Tesla Turbine

Wanted: these sections used to be from separate pages, i just dumped them here in the meantime. if someone can clean these up before i get back to them, that'd be awesome :)

Contents

On the tesla turbine

On the Tesla turbine - proceed to the simple steam engine, please.

I know of one commercial tesla pump, and it is very expensive. I know of no commercial Tesla engines. Point is - to do this right - with longevity and proper seals - is advanced technology, and to my knowledge, not yet the realm of 'appropriate technology' engineering. Sure, small toys work as examples, just like the Picoturbine works to power an LED light.

We considered the Tesla turbine seriously, I had materials quotes lined up - and then I found out that a typical implementation is 40% efficient, and the best documented one is 60 at http://obilaser.com. Piston steam engines are but 15% efficient, steam turbines can be up to 60% efficient but are very complicated and expensive to make. Note btw that most energy is lost in the energy conversion process (to make steam from water), the engine itself has nothing to do with it and even the most optimal design will still have fairly low energy efficiency ratios. Compressed air can be more efficient, but a good full system (so including compressor too is difficult to make)

When I recognized this - and considered limited working fluid in a solar concentrator sytem - I said bye-bye turbine.

I can provide a much longer discussion on the above.

Tesla Turbine Comments (compiled by Jeffery Hayes)

Main > **Energy**

FROM
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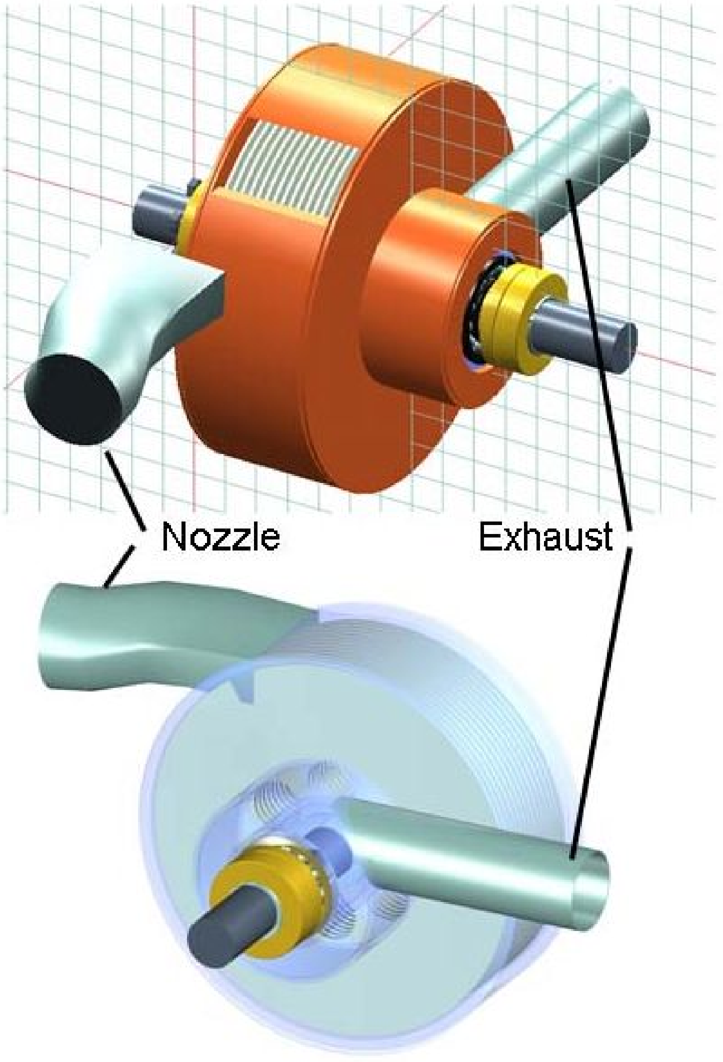
BOUNDARY-LAYER BREAKTHROUGH - THE TESLA BLADELESS TURBINE Compiled by Jeffery A. Hayes



Working fluid (such as steam) enters tangentially to the disks through a nozzle

INTRODUCTION

Most people remember Nikola Tesla for his work and revelations in the field of electrical energy and the invention of radio. However, Tesla had a life long interest in developing a flying machine. Tesla had envisioned himself as the first man that would fly. He had planned to build an aircraft that would operate on electric motors. However, the first men who successfully flew an aircraft used the reciprocating internal combustion engine. Though successful in achieving flight, aircraft using these engines were dangerous and unpredictable, due to the engine's lack of adequate power. Tesla turned his attention to revamping the internal combustion engine so as to make flying safe for all and minimize its environmental impact. Documented in this text is the result of Tesla's endeavors and the resulting marvel of machines called the Bladeless Boundary- Layer Turbine.

Although Tesla's dream for his engines application in aircraft was not realized in his life time, if allowed to be used in aircraft today, it would provide a quiet, safe, simple and efficient alternative to our supposedly advanced bladed turbine aircraft engines. It has been estimated that an increase in fuel efficiency of a factor of three could be realized in aircraft and thus substantially reduce pollution. Not only this, the Bladeless Tesla Turbine Engine can turn at much higher speeds with total safety. If a conventional bladed turbine engine goes critical or fails, watch out, you have exploding parts slicing through hydraulic lines, control surfaces and maybe even you. With the Bladeless Tesla Turbine this is not a danger because it will not explode. If it does go critical, as has been documented in tests at 85,000 rpm, the failed component will not explode but implode into tiny pieces which are ejected through the exhaust while the undamaged components continue to provide thrust to keep you airborne. We. can only speculate on the human suffering that could and should be averted.

The application of this amazing engine was not to be limited to aircraft. Tesla was setting up plans to replace what he considered the wasteful, polluting, inefficient and complicated reciprocating engine in all its applications, including the automobile. Tesla's small but powerful engine has only one moving part and is 95% efficient, which means tremendous mileage. It runs vibration free and doesn't even require a muffler. Not only is this engine 95% efficient, as compared to 25% efficiency or less of the conventional gas engine, it can run efficiently on any fuel from sawdust to hydrogen with no wear on the internal engine components. This engine's speed-torque characteristic allows full torque at the bottom of the speed range eliminating the conventional shifting gear transmission. This provides additional economy as the expensive, complicated and wear prone transmission is eliminated.

Unlike most people of the time, Tesla was very concerned about the long range environmental damage the reciprocating engines would create. He stressed over and over how we must take the long range view and not step out of harmony with our life support systems. Today the widening concern for Spaceship Earth and the renewal of an old ethic "We don't inherit the Earth from our ancestors, we borrow it from our children" is slowly beginning to awaken people to the concerns of Tesla.

