Blade Fracture Accident Analysis of Helium Turbine For HTR-10GT

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INTRODUCTION

Closed Brayton cycle (CBC) coupled with High Temperature Gas-cooled Reactor (HTGR) has potential application due to its compact configuration, high power generation efficiency and inherent safety [1]. Most studies focused on the performance of rated and unrated conditions of helium turbine system [2-5]. But there were very few studies concerned accident analysis such as rotor broken, blade fracture. The higher the turbine inlet temperature is, the higher cycle efficiency is. And the blades of helium turbine are component parts working in the most severe conditions. They have the most complex structure, high rotating speed, high operating temperature, and are apt to fracture. In this paper, A model of helium turbine system based on HTR-10GT was established, and the blade fracture accident was investigated to understand accident's consequences. And measurement to mitigate the blade fracture's impact. It will be helpful for the safety operation of closed Brayton cycle coupled with HTGR

MODELS OF HTR-10GT

HTR-10GT project plans to develop and design the direct closed Brayton cycle coupled with the 10MW high temperature gas-cooled reactor Test Module (HTR-10) [6]. Figure 1 is the schematic layout of HTR-10GT. It is a single shaft inter-cooled recuperated closed Brayton cycle combined with reactor. It has 7 key components: the reactor, low/high pressure compressor (LPC/HPC), turbine, recuperator, pre-cooler (PC) and inter-cooler (IC).

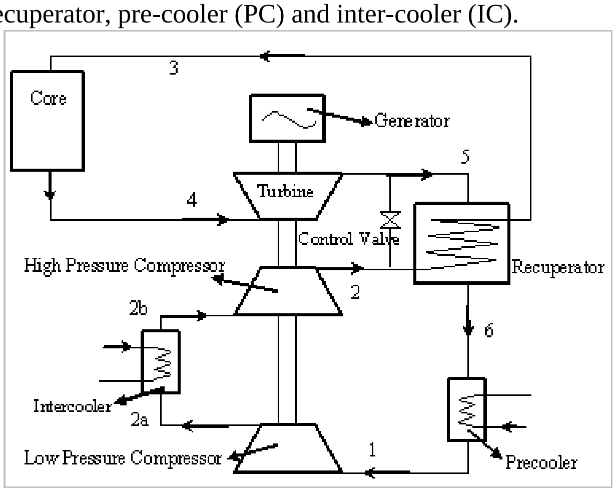

Fig.1 Schematic diagram of HTR-10GT

HTR-10GT was modeled with component by component method. The neutron dynamics of the reactor core is simplified with 6 precursor groups of delayed neutron point-kinetics. For heat exchangers, all flow paths are modeled as single phase 1-demensional flow dominated by mass, momentum and energy conservations. For LPC and HPC, performance maps were used to estimate the off-design performance by corrected mass flow rate wc=$w\sqrt{T}/p$, and the corrected rotational speed Nc=$N/\sqrt{T}$. Flügel Formula was used to estimate the helium turbine's performance.

RESULTS AND DISSCUSIONS

In analysis of blade fraction accident, it was supposed that all turbine blades were broken and removed from the turbine without damage of pressure boundary and other components. In this case, the whole turbine was treated as a nozzle.

As shown in Fig.2, the mass flow rate in turbine would suddenly increase to its peak, about 20 kg/s, after turbine blade fracture accident happened at 0 second, and helium turbine system still connected with the grid. Then it would stabilize to a quite high value, promote the mass flow rates in other components such as LPC, HPC and reactor. It would bring the positive reactivity into the reactor.

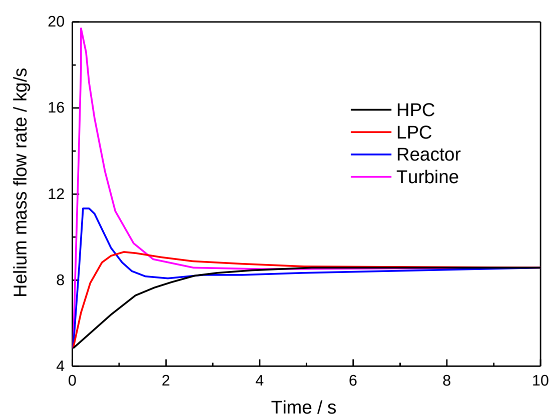

Fig.2 The mass flow rate as connected with grid

If the helium turbine system was disconnected from the grid, there were different situations. As presented in Fig. 3, the mass flow rate would steadily reduce after reach its peak, and the mass flowrates in other components would increase at first and then reduce with decrease of mass flow rate in turbine.

