Design, Fabrication and Analysis of Bladeless Turbine

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Abstract
A bladeless turbine is capable of using the exhaust gas energy adiabatically by converting most of its energy into shaft power. This bladeless turbine is widely known as Boundary-layer turbine or Cohesion-type turbine. The fundamental physics behind the working of the bladeless turbine is boundary layer effect; boundary layer is the layer of fluid in the immediate vicinity of a bounding surface where the effects of viscosity are significant. The heat energy that is being wasted as exhaust in a four-stroke engine can be utilized by using a bladeless turbine which is capable of converting a fast-moving fluid (exhaust gas) to shaft work. This shaft work can be used for various applications like to run an alternator or a compressor. The prototype model of bladeless Turbine has been designed and tested with different experiments were made under varying mass air flow rate of compressed air.

Keywords: Bladeless Turbine, Exhaust gas energy, Skin Friction, Exhaust energy recovery, Boundary layer effect

1. Introduction:
Turbine is defined as a machine for producing continuous power in which a wheel is fitted with number of vanes made to revolve by a fast-moving flow of water, steam, gas or air. In Tesla Turbine instead of turbine blades a stack of discs with minimum distance is arranged. The nozzles are made for directing the airflow tangentially to the disk. The fluid creates drag on the disk by means of viscosity and adhesion to the layer of the fluid. As the fluid adds energy to the disks, it spirals into the center exhaust. A certain distance between the disks is made using a spacer for enhancing the so-called Boundary layer effect. The boundary layer refers to the layer of fluid in the immediate vicinity of a bounding surface where the effects of viscosity are significant. The exchange of momentum between the fluid and the disk causes the disks to rotate smoothly. The tangential entry of compressed air and the design of the casing creates a vortex flow, thereby the molecules of air interact with molecules of the disc. This causes the velocity of the turbine to increase exponentially.
In the table given below the power output and exhaust heat energy loss for various engines are listed. The best engine selection is decided by maximizing the power output and minimizing exhaust wastage.

### Table 1: Heat balance of prime movers

| No. | PRIME MOVER                  | TO POWER (%) | TO COOLANT (%) | TO EXHAUST (%) | TO RADIATION (%) | TOTAL |
|-----|------------------------------|--------------|----------------|----------------|------------------|-------|
| 1   | 4 stroke SI engine           | 26           | 30             | 32             | 12               | 100   |
| 2   | Diesel engines: 2 Stroke     | 30           | 21             | 37             | 12               | 100   |
| 3   | 4 Stroke Diesel              | 31           | 26             | 30             | 13               | 100   |

**Figure 1:** Tesla turbine
4. Diesel Turbo charged
   Engine
   4. Diesel Turbo charged

5. Gas turbine

| Engine       | Power (%) |
|--------------|-----------|
| Diesel Turbo charged | 35        |
| Gas turbine    | 15        |

Naturally aspirated four stroke SI engine is capable of delivering only 26 percent power while 32 percent leaves exhaust. Naturally aspirated two stroke diesel engines is capable of delivering only 30 percent power while 37 percent leaves exhaust. Naturally aspirated four stroke diesel engines is capable of delivering only 31 percent power while 30 percent leaves exhaust. Turbocharged four stroke diesel engines is capable of delivering 35 percent of power while 29 percent leaves exhaust. Gas turbines are capable of delivering 15 percent of power while 70 percent leaves exhaust. All these cases, the amount of exhaust gases that are being wasted is at a larger amount. In order to curb these wastage, turbocharged engines are considered for delivering more power by minimizing the exhaust gas wastage.

2. Materials & Method

The methodology of the project is made simple to fabricate as well as to analyze the flow pattern inside the Tesla turbine. The working model of the project can be elaborated by placing the entire setup on a test bed. This test bed includes a blower, Tesla Turbine, shaft for connecting the turbine, compressor, an air tank and other miscellaneous item such as an alternator for producing considerable amount of electricity. The blower is the essential part as it supplies an adequate amount of velocity and pressure of air to the turbine for the discs to rotate freely with no disturbances. The shaft which is attached to the discs are tightly mounted with the help of bearing to cause rotary motion along with the discs. This shaft is fabricated to the compressor on the other end to compress the incoming air from the atmosphere. This compressed air gets stored in the air tank and can be used for some critical applications. This application can be taken towards either running a compressor or an alternator. In both cases the output power can be scientifically measured. There are four main parts of Tesla turbine which is shown in the elaborated diagram, they are: 1. Turbine discs, 2. Shaft 3. Spacer 4. Casing.

