Abstract—A circulator, which is one of the essential components of the Helium Cooling System (HCS) of Helium Cooled Ceramic Reflector Test Blanket System (HCCR-TBS) for ITER project, has been developed to provide up to 1.5 kg/s of helium flow during nominal operation of the HCS. The circulator is designed for compression ratio of 1.1, maximum speed of 70,000 RPM, and electric power of 120 kW with air-foil type bearing. The prototype circulator and the performance test facility will be assembled and constructed by June 2015. The performance test will be performed to verify design parameters and performance of the circulator. The prototype circulator will be installed the Helium Supply System (HeSS) constructed at KAERI to demonstrate the HCS of HCCR-TBS.

Keywords—he helium circulator, helium cooling system, HCCR-TBS.

I. INTRODUCTION

In Korea, the HCCR TBM has been developed to study tritium breeding technology for a fusion reactor under the ITER project [1]. The HCCR TBM is cooled down with high pressure (8 MPa) and temperature (300 °C) helium coolant, which is supplied by HCS which is the primary cooling auxiliary system of HCCR-TBS. The HeSS test facility has been constructed to verify the HCS design and operational procedures and to obtain thermal-hydraulic test data and experiences [2]. The thermal-hydraulic test data is essential for validation of system codes, such as GAMMA-FR [3, 4].

The HCS is mainly consists of circulator, recuperator, pre-heater, cooler and filter. Based on the HCS design, the HeSS facility had been constructed for demonstrate real scale of the HCS, however only the circulator was 1/3 scaled for helium mass flow rate (0.5 kg/s) [5]. The real-scale helium circulator has been developed since 2014 to upgrade the HeSS facility. In present study, design and manufacture of the prototype circulator and performance test plan are described.

II. CIRCULATOR DESIGN

A. Requirements

The HCS ancillary system shall provide the primary helium coolant at the 8 MPa and 1.15 kg/s for nominal operation condition of HCCR-TBS. The primary coolant pressure drop in the HCCR TBM-set during nominal operation is calculated about 0.45 MPa. In present, considering the other pressure drop points, such as the connection pipe, valves and components etc., design requirement of the overall pressure drop in the HCS during nominal operation is 0.8 MPa.

Based on the HCS operation conditions, the helium circulator requirement is listed as follows:

- Operation (design) pressure: 8 (10) MPa
- Operation (design) helium mass flow: 1.5 kg/s
- Pressure ratio: 1.1
- Operation (design) inlet temperature: 50 (100) °C

B. Design features

A Prototype circulator design has been developed by Jinsolturbo Co. in end of 2014. Previous circulator design had mechanically separated between the impeller and the shaft so that a drive motor operates in air environment in order to avoid corona effect problem and the helium leak problem. The rotational momentum is transfer from the shaft to the impeller by a magnetic coupling device. The 3-D modeling of the circulator and magnetic coupling device are shown in Fig. 1. However, calculated eddy current loss at sealing cap of the magnetic coupling device is very high because of high speed (~70,000 RPM) operation. While non-conductive and high strength material for the sealing cap is under developing to solve the eddy current loss issue, the first prototype circulator
with a mechanical coupling between an impeller and a shaft has been developed.

The technical specifications of the prototype circulator are summarized in Table 1.

<table>
<thead>
<tr>
<th>TABLE I. SPECIFICATIONS OF THE FIRST PROTOTYPE CIRCULATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing type: Air bearing (Oil free operation)</td>
</tr>
<tr>
<td>Impeller and shaft connection type: Mechanical coupling</td>
</tr>
<tr>
<td>Operation (Design) conditions: 50 (100) °C @ inlet / 8.0 (10.0) MPa /</td>
</tr>
<tr>
<td>Flow capacity: 1.5 kg/s of pressurized helium (8 MPa)</td>
</tr>
<tr>
<td>Pressure ratio: 1.1</td>
</tr>
<tr>
<td>Overall Performance: 73 %</td>
</tr>
<tr>
<td>Mechanical speed: 70,000 RPM</td>
</tr>
<tr>
<td>Overall power consumption: Less than 120 kWe</td>
</tr>
<tr>
<td>Power supply: 380 V, AC 3-phases</td>
</tr>
</tbody>
</table>

III. CIRCULATOR MANUFACTURING

In present, most of the parts of the prototype has been manufactured and these parts are being assembled and it will be completed by June 2015. Fig. 2 shows the major parts of the prototype circulator.

IV. PERFORMANCE TEST

To obtain performance curve and to verify the developed circulator a Performance test facility is under construction. The test rig will be constructed by June 2015, at the same time as assembling the circulator. Fig. 3 and 4 show the performance test points and 3-D modeling of the performance test rig, respectively.

The performance test will be done by August 2015 and then the circulator will be installed in the HeSS facility at KAERI.

Fig. 3. Expected performance curve for the developed circulator
V. SUMMARY

The prototype circulator has been developed to provide up to 1.5 kg/s of helium flow during nominal operation of the HCS. The circulator is designed for compression ratio of 1.1, maximum RPM of 70,000, and electric power of 120 kWe with air-foil type bearing. The first prototype circulator and the performance test facility will be assembled and be constructed by June 2015. The performance test will be performed to verify design parameters and performance of the circulator by August 2015. The verified prototype circulator will be installed into the HeSS facility, constructed at KAERI, to demonstrate the HCS of HCCR-TBS.

ACKNOWLEDGMENT

This work was supported by R&D Program through National Fusion Research Institute (NFRI) funded by the Ministry of Science, ICT and Future Planning of the Republic of Korea (NFRI-IN1503)

REFERENCES