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Static behaviour of a shaft with an elliptical crack

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ABSTRACT

Cracks in mechanical components produce changes in their behaviour like increases of displacements or decreases of frequencies due to the flexibility increase. Some works related to the analysis of the behaviour of cracked shafts consider the front of the transversal fatigue cracks to be straight, but experience says that the front of these kind of cracks is approximately elliptical. Many expressions have been given for the flexibility of a cracked shaft with a straight front whereas, for elliptical cracks, only an approximate expression for the flexibility has been found in the literature. In the present work, flexibility expressions for cracked shafts having elliptical cracks are obtained, based on the polynomial fitting of the stress intensity factors, taking into account the size and shape of the elliptical cracks showing results according with reality. The static displacements in bending of the shaft for different support conditions have been calculated. The comparisons between these results and those obtained by FEM analysis and by experimental tests show that the closed-form expressions for the flexibility give us a very good approximation to the behaviour of the cracked shaft.

1. Introduction

As is well known, the presence of a crack in a mechanical element produces an increase in its flexibility which is accompanied by an increase in cross displacements and a decrease in vibration frequencies or modifications of the transversal section orbits for rotating machinery, among others. Those changes could be used to detect the presence of a crack and also, to identify its position and size. So, it is of interest to establish a relationship between the flexibility of a cracked mechanical element and the properties of the crack (shape, position and size), for example, in the case of mechanical elements performing under fatigue conditions, in which a catastrophic failure would be produced as a consequence of the rapid growth of incipient cracks.

The cracked elements are usually modeled considering the classical model proposed by Freund and Herrmann [1] consisting in two undamaged parts of the element connected by a rotational-linear spring. The behaviour of the cracked element is related to the mechanical properties of the spring. The loss of stiffness introduced by the crack has been used to determine the vibrational behaviour of a cracked shaft [2–10] or to study the dynamical behaviour of a cracked shaft [11–13].

In rotating shafts, frequently cracks grow following transversal planes to their longitudinal axis due to the fatigue produced by the cyclic loads to which they are submitted. This type of cracks (surface cracks) in this conditions are supposed to take an elliptical shape front [14–19]. In order to detect the presence of the cracks and to identify their position and length, some studies have been carried out since the first works of Gasch [20]. In many of those works, a

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