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Investigation of Tesla Turbine

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***Abstract*—This project outlines one of the key investigations on tesla turbine on basis of a cogeneration ideology. Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time. The type of fluid flow into the tesla turbine determines the performance and thus a study on a kind of fluid introduced into the turbine and its effect on efficiency becomes necessary. This investigation allows us to narrow down the possibilities of using fluids and overall tabulation of co-generative energy resources which can help us develop alternate energy for existing energy crisis and carbon footprints in the environment.**

***Keywords*- Tesla Turbine, Co-generation, energy crisis, carbon footprints**

I. INTRODUCTION

The beginning of 1913 experienced a revolution in industrialization of machinery when Nikola Tesla patented his bladeless turbine that used series of rotating discs to convert energy of flowing fluid into a mechanical rotation which can be used to perform useful work. It's a simple device that has very few moving parts in which work is produced when the working fluid is introduced tangentially at the outer edge of the plates or the rotating discs around the center shaft. In 1922 Tesla made some basic modifications in design where he introduced two heavier end plater which were tapered towards the periphery for the purpose of reducing the maximum centrifugal stresses developed in his initial design.

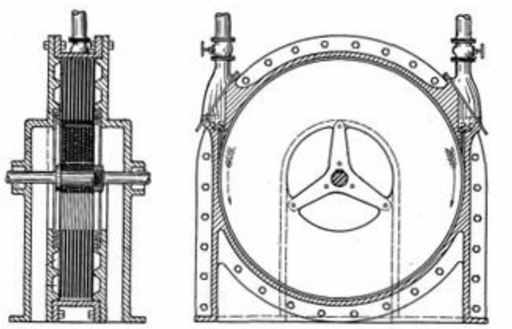

Figure 1.Original Schematic of tesla turbine

This turbine is an efficient self-starting prime mover which may be operated as a steam or mixed fluid turbine at will, without changes in construction and is on this account very convenient. Minor departures from the turbine, as may be dictated by the circumstances in each case, will obviously suggest themselves but if it is carried out on these general lines it will be found highly profitable to the owners of the steam plant while permitting the use of their old installation. However, the best economic results in the development of power from steam by the Tesla turbine will be obtained in plants especially adapted for the purpose.

II. PRINCIPLE

Multiple-disk Tesla-type drag turbines rely on a mechanism of energy transfer that is fundamentally different from most typical airfoil-bladed turbines or positive-displacement expanders. 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. Exhaust holes on each disk are placed as close to the center shaft as possible. A turbine casing surrounds the disks with a low 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 flow enters the channels at a high speed and a direction nearly tangential to the outer circumference of the disks, and exits through an exhaust port at a much smaller inner radius. Energy is transferred from the fluid to the rotor via the shear force at the microchannel walls.

As the spiraling fluid loses energy, the angular momentum drops causing the fluid to drop in radius until it reaches the exhaust port. In a pump, centrifugal force assists in expulsion of fluid. On the contrary, in a turbine centrifugal force opposes fluid flow that moves toward center.

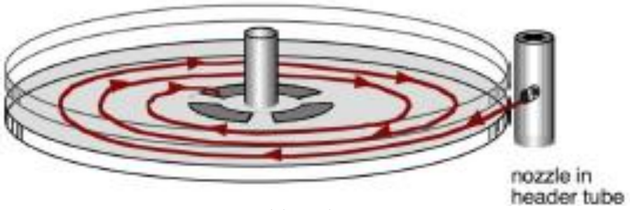

Figure 2.Schematic of fluid flow in tesla turbine

III. COGENERATION CONCEPT

Cogeneration or Combined Heat and Power (CHP) is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy. Mechanical energy may be used either to drive an alternator for producing electricity, or rotating equipment such as motor, compressor, pump or fan for delivering various services. Thermal energy can be used either for direct process applications or for indirectly producing steam, hot water, hot air for dryer or chilled water for process cooling. Cogeneration provides a wide range of technologies for application in various domains of economic activities. The overall efficiency of energy use in cogeneration mode can be up 85 per cent and above in some cases. Cogeneration makes sense from both macro and micro perspectives. At the macro level, it allows a part of the financial burden of the national power utility to be shared by the private sector; in addition, indigenous energy sources are conserved. At the micro level, the overall energy bill of the users can be reduced, particularly when there is a simultaneous need for both power and heat at the site, and a rational energy tariff is practiced in the country.

