

Hybrid Tesla Pelton Wheel Turbine

Keya N Joshi Meet N Sanghvi Tirth D Dave

Abstract: Hybrid Tesla-Pelton wheel turbine works on the principle of boundary layer flow of tesla turbine and the impulse force of Pelton Wheel turbine. It's primary objective is to minimize the mechanical losses and achieve better efficiency. Attaining high efficiency in Tesla turbine poses many complications like high head and, inadequate torque. On the contrary, hybrid tesla turbine produces higher torque and can run on more practical condition. Simulation and analysis shows similar results.

Key words: turbine, tesla turbine, hybrid turbine, bladeless, adhesion, analysis, ANSYS

1. Introduction:

1.1 Tesla Turbine:

The Tesla turbine is a turbine patented by Nikola Tesla in 1913. It is referred to as a bladeless turbine. The Tesla turbine is also known as the boundary layer turbine, cohesion-type turbine, and Prandtl layer turbine (after Ludwig Prandtl) because it uses the boundary layer effect and not a fluid impinging upon the blades as in a conventional turbine. Bioengineering researchers have referred to it as a multiple disk centrifugal pump. One of Tesla's desires for implementation of this turbine was for geothermal power, which was described in Our Future Motive Power.

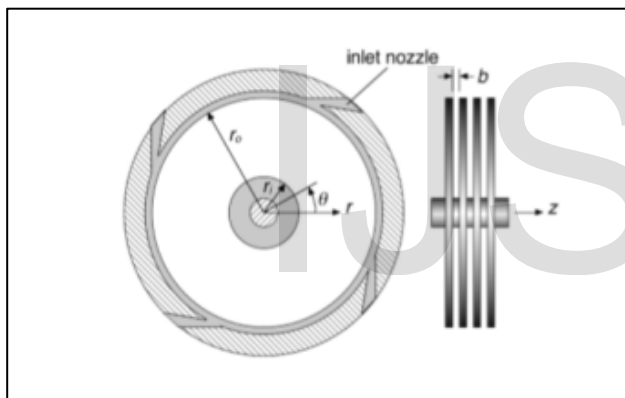


Fig.1 Schematic of Tesla Turbine

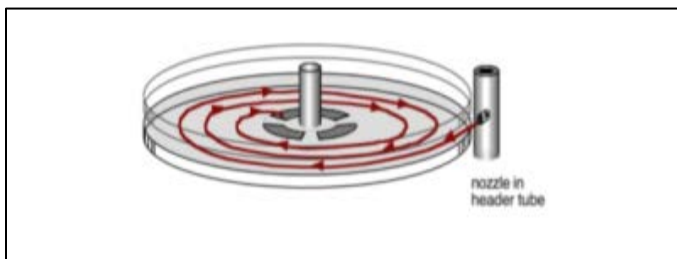


Fig.2 Schematic of flow through microchannel

Multiple-disk Tesla-type drag turbines rely on a mechanism of energy transfer. Exhaust holes on each disk are placed as close to the center shaft as possible. A turbine casing surrounds the disks with a flow pressure port near the exhaust holes in each disk and with a high pressure nozzle positioned at the outer edges of the disks and pointed at the gaps between each disk. The turbine rotor consists of several flat, parallel disks mounted on a shaft with a small gap between each disk; these gaps form the cylindrical micro channels through which momentum is transferred from the fluid to the rotor.

1.2 Hybrid Tesla Turbine:

The parts of the Tesla turbine are: stator, shaft, inlet, exhaust outlet (4) and smooth discs (2). The disc (2) with an innovative format, owns the characteristics of the Pelton Wheel, once it owns cavities (1) that are hit by the working fluid. The 'Pelton type' discs (2) have as purpose to increase the torque provided by the shaft of the turbine.

