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Investigation of Compressor Blade Roughness Increment Effect on Micro Turbine Performance

S. S. Talebi, A. Mesgarpoor Tousi*

Department of Aerospace Engineering, Amirkabir University of technology, Tehran, Iran

ABSTRACT: Because of challenging operating conditions, gas turbine is exposed to fouling, erosion and other damaging factors. Compressor fouling is the main reason of gas turbine performance deterioration and its most important effect is the increase in the roughness of blade surface. This paper aims to study effect of roughness increase in the compressor blade on a micro turbine performance in part and full load and determination of parameters which are sensitive to fouling. To achieve this goal, characteristic of a radial compressor in clean state and three different surface roughness have been used. Characteristic is utilized to simulate off-design performance of a micro turbine in part and full load. Results of off-design performance simulation in clean state are validated against experimental data. Effects of roughness increment as well as sensitivity of performance parameters in different loads have been analyzed. The simulation's results show that blade roughness increment induces new condition which improves recuperator performance and micro turbine thermal efficiency in constant speed. But in this condition turbine inlet temperature is raised and exceeds the maximum allowed temperature. So the maximum allowable output power is decreased. Results show that net output power, combustion chamber inlet temperature and turbine exhaust temperature are the most sensitive parameters to roughness changes while compressor discharge temperature shows insignificant sensitivity to roughness increment.

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1- Introduction

Compressor fouling is main reason for gas turbine performance deterioration which typically cause 70 to 85% of all gas turbine performance loss [1]. Gas turbine health monitoring helps to predict proper time of visual inspection and component change which leads to reduction of operational and maintenance costs. Nowadays gas path analysis is an important method of performance monitoring of gas turbines [2]. This method is based on understanding of performance of gas turbine in case of components deterioration. There are few published research about micro turbine performance deterioration. In Ref. [3] some correction factors are proposed to approximate effect of fouling, erosion, corrosion and foreign object damage on turbine and compressor characteristics. Then, deteriorated performance of micro turbine is simulated. Roughness increasing effect on performance of a centrifugal compressor is studied using a three dimensional method in Ref. [4]. In this research Operating Characteristic of compressor in clean state and also in roughness of 10, 20 and 30 μm has been calculated.

In current study, the result of Ref. [4] has been used to calculate effect of compressor roughness increment on performance of a micro turbine. To achieve this target, a micro turbine configuration is designed according to compressor design point. Then a model is presented to simulate off-design performance of a micro turbine. The model has been validated using experimental data of micro turbine. This validated model is used to simulate performance of the designed micro turbine in clean compressor state and also in deteriorated compressor state. Finally, sensitivity of different performance parameter have been calculated and analyzed.

Corresponding author, E-mail: tousi@aut.ac.ir

2- Micro turbine performance in design point

Schematic view of a micro turbine cycle is illustrated in Fig. 1. The main components of a micro turbine are compressor, recuperator, combustion chamber, turbine and generator.

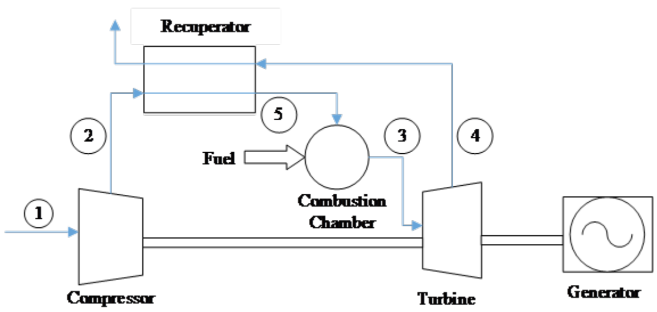

Figure 1. Micro turbine layout

3- Off-design performance

One of the popular methods to predict gas turbine performance in part load is zero dimensional method. This method is based on knowing the operating characteristic of different components of gas turbine. Operating characteristics are presented in several chart, graph or equations. Current research focuses on compressor deterioration effect on micro turbine performance; therefore, only compressor characteristics has been presented. For other component characteristics available equations which are recommended in gas turbine reference has been utilized.

