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THE STRUCTURAL PERFORMANCE OF THE DOE/SANDIA 17 METER VERTICAL AXIS WIND TURBINE*

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The DOE/Sandia 17 meter Darrieus vertical axis wind turbine has been operated since April 1977 for the purpose of gathering engineering data. This report considers one aspect of that test program, the measurement of blade structural response. Additional details on this effort are available in Reference 1.

Instrumentation and Test Set-Up

Each turbine blade is instrumented with strain gages as shown in Figure 1. These gages are located on the blade surfaces to permit determination of the flatwise (motion in the plane defined by the blade and the tower) and edgewise (motion normal to the blade/tower plane) bending strains. All measurements are of direct strain, rather than overall loads, so that readings may be readily interpreted relative to the blade material properties.

The strain gage data are collected and processed on site using a mini-computer controlled data acquisition system (2).

The 17 meter turbine may be configured with either two or three blades. All the data in this summary are for the two-bladed configuration which was tested from April to December 1977.

The blade cross-section on the 17 meter turbine (Figure 2) is similar to a helicopter blade. The blade was designed and built by Kaman Aerospace Corporation. The main structural elements of the blade are the leading and trailing edge spars which are extruded 6061-T6 aluminum. The strain gages are all mounted on the external surfaces of these spars.

Test Results

The qualitative structural behavior of the blades is shown in Figure 3. In Figure 3a, the wind speed is negligible and the two gages shown (a flatwise bending pair on the strut) indicate a steady component of strain due to centrifugal loading. The addition of aerodynamic forces due to wind loading (Figure 3b) introduces periodic loading and vibratory stresses in the blade.

The steady component of the strain depends primarily on the rotor speed. The magnitude of this steady strain is shown in Figure 4 for the strut (Gage 108) and the straight section (Gage 101). All the other instrumented points on the blade indicated much lower steady strain components. All the steady stresses are well below the 35 ksi yield point of the extruded section.

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Regarding the mean-to-peak vibratory strain, experience with the turbine has shown that vibratory stresses in the strut (Gage 108) and the straight section root trailing edge (Gage 105) are of the largest magnitude. Figures 5 and 6 show results for the straight section root and the strut, respectively. These data were obtained at 52.5 RPM on an unusually windy day in Albuquerque. The vibratory stresses measured represent the highest recorded during the entire two-bladed test series.

The scatter in the data is probably due to the difficulty in measuring the wind speed. Vibratory strains are conservatively calculated from the minimum and maximum strains observed in approximately five turns of the rotor. The wind speed, measured with an anemometer directly above the turbine, is averaged over this same period.

An S-N curve supplied by Kaman Aerospace for extruded 6061-T6 spars was used to put a 10^7 cycles-to-failure line on Figure 5. It is apparent that negligible fatigue life has been consumed in the straight section trailing edge. The strut, however, does exhibit some fatigue life consumption in winds above 40 MPH. The cycles-to-failure limits shown in Figure 6 have been reduced using a modified Goodman diagram to account for the steady stresses in the strut. Because of the infrequent nature of this loading, the fraction of the strut fatigue life consumed by operation to date is immeasurably small. Estimates of life consumption for the 17 meter strut if the rotor were operated continuously in a 12 MPH mean wind speed environment indicate an annual life consumption on the order of 2%.

Summary

The structural performance of the 17 meter turbine blades has been satisfactory during the two-bladed test series. The strut, because of the high steady stresses from centrifugal loads, is the highest stressed structural member on the blade. Fatigue life consumption begins in the strut for wind speeds above 40 MPH. Considering the frequency of such winds at typical sites, the annual fatigue life consumption is still very small, on the order of 2%.

References

1. W. N. Sullivan, "Preliminary Blade Strain Gage Data on the Sandia 17 Meter Vertical Axis Wind Turbine," SAND77-1176, Sandia Laboratories report, printed December 1977.
2. B. Stiefeld, "Wind Turbine Data Acquisition, Control, and Analysis System," SAND77-1164, Sandia Laboratories report, to be published June 1978.

