Development of a Plate–Fin Type Gas Turbine Recuperator

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A plate–fin type recuperator for a gas turbine/fuel cell hybrid power generation system was designed, manufactured, and tested. Performance analysis shows that the performance of the system is directly affected by the performance of the recuperator. Therefore, the recuperator should be designed and manufactured carefully, and its performance should be tested and verified before it is integrated into the system. In this paper, the developing procedure including designing, manufacturing, and testing of a cross flow plate–fin type recuperator was presented. Performance test results showed that the design requirements of the recuperator were almost satisfied. Based on the test results, improved design to reduce the size of the recuperator was suggested.

**Key Words**: Heat Exchanger, Plate Fin, Gas Turbine Recuperator, Hybrid Power Generating System

**Nomenclature**

\(d\) : Throat diameter of venturi  
\(D\) : Pipe diameter connected to venturi  
\(m\) : Mass flow rate (kg/s)  
\(P_t\) : Total pressure (kPa)  
\(Re\) : Reynolds number  
\(T\) : Temperature (°C)  
\(\Delta P\) : Pressure difference of venturi  
\(\Delta P_t\) : Total pressure drop per stream  
\(\Delta P_{t,\text{all}}\) : Overall total pressure drop

**Greek**

\(\beta\) : Diameter ratio of venturi (d/D)  
\(\eta\) : Effectiveness of recuperator  
\(\rho\) : Density of air at in–out averaged temperature

\(\rho_1\) : Density of air upstream venturi

**Subscripts**

\(c\) : Cold stream (air side)  
\(h\) : Hot stream (exhaust gas side)  
\(\text{in}\) : Recuperator inlet  
\(\text{out}\) : Recuperator outlet

1. Introduction

In a gas turbine/fuel cell hybrid power generation system, the role of recuperator is to recover heat from gas turbine exhaust gas and to pre–heat compressed air which is supplied to the fuel cell system and the gas turbine combustor. System performance analysis shows that the system efficiency is very sensitive to the performance of the recuperator. One percent decrease of the recuperator effectiveness or one percent increase of the overall total pressure loss results in nearly one percent drop of the system efficiency. Thus, low pressure drop and high effectiveness are essential conditions of the recuperator. Figure 1 shows the schematic of the gas turbine/fuel cell power
development of a plate-fin type gas turbine recuperator

Fig. 1 Schematic of gas turbine/fuel cell hybrid power generating system

generation system, which has been developed by KARI (Korea Aerospace Research Institute). The hot gas from the gas turbine combustor and the fuel cell are mixed and the mixed hot gas drives the turbine. Then, the turbine exhaust gas enters the recuperator and exchanges heat with the compressed air from the compressor, and proceeds to the steam generator. The compressed air from the compressor enters the recuperator and is preheated by the turbine exhaust gas, and sent to the fuel cell system and the gas turbine combustor. The effectiveness of the recuperator determines the temperature of the preheated compressed air and, as a result, determines the amount of fuel supplied to the gas turbine combustor and the fuel cell combustor. Accordingly, the effectiveness of the recuperator affects the system performance directly.

Plate-fin heat exchanger (PFHE) was selected as the recuperator in the project because of its compactness. Compared to other types of heat exchangers such as shell and tube type or plate type, PFHE has much higher surface area density (heat transfer area/volume). Therefore, the overall size of PFHE is much smaller than other heat exchangers with equivalent heat transfer capacity. Because the working fluids of the recuperator are filtered compressed air and burned gas of LNG, the fouling effect, which is one of the major obstacles to use PFHE, can be neglected in this case. The maximum operating temperature of a stainless steel PFHE can be as high as 800°C and the maximum operating pressure of a stainless steel PFHE can be up to 16 bar at the operating temperature of 800°C (Sumitomo Precision Product Co., 2006). Therefore, the required design condition of the recuperator, which will be presented later on, can be achieved by this type of heat exchanger.

Cross flow PFHE was selected as a recuperator in this project because it is easier to design and fabricate than the counter flow PFHE. A counter flow PFHE, which is more compact and efficient but more difficulty to design and manufacture, will be the next step of this development.