EXPERIMENTAL STUDY OF A SAVONIUS- DARRIEUS WIND MACHINE

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ABSTRACT

In this paper, experimental investigations were carried out to study the performance of a Savonius rotor as well as a Savonius- Darrieus machine. For this purpose, two types of models, one Savonius rotor and the other Savonius- Darrieus machine were designed and fabricated. The Savonius rotor was a two- bladed system having 8 cm bucket diameter and 20 cm in height with provision for overlap variation. For the Savonius- Darrieus machine, in the upper part, there was a two-bladed Savonius rotor having bucket diameter of 8 cm and height of 10 cm and in the lower side, there was Darrieus machine having three curved blades of dimension of 10 cm in height and 4 cm in radius. The overlap variation was made in the upper part. These were tested in a subsonic wind tunnel and it was observed that there was an improvement in the power co-efficient for Savonius- Darrieus machine compared to only Savonius rotor under the same test conditions.

Key Words: Savonius- Darrieus machine, power co-efficient, tip speed ratio, overlap.

INTRODUCTION:

Owing to acute energy crisis that most developing countries including India are facing today, the interest in alternative energy sources has increased manifolds in the recent past. And the potential of wind energy as a source of alternative energy perhaps cannot be underestimated. Wind energy can be utilized to windmills, which in turn drive a generator to produce electricity. Wind can also be used for water pumping. Thus it is expected that wind being a non-polluting and non-toxic energy source, will go a long way in solving our energy requirements. However, in India, the interest in windmills was shown in the late fifties and early sixties. Few designs were developed but could not yield expected results. An important reason could be that wind velocity in India, apart from coastal region, is relatively low and varies appreciably with seasons. This low velocity and seasonal winds imply a high cost of exploitation of wind energy. Thus the challenge lies with the design of a windmill which can be used in a small scale manner in remote and rural areas where electricity is very scare.

It is accepted that vertical axis wind machines represent a suitable alternative for wind power extraction in many developing countries. The reason for this is mainly because of the advantage over the horizontal axis type such as –

i) Simple construction
ii) Extremely cost effective

iii) Acceptance of wind flow from any direction without orientation.

In spite of these advantages vertical axis turbine is not gaining popularity because of low efficiency of the Savonius type rotor and low starting torque of the Darrieus type wind machines. From the literature, it is observed that scientists largely deal with Savonius or Darrieus individually [1-5]. There are few works that analyze the combined Savonius- Darrieus configuration [6].

The vertical axis Savonius rotor was initially developed by S.J. Savonius in late twenties [7]. The concept of Savonius rotor was based on the principle developed by Flettner. Savonius used a rotor , which was formed by cutting a cylinder into two halves along the central plane and then moving to two semi- cylindrical surfaces sideways along the cutting plane, that the cross-section resembled the letter `S`. An optimum geometry was obtained by systematically testing more than 30 different models in a wind tunnel and Savonius reported encouraging results. He conducted further tests in natural wind and observed that rotor run at a higher speed than that in the wind tunnel for the same wind velocity. According to Savonius, the best of his rotor had a maximum efficiency of 31% while the maximum efficiency of the prototype was 37%. Following Savonius, Newman, Sivasegaram and Khan[8-10] among others conducted several experiments to investigate the effect of geometrical parameters such as blade gap size, overlap etc.

Darrieus type rotors are lift devices, characterized by curved blades with an air-foil cross-section. They have relatively low starting torque and high power output per given rotor weight. The Darrieus type machine was invented and patented in 1925 by G.J. Darrieus, a French Engineer. Darrieus machine has two or three thin curved blades with air-foil cross-section and constant chord length. Both ends of the blades are attached to a vertical shaft. When rotating, these air-foil blades provide a torque about the central shaft in response to a wind stream.

Based on the literature review, it has been decided to design and fabricate Savonius rotor as well as Savonius- Darrieus machine and to experimentally investigate their performances. The purpose of the present study is to investigate the performance of Savonius- Darrieus machine and to compare its performance with the Savonius rotor under the same test conditions.

