THE USE OF PAPER HONEYCOMB FOR PROTOTYPE BLADE CONSTRUCTION FOR SMALL TO MEDIUM-SIZED WIND DRIVEN GENERATORS

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Windworks, under the sponsorship and direction of R. Buckminster Fuller, began working on wind energy conversion systems in 1970. It was decided, in view of the high cost per kilowatt output and the relative difficulty of construction of conventional or existing wind plants, that the first area of emphasis should be in making wind more accessible for experimentation and use.

With this in mind, we began working with paper honeycomb for the construction of conventional, propeller-type, windmill blades. Using fairly simple techniques and conventional power tools, it is possible to shape both simple foils (NACA 4415) and more complex foils (Wortmann FX-60-126 and FX-72-MS-150A) with or without tapered plan forms with or without varying profile. Still more complex geometries can be developed using router techniques developed by Hexcel Corporation.

For blade diameters up to 30 feet, typical costs are as follows:

Honeycomb	\$ 0.14/ft^2 of blade
Fiberglass/resin	.90/ft^2 of blade
	\$ 1.04/ft^2 of blade
Construction time	8 to 12 hr/blade
Tolerances:	
Paper	$\pm$ 1/32 in.
Aluminum	$\pm$ 1/100 in.

The first step of the process is to cut out the blade blank. A block of honeycomb, in its compressed form, is mounted on a wedge and run through a bandsaw with the table at an appropriate tilt angle. It is the combination of the wedge angle and the table angle that gives the tapered plan form and profile shape.

Next the honeycomb is expanded on the shaft and jigged to give the desired angles of attack. With the honeycomb fixed in position, the blade is covered with a fine weave fiberglass cloth. Any surface quality can then be achieved with filling and sanding.

The process, being both simple and low cost, lends itself particularly to prototype work and tool making. In encouraging individuals to use and experiment with wind energy, we hope to increase the support for wind utilization which will be necessary for the acceptance of large-scale developments in this country.

DISCUSSION

Q: In any of your units do you have any feathering mechanisms or do you keep the angle constant?

A: No. But we do have feathering. We have two types: we have Popular Science typical coning -- incidentally, in the U.N. report there's a Japanese windmill for which are shown test results for absolute constant rpm with a mildly sophisticated feathering system. It's a cone windmill running downwind with variable pitch, and they have been able to run that at constant speed regardless of wind velocity.

We've worked on two different types: the coning straightaway, which is an umbrella structure working against a spring with damping, and the flyball governor wherein as the blades move out they rotate. When the windmill shuts down, the blades go into a partial coning position, which increases the starting torque. As it starts up, the blades begin to rotate into maximum power, and then they rotate further into full feather.

Q: What kind of increase in power did you get with the Venturi prototype?

A: We designed for a 50 percent increase in windspeed. We got about a 35 percent increase.

Q: What was the area ratio, minimum and maximum?

A: It had a 6-foot opening, a 5-foot diameter, a 7-foot exit, and an 80-foot length from entrance to exit.