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Augmenting Thrust in Automobiles by Implementing Microturbine

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Abstract: **In this paper, effect of recirculating exhaust air in an automobile was analyzed by introducing a turbo component called Microturbine. Microturbine is a small scale combined heat and power application with limited power output (50-500KW).The aim is to increase the inward thrust and to generate electric power by recirculating the exhaust air. Therefore, there is a essential intent to increase the engine efficiency and the conversion of mechanical to electrical energy. The primary objective is to design a microturbine coupled with electrical generator in order to increase the inward thrust and for producing electrical power. The velocity of exhaust air from the nozzle is increased by converging the nozzle (silencer). Dynamic simulation of non- continuous recirculation revealed the effect of frequency on average performance. This could be analyzed using FEM (Finite Element Method) method using ANSYS software and the flow over the model is to be examined by CFD (Computational Fluid Dynamics) by using ANSYS Fluent®. It could be applied in normal automobiles which can increase its efficiency. This showed that including the microturbine produced about \3% reduction in fuel consumption over a typical driven cycle.**

1. INTRODUCTION

With the rapid increase of fuel price and the demand for fuel and the environmental problems, People are seeking for way to improve the engine efficiency. And another major thing is the need for electric power for battery usage in automobiles. An external component called Microturbine is implemented.Microturbines are small scale CHP (Combined Heat and Power) applications with Limited power output (50-500KW). Thermodynamic analysis indicates that approximately 30-40% of fuel energy is rejected to the ambient exhaust gas. For this reason, recovering the waste heat from the exhaust is a promising way to substantially improve the engine thermal efficiency.

The waste recovery techniques include turbocharging, turbocompounding, Brayton cycle, Rankine cycle and thermoelectric generators. These techniques have shown increase in thermal efficiencies that range from 2-20%, depending on system design, quality of energy recovery, component efficiency, and implementation.

Microturbine (MCT) is one of the effective component to recover exhaust gas and achieve lower fuel consumption, Further more the component is compiled with the dynamo to produce electric power for battery in automobiles. This technology has been applied in all the vehicles and large marine engine and further investigations are being carried out.

Different kinds of heat recovery components are analyzed for the recirculation of exhaust gas. Here the Microturbine is more efficient and portable one that will convert the mechanical energy in to electric energy as a power can be stored for the further use.

The advantages over the microturbine in recirculation over the other components is that the higher concentration of producing the inward thrust to the vehicle. Generally the vehicle has the actual thrust with the fuel consumption, but by the implementation of microturbine in the exhaust made an extra thrust with the same fuel consumption. Thus for the same fuel consumption we can able to attain the higher inward thrust. At the same time by the Dynamo in the microturbine we can produce little amount of electric power that can be used for the battery storage in the vehicle. In order to obtain high velocity from the exhaust gas to drive the turbine, the exhaust of the vehicle (silencer) was made converged.

2. APPROACH

The implementation of various waste recovery technologies on both theoretical and experimental basis and demonstrated the individual impact of each technology on the improvement of fuel consumption and the stability of the vehicle. These strategies can be effectively implemented in various applications as like our transportation vehicles, marine propulsion and electric power generation. Especially in the field of heavy duty engines, those technologies are as following:

2.1. Mechanical turbocompounding

This Waste recovery technology involves the installation of a power turbine after the Microturbine MCT for extracting mechanical power from the exhaust gas. Studies conducted in the past mainly by engine manufacturers have shown that the implementation of mechanical turbo compounding in HD diesel engines may result in considerable bsfc improvement. It is examined that the installation of an axial power turbine downstream to the MCT turbine of a 14.6-L engine and they reported an average bsfc reduction of about 4.7% for a 50, 000 miles extra-urban driving test. The implemented mechanical turbocompounding on an 11-L 6-cylinder MCT diesel engine and they reported a 5% bsfc improvement at full load.

2.2. Electrical turbo compounding

The concept of this strategy is based on the coupling of an electrical generator to the MCT shaft for extracting excess power produced from the turbine. In this case, the turbine produces more power compared to the one required to drive the compressor. The excess power is converted to electric power using a high speed generator incorporated into the MCT casing.

Earlier studies performed on the field of electrical turbocompounding have demonstrated that the application of this WHR technology in HD diesel engines may achieve comparable or higher bsfc reductions compared to the aforementioned mechanical turbocompounding concept. Specifically, experimental studies performed in the past by an engine development company have shown the implementation of electrical turbocompounding in a HD diesel automobile engine can result in 5% reduction of bsfc on a cycle basis and in a maximum bsfc improvement of approximately 9–10% when using MCT components with high efficiency.