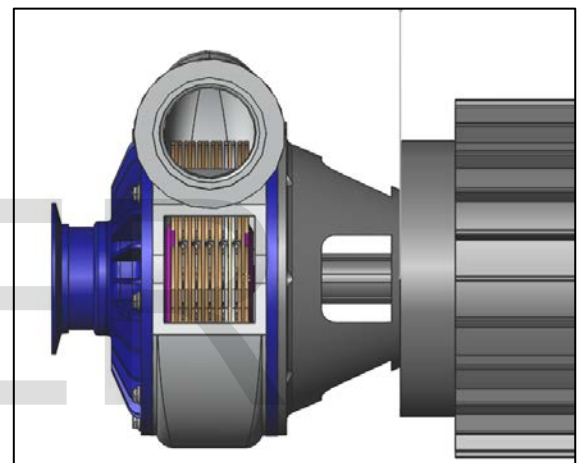


Fig. 3 Side view of Hybrid Tesla Turbine

1. Disk Surface
2. Blades
3. Opening at the center
4. Exhaust

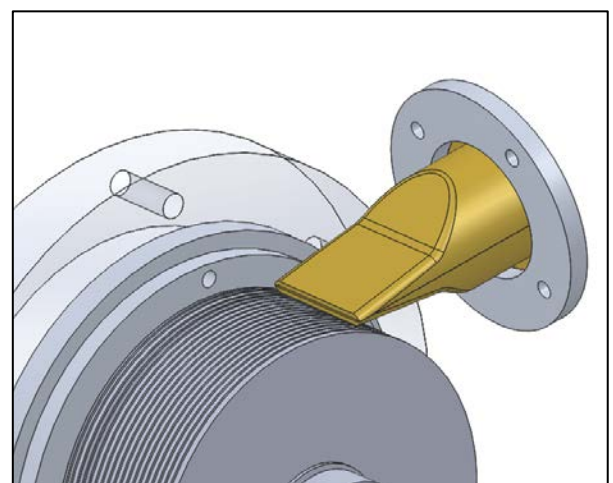


Fig.4 Inlet nozzle position

The Hybrid Tesla-Pelton Wheel Turbine is similar to the Tesla turbine, except for its discs, that are all or in part replaced by the new discs that have characteristics of the Pelton Wheel.

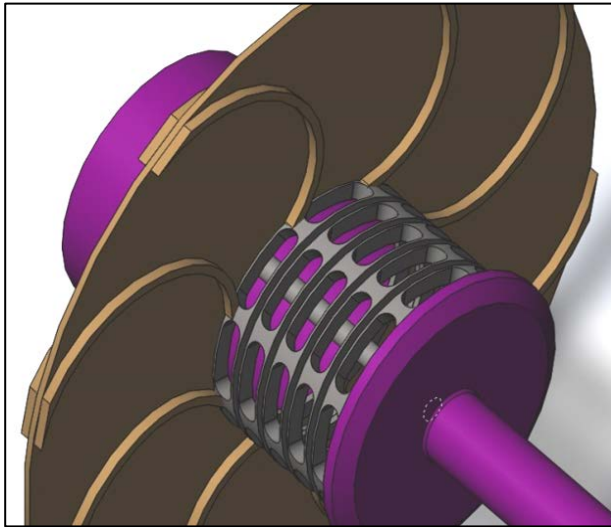


Fig. 5 Rotor assembly

So, when jet of fluid passes through the disk, due to adhesion the disk will rotate. But the torque generated will be less. This is eliminated by providing blades at a certain distance. Now the flow of fluid will collide with fixed blade and create an impulse. This impulse will create resulting torque. The blades are designed such a way that the flow will be directed towards the exhaust port. And so the fluid will leave through the exhaust port.