2.1 Turbine discs

The material of the disc is stainless steel which possesses higher strength. Laser cutting is a technology that uses a laser to cut materials and is typically used for industrial manufacturing applications. The reason for using this technology is to make sure that the material is precisely cut with proper dimensions. In order to facilitate boundary layer effect, discs are ensured to have smooth surface finishing process. Surface finishing process can be defined as a process for removing surface irregularities in the disc. The discs are arranged in a stack like manner with minimum gaps of 0.8 to 1.2mm between each disc. Surface roughness of the disc plays and important role with the effectiveness of the tesla turbine it is characterized based on surface texture. Surface roughness is defined on the deviations found on the surface of a material. If these deviations are large, the surface is rough and if they are small, the surface is smooth. Surface Roughness is critical to determining how an object will interact with other surfaces and
its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces, it is often a good predictor of the performance of a mechanical component, since irregularities on the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. It is this adhesion factor that is going to help us push the fluid in a Tesla turbine.

**Table 2: Surface roughness of steels**

| Material            | Surface roughness ($10^{-3}$ m) |
|---------------------|----------------------------------|
| Weld steel          | 0.045                            |
| Stainless steel     | 0.0015                           |
| Cast iron           | 0.8 – 1.5                        |
| Galvanized Steel    | 0.15                             |
| Rusted steel        | 0.15 - 4                         |
| Worm cast steel     | 0.8 – 0.15                       |
| Stretched steel     | 0.015                            |

2.2 Shaft

The material of the shaft is Aluminum which possesses light weight, high strength, easy machining and good thermal conductivity. The machining of the material is made so accurate to properly mount discs on it. A key is attached to prevent relative rotation between the two parts. Parallel key is a type of key which is used to lock the mating parts into place. Buffing is a finishing process applied to the shaft for smoothing the surface using a work wheel.
2.3 Spacer

The Spacer is a component which is used to maintain the minimum gap between the two turbine discs, so that the gap between the discs were maintained equally. The discs and spacers were fixed alternatively and bolted by M4 bolt. In the spacer, it will have the key way. The key is used to connect the shaft and the stalk of discs. Then the stalk of discs was maintained at the particular distance by using the circlips on the both sides.

![Spacer](image)

**Figure 3:** Spacer

2.4 Casing

The casing is used for sealing outer cover and discs to facilitate zero air leakage and also for enhancing boundary layer effect. The material that is used for casing is nylon which possesses less expensive and easy manufacturing. A small hole is created in the nylon casing for the delivery of air inside the turbine. A pre calculated diameter is sharply made for the seating of nozzle which directs a tangential flow to the boundary surface of the turbine. The material used for outer cover is mild steel which possesses great strength, high durability and easy machining. The main purpose of using this outer cover is to hold all the components tightly sealed with no air leakage. Appropriate bolt and nuts are tightened on four ends of the outer cover.

The construction of the bladeless turbine is made simple such that the material selection is crucial for the concept of boundary layer effect. The material used for the disc is stainless steel which demands better surface finish for boundary layer effect. A 1mm spacer is bolted using a M4 bolt between each disk for proper and regular stack wise arrangement of multiple disks (10). A 20mm hole is created in a set of 10 spacers for inserting the shaft. This shaft helps in the rotary motion of all components together simultaneously. The shaft and the spacers were connected by key, which transmits the power from the discs to the shaft. Totally two circlips are used in both sides of the shaft for aiding in proper rotary motion without any distortion and it will restrict the axial motion along the shaft. The Nylon casing is used for proper sealing so as to maintain no air leaks between the disc and the casing. A mild steel casing is used on both sides with exhaust holes fitted on one side and output shaft on the other side. Deep groove bearing is used on both sides of the casing for the shaft to rotate.
without wobbling. A Silicone gel is used between nylon casing and mild steel casing for no air leakage. A M6 bolt is used to bolt nylon with the plates together. A 1.5-inch diameter hole is made for affixing the nozzle which is properly sealed using M-Seal. In order to curb the vibration at high speeds, rubber bushings are used by drilling a hole in the rubber bushings as well as in wooden plank. This complete set up is properly affixed with rubber bushings on all sides which is held firmly on wooden plank.