2.3. Rankine cycle system

This technology is based on the installation of a Rankine bottoming cycle system, which operates using either exhaust gas or organic fluid (ORC) as working medium, for generating additional power through a reciprocating expander or in most cases, a turbine. Recent theoretical and experimental studies, which examined the application of either steam Rankine cycle (SRC) or ORC system and they were performed considering heat extraction not only from exhaust gases but also from the exhaust gas recirculation (EGR) system and the charge air cooler (CAC), have shown that the maximum bsfc improvement can reach up to 9% in the case of SRC and up to 11% in the case of ORC. Leading engine manufacturers have reported lately that they have developed HD diesel engines for automobile applications with 50% brake thermal efficiency and they are planning to increase it up to 55% in 2016 using various Rankine cycle configurations.

2.4. Thermoelectric generator

This WHR technology is based on the direct conversion of exhaust gas heat to electric power using thermoelectric phenomenon. According to previous studies the application of thermoelectric generators (TEG) has produced relatively lower improvements in overall diesel efficiency compared to the aforementioned WHR technologies. However, the continuous evolution of thermoelectric materials in terms of generated electric power can make this technology more attractive for future HD diesel automobile engine application.

By those technologies we implemented a new one with the compilation of both the electrical and mechanical turbocompounding called Microturbine MCT an effective one that we can produce both the additional inward thrust and electric power. The basic block diagram over the MCT is:

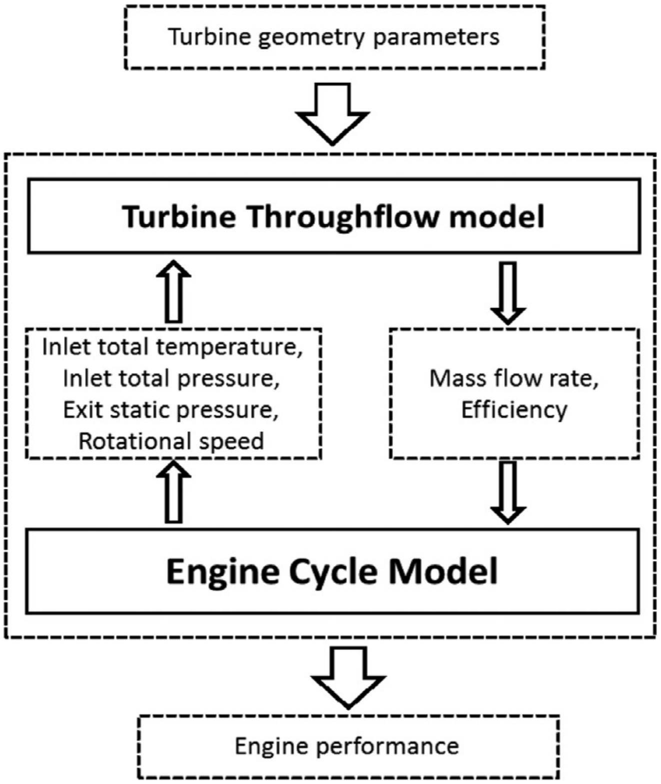
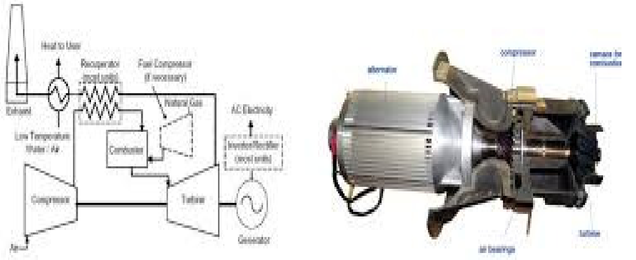


Fig 1.MCT peformance in the recirculation of exhaust gas.

3. CONFIGURATION



(a) block-diagram (b) structural cross-section

CMT-380 is the most effective microturbine used for the recirculation of waste gas and for the generation of the electric power.

