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Increasing the efficiency of hot mandrel bending of pipe elbows

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Abstract

Hot forming, through pressing, forging or spinning, for example, is widely used in the metalworking industry. In small and medium-sized businesses, in particular, considerable potential exists for increasing productivity and efficiency in economic and ecological terms, because current production is often based on empirical experience and manual skills. Taking the example of pipe elbow production by the so-called 'Hamburg Process', new ways of optimizing the process chain are examined. Here, heated pipe sections are pushed over a horn-shaped mandrel, which defines the expansion and the radius of curvature. In this paper, the forming principle and technological process of hot mandrel bending of pipe elbows is presented. An analysis of the manufacturing process and the results of the first experimental investigations have shown that the production speed can be drastically increased without any negative effects on the quality of the pipe elbows. A further improvement in the output quantity and a substantial reduction in production costs are expected following the design and execution of the FEM simulation, which will accurately depict the manufacturing process and can thus be used for the constructive and structural design of the mandrels.

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Keywords: Energy Efficiency, Finite Element Modelling, Tube Forming

1. Introduction

Seamless pipe elbows are important components in mechanical, plant and apparatus engineering (e.g. in power stations) and are typically produced by the so-called 'Hamburg Process' (Fig. 1). In this warm forming process, the initial pipe is pressed over a bending mandrel and, as a result, it assumes the shape of an elbow. For the development of new products and the optimization of existing pipe elbows, new bending mandrels have to be designed and made

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for their specific purpose. Because of the high loads that prevail, bending mandrels are produced from expensive special alloys like steels based on nickel and cobalt. Depending on the dimensions of the elbow, the bending mandrel's mass can be up to several tons and will thus require the use of a corresponding amount of material. [1]

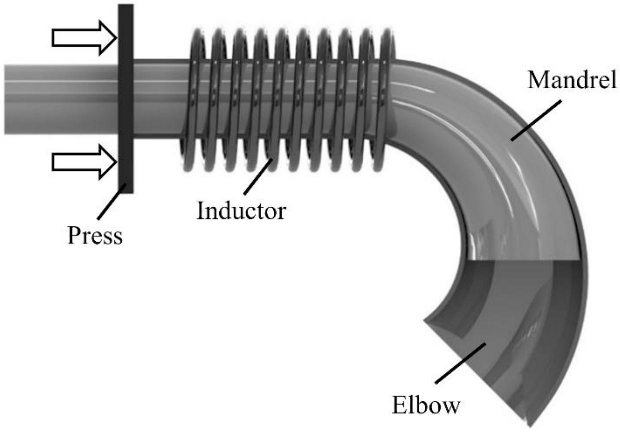

Fig. 1. Hot mandrel bending of pipe elbows ('Hamburg Process')

Today, bending mandrels are designed on an empirical basis, which means that large expanses are required for subsequent optimization. The geometrical layout determines the material needed to manufacture the bending mandrel and the production reliability, on the one hand, and the additional material needed for the forming of pipe elbows, on the other hand. By comparison to other warm forming processes, the forming velocity and the degree of deformation of hot mandrel bending are at a very low level. Hence, from the material and forming point of view, the process has significant reserves to be optimized with regard to higher productivity and better resource efficiency.

The aim of the ongoing project is to optimize the production efficiency of pipe elbows on the basis of modern FEM calculations in combination with experimental investigations and practical operating tests. Through the close interaction between the numerical calculations and experimental tests it is possible to systematically investigate a broad parameter field of different tool geometries and materials, and to develop optimal requirements with regard to the process control and tool design respectively.

To achieve the set targets for improving resource efficiency and increasing productivity, specific parameters of the hot mandrel bending process have to be improved. A reduction in the amount of material required for the production of pipe elbows can be achieved by lowering the amount of excess material and reducing the scrap rate through a higher process stability. This leads, on the one hand, to a reduction in the energy consumption and, on the other hand, to increased productivity, firstly, because of the lower amount of material to be heated, and secondly, because of the higher output quantity. An additional increase in the output quantity can be achieved through higher production velocities and a shortening of heating and cooling times.

2. Analyzing the process

For the production of pipe elbows, the pipe sections used in the form of semi-finished products have to be heated by an inductor until a prescribed minimum temperature is reached. Hence, the actual power of the inductor has to be adapted to the production velocity, which can be regulated through pressure acting on the pipe sections. The pressure is generated by two hydraulic cylinders.

Up until now, different pipe elbows were produced at a velocity which was adjusted to the respective dimensions of the pipe elbow. Among other things, it was considered that, at lower velocities, a better quality of pipe elbow is more readily achieved. Because of that, the maximum possible power of the inductor was not used. This leads to a lower output quantity for the production plant than is theoretically possible.