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APPLICATIONS OF COMPACT SIZE RECUPERATOR ON VEHICLE MICROTURBINES

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Abstract

In this paper, a kind of simple and effiective method is projected for increasing the thermal efficiency of microturbines, it is that recuperator is used on microturbines. For small Turbogenerator, an exhaust heat recovery recuperator is mandatory in order to realize a thermal efficiency of 30% or higher ,the paramount requirements for the recuperator are low cost and high efficieness, these characteristics must be accomplished by a heat exchanger that has good reliability, high performance potential, compact size, light weight, proven structural integrity. Taking into account size restriction in vehicle, the compact size recuperatores was adopted.
In this paper , the several aspect factores for example conduct heat characteristic of using stainless materials affecting heat exchanging efficiency and moulding process、pressure loss、 configuration form, else exchanging manner are discussed .
Keywords: microturbine; thermal efficiency; compact size; primaty surface recuperator

1. Introduction

For long time , the simple cycle of turbine has been dominant in the fields of power generation. To obtaining performance advancements, only increased compressor and turbine efficiencies and turbine inlet temperature. While these will continue to increase, future engine thermal efficiency will likely be incremented little. Compressor and turbine efficiencies are higher level, and further increases in turbine inlet temperature are limited by material and blade cooling technologies. This paper is mainly concerned with exhaust heat recovery of the microturbine, this could improve engine thermal efficiency and form a more complex thermodynamic cycles. To gain the 30% or higher engine thermal efficiency, it is an essential option that a recuperator is used for being more competitive with Diesel engine technology to future generator market.

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However, because early recuperator was bulky size、poor structural integrity and high cost, its application encounters impediments. For long time, many experts have been making great efforts to resolve the impediments. So far, the two sorts structures have been thought that they are appropriate to microturbine recuperator due to their compact size、good thermal efficiency and low cost, namely primary surface recuperator and plate-fin. Because exhaust gas temperature of microturbine is more 660℃, it is essential that recuperator core material was made of stainless which conduct heat coefficient is lower, however there is a right short distance of conduct heat in primary surface recuperator that get over weakness of low conduct heat coefficient, so PSR's heat exchange efficiency is more excellent than plate-fin in theory.

So we adopt the primary surface structure in real application of microturbine recuperator. The test resultes indicate that it has higher heat exchange efficiency and lower pressure loss compareing with plate-fin.

2. Background of the project

Microturbine can meet the total energy needs for a veriety of complexes including hospitals, supermarkets, schools, factories, office buildings and apartmant house, especially tank. The advantage of the gas turbine prime-mover over existing Diesel engine generator sets include the following: smaller size and light weight、multifuel capability、lower emissions、lower noise、vibration-free operation and reduced maintenance.

Because recuperator is used in the same gas turbine cycle to recovery exhaust heat, the engine thermal efficiency could achieve 30% or higher, microturbine with recuperator has a large potential to enter market.

Liming coporation started the R&D project of microturbine with recuperative cycle as avehicle application in 1998 year-end. The project was finance by AVICI-China Aviation Industry Corporation Ⅰ、artillery and tank army. It is projected that 100KW microturbine with recuperative cycle will enter market in 2005 early.

3. Liming microturbine characteristic

3.1 Engine cycle

A schematic diagram of the Liming unit is shown in figure 1. The combustion air flows through the generator and enters the compressor of centrifugal type. To avoid losses of total pressure, the dynamic pressure caused by high air velocities at the outlet of the compressor is transformed to static pressure in a diffuser. After the diffuser, the compressed air is inducted to a recuperative stainless heat exchanger in which the air is recovery by exhaust gases. The fuel is mixed homogeneously with the compressed and recoveryed air prior to entering the combustion zone. In this way, the combustion temperature can be accurately controlled. The combustor is a small conventional combustion chamber, designed to ensure good combustion during start-up and load changes. The flue gases leaving the combustion chamber expand through the gas turbine. At the same time the gas temperature is decreasing by about 240℃. The turbine is of radial centripetal type with uncooled vanes. The hot exhaust gas leaving the turbine enter the recuperator to recovery the combustion air before entering the combustion chamber. Thereafter the exhaust gas flows through a cross counterflow economizer for heat production. Some engine specification is shown in table 1