Although the existence of the automobile on city streets dates back to the first years of the century, its role as a contributor to air contamination did not receive wide acceptance among scientists until the 60's. Factual evidence that urban area smog was chemically related to automobile emissions had been produced and acknowledged by scientific groups in the 1950's. Despite vehement disagreement which ensued between government and the automotive industry on this volatile issue, research and development programs were initiated by both groups in an effort to identify the reciprocating internal combustion engine's sources of pollution and determine what corrective action might be taken. Obviously Tesla's ounce of prevention was not heeded, leaving us with well over the pound required for a cure with nearly half of all air pollution caused by the reciprocating internal combustion engine.

The Boundary Layer Turbine is not only an engine that is hard to comprehend by our currently imposed standards, but can also be used as a pump with slight modification. And like its cousin the engine, it has Herculean power. Unlike conventional pumps that are easily damaged by contaminants, the Bladeless Tesla Pump can handle particles and corrosives in stride as well as gases with no cavitation effect that destroys, in short order, conventional type pumps.

These pumps and engines, though unknown to most, are available for commercial sale. If large scale commercial production was implemented, these engines and pumps would be extremely affordable due to their simplicity of manufacture, longevity, almost total lack of maintenance and the added bonus that they require no crank case oil.

Almost a quarter of the air pollution today comes from the coal being burned to generate electricity. Fuel consumption, resulting in air pollution and acid rain, could be significantly reduced simply by replacing the conventional blade steam turbines currently used by utilities with the Bladeless Tesla Steam Turbine. This also would have the added bonus of drastically reducing maintenance. But the real solution lies in using low temperature wet steam occurring naturally from the ground in the form of geothermal energy. This energy would destroy a conventional bladed steam turbine, unless expensive steam drying is employed. However, the Bladeless Tesla Steam Turbine requires no drying and can be connected directly to the geothermal source. It has been estimated that the geothermal potential in just Southern California alone, could power the entire North American Continent with NO POLLUTION! Large oil companies have comprehended the potential of geothermal energy and have purchased many of these large tracks of prime geothermal land.

Due to the revolutionary concepts embodied in this engine, we can easily end the so called energy crisis and dramatically reduce pollution. Even the vested energy interests are beginning to understand that now is the time for change, realizing their future health and wealth is directly linked to that of the environment. You can't hide or buy your way out of a devastated planet. There must also be a move forward for the many misinformed environmentalists who see our future as one of regression from technology instead of its proper usage.

Tesla from his 1919 autobiography, My Inventions:

"My alternating system of power transmission came at a psychological moment, as a long-sought answer to pressing industrial questions, and altho considerable resistance had to be overcome and opposing interests reconciled, as usual, the commercial introduction could not be long delayed. Now, compare this situation with that confronting my turbine, for example. One should think that so simple and beautiful an invention, possessing many features of an ideal motor, should be adopted at once and, undoubtedly, it would under similar conditions. But the prospective effect of the rotating field was not to render worthless existing machinery; on the contrary, it was to give it additional value. The system lent itself to new enterprise as well as to improvement of the old. My turbine is an advance of a character entirely different. It is a radical departure in the sense that its success would mean the abandonment of the antiquated types of prime movers on which billions of dollars have been spent. Under such circumstances the progress must needs be slow and perhaps the greatest impediment is encountered in the prejudicial opinions created in the minds of experts by organized opposition."

H.G. Wells once said that future history will be a race between education and catastrophe. This book is dedicated to the race for education.

Reprinted from: Boundary-Layer Breakthrough - The Tesla Bladeless Turbine pages 114-118.

Scientific American September 30, 1911, page 290

From the Complex to the Simple

A MARKED step was taken in the simplification of prime movers when Watt's cumbersome beam engine, with its ingenious but elaborate parallel motion, gave way to the present standard reciprocating type, with only piston rod, cross head and connecting rod interposed between piston and crank. An even greater advance toward ideal simplicity occurred when, after years of effort by inventors to produce a practicle rotary, Parsons brought out his compact, though costly, turbine, in which the energy of the steam is developed on a zig zag path through multitudinous rows of fixed and moving blades.

And now comes Mr. Tesla with a motor which bids fair to carry the steam engine another long step toward the ideally simple prime mover - a motor in which the fixed and revolving blades of the turbine give place to a set of steel disks of simple and cheap construction. If the flow of steam in spiral curves between the adjoining faces of flat disks is an efficient method of developing the energy of the steam, the prime mover would certainly appear to have been at last reduced to its simplest terms.

The further development of the unique turbine which we describe elsewhere will be followed with close attention by the technical world. The results attained with this small high-pressure unit are certainly flattering, and give reason to believe that the addition of a low pressure turbine and a condenser would make this type of turbine as highly efficient as it is simple and cheap in construction and maintenance.

Scientific American September 30, 1911, page 296

The Rotory Heat Motor Reduced to its Simplest Terms

It will interest the readers of the Scientific American to that Nikola Tesla, whose reputation must, naturally, stand upon the contribution he made to electrical engineering when the art was yet in its comparative infancy, is by training and choice a mechanical engineer, with a strong leaning to that branch of it which is covered by the term "steam engineering." For several years past he has devoted much of his attention to improvements in thermo-dynamic conversion, and the result of his theories and practical experiments is to be found in an entirely new form of prime movers shown in operation at the waterside station of the New York Edison Company, who kindly placed the facilities of their great plant at his disposal for carrying on experimental work.

By the courtesy of the inventor, we are enabled to publish the accompanying views, representing the testing plant at the Waterside station, which are the first photographs of this interesting motor that have yet been made public.

The basic principle which determined Tesla's investigations was the well-known fact that when a fluid (steam, gas or water) is used as a vehicle of energy, the highest possible economy can be obtained only when the changes in velocity and direction of the movement of the fluid are made as gradual and easy as possible. In the present forms of turbines in which the energy is transmitted by pressure, reaction or impact, as in the De Laval, Parsons, and Curtiss types, more or less sudden changes both of speed and direction are involved, with consequent shocks, vibration and destructive eddies. Furthermore, the introduction of pistons, blades, buckets, and intercepting devices of this general class, into the path of the fluid involves much delicate and difficult mechanical construction which adds greatly to the cost both of production and maintenance.

