COMPARATIVE STUDY BETWEEN SAVONIUS ROTOR MADE ON TWO OR THREE BLADES OF POLYETHYLENE

Prof. Dr. Luiz Guilherme Meira de Souza
Departamento de Engenharia Mecânica da Universidade Federal do Rio Grande do Norte, Natal-RN, Brasil.

Vânio Vicente Santos de Souza
Programa de Pós-Graduação em Engenharia Mecânica da Universidade Federal do Rio Grande do Norte, Natal-RN.

Prof. Dr. João Telésforo Nóbrega de Medeiros
Departamento de Engenharia Mecânica da Universidade Federal do Rio Grande do Norte, Natal-RN.

Carlos D`alexandria Bruni
Programa de Pós-Graduação em Engenharia Mecânica da Universidade Federal do Rio Grande do Norte, Natal-RN.

Carlos Alberto Pereira de Queiroz Lion Filho
Programa de Pós-Graduação em Engenharia Mecânica da Universidade Federal do Rio Grande do Norte, Natal-RN, Brasil.

Aldo Paulino de Medeiros Júnior
Técnico em Mecânica da Universidade Federal do Rio Grande do Norte, Natal-RN, Brasil.

Abstract: *The use of renewable energies for several purposes, such as the eolian energy is one of the maintainable technological directions for the future. This work describes the comparative study between two alternative prototypes of Savonius windmill, made of two and three blades, both of small bodies and with a reception area of 1.8 m^2, yet composed of two stages and blades made of polyethylene drums in order to optimize performance, assembly and maintenance easiness as well as the opening of new directions for the use of technologies of low cost. Its clear that the prototype made of three blades in comparison to the conventional one proposed by Savonius in 1930 is more efficient as evidenced through the potency curves rotations graphic versus natural wind speed.*

Keywords: *Savonius windmill, eolian energy, alternative windmill.*

1. Introduction

The search for the use of clean and renewable energies has become more and more urgent nowadays due to the environmental degrading reflex provoked by the usual production model and its incompatibility with the cycles of environmental energies replacement.

The ECO-92 discussed the maintainable development as the one that is able to guarantee the needs for the future generations. Almeida (1997) apud Ronaldo(2000).

According to Goldemberg (2004) the current governments are not tilted to increase the "curve of learning" of the renewable technologies, as well as reducing the rate of energy consumption, mainly in the industrialized countries. It is illusory not to consider the economical and social inequality as being important for the appearance and application of new technologies, because the board of the world's energy distribution is chaotic, according to Layrargues (2001) apud Ronaldo (2000) it affirms that "If the current production of energy was shared with equality, the USA would have to live with only 1/5 of the one that consume per it captures annually".

In that inequality field the World Bank classified Brazil in last place regarding the incoming taxes distribution, showing that 20% of the poorest citizens contributes with only 2.1% of the total income of the country while the richest 10% ones are responsible for 51.3% of the total Martins(1995) apud Ronaldo(2000) .

It's in that context, where the bad distribution reflected by the economical character not only resists the application of renewable energies as well as excludes the possibility to develop itself at a low cost, that researches on windmills just like Savonius assist the efficient technological socialization, inserting possibilities of use of the proposed prototype in the pumping of water for communities, taking advantage of an energy resource that is free and available in intensity in many places of the world.

This work shows a comparative study between two Savonius rotors, a first conventional one with two and another with three blades, both made of polyethylene drums. The use of such a polymeric material in the blades, that conveniently are built of steel drums or cut out foils and welded to foils, intended to reduce the weight of the prototypes without using profiles of difficult construction as well as increasing the easiness of assembling of the group that passed to have fixation by screws and connected axis to the windmill through a dismountable pin glove.