WIND DATA AT NATIONAL INSTITUTE OF TECHNOLOGY SILCHAR

To know the wind conditions, wind data were collected at National Institute of Technology, Silchar, which is situated in southern part of Assam, a backward place of North-Eastern region of India. Wind data were collected with the help of a cup type anemometer. Data were recorded for the last three years and from the data it is observed that wind velocity is quite low and a sample data has been shown in Fig.1.

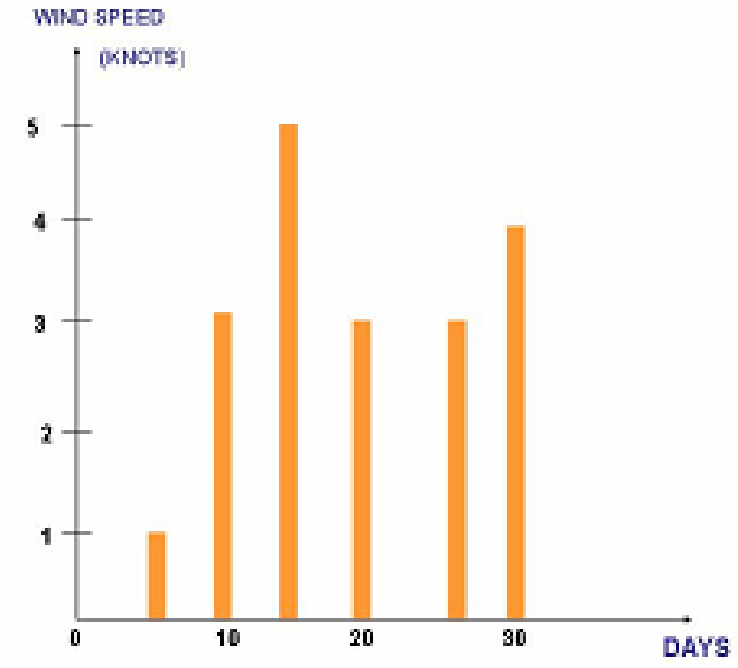


Fig.1. WIND DATA FOR THE MONTH OF APRIL 2003

THE WIND TUNNEL

A brief description of the wind tunnel is given below: (Fig:2)

a) Blower section- The blower section of an axis flow fan having variable pitch blades in a cylindrical casing. The capacity of the fan is 6700 cu ft/min at 2890 rpm. The fan is driven by a three phase 15 kW motor.

b) Honeycomb Chamber- The honeycomb chamber is at the entrance of the tunnel to break the large scale disturbances and eddies. It comprises a number of strawboard placed side by side and their axis parallel with the direction of flow or the axis of the tunnel.

c) Settling chamber- The frictional resistance of the flow is increased by the honeycomb, so improving the distribution of longitudinal velocity .But the wakes of the honeycomb tubes introduced relatively minor disturbances and turbulence into the flow. A settling length of chamber is therefore required downstream after honeycomb is therefore required downstream after honeycomb chamber.

