PERFORMANCE ANALYSIS OF TESLA TURBO MACHINE AS TURBINE USING CFD

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ABSTRACT

Turbo-machine applications have a several alternatives, each of which emanates to help build the world of power. One of these ideas is 'The Tesla turbine', which is also referred to as a bladeless turbine or friction turbine. A turbine is a machine that transforms rotational energy from a fluid that is picked up by a rotor system into usable work or energy. The principle of Tesla turbine comes from two main rudiments of physics: Adhesion and Viscosity, instead of the conventional energy transfer mechanism in traditional turbines. It is referred to as a bladeless turbine because it uses the boundary layer effect and not a fluid impinging upon the blades as in a conventional turbine. In this Analysis by the means of changing mass flow rate and proper design of bladeless rotor the efficiency is to be calculated and the analysis of viscous fluid that can be transferred is to be measured. And the final conclusion has been derived.

Keyword: - *bladeless friction turbine, boundary layer, flow efficiency, CFD simulation*

1. INTRODUCTION

Ludwig Prandtl the German Engineer on August 12, 1904 first introduced the boundary layer concept. The fluid flow equation was simplified by dividing the flow field into two areas:

1. Dominated by viscosity, one inside the boundary layer and hence the majority of drag is created which will be experienced by the boundary layer.
2. Another will be outside from this boundary layer, neglecting the viscosity effects on the solution.

By this there will be significant simplification of the Navier-Stokes equation for closed form solution for the flows in both the areas. Within the boundary layer heat transfer from a body and to a body also takes place which will again simplified the flow field equation outside the boundary layer. Normal to the surface direction pressure distribution throughout the boundary layer remains constant and is the same in as the surface itself.

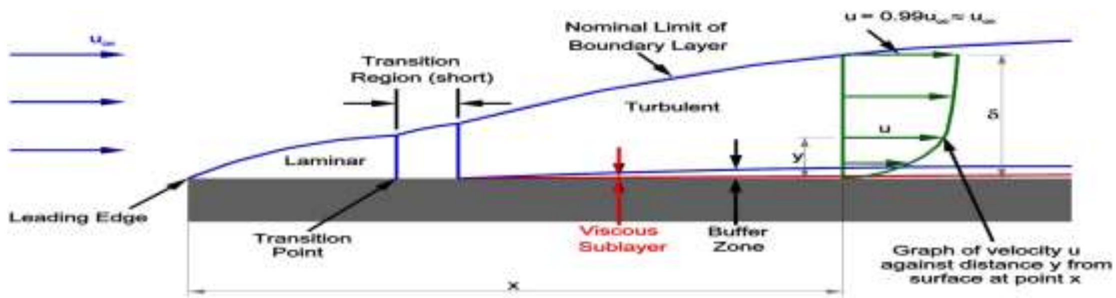

Fig- 1: Boundary Layer concept

The thickness of the velocity boundary layer is normally defined as the distance from the solid body at which the viscous flow velocity is 99% of the free stream velocity (the surface velocity of an inviscid flow). Displacement Thickness is an alternative definition stating that the boundary layer represents a deficit in mass flow compared to inviscid flow with slip at the wall. It is the distance by which the wall would have to be displaced in the inviscid case to give the same total mass flow as the viscous case. The no-slip condition requires the flow velocity at the surface of a solid object be zero and the fluid temperature be equal to the temperature of the surface. The flow velocity will then increase rapidly within the boundary layer, governed by the boundary layer equations, below.

The thermal boundary layer thickness is similarly the distance from the body at which the temperature is 99% of the temperature found from an inviscid solution. The ratio of the two thicknesses is governed by the Prandtl number. If the Prandtl number is 1, the two boundary layers are the same thickness. If the Prandtl number is greater than 1, the thermal boundary layer is thinner than the velocity boundary layer. If the Prandtl number is less than 1, which is the case for air at standard conditions, the thermal boundary layer is thicker than the velocity boundary layer.

