Three-dimensional finite element simulations and experimental validation of fretting and sliding wear

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Wear tests involving thousands of operating cycles can be impractical and costly. Therefore, a Finite Element (FE) method can be a good alternative. A generalised FE method is presented here to determine the wear of mechanical components. The validated method predicts wear profiles of the ball and disc. The wear simulation procedure is based on Archard's wear law using a commercial FE package, ABAQUS. The surface evolutions of both contacting bodies are calculated simultaneously. The generation of artificial roughening of the worn surfaces due to numerical restrictions of element sizes are minimised.

Keywords: Sliding wear, Finite element modelling, Contact mechanics, Bearings

1. Introduction

Wear occurs when two surfaces slide against each other. Predicting wear on the components of any mechanical system efficiently is important in safety-critical industries such as nuclear and aerospace. The most common type of wear study is a pin-on-disc type tribometer test performed in a lab setting which can be inefficient and time-consuming. A method for 3D wear simulation is presented here, where wear occurs simultaneously on both surfaces. This presented method is fully automated and can simulate wear on both similar and dissimilar materials.

2. Methods

The non-linear contact problems on the two sliding surfaces are solved using the commercial Finite Element (FE) package, ABAQUS v2019. Standard Archard's wear model is used. Wear is applied as a function of nodal contact pressures and experimentally derived wear coefficient. The calculated wear parameters are then applied via UMESHMOTION subroutine. This method leads to artificial roughening of the worn surfaces due to numerical restrictions of element sizes [1]. A smoothening method is proposed to reduce this artificial roughening. Smoothening is based on refining the evolved surfaces using the second-order curve fitting method so that the evolved surfaces maintain the parabolic cylindrical shape for the disc and that of a circular paraboloid for the ball. Simulation of the entire sliding test where wear depths are in tens of micron deep is computationally prohibitive. Thus, an extrapolation method based on the best curve fitting approach is used. The method is summarised in Figure 1. Figure 1 shows a FE model for pin-on-disc type sliding test and sample contour plots for the worn ball and disc surfaces. The wear heights are denoted as 'U3', corresponding to the Z-direction.

3. Discussion

Wear calculations from finite element analysis (FEA) are computationally expensive and can be sensitive to the size of wear steps and mesh sizes on the contact region. Decreasing the size of wear steps or decreasing the element sizes results in significant cost on the computational time. Sensitivity studies on mesh sizes on wear step sizes are important to minimise computational time while obtaining sufficiently accurate results.

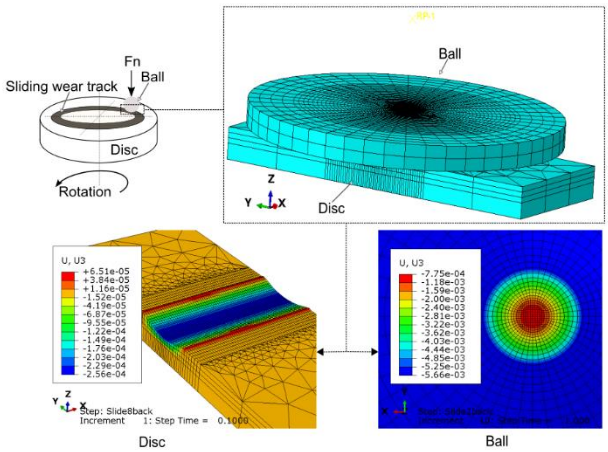

Figure 1: Summary of FE model and wear profiles on the ball and disc surfaces after reduction of artificial roughening

The proposed smoothening method can also be based on higher-order polynomials than the quadratic surfaces used here if required for more complex wear profiles. Since FEA is a versatile tool, the developed method within the FEA framework is applicable to a wide range of fretting and sliding wear tests. The model can be updated to consider tribofilm or oxide layer growth or removal, which is of particular interest when mechanochemical reactions and tribofilm formation are important to capture the system performance.

Comparison of the FEA results with the test results from different applications and different materials show wear profiles can be predicted well for both fretting and sliding tests. The maximum discrepancy was ~10 % considering the statistical error margin of the tests.

4. References

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