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Analysis of end straightness of rail during manufacturing

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Abstract

Analysis has been carried out in order to judge the straightness of a finished rail for a specific set of parameters of the straightening machine. Finite element method has been used here for simulation and analysis. It has been noted that straightness of rail near the ends differ considerably compared to the straightness in the middle portion of the rail. The article provides guidance for the minimum length of the rail to be cut, in order to achieve the end straightness of a new rail within acceptable limits. The present study has also proposed to use a finite element model of 7.0 m rail length only for similar study, in order to save computer time and storage space largely.

Keywords: Straightness; Residual stresses; Sweep; Camber; Elasto-plastic bending

1. Introduction

The rails are manufactured from bloom by hot rolling. They are initially cooled on cooling bed and then inside a closed pit. During cooling, temperatures at different regions of rails differ and the rails bend. The magnitude of bending is generally termed as camber and is measured by the perpendicular distance from the point of maximum bend to the chord joining the two ends of the rail. Subsequently, the rails are straightened in the roller-straightening machine.

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In the straightening machine, the rails undergo alternate bending, and are subjected to elasto-plastic deformations under high magnitude of loads. The straightness of the finished rail and the residual stress developed during straightening, depend on the loads applied in the straightening machine. A suitable methodology has been developed in order to estimate the straightness of a finished rail for a specific set of loading parameters of the straightening machine. The study has been made to examine straightness values along the complete length of the rail. It is observed that the front and rear ends of the rail are subjected to different patterns of loading while passing through the straightening machine compared to the middle portion of the rail. Therefore, the straightness near the ends differs considerably compared to the uniform straightness pattern observed in the middle portion of the rail. The present study also provides guidance for the minimum length of the rail at the ends, which need to be cut to achieve the straightness within the acceptable limit.

The generation of residual stresses in new rails during the process of rail straightening has attracted the attention of many researchers. Both theoretical and experimental studies have been carried out to determine the residual stresses in the roller-straightened finished rail. Finstermann et al. [1] have simulated the elasto-plastic bending process of the straightening operation on a nine-roller machine. A three-dimensional finite element model has been used for the purpose. The study has been made to examine residual stress in rail for a particular camber. Brunig et al. [2] have represented the rail as a bar with cross-section of variable width. The calculated stress values after straightening are interpreted as average value over the width. The simulated model used by Varney and Farris [3] shows encouraging result. However, they used two-dimension model and the method is unable to predict the variation in residual stress in the transverse direction. They have suggested closer spacing of rollers in order to reduce residual stress but expressed doubt in achieving straightness of the rails. While carrying out finite element simulation of a two-plane roller straightening machine, Schleinzer et al. [4] experimentally investigated the plastic behaviour of the rail material. They observed typical Bauschinger effect for different grade of rail steels. Experimental investigations have also been carried out to determine residual stress in new rail by different investigators [5–7]. Ringsberg and Lindback [8] have studied mainly the fatigue damage of rails induced by cyclic loading during service life, on an initially introduced residual stress-state affected rails. The present authors [9] have simulated the cooling process to estimate the magnitude of bending and residual stress developed in the rail after cooling. It has been noted that residual stress in the rail after cooling is of very small magnitude in comparison with the yield stress of the material. They [10,11] have used three-dimensional finite element model to simulate the straightening operation. A method for assessment of residual stress and straightness of the finished rails has been reported by the authors [11] for a straight rail under stress free conditions. They have calculated straightness of the finished rail and residual stress for different setting parameters of the machine. Both the magnitudes of residual stress and the degree of straightness near the front end of the rail have been considered in the article to recommend the machine setting parameters for efficient straightening operation. However, as per the knowledge of the authors, no study for examining the degree of straightness of 'as manufactured' rails throughout the complete length of rail have been yet reported. In order to meet this gap, an effort is given by the authors in the present endeavour to investigate the straightness, achieved after straightening operation of a bent rail.