At high Reynolds numbers, typical of full-sized aircraft, it is desirable to have a laminar boundary layer. This results in a lower skin friction due to the characteristic velocity profile of laminar flow. However, the boundary layer inevitably thickens and becomes less stable as the flow develops along the body, and eventually becomes turbulent, the process known as boundary layer transition [2]. One way of dealing with this problem is to suck the boundary layer away through a porous surface.

At lower Reynolds numbers, such as those seen with model aircraft, it is relatively easy to maintain laminar flow. This gives low skin friction, which is desirable. However, the same velocity profile which gives the laminar boundary layer its low skin friction also causes it to be badly affected by adverse pressure gradients. As the pressure begins to recover over the rear part of the wing chord, a laminar boundary layer will tend to separate from the surface. Such flow separation causes a large increase in the pressure drag, since it greatly increases the effective size of the wing section. In these cases, it can be advantageous to deliberately trip the boundary layer into turbulence at a point prior to the location of laminar separation, using a turbulator.

1.1 Tesla turbine

The first bladeless turbine was designed and manufactured by a Serbian engineer and well known inventor Nicola Tesla in 1913, by turbine also known as a friction turbine. The boundary layer flow which produces the viscous effect is used to run this unusual turbo device. In our general classical bladed turbines, the viscous effects are the reason for the efficiency loss of this typical turbines therefore it is the undesirable source while opposite of this phenomena these viscous effects are the main driver enabling the rotational movement of the rotor. A set of n number of thin disks is attached with a shaft which is perpendicular to its axis of a revolution; “n” numbers of set depends on the size and design. According to the theory the individual each disk must be as thin as possible. The smaller the gap between the “n” number of disks and the distance between one another the higher will be rotation. The highest value of efficiency according to Rice [18] is achievable when the gap is approximately equal to the double boundary layer thickness. Therefore, with respect to the flow conditions and physical properties of the working fluid the gaps between the disks should be maintain. The technology of manufacture, material strength and its assembly has the impact on the thickness of the disks and the gap between them is also limited.

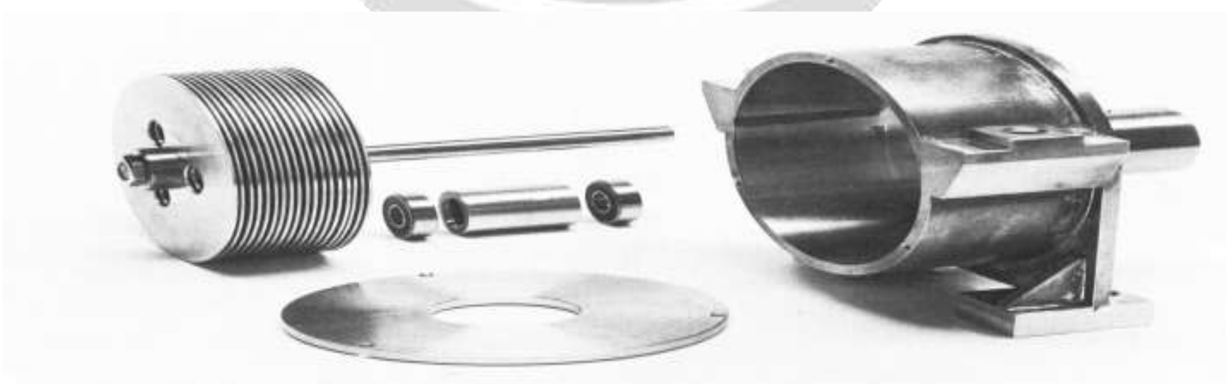

Fig- 2: Parts of the Tesla Turbine

2. CONSTRUCTION AND WORKING PRINCIPLE

The closely spaced disks, in Tesla Turbine are propelling by using the viscosity and adhesion of a moving medium. From the periphery the fluid enters the inner space between the disks and through the central holes located near the axles exists shown in the fig-3. To couple inertia forces there are no constraints or obstacles as in traditional turbines. The fluid entering tangentially at perpendicular to the axis of rotor at the periphery, it transfers momentum to the disks, during this process. If considering ideal conditions, then between the tangential velocity of the fluid entering the disk and the tip velocity of the rotating disk and the tip velocity of the rotating disk there will be no slippage at the nozzle exit. The efficiency of energy transfer is largely is governed by the following:

- From the nozzle the smoothness of the medium flow to the disks.
- The bearing effectiveness for reducing the friction los and
- For the transfer of the momentum the size of the active area.

