(i) Last two years the fusion community studies the problem of increasing the plasma density in tokamaks. In particular the problem of thermal quench and density limit are discussed.

De Vries, P.C. et al 2011 Nucl. Fusion ***51*** *053018.*
D.Kh. Morozov, A.A. Mavrin. Stability of the radiative mode m = n = 0 and density limit in tokamaks. Contributions to Plasma Physics, v. 54, № 4-6, pp 570-574, 2014.
D.Kh. Morozov, A.A. Pshenov. Stabilization of radiation-condensation instability in tokamaks with beryllium wall. Proc. of 40th EPS Conf. on Plasma Phys., Helsinky, Finland, 1-5 July 2013, P1.128.
D.Kh. Morozov, A.A. Mavrin. Heat equilibrium and stability of L-mode in impurity seeded tokamak plasmas. Proc. of 41 th EPS conference on Plasma Phys, Berlin, Germany, June, 23-27, 2014, P4-033.

(ii) The different ways are proposed in order to increase the critical plasma density in tokamaks are proposed. In particular the ECR heating increase critical plasma density in some experiments.

(iii) Next step is more detailed theoretical analysis of disruptions in contemporary tokamaks and in ITER. Also the experiments with high plasma density are to be performed. Our paper is devoted to the density limit in tokamak-reactor. Some new way in order to achieve high parameter Q in controlled discharge is proposed.

Thermal equilibrium and density limit in tokamak-reactor

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The thermal balance in tokamak-reactors is discussed. The critical density is defined by the equality of heating (auxiliary plus fusion) power and radiation losses at the edge. The thermal equilibrium is described by the equation

$$\nabla \kappa_{\perp} \nabla T + P_{\alpha} - Q = 0 .$$

Here P_α is the fusion power input produced by α - particles, and Q describes the radiation losses. The critical plasma density is found from the condition of the total reradiation of the power input. The difference between radiation losses and power input by α - particles is shown in Fig. 1. It must be equal to the auxiliary heating power. There are two parts of the curve in Fig. 1, rising and falling down.

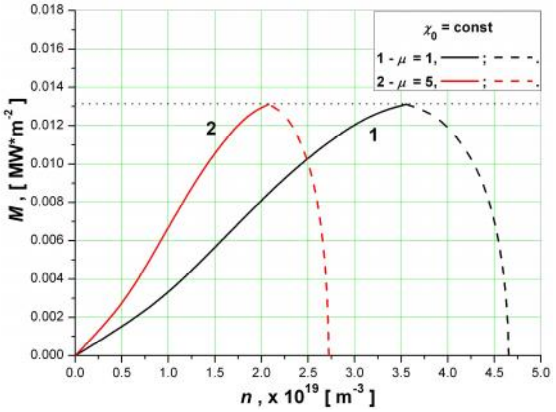

Fig.1

The first one (solid line) separates the stable region of regimes from unstable one. At the stable region the fusion impact is small. The total heating exceeds radiation losses, and is compensated by the heat conductivity. At the unstable region radiation losses exceed the total heating, and the thermal quench occurs. The falling solution (dashed line) separates two unstable regions. The fusion impact is significant. If the auxiliary heating is small the thermal quench takes a place. If the auxiliary heating is high enough the "self-heating" instability develops. Hence, the discharge moves to the ignition. However the regime related to the critical density may be stabilized by feedback control. Hence the discharge may be realizes as the controlled regime with very small level of the auxiliary heating and extremely large relation of the fusion power to the auxiliary heating.