MF-111 GAS TURBINE UPRATING PROGRAM

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1. Introduction

Mitsubishi Heavy Industries, Ltd. (MHI) developed MF-111 and the first engine started commercial operation in 1986 at Nippon Petroleum Refining Co., Ltd. Mizushima Refinery, which locates Okayama prefecture in Japan, and already passed around 20 years after that. There are over 40 units of MF-111 running all over the world, and most users have the deterioration of the power output due to long-term operation.

MHI proposed uprating program aimed at power output increase to cover the deterioration for MF-111 users at the conference of MF-111 user association in 2003. And the first products of this uprating program were also installed to the Nippon Petroleum Refining Co., Ltd. Mizushima Refinery.

This paper describes the features of this uprating program and successful result of the field test.

Table 1 MF-111 engine specification

ISO, dry condition		MF111A (original)	MF111B (original)
GT Power	kW	12,610	14,570
GT Heat Rate	kcal/kWh	2,836	2,779
Exhaust Flow	ton/h	175	203

2. Features of the Uprating Program

Power output will increase around 4% relatively by applying this uprating program, which consists of showerhead turbine row 1 vane (R1V) and the pre-swirl nozzle, which reduces the rotor pumping work for the blade cooling airflow. The breakdown of 4.0% is 3.5% by turbine R1V and 0.5% by pre-swirl nozzle.

2.1 Showerhead turbine R1V

In original design, turbine R1V leading edge is cooled by impingement cooling. In this uprating program, showerhead-cooling structure is applied to cool the turbine R1V leading edge.

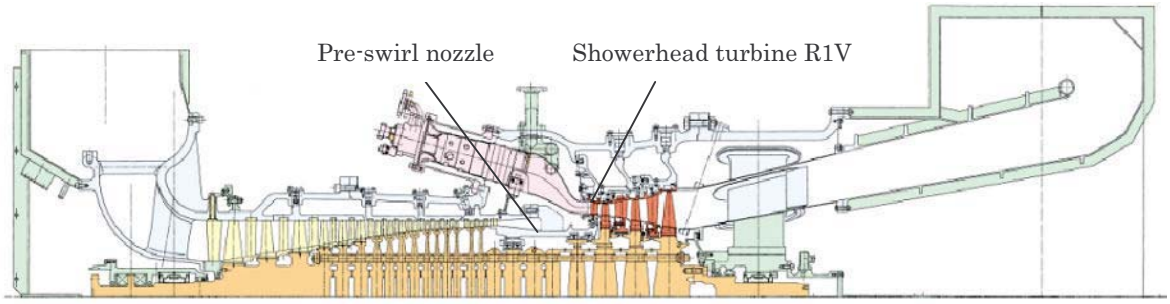

Fig.1 Cross-section of MF111B

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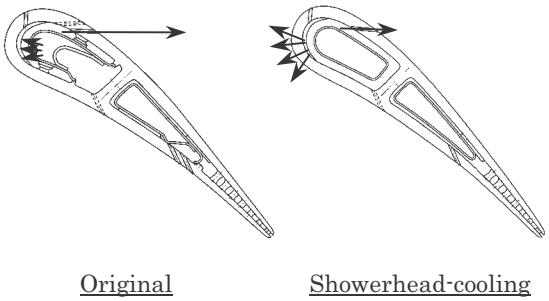

Fig.2 Cooling structure comparison of turbine R1V

Since cooling efficiency of showerhead cooling is superior to the impingement cooling, the amount of cooling air for turbine R1V is reduced dramatically, even though the metal temperature does not exceed the original level.

This showerhead cooling R1V had a lot of operating experience in MHI high temperature gas turbine F(1400℃) and G(1500℃) series.

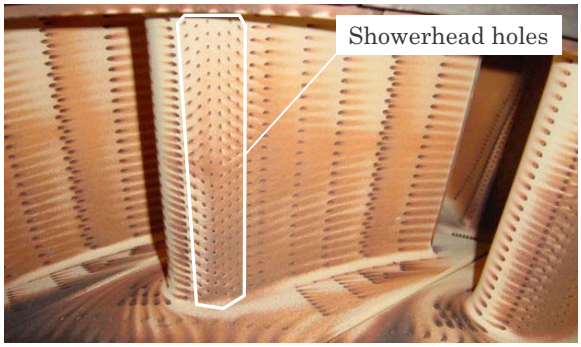

Fig.3 Showerhead cooled R1V of G(1500℃) engine

2.2 Pre-swirl nozzle

Pre-swirl nozzles are bolted on the diffuser cover and have a function to control the blade cooling air supply pressure at the exit of the nozzle. According to the pre-swirl nozzle application, original cooling air feed holes must be plugged. The area of this pre-swirl nozzle was decided to make the rotor cooling air supply pressure same as original to keep the same cooling air amount for blades between before and after this improvement.

