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Using three-dimensional finite element analysis for simulation of residual stresses in railway wheels

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ABSTRACT

One of the most important issues in railway wheels is residual stresses. It is desirable to produce less residual stresses when possible and to decrease the remaining residual stresses in the wheels. The objective of this paper is to provide an estimation of the residual stresses in the rail wheel caused by the stress field from heat treatment process of a railway wheel. A three-dimensional nonlinear stress analysis model has been applied to estimate stress fields of the railway mono-block wheel in heat treatment process. After forging or casting, railway wheels are heat-treated to induce the desirable circumferential compressive residual stress in the upper rim. Finite element analysis model is presented applying the elastic–plastic finite element analysis for the rail wheel under variable thermal loads. Calculative analysis applying a finite element method (FEM) has been used to predict residual stresses. The quenching and annealing segments of the wheel manufacturing process are simulated using a decoupled heat transfer and stress analysis. Three-dimensional finite element analysis results obtained show good agreement with those achieved in field measurements.

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1. Introduction

The railroad wheel has the initial residual stress created by the manufacturing process, and this residual stress changes due to the mechanical stress caused by service conditions. The residual stresses of railroad wheels are influenced by the heat treatment during manufacture processing. In recent decades, numerous studies have attempted to estimate the residual stresses. Residual stresses play an important role in mechanical member [1] or destroy its surface material. Farrahi et al. [2,3] investigated the effects of the residual stress field and relation to fatigue crack closure and crack growth behavior. Residual stresses induced by the manufacturing process and this residual stress changes due to the thermal stress induced by braking, are not apparent visually. The object of several investigations on manufacturing processes is to show a layer of compressive residual stress on the surface of parts to inhibit propagation of cracks. The effects of the residual stress and metal removal on the contact fatigue life have been estimated by seo et al. [4,5]. Okagata et al. [6] evaluated the fatigue strength of Japanese railway wheel and presented the fatigue design method of high speed railway wheel by considering the effect of manufacturing conditions on the fatigue strength of the material. In the literature [7–13], some of these issues are studied using some experimental observation, analytical calculations and FEA calculations within various contexts.

Most of the previous studies described above have estimated the residual stresses using numerical simulations and finite element method in rail. Unfortunately, existing techniques for estimation residual stresses of the rail wheel problems are

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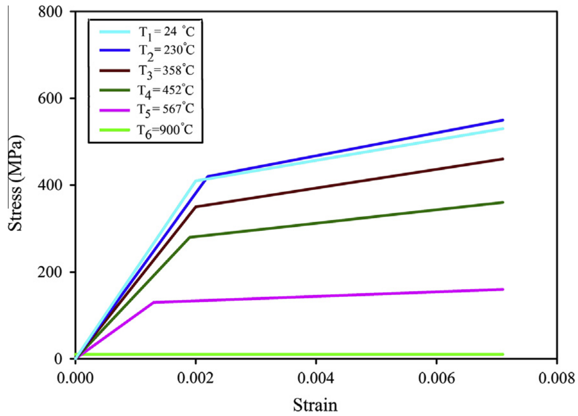

Fig. 1. Mechanical material data for railway wheel.

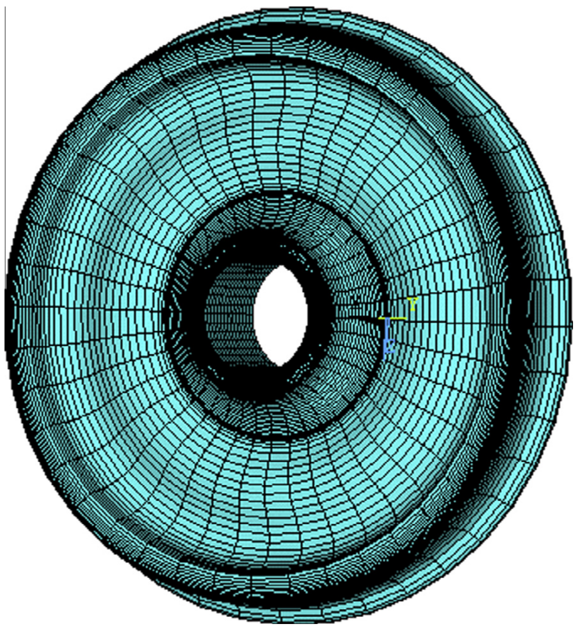

Fig. 2. Finite element modeling of wheel.

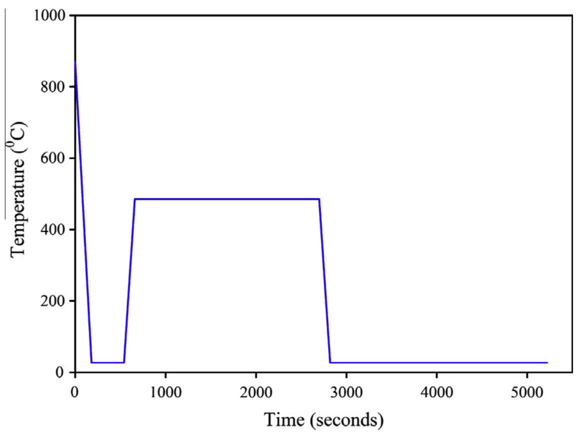

Fig. 3. Thermal load conditions due to the heat treatment process.

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