DISCUSSION

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The significant finding of this paper is that the stresses in the dovetail appear fairly symmetrical despite the severe lack of symmetry in the individual sections through the transition between the airfoil and the root. This observation apparently justifies the conventional two-dimensional root study. However, some of the data presented appear erroneous and hence raises doubt about the authenticity of this finding.

It is noted that the pattern of stresses in the root determined by the three-dimensional analysis as presented in Figs. 4–7 differs considerably from that of the two-dimensional analysis. The pamphlet version of this paper on which discussion was invited, showed impossible lines of zero radial stress cutting across the root between the main portion of the blade and the retention points. The initiation of this discussion resulted in a private response from Dr. Schaller revealing the present corrected versions of Figs. 4–7. However, even these corrected stress patterns do not fully allay the original doubt.

Although identification of the dotted lines as contours of zero radial stress has now been largely omitted, its retention in several locations and the nature of the contours indicate that a change in this identification was not intended. Accordingly, impossible lines of zero radial stress have not been eliminated; two segments now appear in each section.

The islands of compressive radial stress shown in Figs. 4, 5, and 7 are further cause for doubt. A surface cutting through the root between the main portion of the blade and the retention lines through these islands may be imagined. Since the radial stress across a large portion of such a surface would be compressive, high local tensile stresses would be required to maintain equilibrium. No such required tensile stresses are indicated by the stress contours shown. Comparison with the two-dimensional radial stress pattern that may be deduced from Figs. 10 and 11 reveals no such islands of compressive stress. The difference in the root angle does not seem a likely explanation for such drastic difference in stress pattern. Moreover, the large friction force assumed by the three-dimensional study might be expected to extend the region of tension as it does in the two-dimensional study.

It appears possible that Figs. 4–7 are contours of maximum principal stress, as in Figs. 10 and 11. However, even this interpretation would not explain the compressive islands. A clarification of the results is necessary if the promising findings are to be convincing.

Authors' Closure

The authors thank Mr. Klompas for his comments, however, we do not agree with several of his conclusions.

1 The three-dimensional study presented in this paper revealed that the maximum tensile stress occurred in the root (dovetail) of the blade. Despite the lack of symmetry in the individual sections through the transition between the airfoil and root, the maximum tensile stress always occurred between the support point and the neck of the dovetail as shown in Figs. 4–7.

This in conjunction with the fact that it was not economically feasible to carry out a parametric study with the three-dimensional blade model is the justification for the two-dimensional parametric

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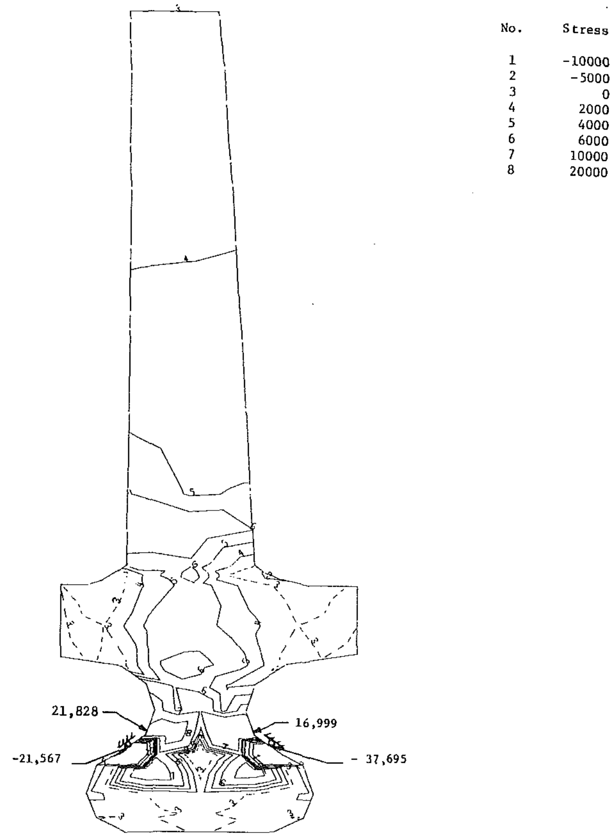

