Gas Turbine Technology for Automotive Use

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Introduction

The objective of this paper was to gather data on gas turbine technology and determine whether this technology is applicable in the automotive industry.

The introduction covers basic technical terminologies and concepts. It also introduces fields where gas turbines are presently in operation. The background of the internal combustion engine is given along with statistical data of fuel consumption and pollution from automobile sources.

Gas Turbine Engine Background

This section details the basic mechanical operation of the gas turbine engine. In the section there are analogies and figures to help explain the mechanics of turbine operation in general. After the basic turbine operation is covered, the section focuses on the gas turbine engine and explains with some detail.

Gas Turbine Efficiencies

To understand why gas turbines are so use full for power generation it is important to understand the gas turbine efficiency and what it depends on. This section summarizes the basics factors that influence the thermal efficiency of the gas turbine and makes some comparison to the internal combustion engine efficiency.

Gas Turbine in the Automotive Industry

This section is divided into three subsections, and presents how and where gas turbines were used in the automotive industry. The first section discusses the Chrysler gas turbine car experimental history. The section is written in chronological form and shows the improvements and results that Chrysler engineers concluded at the end of every experiment and the program.

The second section reviews the history of most experiments that used gas turbines for on road vehicles. These experiments were conducted by various companies, and it goes to show the wide interest that the industry had in gas turbines as a propulsion source.

The last section deals with the use of high tech ceramics and their influence on the future of gas turbines in the automotive industry. In particular it discusses different methods that are used to either replace or coat turbine blades in order to increase their longevity.

Gas Turbines in the Military

In this section the Abrams tank is introduce to show the practical application for gas turbines for on road vehicular use. It presents the military decision to use a gas turbine rather than the conventional diesel engine for the A-1 tank. It was critical to acknowledge that the gas turbine can be used as a propulsion power source an on road vehicle.

Conclusion

The conclusion section covers all the data that was presented in the paper in an analytical form. It uses the data to analyze the pros and cones for the gas turbine and its applicability for on road vehicles. More comparisons are made between the internal combustion engine and the gas turbine, and why one is preferred over the other. And it concludes with the future and likelihood for the gas turbine to be used in the automotive industry.

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Introduction

Imagine getting in to your car, starting it up, and not feeling any vibration or hearing anything other then a low pitch sound that very rapidly transcends to a high pitch sound. This is the experience a driver would have by driving a *turbine-powered** car.
In the paper I will try and prove why this scenario should not be left for the imagination but be experienced as an actual event by every driver. I will try to show that the gas turbine engine has its place in the automotive industry.

There are two distinct types of power turbines: the first and older type is the steam turbine*, which uses steam as source of energy to power the turbine. The second is the gas turbine; this turbine uses compressed air mixed with ignited fuel as an energy source to power the turbine. This paper concentrates on the gas turbine engine. The gas turbine has proven itself to be a viable source for *rotational energy*; this energy in-turn can be put to many uses. Some of these uses are widely known to us, such as: the *Jet Engine* in a Fighter-Jet, the *Turbo-Prop* Engine and the *Turbofan Engine* in commercial planes. Some gas turbines applications are not so evident to the average person. Some of these applications are used for purposes such as to power the blades of a helicopter, serve as ship's main propulsion, and for the production of electrical power in commercial power plants. Recently a new design of gas turbines called Micro-Turbines have been introduced to the market to be used as self contained on the go power plants.
This paper is trying to show that the gas turbine is now an integral part of our daily lives, whether the military protects us with their fighter jets, or we fly in a commercial airline. We can count of receiving electrical power at our homes, and having helicopters deliver the traffic report and rescue people in emergency situations.

All of the gas turbine applications mentioned to this point are either known to us or by observation seem to be in their proper use. A question is raised then, if gas turbines are so useful in so many areas for power production, in particularly in the area of propulsion, then why aren't gas turbines used in the automotive industry?

Before this question may be answered, it is first important to understand the basic mechanics of gas turbines and the internal combustion engine.

