NON-LINEAR ANALYSIS OF A PROPELLER BLADE RETENTION SYSTEM

John C. Lambert

United Technologies Corporation Hamilton Standard division

One Hamilton Road

Windsor Locks Ct. 06096

ABSTRACT

A primary problem in the design of aircraft propeller systems is the prediction of blade natural frequencies. A major problem in predicting these frequencies is determination of the blade retention stiffness. This stiffness is difficult to determine due to the many linear and non-linear variables involved in such systems. This paper discusses the manner in which MSC/NASTRAN V65B was used to advance Hamilton Standard's methodology in evaluating blade retention stiffness.

DESCRIPTION OF HARDWARE:

Figure 1 shows a typical blade retention configuration. The basic components include a blade shank, ball bearing(s) and a propeller hub. During operation the blade shank is subjected to large centrifugal and shear forces along with large in and out-of-plane moments. Variations in these loads coupled with the inherent non-linearities of ball-bearings result in significant fluctuations in the blade retention stiffness.

CURRENT PROCESS:

The current process for prediction of retention stiffness involves the use of MSC/NASTRAN coupled with an in-house ball-bearing program. Blade loads are fed into the bearing program and a ball load distribution is returned. These loads are then applied to a finite element hub and analyzed. The deflections from this analysis are fed back into the bearing program as race deflections. This process continues until a solution is converged upon. This process assumes the shank race to be rigid and is a source of error in the final frequency calculations.

NEW APPROACH:

To increase retention stiffness prediction accuracy a non-linear ball bearing modeling technique was used[1]. This technique involves the use of non-linear CROD elements and sol66 large displacement analysis. Figure 2 shows a finite element model of a hub. Figure 3 shows a detailed finite element ball representation. Each ball in the bearing was modeled in this manner. The model shown in Figure 2 has 128 balls.

With this modeling technique the blade loads are applied directly to the shank. This represents a significant savings over the former method in that each ball load had to be applied to the propeller hub each time an iteration was carried out.

This model ran approximately 20 cpu minutes on a CRAY X-MP. The results were rather promising.

RESULTS:

In order to evaluate the new method results, identical load cases were run with the old and the new method. One of the load cases used was a pure centrifugal load. Figures 4a and b show the inboard and outboard ball bearing load distributions for the two methods. The load distributions for the two methods show large variations. It was suspected that the major reason for the load distribution variations was the rigid shank representation used in the former method. To verify this the new MSC/NASTRAN model was run with a rigid shank. The results of this run are shown with the former method results in Figures 5a and b. As a result of this close correlation the new non-linear ball modeling technique has been adopted as the new analysis technique at Hamilton Standard.

FUTURE DIRECTIONS:

An additional benefit would be determination of the entire propeller system natural frequencies. Due to the absence of a non-linear cyclic symmetry capability in MSC/NASTRAN the entire propeller system would have to be modeled. Modeling the full hub, blades and retentions would require a rather large model. The model size, coupled with material non-linearities, geometric non-linearities, large displacements and superelements, would present quite a challenge for our system and MSC/NASTRAN. Positive results from such a technique would provide significant benefits to our propeller design methodology.

[1] P. McHorney, T. Banholzer, N. Itkin, S. Gassel, S. Goldenberg, "Integrated Nonlinear Finite Element Analysis Of Ball Bearing-Structural Systems" Hughes Aircraft Company, El Segundo, California.

