpha = 30^\circ$ and the spreading angle $\beta = 10^\circ$, as shown in Fig. 4. The design of the wedges for cross rolling is based on the assumption that the values of α and β should satisfy the condition that $0.04 \le tg\alpha\ tg\beta \le 0.08$ [19]. In the analyzed case, the condition is not met because $tg\alpha \cdot tg\beta = 0.1$, which means that uncontrolled slipping of the workpiece may occur during rolling. The value of β was set to 10° in order to reduce the length of the tool segment. In addition, this enabled reducing the duration of a work cycle of the flat-wedge rolling mill. The above condition can be satisfied by decreasing the value of α. However, at smaller values of α may cause such problems as underfilling of the

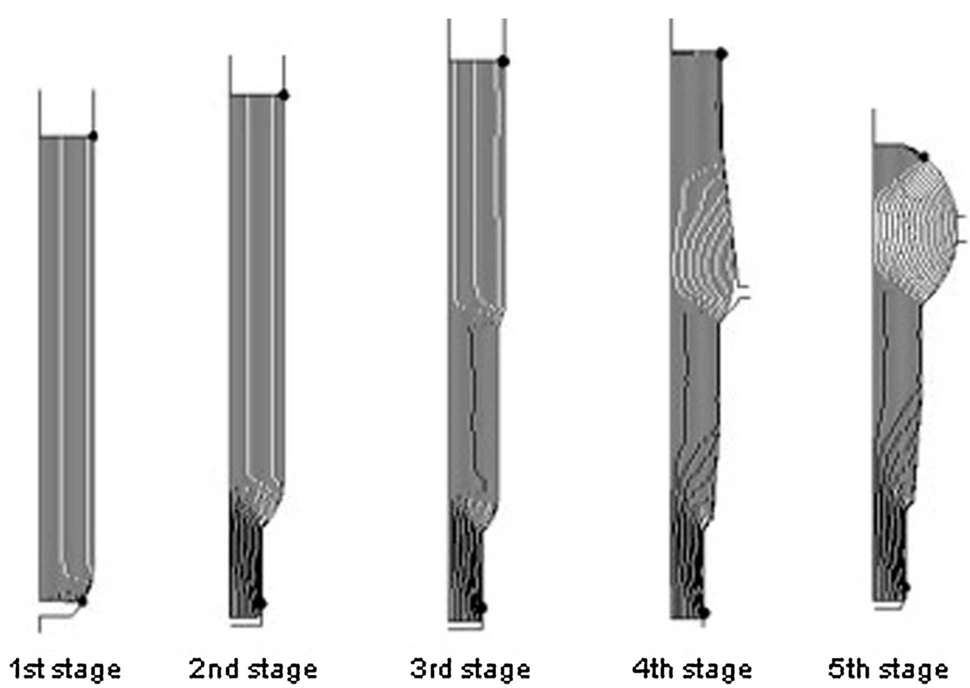

Fig. 2 – Schematic design of a forging process for producing a ball stud in 5 operations [11].