In the current study, the characteristics of compressor SRV2 from [4] is used and is illustrated in Figs. 2 and 3.

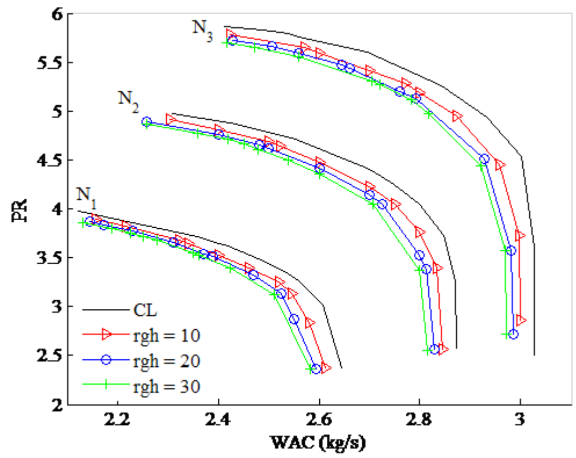

Figure 2. Compressor pressure ratio characteristic [4]

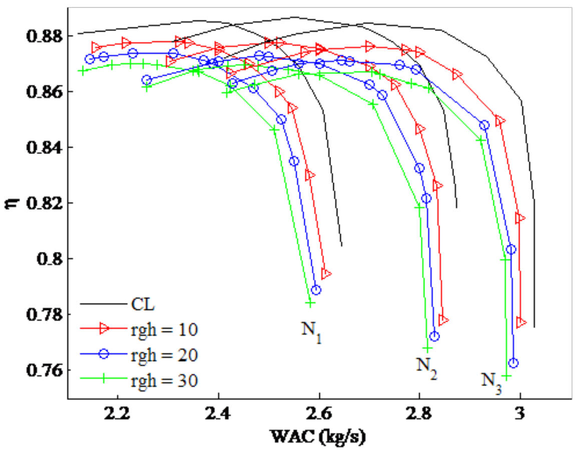

Figure 3. Compressor efficiency characteristic [4]

4- Result and Discussion

The zero-dimensional method is used to simulate off-design performance method of Turbec T100 and validated against experimental data. The simulation results of Turbec T100 using the current paper method and experimental data from [5] are shown in Table 1. As shown in Table 1, the model has enough accuracy to simulate a micro-turbine operation. Therefore, this model has been utilized to predict effect of compressor deterioration on the micro turbine performance. Results are illustrated in Figs. 4 to 6 in form of performance parameter variation with respect to normal condition of compressor.

Table 1. Simulation results and real data of T100 [5]

N_{cor}, rpm/K$^{0.5}$		3382	3805	4017
WAC, kg/s	Exp.	0.522	0.666	0.737
	Sim.	0.515	0.667	0.742
PR	Exp.	2.94	3.77	4.22
	Sim.	2.92	3.75	4.22
TIT, K	Exp	1130	1180	1208
	Sim.	1148	1176	1206
Power, kW	Exp.	45	70	90
	Sim.	47	75	93