** All italics words are defined in the glossary*

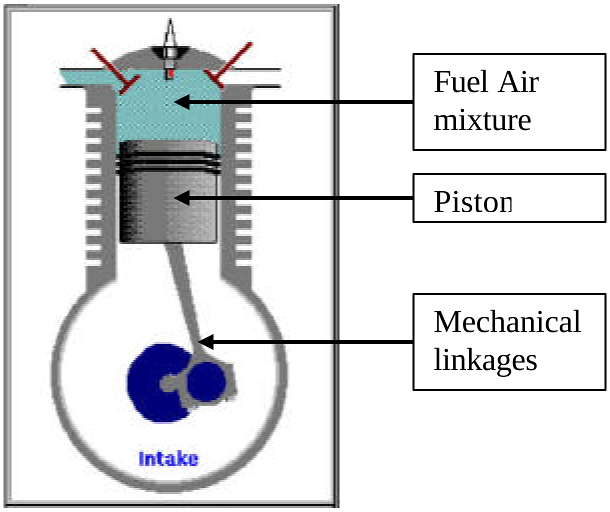


Figure 1, internal combustion engine diagram

The birth of the automobile is actually directly linked to the birth of the internal combustion *piston engine.* Like the power turbines, the internal combustion engine is divided into two main types; the *spark ignition*, and the *compression ignition*. The exact details of the engines will not be discussed for it lies beyond the scope of this paper. However, some basic information about the internal combustion engine background will be presented for reasons of comparison. In principle both types of engines are similar in their mechanical operations, and therefore the dynamics of the engines will be discuss in relation to the internal combustion engine without specifying either spark-ignition, or compression-ignition. The basic operation of the engine is as follows: Air and combustible fuel are introduced into a cylindrical chamber and are compressed via a piston inside the chamber. At a particular point the fuel and air mixture are ignited and as a result of the ignition the mixture is expanded and forces the piston into *linear motion*. This linear motion is then converted to *rotational motion* via mechanical linkages.[fig 1]. This Concept could be analogous to a bullet inside a handgun. When the hammer is released it ignites the gunpowder, this in-turn expands the air present inside the cartridge, which then launches the bullet out of the barrel. In this case the barrel is acting like the cylinder, and the bullet behaves like the piston. If the bullet were then to contact a hinged target, it would cause the target to rotate. In the internal combustion engine the piston's linear motion is converted to rotational motion which in-turn rotates the wheels of the car with the use of a mechanical coupling.

Since the engine is comprised of a piston-cylinder assembly and converts linear motion to rotational motion via mechanical linkages the engine will experience energy losses due to friction and inefficiencies. In sharp contrast to this, the gas turbine engine by design operates strictly with rotational energy. Also since there is no piston and cylinder assembly in the gas turbine engine, it does not experience the heavy frictional losses that are experienced in the internal combustion engine.

Combining these few basic principles we can see that by design the gas turbine engine is more *thermodynamically efficient* then the internal combustion piston engine. At this point it is essential to understand the effect of thermodynamic efficiency of a machine to its environment. The study of thermodynamics defines efficiency as follows: *Net power* divided by *Heat in*. This simply translates to; what we want divided by what we pay for. Since the internal combustion engine is less thermodynamically efficient than the gas turbine engine by design, it would use more fuel to accomplish the same output as the gas turbine engine. This means that if a greater quantity of fuel is required to be burned to produce the same amount of work, then that engine is also producing more pollution per given amount of work done.

The burning of fossil fuels has become synonymous with pollution. When fossil fuel is burned it produces Carbon Monoxide, Carbon Dioxide, and *NOx*, as a result of the chemical reaction.

In 1998 the EPA recorded that 50,000 tons of carbon monoxide emissions were produced from on road vehicles. [fig 2]. Of course this number is much better than 88,000 tons produced in 1970. [National, 2002].

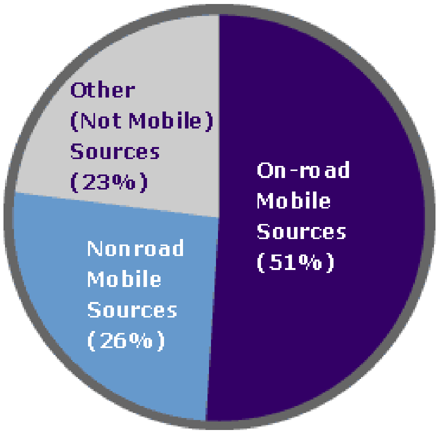


Figure 3, carbon monoxide by source

As discussed earlier the overall inefficiency of the internal combustion engine is a great contributor for high fuel consumption. In 1999 passenger cars alone consumed more then seventy three billion gallons of fuel. [Bureau, 2002]. This statistic is with an average fuel rate of 21.4 MPG. [Motor, 2003]. Today's automobiles operate with about 15% *mechanical efficiency*, [Thermal, 1995] and about 35% thermal efficiency [efficiency, 2003]. In contrast to the internal combustion engine, gas turbines today work on the order of 38% thermal efficiency, and produce negligible carbon monoxide emissions. [New, 2002]. Another reason for the increased efficiency in gas turbines is simply due to the fact that it has 80% fewer parts. [History ,1964].

Based on these facts it is not clear to determine which technology is better suited for automobile propulsion. However, it is pertinent to continue to investigate the possibility of using gas turbines given the close proximity of the thermal efficiency between both types of engine technologies. It is also crucial to remember for this investigation that gas turbines produce fewer carbon monoxide emissions than the internal combustion piston engine.

