FIXED PITCH WIND TURBINES

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ABSTRACT

Wind turbines designed for fixed pitch operation offer potential reductions in the cost of the machine by eliminating many costly components. Our studies have shown that a rotor can be designed which produces the same energy annually as Mod-0 but which regulates its power automatically by progressively stalling the blades as wind speed increases. Effects of blade twist, taper, root cutout, and airfoil shape on performance are discussed.

Unfortunately, fixed pitch rotors are not self-starting when the pitch is set to maximize energy production per year. Various starting techniques are discussed.

INTRODUCTION

Fixed pitch wind turbines are being studied in an effort to produce machines which are less costly than the present variable pitch machines. These machines are intended for uses where load following is not required. The concept is not new. The Danes built a fixed pitch machine in the town of Gedser which operated successfully for many years. Our activity started with a study of the Gedser machine.

In principle the fixed pitch machine is relatively simple. The rotor is designed to stall progressively as the wind speed increases and thereby automatically limit the peak power. With the generator sized to accept the peak power that the rotor can produce, the machine can operate in any wind with no power control. Speed control is provided by synchronizing the generator to a large network--(just as it is in present wind turbines). Thus the fixed pitch machine appeared to have potential for lower cost; the larger generator required is inexpensive compared to the pitch change mechanisms, hydraulic systems and electronic controls required for the variable pitch machine.

It was recognized early that fixed pitch rotors would probably not be self-starting and that some special systems would be needed for synchronization. The objective of this paper is to describe our studies to date which have defined the type of blades needed for optimum performance and some alternative systems for starting and stopping the final pitch wind turbine.

OPTIMUM BLADE SHAPE

Our study of blade shapes was conducted using the computer code developed by Wilson. So far we have studied the effects of twist, airfoil section, taper, and root cutout on performance. To achieve the same annual energy production with the smallest generator, the performance of the fixed pitch machine should approximate the characteristic of a fully pitchable wind turbine. Figure 1 is a comparison of the performance of a fixed pitch wind turbine and Mod-0 for the same annual energy production. In low winds the two are nearly alike. At 18 mph Mod-0 spills wind to hold constant power while the fixed pitch rotor increases its power output and starts to stall. At higher wind speeds more and more of the blades stall until at 35 mph no power is obtained at all.

Effect of Twist

Figure 2 is a plot of rotor power versus wind speed for three (3) rotors having different profiles. The untwisted blade appears superior because it produced a significantly lower peak power (lower installed capacity), more power in very high winds, and about the same power in low winds. In addition it is probably less costly to manufacture an untwisted blade.

Airfoil Section

Unlike a fully pitchable machine, the performance of a fixed pitch machine is dependent both upon the stall and the lift characteristic of the airfoil. The prediction of performance must be based on the best data available over the full range of angles of attack including post stall. Thick airfoils are preferable from a structural standpoint. The 23024 is the thickest 23000 series airfoil for which we have data. In figure 3 the performance of three candidate airfoils is presented. The GAW 1 and the 4424 are clearly inferior to the 23024 which produces more power in both the high and low wind regimes.

Effect of Taper

Figure 4 shows the performance of 3 blades with different taper profiles. The step tapered blade approximated the taper of the Mod-0 blade in 3 steps. It can be seen that the performance of the three blades is not very different. Thus it is possible to maintain the same airfoil section (23024 in this case) throughout the length of the blade. As the thickness varies for structural reasons the chord can be allowed to vary to maintain the same thickness to chord ratio (24%).

Effect of Root Cutout

Figure 5 shows the performance of 3 blades with different lengths of the blade root inoperative. The data show that almost no loss in power is incurred by root cutouts as high as 25%. With greater values power at the lower winds would be lost.

Performance of the Selected Blade

From the above data an untwisted, 23024, linearly tapered blade was selected for the fixed pitch machine. Its performance is compared to that of Mod-0 on figure 7. Both rotors produce the same energy annually and the peak power of the fixed pitch machine is only about 30 kW higher than Mod-0.

