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A Theoretical Study on Surface Finish, Spacing between Discs and Performance of Tesla Turbine

Rakesh Jose [1], Ajay Jose [2], Albin Benny [3], Asbin Salus [4], Bilbin Benny [5]

Asst. Professor, Dept. of Mechanical Engg., Viswajyothi College of Engg & Technology, Vazhakulam, Cochin, India[1]

Viswajyothi College of Engg & Technology,Vazhakulam, Cochin, India [2, 3, 4, 5]

Abstract: This turbine, invented by Nikola Tesla in (1856-1943), is a bladeless turbine. Tesla turbine disks and a flexible test rig was designed and manufactured, and experimental results are studied. An analysis of the performance and efficiency of the tesla turbine is carried out. The entire study of the flexible test rig has been explained in detail. In this Turbine there are no blades, instead parallel and closely spaced discs were used. Resistance to flow of fluid between the plates results in the energy transfer to the shaft on one side. High velocity water enters the disk at the inlet pack through nozzle path tangent towards the outer edge of the discs. Convergent nozzle imparts higher velocity water jet tangentially on disc. Lower-energy water spirals towards the exit port at the centre, adhesion, drag and centrifugal forces continue to convert the kinetic energy to rotate the shaft. The results of the study represent various steps towards the development of boundary layer turbine. It has been determined that the surface roughness and spacing has a major part in the performance of the tesla disc turbines significantly. Efficiency can be improved at least up to 45%, which has been deemed achievable.

Keywords: Boundary layer Turbine, disc Turbine, bladeless, Tesla. Turbine

I. INTRODUCTION

When an aircraft flies through the air, at high speed, there is a thin layer of air that sticks to the wing. This layer of air goes the same speed as the airplane. There is then sheared action or shear plane between that boundary layer and the surrounding air around the aircraft. On that shear plane is where the drag is formed that holds the aircraft back. Aerodynamics tells us that if we could, wave a magic wand over an aircraft and, eliminate or minimize boundary layer drag the aircraft could fly 40% faster. In aerodynamics, boundary drag layer is totally unwanted precept. But, Tesla was able to turn that precept around 180degrees. Tesla perceived that boundary layer drag used to do something useful. High velocity water enters tangentially to the outer periphery of the disk pack through the inlet nozzle; it forms a boundary layer on either side of the discs. The pressure ratio is pushing it towards the center of the turbine. It forms a helical path down into the center of the device, and exit in the center, after it has transmitted all of its energy to the discs through the boundary layer drag. In this present work, A Tesla disc turbine and a flexible test rig designed and manufactured by simple stock material. Experimental results carried out by using water medium. The overall design of the turbine is very flexible allowing parameters to be varied in order that their effect on the performance of the turbine can be measured. It is possible to change the number of discs, disc spacing etc.

II. LITERATURE REVIEW

J.B. Duarte, H.S. Couto, and D. Bastos-Netto [1].reviews the basic physical principles behind Tesla Turbine, using fluid mechanics. They considered the relative motion of rotating surfaces which sets up the transport equations describing the flow between parallel rotating disks and estimated the boundary layer thickness in laminar and turbulent regimes, leading to expressions that gives the width between consecutive disks. H.S. Couto shows how to calculate the total number of disks required for the desired performance. Finally behavior of the device acting as an air compressor or water pump is looked up . Nikola Tesla [2] has filed a patent for a Turbine which uses smooth rotating disks inside a volute casing. In his patent, Tesla described the forces of his machinery to be dependent on the fluid properties of adhesion and viscosity. Several turbines were designed and built by Tesla but they were not commercially feasible at that time. Lack of sufficient manufacturing instruments, difficulties in handling high speeds, and dissipation of heat were the reasons for multiple disk devices not being developed further .Piotr Lampart [3] showed results of the design analysis of another Tesla bladeless turbine which could be used for a co-generating micro-power plant of heat capacity 20 kW, which operated in an organic Rankin cycle using a low-boiling medium. Results showed interesting features in the flow parameters in the turbine inter disk space. The calculated efficiency of flow of the investigated turbine models show that the best solutions could be as good as classical small bladed turbines.

Warren Rice [4] shows the most important parameters that affect the efficiency and performance of disc turbine. Rice constructed six disks turbine and conveys some aspects of them, with the main purpose as to determine the feasibility

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of this kind of turbo machinery. Starting from Tesla´s patent, the turbine was operated with compressed air exhausting into the atmosphere, some changes with the angle of the nozzle and the use of a supersonic nozzle were made. Later, some improvements were made by reducing the gap. The comparison between analytical data and results from these experiment shows that the geometry, speed combination and flow rate used in the turbine where not close to those values indicated by the analyses for optimum turbine efficiency. Rice observed max efficiency of 24%.

