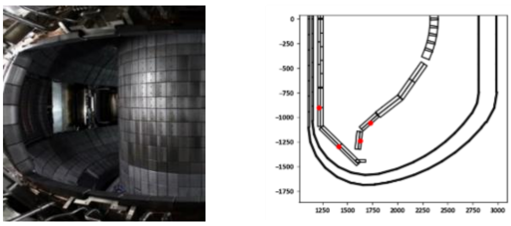
Neutron emission dependence on divertor material in KSTAR plasmas

Jong-Gu Kwak. [*],
[a] *KFE, Daejeon, Korea*
[*]*Corresponding author: jgkwak@kfe.re.kr*

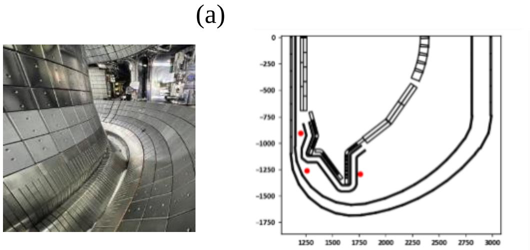
***Keywords : neutron**, diverter, KSTAR

1. Introduction

For future fusion demo reactor, plasma facing components require special conditions such as tritium compatibility so that tungsten is widely known to replace the graphite which has shown the excellent performance in present tokamak experiments due to low z atomic number characteristics. To accommodate this issue and solve the insufficient cooling capacity for the high power and long pulse operation in graphite PFC which has been used from the KSTAR first plasma, KSTAR is equipped with the tungsten mono block cassette type divertor on the lower part of divertors and has experienced two experimental campaign. The presentation will include the results of neutron emission both graphite and tungsten divertor in KSTAR and the correlation with the plasma performance is discussed.



(a)



(b)

Fig.1. lower diverter changes in KSTAR. graphite diverter(a) and tungsten diverter(b)

2. Diverter material change and neutron measurements

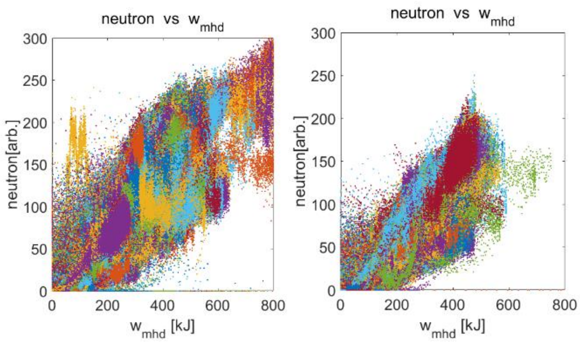
Originally the graphite tile is used at KSTAR since the first plasma as shown in fig1(a) and the cooling capacity was limited so that the new tungsten mon block cassette type is installed as shown in fig1b. and two experimental campaign has progressed.

The neutron emission is monitored by fission counter and diamond detector in KSTAR. The fission counter is used [1] its dependence is reported for whole campaign period. Compared with 2016 paper, new NBI system is added and graphite at the lower diverter is changed by tungsten. Wmhd is in the range of 500kJ with the available beam power of 5 MW. Fig 2 shows the neutron emission for all campaign 2022(a) and 2023 shots(b) when before and after the tungsten divertor is changes. The store energy is decreased and maximum neutron emission is also decreased

Most of KSTAR fusion reaction neutron is characterized by beam target reaction. It is derived by eq. (1)

$$Sn \propto \int P_{nbi} \tau_s n_i \propto \frac{1}{Z_{eff}} P_{nbi} T_e^{1.5} dV \quad (1)$$

Where Pnbi is neutral beam power, τ_s is slowing down time, ni is the ion density, zeff is the effective Z number and Te is the electron temperature.



(a) (b)