STARTING

Figure 7 shows the trade-off between annual power production and starting ability for a 3-bladed fixed pitch rotor. With a pitch angle of -2° the rotor produces 666,000 kWhr but requires 16 kW to motor start. With a pitch angle of -8° the rotor is self-starting but produces only 546,000 kWhr and requires a much larger generator. These data led to the conclusion that fixed pitch rotors are not self-starting.

Alternative starting systems are listed in figure 8. These systems are currently under investigation and it is too early to draw any conclusions.

Synchronous generators are best for power production but are difficult to motor and synchronize. The induction generator has a poorer power factor but good motoring torque and no synchronization problems.

It is theoretically possible to yaw the machine out of the wind to unstall the blades for starting. Once rotation starts we would yaw slowly back to the power position. The generator would be synchronized automatically when the speed reached synchronous.

A 2-position pitch system might be designed such that the outboard section of the blade is pitched for starting and then returned slowly to the power position without feedback control. Calculations show that at least 30% of the blade length would be required for the pitchable part.

Two methods of stopping the machine in the event that the load is lost are being considered: a deam-man brake and a small flap on the blade tip. Calculations show that a 3' flap is sufficient to stop a 125' diameter rotor.

CONCLUSIONS

We believe the fixed pitch rotor concept offers a potential reduction in wind turbine cost. Many costly and sometimes troublesome components can be eliminated.

There are starting problems which need to be solved and these are being investigated.

DISCUSSION

Q. Would you expect power from the grid to motor the rotor through and out of stall due to a high velocity gust?

A. That depends upon the design of the drive train: if torque can be transmitted from the generator to the rotor, the machine would motor through a period of high wind--otherwise the rotor would stop.

Q. How did not determine a start angle on the blade of only 8^o?

A. We used Wilson's "prop" program to predict the speed vs. torque characteristics of a rotor with various pitch angles. Positive torque was found at all speeds with a pitch angle of 8^o.

Q. What about 160 mph when stopped?

A. Actually, we design for a 120 mph wind striking the blade at 90^o line. This is a onetime load which allows the stress to be 5 or 6 times greater than a fatigue stress would be. Consequently, the high wind requirement does not appear to adversly affect the design.

Q. What are the high wind (greater than cutout) and gusty air effects on blade limit loads and fatigue loads? Also what are the effects on drive system requirements to handle the cyclic drive torques?

A. So far we have only looked at operations in steady winds. The effect of gusts will be investigated later. We have not yet identified any changes in the drive train necessitated by changing from variable to fixed pitch rotors.

Q. With the loss of flatwise damping during the proposed stall operation, do you think upwind locating and guying, as with the Gedser machine, would be necessary?

