Simplified method to determine contact stress distribution and Stress intensity factors in fretting fatigue by T. Kimura and K. Sato: A Review.

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Introduction

Fretting means the gradual wear of a surface due to friction. Fretting fatigue [1] occurs in mechanical parts and engineering structures subjected to repeated contact movement. The fact that fretting reduces fatigue strength (ability to withstand fatigue) makes it a very key factor to consider in the design and maintenance of engineering structures and mechanical parts. It is held and indeed obvious that in fretting fatigue cases micro-cracks initiate at the edge of the contact region. These cracks are propagated by the combination of contact pressure, bulk fatigue stress and friction stress [8]. If these cracks occur early they usually lead to the reduction of life in fretting fatigue as well as the high growth rate in the short crack region. Kimura and Sato [8] noted that Rooke and Jones [3] derived the solution for stress intensity factors of K_I and K_{II} under fretting loadings, especially cracks that are perpendicular to the surface and analysed the effects of contact pressure and frictional stress on stress intensity factors. Stress intensity factors are elements of the expressions that determine the state of the stress, and the latter is known as stress intensity. K_I and K_{II} refer to modes of Open and In-Plane Share respectively. They [8] also noted that Edward [5] used the solution of from [3] to establish seven types of stress distributions and their stress intensity factors. In the publication of [4] the method of [3] was extended to oblique cracks morphology. The authors of this paper under review [8] and [4] established a simpler computer program for computing stress intensity factors. This involved the application of boundary element method for various loading geometrical conditions. The establishment of a database of contact stress distributions and their interpolation. The determination of the exact contact stress distribution and stress intensity factors for any arbitrary loading and geometrical condition of fretting fatigue.

Analytical Procedure

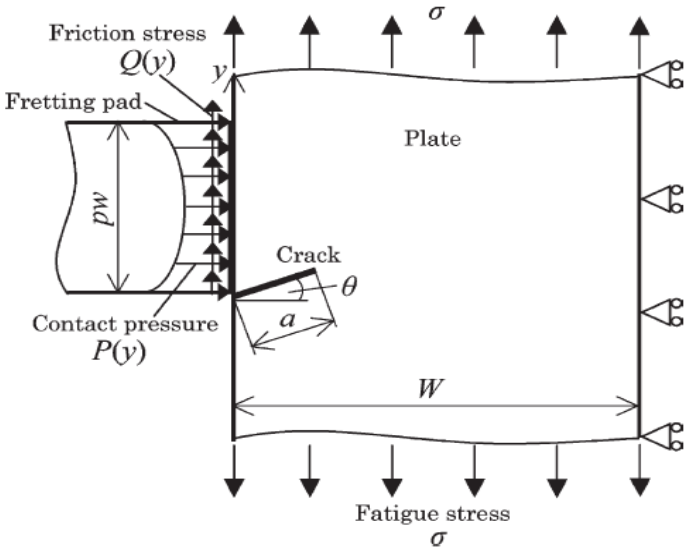

Fig. 1. Fretting fatigue analysis model.

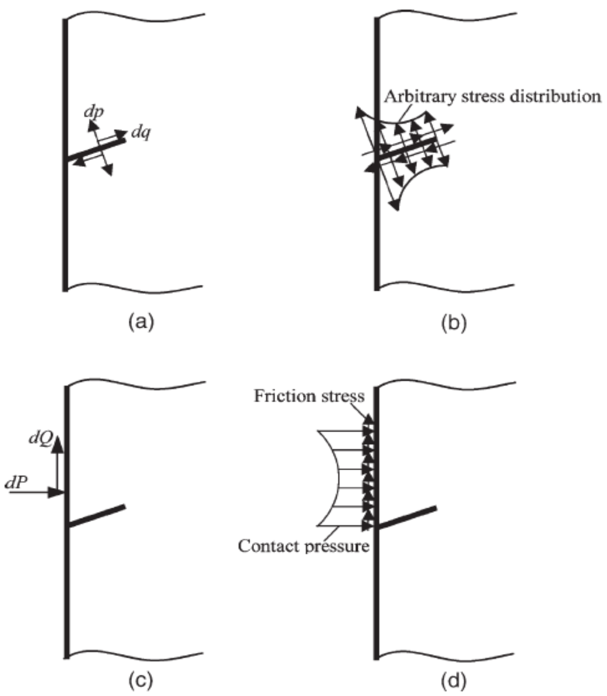

Fig. 2. Schematic illustration of the solution process: (a) internal loads, (b) distribution of internal loads, (c) external loads, and (d) distribution of external loads.