Another innovation in the prototype made of three blades is the cut of these that doesn't add a new drum for the conception of the third blade in each stage, but it uses the cut drum with interval angles of 120° instead of 180° of the conventional model. In the cut there was material economy and intended to add one more useful area that could increase the reception area of the wind frequency that goes through the machine. The used parameters in the comparative study are the rotation and potency curve of the two prototypes, indispensable for visualization of the behavior in the wind regimes several

The prototypes have been created to act in different fields, such as water pumping in a small flowing rate and in lower wind speeds, about 7.0 m/s. Its construction and simple application (storage of water in reservoirs) justify its low cost what could turn it competitive in applications of those types while compared to the American multiblade windmill, common in the entire world.

2. Bibliographical revision

The development of eolian machines has remote and uncertain origin, but it is known that they had been used in Persia in the 7Th century in order to mill grains. In 200 B.C. existed the "Panemones" (dragging blades) precursors of the vertical axis rotors based in drag force, shown in the Fig. (1).

In 1929, S. J. Savonius patented a dragging windmill that took his name. That type of machine is made from steel drums (oil containers) that are longitudinally cut to the middle and shaped like blades, as shown in the Fig. (2). The main advantages of that type of windmill are the construction easiness, assembly and maintenance that offer prominence for devices of small bodies.

Figure 1. Precursor of drag blades

Figure 2. Savonius made drums

The Savonius windmill admits a lot of configurations, especially regarding the size, diameter and the central opening among the blades (gap).

According to Macyntire (1978), although that in 1930 he had already built Savonius of 30 m height in New Jersey, E.U.A, the most common are from 5.0 to 7.0 m.

In 1983, V.J.Mod of the University of British, Columbia, Canada, presented the results of a Savonius composed of sheets with efficiency of 36 %. That prototype was built with four stages.

According to Johnson (2004) Savonius himself claimed that the efficiency of his creation in 37 % for the fresh wind and 31% in the wind tunnel but couldn't explain the discrepancy of his results versus the theoretical data of professor Betz which limits the efficiency of the dragging blades to approximately 15%. Fujisawa (1991) showed through smoke wires that the efficiency reflects the presence of a sustentation force in the Savonius profile with two blades.

In Brazil some institutions build or study profiles, as it is the case of CEFET-RJ that uses a Savonius for didactic purposes since 1997 and the ITEVA that developed and patented a wind director that collects the wind and direct it onto the useful area, in 2001.

Although it's found in some areas and used for pumping or irrigation, flour factory, grinding of grains, and so on, the Savonius rotor is yet restrictedly known due to the expansion of horizontal axis models.

In the Solar Energy and Hydraulic Machine Laboratory of the UFRN the conventional Savonius prototype already has a report of about 10 years, having received some modifications, such as the use of blades of polyethylene and the most recent differentiated conception that is the three blades model.

3. Description of the windmill in study

The conventional Savonius was modified when changing the blades of steel drums by drums of polyethylene, but conserving the same dimension (0.60 x 0.90 m). The constructed windmill is presented in the Fig. (2).
The profiles have the characteristics of a Savonius rotor with two or three blades and two stages with angles interval of 180º or 120º between the blades. The rotor is composed by two or three equal parts of a same drum.

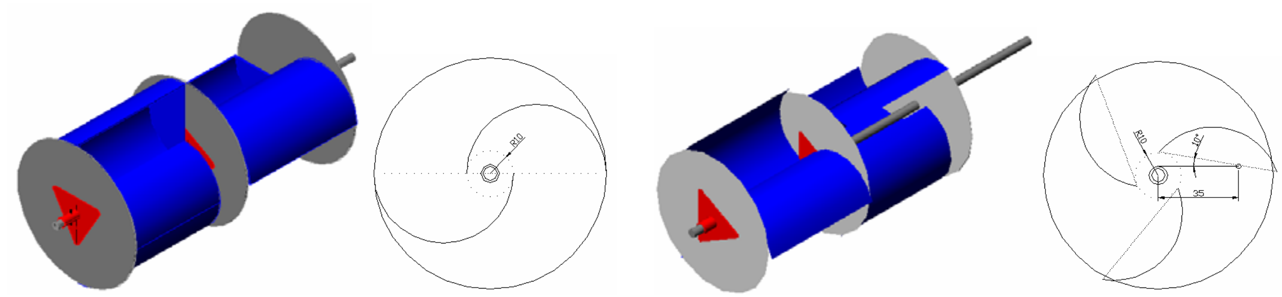

Figure.3. Savonius windmill of two or three blades with their respective oblique views;

The components of the savonius windmill in study is presented in Fig.(4).