Warren Rice and K. Boyd [5] studied laminar flow of a fluid which is incompressible between rotating discs. K. Boyd did propose complete solution for inlet region for various inlet conditions .A complete statement of problem is formulated from the Naiver stokes equation with three parameters flow rate, Reynolds number and tangential velocity. Both the turbulent and laminar flow considered and suggested torque, Efficiency, Power and Pressure drop are the function of flow, velocity and Reynolds number. Almost every literature has considered the fluid to be incompressible and laminar. In general, it is observed that the efficiency of the rotor can be very high, almost equal to that achieved by conventional bladed rotors. Although any kind of fluid can be used in Tesla turbine, most of the literature uses a Newtonian fluid for simplification except for experimental test .From the literature, we establish the parameters that affects the performance of turbine namely Distance between the discs, Number of discs, Discs surface roughness, Number of nozzles. The following assumptions are considered for the
experimental work.

i) Steady flow
ii) Incompressible fluid flow
iii) body forces are neglected
iv) Full admission of working fluid in the outer periphery of the discs.

III. THEROTICAL ANALYSIS

Inlet Nozzle construction fabricated as shown in fig 1 for Test Rig. Water incompressible fluid selected for performance measurement with assuming flow is steady flow. Constant Parameters:

Spacing between Discs: 2mm
Medium: Water
Disc thick: 2mm
Outlet Nozzle Size: 32mm2
Material of Discs: SS304
Disk Dia: 152mm
Inlet Size: 21mm^2
No of discs: 6
Surface Finish: smooth
Medium: Water
Flow rate: 0.22lit/s line
Pressure: 18lb/in^2

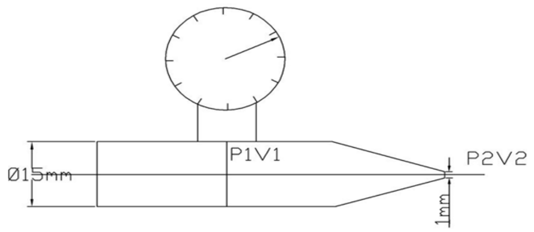

Fig. 1: Nozzle Arrangement – line diagram for Test Rig

By applying Bernoulli's equation, at point1 and at point2

$$P1 / \rho\, g + V1^2 /2g + Z1 = P2 / \rho\, g + V2^2 /2g + Z2 \quad (1)$$

Where,
P1 = Pressure at point 1
V1 = velocity at point1
Z1 = Z2 Pressure head (at same elevation)
P2 = Pressure at point 2
V2 = velocity at point 2
ρ = water density =1000kg/m^3 g = 9.81m/s2

We know the flow rate i.e. Q = 0.22 lit/s=0.00021m3/s and P1 = 19lb/ in2 = 1.18 bar
But, by continuity equation.

$$Q = A1V1 = A2V2 \quad (2)$$

Where A2 = area of cross section at pt 2 = 21 mm^2

$$A1 = \pi / 4 * D2 = 3.14 / 4 * 0.0152 = 0.000225m^2$$
$$V1 = Q/A1 = 0.00022 /0.000225 = 0.98 \text{ m/s}$$
$$V2 = Q/A\,2 = 0.00022/ (22 * 10^{-6}) = 10.48 \text{ m/s}$$

Now put this value of V1 and V2 in equation (1) to get P2.
But Z1 = Z2, both the pt at same level. Now (1) becomes.

$$P / \rho\, g + V1^2 /2g = P / \rho\, g + V2^2 /2g$$

$$P2 = [(1.18 * 10^5 /9810 + 0.98^2/19.62) - (10.48^2 / 19.62)]\ 9810$$
$$= 0.45 \text{ Bar}$$

Now P = F/A .

