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Energy consumption reduction in Ring Rolling processes: A FEM analysis

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ABSTRACT

Ring Rolling is a very high energy consuming hot forming process used for the production of shaped ring, seamless and axis symmetrical workpieces. Different production steps (Upsetting, Piercing, Ring Rolling) are involved in generating the desired ring shape. In particular the Upsetting and Piercing steps generate a hollow circular preform that will be subsequently enlarged by the rolling mills (Driver, Idle and Axial Rolls) during the Ring Rolling step. In order to reduce the energy and the force needed to produce the workpiece it must be observed that they are strictly affected by the speed laws imposed to the rolling mills which depend on the preform and the final ring geometry. As a consequence the setup of the Upsetting and Piercing steps became fundamental because they impose the preform geometry of the workpiece. Starting from this assumption, in the present work different preforms geometries, characterized by different initial heights, are considered to simulate the Ring Rolling process focusing the results analysis not only on the part feasibility, but also on the energy and force required which affect the equipment dimensioning. An industrial case was considered to validate the FE model. The maximum load and the energy needed for the ring production are considered as main figures for optimizing the process.

1. Introduction

Ring Rolling is a hot forming process used for the production of shaped ring, seamless and axis symmetrical workpieces. In this process the metal is rolled between two rolls which move toward each other to form a continuously reducing gap. In Ring Rolling, the rolls are of different diameters and geometries. The Ring Rolling process is basically used in the production of railway wheels, anti-friction bearing and different ring shaped workpieces for automotive, aerospace and wind industry applications. A typical ring produced by means of this process can have a final diameter equal to 3 m and an height equal to 0.5 m [1]. It could be either a hot or cold process and different alloys as steels, light alloys and titanium can be worked. The advantages of Ring Rolling process include short production time, uniform quality, close tolerances and considerable saving in material cost. This process, compared to others as casting or plasma cutting, could provide lower working temperature, less material required and, consequently, a reduction in energy consumption. Moreover, the main advantage of the workpieces produced by Ring Rolling process, compared to other technological processes, is given by the size and orientation of grains, especially on the worked surface which give to the final product excellent mechanical properties [2]. On the other hand, as the ring to be produced increases in dimensions, the force and the energy needed to carry out the process require a more powerful plant/equipment. Moreover, according to the production setup and phases, the total energy required can be heavily changed. In a world in which the environment impact of production activities becomes every day more and more important, it is necessary to understand if there is any possibility of reducing the energy consumption. Also the ability of obtaining the desired part is very important for reducing material scrapping and useless material heating. This means that the correct definition of the geometry of the intermediate parts is a fundamental task for achieving both the desired objectives.

In Fig. 1 the main production steps of the process are summarized: it begins with a bar that is upset (a) and pierced (b) to obtain a hollow circular preform. The preform is placed over the Idle Roll that forces the ring against the Driver Roll (c). At the same time, the Axial Rolls apply pressure in a direction parallel to the ring axis (c). Because the ring does not rotate on its own axis, two Guide Rolls are designed to help the stability of the process (c). The coupled Idle and Axial Rolls displacements define the shape of the cross-section in terms of height (h) and width (w) and, consequently, the increase in the ring diameter.

As it can be observed, in Ring Rolling several moving rolls are involved into the process and so different speed laws must be set. The main curve used in the industrial environment to setup the process is the so called milling curve. This is introduced to study the shape of the workpiece during the deformation in order to ensure a correct ring