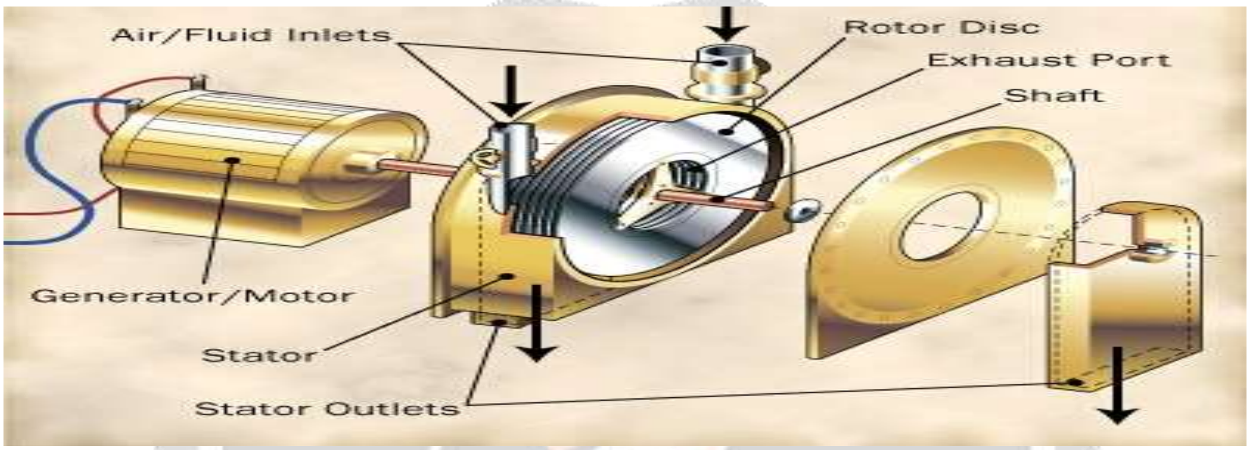

Fig- 3: Construction of Tesla Turbine

From a manufacturing standpoint a most attractive feature of the Tesla turbine is its simplicity. The parts from the Tesla Turbine can be taken apart easily as assembly is very simple, as shown in fig-4. The Tesla turbine designed by its use of flat, fixed and co-rotating disks equally spaced along the rotor shaft which can be seen in fig-4. There is a metal casing by which the rotor is housed which contains the exhaust ports as well as inlet nozzle.