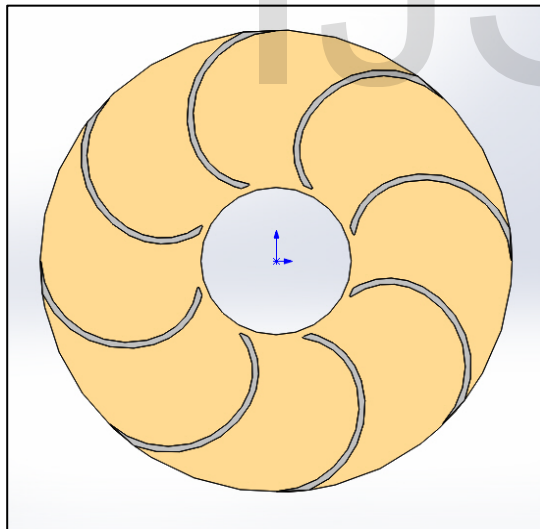


Fig. 6 Hybrid Disk

2. EXPERIMENTAL WORK:

2.1 Model:

- Here 3-Dimensional model of Hybrid Turbine is used for analysis purpose.
- There are two ports as shown in figure, inlet port and outlet port. And fluid chamber casing surrounding the disk.
- For analysis purpose, one disk with six blades is used.

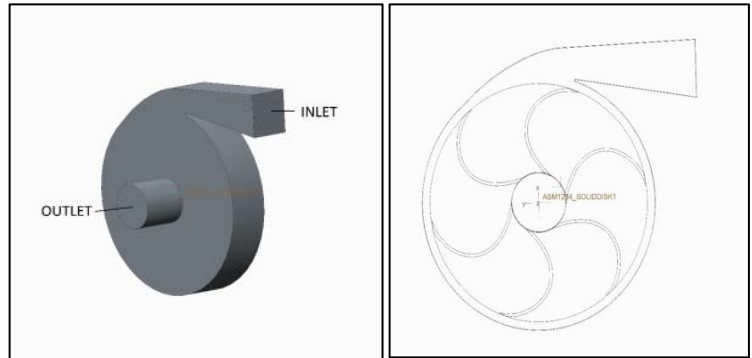


Fig.7 3-Dimensional Hybrid Tesla Turbine Model

In this investigation, model with standard wall treatment is used in FLUENT. Water is taken as the fluid flowing through inlet and through rotor section. CFD-POST is used to calculate velocity and pressure at rotor and fluid at inlet section having inlet velocity 50 m/s. In CFD-POST, fluid is considered as moving from inlet to outlet via rotating disk (rotor) rotating at speed of 250 rad/s. Here outlet is maintained at 0 gauge pressure.

2.2 Process parameters:

| | |
|---------------------------|------------------------------|
| Mesh type | Automesh |
| Precision | Double |
| Solver type | Pressure based, steady state |
| Fluid | Water liquid |
| Outlet boundary condition | 0 gauge pressure |
| Initialization method | Hybrid |
| Inlet type | Velocity-inlet |
| Reference frame | Absolute |
| Inlet velocity | 50 m/s |
| Outlet type | Pressure-inlet |
| Disk and blade type | Moving wall |
| Disk motion | Rotational |
| Disk speed | 250 rad/s |
| Disk shear condition | No slip |
| Reporting interval | 1 |
| Profile update interval | 1 |
| Number of iterations | 2300 |
| Streamline | 3d |
| Start from | Inlet |
| Sampling | Equally spaced |
| # Of points | 100 |

3. Results:

3.1 Velocity streamline in turbine:

As shown in picture, velocity of streamline decreases as it passes over turbine disk and blades. Because streamline gives its energy to disk and blades and hence disk rotates. Maximum velocity occurs at nozzle of inlet pipe.