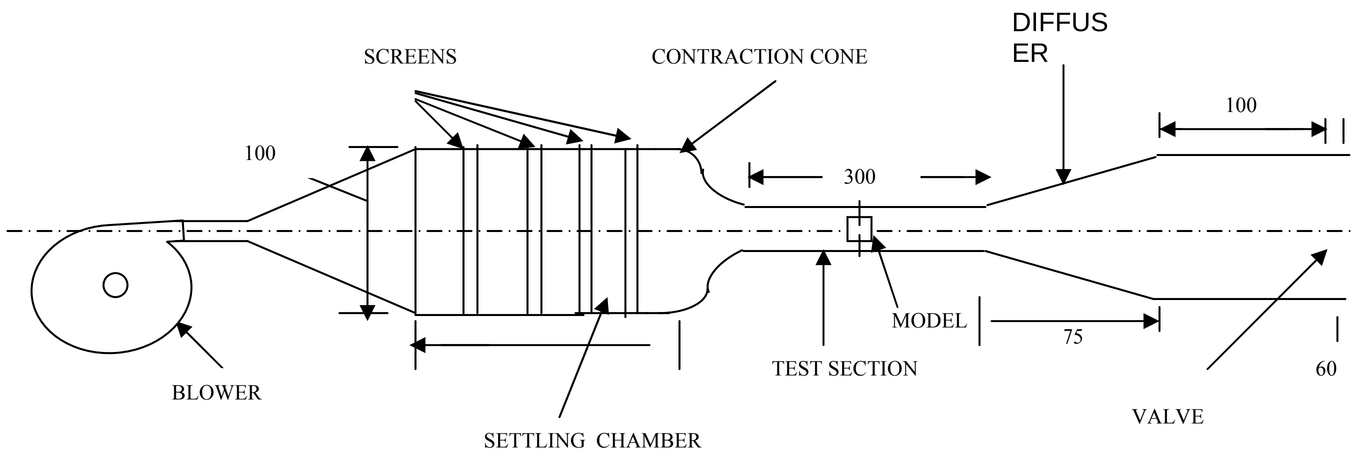
d) Wire mesh or damping screen- Two damping screens of stainless wire netting are placed in the low velocity region up of contraction cone. These remove the large scale eddies, but produce smaller eddies that decay rapidly.

e) Settling Chamber- Just after the damping screen there is another chamber which allows the eddies to decay further.

f) Contraction zone-The contraction cone (or entrance cone) produces a uniform velocity distribution with weak turbulence in the test section, but with a minimum of energy loss.

g) Test Section-The test section has four plates, two of which are made of glass .There are holes in the upper horizontal plate made of wood for inserting a static tube. One of the vertical glass plates can be opened for inserting the work piece sample to be `tested ‘. The four plates make square section of dimension 300mm* 300mm. The length of the test section is 3 meters.

h) Exit valve-At the exit, a value controls the air velocity in the test section.



(*all dimensions are in m.m*)

Fig 2: WIND TUNNEL.

MODEL TESTS

Two types of models, one simple Savonius rotor and the other Savonius-Darrieus machines were designed and fabricated. The simple Savonius was a two-bladed system having 8 cm bucket dia & 20 cm in height with provision for overlap variation [fig 3]. For the Savonius- Darrieus type of machine, in the upper part, a two bladed S-rotor having bucket diameter of 8 cm and height of 10 cm, whereas in the lower side of Darrieus machine having three curved blades of dimensions of 10 cm in height and 4 cm in radius[fig. 4]. There was also a provision for variation of overlap in the upper part of the Savonius- Darrieus machine. The material used for both the cases was aluminum. The experiments were carried out in a low speed open circuit wind tunnel which provide an air velocity adjustable between 0 and 30 m/sec. Tests were conducted for S-rotor with and without overlap and Savonius- Darrieus machine with and without overlap. The overlap variation was 16.2 % & 20% for both the cases.. The rotor speed was measured using a digital tachometer having a least count of 1 rpm and the wind velocity was determined using the Pitot static tube.

ANALYSIS & CONCLUSION:

The purpose of the present study is to investigate the performance of the Savonius-Darrieus wind machine and compare its performance with the simple S-rotor. The performance of the machine can be expressed in the form of Power Coefficient (Cp) versus tip-speed ratio (λ). For analysis, the following relations were used:-

i) Co-efficient of Performance $Cp = \frac{P_{rotor}}{0.5\rho V^2}$

ii) Tip speed ratio $(\lambda) = \frac{\text{Velocity of blade tip}}{\text{Free stream velocity}}$

Graphs between Cp versus TSR for S-rotor without overlap has been plotted in [fig 5]. Figs 6 & 7 show the plot between Cp versus TSR for S-rotor with 16.2% and 20 % overlap respectively. Graph between Cp versus TSR for Savonius- Darrieus wind machine has been plotted in fig. 8. Figures 9 & 10 show the graphs between Cp versus TSR for Savonius- Darrieus wind machine with 16.2% and 20% overlap respectively.