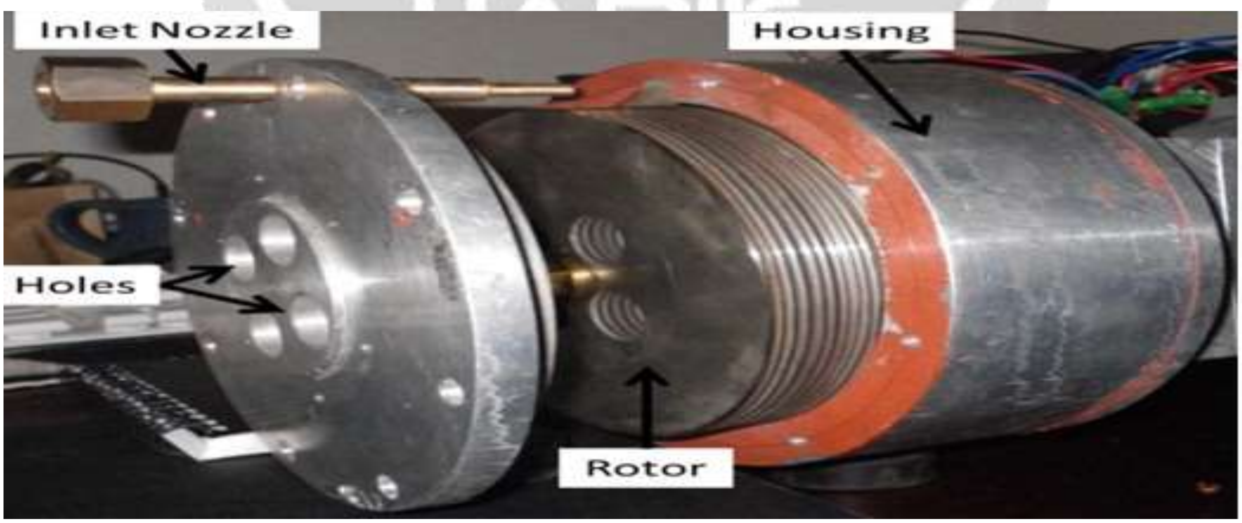

Fig- 4: Entire Tesla turbine assembly showing the rotor blades, housing, inlet nozzle and exhaust Ruler (cm) added for approximate size scale

Fig- 5: Tesla turbine rotor with disks Fixed to a shaft

The fluid velocity is significantly increased when a fluid is introduced through the nozzle and towards the outer edge of the disks it is ejected tangentially.[7] The result in momentum exchange from the fluid to the disks is by the viscosity of the high speed fluid and no slip condition along disk surface power output and shaft torque.

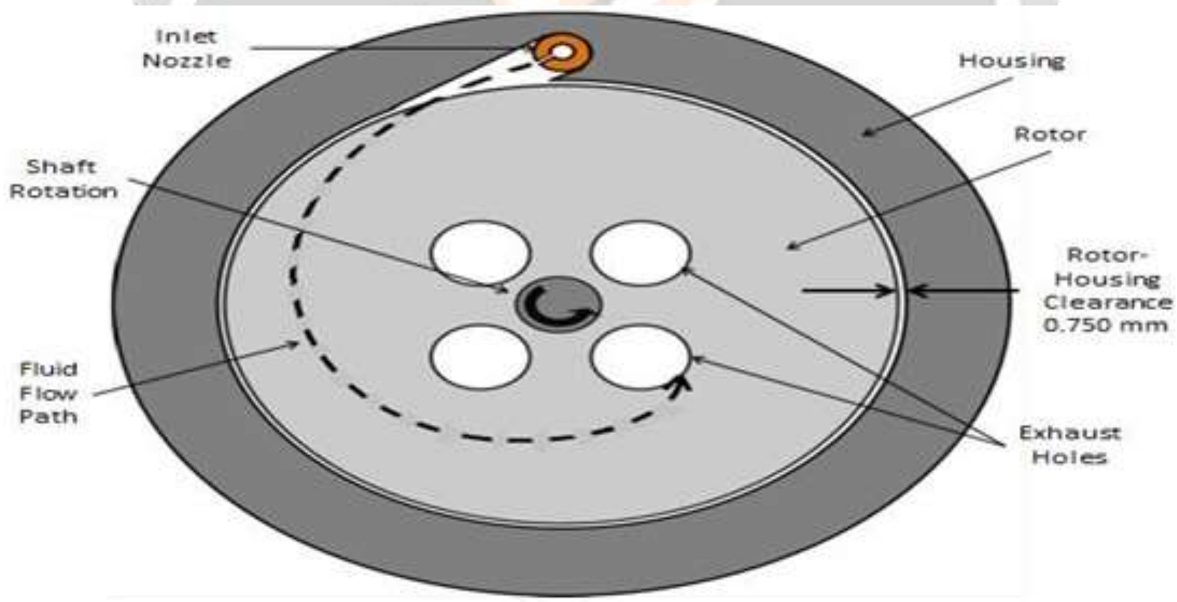

Fig- 6: Schematic of fluid flow through the Tesla turbine All major turbine components are shown and the actual rotor-housing clearance given

As can be seen in Fig-6, there is nothing complicated about the way a Tesla turbine works. The fact that the fluid flows parallel to the turbine disks gives this design a distinct advantage over traditional bladed turbine; abrasive particulates or even water droplets can be present in the working fluid without risking direct impacts which could cause additional wear and damage to the disks. [16][17] Its ability to utilize a variety of fluids without damaging the blades and its extremely low manufacturing cost warrant a renewed interest in the design

