INFLUENCE OF CONTACT CONDITIONS ON FRETTING FATIGUE UNDER SPHERICAL CONTACT

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Summary This work analyzes the effect in fretting fatigue (stresses, stress intensity factor, eccentricity of the stick zone and estimated life) with spherical contact of several assumptions needed to calculate the stresses beneath the contact. These assumptions are: *i)* supposing plane stress or plane strain when introducing the bulk stress on the element; *ii)* taking or not taking into account the eccentricity of the stick zone due to the bulk stress.

INTRODUCTION

Fretting is a particular case of fatigue in which the stresses close to the contact surface are dominated by the contact between two solids that tend to slide. In addition to these local stress fields in the vicinity of contact, one or both of the solids may be subjected to a bulk stress caused by cyclic loads. This initiates many cracks in the process zone. These cracks may grow until final fracture occurs across one of the elements. In order to model this phenomenon correctly it is necessary that the stresses are calculated as accurate as possible. The stresses in the contact due to a normal constant load and a cyclic tangential load with spherical contact were deduced by Mindlin [1]. In this situation the contact zone has the shape of a circle and it has an inner, centered circle where no slip occurs between the surfaces (the stick zone) and an annulus around the stick zone where slip takes place. A bulk stress can be added to one of the elements in contact shifting the stick zone to one side [2]. Until not long ago the eccentricity of the stick zone was not taken into account when calculating the stresses but, obviously, that is an approximation. To solve this problem the deformation due to the bulk load is added, but a hypothesis has to be made, whether it behaves as plane strain or plane stress. These two points (plane stress/plane strain and eccentricity/no eccentricity) may vary the calculated stress field under the contact. The objective of the present work is to decide which option is the best and to determine the influence of it on the stresses, the stress intensity factor (SIF), the eccentricity of the stick zone and the estimated life.

STRESSES AND ECCENTRICITY

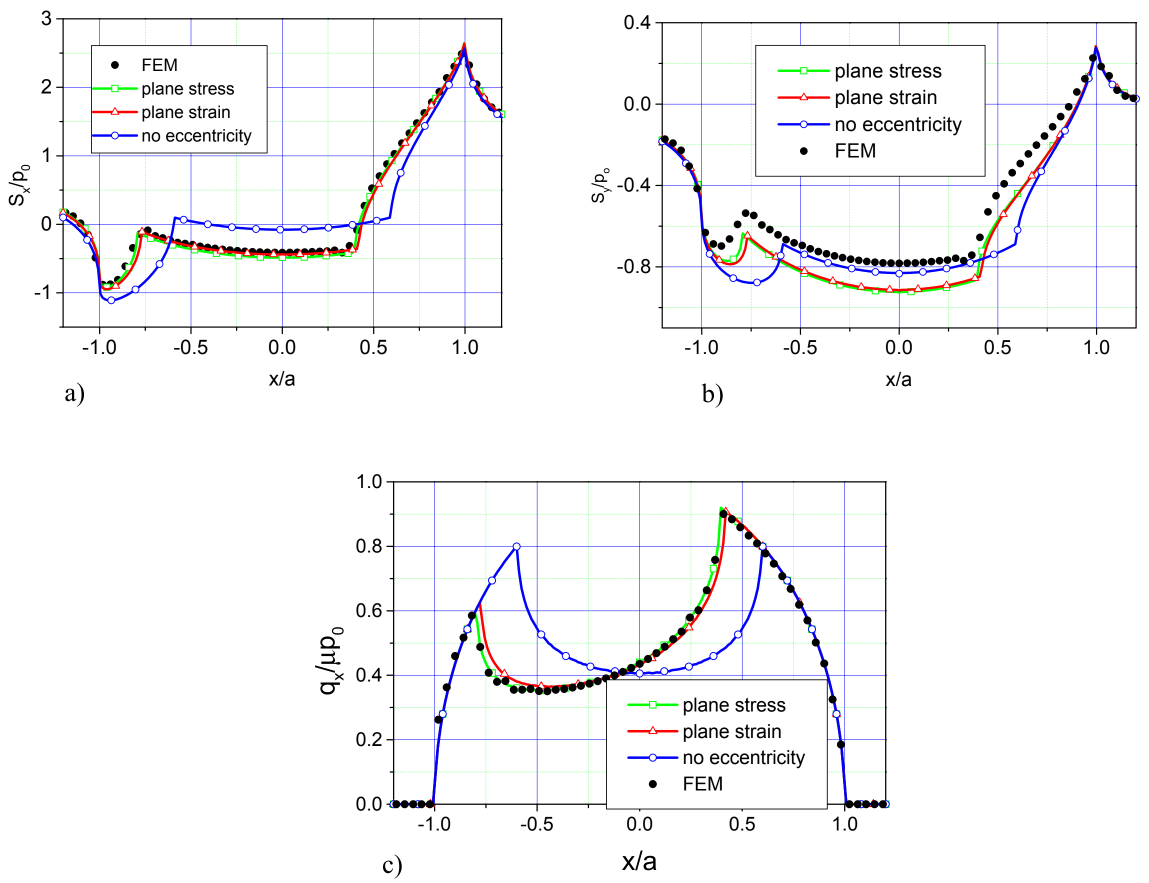

Fig. 1. Stress distribution on the surface on the line of symetry of the contact; a) normal stress in the loading axis; b) normal stress perpendicular to the loading axis; c) shear stress in the loading axis.