From figure 5, it is observed that Cp increases with increase of TSR but up to a certain limit. After that Cp decreases even with the increase of TSR. The maximum Cp obtained is 16 % at about 0.18 TSR. From the fig 6, it is observed that with 16.2 % overlap, there is slight improvement of Cp although the trend of variation of Cp with TSR is similar to that of S-rotor without overlap. The maximum Cp observed here is 18% at about 0.22 TSR. While observing the fig No. 7, i,e, S-rotor with 20 % overlap, it is found that there is further improvement of Cp although the variation of Cp versus TSR is similar. The maximum Cp observed is 21 % at about 0.24 TSR. Thus it is observed that there is improvement of power co-efficient with the overlap conditions.

Figure 8 shows the variation of Cp with TSR for the Savonius- Darrieus turbine without overlap. It is observed that Cp increases with the increase of TSR but up to a certain limit. Beyond this the Cp starts decreasing even with increase of TSR. The maximum Cp obtained is 19 % at about 0.22 TSR. While comparing this with S-rotor without overlap, it is found that there is a definite improvement of Cp with the Savonius- Darrieus turbine.

From fig 9, it is observed that with 16.2% overlap for Savonius- Darrieus wind machine, there is an improvement of Cp and the maximum Cp observed is 22 % at about 0.26 TSR. Further improvement of Cp is observed with 20 % overlap for Savonius- Darrieus wind machine and the maximum Cp observed is 25 % at about 0.28 TSR[fig. 10]. While comparing these observations with the S-rotor, it is found that there is a definite improvement of Cp with Savonius- Darrieus wind machine for both with and without overlap conditions.

From the preliminary results, it indicates that the improvement in the power co-efficient is obtained for the Savonius- Darrieus turbine compared with the Savonius rotor only. However, more investigations are on process for confirmation.

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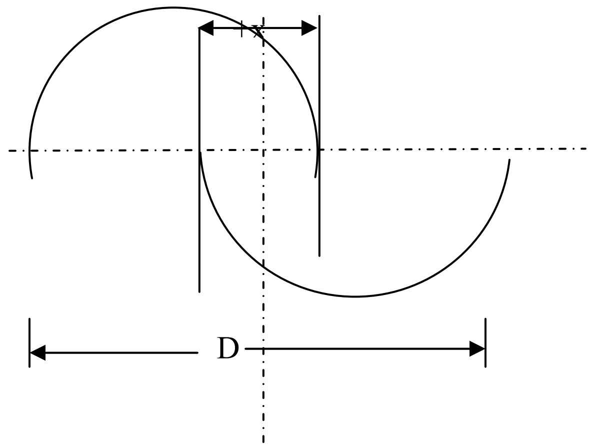
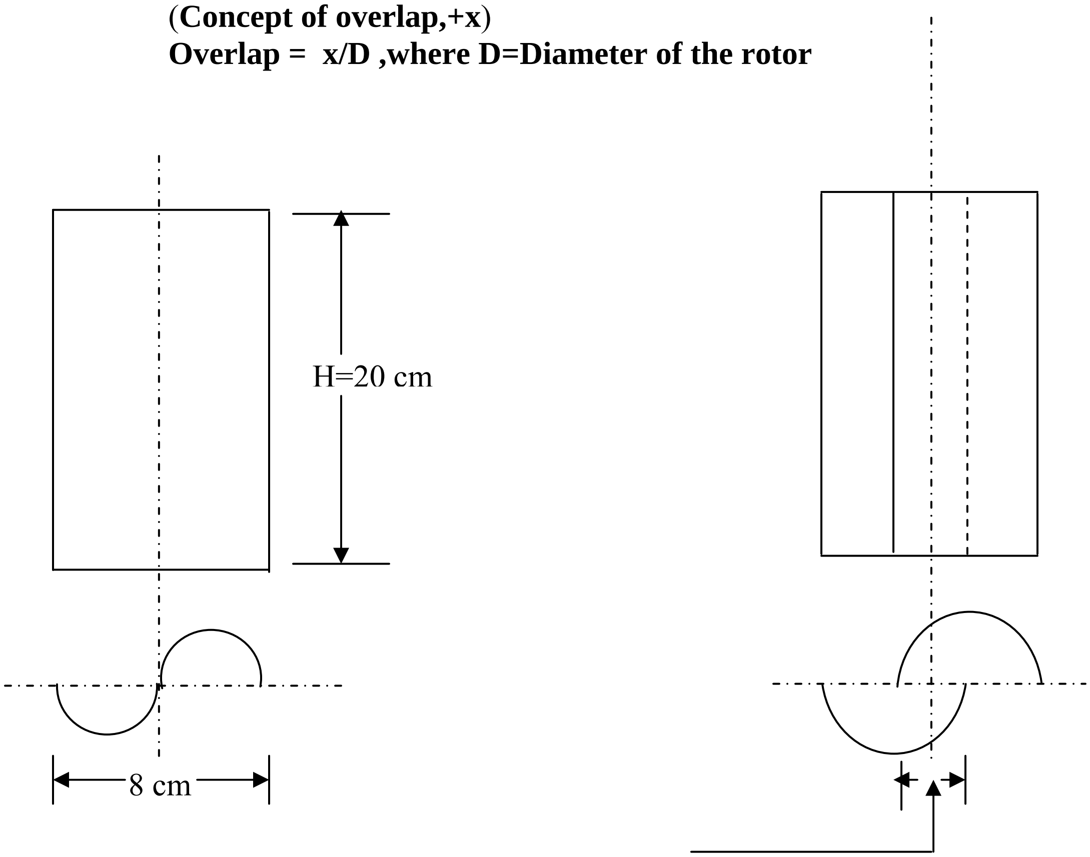


