DEVELOPMENT OF METER-SCALE LARGE W/CU DIVERTOR COMPONENTS FOR FUSION REACTOR AT ASIPP

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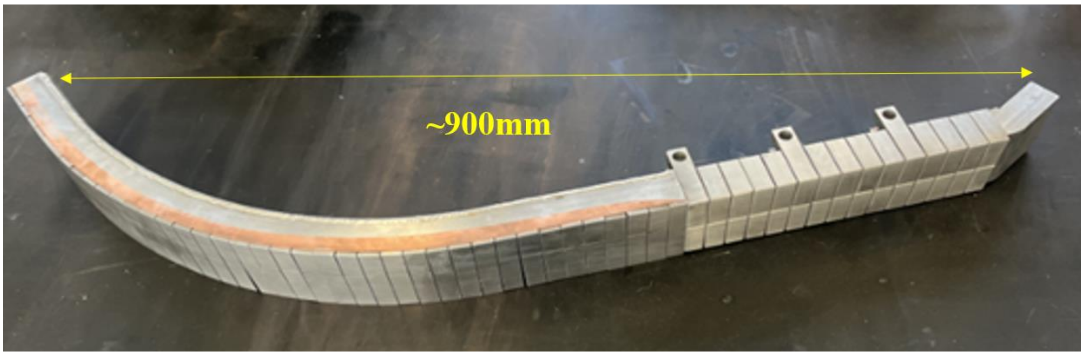
Actively water-cooled W/Cu components are considered as one of the primary choices of technical solution for the high heat flux removal in fusion reactor divertor. ASIPP initiated the first W/Cu divertor project in 2012, and then the EAST upper divertor was upgraded with W/Cu components in 2014 [1]. Afterwards, the W/Cu monoblock technology was further improved and passed the ITER qualification requirements in 2016 [1]. In 2021, the EAST lower divertor was also upgraded with W/Cu components [2]. Both upper and lower W/Cu divertors significantly improve the capability of high-power operation, contributed to the many achievements in plasma research such as the 1066 s H mode operation. In recent years, W/Cu divertor technology have being oriented to the development of meter-scale large components for fusion reactor, mainly including, 1) design exploration for continuous high heat flux removal in the closed V corner, 2) qualification of meter-scale divertor components with monoblock structure and conventional materials of pure tungsten and CuCrZr, and 3) development of flat-type components with advanced materials.

A closed corner slot design was proved to be benefit for the detachment operation while keeping a high performance of core plasma [3]. This corner slot design prefers to have continuous heat flux removal capability around the corner slot, which introduce significant challenges in engineering design [2]. For this purpose, such a divertor design was initially explored with the W/Cu hypervapotron as plasma facing unit (PFU) [4]. However, due to the rigid connection of horizontal target and vertical target in the closed V corner, such design has very high thermal stress which introduce the risk in the life of thermal fatigue. Therefore, much efforts were paid to decouple the water-feeding structure for PFU from the mechanical connection between the horizontal and vertical stainless-steel support for plasma facing components (PFCs). After evolving through three design concepts, a final design with W/Cu monoblock PFU was achieved with the continuous heat flux removal of 15 MW/m^2 on both horizontal and vertical targets in the closed V corner. This closed V shape PFU design was further developed and integrated into the PFCs and a 2-m large divertor module for fusion reactor. The divertor module has a new design for cooling circuit that can effectively reduce the pressure drop without any negative impact on the divertor by rationally allocating the coolant through outer target to inner target and dome [5].

The continuous heat flux removal 15 MW/m^2 lead to a sophisticated design of W/Cu PFCs, which increase the difficulty in the fabrication and assembly. To study the engineering feasibility, at first a W/Cu PFU mock-up was made and successfully tested by 5000 cycles of 15 MW/m^2 without visible failure. A lot of small R&Ds was done, such as the multi-materials tube-to-tube joint by e-beam welding. Afterward, the meter-scale long W/Cu PFU was made for inner and outer target. The full-scale prototype of divertor module has been fabricated and assembled, and now is subjecting to the various testing including the coolant pressure, leak tightness after baking and high heat flux.

Another important work is the development of fusion reactor flat-type divertor with advanced materials, i.e., potassium-doped tungsten (KW) for armor, oxide dispersion-strengthened copper (ODS-Cu) alloy for heat sink, and reduced activation ferritic/martensitic (RAFM) steel for structure [6]. The small to middle scale mock-ups as well as prototypes for CFETR have been successfully tested with 1000 cycles of 20 MW/m^2.

a) 

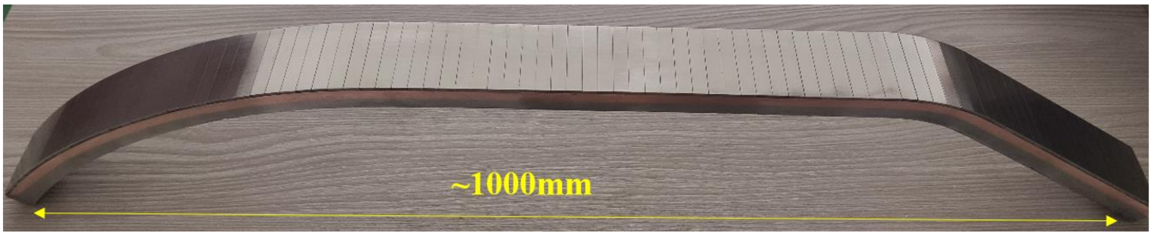
b) 

Figure 1. meter-scale W/Cu plasma facing unit, a) 15 MW/m^2 monoblock structure for target plate and flat type structure for baffle and b) 20 MW/m^2 flat type structure

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