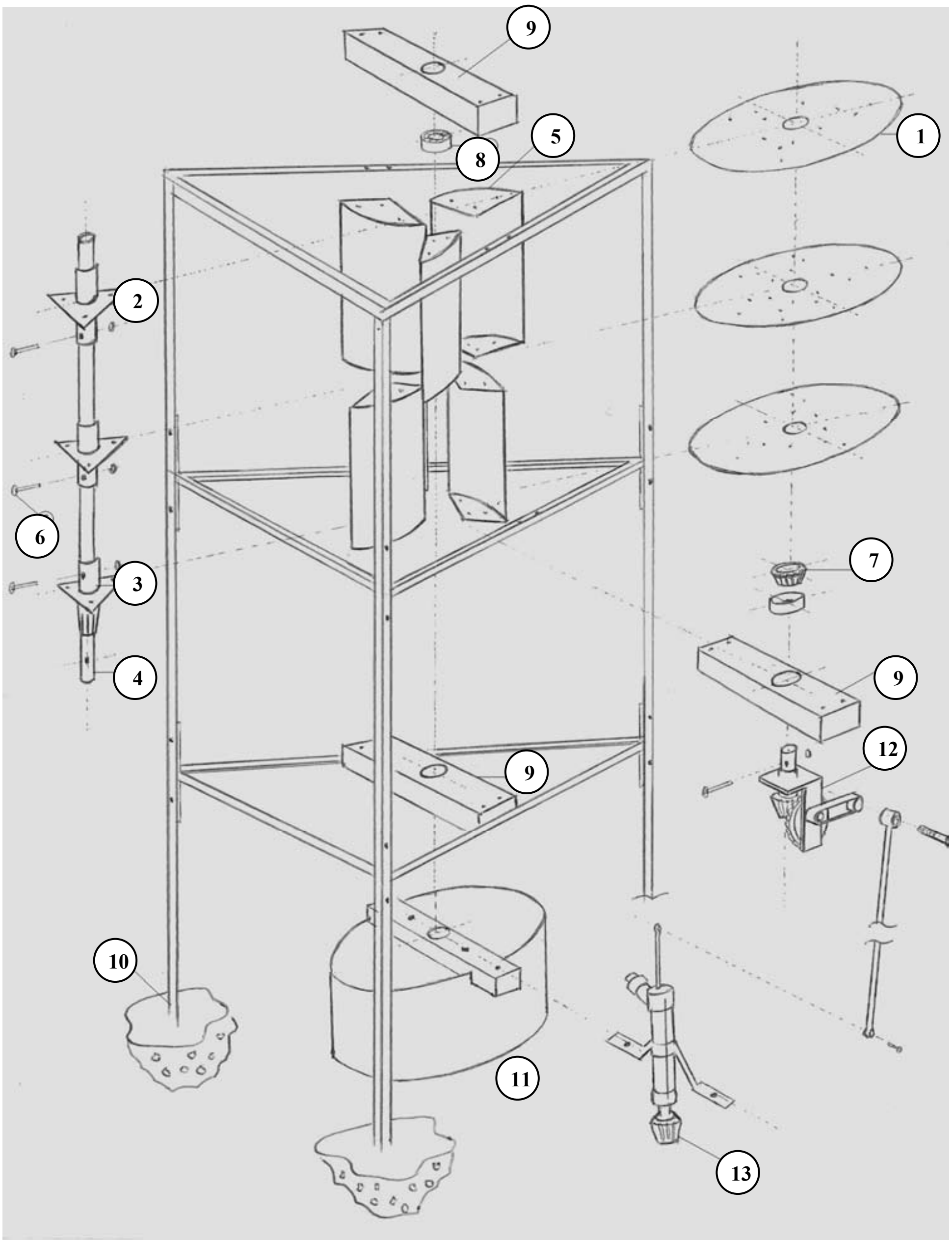

Figure 4. Savonius windmill components.