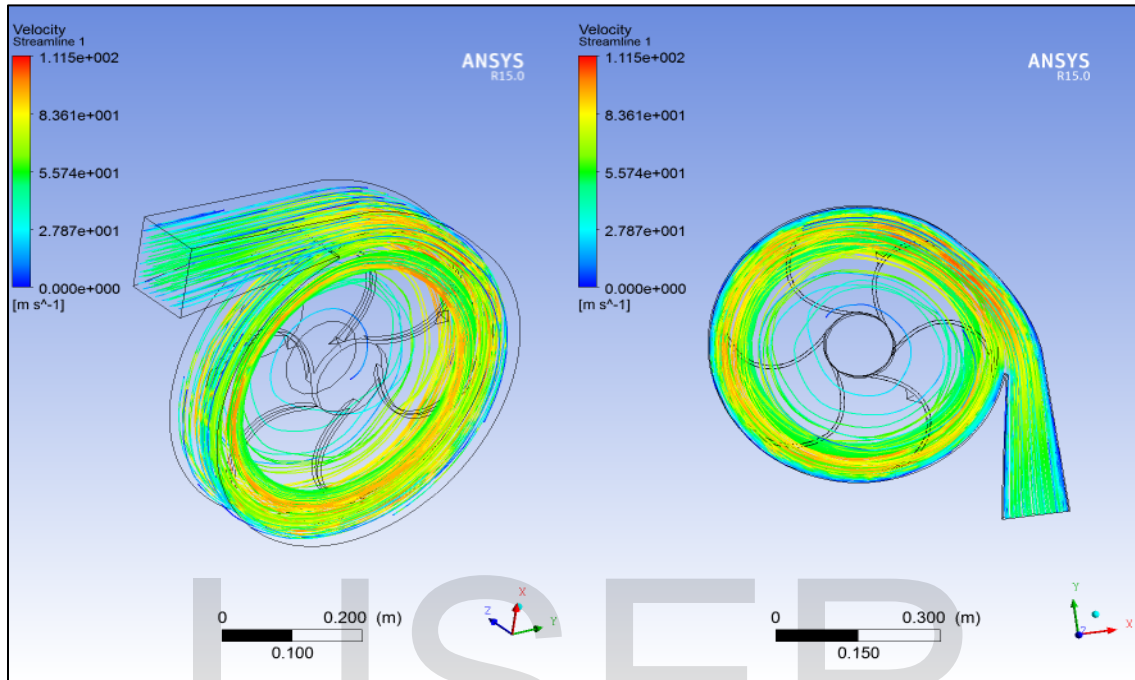


Fig. 8 Velocity streamline in Hybrid Tesla turbine

3.2 Pressure contour at disk surface:

As shown in picture, pressure is high at edges of disk and front portion of blades. As streamline collides with blades, pressure drop occurs at back of blades which is shown by yellow color on the disk. Pressure drop also occurs near center of disk at the back side because of same reason.