A. No, but we need to and will examine stability.

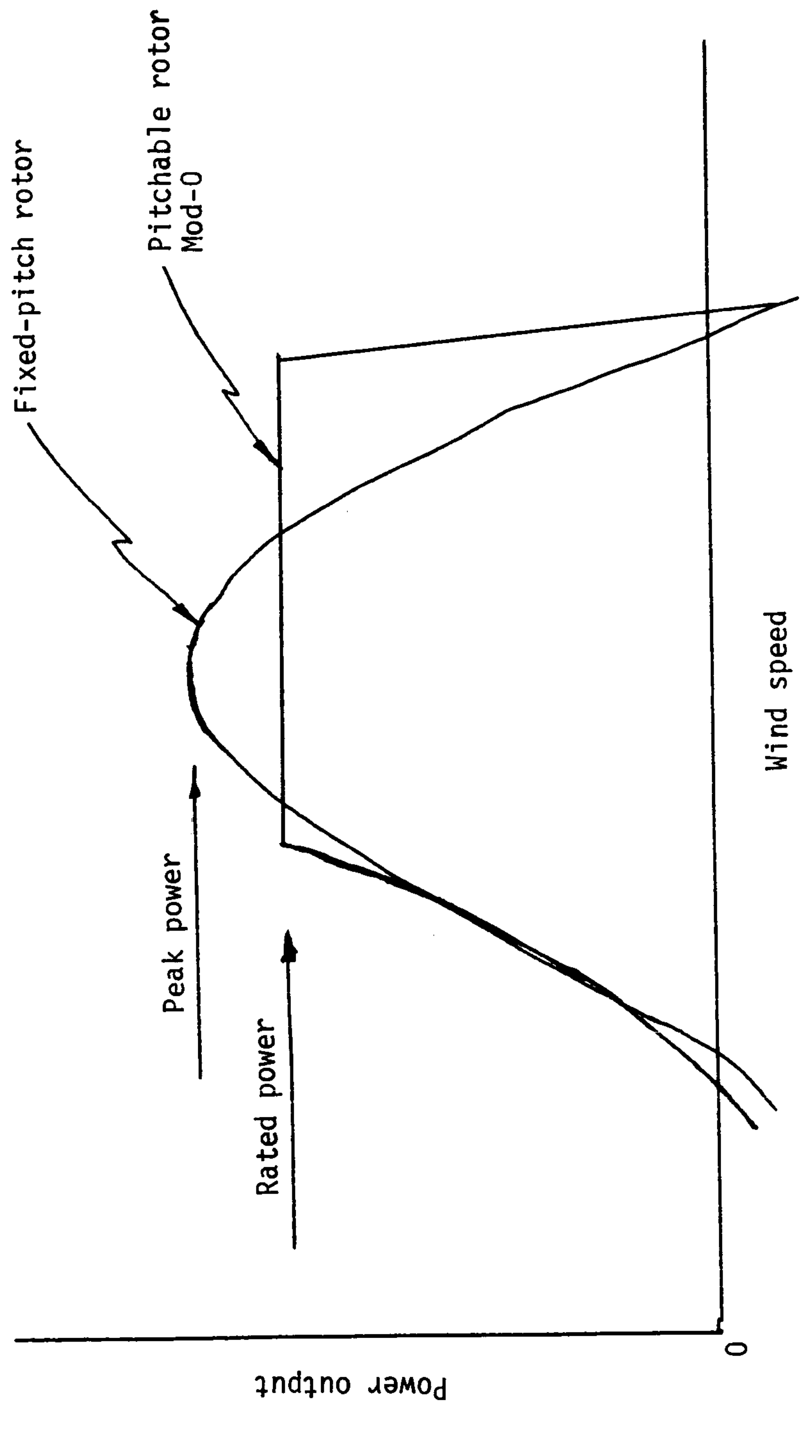

Figure 1. - Fixed-pitch wind turbine performance.