Fig 4: CAD model of exploded view of disc and shaft assembly

1. Key 2. Shaft 3. Circlip 4. Keyway 5. M4 Hex head bolts 6. Discs 7. M4 nuts 8. Spacer

Figure 5: Cut sectional view of disc and shaft assembly
The bladeless turbine consists of a set of smooth disks, with nozzles applying a moving fluid to the edge of the disk. The fluid drags on the disk by means of viscosity and the adhesion of the surface layer of the fluid. As the fluid slows and adds energy to the disks, it spirals into the center exhaust. In this turbine, adiabatic process occurs which helps to keep the momentum of the revolving shaft to stay longer. Moreover, the fluid follows 3 to 4 rotational paths which extract more energy from the fluid to convert it into useful work. This revolving shaft is coupled with a compressor wheel for checking the mass air flow rate at different rpm of the shaft. This bladeless turbine is coupled with the compressor wheel for extracting the compressed air from the compressor wheel. An electric blower is used for injecting fast moving fluid to the nozzle of the turbine. The turbine shaft rotates slowly and gradually the speed of the shaft increases due to adiabatic process. The turbine shaft is coupled with compressor wheel shaft which draws in air from the environment and compresses it. The velocity of the compressed air can be determined by placing an anemometer at the outlet nozzle of the compressor. The complete setup can be simply compared with the existing turbocharger in the automobiles where in the latter part is bladeless turbine while the existing part is vane turbine.
3. Testing & Validation

Computational fluid analysis (CFD) is performed on the 3D model of the tesla turbine using Ansys version 16. Prior to performing the simulation, the data to be input is calculated manually. After determining the values are input to the Ansys platform the pre-processing and the post-processing results are detailed below.

**CALCULATION OF MASS AIR FLOW RATE OF A PETROL ENGINE**

Air fuel ratio of petrol engine = 14.7:1  
Total displacement of the engine = 1197 cubic centimeter (cc)  
1115.57 (for air): 81.428 (for fuel)  
Mass of petrol = 0.77 kg/liter (l)  
Fuel consumption = 0.77*0.081428 = 0.0627 kg  
Density of air = \( \frac{1.2754}{1000} \)  
= 0.001423 kg  
Total = 0.0627 + 0.001423 = 0.06412 kilogram(kg)  
Running rpm = 6000  
Four stroke engines = 6000/2 = 3000  
Mass air flow rate of an engine = 3000 * 0.06412  
= 192.36 kg/min = 3.206 kg/s

3.1 Pre-Processing:

The Physical characteristics values given in the table 3, 4, 5, 6 are those inputted to Ansys platform to proceed with the analysis.

| Table 3: Meshing | Domain | Nodes | Elements |
|-----------------|--------|-------|----------|
| Default domain  | 8595   | 42337 |          |

| Table 4: Domain-default domain | Type | Fluid |
|-------------------------------|------|-------|
| Location                      | B4   |

| Table 5: Air ideal gas | Fluid Definition | Material library |
|-----------------------|-----------------|------------------|
|                       | Morphology      | Continuous fluid |

| Table 6: Settings | Buoyancy model | Domain motion |
|-------------------|----------------|---------------|
|                   | Non-buoyant    | Stationary    |
| Parameter                  | Setting                  |
|----------------------------|--------------------------|
| Reference pressure         | 1.0000 e+00 [atm]        |
| Heat transfer model        | Total Energy             |
| Include viscous work term  | True                     |
| Turbulence model           | K epsilon                |
| Turbulent wall function    | Scalable                 |
| High speed model           | off                      |

3.2 Post-processing results:

**Figure 8:** Iso view of velocity streamline

**Figure 9:** Iso view of wireframe with disc
4. Result & Discussion

Electric blower with the specifications of 2.8m³/min at 16,000rpm (500 w) with variable set speed from 1 to 6 is used for extracting the results.

Set 1 velocity of 22.2 meter (m)/s air is injected to the nozzle of the turbine and maintained for 5 minutes to check the maximum rpm. The maximum Rotation Per Minute (RPM) attained is 2344.

Set 2 velocity of 33.3 m/s air is injected to the nozzle of the turbine and maintained for 5 minutes to check the maximum rpm. The maximum rpm attained is 2680.