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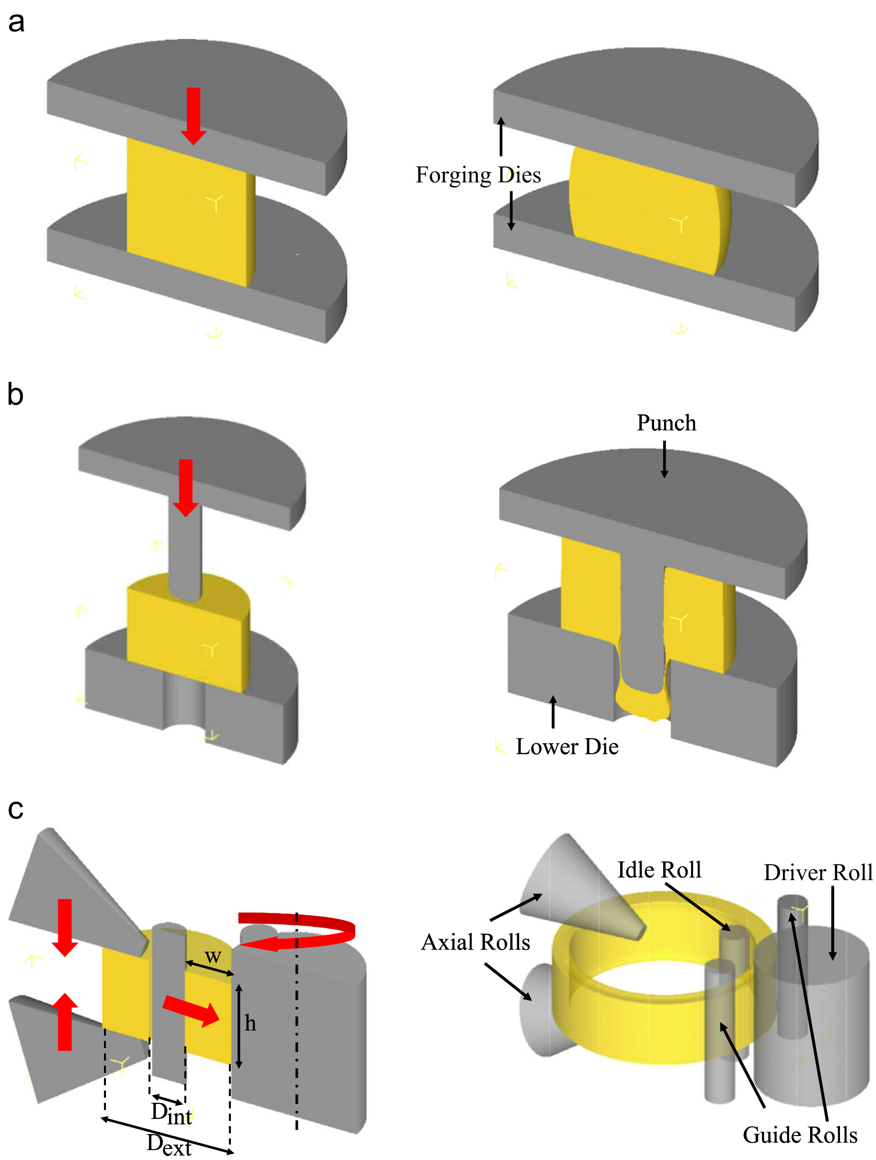

Fig. 1. Main steps of Ring Rolling process. (a) Preform Upsetting step, (b) Preform Piercing step and (c) Ring Rolling step.

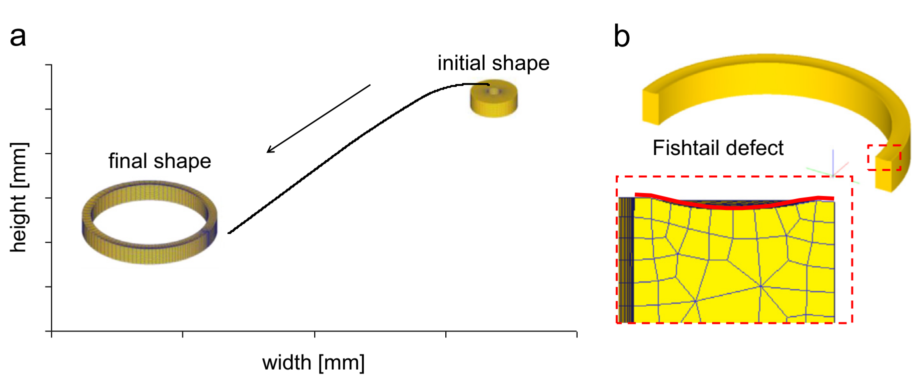

Fig. 2. (a) Milling curve for a Ring Rolling process and (b) fishtail defect.

production: in this curve the instantaneous ring height (h) is plotted as a function of the instantaneous ring width (w) (Fig. 2a).

This curve is fundamental for the industry because it determines how, as an indirect measure, the ring diameter grows. As it can be observed this curve is not depending by the time but it gives an instantaneous idea of the ring cross-section among the deformation process: this information is fundamental in industrial applications because an incorrect milling curve could generate undesired Ring Rolling defects as a too excessive fishtail (Fig. 2b). In order to translate the milling curve in motion law of the Idle Roll, it is necessary to