The desiderata in an ideal turbine group themselves under the heads of the theoretical and the mechanical. The theoretically perfect turbine would be one in which the fluid was so controlled from the inlet to the exhaust that its energy was delivered to the driving shaft with the least possible losses due to the mechanical means employed. The mechanically perfect turbine would be one which combined simplicity and cheapness of construction, durability, ease and rapidity of repairs, and a small ratio of weight and space occupied to the power delivered on the shaft. Mr. Tesla maintains that in the turbine which forms the subject of this article, he has carried the steam and gas motor a long step forward toward the maximum attainable efficiency, both theoretical and mechanical. That these claims are well founded is shown by the fact that in the plant at the Edison station, he is securing an output of 200 horse-power from a single-stage steam turbine with atmospheric exhaust, weighing less than 2 pounds per horse-power, which is contained within a space measuring 2 feet by 3 feet, by 2 feet in height, and which accomplishes these results with a thermal fall of only 130 B.T.U., that is, about one-third of the total drop available. Furthermore, considered from the mechanical standpoint, the turbine is astonishingly simple and economical in construction, and by the very nature of its construction, should prove to possess such a durability and freedom from wear and breakdown as to place it, in these respects, far in advance of any type of steam or gas motor of the present day.

Briefly stated, Tesla's steam motor consists of a set of flat steel disks mounted on a shaft and rotating within a casing, the steam entering with high velocity at the periphery of the disks, flowing between them in free spiral paths, and finally escaping through exhaust ports at their center. Instead of developing the energy of the steam by pressure, reaction, or impact, on a series of blades or vanes, Tesla depends upon the fluid properties of adhesion and viscosity--the attraction of the steam to the faces of the disks and the resistance of its particles to molecular separation combining in transmitting the velocity energy of the motive fluid to the plates and the shaft.

By reference to the accompanying photographs and line drawings, it will be seen that the turbine has a rotor A which in the present case consists of 25 flat steel disks, one thirty-second of an inch in thickness, of hardened and carefully tempered steel. The rotor as assembled is 3 1/2 inches wide on the face, by 18 inches in diameter, and when the turbine is running at its maximum working velocity, the material is never under a tensile stress exceeding 50,000 pounds per square inch. The rotor is mounted in a casing D, which is provided with two inlet nozzles, B for use in running direct and B' for reversing. Openings C are cut out at the central portion of the disks and these communicate directly with exhaust ports formed in the side of the casing.

In operation, the steam, or gas, as the case may be is directed on the periphery of the disks through the nozzle B (which may be diverging, straight or converging), where more or less of its expansive energy is converted into velocity energy. When the machine is at rest, the radial and tangential forces due to the pressure and velocity of the steam cause it to travel in a rather short curved path toward the central exhaust opening, as indicated by the full black line in the accompanying diagram; but as the disks commence to rotate and their speed increases, the steam travels in spiral paths the length of which increases until, as in the case of the present turbine, the particles of the fluid complete a number of turns around the shaft before reaching the exhaust, covering in the meantime a lineal path some 12 to 16 feet in length. During its progress from inlet to exhaust, the velocity and pressure of the steam are reduced until it leaves the exhaust at 1 or 2 pounds gage pressure.

The resistance to the passage of the steam or gas between adjoining plates is approximately proportionate to the square of the relative speed, which is at a maximum toward the center of the disks and is equal to the tangential velocity of the steam. Hence the resistance to radial escape is very great, being furthermore enhanced by the centrifugal force acting outwardly. One of the most desirable elements in a perfected turbine is that of reversibility, and we are all familiar with the many and frequently cumbersome means which have been employed to secure this end. It will be seen that this turbine is admirably adapted for reversing, since this effect can be secured by merely closing the right-hand valve and opening that on the left.

It is evident that the principles of this turbine are equally applicable, by slight modifications of design, for its use as a pump, and we present a photograph of a demonstration model which is in operation in Mr. Tesla's office. This little pump, driven by an electric motor of 1/12 horse-power, delivers 40 gallons per minute against a head of 9 feet. The discharge pipe leads up to a horizontal tube provided with a wire mesh for screening the water and checking the eddies. The water falls through a slot in the bottom of this tube and after passing below a baffle plate flows in a steady stream about 3/4 inch thick by 18 inches in width, to a trough from which it returns to the pump. Pumps of this character show an efficiency favourably comparing with that of centrifugal pumps and they have the advantage that great heads are obtainable economically in a single stage. The runner is mounted in a two-part volute casing and except for the fact that the place of the buckets, vanes, etc., of the ordinary centrifugal pump is taken by a set of disks, the construction is generally similar to that of pumps of the standard kind.

In conclusion, it should be noted that although the experimental plant at the Waterside station develops 200 horse-power with 125 pounds at the supply pipe and free exhaust, it could show an output of 300 horse-power with the full pressure of the Edison supply circuit. Furthermore, Mr. Tesla states that if it were compounded and the exhaust were led to a low pressure unit, carrying about three times the number of disks contained in the high pressure element, with connection to a condenser affording 28 1/2 to 29 inches of vacuum, the results obtained in the present high-pressure machine indicate that the compound unit would give an output of 600 horse-power, without great increase of dimensions. This estimate is conservative.

The testing plant consists of two identical turbines connected by a carefully calibrated torsion spring, the machine to the left being the driving element, the other the brake. In the brake element, the steam is delivered to the blades in a direction opposite to that of the rotation of the disks. Fastened to the shaft of the brake turbine is a hollow pulley provided with two diametrically opposite narrow slots, and an incandescent lamp placed inside close to the rim. As the pulley rotates, two flashes of light pass out of the same, and by means of reflecting mirrors and lenses, they are carried around the plant and fall upon two rotating glass mirrors placed back to back on the shaft of the driving turbine so that the center line of the silver coatings coincides with the axis of the shaft. The mirrors are so set that when there is no torsion on the spring, the light beams produce a luminous spot stationary at the zero of the scale. But as soon as load is put on, the beam is deflected through an angle which indicates directly the torsion. The scale and spring are so proportioned and adjusted that the horse-power can be read directly from the deflections noted. The indications of this device are very accurate and have shown that when the turbine is running at 9,000 revolutions under an inlet pressure of 125 pounds to the square inch, and with free exhaust, 200 brake horse-power are developed. The consumption under these conditions of maximum output is 38 pounds of saturated steam per horse-power per hour - a very high efficiency when we consider that the heat-drop, measured by thermometers, is only 130 B.T.U., and that the energy transformation is effected in one stage. Since about three times this number of heat units are available in a modern plant with super-heat and high vacuum, the above means a consumption of less than 12 pounds per horse-power hour in such turbines adapted to take up the full drop. Under certain conditions, however, very high thermal efficiencies have been obtained which demonstrate that in large machines based on this principle, in which a very small slip can be secured, the steam consumption will be much lower and should, Mr. Tesla states, approximate the theoretical minimum, thus resulting in nearly frictionless turbine transmitting almost the entire expansive energy of the steam to the shaft.