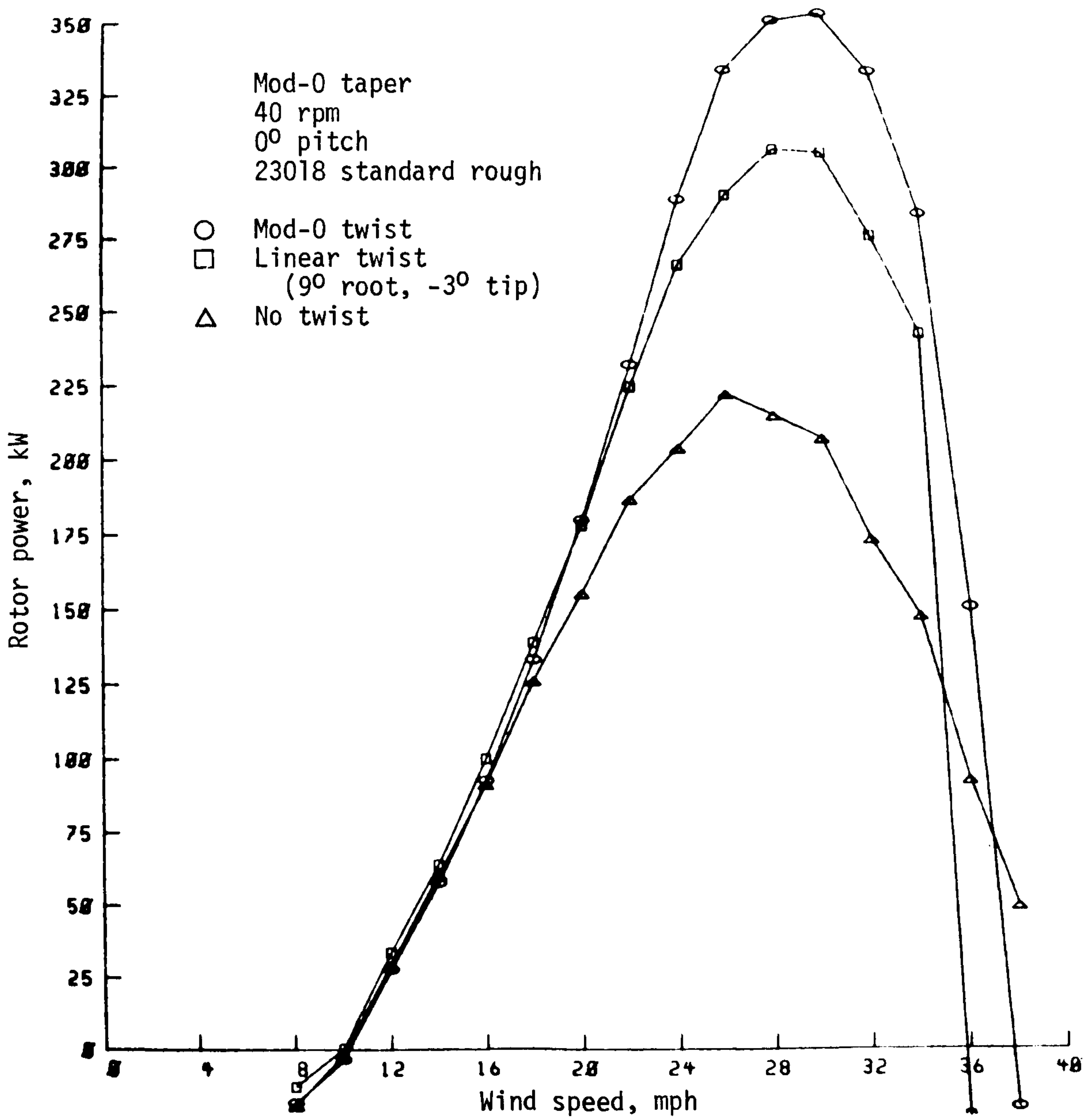

Figure 2. - Effect of twist on fixed-pitch wind turbine power.