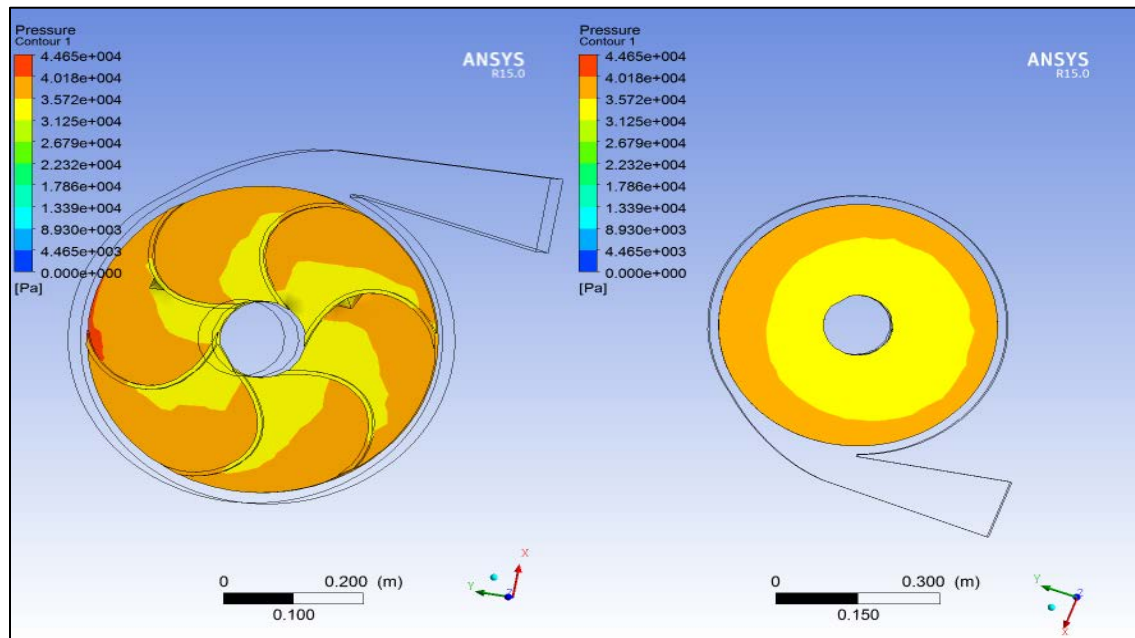


Fig.9 Pressure contour at Hybrid turbine Disk

4. Equations:

The purpose of the ANSYS model is to observe the flow pattern and analyze the velocity at different point of a disk to find the torque and efficiency.

Torque and accordingly the output is given by,

$$\tau = J(\alpha_1 - \alpha_2)$$

$$\dot{W} = 2\pi f\tau$$

Where.

J=mass moment of inertia

And α_1 and α_2 =angular acceleration at inlet and outlet respectively

W=power produced (output)

f=rotational frequency of rotor

Assuming that output angular acceleration is zero the torque equation turns out to be,

$$T_{FS} = \frac{\omega_0 r^2 \Delta V}{308 t_{accel}}$$

T_{fs} = final torque after the assumption

ω = angular velocity of rotor

r = outer radius

ΔV = change in velocity

T_{accel} = time between the starting to reach up to steady state equation

Efficiency equation,

$$\eta_{exp} = \frac{\dot{W}}{(\dot{m}/\rho)P}$$

5. Calculation:

Velocity change between the outlet of a nozzle to the outlet of a disk is calculated using any one particle stream line passing through both. And the values are taken from the graph shown above.

$$\text{Estimated velocity change} = (83.61 - 55.74) \text{ m/s}$$

$$= 27.84 \text{ m/s}$$

$$\text{Volume of the disk} = 155 \text{ in}^3$$

$$= 0.00254 \text{ m}^3$$

$$\text{Volume Flow rate (Q)} = \text{Area of nozzle} * \text{inlet velocity}$$

$$= 0.0127 \text{ m}^2 * 50 \text{ m/s}$$

$$= 0.6345 \text{ m}^3/\text{s}$$

Angular velocity of disk = 250 rad/s

Mass moment of inertia of aluminum disk = 0.0358 kg-m² (assuming cylindrical section)

$$\text{Input} = \text{Volume flow rate} * \text{Pressure}$$

$$= 0.6345 * 100000$$

$$= 63.45 \text{ KW}$$

$$\text{Output} = \text{Torque} * \text{Angular velocity}$$

$$= (22.5171) * (250)$$

$$= 5629.25 \text{ W}$$

Now assuming number of disk to be = 6

Output = 33.774 KW

$$\text{Efficiency}(\eta) = \text{Output/Input}$$

$$= 53.229\%$$

This efficiency is based on many assumptions, such as ideal nozzle and no friction condition. But in real life many more parameters affects the efficiency of a turbine. So efficiency of this turbine will always be less than the theoretical value.

These are few criteria which directly affects efficiency:

1. Changing the number of blades:

Blades extruded over the disk is used to transmit higher torque than the disk itself. So, higher the number of disk higher will be the torque generated. But it also increases the friction, wear resistance and corrosion resistance. Which leads to drop in efficiency. Also the complexity of the disk increases and so as the cost.

