Performance test for the helium circulator of the HeSS test facility

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1. Introduction

In general, Helium, Water, Liquid Metal coolants are considered as a cooling system for fusion breeding blankets. In Korea, a helium cooled ceramic reflector (HCCR) concept was adopted to be tested as a Test Blanket Module (TBM) and the design of TBM and R&Ds for relevant systems are performed through the ITER TBM program in Korea [1, 2, 3]. The HCCR TBM is designed to be cooled down with helium coolant, which is supplied with 8 MPa, 300 ºC and 1.14 kg/s of flow condition. The Helium Supply System (HeSS) had been constructed to verify the HCS design and to obtain operational test data and experiences [4]. Recently, the status of HeSS construction and its commissioning tests were briefly introduced [5].

In this paper, present status of HeSS facility and performance test results of the upgraded real-scale circulator is described.

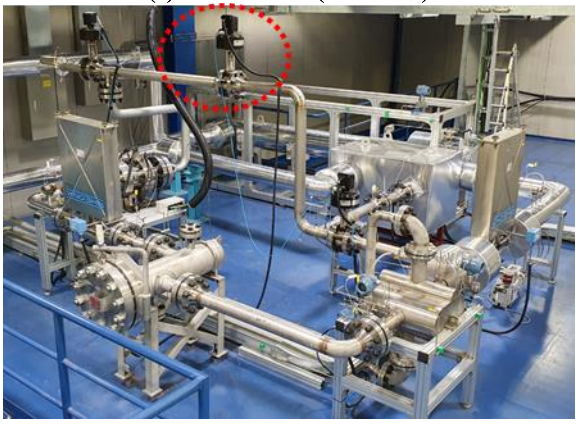
2. The present HeSS facility

The present HeSS facility is designed and constructed to obtain experimental data and operation experience for the HCS, so HeSS is consists of key components, such as circulator, recuperator etc., with specifications consistent with the HCS components. The specifications of the key components of HeSS are summarized in Table I.

The first real-scale helium circulator had been installed at HeSS in 2016 [6]. Several design improvements for the circulator were identified due to huge axial load during the HeSS operations. It was necessary to improve the circulator design to reduce the axial load, so the design had been modified to improve the axial load through increase of motor power and decrease of shaft length. The second prototype circulator has been redesigned and manufactured by Jinsolturbo; the company designed and manufactured the formal circulator. The upgrade real-scale circulator was installed at the HeSS facility in 2019 and trial test operation was performed successfully [5].

Considering the HCS design, present HeSS facility has been modified by installing additional control valve on the main pipeline (between the circulator and the pre-heater) for control helium flow (Fig. 1).

(a) Formal HeSS (Feb. 2020)



(b) Present HeSS (Aug. 2020)

Fig. 1. Present HeSS facility (adding CV on the main pipe)

Table I: Specifications of the key components of HeSS

Components of HeSS	Specifications
Pre-heater	Power: 150 kW, Operating/Design press.: 10/8 MPa Operating/Design temp.: 300/450 ℃
Circulator	Power: 150 kW Pressure ratio: 1.1 Operating/Design press.: 10/8 MPa Operating/Design temp.: 50/100 ℃ Speed: up to 70,000 rpm Flow rate: 1.5 kg/s
Recuperator	Effectiveness: more than 0.92 Operating/Design press.: 10/8 MPa Operating/Design temp.: 300/450 ℃

3. Performance tests of the circulator

The upgraded circulator was tested to check integrity and to obtain performance curve. Several mechanical tests; such as 1) corona discharge test for the stator of high speed motor, 2) high pressure and leakage test for the body vessel, 3) high speed rotor tests with dummy/real impellers to check rotor dynamics and air foil bearings. After completing the mechanical tests successfully, performance curve data of the circulator was obtained with the HeSS test facility.

Performance tests for the circulator were conducted with argon and helium gases and various pressures conditions (Table II) and the flow rate in each test condition was corrected to non-dimension values to compare with the reference conditions of 80 bar, 50 C helium condition.

Fig. 3 shows the circulator performance curve results. The pressure ratio test results according to the corrected flow rate in each test are measured in groups with each corrected speed (Nc), showing the performance characteristics of the circulator well (Fig. 3-a). However, only 60 bar helium test results do not correspond much to this tendency (Fig. 3-b) and this result is hardly understandable because it was performed by the same test procedure and measurement methods with only different pressure following right after the previous test (40 bar of helium condition). Re-tests shall be carried out to find the cause of this discordance.

Table II: performance test condition

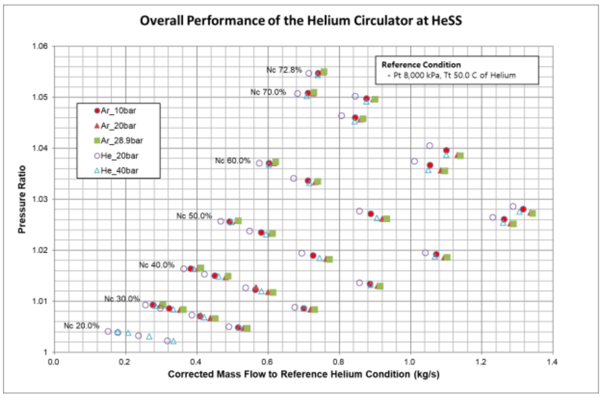
Gas	Argon	Helium
Pressure [bar]	10, 20, 28.9	20, 40, 60, 80
Speed (Nc)[1)] [%]	30, 40, 50, 60, 70, 72.8	20, 30, 40, 50, 60, 70, 72.8

1) Non-dimensional corrected speed to the rated operation condition (8MPa, 50C of helium with 70,000 RPM impeller rotation speed)
※Non-dimensionalized impellar speed: [(RPM)/√(γRT)]
※Non-dimensionalized mass flow rate: [(kg/s) X √(γRT)/(γP)
γ: specific heat ratio
R: specific gas constant

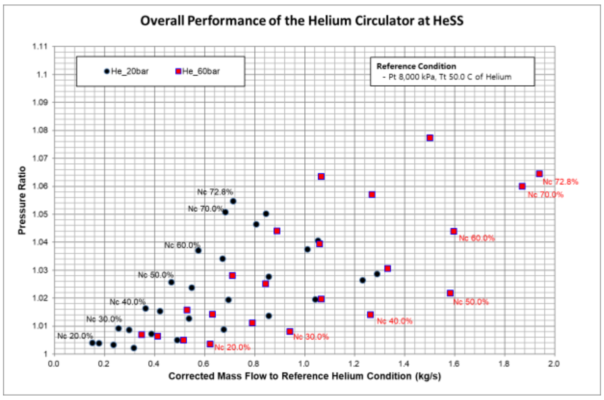
4. Conclusions and future works

The HeSS facility has been modified by adding a control valve on the main pipeline to control helium flow and the performance tests were conducted for the upgraded real-scale circulator installed HeSS with various pressure of argon and helium gases conditions. The performance curve data were successfully measured to identify the circulator characteristics; however, only 60 bar of helium performance test results shows far from the other test results. Investigation and re-tests shall be carried out to find the cause of this disharmony.

Operation scenario for the HCS will then be tested to verify the preliminary operation scenario and to update the HCS operation condition and procedure in detail.



(a) Performance curve test data



(b) comparison between He 20 bar and 60 bar results
※ Corrected mass flow to the reference helium condition (8MPa, 50C of helium mass flow)
Fig. 3. Performance curve results for the real-scale circulator

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