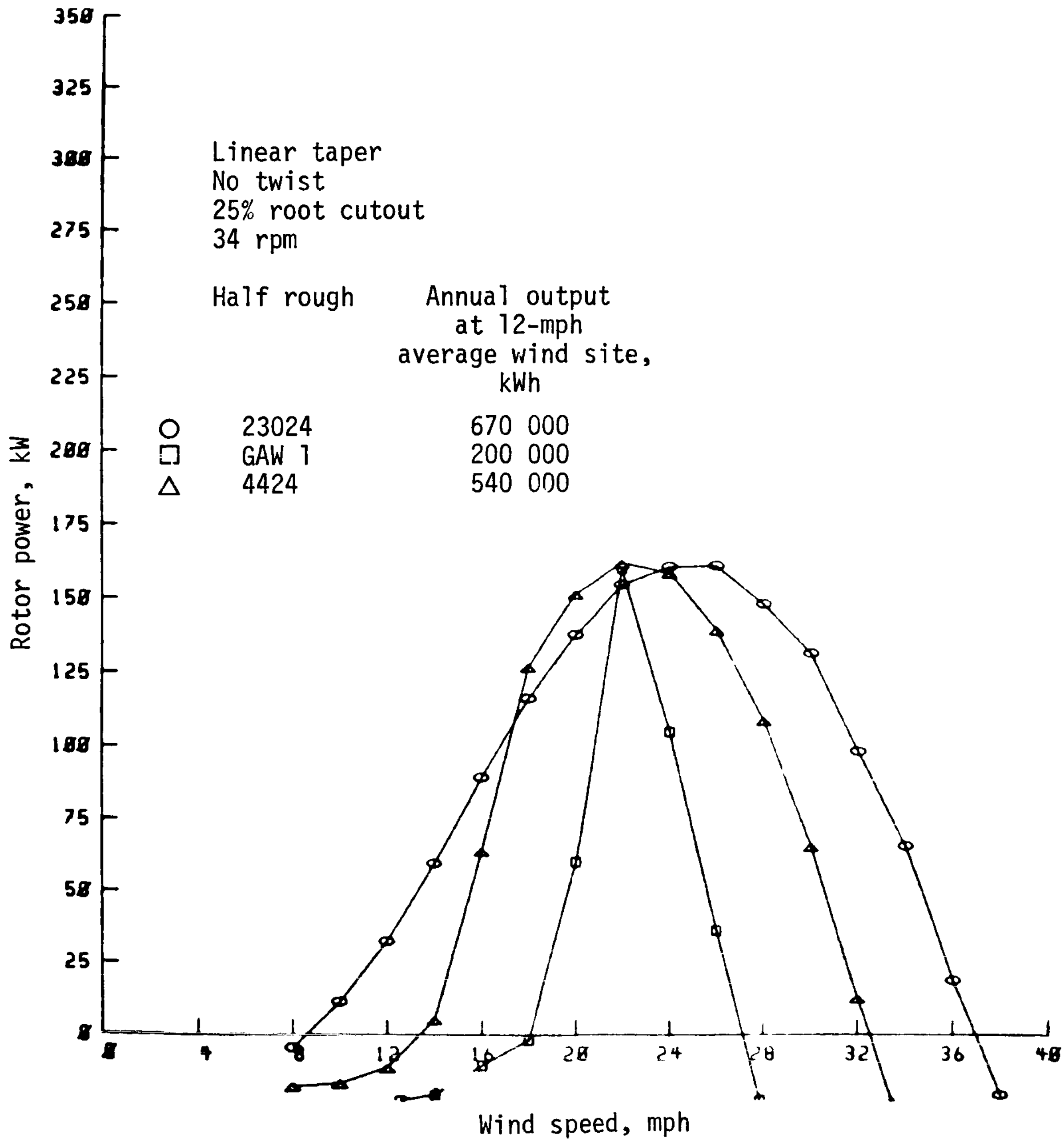

Figure 3. - Various airfoils on a fixed-pitch rotor.