3. GOVERNING EQUATION AND COMPUTATIONAL FLUID DYNAMIC FOR ANALYSIS OF TESLA TURBINE

Owing to a number of causes affecting the performance, it is difficult to frame a precise rule which would be generally applicable, but it may be stated that within certain limits, and other conditions being the same, the analysis can be carried out. So for that reason for carrying out the performance analysis CFD will be extremely helpful to provide a basic knowledge which will be used in construction of experimental setup.CFD has many advantages over the experimental work so the analysis of Tesla Turbine is going to be carried out using ANSYS-CFX and then using experimental setup the performance evaluation is to be carried out which will eventually use the CFD results. In this chapter initially basic analytical calculation is also carried out.

3.1 Calculation for Tesla Turbo Machine

The data was

1) Boundary layer thickness of the plate at δ_1

$$\mathrm{Re}_x = \frac{\rho UD}{\mu} = \frac{UD}{\upsilon} = \frac{30\times 0.03}{1\times 10^{-6}} = 900000$$

Hence on the front portion, boundary layer is laminar and on the middle it is turbulent.

$$\mathrm{Re}_x = \frac{Ux}{\upsilon} = 5\times 10^{5} \therefore \frac{30\times x}{1\times 10^{-6}} = 5\times 10^{5} \therefore x = \frac{1\times 10^{-6}\times 5\times 10^{5}}{30} \therefore x = 0.0167m$$

Hence the boundary layer is laminar on 0.0167 m diameter of the plate.

Thickness of the boundary layer (laminar) δ_1

$$\delta_1 = \frac{5x}{\sqrt{\mathrm{Re}_x}} = \frac{5\times 0.0167}{\sqrt{900000}} = \frac{0.0834}{948} = 8.79\times 10^{-5} m$$

2) Shear stress at the location where boundary layer ceases to be laminar, τ_0

Local co-efficient of drag

$$C_{fx} = \frac{0.644}{\sqrt{900000}} = 0.00070042$$

$$\tau_0 = C_{fx}\times \frac{1}{2}\times \rho U^2 = 0.00070042\times \frac{1}{2}\times 998\times 30^2 = 3140.6\frac{N}{m}$$

3) Total drag force on both sides of plate F_D

$$F_D = 2\overline{C_f}\times \frac{1}{2}\rho A U^2$$

$$\overline{C_f} = \frac{1.328}{\sqrt{5\times 10^5}} = 1.878\times 10^{-3} \quad \because A = \pi\times x^2 = \pi\times 0.0167^2 = 8.76\times 10^{-4}$$

$$F_D = 2 \times 1.878 \times 10^{-3} \times \frac{1}{2} \times 998 \times 8.76 \times 10^{-4} \times 30^2 = 1.477N$$

4) Boundary layer thickness of the plate δ_2

$$\mathrm{Re}_x = \frac{\rho UD}{\mu} = \frac{UD}{\upsilon} = \frac{30 \times 0.015}{1 \times 10^{-6}} = 450000$$

$$\delta_2 = \frac{4.64x}{\sqrt{\mathrm{Re}_x}} = \frac{4.64 \times 0.015}{\sqrt{450000}} = 1.37 \times 10^{-4} m$$

