Impact of negative triangularity plasma shaping on the n=0 resistive wall mode in a tokamak

ID: P8

Junhyuk Song[1], Carlos Paz-Soldan[2], Jungpyo Lee[1,3]
[1]Nuclear Engineering Dept. Hanyang University, South Korea
[2]Applied Physics and Applied Mathematics Dept. Columbia University, USA
[3]Plasma Science and Fusion Center, MIT, USA
jungpyo@hanyang.ac.kr

ABSTRACT

The axisymmetric (n=0) resistive wall mode instability is numerically investigated using a MHD instability code AVSTAB (Axisymmetric Vertical STABility) for the negative triangularity plasma shape, which has shown several benefits in terms of improved confinement time and fusion engineering. The plasma characteristics (poloidal beta and internal inductances) as well as the geometric effects (wall shape and plasma location) are important to determine the instability. In contrast to positive triangularity, the higher poloidal beta provides more instability drive for the negative triangularity because of the higher Shafranov shift and the higher elongation of the inner flux surface of the MHD equilibrium. Non-conformal wall shapes to the plasmas (positive triangularity wall and negative triangularity plasma) are found to be rather helpful to stabilize the n=0 mode, unless the plasma is too close to the walls at the nulls for the opposite triangularity.

BACKGROUND

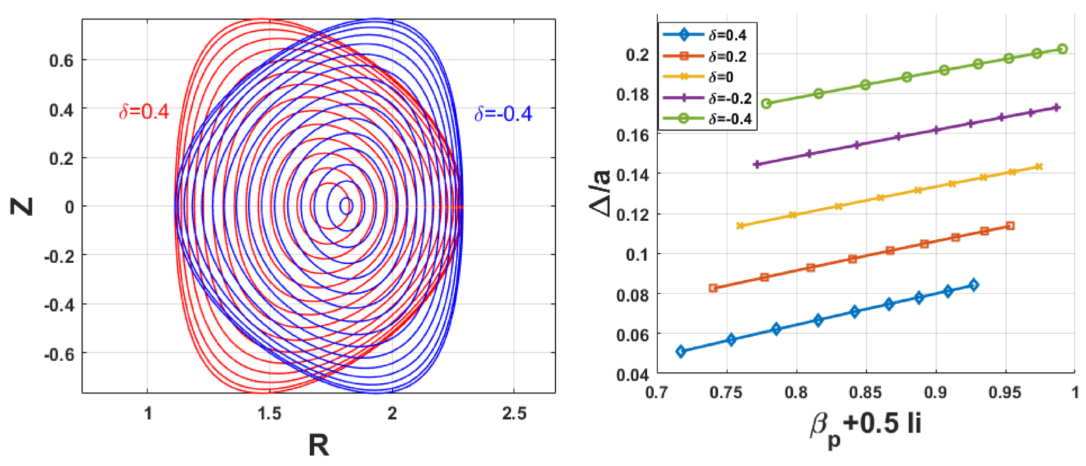
- Recent experiments with a negative triangular plasma in the TCV and DIIID tokamaks [1] have revealed several benefits, but the elongations of the plasma shape ($\kappa \simeq 1.3$) was relatively smaller than the conventional values ($\kappa \simeq 1.7$) of the positive.
- Higher elongation would result in the increased energy confinement time and it is limited by the n=0 RWM, which is numerically investigated by AVSTAB [2] and the MHD equilibrium code ECOM [3] in terms of the plasma characteristics (poloidal beta and internal inductances) and the geometric effects (wall shape and plasma location).
- In AVSTAB, the maximum allowable elongation κ_{max} (in which the RWM is marginally stable) is calculated with given feedback capability parameter $\gamma\tau_w$, γ is the instability growth rate and τ_w is the wall diffusion time.

CHALLENGES & OUTCOME

MHD equilibrium of negative triangular plasma shape

- **Shafranov shift**

- The negative triangular plasma shape has larger shift than the positive triangular plasma shape.