Background of the Gas Turbine Engine

The main principles of the gas turbine engine are simple in nature and easy to understand. The first and most critical principle relates back to Sir Issac Newton's Laws of Motion; in particular the third law. It states that for every action there is an equal and opposite reaction. An example of this can two people pushing against each other, the person applying force to push the other person is also pushed back by the exact force that he is using. A popular kid's toy is a pinwheel, when facing the wind the pinwheel would turn as a result of the wind blowing on its curved blades. The gas turbine operates on this exact principle, only that the turbine also produces its wind to move the blades with the use of fuel as an energy source. [Fig 3]. This is how it happens; the gas turbine has two sets of blades; compressor blades and turbine blades, both of these sets are normally situated on one shaft, (rotor) [figure 4]. The compressor blades take in air from the atmosphere and through a number of stages of repeating rows of

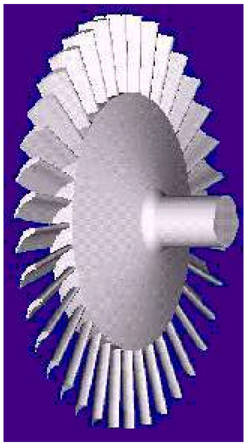


Figure3, Turbine Blades

blades, [figure 5] bring the air to high pressure.

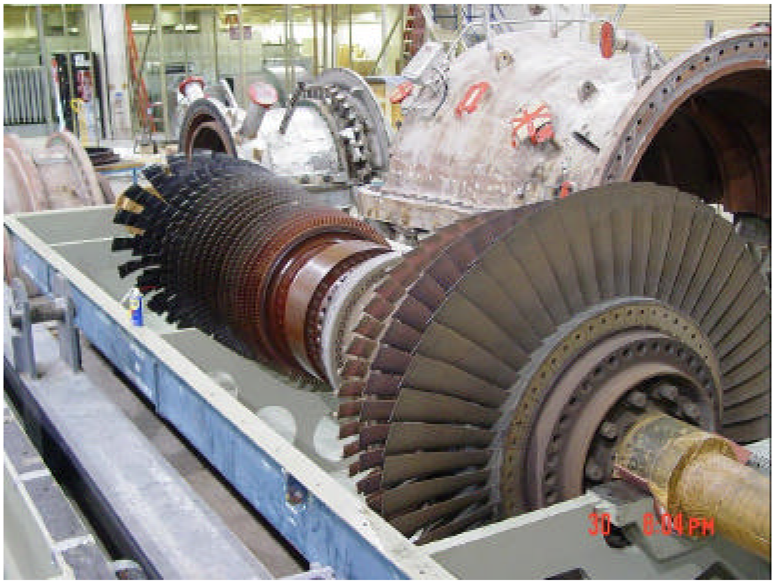


Figure 4, Compressor and Turbine Blades on a Single Rotor. (UT Power Plant)

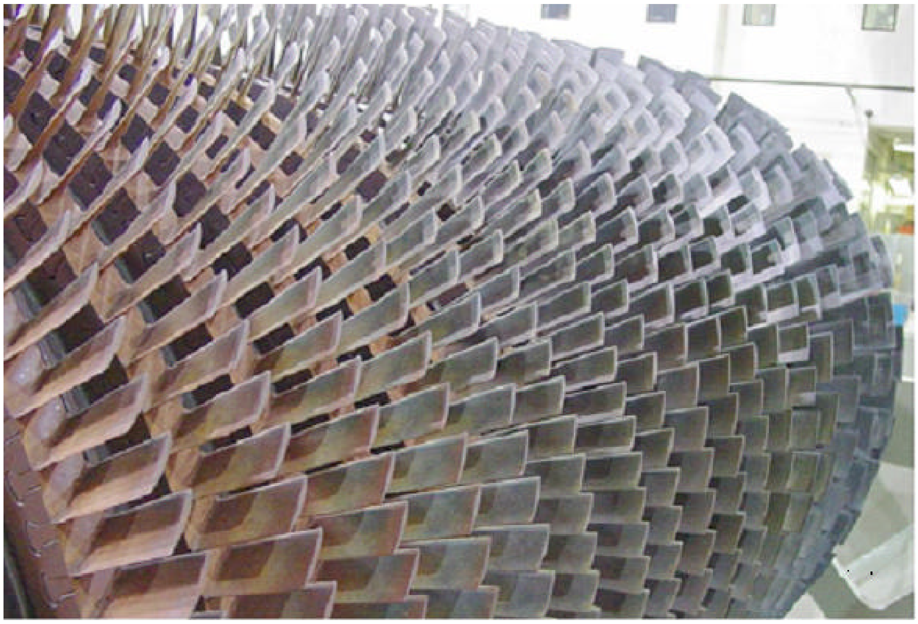


Figure 5, repeating rows of compressor blades,(UT Power Plant)

The compressed air then enters into a continuous combustion chamber, where the fuel is introduced, and mixes with the air in a chemical process. Then, from the combustion chamber the high-temperature, high-pressure gas-mixture is directed towards the turbine blades. The gas-mixture has sufficient energy not only to rotate the turbine blades that in turn rotate the compressor blades, but also to rotate other pieces of equipment that may be attached to the gas turbine rotor. The gas turbine rotor may be attached via some transmission or reduction gears to any piece of equipment that needs to be turned. This could be electrical generator, ship screw, propeller, or car wheels.