01 - steel plates with thickness of 1 mm and 1,5 mm
02 - triangular flanges
03 - fixation gloves of steel tube of 1”
04 - steel tube of ¾”
05 - blades of polyethylene done with cuts drums;
06 - pins of fitting of the axis;
07 - rolling of conical rolls;
08 - upper rolling of spheres;
09 - wooden bases;
10 - steel profile for tower structure;
11- Reservoir;
12- reducer composed for conical gears, motor 11 teeth and moved 44 tooth (Relation 1:4);
13- volumetric pump (diameter of 3 "and course of 150mm);

The production process can be summarized in the following stages:

1) Cuts of drums: for the two blades profile, only one central cut; for the tri-blades model, three cuts with angle interval of 120°, drums with diameter of 1.00 m and 0,90 m height;
2) Cuts of the foils: cut of three inferior foils, central and superior thickness nº 16 (1.5 mm) for the Savonius prototype of two blades and nº 18 (1.0 mm) for the three blades in the circular shape that will serve as support for the set;
3) Cut of tube of 2 inches for conception of three gloves for fixation of the foils;
4) Foil cut and central puncture (2 inches) of the flanges that have the shape of an equilateral triangle with sides measures of 0.25 m;
5) Puncture of the flanges, foils and tubes for fixation with a 10 mm drill;
6) Welding by electric arches of the flanges on the gloves;
7) Superficial anti-corrosion treatment of foils and metallic tubes;
8) Fixation of the set by screws and pins;
9) Puncture of the command axis (patent tube ¾ “x 3 m);
10) Glove making for fitting with reducer;
11) Construction of the reducer (4:1) starting from two conical gears with 44 and 11 teeth;
12) Construction of the knuckle set (2.40 m) and the winch one (0.075 m) that will be interlinked to the piston bomb (path of 0.15 m and nominal diameter of 3 ") obtained at the market and used in the commercial windmill.

4. Experimental procedure

4.1. Methodology

The period of accomplishment of the rehearsals was from January 3rd to March 10th 2005 in the same place and within 14:00 and 18:00 h (schedule for better wind intensity). The components were set up in a tower made of angle irons in prismatic shape and regular triangular base. That profile was chosen due to its building easiness, stability and easy fixation to a concrete base. The tower is 5.5 m eight with three parts; one regarding the fitting of the two stages of the windmill, other for measurement and adaptation of the gear box and another for fixation, what could be increased according to the needs and characteristics of the place of assembling.

In order to provide better stability, six strain wires were settled, avoiding the characteristic vibration of the structures that had been exposed to the variation of the wind speed.

The final test of each prototype refers to water pumping; For this operation a reduction box was connected to the axis 4:1 (with the aim of quadruplicating the torque), crank with ray of 0.075 m, connecting rod of 2.40 m and volumetric piston pump used in the market with diameter of 0.10 m, path of 0.15 m and medium pumped volume by cycle of 600 ml.

The water used for the pumping rehearsal was got from a water container with capacity of 1,000 liters and located under the windmill, so simulating a superficial water source as a well a dam. That water flow is pumped to a wanted height of 6m (height usually used by small properties to store consumption water) and returns back to the same container.

The flow date were taken in a period of constant winds with average speeds from 8.0 to 12.0 m/s and measured by using a chronometer and reservoirs of 3.0 liters, 20 liters and 200 liters. Such variation was provoked by the terrain, which was composed of dunes. The Figure (5) shows the constructed savonius windmill.

Figure 5. Constructed savonius windmill.