Fig.2. Neutron emission in 2022(a) and 2023(b) KSTAR campaign

3. neutron emission at L and H-mode in graphite and tungsten divertor

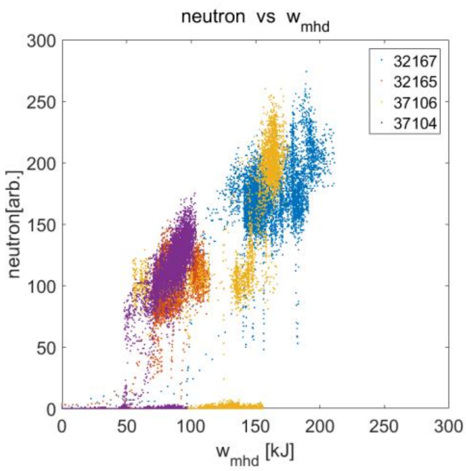
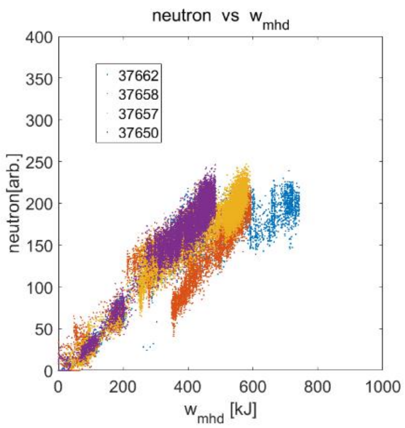


Fig.3. Neutron emission vs. Wmhd at L-mode in graphite and tungsten diverter

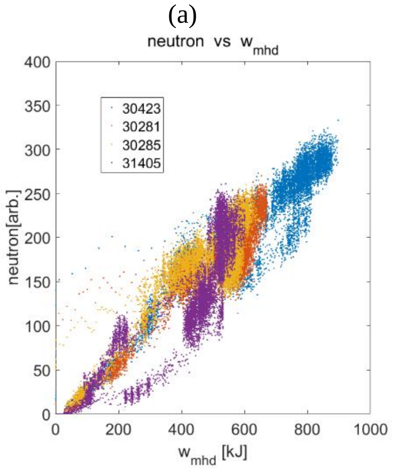
Shot #	32165	32167	37104	37106
Teo(keV)	1.5	1	2.2	1.6
Pnbi(MW)	0.8	1.0+0.4	1.0	1.8
Prad(arb.)	0.06	0.11	0.11	0.19
Ip(kA)	500	800	500	800
Diverter	graphite	graphite	tungsten	tungsten

Table 1. Electron temperature at center, nbi power and radiated power for typical L-mode shot in graphite and tungsten divertor.

Neutron emission vs. Wmhd for L-mode in typical shot in 2020(graphite) and 2024 campaign(tungsten) is shown in figure 3. Where neutron detector(#5) is used for low signal in L-mode. In graphite, the neutron emission is increased in Ip, but it is decreased in Ip at tungsten.
Due to short campaign period of 2023 after tungsten divertor was installed, plasma current up to 1 MA is not done and high Ip operation is not easy. Comprehensive analysis of high current operation can be done for 2024 long period. Especially for standard H-mode. Fig4 shows the neutron vs. Wmhd for Ip of 700, 800, 900, 1000 kA. At Ip is increased, neutron and Wmhd is increased in graphite. However, as Ip is increased, the neutron emission is saturated in tungsten diverter.



(a)



(b)

Fig.4. neutron emission vs. Wmhd for graphite(a) and tungsten(b)at H-mode

Ip(kA)	700	800	900	1000
Tio/Tiped	1.8/0.8	2.5/1	1.6/1	?
Teo/Teped	3/0.7	3.5/1	2.5/1	2.5/1
Pnbi(1+2)	3+3.9	2.6+3.9	2.6+3.9	2.8+3.9
Shot#	37650	37657	37658	37662

(a)

Ip(kA)	700	800	900	1000
Tio/Tiped	5.5/1.5	3.5/2	5/2	4/2
Teo/Teped	6/1	4.5./1.5	5.5/1.5	5.0/2
Pnbi(1+2)	3+1.9	3.5+1.8	3.6+1.8	3.6+2.2
Shot #	31405	30285	30281	30423

(b)

Table. 1. Ion and electron temperatures at peak and pedestal position for H-mode plasma shots in graphite(a) and tungsten diverter(b)

4. Summary

Neutron emission is compared in graphite and tungsten divertor in KSTAR. It is observed that neutron emission as well as plasma confinement is decreased at tungsten diverter than graphite diverter.

Acknowledgement
This research was supported by the R&D Program of "High Performance Tokamak Plasma Research & Development (EN2501)" through the Korea Institute of Fusion Energy (KFE) funded by the Government funds, Republic of Korea.

REFERENCES

[1] Jong-Gu Kwak, et al., Neutron emission in neutral beam heated KSTAR plasmas and its application to neutron radiography, FED, Vol.109, p. 186, 2016.
[2] K.M. Kim, et al., Thermal behavior of the KSTAR tungsten cassette divertor in KSTAR 2023 campaign, FED(211), 2025.