In fact gas turbine propulsion is now the number one choice for all for Destroyer type ships in the US Navy. And gas turbines are the first choice for the use in electrical generation. The reason gas turbines are put to use in so many areas of power generations is the high thermal efficiency that the gas turbine has.

Gas Turbine Efficiencies

As noted earlier in this paper overall efficiency is essentially the bottom line in evaluating machinery. Most inefficiencies are produced due to some losses generated by the equipment. Generally these losses would be caused by frictional and heat losses. For example in the internal combustion engine, there are many losses due to friction, required lubrication, and the translation of reciprocating motion to rotational motion. All these factors require energy, and it is this energy that is subtracted from the overall energy produced. In the case of the internal combustion engine these losses add up to between 70 and 90 %,[thermal, 1995], whereas in the gas turbine losses add up to about 64%. This is tremendous difference between the two, and it means that the internal combustion engine is using more percent of fuel per *shaft work output*. The gas turbine experiences these high efficiencies due to the fact that it has almost no friction losses, hardly any moving parts other then the turning rotor, and it is continuous fired engine. That is, the engine is constantly burning fuel to produce hot gases for the turbine. And unlike the piston engine that reciprocates, meaning that it only produces work per downward stroke, the turbine produces power continuously.

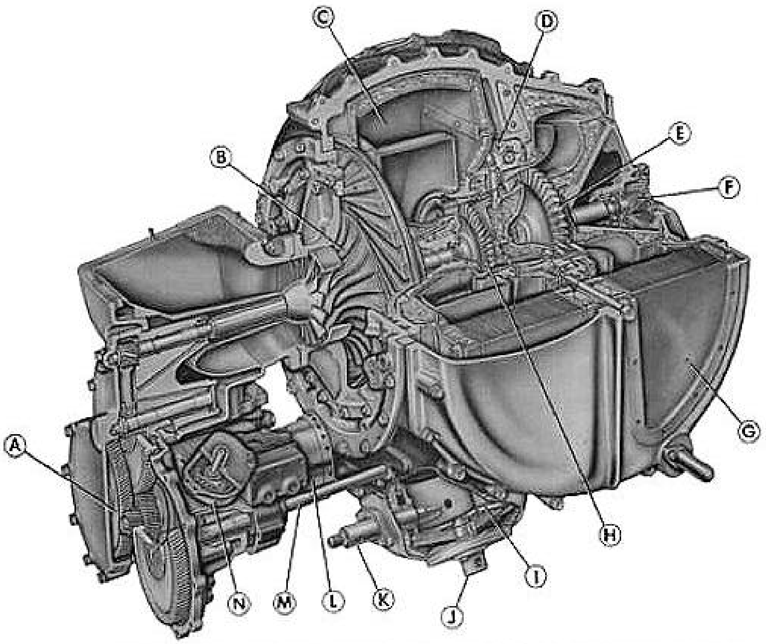
It is essential to understand that the thermal efficiency of the gas turbine is not a constant, but varies with respect to multiple factors. Some of these factors can be controlled to maximize the efficiency of a particular gas turbine. However some factors can not be controlled and will directly influence the performance of the gas turbine. For example: the efficiency will increase or decrease depending on atmospheric conditions. In general when the air is cooler the gas turbine performs better since the air is denser. As stated some factors can be controlled to increase efficiency: these are the physical engineering design of the gas turbine. With better design some components will perform better and thereby increase efficiency. Also some supplement equipment may be added to the gas turbine to increase efficiency: such as a regenerative cooler. The regenerative cooler is a *heat exchanger* that takes the hot exhaust gas from the turbine and uses to heat up the incoming air to the compressor. It has been shown that the efficiency of the gas turbine is greatly improved when a regenerative cooler is used. And in fact it exactly what Chrysler engineers discovered when they first experimented with gas turbines in their cars.