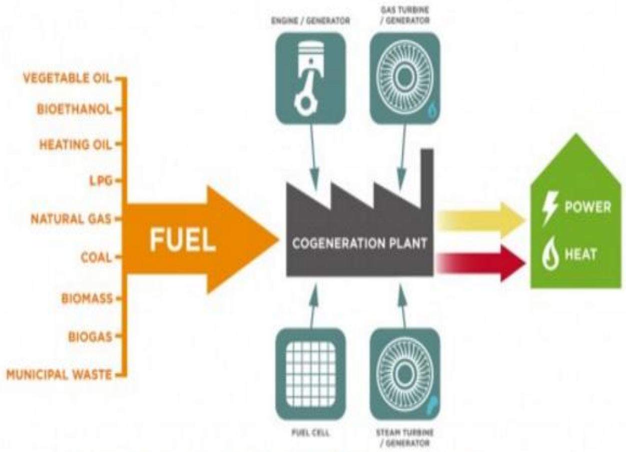

Figure 3. Schematic of co-generation concept

IV. ADVANTAGES OF CHP

In cogeneration plant the low pressure steam coming from turbine is not condense to form water, instead of it its used for heating or cooling in building and factories, as this low pressure steam from turbine has high thermal energy. The cogeneration plant has high efficiency ofaround 80 - 90 %. In India, the potential of power generation from cogeneration plant is more than20,000 MW. The first commercial cogeneration plant was built and designed by Thomas Edison in New York in year 1882. In convention power plant, with 100 % energy input, only 45 % of energy is used and rest 55 % is wasted but with cogeneration, the total energy used is 80% and energy wasted is only 20 %. It means with cogeneration the fuel utilization is more efficient and optimized and hence more economical.

Every heat engine is subject to the theoretical efficiency limits of the Carnot cycle. Mechanical energy from the turbine drives an electric generator. The low-grade (i.e. low temperature) waste heat rejected by the turbine is then applied to space heating or cooling or to industrial processes. Cooling is achieved by passing the waste heat to an absorption chiller. Reduces utility costs and improves economic competitiveness. Increases power reliability and self-sufficiency. Reduces GHG emissions and other pollutants. Reduces demand for imported energy supplies. Capable of operating on renewable or nonrenewable resources. Suite of proven, commercially available technologies for various applications. Additional financial incentives through the feed-in-tariff, Self-Generation Incentive Program (SGIP) and investment tax credits available for eligible customers. Cogeneration optimizes the energy supply to all types of consumers, with the following benefits for both users and society at large:

- Increased efficiency of energy conversion and use. Cogeneration is the most effective and efficient form of power generation.
- Lower emissions to the environment, in particular of CO_2, the main greenhouse gas. Cogeneration is the single biggest solution to the Kyoto targets.
- Large cost savings, providing additional competitiveness for industrial and commercial users, and offering affordable heat for domestic users.
- An opportunity to move towards more decentralized forms of electricity generation, where plants are designed to meet the needs of local consumers, providing high efficiency, avoiding transmission losses and increasing flexibility of system use. This will particularly be the case if natural gas is the energy carrier.
- Improved local and general security of supply – local generation, through cogeneration, can reduce the risk of consumers being left without supplies of electricity and/or heating. In addition, the reduced need for fuel resulting from cogeneration reduces import dependency – helping to tackle a key challenge for Europe’s energy future.
- An opportunity to increase the diversity of generation plant, and provide competition in generation. Cogeneration provides one of the most important vehicles for promoting energy market liberalization.