When the vehicle in driving mode the microturbine CMT-380 can operate in three driving modes. The selection of these modes can be done at any time, and the vehicle control system will automatically take care of the rest:

- Battery Only – in Battery Only Mode, the microturbine is left in the off mode and power comes solely from the energy stored in the vehicle’s battery system. The microturbine will automatically start when a minimum battery state of charge is reached.
- Full Performance – in Full Performance Mode, the microturbine is started to sustain the battery state of charge and maintain optimal vehicle performance. This preserves the full regenerative braking capability for highest fuel economy, and simultaneously assures that maximum power is available to the drive motor.
- Max Range – the Max Range Mode provides the user the option to automatically determine when the Microturbine should start based on the calculated energy to reach the planned destination. Using input from a GPS Navigation system, the vehicle control system ensures there will be sufficient battery energy remaining. This minimizes use of on-board fuel, while eliminating driver “electric range anxiety.” When parked, the Microturbine CMT-380 can be connected to an electrical system through its charging port. While connected to an electrical distribution system, several operating modes are possible.

Fig3.1 Shows the implementation og MCT in supercar without an electric component

- Immediate Recharge – plug it in, and tell the system to charge immediately.
- Time-of-Use Recharge – delay recharging to when the electric rates are most economic.
- User Power – the CMT-380 can also output power to an electric distribution system or critical load.
- Utility Coordinated (future) – as more plug-in hybrid electric vehicles get into service, there will be Standards established that will allow local electric utilities and/or recharge providers to provide added Value to both the vehicle user and the electric distribution system.

4. SIMULATION

The schematic diagram of the MCT is with the device which comprise of rotating shaft and the vanes that can rotate through the exhaust gas and the dynamo at the end of the MCT can produce the electricity through the circulation motion.

5. WORKING DESCRIPTION

Torque and power of the Microturbine have been tested up to a speed of 500 rpm of the exhaust. For this purpose, a 30 mm diameter brass wheel has been fixed to the Turbine axis. An optical sensor measures the rotation of the wheel in a contactless way: two Vanes on the wheel interrupt the optical path of a Photo sensor. The turbine is tested by switching on the pressure and accelerating the turbine to 500 rpm.

The torque is then derived from the acceleration and the moment of inertia of the wheel and turbine rotor. As the turbine passes through the whole speed range, acceleration, torque and power are known as a function of speed. When the turbine is rotating at full speed, the pressure is switched off and a new measurement is done while the turbine slows down.

This gives the Friction torque as a function of speed. Friction mainly occurs between the wheel with vanes and the surrounding air. The friction torque and power are added to the results of the acceleration test to obtain the total torque and power of the turbine. The maximum torque and power are respectively 3.7 Nmm and 28 W. The dashed lines represent the friction losses determined with the deceleration test. At 1 bar, the turbine consumes 8 Nm3/h of compressed air, which corresponds to a power consumption of 152 W when assuming an ideal Isentropic expansion.

This means that the mechanical efficiency of the turbine lies around 18 %. These observations are made for heavy duty vehicle. for light duty vehicle we got up to 14% of mechanical efficiency towards the circulation of exhaust gas and the electrical efficiency of about 12% is obtained towards the recirculation of exhaust in MTC.

6. SIMULATION OF EXHAUST AIR RECIRCULATION

6.1 Steady state simulation

Due to the exhaust gas recirculation, combustion products enter the inlet air the increasing share of the combustion product in the inlet air is as expected, the exhaust recirculation has a negative effect on the electric efficiency, due to the rising inlet temperature. The results are also compared with the results from simulations Without recirculation.

The loss in electric efficiency is not only the result of the rising temperature. That the presence of combustion products in the inlet air has a non-negligible influence on the microturbine performance, which has also been noticed by other researchers during simulations of a NGCC with EGR.

The amounts of work and heat to compress and heat these inert components (H2O and CO2) have a noticeable part in the efficiency loss. This conclusion is important for the validation of the microturbine's simulation models. Within these models, the composition of the inlet air is kept constant (dry air).

This will result in an overestimation of the microturbine's efficiency once recirculation occurs. Changing the composition of the inlet air of the compressor in the simulation is easy; however it is hard to model the recirculation process, because it happens randomly and noncontinuously.

6.2 Dynamic simulation

Steady-state simulations have shown the influence of the flue gas recirculation on the electric efficiency of the microturbine. There circulation is however not a continuous process, but depends on the wind direction and the presence of vortices in the wind. Two series of simulations on the dynamic behaviour of the microturbine have been performed.

First, the step response of the engine control unit on a change in inlet air temperature and composition was studied, using a dynamic model of the micro gasturbine in Simulink_ A white box model of the microturbine was built in Simulink. Recuperator, compressor and turbine are considered quasi-static; however the inertia of the axis and the thermal inertia of the recuperator are taken into account.

