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DYNAMIC CHARACTERISTICS OF SINGLE CRYSTAL SSME BLADES

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The SSME High Pressure Fuel Turbopump (HPFTP) blades are currently manufactured using a Directionally Solidified (DS) material, MAR-M-246+Hf. However, a necessity to reduce the occurrence of fatigue cracking within the DS blades has lead to an interest in the use of a Single Crystal (SC) material, PWA-1480.

A study was initiated to determine the dynamic characteristics of the HPFTP blades made of SC material and find possible critical engine order excitations. This study examined both the first and second stage drive turbine blades of the HPFTP. The dynamic characterization was done analytically as well as experimentally. The analytical study examined the SC first stage HPFTP blade dynamic characteristics under typical operating conditions. The blades were analyzed using MSC/NASTRAN and the finite element model shown in Figure 1. Two operating conditions, 27500 RPM and 35000 RPM, were investigated. Each speed had a unique blade temperature distribution. Bench experiments were conducted to determine the non-rotating natural frequencies and mode shapes.

Parametric studies were done varying the crystal orientation with respect to the blade. Crystal orientation was important because of the anisotropic nature of the material. Youngs Modulus was greatest along the crystal's <111> direction. The crystal <111> direction was referenced within the blade according to its projected rotate angle and tilt angle shown in Figure 2. The SC blades were initially analyzed at a tilt angle of 54.74 degrees such that its crystal growth direction was aligned in the blades' span direction, similar to the DS blade.

For the first three modes the frequency appeared to be least dependent on the crystal rotation angle. For the same modes the crystal tilt angle had a greater influence on the modal frequencies as shown in Figure 3. For modes four through six the crystal rotate angle had a more significant effect on natural frequencies as shown in Figure 4.

Campbell diagrams were constructed with the following critical engine orders determined by Rocketdyne; 11, 13, 15, 24, 26, 28, and 41. The modal analysis results for the SC blades were found to be worse than the DS when considering the engine order interferences (see Figures 5 and 6). These results indicated critical engine order crossings may occur over the first three modes of the SC blades.

Additional investigations attempted to determine an optimum crystal orientation which would most effectively avoid the above interferences. The procedure was to vary the orientation of the crystals <111> direction between the extremes. The extremes would be strongest crystal direction either blade spanwise or chordwise. The best orientation when considering the a +/- 5% deviation of excitation frequency occurred at a tilt angle of 90 degrees and a rotate angle of 0 degrees (see Figure 7). It appears that for any orientation, the third mode interference will exist (Figure 8).