Fig.a

(**Concept of overlap,+x**)
Overlap = x/D ,where D=Diameter of the rotor



(b) Without Overlap (c) With Overlap

Fig.3(SAVONIUS ROTOR)

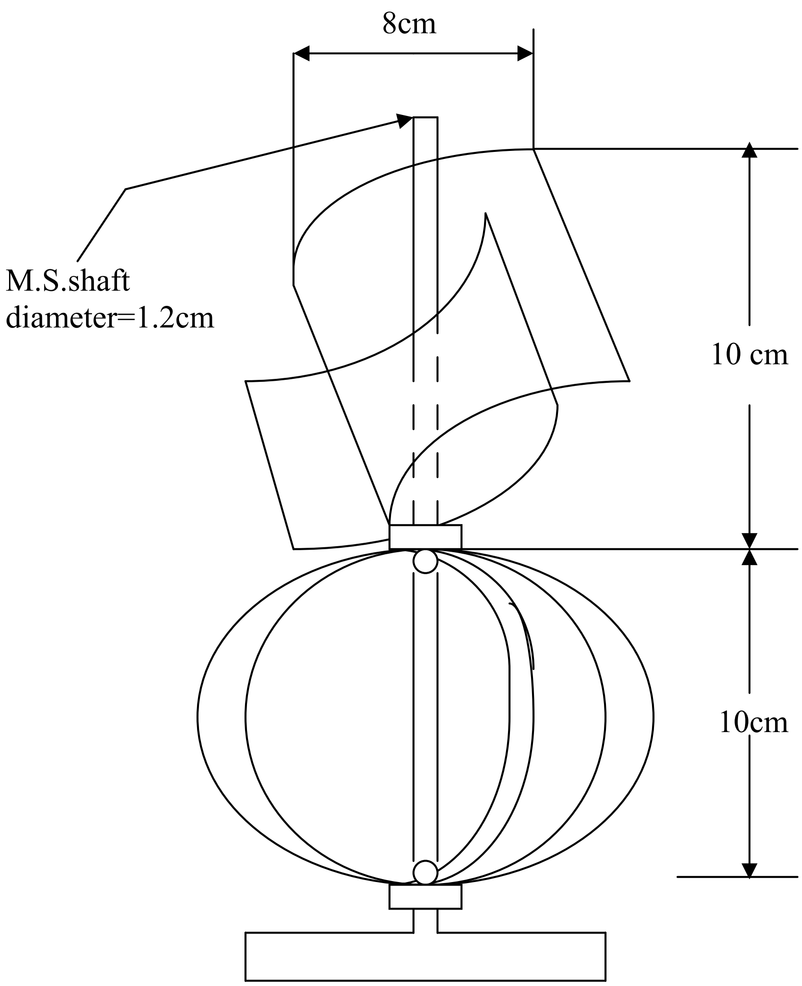
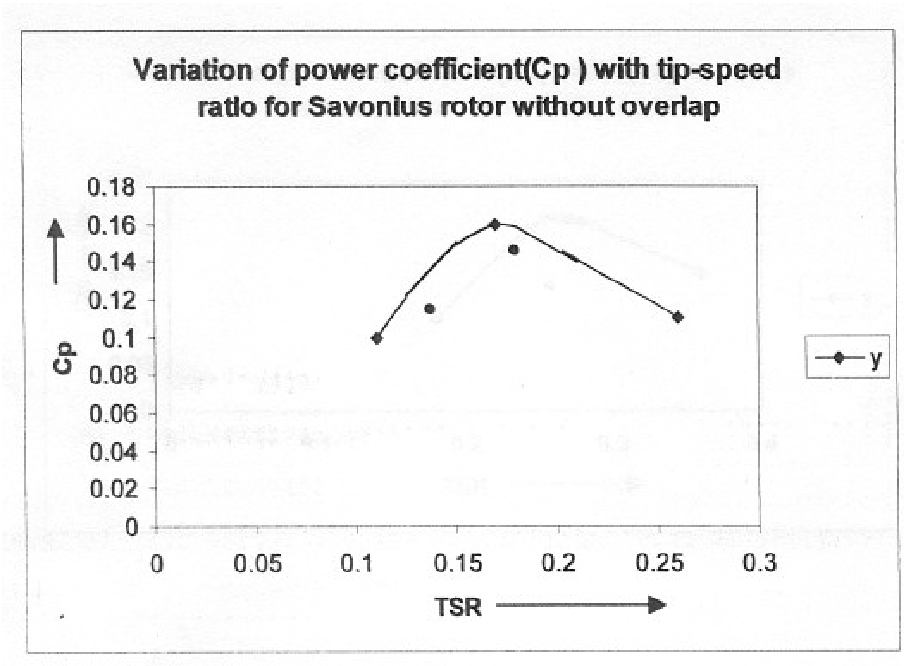
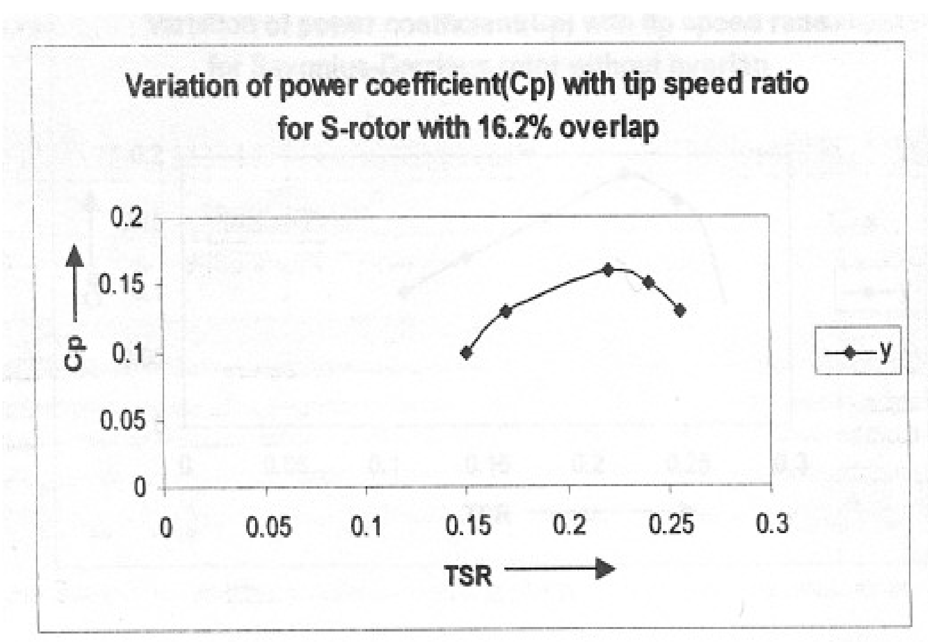


