

# Automated Procedure for Roll Pass Design

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The aim of this work has been to develop an automatic roll pass design method, capable of minimizing the number of roll passes. The adoption of artificial intelligence technologies, particularly expert systems, and a hybrid model for the surface profile evaluation of rolled bars, has allowed us to model the search for the minimal sequence with a tree path search. This approach permitted a geometrical optimization of roll passes while allowing automation of the roll pass design process. Moreover, the heuristic nature of the inferential engine contributes a great deal toward reducing search time, thus allowing such a system to be employed for industrial purposes. Finally, this new approach was compared with other recently developed automatic systems to validate and measure possible improvements among them.

**Keywords:** automated process design, expert system, roll pass design, process simulation

## 1. Introduction

Hot rolling is a basic metal forming process used for transforming performed shapes, usually square billets, resulting from the fusion process, into final products, e.g., bars, rods, section bars, plates, etc., or into forms suitable for further processing. Hot shape rolling typically involves passing billets through multiple sets of forming rolls until the desired cross-sectional shape is obtained. The resulting deformation is usually a matter of metal elongation in the rolling direction. The material being compressed will, however, always flow in the direction of least resistance. Thus, the elongation effect also produces lateral spreading perpendicular to the rolling direction (Ref 1). The maximum compression is limited by the bite angle and/or the mill load (roll force, torque, power). Lateral spreading reduces the elongation and area reduction in the pass. Hence, it is desirable to reduce lateral spreading as much as possible, and above all, keep it under control (Ref 2). This is a requirement that presents a key practical problem for rolling designers, who have to estimate what fraction of the total deformation produces elongation, and what fraction produces spreading. Incorrect spreading estimations result in underfills or side fins.

Several approaches have been used to forecast the rolled bar shape profile, including analytical, semi-empirical, and numerical ones.

Despite the great improvements in recent years in roll pass design, the technology is still, to a high degree, based on the empirical rules developed a century ago.

The traditional approach to the design of the profile of the roll passes is based on subdividing the entire sequence into

sub-sequences (Ref 1), e.g., diamond-diamond, square-diamond-square, square-oval-square, and round-oval-round (Fig. 1). The calculation of the number of passes is then made by considering an average elongation ratio. Finally, the sequence is subdivided into the above-mentioned sub-sequences, and the grooves are defined according to empirical rules.

Although this approach continues to be successfully employed, it does, unfortunately, suffer from a number of limitations. First of all, the complexity of the shape rolling process requires the hiring of highly expert designers, who often base their designs on experience and intuition, rather than on a well-structured scientific approach and this leads to high development and introduction costs for new passes and sequences.

On the other hand, a growing number of researchers have, in recent years, introduced a more scientific approach to roll pass design. Perotti and Kapai (Ref 3) conducted a pioneer study on automatic roll pass design of round bars using geometrical data available in literature. The results of the calculation showed good agreement with industrial rolling sequences. Although they did attempt to perform some sort of process optimization, their system was still based on the old approach, which forced the expert system to choose from among a low number of predefined passes, thus limiting the flexibility and expandability of the system.

Kim and Im (Ref 4) developed an expert system for shape rolling of round and square bars based on a backward chaining algorithm. In particular, the inference engine determined the manufacturing sequences in reverse order based on design rules extracted from the literature. Relevance was also placed on expandability and flexibility; for instance, object-oriented programming was used to permit the addition of new shapes for the groove. This attempt too, however, was based on empirical rules (Ref 1). Hence, single pass optimization was not yet functional. Moreover, the total number of passes were, therefore, not given as input.

Kwon and Im (Ref 5) developed a computer-aided-design system to support roll pass and roll profile design of bar rolling of simple shapes to reduce the trial and error in industry. Furthermore, an algorithm for generating automatic roll pass design of local passes was proposed. That system allowed the forecast of material flow and engineering data such as roll

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