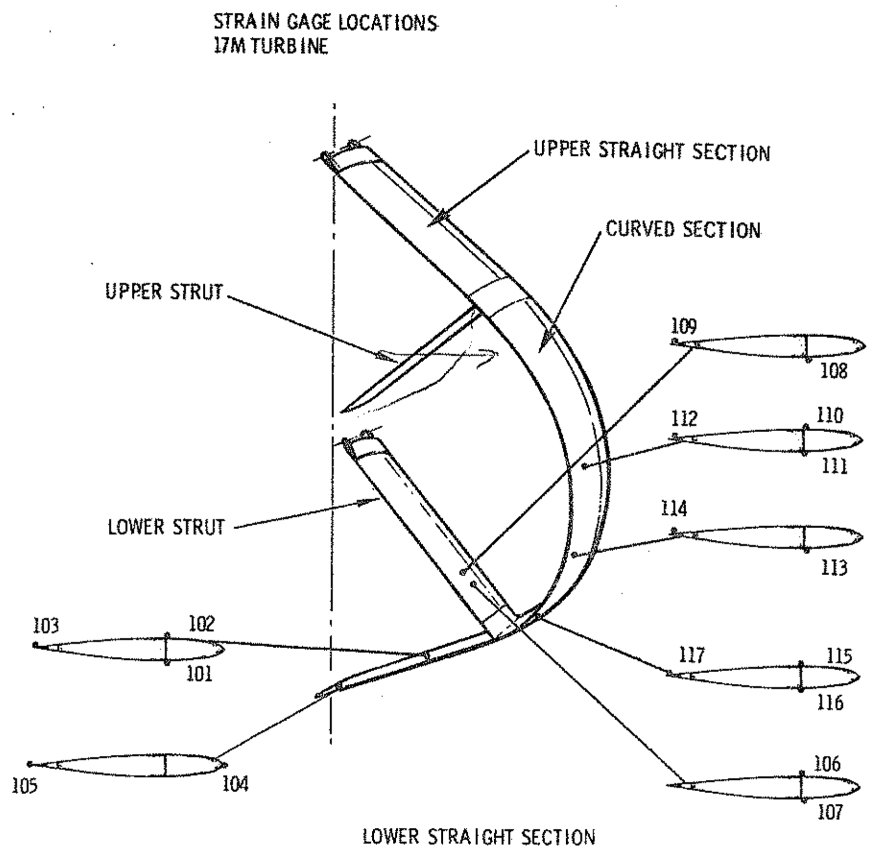


Figure 1. Strain Gage Locations on the 17 M Turbine

