Simulation of carbon plasma transport at ITER-relevant conditions in GOL-3 facility

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ITER tokamak design is a reactor with heat flux on the divertor several times higher than in modern tokamaks. ELMy H-mode of ITER performance is the best operational scenario with good confinement and high thermonuclear plasma density. However, high heat flux during ELMs, have a severe impact on the divertor armour. Modern tokamaks do not produce ELMs powerful enough to damage the divertor but anticipated type I ELMs in ITER will vaporize the divertor armour. Vaporized armour material (carbon) is ionised by impact plasma stream and expands along the magnetic field to the thermonuclear core of the tokamak. Investigation of core plasma contamination in ITER is an important issue because massive influx of carbon plasma into pedestal may run the confinement into disruption. FOREV-2D code [1] is used for numerical simulation of this phenomenon and verification of the simulation results on the available plasma facilities improves their predictability.

The 12-meter linear GOL-3 facility was used for validation of FOREV-2D simulation results at plasma conditions, close for ITER type I ELMs. GOL-3 facility is a long open trap with corrugated (multumirror) field which consists of 55 cells with H_{max}/H_{min}= 4.8/3.2 T. Plasma is heated by ~120 kJ (~8 μs) electron beam. Collective plasma heating by the E-beam results in T_e~2 keV at ~10^{21} m^{-3} density. High T_e exists for ~10 μs. At this time T_i reaches 1-2 keV. Then the electron temperature rapidly decreases to the value below 100 eV. Ion temperature keeps at the high level. Energy confinement time in this configuration is ~1 ms at initial density of deuterium ~10^{21} m^{-3}.

Special experiments were carried out for investigations of carbon plasma transport along and across the magnetic field and validation of numerical results. Carbon pellet with diameter of 2 mm was placed in the centre of vacuum chamber of the facility. During the beam injection (~8 μs) carbon vapour cloud is formed around the pellet under the action of electron stream and deuterium plasma. The energy yield to the target can be varied in the range of 0.5-10 MJ/m^2 that is similar to conditions of ITER type I ELMs.

After the plasma heating (several microseconds) a dense carbon jet propagates along the magnetic field in the background hot plasma. Carbon plasma was registered at the maximal for GOL-3 distance of 5 meters from the pellet. The major task of experimental activity is the study of dynamics of plasma expansion, evaluation of carbon plasma transverse transport and estimation of the transport coefficients for numerical modelling. Spectra of radiation in visible and VUV regions at the different distances from the target as well as full transverse energy flux were measured. The spectral lines of single and double ionised carbon atoms dominate in the spectra. The energy loss is determined by line radiation in VUV spectral region. Experimental results and comparison with calculations are presented.

[1] http://eps2004.clf.rl.ac.uk/pdf/P1_135.pdf and references there.

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