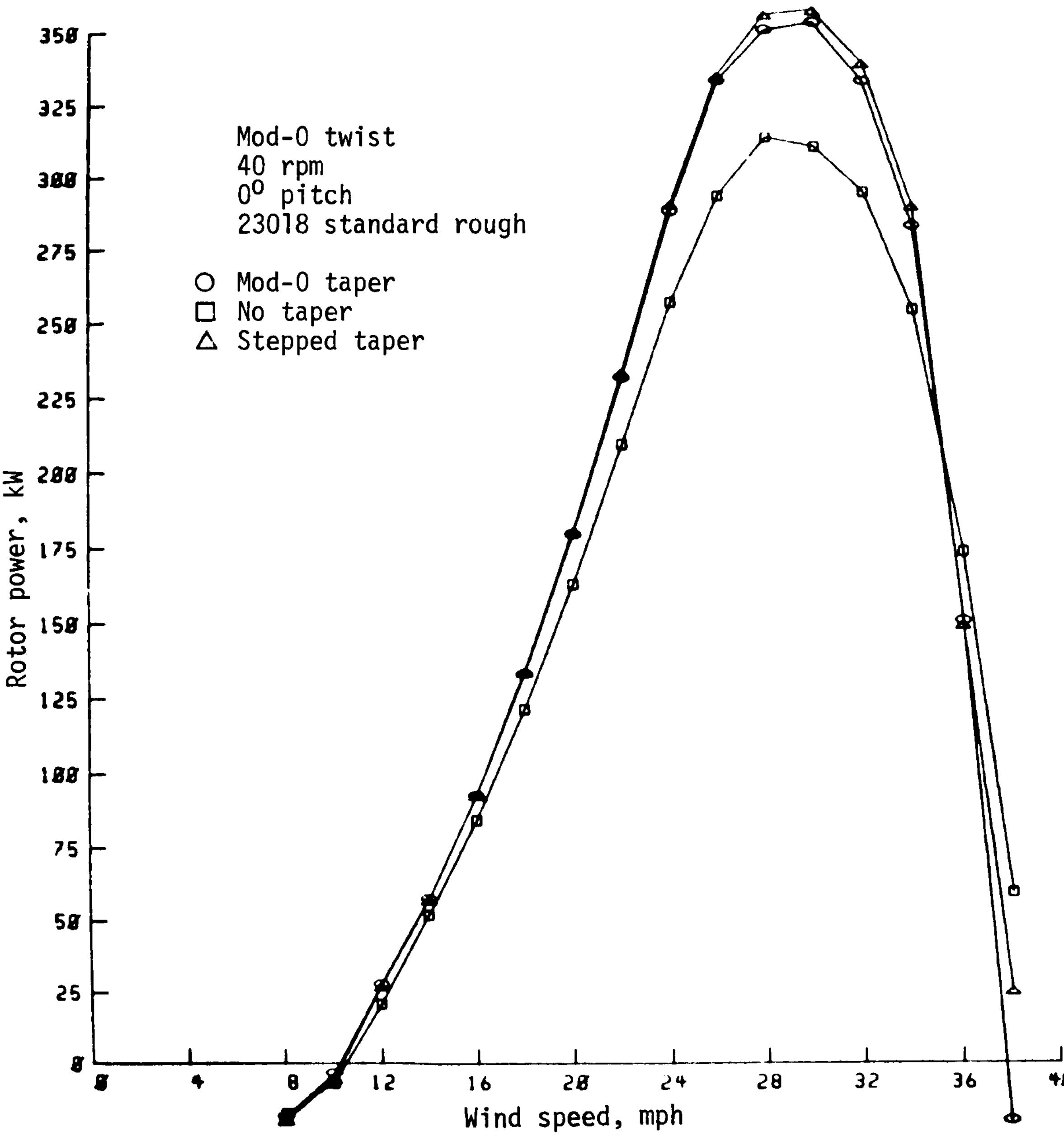

Figure 4. - Effect of taper on fixed-pitch wind turbine power.