4.2. Instrumentation of tests

For the accomplishment of the tests the instrumentation was set up directly to the exiting axis of the windmill without the influences of the reduction. In the figure 6, it is shown the assembly of the rehearsals that followed the order to proceed:
1) Acquisition of the wind speed of each measurement point through CPS term-anemometer presenting a “YAW” direction command that was built at the laboratory;
2) Acquisition of the axis punctual torque through the assembling of the Proni brake (manually directed) conjugated by an arm of 0.5 m to a 10.0 Kg balance;
3) Acquisition of the axis rotation through an optic digital tachometer with a reflection point set on it.

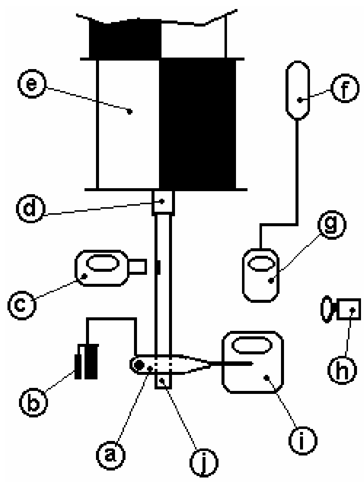

Fig.6. Assembly of the system for collecting data.

Where:

a) Prony Brake;
b) Brake commander;
c) Tachometer;
d) Glove for fitting the axis to the set;
e) Blades of polyethylene;
f) Anemometer;
g) Reader of the anemometer;

h) Video Camera;
i) Balance;
j) Axis transmitter.

For obtaining of the potency curve starting from the collected data it was used the Eq.(1), (2) and (3), shown below.

$$V_t = \frac{(\pi . R . f)}{30} \tag{1}$$

$$T = m . g . b \tag{2}$$

$$P = \frac{(\pi . T . f)}{30} \tag{3}$$

Where:

P - out power (Watt),
V_t - tangential velocity of the tip of the blade (m/s),
T - axis torque (N.m),
R - the windmill radius (m),
m - the suitable mass in the balance during the measurement of the torque (kg),
b - the lever arm in the brake (m),
g - the gravity local=9.81 m/s^2,
f - the wind frequency measured by the tachometer (RPM).

5. Results Analysis

The result obtained in the measurements of torque, tangential velocity and power curves in agreement with the wind speed for the two prototypes are presented in the graphs of Fig. (5), (6),(7),(8), (9) and (10).

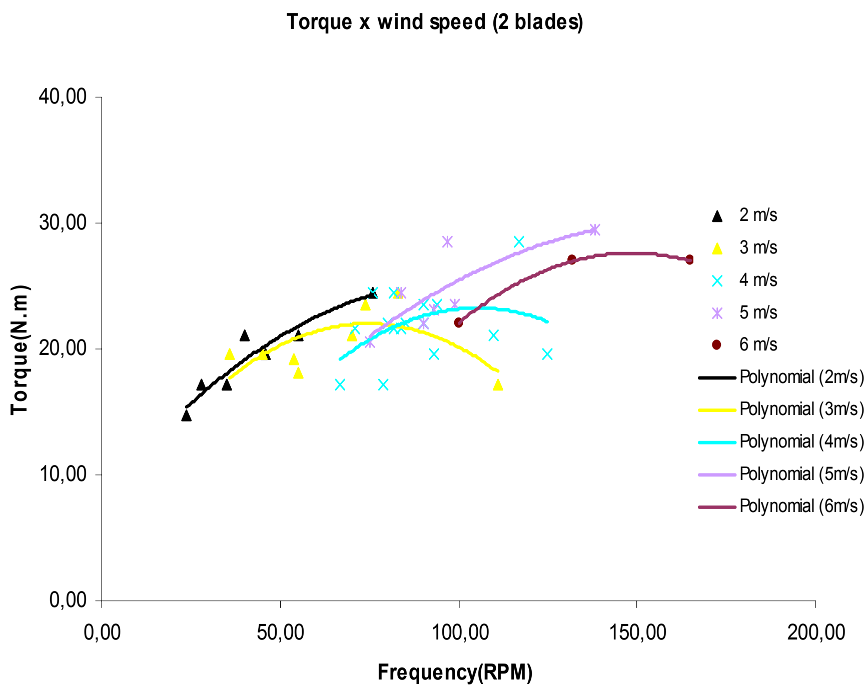

Figure 7. Torque versus wind speed (two blades prototype)