AUTOMOBILE COOLING SYSTEM PUMP

These are photographs of a four inch diameter water pump. It is specifically designed to pump cooling water for internal combustion engines of all sizes and types. It has an inch and a quarter inlet and a one inch outlet. It will pump approximately 1,000 gallons of water per hour at 12 PSI. It is driven by a flat pancake type D. C. motor that is only 1?2" thick. It's power requirement is 100 watts. The pump itself is fabricated from 6061 aluminum, hard anodized, which is equivalent to a type of stainless steel that is capable of going through a 200 hour salt spray test. The bladeless pump can pump boiling water without cavitation without loosing its prime. Conventional pumps cannot pump boiling water, leading to engine damage if the cooling system does reach the boiling point. This will allow a new type of cooling system for automobiles that will replace the belt driven water pump. The electric motor that drives this pump will not operate when the temperature engine indicates that it is not required. The pump will only operate when it is needed. The operating temperature can easily be adjusted in the field from 180 degrees to 200 degrees without having to replace a mechanical thermostat as is the normal procedure. The conventional lifting surface centrifugal pump that is normally used requires from 6 to 10 HP to drive it off a belt. The new bladeless pump will operate only when needed and then consumes less than one HP. Another example of reduction of parasitic horse-power. This pump is currently available for commercial sale and has been fully tested.

BOUNDARY-LAYER BREAKTHROUGH - THE TESLA BLADELESS TURBINE

Journey back to the future and discover the fascinating secret behind the most powerful and economic internal or external combustion engine of all time: Tesla's Bladeless Boundary-Layer Turbine.

You will experience the excitement of understanding as Tesla's mechanical breakthrough is explored, shattering the boundaries of our current mechanical standard. You will be swept into the awareness of discovery as the simplicity of this whirl wind machine of natural harmony is revealed. Unveiled here today how it is possible to convert the normally undesired energy of drag into the tremendous vortex energy of Tesla's perfectly controlled mechanical tornado. The real answer to energy.

The history of Tesla's monarch of machines is then followed into the present day work of researcher and inventer C.R. "Jake" Possell [1]. You will learn how modern day applications of the bladeless turbine could improve all aspects of our mechanical life. Today's applications range from indestructible pumps and freon free air conditioning to speed boats and supersonic aircraft.

Conventional pumps and engines pale in comparison. This jewel of mechanics has no equal. It stands alone above all others. No other pump or engine can match the longevity, economy, size, safety, silence and vibration free Herculean power of this truly elegant machine. It waits patiently to solve the efficiency and pollution problems of today and could literally usher in A NEW

WORLD. Fully Illustrated

[1] Mr. C. R. "Jake" Possell Is President of a Public Company called QUADRATECH, Inc., 1417 South Gage Street, San Bernardino, CA 92408

BOUNDARY-LAYER BREAKTHROUGH - THE BLADELESS TESLA TURBINE Volume II. The Tesla Technology Series, ISBN 1-882137-01-9

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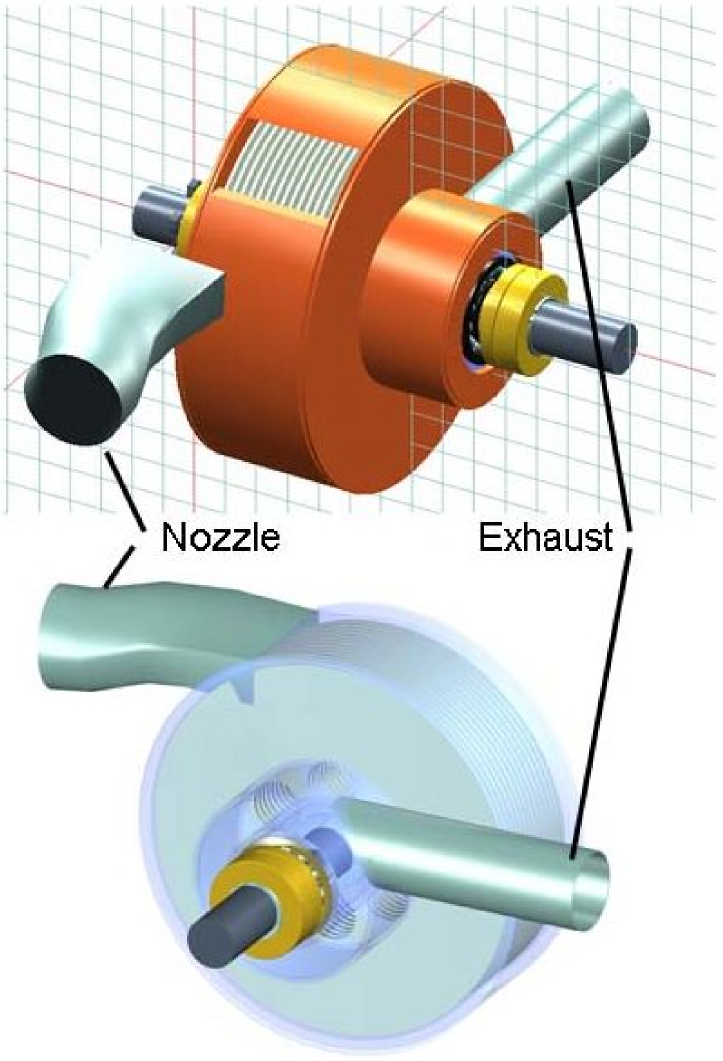
Tesla Turbine Comments (by Harry Valentine)

Main > **Energy**

Researching a Shock-wave Tesla Steam Turbine Locomotive



Working fluid (such as steam) enters tangentially to the disks through a nozzle

The concept of a boundary-layer turbine originated about a century ago, in the research of Nikola Tesla. Tesla's version of a boundary-layer turbine consists of a stack of closely spaced discs. A high-velocity of fluid is injected tangentially into the spaces between these discs, flowing inwardly in a spiral toward a centrally located exhaust. The drag between the surface of the discs and the fast moving fluid results in the conversion of fluid flow to mechanical power.

Most tests involving Tesla turbines have used subsonic flows of liquids or gases, with less than spectacular results. Unlike conventional bladed turbines that are subject to blade erosion, boundary layer turbines can operate when a partially saturated fluid is injected at supersonic speeds. Superheated steam is one fluid that can be injected into Tesla turbines under high-pressure and at supersonic speeds. When a fluid is accelerated to supersonic speeds, it undergoes a drop in both temperature and pressure. To generate the supersonic speed from a high pressure region, the fluid first flows through a converging duct into a throat (minimum area cross-section) where sonic speed will be reached, then into a diverging duct where supersonic speeds will occur if the downstream pressure is low enough.