For the fuel flow rate, at the step time (¼ 500 s), fuel consumption drops, along with the power production and the electric efficiency, due to the sudden change in inlet air temperature and composition. The controller will interfere and speed up the machine, by giving more fuel to the combustion chamber, as can be deducted. The electric power will rise again, until the requested output has been reached. Due to the change in inlet air temperature and composition, the microturbine will consume more fuel to produce the same amount of electric power, resulting in a lower electric efficiency.

The higher the recirculated part in the inlet air, the lower the efficiency will be after the step, which is in complete agreement with steady-state simulations. Depending on the step height, the controller needs more time to restore the steady-state condition. For a step of 5% exhaust air in the inlet air, the controller needs 100 s to restore the electric output.

7. EFFECT OF POWER TURBINE SPEED ON GENERATED ELECTRIC POWER AND ON NET ENGINE POWER

The variation of the generated electric power with power turbine speed is shown in Fig 4 As observed, the gains in generated electric power are enhanced with increasing engine load due to the higher thermal energy availability of exhaust gases, which expand in the power turbine. The increase of power turbine speed results in a continuous increase of generated electric power at full load. At 75% load, produced electric power initially increases with increasing power turbine speed up to a certain value and then Fig. 4 Effect of power turbine speed on bsfc percentage variation with reference to standard engine operation without turbocompounding.

Predictions are given for an electrically turbo compounded HD diesel engine at 1700 rpm and at 100%, 75% and 50% of full engine load.starts to decline returning back almost to its initial value. In the case of 50% load, the influence of power turbine speed on generated electric power is rather imperceptible. Observed variations of the power turbine speed effect on produced electric power with engine load can be related to pertinent variations. It is noteworthy to mention that the maximum generated electric power are 62 kW, 39 kW and 23 kW at 100%, 75% and 50% of full engine load respectively.

According to Fig. 4, the application of electrical turbocompounding technology to the examined HD diesel, results in significant reduction of net diesel engine power. This is ascribed to the negative effect of electrical turbocompounding operation on engine average air to fuel ratio, results in deterioration of diesel combustion efficiency. This reduction varies with engine load and power turbine speed. The highest reductions of net engine power observed at 50% and 100% load reaching upto15%.

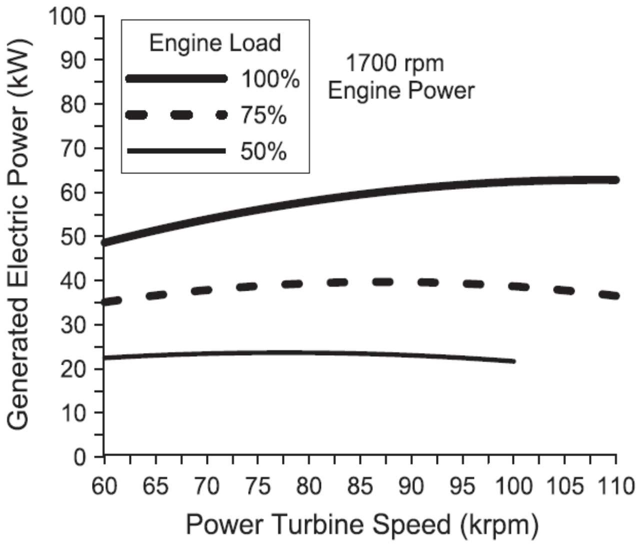


Fig. 4 Effect of power turbine speed on generated electric power. Predictions are given for an electrically turbo compounded HD diesel automobile engine at 1700 rpm and at 100%, 75% and 50% of full engine load.