BLADE RETENTION

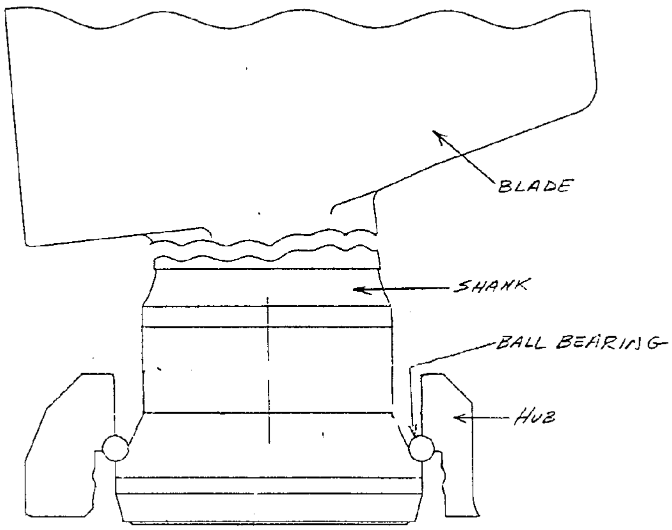

FIGURE 1

FINITE ELEMENT HUB MODEL

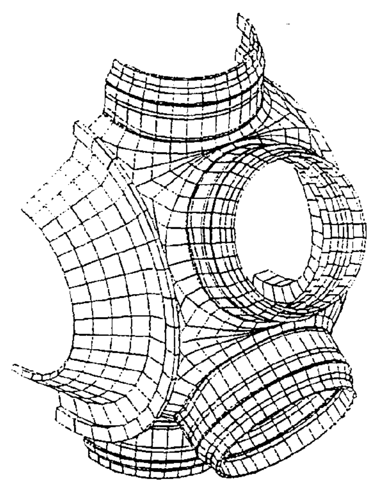

FIGURE 2

BALL/RACE FINITE ELEMENT REPRESENTATION