So number of disk is very important criteria.

2. Outlet design:

Outlet design is irrelevant for the torque and power transmission but it provides a path or a way for a fluid to flow for a recirculation or for any other purpose such as reheating or regeneration.

Outlet design is very crucial as it supports vortex flow of a fluid in a disk.

3. Material used for disk:

A perfectly smooth disk will not allow adhesion of fluid to the disk, and fluid will flow right across the disk without creating the necessary boundary layer effect. Too much surface roughness creates turbulent flow, which then hinders turbine performance. Thus the surface must have some roughness, in order to create the boundary layer effect. In addition to that disk blade should have enough strength to withstand the pressure of a fluid.

Now a days preferred material is carbon fiber which is available in wide variety of properties. Its surface roughness can be altered by various polishing method according to the requirement.

| Material | Surface Roughness(mm) |
|----------------------------|-----------------------|
| Steel Pipe(drawn new) | 0.02-0.1 |
| Steel Pipe(welded new) | 0.05-0.1 |
| Cast iron-pipe | 0.25-1 |
| Sheet steel | 0.07 |
| Glass, lead, copper, brass | 0.0001-0.0015 |

6. Conclusion:

➤ Analysis of tesla Turbine and comparing it with Hybrid Tesla Turbine:

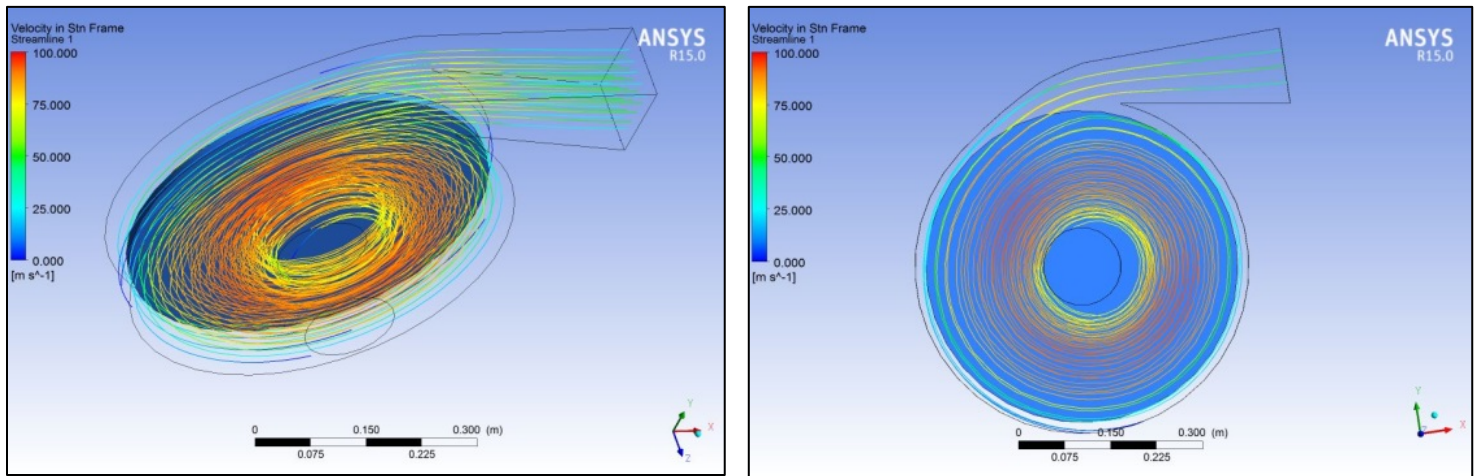


Fig.10 velocity streamline in Tesla turbine

Velocity change between the outlet of a nozzle to the outlet of a disk is calculated using any one particle stream line passing through both. And the values are taken from the graph shown above.