Set 3 velocity of 38.8 m/s air is injected to the nozzle of the turbine and maintained for 5 minutes to check the maximum rpm. The maximum rpm attained is 3552.

Set 4 velocity of 47.2 m/s air is injected to the nozzle of the turbine and maintained for 5 minutes to check the maximum rpm. The maximum rpm attained is 4428.

Set 5 velocity of 52.77 m/s air is injected to the nozzle of the turbine and maintained for 5 minutes to check the maximum rpm. The maximum rpm attained is 5116.

Set 6 velocity of 63.8 m/s of air is injected to the nozzle of the turbine and maintained for 5 minutes to check the maximum rpm. The maximum rpm attained is 5869.
An electric blower of initial Set 1 velocity 22.2 m/s of air is injected to the nozzle of the turbine and the output of compressor wheel which is coupled to the turbine is taken. The maximum rpm attained is 1605 with mass airflow rate at the end of compressor wheel is 4.59-meter cube per second. The graph clearly explains a gradual increase of speed due to adiabatic process generated inside the turbine and after few minutes the rpm is sustained and gets stable.

A set velocity of 33.3 m/s of air is injected to the nozzle of the turbine. The maximum rpm attained in this case is 1807 with mass airflow rate of 5.3-meter cube per second. A gradual increase at every interval can be viewed clearly and after a certain amount of time, the speed of the shaft gets constant. This occurs due to surplus energy available at the turbine which makes it to achieve higher rpm.

A set velocity of 38.8 m/s of air is injected to the nozzle of the turbine. The maximum rpm attained in this case is 2451 with mass airflow rate of 6.8-meter cube per second.

**Figure 12:** Set 1 with inlet air velocity 2.2 m/s

**Figure 13:** Set 2 with inlet air velocity 33.3 m/s
Figure 14: Set 3 with inlet air velocity 38.8 m/s second. A steady increase of the graph explains that the turbine is capable of producing higher speed as the fluid follows more than one rotational path.

Figure 15: Set 4 with inlet air velocity 47.22 m/s

A set velocity of 47.2 m/s of air is injected to the nozzle of the turbine and the output of compressor wheel which is coupled with the turbine is taken. The maximum rpm attained in this case is 2902 with mass airflow rate of 7.9-meter cube per second. The graph clearly says that the turbine gains energy when the velocity of air increases slowly.
Figure 16: Set 5 with inlet air velocity 52.77 m/s
A set velocity of 52.7 m/s of air is injected to the nozzle. The maximum rpm attained in this case is 3307 with mass air flow rate of 9.905-meter cube per second. This graph proves efficient acceleration of turbine as the fluid follows more rotational path and spirals it to the exhaust.

Figure 17: Set 6 with inlet air velocity 63.88 m/s
A set velocity of 63.8 m/s of air is injected to the nozzle. The maximum rpm attained is 4188 with mass air flow rate of 9.58-meter cube per second. The velocity attained at the end of the process is 12.1 /acm/s. This graph follows a slow increase of speed as the fluid drags the disc slowly and the maximum speed is attained when the energy is increased.

5. FUTURE SCOPE AND CONCLUSION
As per the results obtained from testing it can be seen that the designed bladeless turbine is functional. This is concluded based on the computer analysis and the data plotted by practical testing of the designed setup on a rope brake dynamometer. The characteristic curves from figure set 1 to set 6, shows us that bladeless turbine attached to a compressor under increasing RPM is able to provide an increase in the mass airflow rate at the end of the compressor. Thus
this project can be evaluated with the use of bladeless turbocharger by replacing the existing turbocharger in automobiles. An important parameter that should be considered here is the amount of heat generated at the exhaust. As mentioned above, the bladeless turbocharger can couple with a compressor can compress the air equivalent to an existing turbocharger or more. This compressed air can be stored in the tank for injecting timely and precise amount of flow into the intake manifold of the engine. Its best suits for petrol engine and not diesel engine. Matching the engine with the bladeless turbocharger is the crucial part which can be done but it is time taking process. The compressor can also be manufactured with no vane angles. The bladeless turbine can be coupled with the alternator for producing more current by minimizing the engine parasites or it can also be coupled with an AC compressor. Thus, the target of the intended project is experimentally achieved. The possible characteristics of bladeless turbine have been studied thus proving our objective that bladeless turbine uses more energy from its input and convert it into work.

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