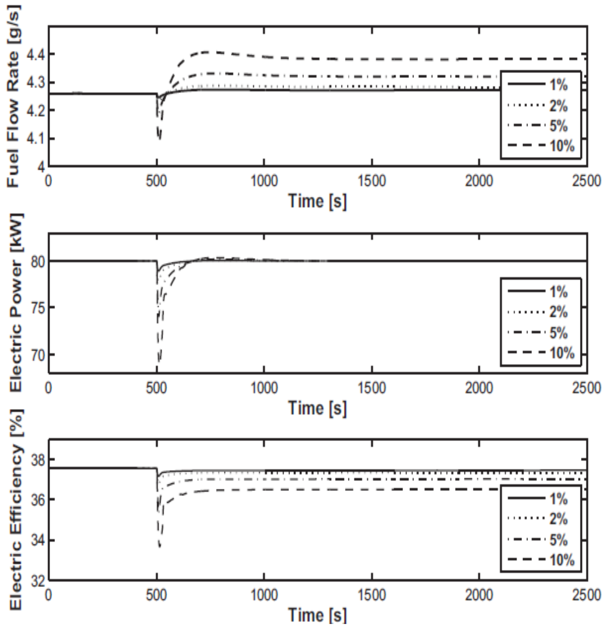


Fig. 5 Step response of the fuel flow rate to the combustion chamber, the produced electric power and the electric efficiency of the CMT-380 on a change in inlet composition

The electrical efficiency, Electric power, Flow rate against time has dropped in to a graph which states that they have the optimized values. The microturbine was analyzed through the Industrial turbine and electric power generator. Fig 6 gives the result 10% of recirculated exhaust air in the inlet air are simulated. For the fuel flow rate, at the step time (¼ 500 s), fuel consumption drops, along with the power production and the electric efficiency, due to the sudden change in inlet air temperature and composition

The controller will interfere and speed up the machine, by giving more fuel to the combustion chamber, as can be deducted from Fig. 5. The electric power will rise again, until the requested output has been reached. Due to the change in inlet air temperature and composition, the microturbine will consume more fuel to produce the same amount of electric power, resulting in a lower electric efficiency.

The higher the recirculated part in the inlet air, the lower the efficiency will be after the step, which is in complete agreement with steady-state simulations. Depending on the step height, the controller needs more time to restore the steady-state condition. For a step of 5% exhaust air in the inlet air, the controller needs 100 s to restore the electric output.

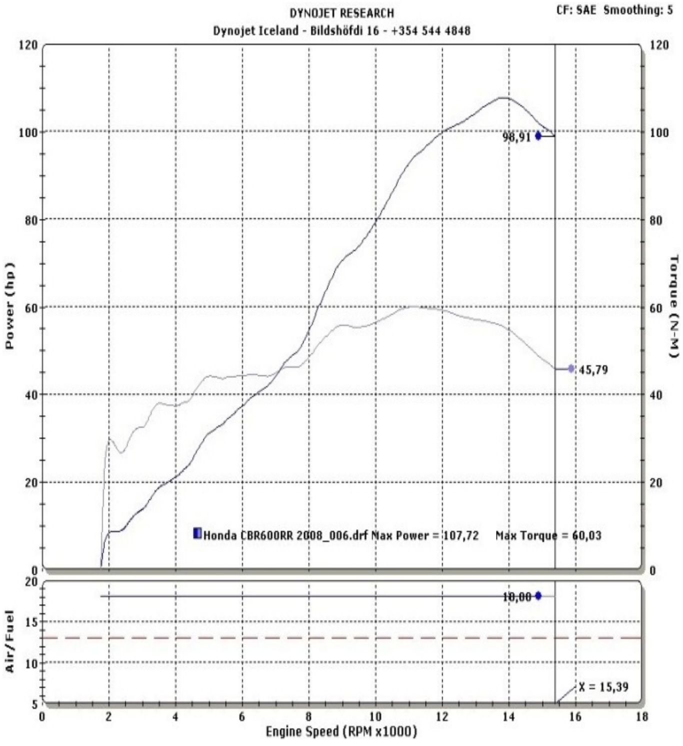


Fig 6 shows the Engine exhaust speed with the Power obtains.

It brief describes the validated data and results for the power obtained and the production of thrust. It has been analyzed through the obtained values of know temperature, velocity.

8. CONCLUSION

The recent analysis over the turbine exhaust has made a high efficiency over the different types of vehicle's where the normal car ford has attained about an accepted values .This shows that the microturbine at the exhaust of normal car is also can able to attain the successful efficiency over the others.

Experiments for diesel engine waste heat recovery performance have been conducted to validate the accuracy of the model. Engine performance data including BSFC, brake torque, power, pressure, temperature and air mass flow rate at different engine speeds were measured.

This paper provides a method combining the Micropower turbine design and engine performance evaluation. It should be noticed that the power turbine contains many geometry parameters. It is not likely to achieve best engine performance by changing just a single parameter. In future, statistical optimization techniques can be used to optimize the geometry parameters to achieve highest efficiency and most appropriate expansion. Besides, the influence on engine emissions should also be considered in the future.

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