Gas Turbines in the Automotive Industry (The Chrysler Experiment)

March 25th, 1954 was a pivotal moment in the history of the gas turbine engine in the automotive industry. This was the date when the Chrysler Corporation disclosed the successful development and road testing of the turbine-driven Plymouth sport coupe. [History, 1964]. The new sport coupe proved to be a milestone in automotive engineering for it was able to tackle two main issues synonymous with cars at the time: high fuel consumption and damaging exhaust gases. [History ,January 1964]. Work at Chrysler Corporation on the gas turbine started before WW II, when it was concluded that the turbines of the time were not sufficient to be used as a *prime mover* in an automobile. At the end of WW II things changed when Chrysler was awarded a research and development contract from the Bureau of Aeronautics in order to create a turboprop engine for aircraft. Results from this research showed that the turboprop engine fuel consumption was approaching those of the aircraft piston engine. As a result, Chrysler began again to research the possibilities of using gas turbines for cars. By the early 1950's experimental gas turbine power plants were operated in test automobiles. Some problems that were tackled by Chrysler were fuel consumption, high temperature exhaust gases, noise, and slow acceleration. Another critical milstone was bad turbine efficiencies. It was clear to Chrysler engineers that in order to increase efficiencies they had to increase the temperature of the incoming compressed air to the turbine blades. However this proved to be a hard feat to accomplish since the materials of the time used for turbine blades could only sustain so much heat before they would melt. Despite these

difficulties Chrysler engineers were convinced that the gas turbine has great potential and that it warranted further development. [History ,January 1964].

The turbine that was installed in the working Chrysler turbine car of 1954 was a 100 horsepower engine. [Figure 6]. One of the key features for the success of this model was regenerative heat exchanger device that was installed between the existing exhaust gasses and the inlet to the compressor. This device increased the efficiency of the engine without increasing fuel consumption. In turn it also lowered the existing exhaust enough that it was actually cooler than the exhaust of a normal piston engine car.



MAIN COMPONENTS OF THE TWIN-REGENERATOR GAS TURBINE:
(A) accessory drive; (B) compressor; (C) right regenerator rotor;
(D) variable nozzle unit; (E) power turbine; (F) reduction gear;
(G) left regenerator rotor; (H) gas generator turbine; (I) burner;
(J) fuel nozzle; (K) igniter; (L) starter-generator; (M) regenerator
drive shaft; (N) ignition unit.

Figure 6, 100 horse power Chrysler Turbine engine, [history,1964]

In 1956 Chrysler ran across the US a Plymouth sedan equipped with an improved model of the 1954 turbine engine car. Fuel economy had reached 13 miles per gallon, which was about the same as a piston engine performance. The engine itself did not suffer any misshapes along the journey, and the trial was deemed a successful run. In December 1958, another car was released; this time it was a 200-horse power turbine engine and was driven from Detroit to New York. This second-generation turbine showed two significant improvements: the engine efficiency and its materials. The compressor was brought up from 70% efficiency from the old turbine engine, to 80%efficiency; this

was a considerable improvement. The regenerator was brought up to almost 90% efficiency. Chrysler developed its own metallurgical department that in turn tried to manufacture turbine materials that could sustain higher temperatures. Tests showed that the materials developed for turbine blades could sustain up 2000 deg F for over 150 hours. More testing and implementations for gas turbines in cars continued. Then in 1962 a Dodge Dart was fitted with a 145 HP turbine engine that was tested by driving the car from coast to coast. The car performed better then expected. Its fuel mileage was better then the conventional car traveling along side it. And although the turbine engine was exposed to adverse weather conditions, it performed without fail. This engine employed automatic second stage turbine nozzles which provided optimum results through the entire operation range of the engine. Another breakthrough was the acceleration lag. In contrast to the 7 seconds delay experienced by the 1954 turbine design, in the 1962 design max acceleration was reached in 1.5 seconds. This means that after depressing the pedal for maximum power, the turbine engine reached full power in only 1.5 seconds.

In 1963, Chrysler announced that it would build 50 turbine driven passenger cars for the public. [Figure 7, 8]. These cars would have the fourth generation turbine engine. The engine had 130 HP output, and could use unleaded gas, diesel fuel, kerosene, and JP-4 type jet fuel. [history 1964]

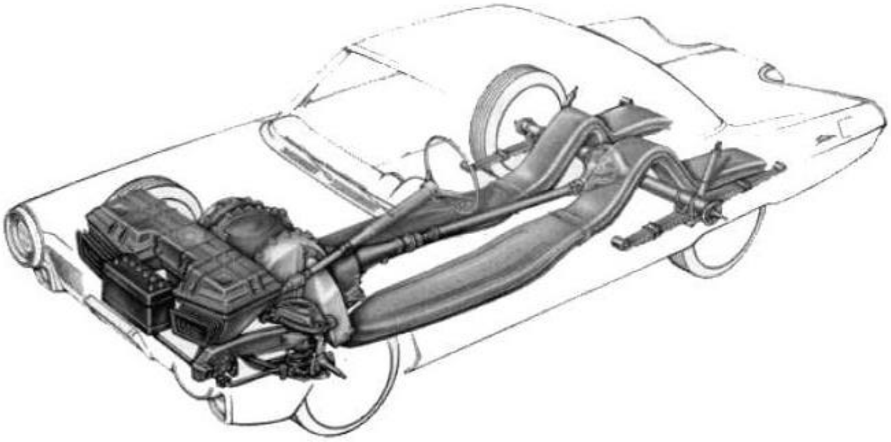


Figure 7, schematic of the 1964 turbine engine car [history, 1964]