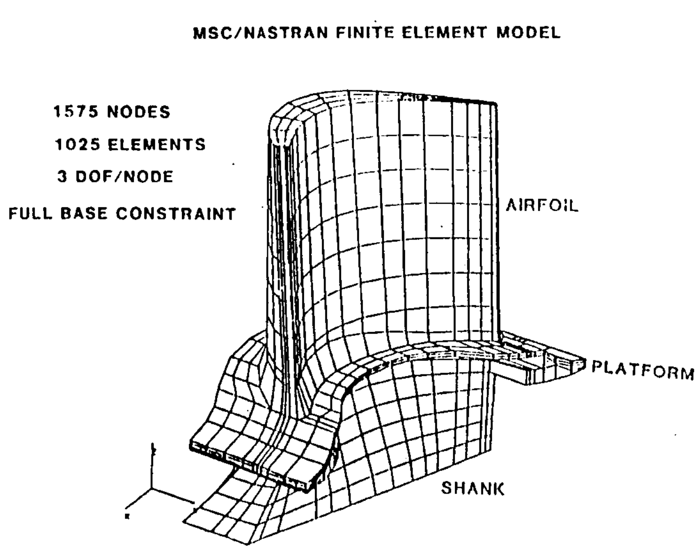

FIGURE 1

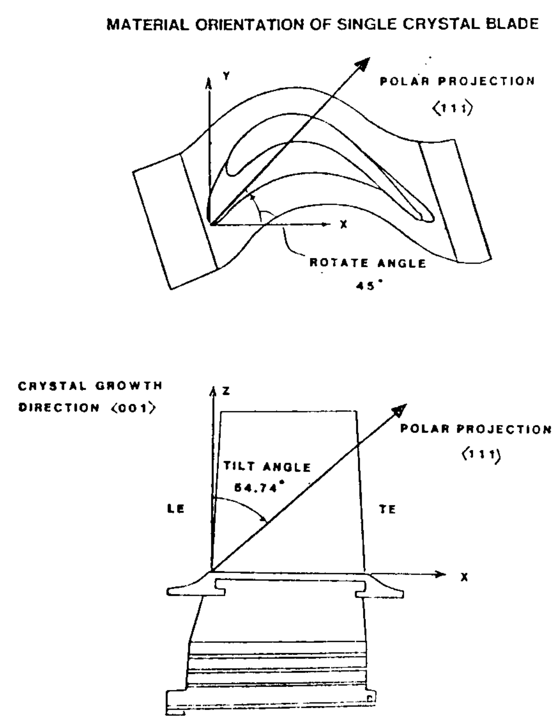

FIGURE 2

SSME HPFTP - 1st Stage Blade
PWA-1480; 35000 RPM; Taf=1400 F. and Tsh=1200 F.
1st Mode

