Abstract

The existing standards for thread fastener defects, which specify the acceptable level of defects, are antiquated and overly cautious as they allow no defects in the thread root. To address this issue, a mathematical model has been created to determine the appropriate size of thread defects that should be permitted. The model utilizes Murakami’s equation on fatigue strength and is integrated into a user-friendly graphical interface. This interface allows for the assessment of a batch of bolts with defects in the thread root to determine if they meet customer standards.

Background & Objectives

- Current standards (e.g. ISO 8573-3) are outdated and too conservative. This can be seen in Figure 1, which shows that no defects are permitted in the thread root.
- Can potentially cause Caterpillar to discard usable bolts.

Purpose of Project:
- Create a mathematical analysis of defects in Caterpillar bolts.
- Create an updated method (mathematical model) of determining if specific defects in fasteners are acceptable to be used in engine manufacturing.
- Create graphical user interface with new mathematical model for customer use.

Experimental Procedure

Fatigue Testing Method:
- The bolts were cycled up to five million cycles, or until they failed.
- The mean load was 370 kN for countertorque bolts, and 320 kN for damper bolts. The amplitude of the cycling was about 23 kN for countertorque bolts, and 13 kN for damper bolts.

Data Collection
- Specimens were pre-mounted cross sections of bolts, whole bolts, and bolts that had failed during testing. Examples of these are in Figures 4 and 5.
- Data collection process is summarized in Figure 6, with the bolt sectioning diagram in Figure 7.

Model Development

Stress Concentration Factor (SCF)

- The bolt in an active engine vibrates and causes stress variations as shown in Figure 12. It is assumed the amplitude and mean stress are constant for the life of the bolt.
- Murakami’s Equation
  - Equation 1 is Murakami’s equation for calculating fatigue strength where \( c \) is the fatigue strength amplitude (MPa), \( H \), is the Vicker’s hardness, \( R \) is the stress ratio, and area refers to the defect area (μm) [8].
  - The approximate \( \mu \) value is to be used for shallow cracks, which is \( \frac{c}{\sqrt{6}} \), where \( c \) is the depth of the crack (μm).
  - Equation 2 gives the equation for the stress ratio.
  - Equation 3 gives the value of alpha in the Murakami equation.
  - Equation 4 gives the calculation for \( c \) where FF is the fatigue factor which is a tolerance factor defined as \( \frac{c}{\sqrt{d}} \) where \( d \) is the maximum depth of the defect.
  - The approximation is accurate up to 10⁷ cycles of fatigue.

Conclusions & Recommendations

- Future work can look towards implementation of defects located at the fillet of the bolt by adding the stress concentration factor of the fillet.
- FEA analysis can be done to determine the change in stress concentration factor on the defect as it moves along the flank of the threads of the bolts in order to incorporate the position of the defect on the thread into the model.

References