Fig.4 SAVONIUS-DARRIEUS WIND MACHINE



Variation of power coefficient(Cp) with tip-speed ratio for Savonius rotor without overlap
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Cp
0
0.05
0.1
0.15
0.2
0.25
0.3
TSR
y

FIG- 5



Variation of power coefficient(Cp) with tip speed ratio for S-rotor with 16.2% overlap
0.2
0.15
0.1
0.05
0
Cp
0
0.05
0.1
0.15
0.2
0.25
0.3
TSR
y

FIG- 6

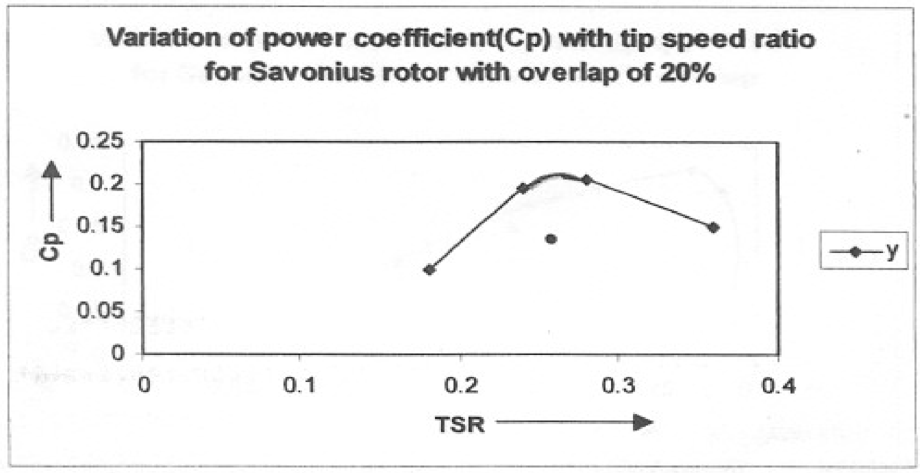

Variation of power coefficient(Cp) with tip speed ratio
for Savonius rotor with overlap of 20%
0.25
0.2
0.15
0.1
0.05
0
Cp
0
0.1
0.2
0.3
0.4
TSR
y