Supersonic flow develops when there is a large enough difference between the upstream and downstream pressures. Pressure reductions will occur in both the throat area as well as in the diverging duct. To ensure a high enough upstream pressure, a water tube boiler would need to generate at least 1,000-psia at 1,000-degrees F. Power output may be varied by adjusting steam mass-flowrate by using a series of valves. By varying mass-flowrate at constant pressure and temperature, steam flow speeds will remain essentially constant. The constant high flow speed over a wide range of mass-flowrate is essential to maximizing fluid friction within a boundary layer turbine. The dominant term in the mathematical equation of boundary layer drag friction, is the velocity-squared factor.

The power output and efficiency of a boundary layer turbine increase with both fluid flow velocity as well as with physical size. The length over which the fluid flows, as well as the surface area with which it interacts, are also dominant factors. One of the terms that needs to be calculated, is the Reynold's number (a dimensional number which contains factors such as density, gravity, flow velocity, viscosity and a length factor). The higher the Reynold's number, the lower the friction or coefficient of friction. However, the product of velocity-squared and friction (Cf x V-squared) increases even as the friction factor decreases at higher flow speeds. One of the idiosyncracies of Tesla turbines is that if they are to develop higher levels of efficiency, they have to be of very large diameter (to maximize disc surface area). To reduce parasitic losses against the inside of the casing, they need to be of low height at the casing's inside circumferential surface, with at least 1-inch clearance between the casing and the upper and lower disc surfaces.

As flow speed exceeds the speed of sound, shock waves begin to appear. At sonic speed, the shock wave will appear in the throat section at lower upstream steam pressures. As steam pressure increases, the shock wave moves down toward the exit of the diffuser section, where it is called a "normal" shock wave. As the difference between upstream and downstream pressures increase, the shock wave becomes oblique at the diffuser (nozzle) exit (an over-expanded nozzle). Larger upstream and downstream pressure differences result in expansion waves forming at the exit (an under-expanded nozzle). In order to maintain a high relative speed between the rotating bounday-layer turbine and the incoming jet of fluid, very high subsonic and supersonic fluid flow speeds would be essentail. Whereas shock waves (pre-ignition "pinging") can shatter pistons in internal combustion engines, Tesla turbines are immune to shock wave damage.

If a Tesla multi-disc turbine of 6'4" outer disc diameter (20-ft circumference) rotates at 4500-RPM or 1500-ft/sec at the disc edge, steam injected tangentially at a speed of 3500-ft/sec (Mach 2.0) into the discs would result in a relative speed of 2000-ft/sec. Steam leaving the water-tube boiler at 1,000-psia at 1000-deg F would drop to 540.5-psia and 793.7-deg F in the throat section and 420.2-deg F at the nozzle exit. The critical exit pressures are 129.7-psia and 573.7-psia. If the back-pressure in the turbine is between these 2-values, oblique shock waves will eminate from the nozzle exit into the turbine. If the back-pressure is above the higher value, a normal shock wave will appear at the exit. If the back-pressure is below the lower value (eg; 50-psia downstream "resistance" pressure), expansion shock waves will blast forth from the nozzle exit and into the turbine at 3500-ft/sec. This will happen if the nozzle exit area is 1.746-times the throat area. Supersonic speed steam flowrates entering the Tesla turbine discs could be partially saturated, however, boundary-layer turbines can operate under such conditions (shock waves plus saturated steam) without damage.

If a locomotive Tesla turbine has 8-discs with 7-spaces between them, the nozzles could be arranged in a 1:2:4 mass-flowrate ratio, which would correspond to the cross-section area ratios of the three throats. The largest nozzle would fire expansion shock waves into 4-spaces, the mid-sized nozzle into 2-spaces and the small one into one inter-disc space. This arrangement allows for 7-combinations, corresponding to 7-equally spaced steam mass-flowrates and in turn 7-equally spaced power levels, all at maximum pressure and temperature. Alternatively, a stack of 16-discs may be used with 15-spaces between them. The nozzles may then be arranged in a 1:2:4:8-mass-flowrate ratio, giving 15-combinations which will correspond to 15-equally spaced power levels. Nozzles will be either "on" or "off", depending on locomotive power requirements.

The number of disc spaces per nozzle may be doubled or tripled, increasing the interactive surface area (using the same disc radius) to increase fluid friction and overall engine efficiency. In view of the temperature drop incurred in accelerating steam to supersonic speed, it is possible to heat the nozzle's diffuser downstream of the throat, by using steam at 1000-deg F from the boiler. Two sides of the (high and narrow) fixed diffusers may be heated and insulated, raising exit steam temperature by an extra 100-deg F and exit speed to 3700-ft/sec (Mach 2 at the higher temperature). The steam used to heat the diffuser may used for feed heating and also for pre-heating water.

A variable geometry nozzle of rectangular cross-section is also possible. Variable geometry rectangular intakes are used on supersonic aircraft. Adjustable cross-section areas for both the throat as well as the nozzle exit could maintain a constant area-ratio (1.746 for Mach 2.0) between the two, by using a curved plate on a pivot and connected to a mechanical linkage (except only one side of the diffuser could then be heated). Variable steam mass-flowrate would result from varying the cross section of the throat to a maximum of 1.5-square inches, which would allow 16.56-lbs/sec of steam (1000-psia at 1000-degrees F at the boiler has 1505.4-Btu's/lb) to flow through, allowing 24,930-Btu/sec to leave the boiler (35,260-horsepower). At an estimated conversion efficiency of 21% between boiler and turbine, a maximum of 7400-Hp would be available to drive an electrical generator (91%-efficiency), developing an estimated 6700-Hp at the rim of the locomotive drive wheels. Higher overall thermal efficiencies and power output levels are possible using a single-pass system, though a higher-efficiency compound-reheat variant is quite possible (some Tesla turbine researchers claim conversion efficiencies exceeding 30% from boiler to turbine output, for a single pass layout).

The centrifugal forces generated within a Tesla turbine tend to push higher density compressible fluid toward the outer edges of the discs. This increased density increases the skin friction between the fluid and the discs. The injection of shock waves into the high density fluid sustains a rapidly swirling vortex, with the less dense fluid being pushed toward the central exhaust. When the injected steam passes through the shock waves, almost instantaneous pressure and temperature rises occur. The high density swirling mass presents a high back-pressure which needs to be overcome, despite pressure drops in the nozzle. The high-pressure water-tube boiler compensates for this loss in pressure. The water pump will require less than 1.5% of total output energy for a 1,000-psia water tube boiler.