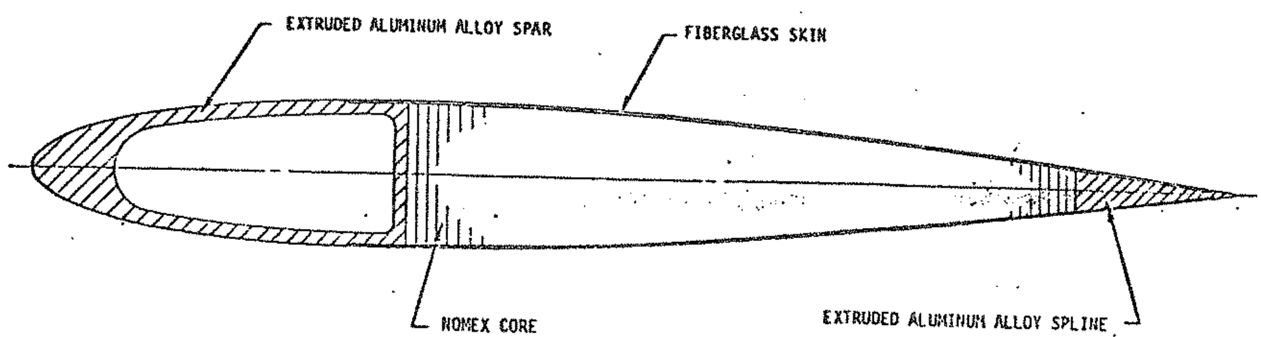
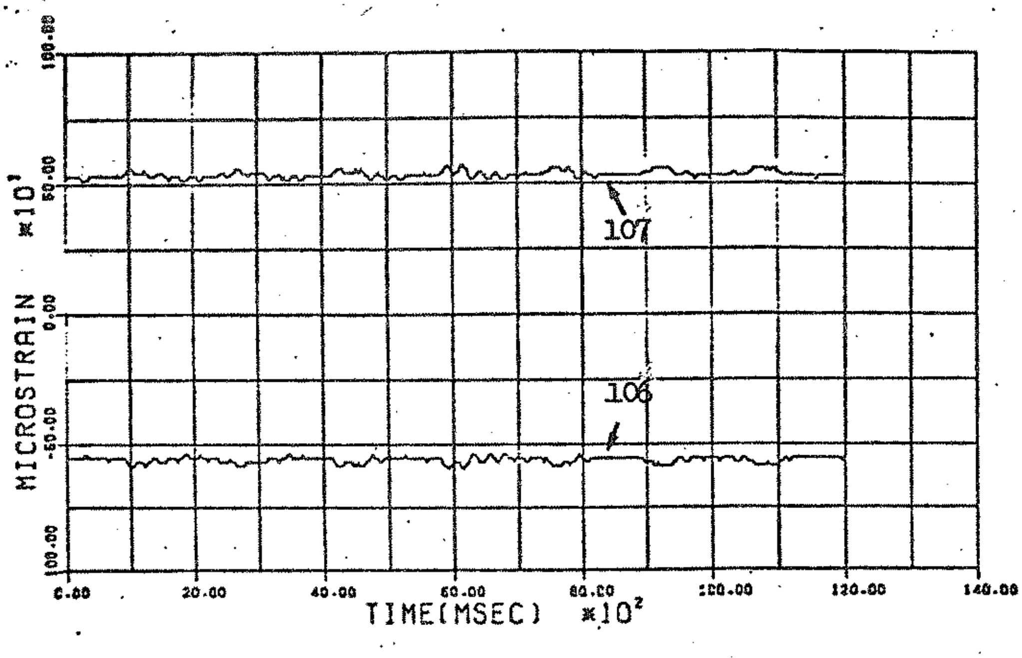
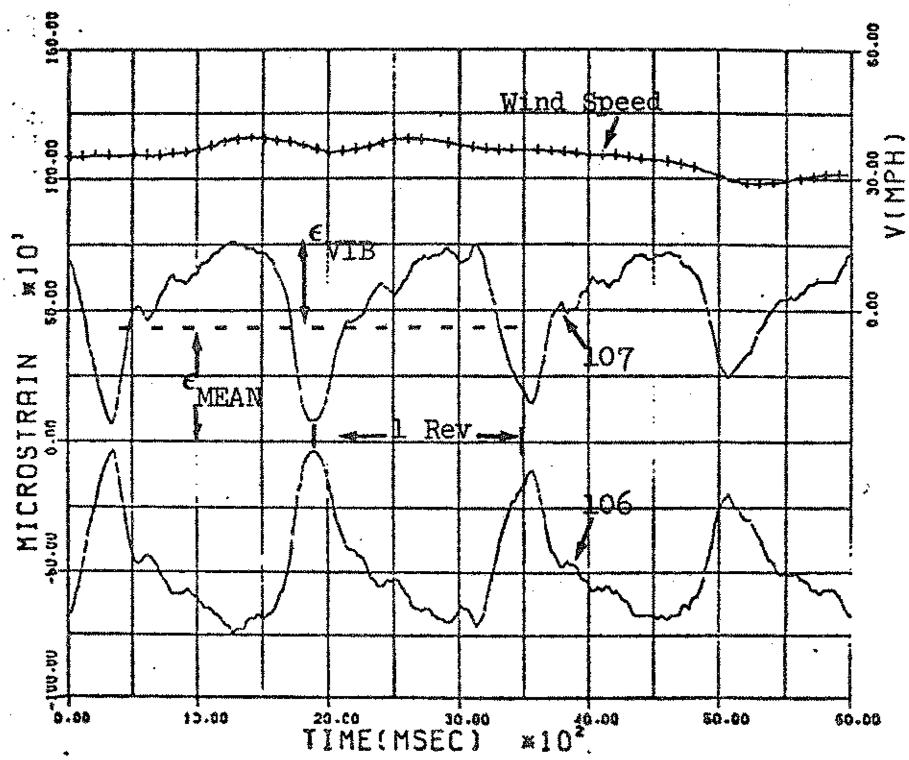


