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Robust Design of Case Hardening Depth to Optimize Rolling Contact Fatigue Performance: Numerical Methodology and Theoretical Applications

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ABSTRACT *(USE STYLE: HEADING 1)*

Mechanical components subjected to repeated contact loads (e.g., gears, cams, ball bearings) experience complex subsurface fatigue phenomena, particularly when the steels have undergone case hardening. An insufficient hardening depth can lead to subsurface fatigue failures, such as tooth flank fractures of gears, while an excessive hardening depth may significantly increase costs. Striking a balance between these factors is essential to achieving an optimal techno-economic compromise.

This study proposes a numerical approach based on Hertz theory, extended by Johnson, to evaluate stress fields in depth while accounting for the movement of the contact point.Two models have been developed: a multiaxial fatigue model (DangVan) utilizing stress tensors, and a uniaxial model focused on maximum shear stresses. The integration of the steel hardness gradient and residual stresses, expressed either in tensorial form or through a scalar approach, allows the analysis to capture the specificities of the case-hardening treatment.

The effect of case-hardening depth is explored using two main criteria. The first is a fatigue damage threshold, while the second, referred to as a "robust" criterion, ensures controlled variations in fatigue damage despite potential fluctuations in the case-hardening depth. This methodology defines the minimum required depth for effective performance.

This approach is illustrated through configurations such as cylinder-to-cylinder contact and cylindrical gears, highlighting optimal conditions and limitations in the design process. Ultimately, this methodology aims to provide practical recommendations and develop a set of design rules considering geometric, mechanical, and metallurgical parameters.