We know the value of P2; Put this value in above equation to get Force acting on discs thickness.
F = P2 * A2 = 69622.74 *20 * 10^{-6} = 1.532 N (force acting on 12mm area only)
But, we know the jet force formula from pelton turbine

$$F = \rho\, A(V - U)^2 \cos \text{Ø} \quad (3)$$

Where, A = jet area = A2 = 21 mm^2,
V = velocity of jet = V2,
U = Relative velocity of discs. & Ø = 10º angle of jet.
Now put the values in above equation to get U

$$\therefore (V-U)^2= 1.532 /(1000*21*10^{-6} *0.98) = 12.47$$

$\therefore$ (V - U) = 8.66
$\therefore$ U = 1.81 m/s
We know the angular momentum for rotating part

$$L = mrU \qquad (4)$$

Where L = angular momentum, r= radius of disk.

$$\text{But, } L = I\omega \qquad (5)$$

Where I = moment of inertia & ω = Angular velocity
In this case,

$$I = I_{SHAFT} + I_{DISCS} \qquad (6)$$

$I_{SHAFT} = MR^2$
Where M= mass of the shaft=1.09kg, R= Radius of shaft = 15mm.

$$I_{SHAFT} = 1.082*(15/100)^2 * 9.81 = 0.0238 \text{ N/mm}^2 \qquad (7)$$

$$I = 1/2 * M d (a^2 + b^2) \qquad (8)$$

Where, Md= Mass of disk= 0.280 kg,
a = inner radius of disc = 30mm,
b= outer radius of disc = 76mm.

$\therefore I_{DISC} = 1/2 * 0.280(0.0152+0.0762)= 0.032\text{Nm}^2$
For 6 discs

$\therefore I_{DISCS} = 0.032 * 6 = 0.192\text{Nmm}^2$
Now from (6)
$I = 0.032 + 0.192 = 0.195\text{N/mm}^2$
now, from (4) & (5) L = Iω

$\therefore \omega = mrU / I = (2.73 * 0.076 * 1.81)/ 0.195$
$\therefore \omega = 19.20$ rad /s For 6 discs

But,
$$\omega = 2\pi N / 60 \qquad (9)$$
N = 19.20 X 3.75 X 60 / 6.28 = 183.44 rpm.

$$\text{Now Torque } T = F * R \qquad (10)$$
From equation (3) & (10)

T = 1.532 * 0.076 = 0.116Nmm.

Now,
$$P = 2\pi NT / 60 \qquad (11)$$
By putting the values of N and T, we get

$\therefore$ P = (6.28 X 183.44 X0.116)/60
$\therefore$ P = 2.22 watt.

IV. EXPERIMENTAL SET UP

The design of the turbine is very flexible as shown in fig.2, which allows varying the parameters to measure their effect on the overall performance of the turbine. The features of this turbine Test Rig designed and manufactured according to the experience noted from the reviews. The disc diameter is 152mm (6in), the thicknesses of each of the discs are 2mm, and rotor-to-housing diametrical clearance is 1mm. An overall view of the turbine is shown in Fig. 1(a). The discs have 2 central outlet port, since this configuration was observed to be more efficient by Rice [4].

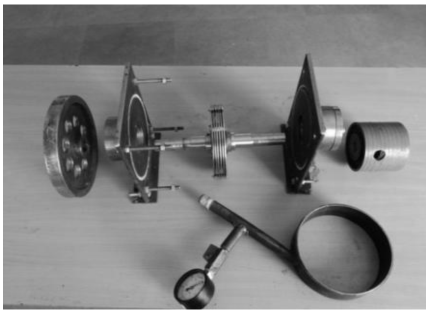

Fig. 2: Parts of Multiple disc Turbine.

The nozzle was designed so as to increase the kinetic energy of the flowing medium by making use of its internal energy and pressure and the nozzle must supply effective mass flow on each disc & space. Nozzle is designed by keeping in mind coefficient of discharge and energy conservation law . Like in venturimeter, it imparts equal jet on each disc and with its convergent shape it increases the kinetic energy of the jet as shown in fig.3. The diameter of the central hole is 30mm. In order to include the outlet of the fluid, the shaft is supported by means of bearings inside it

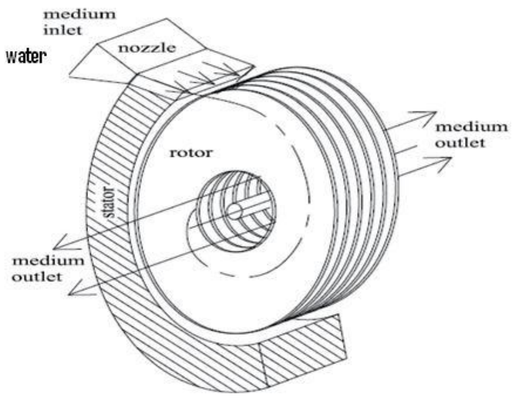

Fig. 3: Cross Section of Test Rig

An Effect of Spacing between Discs and Surface finish on the Performance of Disc Turbine The experimental test rig was designed to study the Turbine performance as in Fig.4.The test rig used for the present work consists of a 3 cylinder piston pump. Rubber O-rings are also used for air tight joint between casing and side plate. The shaft with disk supported on two bearings. In previous studies medium used was air, but in this work, water is considered as the medium. And at the constant flow rate, to provide high-pressure water we use positive displacement pump as in fig.4. The test rig is developed such that, it can measure the various parameters that are required to determine the performance of the Turbine. Flow rate varies from the 9Lit/m to 30lit/m.