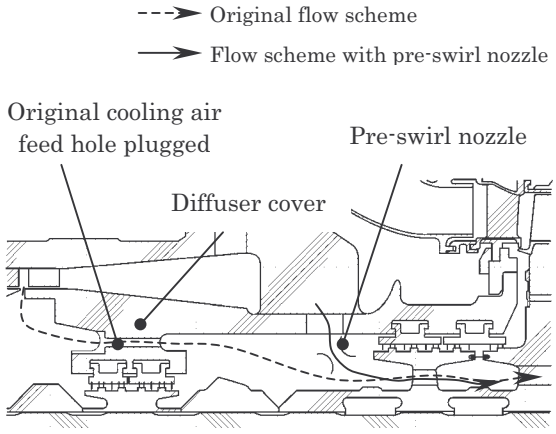

Fig.4 Pre-swirl nozzle allocation

This pre-swirl nozzle contributes to reduce the cooling air temperature of turbine blades by expansion of nozzle and reduce the rotor pumping work, which is generated by bringing the air on board. The rotor work to bring the air on board becomes small with pre-swirl by incorporating tangential injection through pre-swirl nozzle. This rotor pumping work saving also leads to recovering the turbine power output.

MHI already had experiences to apply pre-swirl nozzles for the same objective to the large-sized M501G engine. But it was the first time to apply for such small-sized engine like MF-111. So, CFD analysis (Fig.5) was carried out to predict the effect of this pre-swirl nozzle for MF-111 and a scaled experimental rig (Fig.6) was also utilized to verify the prediction in advance and confirmed good results.

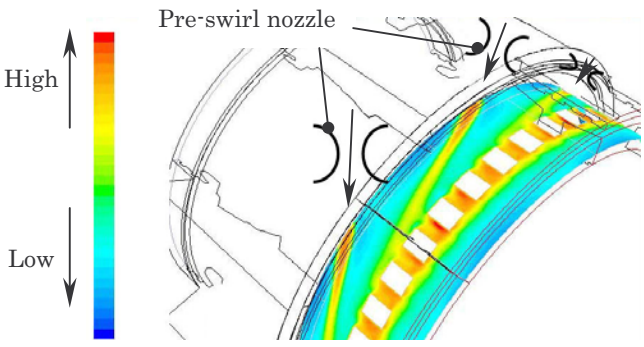

Fig.5 Air velocity distribution around pre-swirl nozzle

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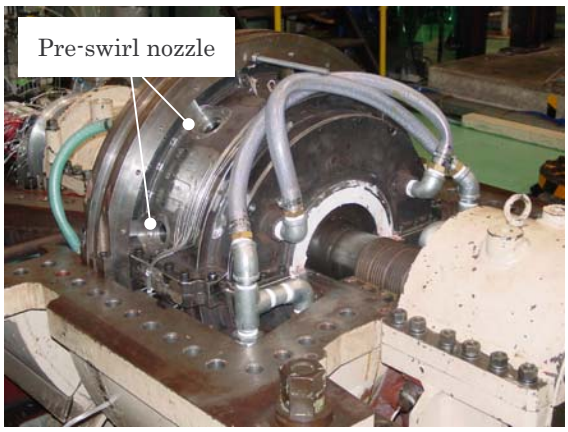

Fig.6 Scaled experimental rig

This uprating program can be applied within normal overhaul time.

3. Results

Nippon Petroleum Refining Co., Ltd. Mizushima Refinery purchased and installed the both 2 products, showerhead turbine R1V and pre-swirl nozzle, at the last inspection in Oct. 2004.

We could confirm that the power output increase was 4.0% by the performance measurement. And the special measurement result, regarding the metal temperature of turbine R1V and pressure balance of rotor cooling system, also showed sound condition.

Fig.7 Nippon Petroleum Refining Co., Ltd. Mizushima Refinery

4. Conclusion

MF-111 uprating program was designed to increase 4% power output and performance and reliability was demonstrated in Nippon Petroleum Refining Co., Ltd. Mizushima Refinery in Oct.2004.

This uprating program can be applied within normal overhaul time and expected to improve the energy economics of MF-111 gas turbine users.

Reference

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