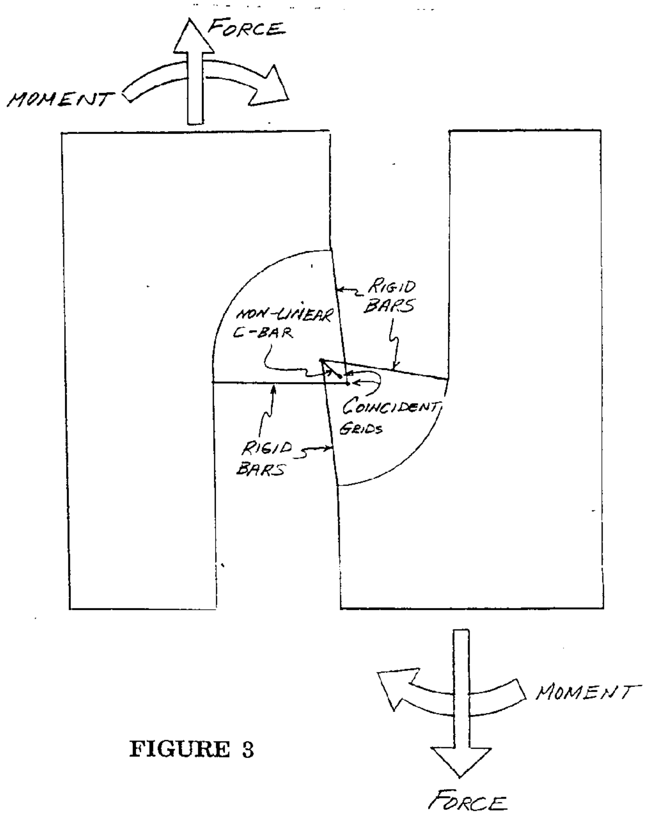

FIGURE 3

BALL LOAD DISTRIBUTION RESULTS

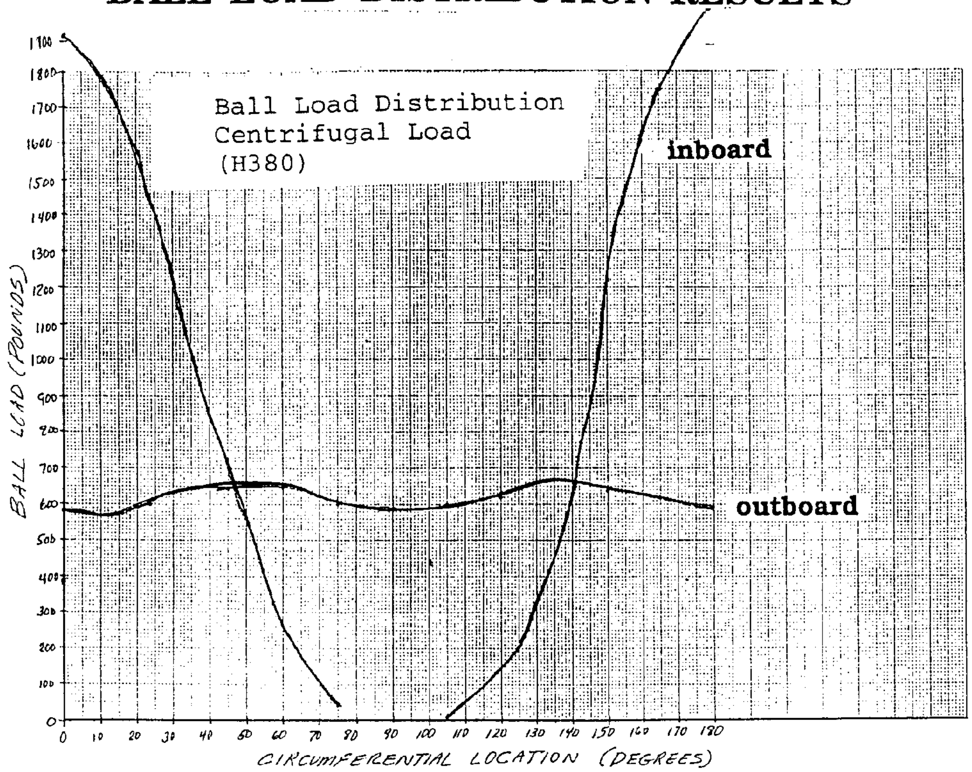

FIGURE 4A