Figure 2. Kaman Blade Cross Section



a) Strut Strains, Wind Speeds Below 10 MPH, 37.0 RPM



b) Strut Strains in High Winds, 37.0 RPM

Figure 3. The Effect of Wind Speed on Vibratory Strut Strains

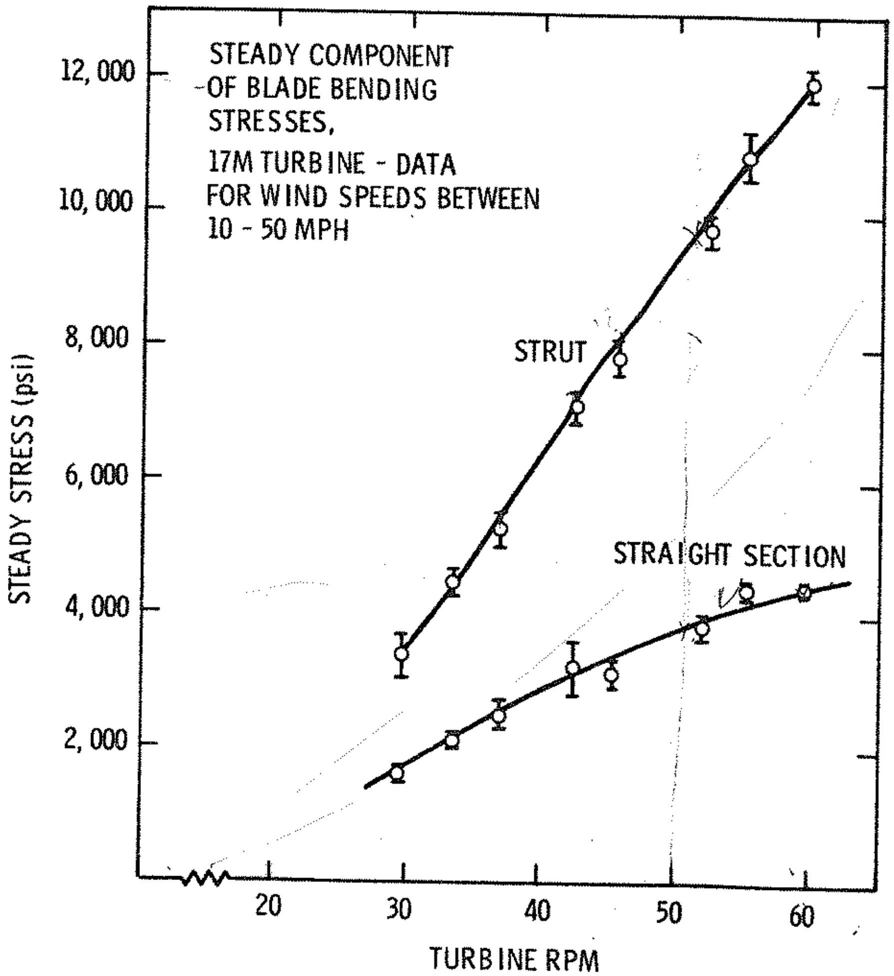


Figure 4. Steady Blade Stresses, 17 M Turbine

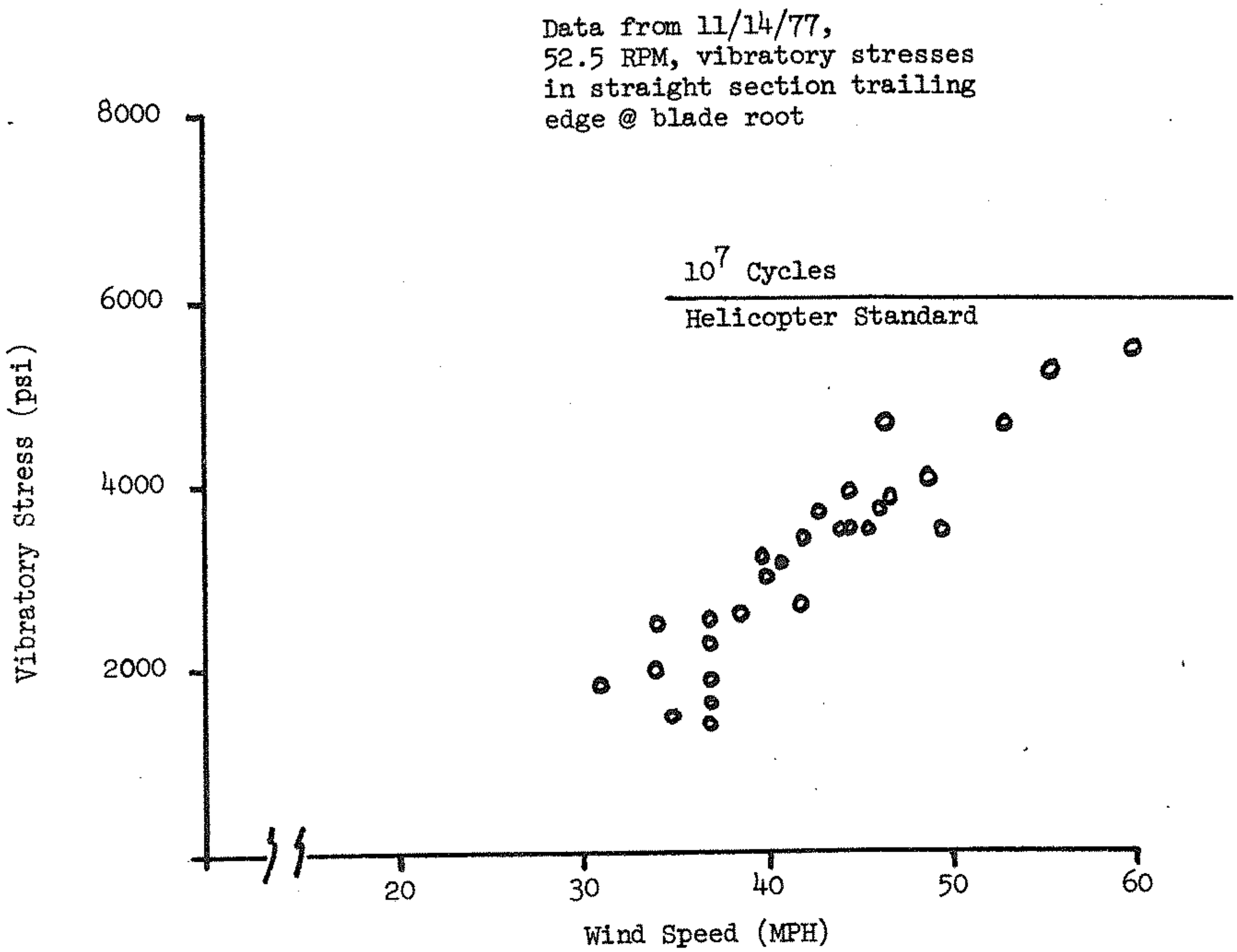


