Problems with Residual Stress in the Railroad Industry

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Introduction

Residual stresses are of principal concern to the railroad industry with respect to two components, wheels and rails.

While railway wheels are manufactured with an aim to producing residual compressive hoop stresses, normal aspects of their usage tend to alter the stress pattern induced during manufacturing. The cold working of the wheel tread surface alters the residual stress pattern of the wheel, but it is probably beneficial as the work hardening decreases the rate of wear. For more important, is the fact that locomotive and freight car wheels also serve as a brake drum. During normal service braking conditions, wheel temperatures can increase to 455°C (850°F). However, under severe or improper conditions thin layer of martensite may be formed on the wheel surface indicating tread surface temperatures in excess of 732°C (1350°F). Such thermal inputs can lead to residual tensile hoop stresses which in term can lead to spontaneous wheel fracture.

Residual stress creates two sets of problems in rails. The first is the contribution to the formation and growth of defects, and the second is the problem of buckling of track employing continuous welded rail. Continuously welded rails are one of the most remarkable and most economical railroad developments of this century. Continuously welded rails represent a truly revolutionary technology, one in which the physical principle of the expansion of steel under the action of heat has apparently been overcome. As numerous inquiries indicate, even today it is still inexplicable.
to many people how railroads can neutralize this natural law.

These conceptions naturally are based on the mistaken ideal that it is really possible to cancel a physical law. In reality, all that is involved is preventing the phenomenon of the expansion of a material under the action of heat, by means of a track structure as rigid against distortions as possible and anchored in a well-filled and compacted ballast bed. If the rail were mounted without friction it would expand like any other body according to the law $\Delta l = \alpha \cdot \ell \cdot \Delta t$. If the expansion is prevented, energy must be stored in the form of a compressive stress. In the case of inhibited contraction, under the action of cold, the rail experiences a tensile stress of magnitude $\sigma_t = \alpha \cdot E \cdot \Delta t$.

However, the track structure if subjected to sufficiently high longitudinal compressive forces in the rail, can exhibit sudden and rapid lateral or vertical movement over a relatively short length. This lateral movement, or buckling of the track, results in a severe misalignment condition that may not permit the safe negotiation of train traffic (Figure 1). If buckling occurs under the train, a derailment is likely to occur. If it occurs between trains, traffic must either be stopped or slowed down until the buckled track condition is corrected.

![Figure 1. Buckled Track](image)

The magnitude of this problem can be seen in the fact that, during 1977, there were 109 train derailments attributed to buckling of the track. The reported damage for these derailments