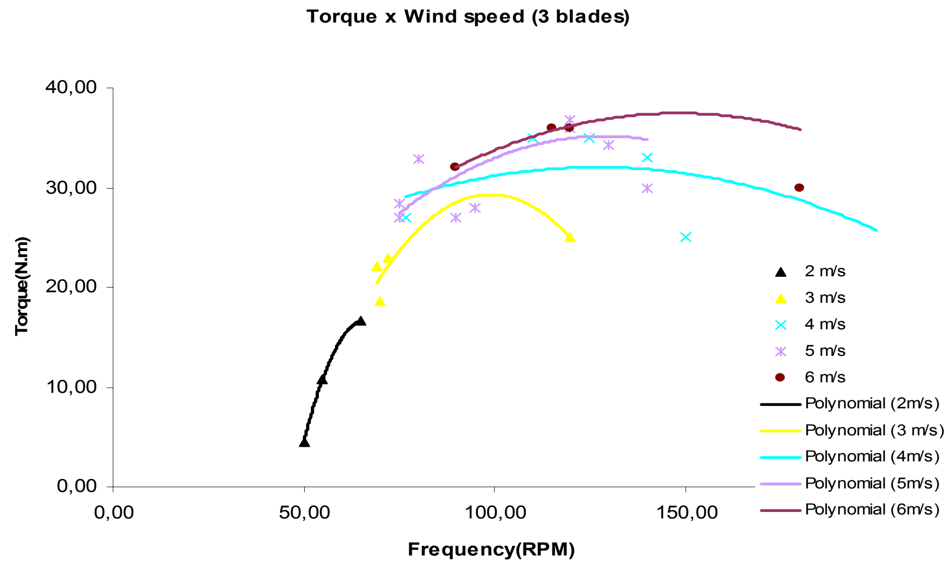

Figure 8. Torque versus wind speed (three blades prototype)

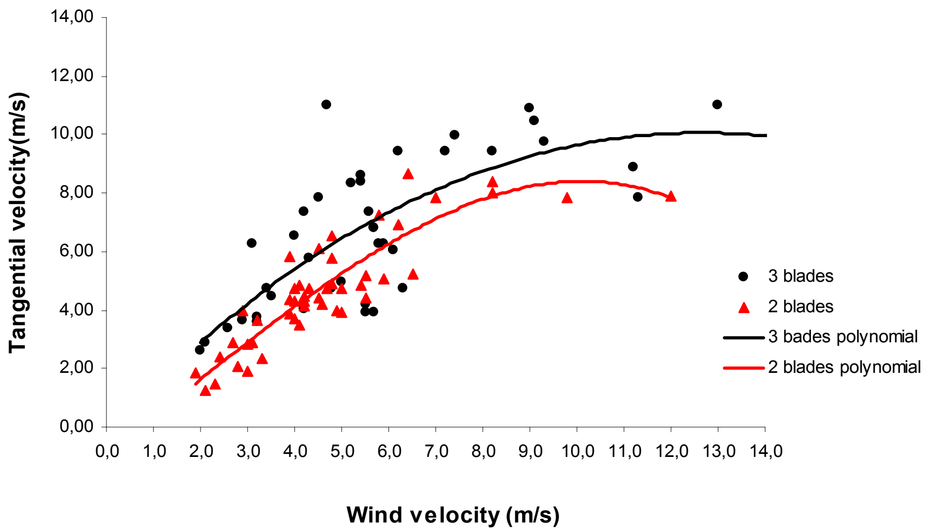

Figure 9. Tangential velocity versus wind velocity.