Fig. 16 Computer plot of radial stress contours on section 400

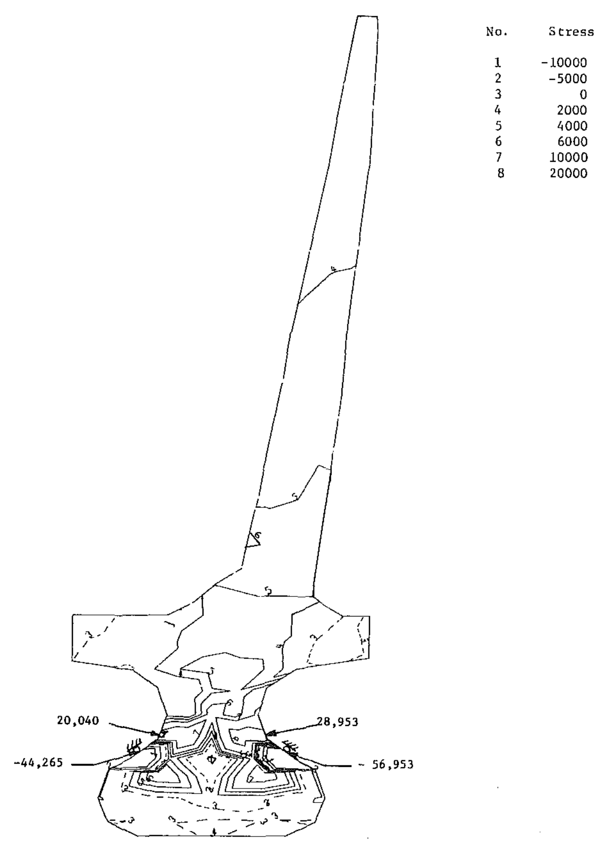

Fig. 17 Computer plot of radial stress contours on section 700

No.	Stress
1	-20000
2	-10000
3	-5000
4	-2000
5	-1000
6	0
7	1000
8	2000
9	4000
10	6000
11	8000
12	10000
13	15000
14	20000

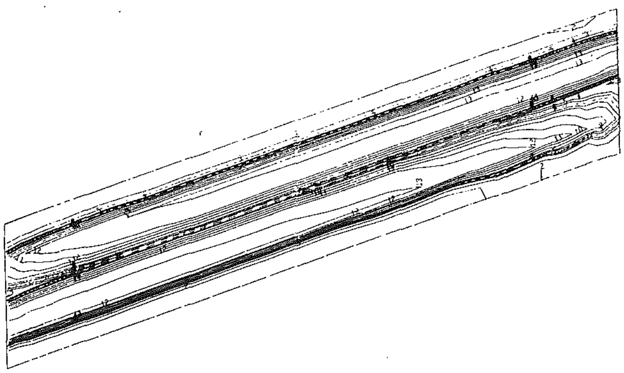

Fig. 18 Computer plot of radial stress contours on horizontal section slightly above the supports

No.	Stress
1	-20000
2	-15000
3	-10000
4	-5000
5	0
6	5000
7	10000
8	15000
9	20000

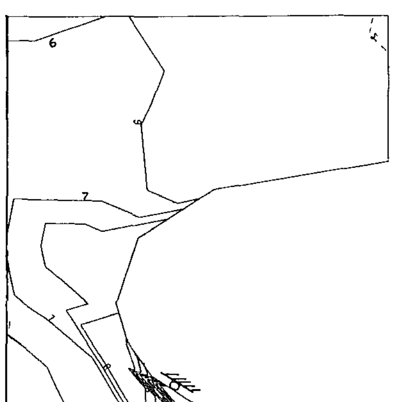

Fig. 19 Radial stress contours in a 60 deg root two-dimensional analysis

No.	Stress
1	-20000
2	-15000
3	-10000
4	-5000
5	0
6	5000
7	10000
8	15000
9	20000
10	30000

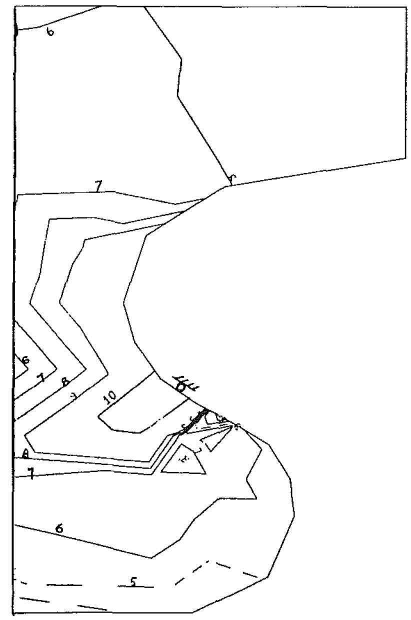

Fig. 20 Maximum principal stress contours in 60 deg root two-dimensional analysis

study presented in the paper.

2 Figs. 4–7 show only selected contours. The contours shown were drawn by hand and are based on element stresses. In a displacement formulation the element stresses are not continuous across element boundaries. This causes difficulties in drawing contours particularly for three-dimensional problems where the section on which the contours are to be drawn does not coincide with the element boundaries.

Numerical procedures can be incorporated in three-dimensional finite element codes to generate stress contours on arbitrary planes. Figs. 16 and 17 show the computer generated radial stress contours for sections 400 and 700 which include additional contours not shown in Figs. 5 and 7.

Comparison of the contours of Figs. 5 and 7 with those of Figs. 16 and 17 shows that except for the additional contours only minor differences exist between the hand and computer drawn contours. As a further check the equilibrium at a section parallel to the θ-Z plane slightly above the supports was computed based on the centrifugal loads and the radial stress contours shown in Fig. 18. Numerical integration of the radial stresses acting on this section check to within 7 percent of the applied centrifugal load acting above the section.

3 Since high compressive stresses occur at the roller supports and tensile stresses occur elsewhere in the root, a zero stress contour is not only possible but is a necessary condition if the stresses are to be continuous. It should be noted that large shearing stresses may occur on a zero radial stress contour surface.

4 The occurrence of "islands" of compressive stress depends on the magnitude of the friction force. Fig. 19 shows the radial

stress contours obtained with a two-dimensional analysis of a 60 deg root under slightly different loading conditions than those shown in the paper. The islands of compressive stress are present in this case, however, when the friction force is decreased in magnitude these islands will disappear. Fig. 20 shows the major principal stress contours for the same case as shown in Fig. 19. It can be seen that the islands are not present in the principal stress plots. This is, of course, due to the presence of other stress components.