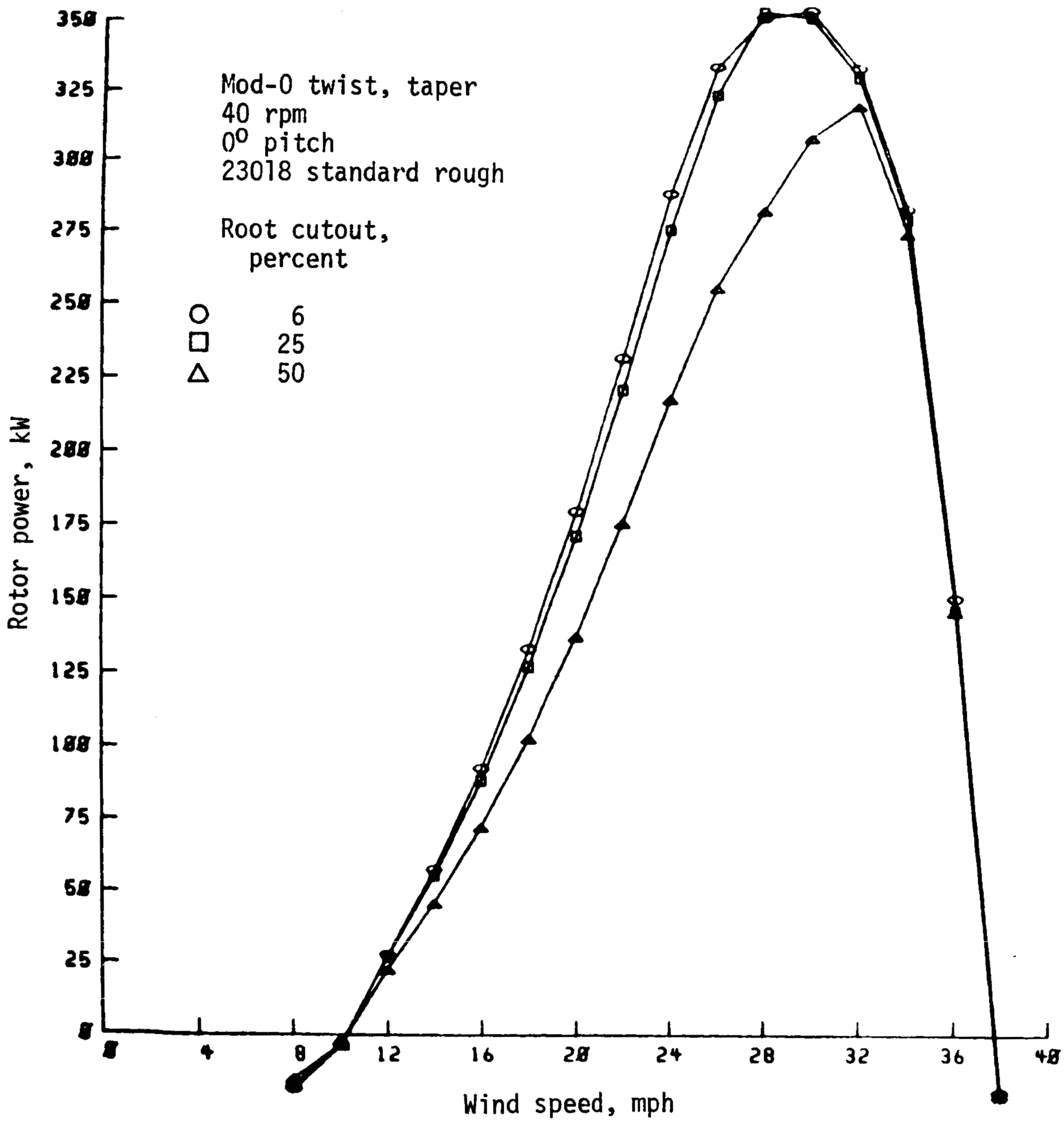

Figure 5. - Effect of root cutout on fixed-pitch wind turbine power.