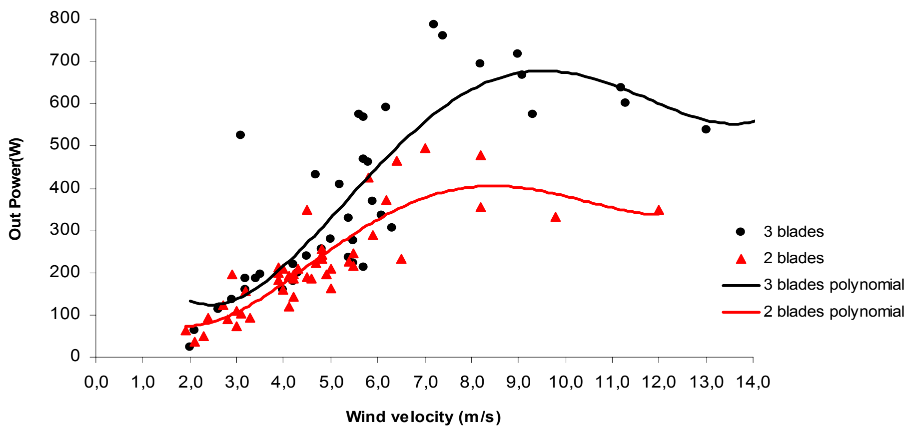

Figure 10. Power curves of savonius windmill proposed.

The Table (1) shows the comparative values with relationship to the pumping obtained with the savonius windmill with two and three blades. The graphs of the Fig. (11) shows the comparative comportment for the two models of the savonius windmill.

Table 1. Outflow for three measured points.

V (m/s)	Two blades (m^3/h)	Three blades (m^3/h)
6 m/s	0.3	0.36
8 m/s	0.5	0.63
12 m/s	0.6	0.78

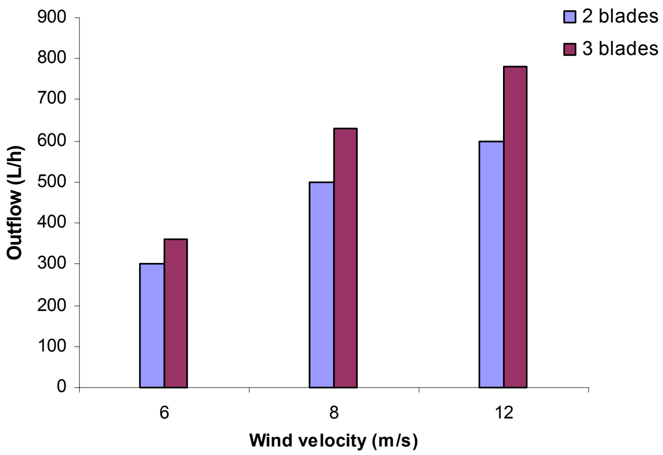

Fig.11. Outflow of water pumping versus wind speed.

Starting from the obtained results it can be affirmed that the windmill prototype of three blades is more efficient than the one of two regarding rotation and the production of exit potency. The diminishing of mass of the three blades windmill provoked by the diminishing of thickness of the foils reduced the intensity of necessary wind to the admission from 3.3 m/s for 3.0 m/s.

Starting from the obtained results its possible to affirm that the savonius windmill with three blades is more efficient than the one of two in rotation and in the exit potency production of. The mass decrease of the windmill of three blades provoked by the decrease of the thickness of the steel foils it reduced the wind intensity necessary to the start of 3.3 m/s for 3.0 m/s

Analyzing the results we can interrogate ourselves if it is possible, that with a same entrance potency provided by the wind, to have rotation and larger Torque, considering the fact that the rate of kinetic energy that moves the prototype of three blades is superior than the one of two, providing better performance torque when the speed is superior to 4.0 m/s.

A small prototype model with three blades had been tested before the research, but that model differed due to absence of the central space resulting smaller speeds than the conventional Savonius, taking to a reevaluation of the importance of the central space in the aerodynamics of the Savonius profile that was preponderant in the increase of the efficiency of the three blades, which has absorbed the concept of a larger wind speed incidence rate, conserving the same gap used in conventional Savonius.