Figure 8, picture of the 1964Chrysler turbine engine car [Thomasland,]

Though the program was terminated for reasons which will be discussed later, with the unfortunate decision to destroy all turbine cars Chrysler did note the following conclusions: there was a definite potential for the gas turbine car. With an increase of 400 deg F in the combustion chamber, fuel economy would increase by 20% without any increase in mechanical efficiencies. The following were noted as advantages for the gas turbine over a conventional piston engine: 80% less parts, rotary motion versus reciprocating, with excess air flow all fuel is burned reducing harmful emissions, engine warm-up is not essential for best operation, no lubrication for piston-cylinder assembly, and for the consumer benefit no tune ups are ever necessary, and very low maintenance.

[Chrysler 1963]. Chrysler did however produce more turbine cars in the future; some are discussed in the next section.

Gas Turbine in the Automotive Industry (Experimental Gas Turbines in Vehicles)

Another important factor to consider in the performance of gas turbines is that the gas turbine operates in its optimum thermal efficiency for a specific designated rpm. For this reason many trials were conducted over the years by various companies and organizations including Chrysler. These trials were more concerned with the variability of the transmission and drive train components rather than the improvement of the gas turbine itself. By the early 1970's, it was clear to researchers that the gas turbine engine had reached its maximum thermal efficiency for the given materials at the time. With this knowledge, it was clear that the next step that should be taken in order to increase performance of a gas turbine driven vehicle is to find an optimum solution based only on engine and transmission compatibility. The following is a list of the companies and their respective experiment vehicles that tried to reach an optimum set up. The list shows that the industry was willing to spend time and money on research that incorporated gas turbines in vehicles. It proves that the industry must have seen the potential in gas turbine technology and were willing to under take these trials.

In 1973 Chrysler's Dodge Baseline, incorporating the 6th generation gas turbine. In 1976 Dodge Aspen upgraded Turbine Car, followed by 1977 Chrysler Corporation "public Interest" Gas Turbine Car. In 1954 General Motors Corporation also experimented with the Firebird one, GT-302, followed by the 1955 Firebird two, GT-304. In 1958 it was the Firebird 3, GT-305. In 1959 General Motors joint hands with Detroit Diesel Allison and applied gas turbine technology for heavy equipment use. The joint group installed the first gas turbine for the military and commercial application. In 1971 a gas turbine was tried in a Greyhound bus, using the GT-404 gas turbine. And in 1979 it was the GT-404-4 Advanced Design Bus, model RTS 2.

In 1971 it was the Impala GT-225, and in 1973 the Cadillac Deville. In 1974 Olds Cutlass, AGT-1, followed by the 1975 Buick regal. And the last trial for GM was the 1977 Olds 88 with the AGT-5. Ford Motor Company tested five various gas turbine engines all of which were produced with high HP outputs. And the Williams Research Corporation experimented with three vehicles from 1958 to 1972.[Advanced, 1980].

Gas Turbine in the Automotive Industry (Advanced Ceramics For Gas Turbines)

As mentioned earlier it is essential to raise the thermal efficiencies of the gas turbine engine so that it will be compatible with industry's conventional piston type engines. One way to accomplish this is simply to raise the temperature of the gas entering the turbine blades. The reason that the efficiency is raised by this method is explained through the study of Thermodynamics which I will briefly explain here. The basic design of the turbine dictates that the turbine alone will run the compressor. This means that the power supplied by the turbine has to be sufficient to run the compressor and have left over power to run what ever it is that the turbine is designed to run. Through the addition of heat via combustible fuel in the combustion chamber, the energy from the heat is added to the energy from the compressor. Essentially by enabling the addition of more heat, the input of that extra energy will be used to produce net power. Unfortunately the amount of heat that can be added is limited by the materials used inside the gas turbine, in particular the turbine blades. The turbine blades must be able to resist the oncoming hot gases coming from the combustor. Should the temperatures exceed the allowable resistance of the blade material, rapid blade wear will occur, and as a result the efficiency of the gas turbine will drop substantially. [Figure 9]

Figure 9, breakdown of turbine blades.

For this reason many researchers are trying to come up with methods to enable turbine blades and rotors to withstand higher incoming temperatures. Some methods try to cool the blades from inside the blade using a bleed-off air from the compressor in-order to maintain a permissible temperature throughout the blade. Doing so helps the blade resist high temperatures for prolong periods of time. Other methods are attempting to create a boundary film layer of air around the blade so that the blade will not face the oncoming temperatures. And the method that is most pertinent and the one I will be discussing here is the use of special ceramic materials that by themselves can withstand extremely high temperatures.