3.2. Recuperator

A heat exchange is used to recovery most of the content in the exhaust gases from the gas turbine by preheating the combustion air. This will boost the cycle efficiency. Furthermore, when using a recuperator, the efficiency of the cycle will be slightly affected by pressure losses in the recuperator. Pressure losses occur on both cold and hot side of the heat exchanger. The approach temperature and the material for the recuperator are optimized for acceptable availability rather than high efficiency, so we adoped a thickness of

table 1. Engine Specification

Air flux kg/s	1.03
Inlet air temperature ℃	15
Pressure ratio	3.8
Turbine inlet temperature ℃	900
Recuperator outlet gas temperature ℃	231.6
Recuperator inlet air temperature℃	184
Output Power kw	100
Electrical efficiency %	29

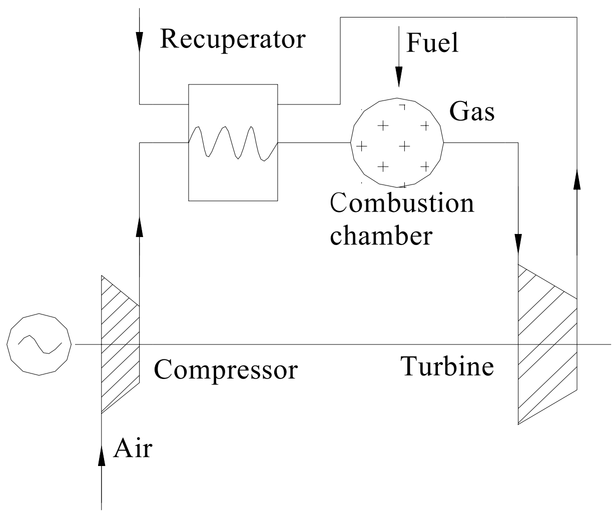


Figure1 Main components of the Liming microturbine unit

0.2 mm stainless,this stainless contains Nb and Ni alloys to endure high temperature and to mould conveniencely. The efficiency of the recuperator depends on maximum cycle temperature and pressure ratio. At the performance test run the air temperature was increased from 184℃to about 610℃ in the recuperator. The cold side pressure loss was 2%, the hot side pressure loss was 4%.The recuperator thermal effectiveness is 90%. This is satisfactory due to the compact recuperator design in the unit.

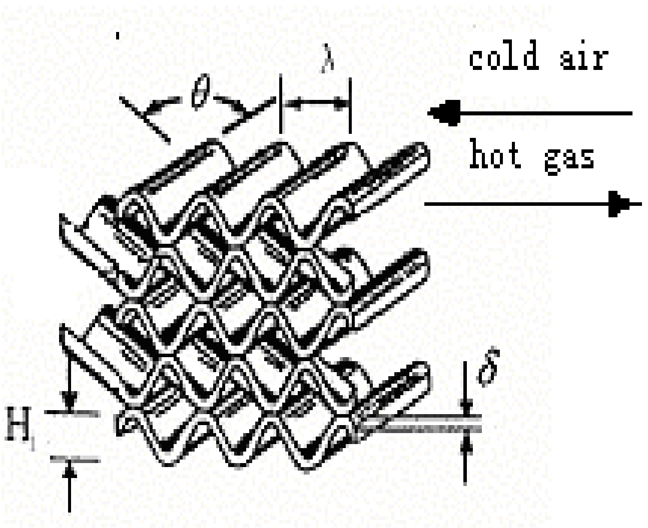
The real good application resultes profits from primary surface recuperator. For hybrid electric vehicles, the very small gas turbine has the attributes of multifuel capability of compact size and light weight package. An applied primary surface recuperator in microturbine satisfys this requirement of compact and light weight as well as excellent heat exchange efficiency commendably.
There is a short distance of conduct heat (only 0.2mm) in this primary surface recuperator , thus could gain a higher thermal efficiency and lower pressure loss as well as small volume size. Liming primary surface recuperator feature of microturbine is shown in table 2.

