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# Effect of bolt preload on fretting fatigue behaviour of double lap bolted joints with Class B surface finish in high-cycle fatigue: experimental and numerical investigation.

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**Abstract**
Slip-critical bolted connections are prone to developing fretting damage between the contacting surfaces. In this study, the effect of two different bolt preload values, 90 and 145 kN, on the fretting fatigue behaviour of steel double-lap bolted joints with a Class B (shot-blasted) surface under high-cycle fatigue conditions is investigated experimentally and numerically. The experimental results show that increasing the bolt preload decreased the total fretting fatigue life significantly. Moreover, the proposed numerical method was able to predict the crack initiation and crack propagation behaviours successfully.

## 1. Introduction

Slip-critical bolted connections are joints that have a low probability of slip within their design life, and generally demonstrate improved fatigue performance relative to bearing-type bolted connections. However, slip-critical bolted steel connections are prone to developing fretting damage caused by the inevitable micro slip between the contacting surfaces under repetitive loading conditions, which can lead to fretting fatigue failure. Although significant progress has been made to improve the fretting fatigue performance of bolted connections, there is still a lack of understanding of the fatigue behaviour of slip-critical connections due to its intrinsic complexity. Numerous factors can affect the fretting fatigue behaviour of bolted connections; among them, the effect of the bolt preload is considered significant. In this study, the effect of two different bolt preload values, 90 and 145 kN, on the fretting fatigue behaviour of steel double-lap bolted joint specimens with a Class B surface finish (shot-blasted) was investigated under high-cycle fatigue conditions. From the theoretical perspective, fretting fatigue failure consists of two distinct stages: crack initiation and crack propagation. The contact area between mating plates in bolted connections is hidden and it is very difficult to distinguish fretting damage in terms of crack initiation and crack propagation experimentally; thus, numerical simulation techniques are very desirable.

To predict the crack initiation life and location, a coupled solution based on finite element (FE) simulation using ABAQUS and the fatigue analysis package FE-SAFE was employed. The efficacy of three different multiaxial fatigue analysis approaches adopted in FE-SAFE, including Brown-Miller (BM), Maximum Shear Strain (MSS), and Smith–Watson–Topper (SWT), was assessed in terms of crack initiation location and life. A novel approach based on coupling the virtual crack closure technique (VCCT) and extended finite element method (XFEM), founded on the direct cyclic approach in ABAQUS, was implemented to predict the fretting fatigue crack propagation. Subsequently, the predicted results were compared to the experimental results to verify the accuracy of the proposed methodology.

## 2. Results

The experimental results indicated that all specimens failed due to fretting fatigue in the middle plates. They also showed that increasing the bolt preload resulted in a significant decrease in the fretting fatigue life. Comparison between the predicted and experimental crack initiation locations using FE-SAFE revealed that SWT was the only parameter that was able to estimate the location of crack initiation with good accuracy. Although the BM and MSS approaches showed local minima near the actual location of crack initiation, they both predicted crack initiation locations at the hole edge, which was not consistent with the experimental observations. The FE results also showed that increasing the bolt preload decreases the fretting fatigue crack initiation life significantly under high-cycle fatigue conditions. In terms of the crack propagation, despite some differences, the simulated and experimental crack paths were quite close. The numerical results for crack propagation showed that increasing the bolt preload caused the crack to propagate more quickly, thereby deacrising the fretting fatigue crack propagation life.

## 3. Conclusions

The experimental results showed that increasing the bolt preload decreased the total fretting fatigue life. Moreover, the proposed numerical method was able to predict the crack initiation and crack propagation behaviours successfully.