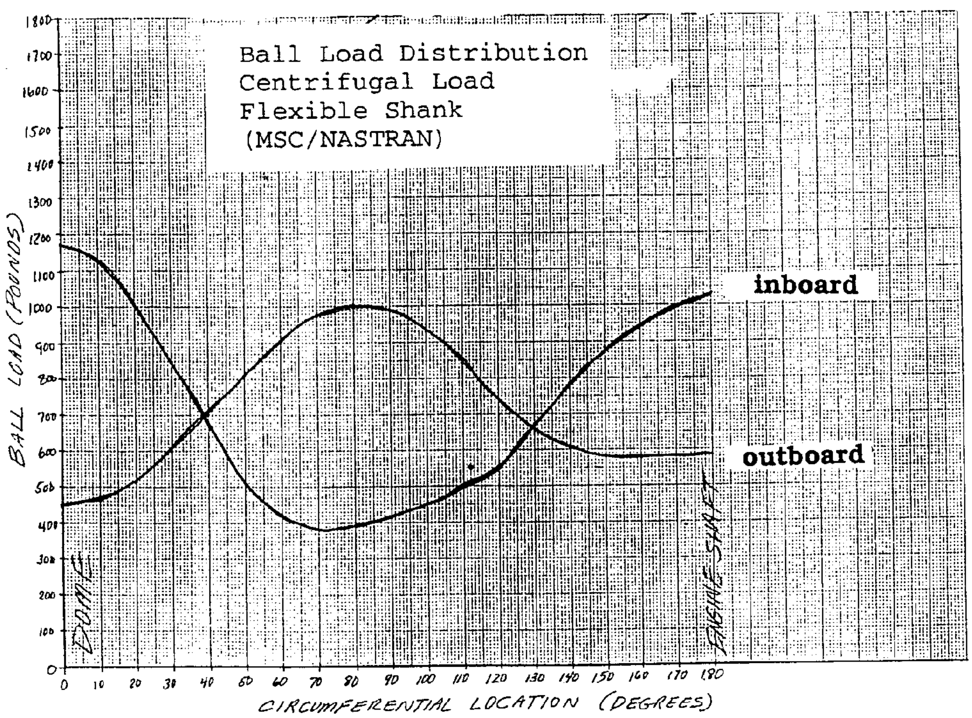

FIGURE 4B

BALL LOAD DISTRIBUTION RESULTS

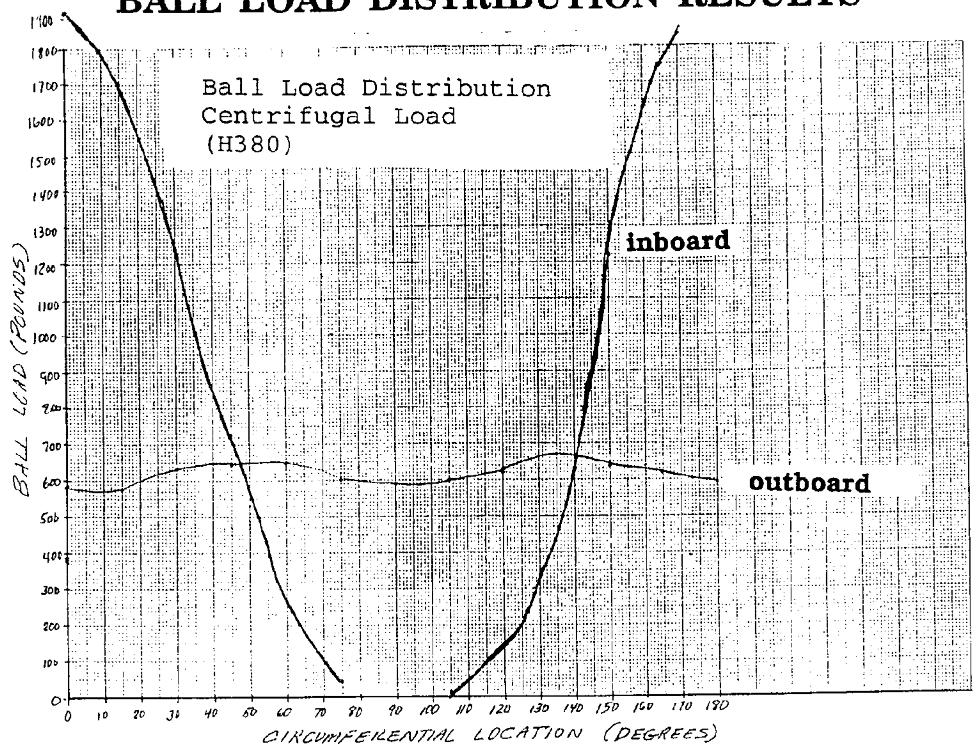

FIGURE 5A

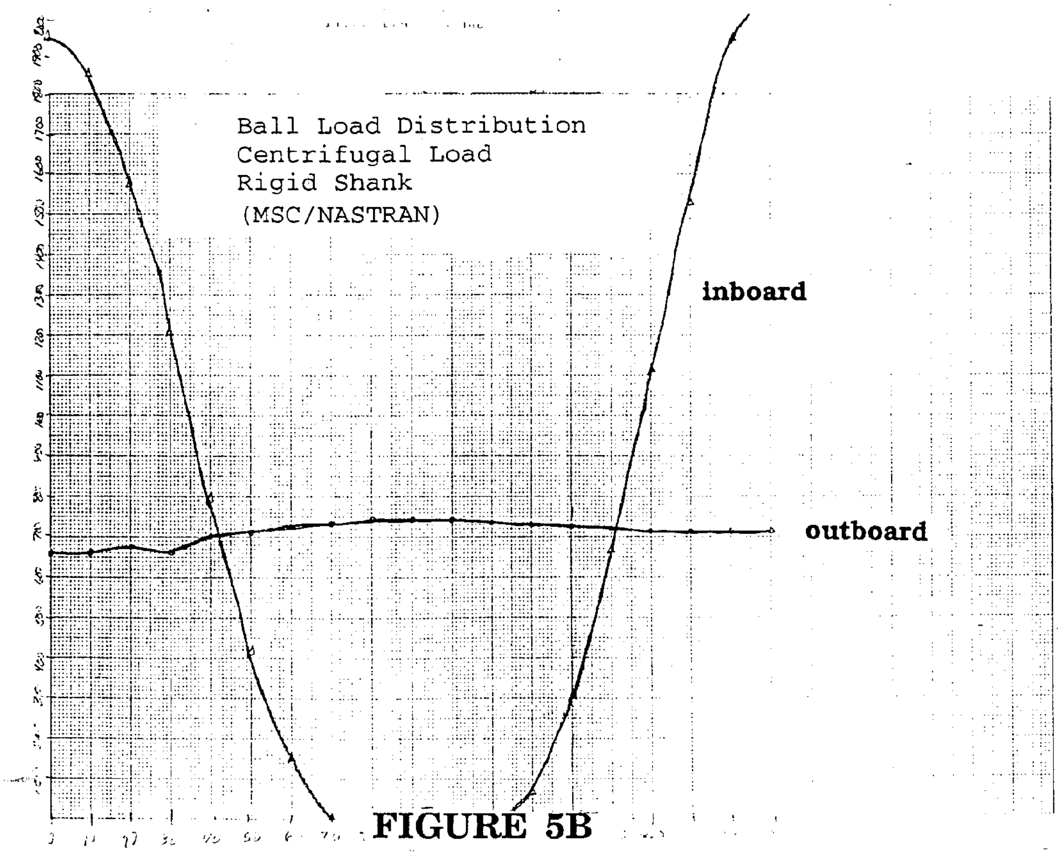

FIGURE 5B