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Modeling of Steel Components Hardened by Induction and Subjected to Rolling Contact Fatigue

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Abstract

Induction hardening is a heat treatment process used to enhance the hardness and resistance of steels. Because of its environmental advantages in comparison to other approaches such as the carburation process, induction hardening becomes more widely adopted. The common goal of heat treatment processes is to improve fatigue performance. In addition to hardness augmentations, heat treatments also generate residual stress distributions within the material. Residual stresses can also contribute to improved fatigue resistance. Residual compressive stresses near the surface are beneficial, while residual stresses in the over-tempered zone can occasionally pose a problem. While numerous studies have examined the connection between the hardness profiles and the residual stress distributions resulting from the carburation and other more classical heat treatment processes, the literature on induction hardening is more limited. Indeed, the greater number of control parameters makes precise analysis more difficult. The objective of this study is to determine optimal induction operation settings that generate hardness and residual stress profiles enhancing material performance under specific rolling contact conditions. Ultimately, the goal is to develop an empirical rule for quickly estimating the required hardening depths to control the over-tempered zone position and prevent early subsurface microcracks in contact zones. The present study concentrates on disc-to-disc frictionless contact fatigue. This configuration reduces the influence of dynamic force fluctuations. First a semi-analytical contact formulation based on the Boussinesq relations models the problem and establishes the contact pressure distributions. The procedure accounts for the free boundary effects on the contact zones. This contact model also defines the stress distributions beneath the disc surfaces. After that, residual stress profiles are superimposed to produce the complete stress field. Experimental residual stress profiles were measured in France at the CETIM laboratories. The study predicts damage accumulation using multiaxial fatigue criteria. Fatigue life predictions combine stress distributions with hardness profiles modifying the material resistance. They thus incorporate the over-tempered zone influence. Moreover, for an accurate description of real materials, and determine the location of micro-crack formation, the calculation also incorporates the impact of inclusions.