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High heat flux test on the thermocouple embedded ITER neutral beam duct liner mock-up

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HIGHLIGHTS

- Twenty thermocouples have been installed on the NB duct liner full scale mock-up.
- High heat flux test has been performed.
- Four thermocouple fixation schemes had been verified by high heat flux test.
- Temperature behavior of the NB duct liner has been successfully simulated.

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ABSTRACT

The ITER neutral beam duct liner is located within the tokamak VV port extension and is mounted on the VV port extension flange. The duct liner is made from CuCrZr copper alloy and is actively cooled through deep-drilled channels. A number of thermocouples should be installed on the neutral beam duct liner in order to provide the ability to detect temperature excursions on the surface of the duct liner. Twenty thermocouples have been installed on the neutral beam duct liner full scale mock-up, and a high heat flux test has been performed at the KoHLT-EB test facility, in order to simulate temperature detection in the neutral beam duct liner during ITER operation. For each thermocouple, the fixation method has been verified by high heat flux test with uniform electron beam profile, and the temperature behavior of the neutral beam duct liner has been successfully simulated by Gaussian electron beam profile.

1. Introduction

ITER (ITER is a Nuclear Facility INB-174) Vacuum Vessel has 18 ports at the upper level of the machine, 14 regular and 3 NB (neutral beam) ports at the equatorial level, 9 ports and 18 local penetrations at the lower level. The NB ports will provide access for the neutral beams for plasma heating, current drive and for diagnostic purpose [1].

The NB duct liner is located within the tokamak VV (Vacuum Vessel) port extension and is mounted on the VV port extension flange. Main functions of the duct liner are to define the edge of the beamline as it passes through the HNB (Heating Neutral Beam) duct and to protect the VV port extension from direct beam interception and re-ionized power deposition [2]. The NB duct liner assembly consists of the Duct Liner Modules (DLMs), Neutron Shield (NS), Pipework and C&I hardware. (Fig. 1).

The DLMs will be made from CuCrZr alloy and will be actively cooled through deep-drilled channels. The DLMs should withstand a beam flux of 2.4 MW/m^2 and the peak temperature does not exceed 300 °C for a conservative maximum coolant temperature of 130 °C. The main function of C&I hardware is to provide the ability to detect temperature excursions on the surface of DLMs [2]. C&I hardware consists of thermocouples and connectors. Fig. 2 shows the basic features of a typical DLM.

2. Thermocouple fixation

2.1. Engineering study of thermocouple fixation

In order to determine a reliable thermocouple fixation method taking into consideration ITER operation, four preliminary design of thermocouple fixation have been proposed by ITER organization.

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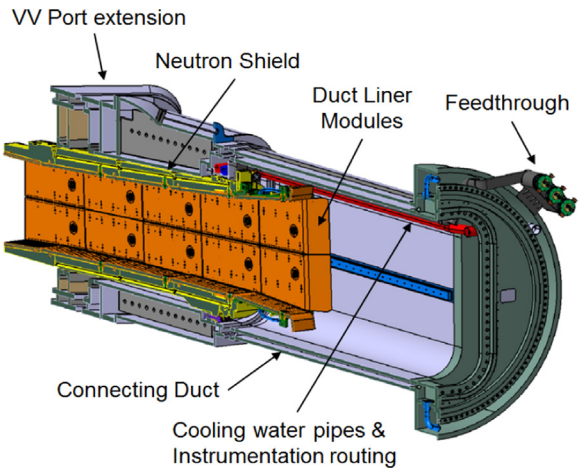

Fig. 1. Section view of NB duct liner assembly.

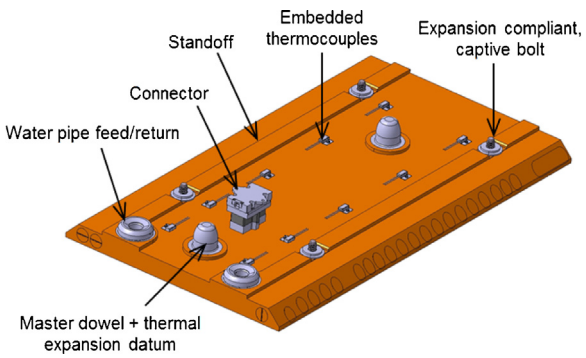

Fig. 2. Basic features of a typical DLM.