FIG- 7

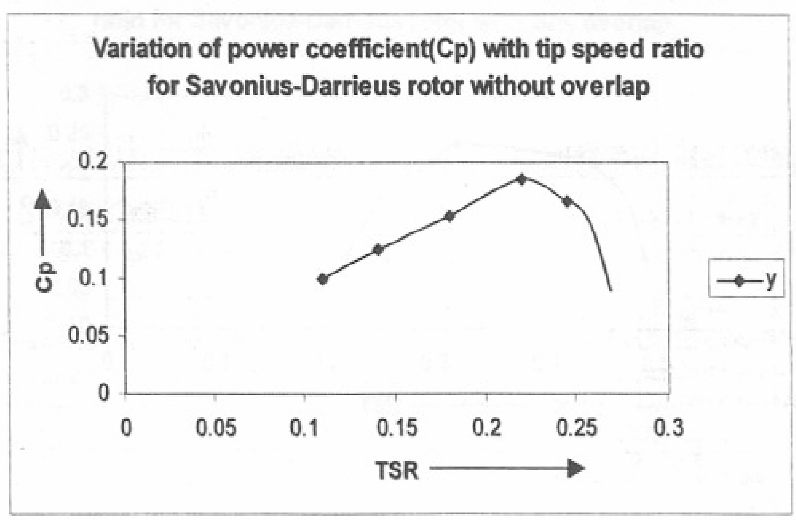
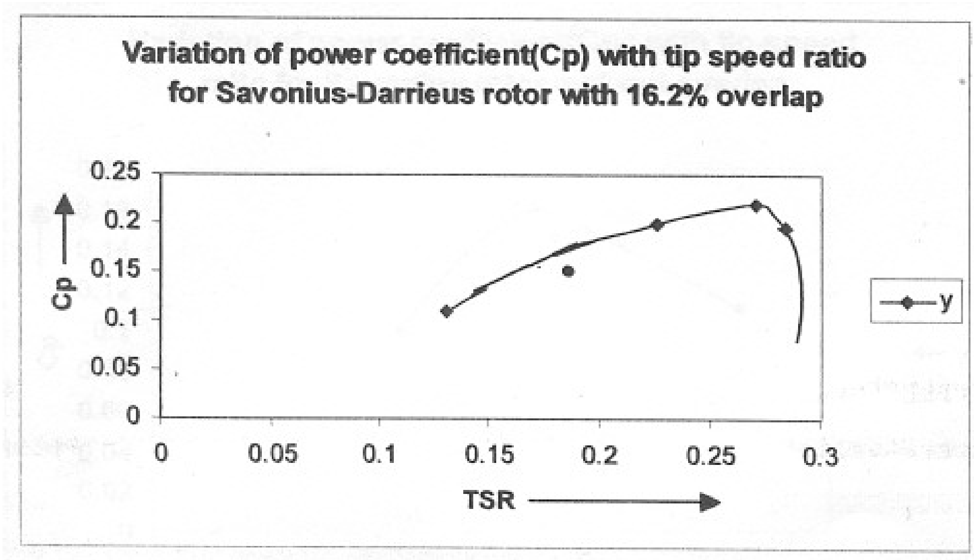
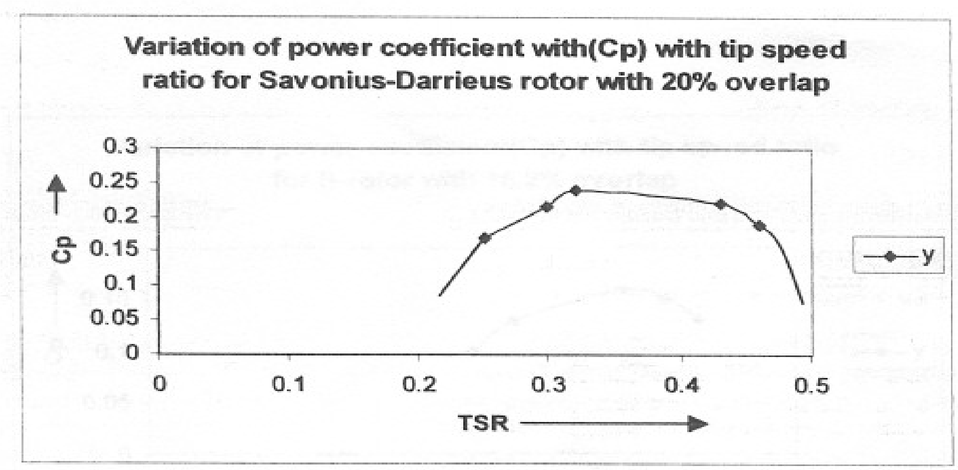

Variation of power coefficient(Cp) with tip speed ratio
for Savonius-Darrieus rotor without overlap
0.2
0.15
0.1
0.05
0
Cp
0
0.05
0.1
0.15
0.2
0.25
0.3
TSR
y

FIG- 8



Variation of power coefficient(Cp) with tip speed ratio for Savonius-Darrieus rotor with 16.2% overlap
0.25
0.2
0.15
0.1
0.05
0
Cp
0
0.05
0.1
0.15
0.2
0.25
0.3
TSR
y

FIG- 9



Variation of power coefficient with(Cp) with tip speed ratio for Savonius-Darrieus rotor with 20% overlap
0.3
0.25
0.2
0.15
0.1
0.05
0
Cp
0
0.1
0.2
0.3
0.4
0.5
TSR
y

FIG- 10