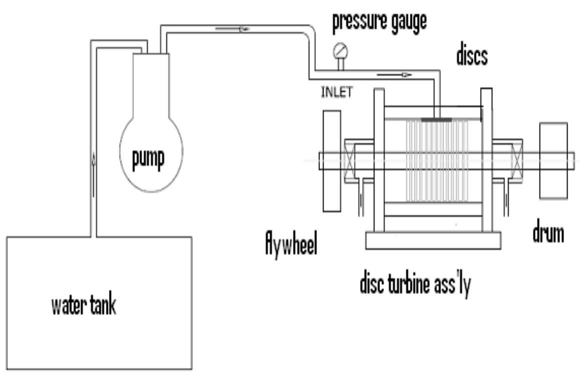

Fig. 4: Experimental Set up.

In this study 4 variations in the number of discs used for same set up. Experiments carried out 6 discs and spacing 0.55mm, 1.10mm, 1.4mm, 2.6mm, 3mm. And surface finish varies from smooth to 500ra.

Design of Experiments carried out in the following manner. Spiral grooves machined on discs surfaces by using lathe machine and fixture.

TABLE 1 EXPERIMENTAL DESIGN MATRIX

flow	Spacing	Surface finish
+	+	+
-	+	+
+	-	+
-	-	+
+	-	-
-	-	-
+	+	-
-	+	-

Flow + = 30Llit/m and
Flow - = 9.2lit/m
Spacing + = 3mm and Spacing - = 0.55mm
Surface finish + =smooth and Surface finish - = 500ra

A. Determination of Speed of the Rotor.

In the test rig used in this research, the speed output (N) can be obtained directly by means of a Taco Meter. The methodology for the use of this device is simple. At the both end the shaft centering operation done which is provision to insert a tip of Taco Meter. This method was found to be accurate and inexpensive. Then angular velocity obtained by using formula.

$$\omega = 2\pi N / 60 \qquad (12)$$

Using this for changing parameters used by the turbine , these investigation permits, variations in the number of discs to get the Performance comparisons data. In this study five variations in discs spacing and three variations in surface roughness is considered. Same constant parameters are considered in theoretical analysis. Variable parameters are the spacing between discs, flow and surface finish of the discs.

V. RESULT AND DISCUSSION

Nozzle size are designed in such way that it should impart equal forces on all the discs for minimum spacing and also for maximum spacing between the discs. After conducting all the experiments according to the experimental matrix, we studied that this turbine works efficiently for six discs. Due to the nozzle opening, for three discs jet imparted on $6mm^2$ areas only and for six discs jet area imparted on $12mm^2$ area means six disc pack use more jet forces comparatively three discs. Then all the experiments were carried out for six discs and by varying spacing like 0mm 0.55mm, 1.4mm, 2.60mm, 3mm Fig 5a & 5b shows the variation of speed with respective flow. As flow increases speed increases. But when spacing increases the speed decreases, because for Minimum spacing, friction or shear force between disc and jet increases, rotating disc form a boundary layer around the wall and jet also form boundary around it. Jet high velocity boundary layer drags the discs. Disc is rotating comparatively at low speed hence disc trying to oppose jet velocity. Due to this shear forces developed between two boundary layers. And Kinetic energy of jet utilized for disc rotation.