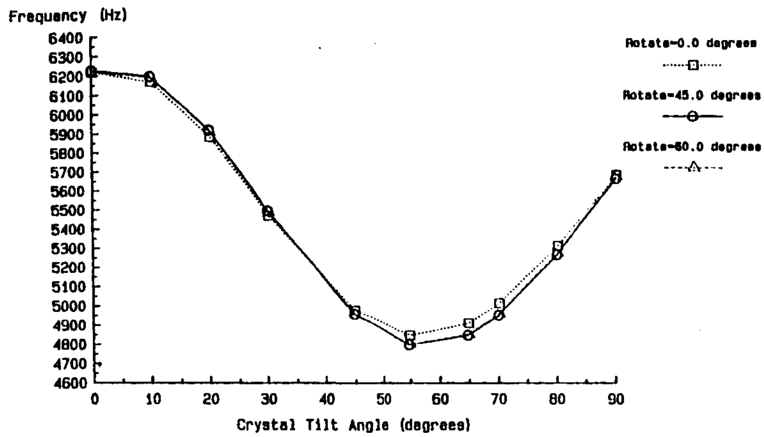

FIGURE 3

SSME HPFTP - 1st Stage Blade
PWA-1480; Nonrotating; 70 degress F.
4th Mode

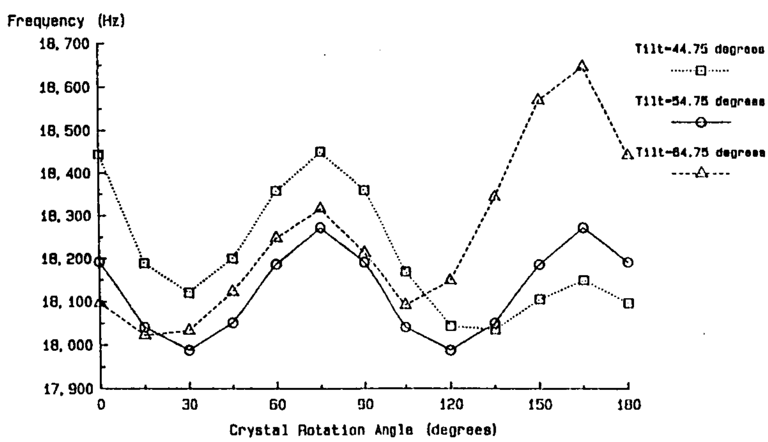

FIGURE 4

SSME HPFTP - 1ST STAGE BLADE
CAMPBELL DIAGRAM; DS MAR-M-246 Hf MATERIAL

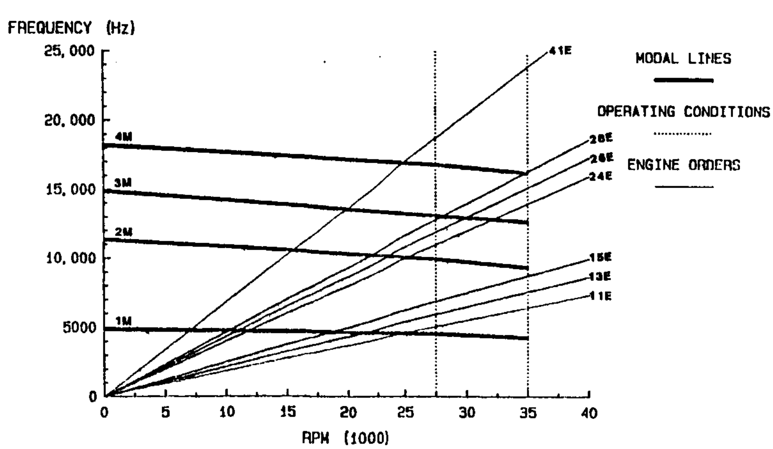

FIGURE 5

SSME HPFTP - 1ST STAGE BLADE
CAMPBELL DIAGRAM; PWA-1480 MATERIAL
SC ORIENTATION; TILT=54.74, ROTATE=0.0

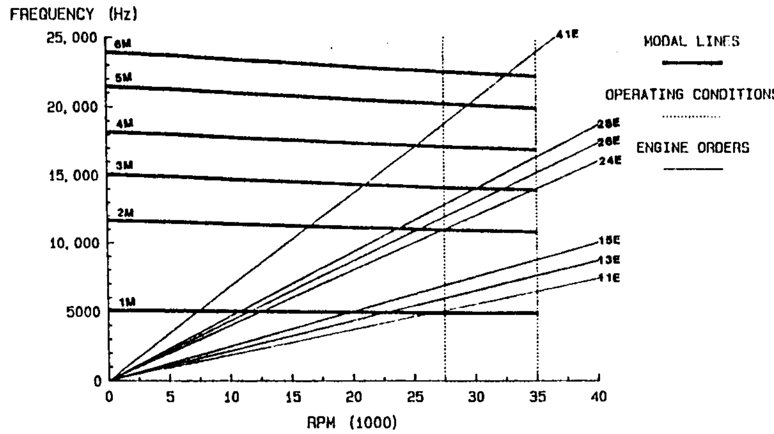

FIGURE 6

SSME HPFTP - 1ST STAGE BLADE
CAMPBELL DIAGRAM; PWA-1480 MATERIAL
SC ORIENTATION; TILT=90.00, ROTATE=00.0

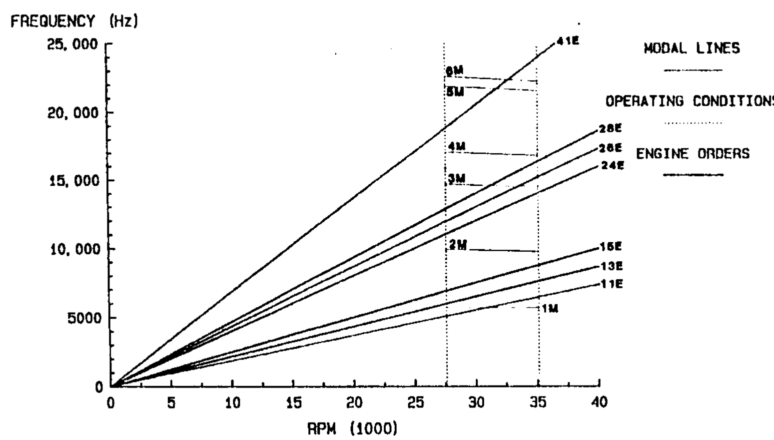

FIGURE 7

SSME HPFTP - 1st Stage Blade
PWA-1480; 35000 RPM; Taf=1400 F. and Tsh=1200 F.
3rd Mode

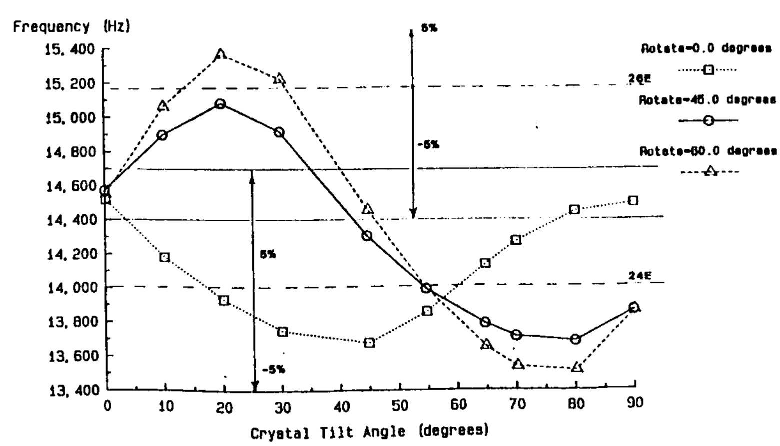

FIGURE 8