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# Impact of the negative triangularity plasma shape on the n=0 resistive wall mode and vertical displacement event of tokamak

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Recently, some experiments with a negative triangularity plasma shape in TCV and DIIID tokamaks show promising performances by the reduced electron heat flux [1] and the increased plasma beta beyond the Troyon limit [2]. Theoretically, the normalized plasma beta may be explained by the reduced localized Mercier/Ballooning mode in the negative triangular shape [3]. For the negative triangularity ($\delta=-0.4$) of the last DIIID experiment [2], the elongation of the plasma shape was limited up to about $\kappa=1.3$ because of the poloidal magnetic field coil engineering. In the future experiments, more elongated shape is desirable for the high confinement, while it may be susceptible to have the vertical instability due to the non-optimized the triangular shape against the n=0 resistive wall mode [4]. In this study, we investigate the characteristic of MHD equilibrium of the negative triangularity, and its impact on the n=0 resistive wall mode, which can initiate the vertical instability.

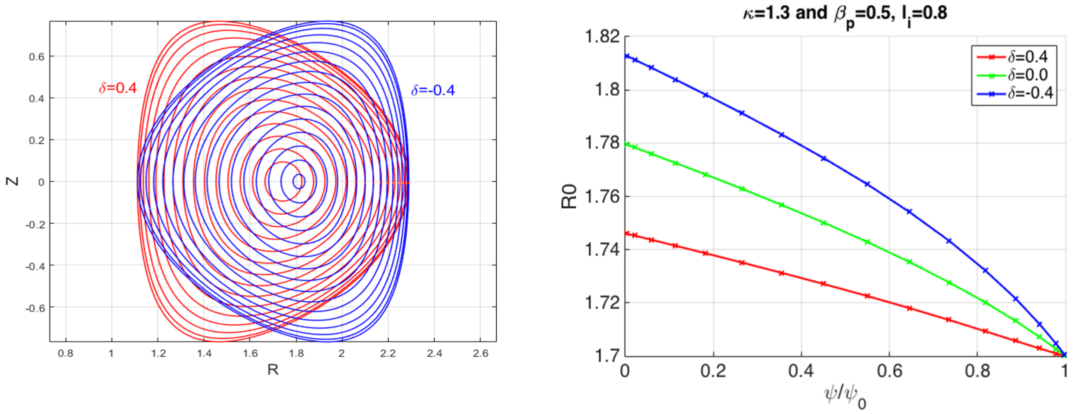

Figure 1: MHD equilibrium computed by ECOM for the DIIID tokamak parameters [2] Ip=0.9 MA, BT=2.0T, $\kappa=1.3$ with different triangularity: (a) 2-D contour plot of poloidal flux for $\delta=-0.4$ (blue) and $\delta=0.4$ (red) (b) Major radius change (Shafranov shift) of the flux surface center in terms of the normalized radius when the last closed flux surface is fixed as R0=1.7 m

Figure 1-(a) shows the MHD equilibrium of the DIIID case [2], which were computed by a Grad-Shafranov solver, ECOM [5] for different triangularity $\delta=-0.4$ (blue) and $\delta=0.4$ (red) when their inner and outer mid-points of the last-closed flux surfaces are coincided. We found several interesting points in the comparison of the equilibrium. As shown in Figure 1-(b), the shift of the magnetic axis (Shafranov shift) due to the pressure is much larger in the negative triangularity case. It turns out that the change of the shift due to the triangularity is proportional to the factor triangularity $-\delta/\sqrt{(1-\delta^2)}$ because of the boundary condition of the Grad-Shafranov equation. More interestingly, this change of the shift is severe when the elongation is smaller. Additionally, for the inner flux surface (as the radius decrease), the elongation rather increases in negative triangularity, while it decreases to $\kappa=1.0$ for the circle shape in the positive triangularity. The complicated characteristics of the MHD equilibrium contributes differently to determine how much n=0 RWM is destabilized in the non-optimized negative triangularity shape.

Figure 2 shows the results of the n=0 RWM fast computation code, AVSTAB [4], which shows the maximum elongation marginally stable against the n=0 mode for different triangularites in a given feedback parameter $\gamma\tau_W$. We modified the code AVSTAB to fix the wall shape and change the plasma shape and position to be compared with the experimental results. As expected in [4], the optimized triangularity occurs in the positive triangularity and the maximum elongation is reduced significantly in the negative triangularity. The blue curve of Fig 2-(a) for a fixed internal inductance ($l_i \simeq 0.55$) shows that $\kappa_{max}=2.0$ in the optimized triangularity $\delta=0.2$, while $\kappa_{max}=1.5$ in the negative tirangularity $\delta=-0.4$. However, the unstable degree of the negative triangularity is also sensitive to the plasma profile and the relative distance between the plasma and walls.

Fig 2-(a) shows that the different plasma internal inductance makes the different pattern of the maximum elongation in terms of the triangularity. The peaked profile for the larger internal inductance is helpful to reduce the instability and the decrease of the maximum elongation due to the negative triangualrity. It may be due to the larger Shafranov shift and the less dependency with the shape of the last-closed flux surface. Fig. 2-(b) shows that the move of the plasma centre toward the low magnetic field side (R_0=1.56⟶1.77) when the wall centre is fixed as R_W0=1.7 is useful to increase the stabilization and the maximum elongation for the negative triagnularity δ =-0.4.
By finding the complicated relation between the Shafranov shift, the plasma profiles, the wall geometry in MHD equilibrium and n=0 RWM stability, we may find a way to reduce the harmful effects of the negative triangularity on the vertical instability, while keeping the beneficial effects found in [1] and [2].

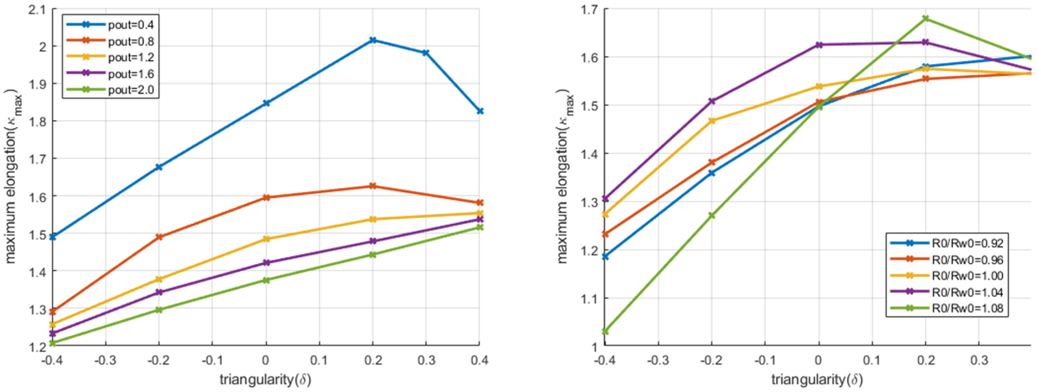

Figure 2: Maximum elongation κ_max against n=0 mode for the same DIIID condition as Fig. 1: (a) in terms of the triangularity δ for different internal inductance l_i, and (b) in terms of the plasma center position (R_0/R_w0) relative to wall. The poloidal beta and the feedback capability parameter are fixed in all simulations as β_p≅0.7 and γτ_W≅1.5. The internal inductance changes depending on the plasma profile parameter p_out in (a): l_i≈0.55 for p_out=0.4, l_i≈0.7 for p_out=0.8, l_i≈0.85 for p_out=1.2, l_i≈1.0 for p_out=1.6, and l_i≈1.1 for p_out=2.0.

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