Primary surface recuperator's matrix is shown in figure 2 and in figure 3.

PSR's the relationship between hear transfer coefficient(k) and hot gas speed(u_h) is shown in figure 4.

PSR's the relationship between attrition (f) and Re shown in figure 5.

Primary surface recuperator's outline is shown in figure 6.

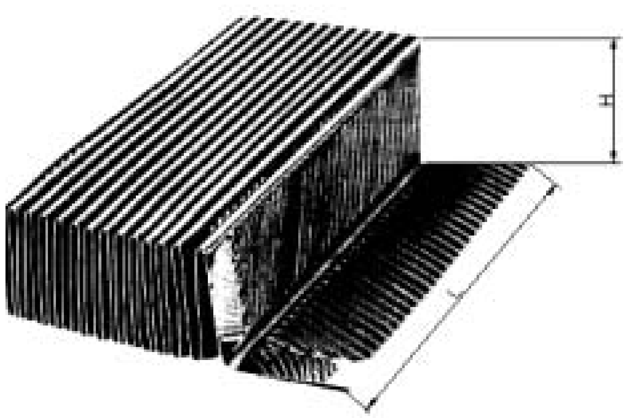


H_i—1 θ—60° λ—1 δ—0.2

Figure2 Herringbone corrugation details for Primary surface recuperator matrix

table 2. Feature of PSR

Matrix construction	Stamped and folded metal foil
Material	Stainless
Flow configuration	counterflow
Matrix envelope	rectangular
Pressure loss of cold side	2%
Pressure loss of hot side	4%
Material thickness mm	0.2
Hydraulic diamete mm	1.0～1.2
Total surface compactness m^2/m^3	2100～2500
Recuperator effectiveness	90%