Though there are many different types of ceramics, two prominent characteristics of the material behavior are found throughout the ceramic world. These two qualities are brittleness and high temperature resistance. These qualities are imbedded in the crystal structure of the material and its formation. Most ceramics are actually formed only through high temperatures. The brittle aspect of the ceramic is actually not beneficial for the use in turbine blades, because it is not beneficial to have a blade that will easily fracture under stress. However the quality that is useful is the ability of ceramics to withstand high temperatures. If through the study of material behavior and crystalline structure scientists can produce a ceramic that is not brittle yet maintains its temperature resistance, then gas turbines have a great future in cars.

In the mid 1980's DOE sponsored research for the development of ceramic usage in gas turbines, the programs were known as "Advanced Gas Turbine" and "Advanced Turbine Technology Application Program" [Impact 1991]. This program explored the use of Monolithic Ceramics. These are mainly composed of Silicon Nitride, and Silicon Carbide. Still the drawback with these types of ceramics is high brittleness. Some other ceramics were tried as well, these were: In-Situ Toughened ceramics, which proved to be less brittle but with less strength overall. Another type was the ceramic composite, which shows some promising results. It has increased toughness and maintains its high temperature durability, however it still requires a protective coat against *oxidation* [Impact 1991]. Greater potential is found however, in the ability to coat a particular alloy such as a Nickel base, with a ceramic for thermal protection. Another method for coating is called thermal barrier coating (TBC). In this method the blade is coated with two layers: the outer layer is a ceramic and is used in order to reduce heat penetration into the blade material. And beneath that is a metallic bonding coat, to protect the blade from oxidation. This field requires further research to be conducted; however the main goals are being reached. The main problem that is facing blade manufacturers, is the high cost which is associated with this type of technology. [NDE, 2001].

Gas Turbines in the Military (Abrams Tank)

I would like to look at the A-1 tank for two reasons: vehicle acceleration with gas turbine, and the military view at gas turbines. One of the reasons provided by Chrysler for the termination of the turbine car program, was the car's slow acceleration. Given that a tank necessarily is required to get out of an area quickly, it is clear that the military solved the acceleration problem. Another reason I wish to look into Abrams program is that it has been my experience that the military carefully evaluates all options before implementing what it deems best as a final choice and so it is very likely that the military found a great potential in implementing a gas turbine in the A-1 Tank. [Figure 10].

Figure 10, the A-1 Abrams tank

The older Army Tanks used diesel engines and in fact when the Army requested bids for the new A-1, GM proposed to use the MBT-70 diesel engine, whereas Chrysler the second bidder chose the Honeywell AGT 1500 gas turbine engine. [Figure 11]. The 1500 horse power engine can accelerate the tank which weighs 70 tons from 0 to 20 mph in 7.2 seconds. [Wanadoo, 00] ,this calculates to 1.24 meters per second squared. If the comparison is made with a car that accelerates from 0 to 60 mph in 5 seconds, that means

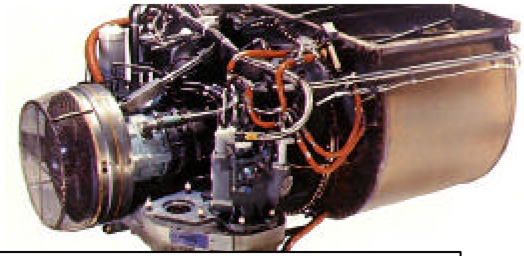


Figure 11, the Honeywell 1500 gas turbine

that the car is only 4.32 times faster than the A-1 Tank. This clearly demonstrates that gas turbine can be used strictly as prime movers in cars with great confidence in cceleration..

The military is now looking to renew its tank supply, and the discussion is again whether or not to purchase gas turbines as a propulsion source. Honeywell, the manufacturer of the AGT 1500 turbine, says it has now designed a new turbine that is 30% more fuel-efficient then its predecessor. With this in mind it is very likely that the Army will again choose to go with the Gas Turbine as the main propulsion for the tank.[Development, 1999]

Conclusion

The objective set forth in this research paper was to determine if the gas turbine engine can one day replace the role of the internal combustion piston engine. The reason for this interest is that the internal combustion engine, though greatly improved over the past 100 years, is still a very inefficient mode of power generation. The main reason for this inefficiency is the basic design of the engine: the piston-cylinder assembly. The engine has to convert reciprocating linear motion into rotational motion. The piston-cylinder assembly is also responsible for great losses due to friction. This shows that simply by design the internal combustion piston engine is not an optimum source of power generation. Another detrimental fault of the engine is the fact that it does not completely burn the fuel during the combustion process, leading to the production of harmful exhaust gases (i.e. carbon monoxide). Summing all these facts and multiplying them with all the vehicles found on the world's roads today, it is clear to see the problem and danger facing us. This is not something that should be dismissed with a wave of the hand; it is essential that a solution will be sought.