Figure 5. Vibratory Stresses in Straight Section Trailing Edge

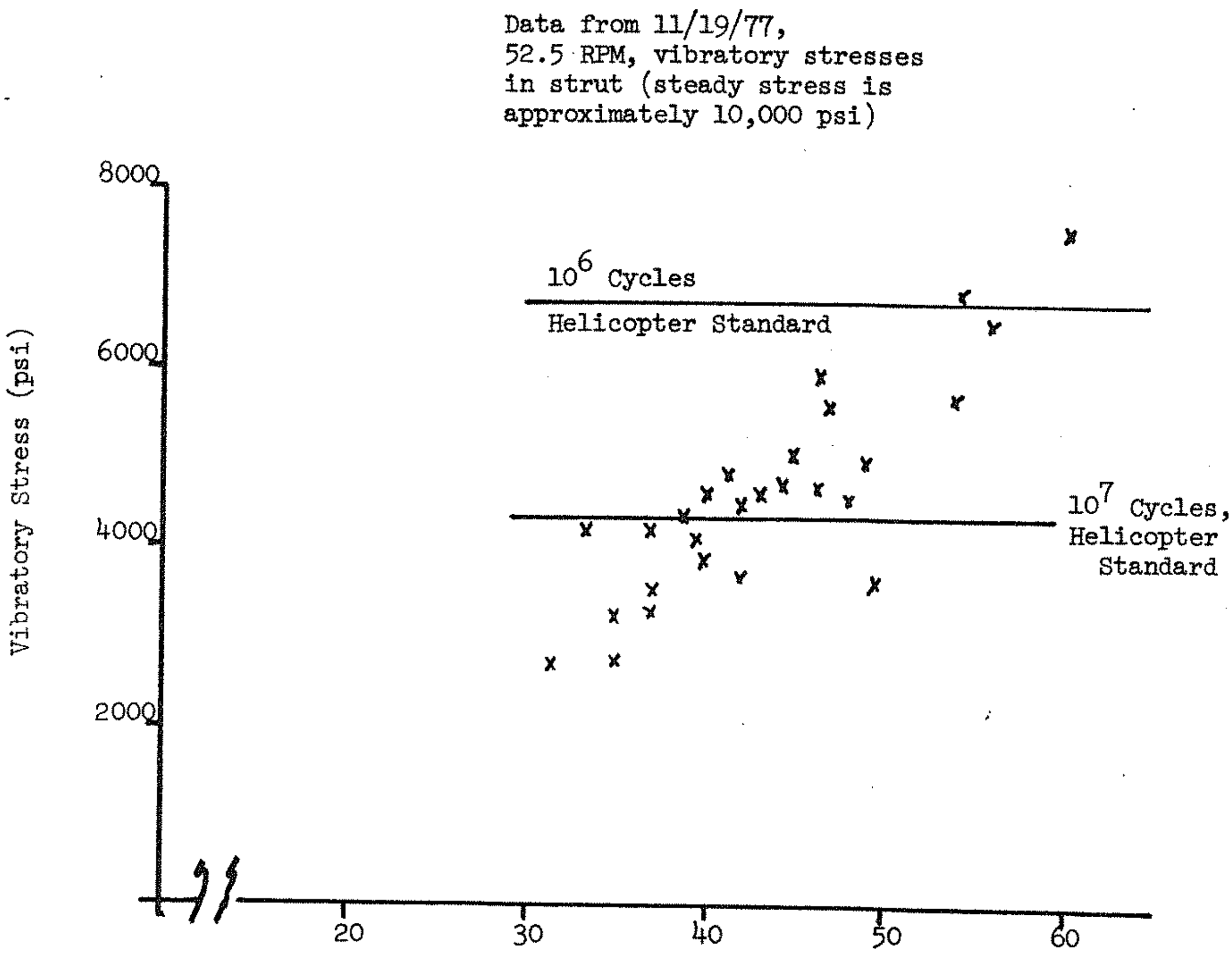


Figure 6. Wind Speed (MPH)

Vibratory Stresses in Strut