To counter the gyroscopic effects of a Tesla turbine, a vertical shaft will need to be used (the unit may need to be mounted in gimbals, inside a 10-ft wide locomotive carbody). An electric alternator may be mounted above the turbine. Flexible couplings may need to used in the steam lines leading to the Tesla turbine, to compensate changes caused by locomotive pitching (gradient changes) and roll (tilting on curves). Variations of boundary layer turbines other than the inward radial flow Tesla turbine are possible, including a variant that uses a small axial component (a tornado swirling in an annulus). In this variant (a tubular boundary-layer turbine), a very large surface area interacts with the vortex which swirls in between the spaces (annuli) of several concentric tubes. The outer (largest diameter) annulus may taper to a small diameter at the votex entry point, where the injection nozzle would be located (steam would be injected tangentially, with a small axial component).

The vortex would swirl inside the outer annulus (level 1) from the entry point (region 1) to the opposite end (region 2), where it would progress into a smaller diameter annulus (level 2) and spiral back toward region 1. When it reaches the end of the smaller annulus (level 2), the vortex would spiral into an even smaller diameter annulus (level 3) and spiral back toward region 2, where outward radial flow curved diffusers would reverse the flow direction to a larger diameter. The exhaust steam would exit the tubular turbine in a direction opposite to the steam injection entry direction. Spiral blading similar to the spiral blade on agricultural augers (used to drill large holes into the ground) may be included inside the annuli to increase interactive surface and raise the fluid drag friction, in turn increasing overall turbine efficiency (into the 26% to 32% range).

The use of the spiral restricts the fluid flow within a measurable cross section, changing the way the Reynold's number is calculated, from flow length to the hydraulic radius. The hydraulic radius of a rectangular cross section equals 4-times cross-section area divided by the "wetted perimeter". Steam at 800-deg. F has a kinematic viscosity of 5.056 x 10E-7 (0.0000005056) lbf-sec/sq.ft . The Reynolds number can be calculated by multiplying the steam flow speed by the hydraulic radius, then dividing by the kinematic viscosity. The friction coefficient derives from the Reynold's number and would typically be in the range of 0.0015 to 0.002 in this situation. The total drag would equal (density x speed squared x total "wetted" surface area x drag coefficient) divided by 2 x gravity. If the spiral has a cross section of 2" x 2" (8" perimeter or 2/3-ft) and a total internal length of 240-ft, total area would be 160-sq.ft. For a relative speed of 1,500-ft/sec, steam density of 0.25-lb/cu-ft. and a drag coefficient of 0.0015, total drag would be 3144.4-lbf. At a radius of 2.5-ft and a rotational speed of 4800-RPM, this would yield 7180-Hp. Like a Tesla multi-disc turbine, the tubular/annular turbine would also have to be mounted using a vertical shaft to counter gyroscopic effects.

Boundary layer turbines are among the many options available to expand steam for traction generation in a renewable-fuel modern steam locomotive. There is a great deal of controversy involving the overall thermal efficiency of such turbines Both the proponents and sceptics may still have to prove their case. The boundary layer turbine is one of the few engine concepts that can utilize the energy from shock waves.

Harry Valentine, Transportation Researcher, harrycv@hotmail.com

Click here to return to the modern steam locomotive developments page (http://www.internationalsteam.co.uk/trains/newsteam/modern.htm)

Tesla Turbine Comments (from Hypography forums)

Main > **Energy**

(original found here (http://scienceforums.com/topic/19098-the-tesla-turbine-overhyped-or-feasible/))

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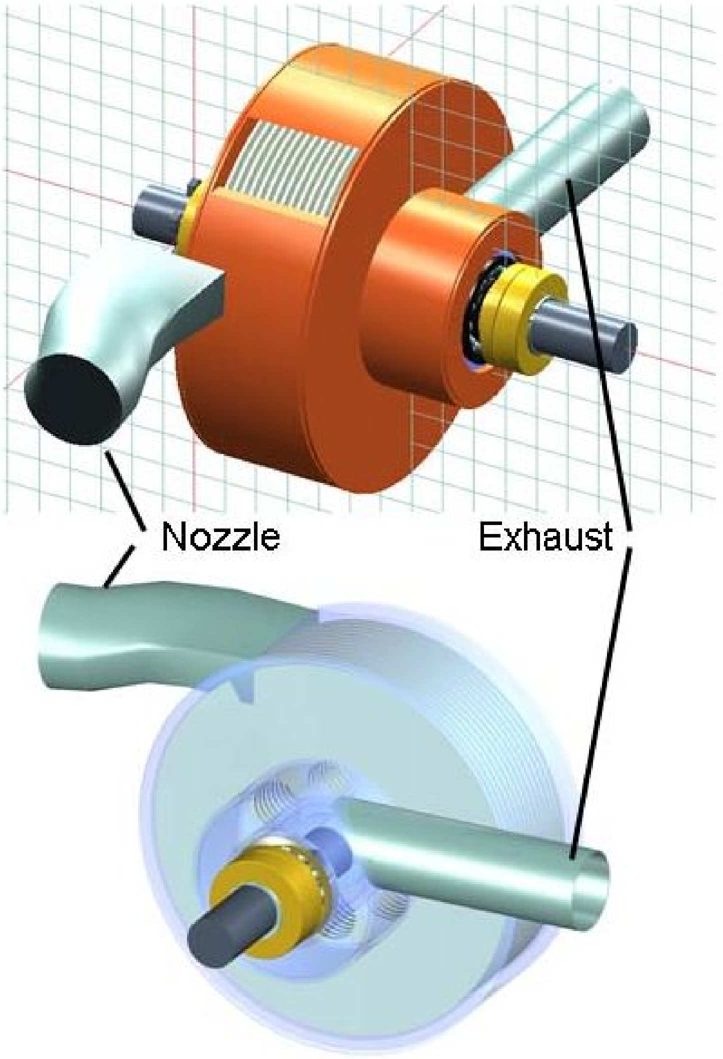
maikeru: I'm not an engineer, but I have always been somewhat interested in mechanical and electronic things, as an aside from microbiology. However, my math abilities are limited, and maybe that's why I never became an engineer like my dad. I've spent a lot of time recently looking at alternative energy and new emerging technologies, and something I encountered every now and then among blogs and websites was the Tesla turbine. So I looked it up on Wikipedia a while back:

Tesla turbine - Wikipedia, the free encyclopedia (http://en.wikipedia.org/wiki/Tesla_turbine)

And watched YouTube videos of the Tesla turbine made by gadgeteers and amateur scientists or experimenters. I must admit this is a fun little invention, and it's remarkably simple and elegant.

It seems that Tesla invented this in response to problems with bladed turbines and also with the intent to use it to help generate electricity from steam from geothermal sources. (Yeah, I have to admit geothermal energy and how to harvest it has also been on my mind a lot, since people have been claiming we're in an "energy crisis." I've also noticed that among the "Green Energy Revolution" that geothermal energy is being ignored or criticized...but that's a separate subject.)