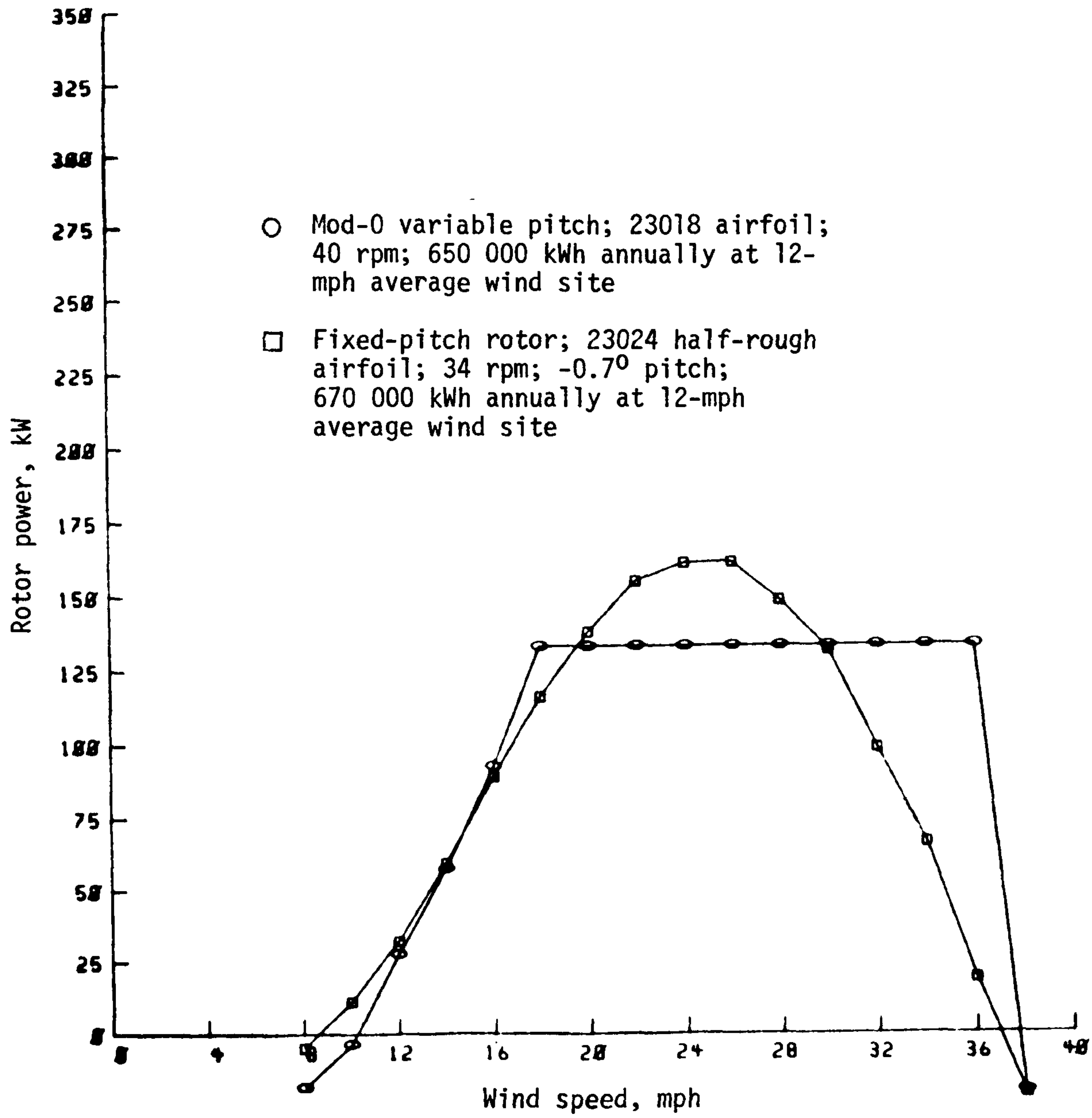

Figure 6. - Fixed-pitch rotor performance.

FIXED PITCH WIND TURBINE

Twist	Number of Blades	RPM	Angle	Peak Power	Annual Power	Power at Start
0	3	28	2^{o}	156 kW	666,000 kWhr	16 kW
0	3	28	8^{o}	249 kW	546,000 kWhr	0

Figure 7. - Starting ability versus annual power production.

FIXED PITCH WIND TURBINE

- Synchronous Generator - Motor Start
  - Clutch
  - Automatic Synchronizer
- Induction Generator - Motor Start
  - Poor Power Factor
  - Poor Efficiency at Low Power
- Yaw out of the Wind - Over Running Clutch
  - Automatic Synchronizer
  - Requires Experimental Verification
- Pitch Control on Blade Tip
  - Need 30% of Blade Length
  - More Complex Rotor

Figure 8. - Starting systems under investigation.

- Dead-man brake
  - Energized on loss of load
  - Scaleup effect
- Two-position tip flaps
  - Simple control
  - Approx. 4 ft^2 required

Figure 9. - Stopping systems for fixed-pitch wind turbines.