L-200 H-25

Figure3 Stamped and folded Primary surface recuperator matrix

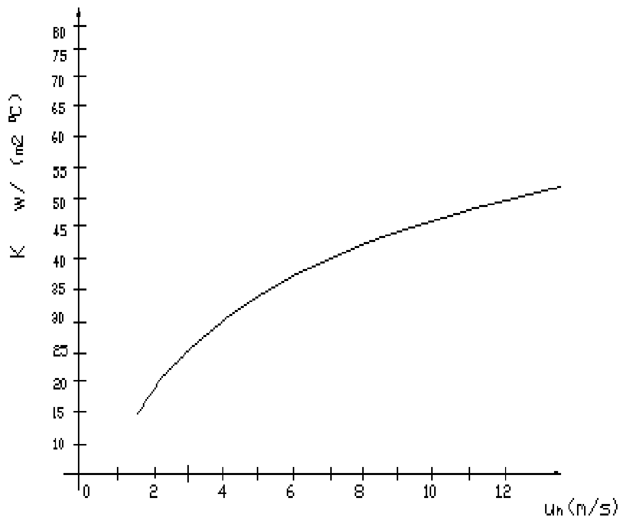


Figure 4 The relationship between k and u_h

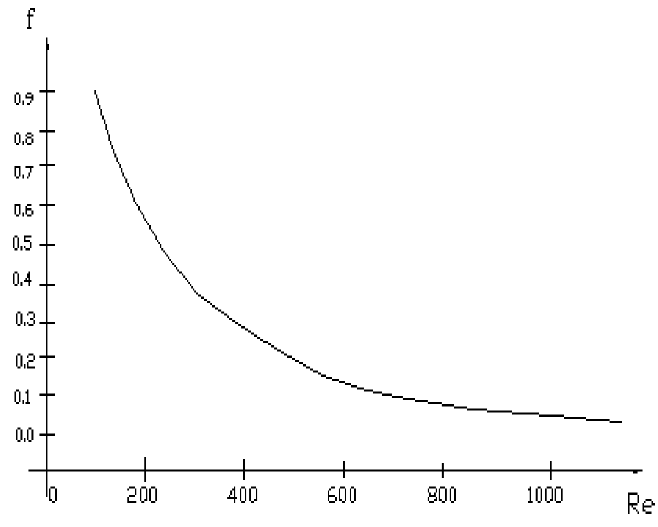


Figure 5 The relationship between f and Re

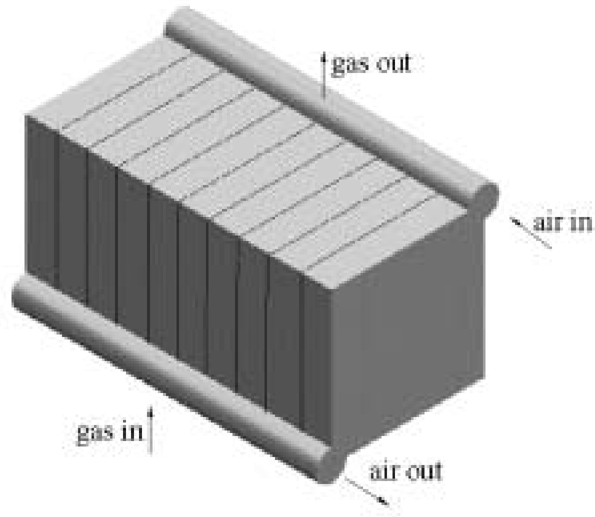


Figure 6 outline of Primary surface recuperator

It is very important that the matrix of PSR （primaty surface recuperator）was formed . PSR matrix is made up thin foil stainless metal with herringbone corrugation. The major fabrication processes involve stamping and folding of this thin foil stock. The matrix is formed by the to and fro folding of a herringbone metal sheet, and is made leak tight by external welding. In the production, the stamping and folding process were half-automated. The formed herringbone corrugation in the counterflow section has a sine curveform and a unique flow geometry. Rig testing of prototype module revealed turbulent flow down to very low Reynolds numbers and good thermal-hydraulic characteristics were obtained.

4. Conclusion

In the current pre-production manufactureing phase of microturbines for power generation use , the existing type of primary surface and plate-fin recuperators are meeting the engine manufacturer's needs in terms of performance and structural integrity. But from both theory and real aspects ,it has been revealed that the heat exchange efficiency of primary surface recuperator was higher than plate-fin because of a short heat conduct distance and bigger heat exchange area of per stere . When PSR's effectiveness is 88～90%，Pressure loss of cold side is 2% , Pressure loss of hot side is 4% , correspondingly the plate-fin recuperator's effectiveness is 80～82% ,Pressure loss of cold side is 3.5% , Pressure loss of hot side is 6% at the same inlet specification and volume. Another the feature of its easily producted matrix and welded contruction avoids the cost and time consuming as well as high temperature furnace brazing operation with its need for close process control that is used in the manufacture plate-fin service. We know that the space of allowed microturbine in veheicle is limited on any style veheicle., so It is a wise option that compact primary surface recuperator was used on veheicle microturbines for its little size and excellent thermal efficiency.

The microturbine is the first class of very small gas turbines where a recuperator is mandatory to achieve an engine thermal efficiency of 30% or higher, this being necessary for it to compete with contemporary Diesel generator sets.The turbogenerator for combined heat and power production is a very compact unit suitable for those customers with small power and heat demand. The efficiency is very high compared to other power units in this scale. There is also a potential of increasing the electrical efficiency by develoment of a more effective recuperator.

The producted heat and power generation by microturbine today has been not commercially profitable in China. There is a good production system for electricity, as well as a good power distribution system in China. Each new power generation technique must be able to show very low costs for electricity production in order to appear as an interesting alternative. Before long ,a small scale power generation probably has very good opportunities to become a competitive alternative to more convetional techniques with respect to environmental aspects and adjustment as well as satisfaction for the customers.

5. References

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