

## DISCUSSION

### E. Atkinson

The application of a more computer efficient dynamic analysis to a potentially costly real problem area is a welcome step along the road towards the goal of making this technique a viable design and troubleshooting tool.

Cage and guide land wear has, at times, been a major irritant to several aero engine manufacturers and can prove, in the discussor's experience, to be less than consistent in its response to normal modifications. The ability to theoretically compare potential design solutions and to subsequently correlate with service experience over several million hours is therefore a goal worthy of sustained effort.

Within the general debate on cage wear the subject of cage balance periodically claims the focus of attention and hence the comments of the authors would be particularly welcome on the following observations.

Examination of ex-service cages from mainshaft applications, mostly in excess of 2 million DN, has shown frequent evidence of uniform light polish of the silver plate. The inference drawn was that the mass eccentricity was less than 50 percent of the diametral clearance and cage/race contact was essentially due to ball excursions and rotor dynamics.

The authors' suggestion that the cage eccentricity approached 1.0 for all levels of out-of-balance and that the contact was always opposite to the out-of-balance is therefore of specific interest. It would be particularly useful if the authors could indicate the calculated mass eccentricity at each level of out-of-balance and how it compares with the hot running diametral clearance between the cage and the locating lands.

In conclusion, the authors are strongly encouraged to expand this work to encompass variations in cage mass, flexibility, location land geometry, and lubrication.

### Authors' Closure

The authors are thankful to Mr. Atkinson for his very practical and encouraging comments.

Actual values of mass eccentricity for the levels of unbalance investigated in the paper are as follows:

Unbalance (gm.cm)	Mass Eccentricity (mm)	Mass Eccentricity
		Radial Clearance
0	0.	0.
9	0.133	0.511
17	0.249	0.958

The values of mass eccentricity, indicated above, represent actual shift of the cage mass center relative to its geometric center. The position of cage mass center relative to the center of the guiding race is equal to the radial clearance at all levels of unbalance, which results in a steady cage/race contact, as reported in the paper. A light uniform polish on the cage guide surfaces basically implies a very light cage/race contact force and a continued variation in cage/race contact angle from 0 to 360 degrees, as shown in figure 8 for the balanced cage. Thus, the observation of a uniform light polish on the cage surfaces, as reported by Mr. Atkinson, would indeed imply that the cage/race interaction was essentially a result of ball excursions within the cage pockets, and there was no significant unbalance on the cage.