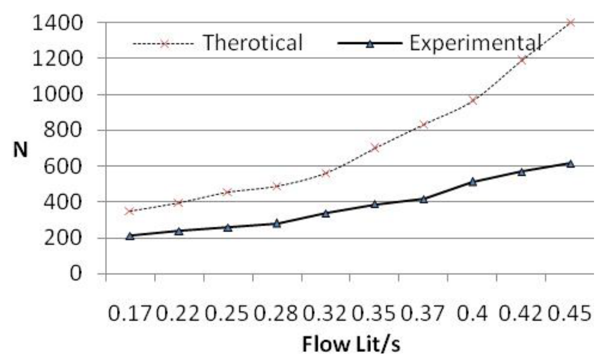

Fig.5a: A plot of Flow v/s Speed for 6 smooth discs and 2.5mm spacing

For 2.5 mm spacing, more amount of jet water passing through the gap comparatively 0.5mm spacing, boundary layer forms between discs, but jet boundary layer and disc boundary layer apart from each other. Jet uses the maximum kinetic energy to carry the fluid between discs. And flow rate difference is also observed at the outlet. For minimum spacing flow rate is comparatively less than maximum spacing. For 0.55 mm spacing, boundary layer forms between discs, but jet boundary layer and disc boundary layer overlap with each other. Jet uses the maximum kinetic energy to drag discs.

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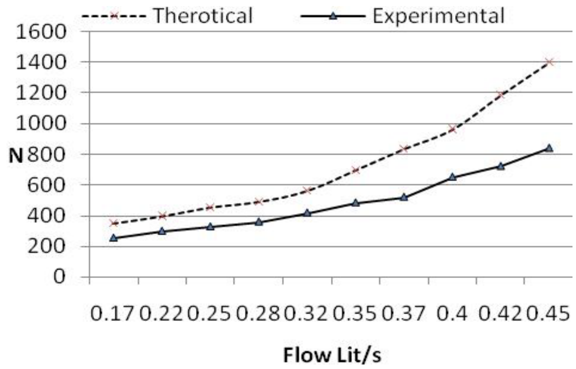

Fig. 5b: A plot of Flow v/s Speed for 6 smooth discs and 0.55mmn spacing

Fig.6 shows the speed variation with respective flow, Here 6 rough (spiral grooves) discs used with 2mm spacing. From these readings plot, we observed that the experimental curve closer to the theoretical curve, actually theoretical curve plot by considering impulse force only but existence of friction force or drag force due to boundary layer effect difference found for three various conditions as shown in fig 5 & 6. Spiral grooves on discs surfaces machined in such way that once jet enters the groove it follows the spiral path and exists thru central port. During rotation of discs centripetal force also exist which act inward to outward and that opposes to jet to come rapidly at the central port and due to this jet passes thru long spiral path and kinetic energy of jet utilized to drag the discs

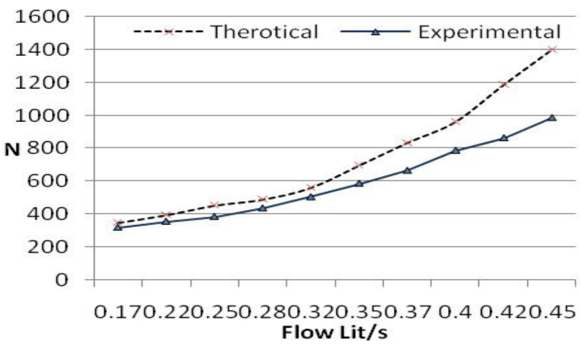

Fig. 6: A plot of Flow v/s speed for 6 Rough discs and 1.4mm spacing

A. Output torque, power and efficiency

Torque on the shaft measured by Prony Break dynamometer. The methodology for the use of this device is simple. Essentially the measurement is made by wrapping a belt around the output shaft of the unit and measuring the force transferred to the belt through friction. The friction is increased by tightening the belt until the frequency of rotation of the shaft is reduced. In its simplest form an engine is connected to a rotating drum by means of an output shaft. A friction band is wrapped. Around half the drum's circumference and each end attached to a separate spring balance. A substantial pre-load is then applied to the ends of the band, so that each spring balance has an initial and identical reading. When the engine is starting the frictional force between the drum and the band will increase the force reading on one balance and decrease it on the other.

The difference between the two readings is used to calculate torque, because the radius of the driven drum is known. Once we knew the spring balance we can determine the torque by equation.
S = Spring Balance
Where, D = Drum Dia.,
t_b = Belt thickness,

$$T = (D + t_b) \times 9.81 * S \qquad (13)$$

Then the Output Power calculated by
$P = 2\pi NT / 60$

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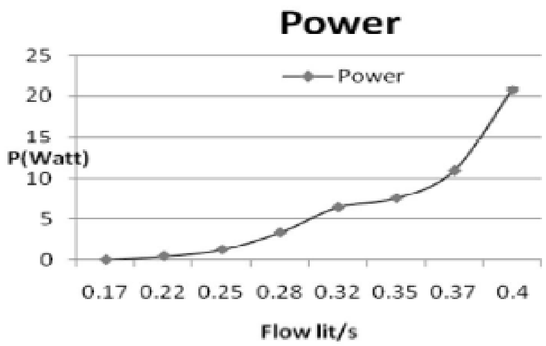

Fig.7: A plot of flow v/s Power at various flow rates for six discs and 05mm spacing.