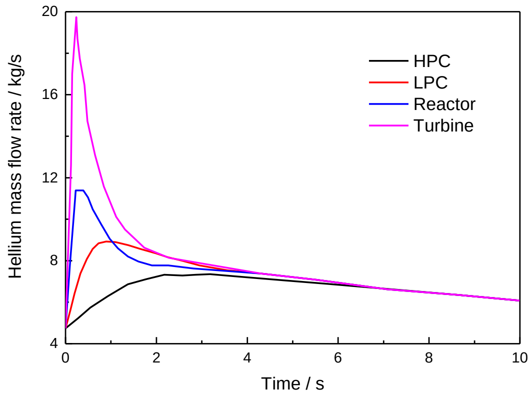

Fig.3 The mass flow rate as disconnected from grid

After the blade fracture accident, the output work of turbine would be zero. As shown in Fig. 4, if the helium turbine system still connected with grid, the rotor speed was fixed at rated condition. It was found that after the disconnecting from grid, the compressors played as the brake and reduce the rotating speed of rotor.

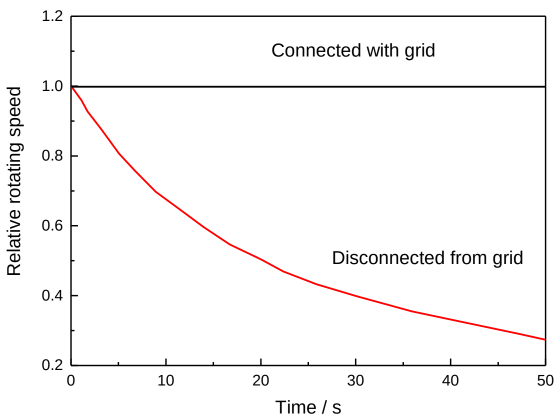

Fig.4 Rotor's rotating speed

As show in Fig. 5, the reactor power would slightly grow at initial several seconds, then reduce slowly if the helium gas turbine system disconnected from the power grid after accident. Or the reactor power would grow about 50% and then stabilize at that power level if the helium turbine system connected with power grid after the accident. It could make the reactor operating at high power over the rated condition.

The results indicated that disconnecting helium turbine system from grid was an effective measurement to mitigate the accident consequences.

CONCLUSIONS

Blade fracture of turbine is the severe accident for helium turbine system coupled with HTGR. A model was established and the consequences of turbine blade fracture were investigated.

1. Blade fracture would vastly increase the mass flow rate in turbine and reach its peak quickly, then it would decease and stabilize in a quite high value if the helium turbine system connected with power grid. Meanwhile, the mass flow rate in other components would also increase.
2. The results indicated that disconnecting helium turbine system from grid was an effective measurement to mitigate the accident consequences of turbine blade fracture. It can reduce the mass flow rates, rotor's rotating speed and decrease the reactor power.

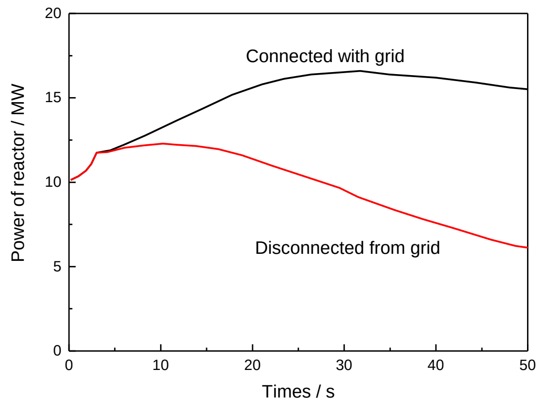

Fig.5 Change of reactor power

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