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LETTER TO THE EDITOR

Comments on "Failure Analysis of Rotating Disks" *Int. J. Solids Structures*, Vol. 32, pp. 1307–1318 (1995)

After having noticed the publication of the Bert and Paul paper, we feel it necessary to make the following comments since:

—their paper makes incorrect statements about our previous paper (Köhl and Dhondt, 1993), and
—their method of analysis gives rise to a number of questions.

The intention of our analysis was to find out whether the worst failure case—i.e. the emergence of disk-pieces having a size with maximum translational energy—is possible. For this reason an example was calculated whose geometry corresponds to a real existing engine disk. We showed for this special example that after primary radial cracking a second failure can happen at about 120° away from the original failure which indeed means a resulting disk piece of about the maximum possible translational energy. The same result was obtained in a subsequent publication using a higher order theory (Dhondt, 1994).

However, for other geometries our analysis predicts secondary failures at angles generally different from 120°.

Thus, Bert and Paul incorrectly state that our analysis implies a prediction of a 120° angle independent of the geometry. They even argue using their own method that a uniaxial treatment like the one we used in combination with a maximum principal stress criterion necessarily leads to a failure angle of 120° regardless of the geometry. They state:

"It is evident from our analysis that the maximum tensile principal stress always occurs at about 120° for $\gamma = 0.1$–0.5, which implies failure of the disk into three equal pie-sector shaped fragments. The uniaxial treatment of the problem has been demonstrated by Köhl and Dhondt (1993). They have addressed failure of the disk into three equal pie-sector shaped fragments by the modal analysis technique." (Note: γ is the ratio of inside radius to outside radius of the disk having constant axial thickness.)

Contrary to this "proof", our work reveals by simple evaluation of eqn (64) and Fig. 9 for disks with constant axial thickness for $\gamma = 0.1$ the second failure at 108°, for $\gamma = 0.5$ at 90°, and for $\gamma = 0.9$ at 58°. Thus, Bert and Paul derived an obviously wrong conclusion from their analysis.

The conceptual approach of their disk analysis—extensively explained in Section 2—is hard to understand. The analysis performed in Section 3 gives rise to the following questions: no assumption is made about the radial stresses at the inside and outside boundary of the ring and about the shear stresses inside. These quantities are forced by the selected solution (5), (6) in connection with the boundary conditions (7). Why should the resulting radial and shear stresses be representative for real conditions? Take the example of an engine disk like that of our research: because of a load-free inside boundary the radial and shear stresses must be zero. Even for a disk fitted to a shaft, how is it possible that radial tensile stresses occur as in Figs 6–13?

Bert and Paul emphasize the necessity of considering a part-radial crack rather than a complete crack which was calculated by us. However, their results don't support this necessity since the resulting failure angle in the part-crack analysis is exactly the same as in the complete crack analysis:

Fig. 6 (part-crack) and Fig. 10 (complete crack) yield 90° for $\gamma = 0.1$, analogously Fig. 7 and Fig. 11 also 90° for $\gamma = 0.3$, and Fig. 9 and Fig. 12 show 74° for $\gamma = 0.5$.

They mention repeatedly that a disk broken into three pie-sector shaped fragments, corresponding to symmetrically occurring secondary failures at 120° away from the original crack, has been observed neither in their analysis nor in the quoted experimental work of Sato and Nagai. However, in their introduction they cite Bandera *et al.* (1993), who for small γ-values analytically predict the occurrence of three fragment pieces and quote papers (e.g. Suzuki and Wada, 1972) which have documented experimental evidence for a failure in three parts.

Another question concerns the assertions Bert and Paul make about the total number of disk fragments being produced after an initial failure. For example, according to Fig. 6, a stress maximum occurs at 90°, from which they conclude that the disk will break into four equal pie-sector shaped fragments. However, this does not follow from their analysis. Their criterion simply leads to a second failure at 90° and a third one symmetrically at $-90°$, yielding two 90°-sectors and one 180°-sector, but there is no evidence following from the analysis that the last piece will be split into two halves.

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