Dynamic Behavior Analysis of a Micro Gas Turbine due to Internal Leakage

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Long Abstract

Introduction

Main flow channels of a micro gas turbine (MGT) are comprised of thin plates and seals because MGTs were designed to have a compact layout and a small volume. The thin plates and seals are prone to fractures which are caused by high thermal stresses during cyclic operations. For these reasons, flow can leaks through a demaged wall between two channels having different pressures. The internal leakage decreases MGT performance (power and efficiency) and causes abnormal dynamic behaviors. Therefore, diagnosis of the internal leakage is important for the stable operation of an MGT, and analyzing the abnormal operating bahaviors caused by internal leakage is required as the first step to set up a diagnosis model. In this research, the abnormal dynamic behavior of an MGT according to internal leakages at several parts was simulated and analyzed. The research on the dynamic behavior is important because MGTs usually suffer frequent load changes. Two kinds of abnormal dynamic behaviors were assumed. The first is responses to sudden internal leakage. The next is load following operations of an MGT with internal leakage.

Methods

The object of simulation is a 30 kW class MGT (Capstone C30) installed in our laboratory. Fig. 1 is the schematic layout of the MGT. An in-house program for simulating dynamic behavior developed by the present authors [1] was used for the simulation. The program is based on MATLAB [2]. The thermal inertia of a recuperator and rotating inertia of a shaft have an important role for the dynamic simulation. Normalized performance maps described by semi-dimensionless mass flow, pressure ratio, efficiency, and semi-dimensionless speed was used to model the compressor and turbine. Complete combustion is assumed in the combustor. The design point of the MGT was modeled with a high accuracy using the known design parameters. To increase the reliability of the simulation program, the component models were refined with measured data of the engine. A PD (proportional-derivative) logic was applied to the control of the engine. Only internal leakages between main steam flow channels were considered : leakages to the outside (ambient) were not considered. The possible leakage locations and leakage flow directions were selected based on the engine layout and the final report from the manufacturer [3]. The maximum flow rate of the leakage was assumed to be 5% relative to main flow rate.

Results

Leakages from combustor inlet to turbine outlet, from compressor outlet to combustor inlet, and from compressor outlet to turbine inlet were simulated, and the results of the first case are presented in this presentation. Dynamic behavior simulation result for a 5% suddden leakage from combustor inlet to turbine outlet is presented in Fig. 2. Shaft power decreased temporarily with a reduced mass flow rate of turbine inlet. Then, shaft power was controlled to match the demanded load. Rotating speed increased to satisfy the load. Fig. 3 describes engine responses to a sudden 5kW load removal. The solid lines represent the case without leakage, while the dotted lines denote the case with the leakage. In the latter, the leakage was assumed to be initiated sufficiently prior to the load removal. In other words, the new steady state condition after a sufficient time in Fig. 2 was the inital condition of the dotted case. The operating case with the internal leakage exhibite larger undershoots of both the shaft power and rotating speed than the normal case without leakage.

The impact of the leakage from combustor inlet to turbine outlet on the performance and dynamic responses of the MGT is the largest among three leakage cases. In the presentation of this paper, a detailed comparison among the three cases will be made.

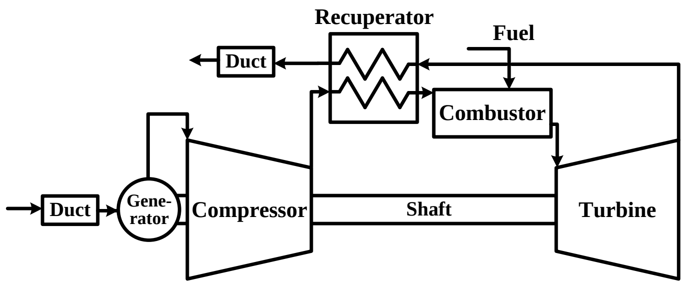

Figure 1. Schematic diagram of a micro gas turbine

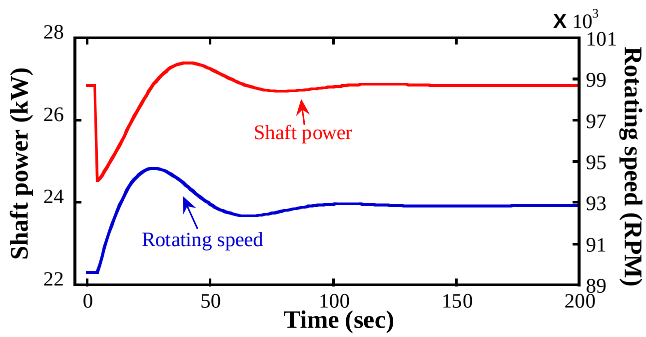

Figure 2. Dynamic simulation results according to a sudden 5% internal leakage from combustor inlet to turbine inlet

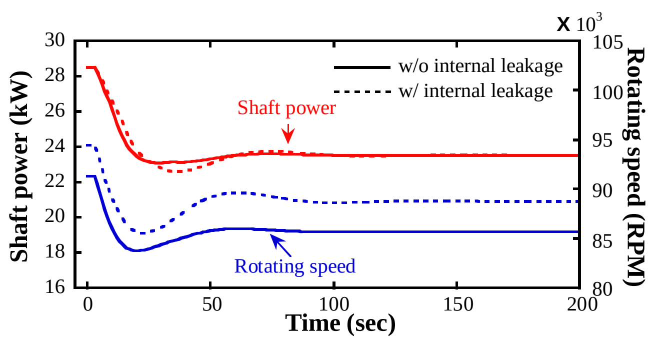

Figure 3. Dynamic simulation results according to the load following operation

References

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[2] MathWorks. MATLAB R2016a, 2016.

[3] Capstone Turbine Corporation. Final technical report – Advanced micro gas turbine system. DOE Project ID # DE-FC26-00CH11058, 2008.