Working fluid (such as steam) enters tangentially to the disks through a nozzle

- Simple to build, maintain, and modify the design. Fluid/air injectors, valves, discs, size, materials, etc. can all be modified. Hard to get simpler than discs with holes punched in them for exhaust, attached to a rotor in a case.

- Safer in the case of disc/blade failure or other parts failure, since the housing compartment or casing can be made strong enough to contain broken or cracked discs, and often the failure of one or more discs will not necessarily lead to the failure of the entire turbine. This design is often described as very sturdy, because the discs and rotor are bolted solidly together and there's minimal wear except on bearings.

- Does not suffer from cavitation or particulate problems that many turbines and fans must deal with.

- Can work with a wide variety of working fluids and over a wide range of temperatures. Water, steam, conventional air, corrosive working fluids, high-temperature working fluids, or complex mixtures which may have particulates or contaminants in them. This adds a great deal of flexibility to it, and may make it able to be powered by several types of fuels such as charcoal or biodiesel when incorporated into an engine, vehicle, or power generator.

- Allows the ability to work in both "forward" and "reverse," since the discs can be made to rotate in either direction.

- Supposedly has a good power-to-weight ratio, because the discs are thin, compact, and there are few other moving parts in it and not a lot of pistons, casing, gears, etc. I remember reading criticism of Stirling heat engines as often being cumbersome because of their pistons, flywheels, and gears. (Although I've seen some really cool-looking Stirling engines!)

- Directly converts kinetic motion of the fluid into rotary motion via the boundary layer effect and adhesion.

- Now is poised to take advantage of new materials, construction, and high-tech stuff that was not available in Tesla's day. For example, I've read suggestions that the turbine's discs can be manufactured from high-strength carbon fiber, plastics like Kevlar, high-performance ceramics, steel alloys, titanium alloys, or aluminum. Given that new cars and parts are increasingly being manufactured from high-tech materials, it makes me wonder how this "old technology" can perform when it's upgraded.

- It has been touted as being one of the most efficient turbine designs, with theoretical efficiency approaching 90% or slightly more of Carnot cycle efficiency in a single stage or few stages, I think. If I make a mistake, though, please correct me. I've read that only a few engine and some turbine designs can approach this level of efficiency. For example, the internal combustion engine is often cited as having about 20-30% efficiency, with most of the energy being lost as heat.

These, however, are the disadvantages and criticisms I've seen leveled at Tesla's design and the Tesla turbine in general:

- It attains high rpm but cannot translate the rpm into useful or high torque. Is this true? I spent a lot of time reading about steam engines and steam-powered vehicles like locomotives and steam-powered cars, and one of the advantages of the steam engine, from what I read, was that it provided high torque and power at relatively low rpm.

It might be pointed out that Tesla did envision this primarily used for geothermal energy from steam, but most studies, tests, and experiments I've seen have not been conducted with steam or any other working fluid than regular air.

- Testing of experimental Tesla turbines have yielded efficiency measurements of around 35-40ish%. In other words, better than most internal combustion engines, but really nothing to write home about. Many bladed turbine designs can can exceed this.

- It suffers from too much friction and energy losses when heat is produced as the fluid flows over the discs. These are parasitic losses that cripple the turbine.

- It currently uses ball bearings, which cause further efficiency losses due to friction, heat, sound, etc. Most engines and turbines use oil and bearings for lubrication, and the newer designs have foil bearings, such as the Capstone microturbine, which significantly reduce friction and increase efficiency.

- The high rpm can cause disc warping or cracking, and this was a serious problem with it in Tesla's day. Apparently metallurgical knowledge in the early 1900s wasn't quite good enough to provide Tesla with strong enough materials to make his turbine function as he wanted. The iron/steel discs he used would warp and stretch, raising concerns about the viability of the turbine. No one is quite sure about long-term functionality of this turbine, since it has not been used widely commercially or rigorously tested and validated.

- If it worked well, it would've been adopted by industry and for a wide variety of applications. Most of the Tesla turbine builders are "eccentric academics" or "backyard tinkerers." That's what I've read on some blogs. However, I have found some papers and experiments done by mechanical engineering students and professors, who seem rather intrigued by it. Most of these academics are connected to "green technologies" or research into alternative energies/fuels.

Sorry for the long post. I find this little machine to be really fascinating, much like the Stirling engine, and I wonder if it has any use or practicality...or if it's another "footnote" in the history of science and technology. Any answers, explanations, or musings would be much appreciated. I'd like to try to improve my understanding on this. Wiki and net surfing only go so far.

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lawcat:

> maikeru said:
> - It attains high rpm but cannot translate the rpm into useful or high torque. Is this true?

Not sure if it's true in all applications, but it certainly has been a complaint on some sites. Of course, torque is function of design. Any desired torque may be achieved, but at what price. Remember Archimedes pushing the moon with a long stick. Here, notice that the power comes from the forces of adhesion of the fluid to the edges of disks. This is the laminar part. If you needed to produce higher torque, which is : Force x radious; you would need to up either. To create movement, you need to introduce fluid velocity. The velocity of the fluid between the disks is what produces the forward force. This force is translated to the disk by laminar adhesion--laminar means right next to the disk. But as you increase the fluid velocity to create more force, your laminar force of adhesion decreases because the flow of the fluid between the disks becomes turbulent. So, in this turbine, it seems to me the fluid velocity, and force, have optimal operating range, beyond which the turbine will stall due to flow. Turbulence - Wikipedia, the free encyclopedia (http://en.wikipedia.org/wiki/Laminar_flow)

So the only way to increase torque, to account for higher loads on the turbine's shaft, would be to increasae the radius of the disks. And this presents physical challenges. That maybe the reason that this invention has not been widely used.

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alexander:
So what if we consider using electro-magnetic bearings? Also, you would have to define the operating range pretty clearly to get a consistent 60 hertz, and have to set that in gearing from the start, or else you have to go with a DC generator, to convert this to useable energy (talking green household, ofcourse). Actually perhaps DC motor would be the best for this motor's operation, as you can adjust the water flow to maximize on the efficiency of the engine/generator a little more easily then you can do with AC, but then you have to consider the inefficiencies of inverters (which will inevitably give you the cleanest power, unless you figure out a constant pressure source)

But consider a solar collector, that heats up water (well some sort of a heat-absorbant surface) , that drives a turbine with a heat recovery system to warm up incoming water... Something that takes relatively little space, and i am wondering if the efficiency of the system would be higher then that of piston driving ones used today...

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maikeru:

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lawcat said:
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Good points.

