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Research Paper

Loop thermosiphon as a feasible cooling method for the stators of gas turbine

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HIGHLIGHTS

- Loop thermosiphon developed to protect the stator of gas turbine from overheating.
- A loop thermosiphon stator sample (LTSS) was developed to have 8 hollow vanes.
- Sodium-potassium alloy (Na-K) was filled as working fluid to realize thermosiphon.
- LTSS was tested under 1500 K and average wall temperature was 340 K lower than 1500 K.
- Passive thermosiphon cooling needs introducing less/no air flows from compressor.

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ABSTRACT

A stator sample of a gas turbine was developed with loop thermosiphon structure to seek a feasible cooling method for high-temperature stators of gas turbine. The sample was comprised by 8 hollow vanes and a cooling tube. Its inner space was filled by sodium-potassium alloy (Na-K) to become a loop thermosiphon stator sample (LTSS). The thermosiphon structure could transfer the heat from the hot surfaces of the vanes heated by the high-temperature gas mainstream to its own cooling tube, which would be blown by the cold air in the external duct of a gas turbine. Heatproof ability of the LTSS was experimented at 1230 °C in a hot wind tunnel to judge whether loop thermosiphon is a feasible cooling method. Results indicated the average wall temperature of 8 vanes was about 340 °C lower than 1230 °C.

1. Introduction

The first stage turbine stator which is close to the outlet of gas turbine combustion chamber could be higher than 1800 K [1]. Many research work have indicated film cooling is one of the most effective cooling methods [2,3]. Stator endwall heat transfer was researched by experiments and local film cooling was thought to be necessary [4–6]. Satta and Tanda discovered discrete holes for the film cooling of a turbine cascade endwall has a marked effect on the distribution of the film-cooling effectiveness [7]. Mensch and Thole found film cooling influenced adjacent hole areas strongly while impingement has comprehensive cooling effectiveness [8]. Coletti et al. and Jung et al. experimentally investigated conjugate cooling effects by film cooling and impinging jet [9,10]. Williams et al. researched how film cooling and internal cooling affected stator cooling [11]. Liu et al. numerically performed the impingement and film composite cooling of blade leading edge model [12]. Thermal barrier coating is also an effective heatproof method and could bring vanes down about 150 °C at high-temperature condition [13,14]. Thermosiphons/heat pipes may also be used to cool down gas turbines because of their high heat transfer ability [15,16]. The devices were used in the Stirling power generation system [17] and performanced good heat transfer capacity with more than 10 years [18]. Loop thermosiphon/heat pipe can be made into different shapes in need [19]. They succeeded to retreat waste heat as a collector [20] and maintain LED below 85 °C [21]. Given above examples we thought loop thermosiphon structure may cool down the stators of gas turbine.

We figured out a passive cooling method for the stators of gas turbine which could avoid introducing air flow from the compressor: the stator was made into a loop Na-K thermosiphon. Development of the loop thermosiphon stator sample (LTSS) and experimental test were done to judge its possibility as a feasible cooling method for the stator.

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Fig. 1. The developed LTSS.

2. Development and experiments of LTSS

2.1. Development

The LTSS had 8 hollow vanes. The inner channels connected the 8 vanes. A cooling tube was assembled with some ribs, and a short tube was used to fill Na-K into the whole closed interconnected room of the LTSS. The finally developed LTSS was shown in Fig. 1. Actually the stator with its 8 vanes functioned as the hot end of the LTSS while the cooling tube functioned as the cold end, which is a radiator and would be cooled by the air in the external duct without introducing extra air when working on a real turbine.

2.2. Design and preparation of the experiment

In order to research the heatproof ability of LTSS, it was experimented in a hot wind tunnel as high- temperature as 1230 °C (just above 1500 K). During the temperature rising process of the hot mainstream up to 1230 °C, we would test whether LTSS could start to work like a thermosiphon. When the mainstream temperature had risen up to no lower than 1230 °C, we would test the wall temperature reduction of the 8 vanes compared to the mainstream to evaluate the LTSS's heatproof ability.

The 8 vanes' wall temperatures of the LTSS, the upstream and downstream wind temperatures of the LTSS were measured by some thermocouples (precision: 2.5‰), and their specific measuring points and according numbers are shown in Fig. 2. Each of the 8 vanes had a separate thermocouple, from S1–S8, and another 5 thermocouples named HG1–HG5 were placed on key locations of the cooling tube. The upstream and downstream wind temperatures of LTSS were separately measured by each 3 thermocouples.

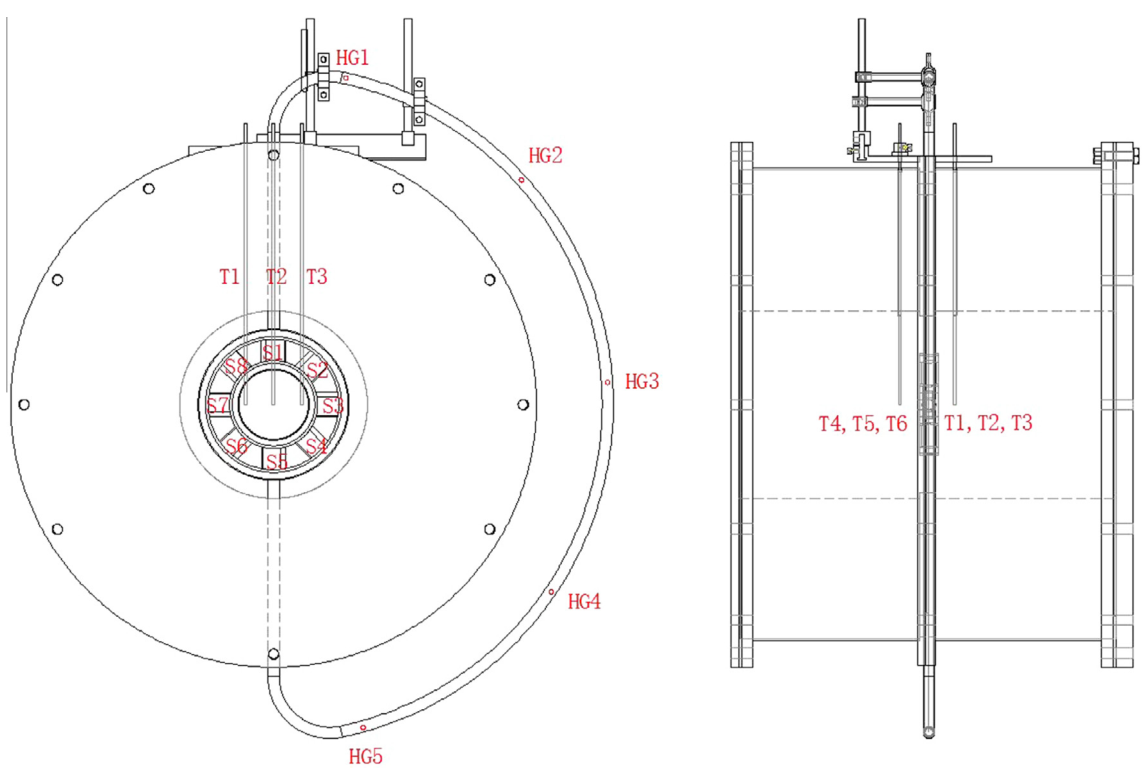

Fig. 2. Temperature measuring points distribution.