RESEARCH OF LOW COST WIND GENERATOR ROTORS

Demeter G. Fertis
University of Akron
Akron, Ohio 44325

and

Robert S. Ross
Concept Development Institute, Inc.
1790 Stoney Hill Drive
Hudson, Ohio 44236

ABSTRACT

This feasibility program determined that it would be possible to significantly reduce the cost of manufacturing wind generator rotors by making them of cast urethane. Goodyear developed several high modulus urethanes which were structurally tested at the University of Akron. A section of rotor was also cast and tested showing the excellent aerodynamic surface which results. A design analysis indicated that a cost reduction of almost ten to one can be achieved with a small weight increase to achieve the some structural integrity as expected of current rotor systems.

INTRODUCTION

Recently NASA has been given the task of trying to find some way that wind energy could be harnessed at a large enough scale to become significant as a world energy source. In preliminary investigation NASA has determined that large size windmills might be one solution to this problem. In their studies, however, they find that the cost of the initial installation is considerable and if the overall system is to be economically feasible, the initial cost of the equipment must be reduced. These first costs can be divided into three major components; 1) the rotor blades themselves, 2) the tower that supports the equipment, and 3) the electrical and electro-mechanical tie-ins. In this particular program CDI has proposed a solution for reducing the cost of the rotor blades.

In the first NASA installations and systems, rotor blades were based on either propeller or airfoil design and fabrication techniques. These provided workable blades, but at a relatively high cost. It appeared that an entirely new approach would be required if a significant cost reduction was to be expected. CDI, therefore, looked to new materials and fabrication techniques as the solution to this problem. Since urethanes had a wide capability of structural properties, and they could be cast in low cost molds, where they generate their own internal heat, it appeared that these may be likely candidates for rotor components.

Through CDI, therefore, NASA funded a program to examine the physical properties of the urethanes both experimentally and analytically and to determine if full scale rotor blades could be made using this technique. The program involved not only physical testing of specimens, but also the fabrication of a model airfoil and a preliminary study of a full scale blade design to determine the practicability of the approach. The majority of the work was performed at the University of Akron and the Goodyear Tire & Rubber Company Research Laboratories.

MATERIAL EVALUATION

Urethanes are relatively new materials and, therefore, very little is known regarding their physical properties and structural behavior as a construction material. Two specific types of urethanes, microcellular foam and rigid foam, were selected for evaluation on this program. The properties examined were: density, tensile strength, compressive strength, shear strength, bearing strength, impact strength, creep resistance, fatigue strength, temperature effects and Poisson's ratio. Typical other behaviors examined were: hysteresis, modulus of elasticity, repeatability, experimental and analytical similarity, etc.

Using specimens 3/4" x 3/4" x 30" and three and four point loading systems, a large number of tests were conducted and data collected on load-deflection properties. The data proved to be very linear and creep was not significant for the most interesting formulations. Table 4 summarizes some of the properties obtained. Temperature effects were also briefly examined from 20°F to 150°F and appear to be within practical limits.

Fatigue tests were also conducted on tensile specimens at stress levels of 2200 psi at 5 and 10 cycles per second and went 2,000,000 cycles before being taken off the test machine. Strain gages tests were also conducted and they verified values of E of about 450,000 psi were achieved.

The test program indicated that the urethanes were a good structural material which behaved in a predictable engineering fashion and could be expected to perform as analytically shown similar to standard materials.

ROTOR DESIGN

This portion of the program consisted of two major areas: 1) The design of a test section to permit the casting of a urethane blade component which would demonstrate the structural capabilities of the material in a typical rotor blade configuration; and 2) the preliminary design of a full scale rotor blade that would permit the determination of a reasonable weight estimate.

For the purpose of this program a test section 7' long with a chord of 30" was planned. With a thickness of 15%, this represented a section of the 125' Mod O system at 80% of the radius. The model was made in two halves and cemented together. Two models were made and tested, one all urethane, and the other containing some typical reinforcing bars. This was to illustrate how readily metal could be used to vary the structural properties as needed.

The models were mounted in a cantilever fashion and tested to destruction in bending. Before this, however, they were tested in torque and were equipped with an accelerometer to check the natural frequency. As expected, the unit with reinforcing rods increased the stiffness of the test specimens. The surface was extremely smooth and did not require additional machinery.

The blade sections actually broke at stress concentration points at the root and indicated that the predicted structural properties were achieved. The blade was very stiff in torsion and was only tested up to 4° when 20,000 in-lbs was applied.

FULL SCALE ROTOR DESIGN ESTIMATES

Using design goal structural properties supplied by NASA on full scale preliminary designs of a 125' radius blade was made, assuming that it were to be cast urethane with metal stiffeners. It turned out that the stiffeners criteria was the most critical and a blade using this technique would be slightly heavier than the present Mod O design to meet this structural goal. Since no attempt was made to optimize the designs, it is not known if the same weight could be achieved.

For casting purposes, the blade mold and fabrication costs were estimated and it was determined that costs in the vicinity of $2 to $3 per pound were not out of line, depending, of course, on the number of blades to be built. Size was not a limit in the technique considered.

It is now necessary to build and whirl test a set of blades as well as establish more precisely all the design parameters.

DISCUSSION

Q. What would be the weight of a MOD O sized blade constructed from urethane?

A. Preliminary estimates of blade weight vary from 2,750 to 3,300 pounds, which is slightly more than the present blade weight. Judicious design, however, could possibly bring it close to the same weight.

Q. Do you have data and/or plans to obtain data on fatigue properties of your urethane foam samples?

A. Samples of urethane were cycled at repeated tensile stress levels of 2,200 psi at speeds of 5 and 10 cycles per second and reached 2,000,000 cycles before being taken out of the machine. No visible signs of failure was present.

Q. Are properties you showed for an isotropic material or did they include the high density of the skin which would form at the mold interface?

A. The properties we showed did not include the ability to create a skin density at the mold surface greater than the rest of the specimen.