Rehearsals accomplished by the laboratories Sandia resulted in a 0.10 m central space when we have a Savonius profile with the dimensions and close characteristics to the prototype tested in the work.

The water pumping in accordance with data measured is proportional to the resulting torque in the axis. Taking in consideration the variations of the wind speed was made a pumping test with a reservoir of 200 liters, resulting for the windmill with two blades a time of 20 minutes and for the three blades about 15 minutes, in other words, medium flow of 0.6 m^3/h and 0.8 m^3/h.

6. Conclusions and suggestions

Starting from the experimental results that show the technical viability of the Savonius windmill we can have the followed conclude and present the suggestions for the improvement of the proposed blades three prototype.

6.1. Conclusions

1) The prototype built with three blades is, at least, 20% more efficient in terms of exit potency than the conventional Savonius with the same material expense;
2) The rotation of the three blades profile is, at least, 12% larger than the prototype of two blades;
3) Starting from 4.0 m/s the torque of the three blades prototype is superior;
4) The substitution of the foils of 1.5 mm instead of foils of 1.0 mm reduced the weight of the windmill, increasing its efficiency in the admission;
5) The polyethylene used in the blades resisted to the applied loads and slightly degraded in the presence of ultraviolet rays after one year of exposition, bringing no hazard to the blades;
6) The use of reduction 4:1 was adapted for medium regimes of winds of 6.0 m/s;
7) The amount of pumped water is satisfactory considering the mainly objective this work, that is the water pumping to consumption water box around 2.000 liters /day;
8) The proportional cost of construction and pumped water is about 5% smaller than the implementation of a multiblade American model;
9) The savonius windmill proposed present superior of assembly and maintenance easiness if compared to the conventional savonius windmill made of metal;
10) The use of polyethylene for the manufacture of the blades is advantageous due to corrosion absence and satisfactory resistance.

6.2. Suggestions

1) To substitute of the shelves corner square tower of welded by screwed triangular tower;
2) To study the influence of the inclination of the blades for the increase of the performance of the windmill;
3) To substitute the positive displacement pump with vertical piston for a bomb of radial pistons that can be linked directly to the axis;
4) To use radial limps instead of conical rolls in the base, reducing the attrition;
5) To build devices of safety for wind speeds high;
6) To increase the durability of the blades through a superficial painting;
7) To accomplish a deeper study on pumping with larger times of admission, one year for instance, making possible the analysis of the influence of the variations of wind in the stations;

7. References

ALMEIDA, J., 2001, Da ideologia do progresso a idéia de deesnvolvimento(rural) sustentável, In: ELISABELA, Virgínia Etges. Desenvolvimento Rural: potencialidades em questão – Santa Cruz do Sul, EDUNISC.

ANDREAS, J., 1998, Windenergienutzung in einem regenerativen Energiesystem, Analyse gives Windkraftanlagen Eberschwang und Laussa 1 ed., Graz,.

FUGISUWA, N., 1991, On the mechanism of savonius rotors; Department of Mechanical eEgineering, Gunma University, Japan,.

GOLDEMBERG, J., 2003, Energy, environment and development - USP - São Paulo-SP.

GOUVEIA, A. M., 2004, O clima de Natal, Editora Foco, Natal-RN.

JOHNSON, G. L., 2001, Wind energy systems, Chapter 4..

LAYRARGUES, F., 2001, Do desenvolvimento ao ecodesenvolvimento sustentável: Evolução e um conceito. In: ELISABELA,, Virgínia Etges. Desenvolvimento Rural: potencialidades em questão – Santa Cruz do Sul, EDUNISC.

MACINTYRE, A. J., 1983, Máquinas Motrizes Hidráulicas, Guanabara Dois, Rio de Janeiro-RJ.

RONALDO, G. L. 2001, O paradigma da sustentabilidade In: ELISABELA, Virgínia Etges. Desenvolvimento Rural: Potencialidades em questão- Santa Cruz do sul: EDUNISC,.

8. Responsibility notice

The authors are the only responsible for the printed material included in this paper