These thermocouples should be located from outside as deeply as possible to inner surface (2 mm apart from inner surface at least). This depth is desirable for measuring of local surface temperature of the DLM [2]. Fig. 3 shows four fixation schemes that had been developed by ITER Korea taking into account the manufacturability. Each thermocouple had been copper electroplated at the tip and surrounded with copper ring. Copper electroplated tip is to make a plastic deformation and the copper ring is to prevent damage of thermocouple while mechanical fixation.

In order to compare the characteristics for the fixation with hammering schemes, two types of thermocouples (45° and 90° bend) had been adopted. Dedicated hammer will be used for fixation of thermocouple and this hammering operation can make plastic deformation to the wall of the thermocouple installation hole and copper ring. The difference between both fixation schemes is only the direction of hammering. In addition, for the purpose of comparison of the contact conditions, fixation with set screw scheme and threaded thermocouple fixation scheme had been developed. By doing fasten the set screw and threaded thermocouple itself, thermocouple can be located the bottom of the hole. As a result, all thermocouples can be located 1 mm apart from inner surface during assembly process.

The locations of the thermocouples had been decided on with consideration for the coolant channel of the NB DLM full scale mock-up and the High Heat Flux Test (HHFT) area. Fig. 4 is schematic diagram for the location of each thermocouple fixation scheme and Fig. 5 is manufacturing drawing of thermocouple

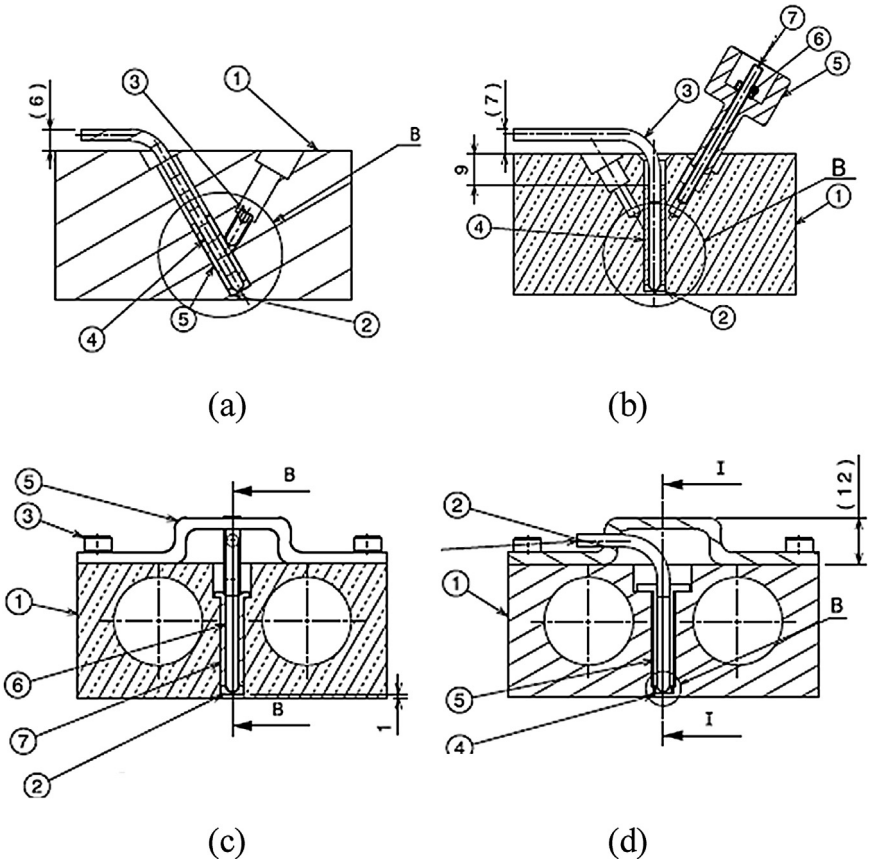

Fig. 3. Developed thermocouple fixation scheme. (a) Hammering on one side, (b) Hammering on both side, (c) Fixation with set screw, (d) Threaded thermocouple.

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