To determine the efficiency, we have to determine I/P power [10].
By the following formula

$$P_{i/p} = = \rho\, g\, Q\, h \qquad (14)$$

Where , P static Pressure

$$\text{But , } P = \gamma \times h \qquad (15)$$

And ρ g γ
h = Water column height.
Where ,ρ = Density of water Q = flow of fluid m/s ,

$$\text{Input Power } P_{i/p} = P = \rho\, g\, Q\, h \qquad (16)$$
$$\text{Hydraulic Efficiency} = \text{Power}_{O/P} / \text{Power}_{I/P} \qquad (17)$$

By considering one case for sample calculations of efficiency.

$\therefore$ Q = 0.22lit/s = 2.2 * 10 -4 m^3 /s
P_{line} = 0.47 bar = 3238.3N/mm^2
Hydraulic Efficiency = 2.2 X 10-4 *3238.3 = 7.1%

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VI. CONCLUSIONS

Study and analysis of this work concludes that the Number of discs, spacing between the discs and the surface finish of discs affects the performance of tesla turbine significantly This work was carried out to study the performance of tesla disc turbine operating on water medium, however previous studies and experimentation carried out with air and steam medium. Rotor speed increases with the number of discs up to a certain level due to increasing area of contact of jet water and wall and it leads to the increase in friction force and boundary layer effect. For wide spacing between the discs it works as impulse turbine only. For appropriate spacing between discs it works with impulse force and also boundary layer effect. For minimum spacing equipment vibration also increases for high speed compare to maximum gap, Hence vibration analysis became important factor. Present experiments showed that the losses occurring in the nozzle are large and hence this needs to be tackled for improving the overall efficiency of the Tesla disc turbine. Experimental work shows that the efficiency of disc turbine may be increased by 5 to 6% by using spiral groove discs (Rough discs).

A. Suggestion for Future Work

Some of the following topics would be interesting for further investigation. In a future study, it will be interesting to analyze the influence of the inlet nozzle numbers and positions .The influence of the disc holes and the outlet nozzle size must be also analyzed. Influence of the composite material for discs on the turbine performance. Compressible analysis of the multiple disc turbines

REFERENCES

[1] H.S.Couto, J.B.F. Duarte and D. Bastos-Netto,Tesla Turbine Revisit, Department of Mechanical Engineering, 8th Asia- Pacific International Symposium on Combustion and Energy Utilization, October 2006, Sochi, Russian Federation
[2] N Tesla, Tesla turbine, United States Patent, May 1913.
[3] Piotr Lampart and Krzysztof Kosowski. Design analysis of Tesla micro-turbine operating on a low boiling medium, Polish Maritime Research, Special issue 2009S1; pp. 28-33.
[4] W. Rice, An Analytical and Experimental Investigation of Multiple- series A, Vol. 87, No. 1 Jan. 1965, pp. 29-36 Disk Turbines, Journal of Engineering for Power, Trans. ASME.
[5] K.Boyd and W. Rice, Laminar inward flow of an incompressible fluid between rotating disk, with full Peripheral Admission, Journal of Applied Mechanics, June 1968, pp. 229-237.
[6] N.Huybrechts, Numerical Study of a Tesla Turbine, Free University of Brussels, Applied Mechanics Department.
[7] F.William Beans, Investigation into the Performance characteristics of a Friction Turbine Flow, Journal of Space Craft, Vol. 3, No. 1, January 1966, pp. 131-134.
[8] L.Matsch, and W.Rice. Flow at low Reynolds number with partial admission between rotating disk. Journal of Applied Mechanics, Vol. 35, Trans. ASME, Vol. 90 series E, March 1968. pp. 768-770.
[9] P.N.Modi and S.M.Seth. Hydralics and Fluid Mechnics including Hydralic Machines. HFM Publication, Fifth Edition 2005, pp.221, 284-289, 915-973.
[10] K. SheshagiriHebbar, K.Sridhara and P. A. Paranjpe. 1970, Performance of Conical Jet Nozzles in Terms of Discharge Coefficient, Journal of the Aeronautical Society of India, Vol. 22, No 1, pp.3-9