5) The Mass entrainment between the two sections

$$= \frac{5}{8}\rho U(\delta_2 - \delta_1) = 0.92814 kg/s$$

6) Power

$$P = \frac{F_D U}{1000} = 44.31KW$$

3.2 Model generation and CFD Analysis

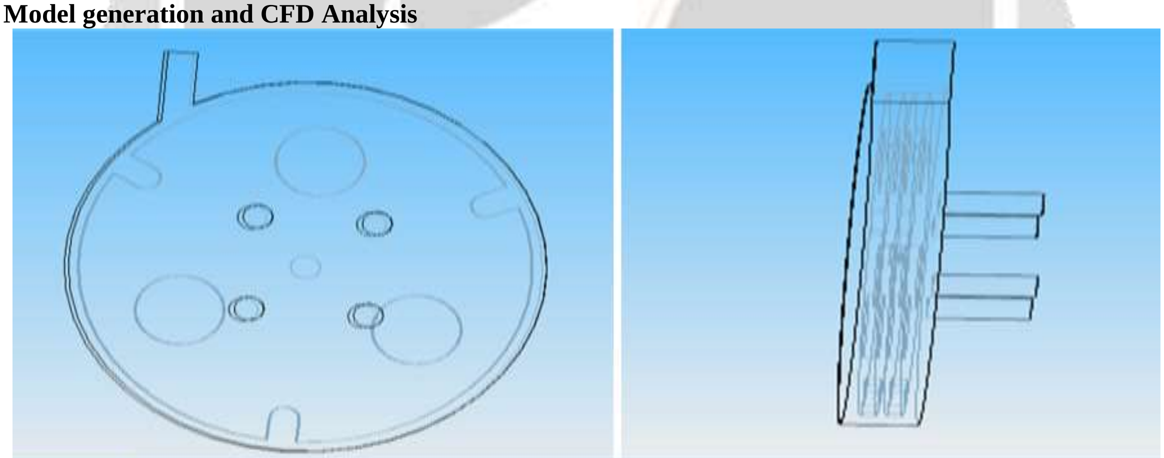

Fig- 7: Tesla Turbo Machine in solid edge

Two different domains were constructed in which there was casing and another one rotor. Using the solid edge the assembly was done in which three different materials for rotor were taken.

3.3 Grid Independence test

Purpose for the grid independence test is to get the near to accurate analysis of the particular domain. As the number of the nodes keeps on increasing there will be a constant outcome from the same model hence it will give the better iteration having low residual value.

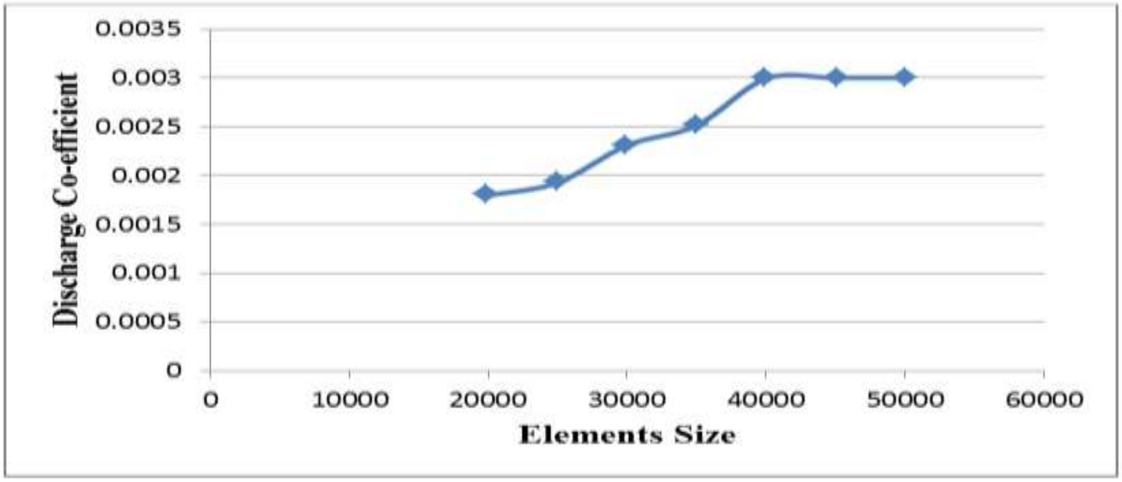

Chart- 1: Discharge co-efficient with respect to the Elements Size

After doing the grid independent test it was found out that for the elements size from 20000 to 40000 there is a variation in the outcome parameters but further from this size there will be a constant output hence 40000 to 50000 elements size is the optimum element size for final simulation

Firstly the Aluminum rotor which was assembled with the casing having 50 mm diameter was taken in the ansys bench work 2015 where the inlet velocity of 30m/s and the relative pressure of 1 Pa was given. The element size was taken as per the grid independence test and the setup was created. The result is as shown in fig-8

Further same as the above the iron rotor analysis was carried out using the same input data as used in the aluminum rotor. Then the result for the domain was found out same as shown in fig-8 showing the velocity stream line and pressure volume rendering for iron rotor and it was observed to be same as aluminum rotor.