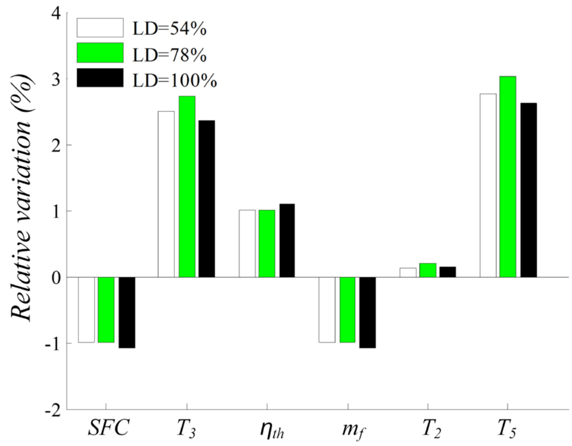

Figure 4. Part load's performance parameters in roughness 30μm

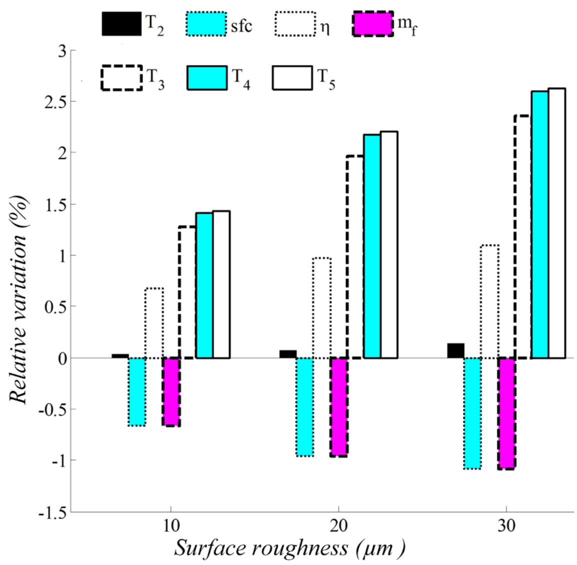

Figure 5. Performance parameters variation in max speed

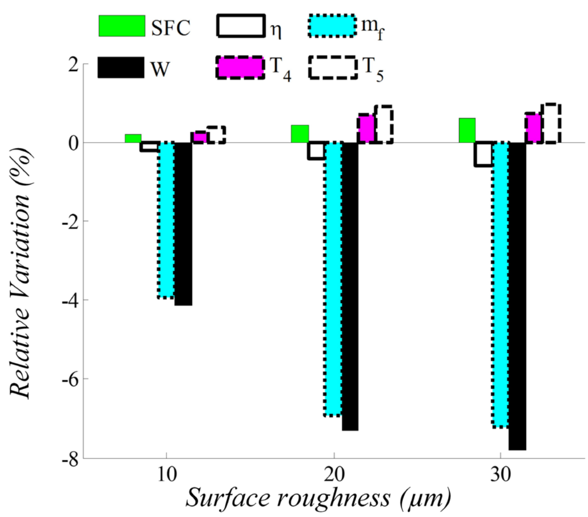

Figure 6. Performance parameters variation in max speed

Sensitivity of different parameter variation to load change and roughness is shown in Fig. 4. As is cleared in this figure Turbine Inlet Temperature (*TIT*) and Combustion Chamber Inlet Temperature (*CCIT*) are most sensitive parameter to roughness increment while Compressor Discharge Temperature (*CDT*) is insensitive. More over *SFC*, thermal efficiency, fuel mass flow and *CDT* show insignificant sensitivity to load change while *TIT* and *CCIT* show noticeable sensitivity.

The conflict between maximum available power and limit *TIT* can be cleared by comparison of Figs. 5 and 6. If in full load the maximum rotation speed remains constant, Fig. 5 is obtained. As is cleared in this figure, in this condition all of performance parameters improve but *TIT* exceeds the limit value. Now if maximum *TIT* limit be considered as a limit for rotational speed, Fig. 6 is obtained. As is shown in this figure, in this condition thermal efficiency and *SFC* reduce slightly while maximum allowable power fall down considerably.

5- Conclusions

In this paper effect of compressor blade surface roughness increment on off-design performance of a micro turbine is investigated. The simulations show that roughness increment leads to thermal efficiency increasing and *SFC* decreasing in constant load but because of exceeding the allowable *TIT* maximum available power fall down. Calculations show that *CDT* is the insensitive parameter and is not a proper parameter to roughness detection while *CCIT* is the most sensitive and proper parameter to this target.

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