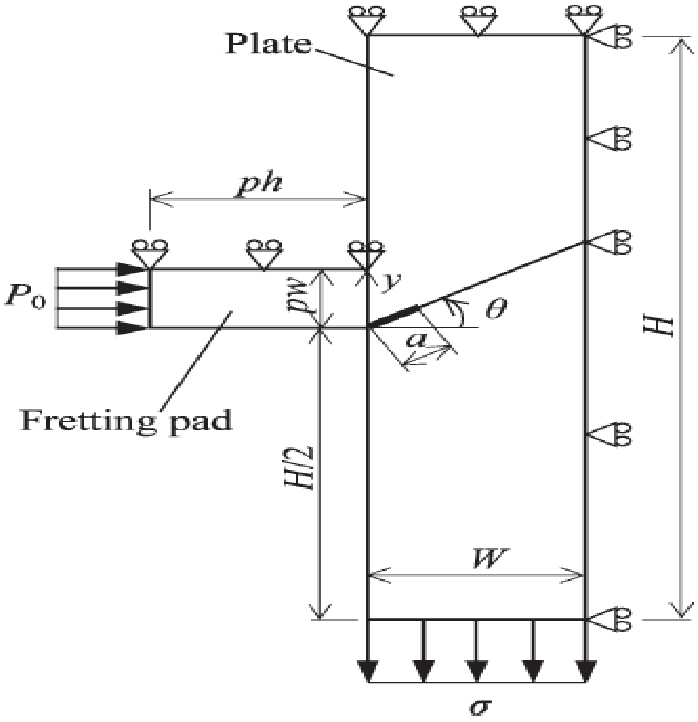

Fig. 3. Boundary element analysis model.

The authors [2] and [8] adopted the models above which were also the case with authors [5-7]. In this case it is assumed that a single straight crack is initiated at the contact edge of the fretting pad. A general expression was derived by the authors in [4] for calculating the stress intensity factors of oblique cracks in fretting fatigue. This is simply done by substituting the values of crack length *a*, crack angle q, pad width *pw*, plate width *W*, fatigue stress s, distributions of contact pressure *P*(*y*) and friction stress *Q*(*y*) into the expressions[4]. They established a database by analysing the elastic boundary elements of certain geometrical and loading conditions. They obtained the distributions of contact pressure and friction stress at the contact interface; see fig.3 above. The contact boundary between the fretting pad and the plate had 213 nodes after a very fine mesh [4]. Note that *y* is the distance from the crack tip and *pw* the width of the fretting pad. They summarized the calculated values of normal and tangential stresses at the 213 nodes of the contact boundary noted above represented by $P(y_i/pw)$ and $Q(y_i/pw)$ ($i = 1,2,3, \ldots, 213$), respectively, then arranged them by the parameters a/pw, Θ, μ and σ/P_0. In fig. 3 above the contact stress P_0 and fatigue stress σ are given as uniform distributions at the ends of the plate and fretting pad respectively. Uniform Distribution is a distribution that has a constant probability, so in the case we have in fig. 3 it can be said that the contact pressure from the fretting plate will yield a fatigue stress in the plate that is uniformly distributed relative to it or directly resulting from its application. If it is uniform then the probability of the fatigue stress occurring on the plate is expected to be constant or predictable as far as the contact stress has been applied. This also goes to say that the fatigue stress on the plate is a fraction of the contact stress from the pad hence the reason we have σ/P_0 so far. In essence distributions refer to portions, divisions and fractions.

With the established database the contact stress distributions were obtained by interpolations for arbitrary values of the four parameters a/pw, θ, μ and σ/P_0. So for each value of the 213 nodes the normal and tangential stresses were obtained by four dimensional interpolations with the least square approximation with respect to the four parameters a/pw, θ, μ and σ/P_0. This means that some or at least four of these dimensions have to be established empirically or referring to reference data. These dimensions can be as it concerns any of the four parameters; in other words four known values of σ/P_0 or that of any other one. The unique feature of this program as the authors put it is such that it can be used in a wide range of fretting fatigue conditions for the determination of stress intensity factors without fore knowledge of the stress distribution figures.

In the results it was noted that K_I decreases with an increase in the crack angle and the increase of the latter results in an increase of K_{II}. These changes are much prominent under the fretting fatigue conditions relative to plain fatigue cases.

In the discussion the crack growth rate came into the picture as σ = 0 MPa will yield a negative K_I and the need to see the evolution of the former with an increase in the values of σ. The determination of the crack growth rate was pursued by using the stress intensity factor range ΔK and it had to be within the positive values of K_I for ranges of modes I and II [4]. The point at which K_I goes from negative to positive the ratio of the fatigue stress to the contact stress is denoted as $(\sigma/P_0)_{open}$ according to the authors [4]. With that in mind it can be seen that if the fatigue stress is not significant that the ratio will be small as such resulting in the closure of the crack since the fatigue stress is expected to keep it open or open it up as the case may be. The authors [4]; have it that contact pressure of the fretting pad leads to crack closure and yields a negative K_I value. When the value of the ratio σ/P_0 increases friction and fatigue stresses become more significant and more effective and since they are expected to keep the crack open or open it up the K_I value becomes positive. It can also be deduced that contact pressure affects crack closure when the crack angle is increasing because if the crack angle is increasing then it has to be that the fatigue stress is also doing likewise the contact pressure and frictional stress. This then implies an increasing value of $(\sigma/P_0)_{open}$ for obvious reasons will affect the crack angle.

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