Finally the output for the steel rotor was carried out fig-8 shows the velocity stream line and pressure volume rendering for the steel rotor.

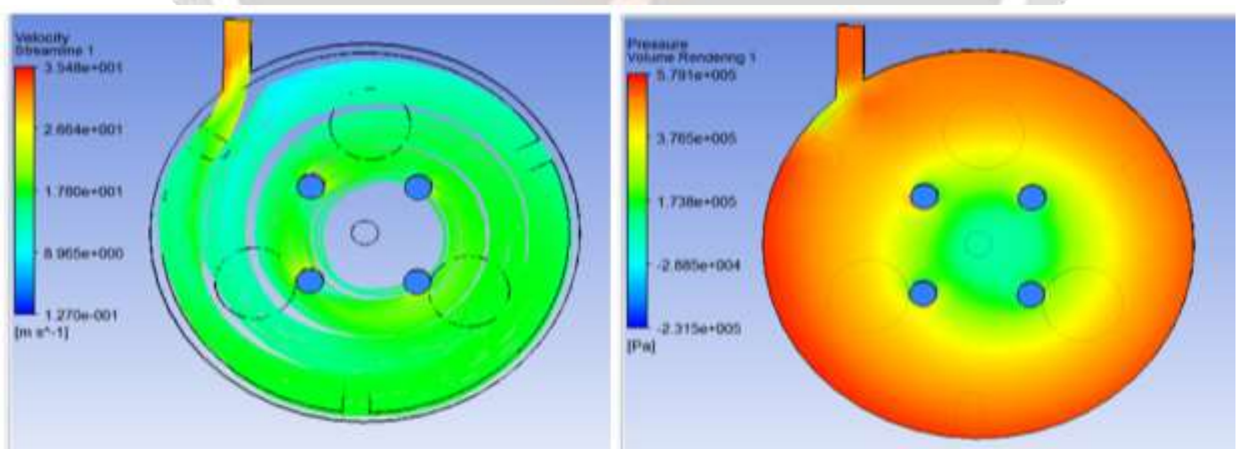

Fig- 8: Velocity streamlines and pressure volume rendering

After the analysis of the three different materials aluminium, iron and steel rotor it was find out that the torque, power, efficiency etc. was same for all the cases. The velocity stream line and pressure volume rendering showing the same output for all the cases, hence **c**hanging materials doesn't affect the efficiency hence it is of no use change the different materials in design of Tesla turbine blade.

3.4 Analysis by changing parameters inlet velocity and size of disk

The same boundary domain and physics domain was taken for finding the efficiency by changing the different parameters. The disk diameter was kept constant and as well the others parameter but the inlet velocity was changed. Each time in different simulation the output was find out by varying the inlet velocity, the efficiency for each time was noted down and a graph was plotted for efficiency with respect to the inlet velocity.