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I believe Tesla noted that he was able to increase torque by adding washers and settled on a star-shaped design (as opposed to his earlier circular washer choice, but I'm not sure how a star-shaped washer influences and enhances the torque exactly), increasing the size of the rotor shaft, and of course increasing radius of the discs.

Wouldn't adding more discs to the turbine also increase torque? Most of the turbines I've seen used or designed so far are running perhaps 5-10 discs. I was wondering if adding more similarly sized discs might help to increase torque so long as they are supplied by additional and sufficient amounts of air. Let's say instead of 10, you could increase this to 20 or 30. Or do you think performance would suffer in comparison to simply making the radius of fewer discs larger?

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maikeru:

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alexander said:
So what if we consider using electro-magnetic bearings? Also, you would have to define the operating range pretty clearly to get a consistent 60 hertz, and have to

But consider a solar collector, that heats up water (well some sort of a heat-absorbant surface) , that drives a turbine with a heat recovery system to warm up inc
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You know, that's a really good suggestion. One that I hadn't considered. As far as I know and have researched, I've never seen anyone design this particular turbine with electromagnetic or any kind of magnetic bearings. That might help reduce the friction losses from ball bearings a lot. In a similar application, I believe NASA pioneered the use of magnetic bearings for use in flywheel energy storage and it makes a huge difference in performance.

Flywheel energy storage - Wikipedia, the free encyclopedia (http://en.wikipedia.org/wiki/Flywheel_energy_storage#Bearings)

Perhaps some type of constant pressure source could be provided by water reservoirs, streams, etc. or steam created by a solar apparatus as you mentioned.

I really wish I had the proper machines and materials to give these suggestions a go. Perhaps I can build a model Tesla turbine out of plastic or wood and tinker a bit. I've thought about it.

VirtualGathis:

With regard to the comments on toque: The Tesla turbine is a very high RPM low torque device. Tesla stated that his turbine works best in excess of 10K RPM. Experimenters have shown 20-30K is a good target range, but some have used it up to 60K RPM (http://www.teslaengine.org/). As such the turbine would need to be geared down to produce reasonable toque at a more normal working speed similar to turbo-shaft engines used in helicopters.

Tesla also stated that increasing the viscosity of the working fluid will increase the torque and efficiency. As an example it is much better at pumping oil than water or air (http://www.discflo.com/). The reverse is also true; oil will transfer more force to the discs as it passes them than steam, air, or combustion gasses (http://www.teslaengine.org/).

I have seen some experimenters on YouTube who have placed magnets instead of spacers on/in the perimeter of the discs coupled to coils in the housing to bypass the complex gearing and turn the turbine itself into a generator. Sixty thousand RPM generates a fairly smooth wave after rectification.

With regard to bearings: The more modern test turbines used in the T.E.B.A site, http://www.teslaengine.org/, use long lasting ceramic sleeve bearings, but magnetic bearings would probably outperform them. The question I would have is “Would the increased longevity and reduced drag make it worth the complexity and cost of using them?”.

Dwight Draves:

I have recently been reading through Nikola Tesla's patents and he had a few variations of his design that I found interesting, but I didn't fully understand how they worked. The above articles help me see how and why they worked. The patents are a bit unclear as the are 2 dimensional drawings and the way he describes them is beyond me. He talks like a man who truly understands what it is he is designing and the implications for it, however, I'm simply an interested party who likes to figure out how things work and operate. For Nikola Tesla's patents on these designs a good source is: [1] (http://www.teslauniverse.com/nikola-tesla-patents-1,061,142-fluid-propulsion) [2] (http://www.teslauniverse.com/nikola-tesla-patents-1,061,206-turbine?pq=Zmx1aWQgcHJvcHVsc2lvbg==) [3] (http://www.teslauniverse.com/nikola-tesla-patents-1,329,559-valvular-conduit?pq=Zmx1aWQgcHJvcHVsc2lvbg==)

Cody Harper

I wanted to add to this as you guys have so many good ideas after reading this. I actually didn't come up with it but found it to be rather interesting way of increasing power in this type of device. It comes from originally, trying to reduce friction. In some designs of generators or engines they will pump the case full of helium, as it is lighter than air, and more sparse, allowing for less friction and better effeciency. Well, the same should hold true if you were to use something say like compressed co2 instead of air since in this design you want friction, as it's heavier, and more dense, as such it will cause more friction in theory as it runs over the discs, increasing overall effeciency and torque.

Christnthms

Just to add a point for consideration... When Tesla designed this machine, he did not have the extensive aerodynamic work of the NACA to lean on. As such, he cannot be faulted for not seeing how far the efficiency of the turbine blade would develop. That does not, however, undo any of his design. All engineers are overly optimistic about their design. The many compromises necessary to realize an idea don't necessarily make the the idea wrong.

All that to say... What if the real benefit of the boundary layer turbine/pump isn't in outright greater efficiency or in its ability to scale up to massive outputs. What if the true benefit is that it can achieve efficiency that competes with or slightly betters what is available to the common man, in a machine that can be built for fractions of what other machines of comparable output can be built.

- A traditional turbine blade is machined in a 7-axis CNC jig, and made from rather exotic alloys, even titanium. - A boundary layer turbine wheel could be stamped out of a sheet of 6061 aluminum (a very common an inexpensive alloy). Tapering the edges would offer some efficiency benefits, but if the true lowest cost is the objective the stamped blanks could be run with only minor truing. - Because of the cost involved with machining and the alloys used, bladed turbines don't "scale down" effectively. It might be worth a million dollars to build a power plant sized turbine, but a backyard sized one would still cost a hundred thousand and that doesn't have a market. -The boundary layer turbine doesn't scale up as well as bladed turbines, but it DOES scale down very effectively-- even to the fractional horsepower ratings that might power mundane consumer goods. - Modern aerodynamics might make the bladed turbine more efficient in the extreme, but if the boundary layer turbine is considered for smaller power production, it is competing with rather crude versions of the ICE that mostly don't even achieve 20% efficiency. As such, minimal development would be necessary to make it a viable power source.

So, to wrap up this rather lengthy comment... Maybe the best place and form to consider the boundary layer turbine is NOT as a primary power source for a commercial power plant. Maybe the best place to use this design is in smaller units whose primary attributes are inexpensive production, quiet and reliable operation, and efficiency that meets or beats the crude ICEs currently in use. Imagine, if you will, Tesla turbines in the 10-30kW range that could be manufactured for a couple hundred dollars each and sold for under a thousand (with appropriate profit included) in competition with the "lawnmower engine powered home generators" currently in use.

See also

- Bladed Turbine
- Boundary Layer Turbine
- Tesla Turbine Design Discussion

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