In-situ leading edge induced thermal damages of melting and cracking on ITER-like W/Cu mono-blocks during long pulse operations in EAST

Dahuan Zhu\textsuperscript{a}, Changjun Li\textsuperscript{a,b}, Rui Ding\textsuperscript{a}, Baoguo Wang\textsuperscript{a}, Binfu Gao \textsuperscript{a,b}, Junling Chen\textsuperscript{a}

\textsuperscript{a} Institute for Plasma Physics, Chinese Academy of Sciences, Hefei, 230031, China
\textsuperscript{b} Science Island Branch of Graduate School, University of Science and Technology of China, Hefei, 230021, China

E-mail: dhzhu@ipp.ac.cn

Leading edge induced thermal issue is critical in future fusion devices which may use cassette structure for plasma facing surface [1]. EAST as a full superconducting tokamak with long pulse operation capacity has been successfully installed the actively cooled ITER-like W/Cu plasma facing components with W/Cu mono-blocks on its upper divertor target for high power exhaust [2]. The misalignments between neighboring W/Cu monoblocks are formed inevitably during fabrication and assembly processes, providing the possibility to investigate leading edge induced damages which are important references for ITER.

The severe damage of melting both on inner and outer targets was successfully observed during operation with a large number of droplets ejection from divertor by CCD camera, which was also identified at leading edges by postmortem inspection. Meanwhile, a lots of macro cracks with width of several tens \(\mu\)m and depth of several mm along toroidal and radial directions were also found universally at leading edges. Thermal analysis by means of finite element simulation shows that the peak temperature can easily reach up to several thousands of centigrade under current perpendicular heat load around 2 MW/m\(^2\) on flat surface (the corresponding parallel heat load of about 88 MW/m\(^2\)) with large misalignment up to several millimetres, which is high enough to induce melting of tungsten. Moreover, the residual thermal stress by thermal-mechanical analysis can also exceed the tensile strength, resulting in the formation of cracks at leading edges.

Although plasma operations, to some extent, could be operated with damaged W/Cu monoblocks, plasma disruptions were often observed after droplets ejection induced by melting [3]. What is more, such kind of melting could even cause the suspending of the operations for a time to replace the melted monoblocks during the last spring plasma campaign in 2019. Furthermore, it can be foreseen that leading edge induced thermal damages will become more serious with gradually increasing of perpendicular heat load up to 10 MW/m\(^2\) in future, which may be likely to restrict the acquirement of long pulse and high parameters plasma. So, such leading edge induced thermal damages on divertor target should be mitigated or avoided by further efforts in view of engineering design and optimization.