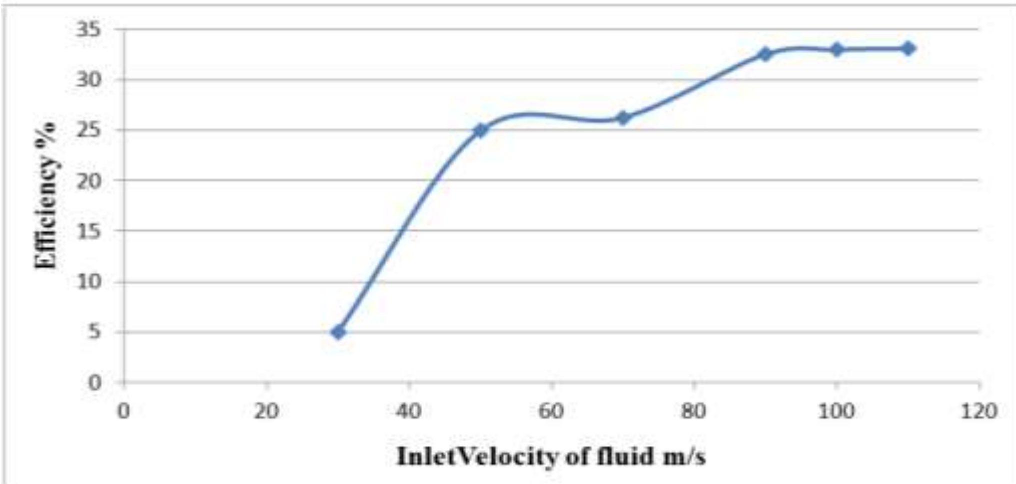

Chart- 2: Efficiency from Power with respect to Inlet velocity

From the graph shown in chart-2 it can be seen that increasing the inlet velocity will increase the efficiency but with constant diameter, the increase in inlet velocity up to certain point will bring the constant output. Now for the same inlet velocity the diameter of the rotor will be changed and respect to that the efficiency was found out same as above the output was noted down same will be done and the final graph was plotted. As it can be seen from chart-3 the graph that the showing efficiency with respect to the disk diameter it can be clearly observed that on keeping the inlet velocity constant and changing the disk diameter there will be increased in the efficiency.

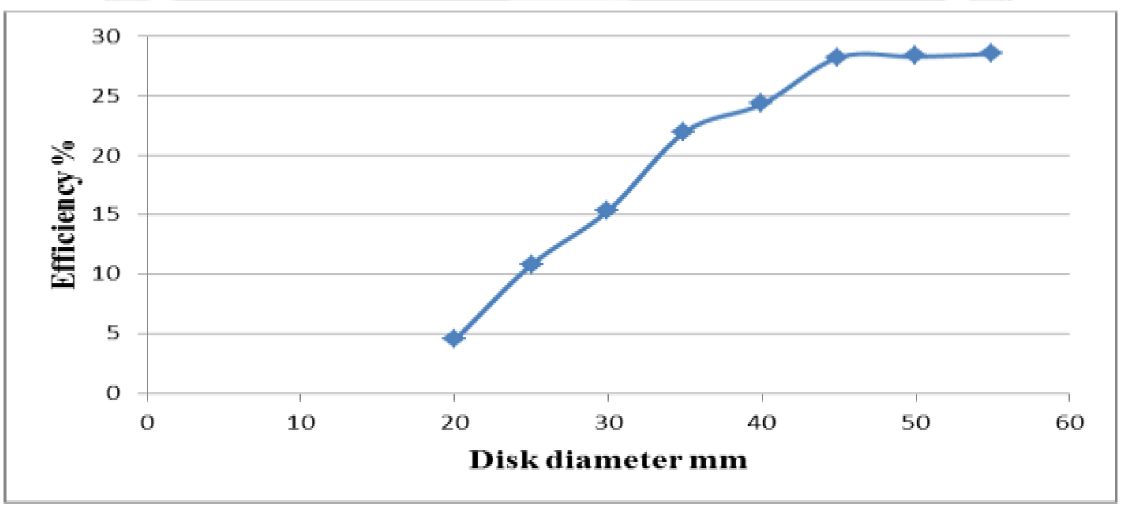

Chart- 3: Efficiency with respect to Disk Diameter

But just as above after some point in between 40 to 50 mm diameter of rotor the efficiency will be constant. This data will be used in the experimental setup for creating the working model which will play important role in design then the analysis by experiment setup will be carried out.

4. CONCLUSIONS

Rapidly increasing demands of the power generation are asking for fast development in the area of renewable energies. The generation of home level energy and use of distributed generation system is the key necessity of the present age. So the idea to return back the out of market turbine again to the practical implementation will be a great milestone in the way of achieving the green energy. For the revival to Tesla turbine it was necessary to withdraw its limitation. The new design of Tesla turbine which uses both the pressure pull and the boundary layer effect has been proved very economical and efficient design and it can be used in the future to get rid of the polluted power generation. Providing the right design will bring the best efficient machine that will replace the traditional turbine.

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