V. EASE OF USE

Prior to 2006, Tesla turbine was not commercially used. On the other hand, Tesla pump has been commercially available since 1982. It is used to pump fluids that are abrasive, viscous, contain solids or are difficult to handle with other pumps. The concept of Tesla turbine is used as a blood pump and gave good results. Research in this field still continues. In Tesla’s time efficiency of classic turbines was low, because aerodynamic theory needed to construct effective blades did not exist and quality of materials for blades was low. That limited operating speeds and temperatures. Its other drawbacks are shear losses and flow restrictions. But that can be an advantage when flow rates are low. Tesla’s design can also be used, when small turbine is needed. Efficiency is maximized, when boundary layer thickness is approximately equal to inter-disc spacing. So at higher flow rates, we need more discs, which means larger turbine. Because thickness of boundary layer depends on viscosity and pressure, various fluids cannot be used as motive agents in the same turbine design. Discs have to be as thin as possible, to prevent turbulence at disc edges. Due to technology limitations, it has not seen widespread use in time of its conception. During last three decades, design has been used in some areas, but not widely. If last issued patents live up to expectations of their inventors, things may change.

VI. NEED FOR THE SYSTEM

Thermal power plants are a major source of electricity supply in India. The conventional method of power generation and supply to the customer is wasteful in the sense that only about a third of the primary energy fed into the power plant is actually made available to the user in the form of electricity. In conventional power plant, efficiency is only 35% and remaining 65% of energy is lost. The major source of loss in the conversion process is the heat rejected to the surrounding water or air due to the inherent constraints of the different thermodynamic cycles employed in power generation. Also further losses of around 10-15% are associated with the transmission and distribution of electricity in the electrical grid. More promising are the conditions for the development of cogeneration in industry. The reducing heat demand in this sector is compensated by 2 factors: by the higher technical potential of cogeneration compared to the heat demand in industry, related to higher fuel prices, and by the high utilization related to a heat demand all year round. Higher CHP coefficients provide an additional driving force. With a proper comparison between separate or combined production of heat and power inmodern facilities, the energy advantage amounts to 15-20%, which is still significant from an ecological viewpoint.

VII. TURBINE ANALYSIS

A. Analytical Approach- Laminar Flow: -

For steady, incompressible flow over a flat plate, the laminar boundary layer equations are:

Conservation of mass: $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

‘X’ momentum: $u\,\frac{\partial u}{\partial x} + v\,\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{dp}{dx} + \frac{1}{\rho}\frac{\partial}{\partial y}\left(\mu\frac{\partial u}{\partial y}\right)$

'Y' momentum: $-\frac{\partial p}{\partial y} = 0$

The solution to these equations was obtained in 1908 by Blasius, a student of Prandtl's. He showed that the solution to the velocity profile, shown in the table below, could be obtained as a function of a single, non-dimensional variable defined as:

$$\eta = y\left(\frac{U_\infty}{\upsilon x}\right)^{1/2}$$

With the resulting ordinary differential equation:

$$f''' + \frac{1}{2}\,f\,f'' = 0$$

$$f'(\eta) = \frac{u}{U_\infty}$$

Boundary conditions for the differential equation are expressed as follows:

At y = 0, v = 0 f (0) = 0;
y component of velocity is zero at y = 0.

At y = 0, u = 0 f’ (0) = 0;
x component of velocity is zero at y = 0.

The key result of this solution is written as follows:

$$\left.\frac{\partial^2 f}{\partial \eta^2}\right)_{y=0} = 0.332 = \frac{\tau_w}{\mu U_\infty \sqrt{U_\infty / \upsilon x}}$$

With this result and the definition of the boundary layer thickness, the following key results are obtained for the laminar flat plate boundary layer:

Local boundary layer thickness:

$$\delta(x) = \frac{5x}{\sqrt{\mathrm{Re}_x}}$$

Local skin friction coefficient:

$$C_{f_x} = \frac{0.664}{\sqrt{\mathrm{Re}_x}}$$

Total Drag coefficient for length L:

$$C_D = \frac{1.328}{\sqrt{\mathrm{Re}_x}}$$

Where by definition,

$$C_{f_x} = \frac{\tau_w(x)}{\frac{1}{2}\rho U_\infty^2}$$

$$C_D = \frac{F_D / A}{\frac{1}{2}\rho U_\infty^2}$$

With these results, we can determine local boundary layer thickness, local wall shear stress, and total drag force for laminar flow over a flat plate.

B. Analytical Approach- Turbulent flow

While the previous analysis provides an excellent representation of laminar, flat plate boundary layer flow, a similar analytical solution is not available for turbulent flow due to the complex nature of the turbulent flow structure. A summary of the results for boundary layer thickness and local and average skin friction coefficient for a laminar flat plate and a comparison with experimental results for a smooth, turbulent flat plate are shown below.