The stresses for the different conditions are obtained in a specific example, a 10x10mm cross section specimen of Al7075-T6 subjected to a normal load of 100N, a cyclic tangential load of 94.77N and a cyclic bulk stress of 110MPa. Figure 1 compares the analytical solutions for this problem with the Finite Element Method (FEM) solution. They show that the stress distribution for plane stress, plane strain and FEM are very similar but quite different for the case of no eccentricity. Nevertheless, the maximum normal stress in the direction of the loading axis and perpendicular to it has approximate the same value in the four curves, Fig. 1a and 1b. It can also be observed in the three figures, but more clearly in Fig. 1c, that the stress distribution and the value of the eccentricity of the stick zone is better represented by assuming plane stress.

STRESS INTENSITY FACTOR

The SIF is obtained analytically integrating, along the crack path, the stresses multiplied by a weight function. Figure 2 shows the analytical solution for the three possibilities (no eccentricity, plane stress and plane strain) for the example chosen. It can be seen that plane stress and plane strain give similar results. The SIF with no eccentricity is lower during initiation but very similar when the crack is long. The reason is that in the latter region the principal stress is due to the bulk stress which is the same for the three cases.

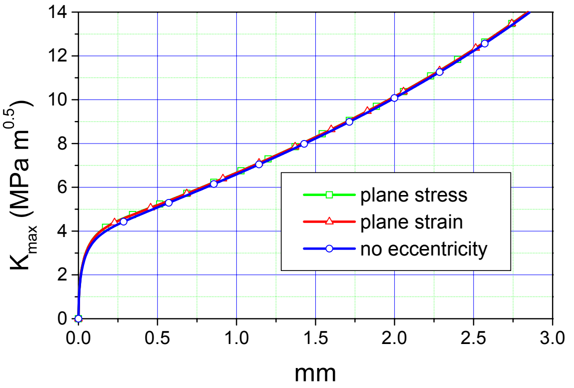

Fig 2a. SIF along the crack path.

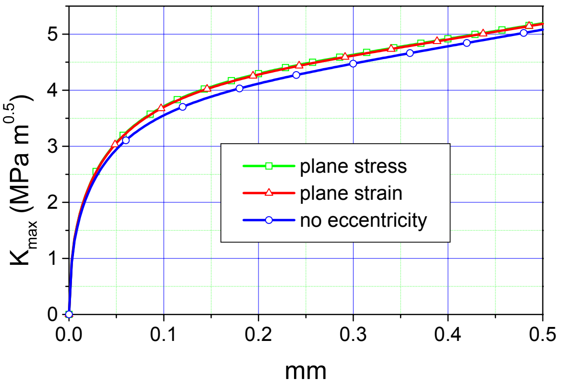

Fig2b. SIF along the crack path during initiation.

ESTIMATED LIFE

The influence on the estimated fretting fatigue life is studied using a model developed by the authors [3]. This model separates fatigue life into two phases, initiation and propagation, without fixing in any way beforehand the limit between initiation and propagation. The model uses a multiaxial fatigue criterion based on the calculated stresses to determine the initiation life and a crack propagation law together with the stress intensity factor to obtain the propagation life. The higher stresses in the case of plane stress produce shorter initiation and propagation lives, making the result more conservative, although quite similar to that of plane strain. Table I shows the estimated life for the three cases, the increment of the estimated life compared to that of plane stress, the maximum normal stress on the surface and the increment of this stress compared to that of plane stress. It can be observed that small variations of stresses produce large variations of the estimated life.

Table I. Results of the obtained estimated life.

	Life	Δ%	Max Stress (MPa)	Δ%
Plane stress	133078	-	387	-
Plane strain	134511	1.1	386.06	-0.24
No eccentricity	151086	13.5	375.6	-2.95

References

[1] Mindlin R. D.: Compliance of Elastic Bodies in Contact, *Journal of Applied Mechanics*, **16**:259–268, 1949.

[2] Navarro C, Domínguez J.: Contact conditions and stresses induced during fretting fatigue. Computational Methods In Contact Mechanics IV, L. Gaul y C. A. Brebbia, Eds. WIT Press/Computational Mechanics Publications, pp. 453-462, 1999.

[3] Navarro C, García M, Domínguez J, A procedure for estimating the total life in fretting fatigue, *Fatigue and Fracture of Engineering Materials and Structures*, **26**:459-468, 2003.