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A study of the effect of residual stresses on the rolling contact fatigue behavior of a ductile cast iron

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The effect of compressive residual stresses on the rolling contact fatigue behavior of a quenched and tempered ductile cast iron was studied. The shot-peening process was used to produce a compressive residual stress profile in a group of the specimens. Weibull analysis of the failure data revealed that compressive stresses were detrimental to fatigue life. Additionally, a two-dimensional finite element analysis indicated that compressive residual stresses increased the mode II stress intensity factor of a crack in the contact zone, which agrees with fatigue life findings.

Keywords: rolling contact fatigue, ductile cast iron, residual stress, finite element modeling

1. Introduction

The rolling contact fatigue (RCF) is a phenomenon that can cause mechanical failure of parts as gears, bearings, rail tracks, and cams [1]. Nodular cast iron presents similar mechanical behavior compared to some steels, but the benefits of being cheaper and with better castability [2]. On the other hand, when subjected to cyclic contact loadings, it presents a shorter fatigue life than steels. The use of residual stresses can be a form to improve the performance of materials that might fail in this situation. Studies have been conducted in this way, such as using nitriding [3], but without improving lives. Given this, the effect of shot-peening was verified in the current investigation.

2. Methods

Flat-washer specimens were machined from a casting rod with a graphite count of 210 nodules/mm^2. After quenching and tempering, the hardness of specimens reached 607 HV50. Half of the specimens were tested as quenched and tempered (QT), and the other half were shot-peened to produce a surface with compressive residual stresses (QTS). Both groups of specimens were polished to Ra ≈ 0.1 µm to isolate the effect of roughness.
Residual stress profiles were accessed by X-ray diffraction (XRD), which was applied to control specimens.
RCF tests were carried out in a ball-on-washer machine, under flood lubrication, with a maximum contact pressure of 2.2 GPa. The depth of maximum shear stress for the loading conditions was 65 µm, and compressive residual stress was around 520 MPa in this region.
Additionally, a two-dimensional finite element analysis (FEA) was carried out to verify the influence of the residual stresses on the stress intensity factors K_I and K_{II} of preexisting cracks in the contact zone.

3. Results

Weibull analysis of the failure data revealed that compressive stresses were detrimental to fatigue life since mean life decreased from 7.6×10^6 to 4.0×10^6 cycles, as shown in Figure 1.

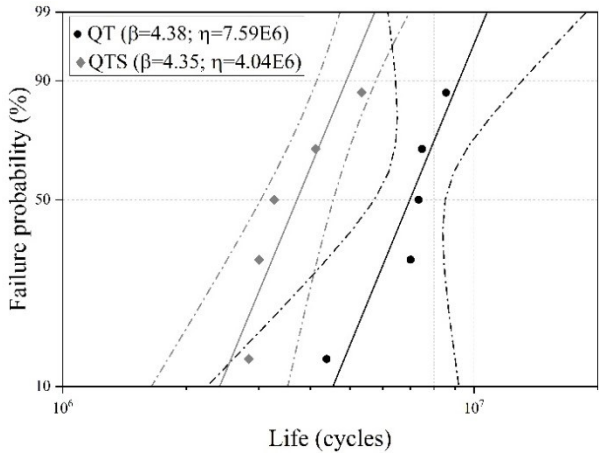

Figure 1: Failure probability curves for QT and QTS groups of specimens. Confidence interval: 90%.

FEA results have shown that the K_{II} stress intensity factor increased with compressive residual stresses.

4. Discussion

In ductile cast irons, the presence of many stress risers, represented by graphite nodules, facilitates crack initiation. In this scenario, crack growth takes an essential place in failure mechanisms. The higher K_{II} stress intensity factor presented in the finite element model that considered compressive residual stress can explain the better performance of QT specimens..

5. References

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