Laminar	Turbulent
$\delta(x) = \frac{5x}{\sqrt{Re_x}}$	$\delta(x) = \frac{0.16x}{Re_x^{1/7}}$
$C_{f_x} = \frac{0.664}{\sqrt{Re_x}}$	$C_{f_x} = \frac{0.027}{Re_x^{1/7}}$

C. Analytical Approach- Combined Flow

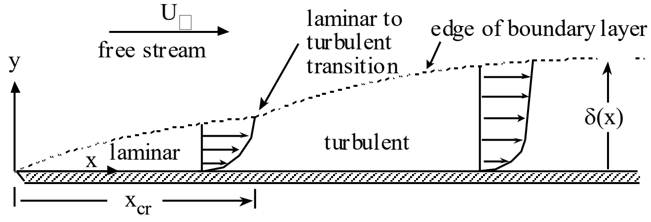

Fig. 4. Flat plate with both laminar and turbulent flow sections

For conditions (as shown above in fig. 4) where the length of the plate is sufficiently long that we have both laminar and turbulent sections:

1 Local values for boundary layer thickness and wall shear stress for either the laminar or turbulent sections are obtained from the expressions for f(x) and Cfx for laminar or turbulent flow as appropriate for the given region.

2 The result for average drag coefficient C_D and thus total frictional force over the combined laminar and turbulent portions of the plate is given by (assuming a transition Re of 500,000)

$$C_D = \frac{0.031}{Re_L^{1/7}} = \frac{0.031}{\left(5x10^6\right)^{1/7}}$$

Calculations assuming only turbulent flow can typically be made for two cases:

1. When some physical situation (a trip wire) has caused the flow to be turbulent from the leading edge.

2. If the total length L of the plate is much greater than the length x_{cr} of the laminar section such that the total length of plate can be considered turbulent from x = 0 to L. Note that this will over predict the friction drag force since turbulent drag is greater than laminar.

With these results, a detailed analysis can be obtained for laminar and/or turbulent flow over flat plates and surfaces that can be approximated as a flat plate. Figure in the text shows results for laminar, turbulent and transition regimes. Equations used to calculate skin friction and drag results for the fully rough regime.

$$c_f \approx \left(2.87 + 1.58 \log \frac{x}{\varepsilon}\right)^{-2.5}$$

$$C_D \approx \left(1.89 + 1.62 \log \frac{L}{\varepsilon}\right)^{-2.5}$$

Equations be used to calculate total CD for combined laminar and turbulent flow for transition Reynolds numbers of 5x105 and 3x106 respectively.

$$C_D \approx \frac{0.031}{Re_L^{1/7}} - \frac{1440}{Re_L} \qquad Re_{trans} = 5x10^5$$

$$C_D \approx \frac{0.031}{Re_L^{1/7}} - \frac{8700}{Re_L} \qquad Re_{trans} = 3x10^6$$

VIII. CONCLUSION

There seems to be a growing consensus that cogeneration is the way forward for large-scale electricity and heating supplies, and we're likely to see thousands more CHP plants appearing all over the world in the coming decades.

- Markets for technologies also could change as a result of the widespread use of cogeneration. Electric utilities or their construction contractors generally interact directly with the major manufacturers of power plant equipment. Cogenerates, on the other hand, will be more likely to purchase a total system from vendors acting as middlemen between manufacturers and purchasers.
- Cogeneration continues to play an important role in controlling industrial or commercial energy costs through the effective integration of power generation options into the planned energy supply system.
- The overall performance and application flexibility of the cogeneration equipment and system is critical to the success of these ventures. The use of automatic extraction steam turbines to control process pressures, integration of gas turbine exhaust energy for process steam generation, process fluid heating and preheated

combustion air for fired process heaters are a few examples of the many options available.

- As more and more industrials, commercial/educational establishments, developers and utilities around the world search for low-cost electric energy and process heat, cogeneration is found to offer high efficiency and possibly environmental benefits as well.
- The industrial steam host is one important key to success. The host provides the thermal energy demands that can be leveraged to highly efficient cogeneration systems as well as land for utilities and developers to site new generation facilities.

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