Luckily there exists a power generation source that has much greater overall efficiency by its own design. This is the gas turbine of course. We know from observation that the gas turbine engine is a viable source of power. We see it perform its magic on a daily basis when it lifts fantastic commercial planes into the air and generates enough power for the planes to reach velocities exceeding 500 mph, and carrying as much as 774,600 pounds in its cargo. [Boeing, 2003]. There is a reason why planes use gas turbines as a power source rather then combustion engines as they were used to. The reason is simply that, the gas turbine is much more efficient in a number of ways. First, the gas turbine, by design, operates in rotational motion and there for is not required to convert linear motion to rotational motion as the piston engine does. Second, the gas turbine burns all its fuel completely; it accomplishes this by introducing excess air to satisfy a complete chemical reaction of the fuel and air mixture. Third, the gas turbine has about 80% fewer parts than the internal combustion engine. Summing these facts together, it is evident that the gas turbine is a more economical source of power generation. Then the obvious question is asked, why is it then that the gas turbine engine is not used in the automotive industry?

This question has several reasonable answers. The gas turbine engine, though is a great engineering marvel, has some distinct limiting factors. The efficiency of the gas turbine is mainly dependent on the amount of heat that the turbine can withstand. The advancement in material technology is closing in on the race to provide materials that can withstand higher temperatures; however, at present the costs associated with the production of these materials are staggering. Another factor to consider for the efficiency of the gas turbine is that the gas turbine can reach these high thermal efficiencies only when operated at rated speeds. This means that when the turbine is run in lower capacities then it is rated for, the thermal efficiencies are greatly reduced. In viewing of these limitations it is understandable why the gas turbine has not found its way into the automotive industry as of yet.

When examining the limitation of rated speed versus thermal efficiency, again it is evident that for a commercial plane the turbine is ideal. The plane spends most of the time in the air and therefore can operate the turbine in its rated capacity and maximum thermal efficiency. For the car on the road however, this is simply impractical. Most cars are used in city driving, which translates to stop and go traffic, and stopping in intersections. This would mean that the turbine would operate a great amount of time outside its optimum range and therefore would be highly inefficient. If a way could be found to have the turbine operate in a greater thermal efficiency range, then it would be feasible to incorporate it into a car.

In fact the major complaint from the critics regarding the A-1 Tank, is that when the tank is not in motion the turbine continues to operate for maximum efficiency at rated speed even when not required. Naturally this leads to great unnecessary fuel consumption.

The solution presented by the Honywell Corporation for the new A-2 Tank, is an idle auxiliary power unit. This unit will provide power for the tank while the tank is not in motion, and will allow for the turbine to be shut down or be put in idle speed.

Unfortunately the Department of Energy has ceased further sponsoring of any research dealing with the applicability of gas turbine for automotive industry. Never the less research to improve material resistance to heat at lower costs is on the rise. Japan however, is investing in a seven-year program to introduce gas turbines in cars. With this and new materials at hand it is only a matter of time before the rest of the industry takes the challenge again for the use of gas turbines in automobiles.

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Glossary

Turbine-powered-----A power generation method that uses the principles of action-reaction, by the use of blades spread in a circumference a round a rotor.

Steam Turbine---------The usage of turbine power via steam as a the working medium

Rotational Energy-----Energy that is produced via mechanical rotation

Jet Engine ----------- Usage of turbine power via hot gasses as the working medium

Turbo-Prop ------------The use of a jet engine to rotate a plane propeller

Turbofan Engine ------The use of a jet engine to rotate a set of blades for the generating of massive air flow

Internal combustion piston engine –A piston cylinder assembly that reciprocates to deliver rotational motion, where the reciprocation is caused by an exploding air-gas mixture

Spark ignition---------An explosion in the piston cylinder assembly that is triggered by The heat generated by an electric spark

Combustion ignition-- An explosion in the piston cylinder assembly that is triggered by The heat generated from compressed gasses in the assembly

Linear motion----------Motion of an object or device that does not curve or turn, but is on a straight line

Rotational motion----- Motion of an object or device that follows a circular path

Thermal efficiency-----Net power generated by a device divided by the amount of fuel used by the device

Net power----------------The left over power generated by a device that may be used to power another object by some means of a coupling device

Heat in--------------------Generally a thermo property for the amount of fuel that is used in a device

NOx------------------------Some form of nitrogen and oxygen molecule. Generally known as N_2O, or NO_2, where the second impacts the increase in ozone

Mechanical efficiency-The efficiency of a device that is determined by efficiency losses due to the mechanics in that device

Shaft work output-----Normally the net power of a device that is transmitted from the device in a form of a rotating shaft

Heat exchanger---------A device that uses two separate mediums to either remove or add heat to either of the participating mediums

Prime mover-----------A device that is used as the only power source for generation or Propulsion

Oxidation----------------A dehydrogenating affect, normally on iron based metals