$$\text{Estimated velocity change} = (100 - 75) \text{ m/s} = 25 \text{ m/s}$$

$$\text{Volume of the disk} = 155 \text{ in}^3 = 0.00254 \text{ m}^3$$

$$\begin{aligned} \text{Volume Flow rate (Q)} &= \text{Area of nozzle} * \text{inlet velocity} \\ &= 0.0127 \text{ m}^2 * 50 \text{ m/s} \\ &= 0.6345 \text{ m}^3/\text{s} \end{aligned}$$

Angular velocity of disk = 250 rad/s

Mass moment of inertia of aluminum disk = 0.0358 kg-m² (assuming cylindrical section)

$$\begin{aligned} \text{Input} &= \text{Volume flow rate} * \text{Pressure} \\ &= 0.6345 * 100000 \\ &= 63.45 \text{ KW} \end{aligned}$$

$$\begin{aligned} \text{Output} &= \text{Torque} * \text{Angular velocity} \\ &= (20.4) * (250) \\ &= 5110 \text{ W} \end{aligned}$$

Now assuming number of disk to be = 6

Output = 30.6 KW

$$\begin{aligned} \text{Efficiency}(\eta) &= \text{Output}/\text{Input} \\ &= 48.57\% \end{aligned}$$

As per analysis and calculations shown we get,

| Parameter | Hybrid Turbine | Tesla Turbine |
|--------------------------------------|----------------|---------------|
| Velocity change(m/s) | 27.84 | 25 |
| Volume of disk(m ³) | 0.00254 | 0.00254 |
| Volume Flow rate (m ³ /s) | 0.6345 | 0.6345 |
| Input Power(KW) | 63.45 | 63.45 |
| Output Power(KW) | <u>33.774</u> | <u>30.6</u> |
| Efficiency(η) | <u>53.229%</u> | <u>48.57%</u> |

- So it is clear that by combining both Impulse force of Pelton wheel turbine and boundary layer flow of Tesla (Bladeless turbine) turbine in Hybrid turbine, higher output power and higher efficiency can be achieved than simple tesla turbine.
- From our analysis we have achieved around 5% efficiency benefit from hybrid turbine than Tesla turbine.
- With our diligent research in this turbine and field, we speculate that by changing various variable parameters we can get more efficiency.

7. Experimental Model:

- Hybrid Tesla Turbine can be easily made using advance Rapid Prototyping Technique.
- For example, we have manufactured hybrid tesla turbine disks and outlet rings using 3D printer - Dimension sst 1200es. Here the material used is ABS-P430(Acrylonitrile butadiene styrene). It shows great resistance against impact and heat. As well as higher toughness.



Fig.11 3D printed hybrid disks and outlet ring

8. References:

- [1] <http://www.google.com/patents/US20110027069>
- [2] <http://www.basharesearch.com/IJATP/3020102.pdf>
- [3] http://peswiki.com/index.php/PowerPedia:Tesla_turbine
- [4] <http://large.stanford.edu/courses/2012/ph240/nam1/>
- [5] N. Tesla, "Fluid Propulsion," U.S. Patent 1061142, 6 May 1913.
- [6] "Rebirth of the Tesla Turbine", Published in "*Extra Ordinary Technology*" magazine – July 2003.
- [7] Danny Blanchard, Phil Ligrani, Bruce Gale. "*Single-disc and double-disc viscous, Micro pumps*".
- [8] Petr Bloudicek, David Palousek. "*Design of tesla turbine*".
Konference diplomovych praci 2007
- [9] Warren Rice, "*Tesla Turbomachinery*", Proc. IV International Nikola Tesla Symposium (Sep. 23 – 25 1991).
- [10] H. S. Couto¹, J.B.F. Duarte² and D. Bastos-Netto, "*The Tesla Turbine Revisited*", 8th Asia-Pacific International Symposium on Combustion and Energy Utilization October 10-12, 2006, Sochi, Russian Federation.

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