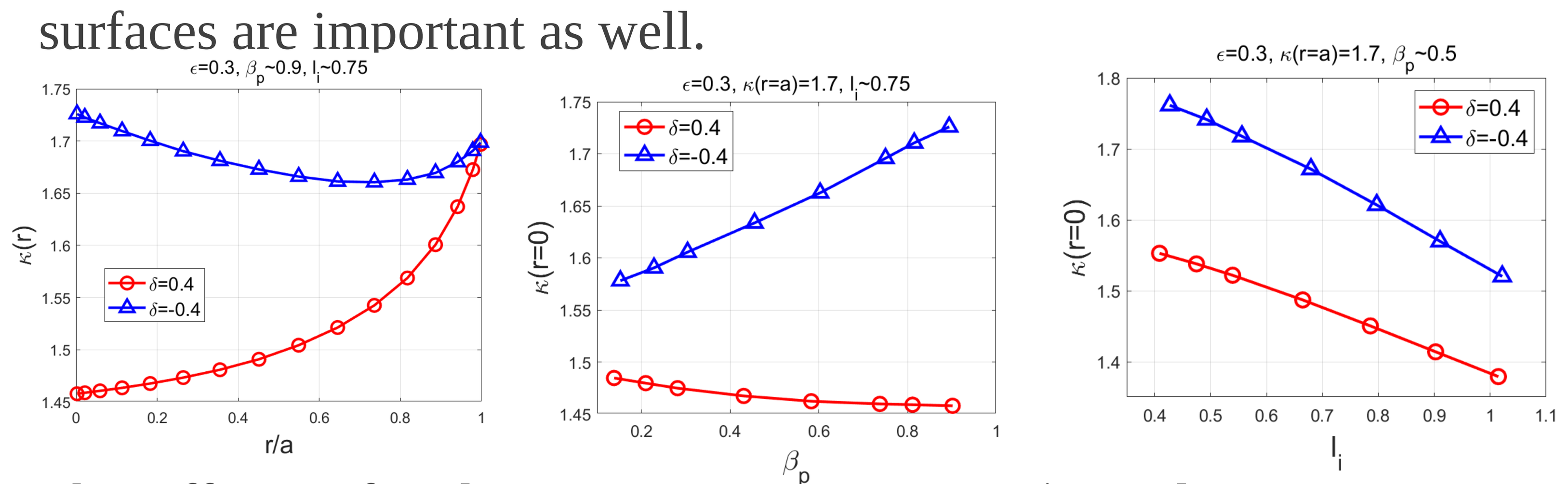


- The shifts are proportional to beta poloidal +0.5 internal inductance, but the shift also increases by the degree of the negative triangularity almost proportionally $\Delta(\delta) - \Delta(\delta = 0) \propto -\delta a$,
- In a simple interpretation, the first poloidal Fourier mode of the distance from the magnetic axis to the LCRF in the Miller parameterization determine the Shafranov shift.

$r_a(\theta) = a\sqrt{(\cos^2(\theta + \sin^{-1}(\delta)\sin\theta)) + \kappa^2 \sin^2\theta)}$, ⇒ $\hat{r}_{m=1} \simeq -\delta/4$ for κ = 1.0 and a small δ

- **Elongation of inner flux surfaces**

- Elongated plasma is vertically unstable, so elongations of the inner flux surfaces are important as well.



- The effects of poloidal beta on inner surface elongation are totally different between the negative and the positive triangularities.
- the elongation at the center increases as the internal inductance decreases.

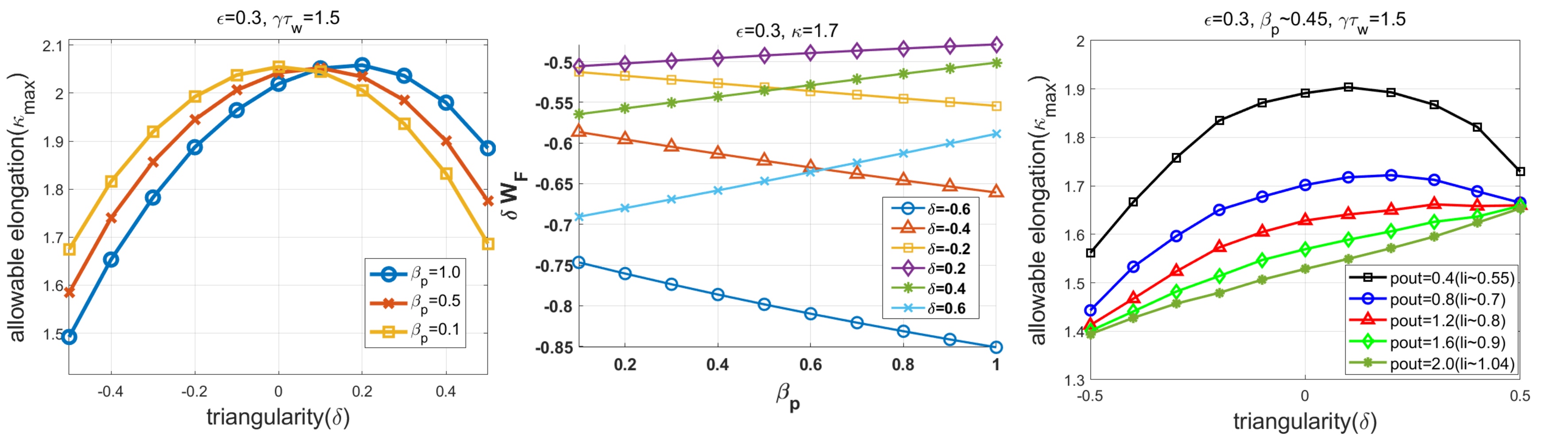
n=0 resistive wall mode of negative triangular plasma shape

- From the energy principle, the Lagrangian integral δW is expressed as follows, $\delta W_{total} = \delta W_F + \delta W_{VI} + \delta W_{VO} + \alpha W_D$. Where each contribution of fluid, inner vacuum, outer vacuum and wall is

$$\delta W_F = \frac{1}{2\mu_0}\int_{V_P}\left[\frac{(\nabla\psi)^2}{R^2} - \left(\mu_0 p'' + \frac{1}{R^2}F''^2\right)\psi^2\right]d\vec{r} + \frac{1}{2\mu_0}\int_{S_P}\left(\frac{\mu_0 J_\phi}{R^2 B_P}\psi^2\right)dS, \quad W_D = \frac{1}{2\mu_0}\int_{SW}\frac{\hat{\hat{\psi}}^2}{R^2}dS,$$

$$\delta W_{VI} = \frac{1}{2\mu_0}\int_{VI}\frac{(\nabla\hat{\psi})^2}{R^2}d\vec{r}, \quad \delta W_{VO} = \frac{1}{2\mu_0}\int_{VO}\frac{(\nabla\hat{\hat{\psi}})^2}{R^2}d\vec{r}.$$

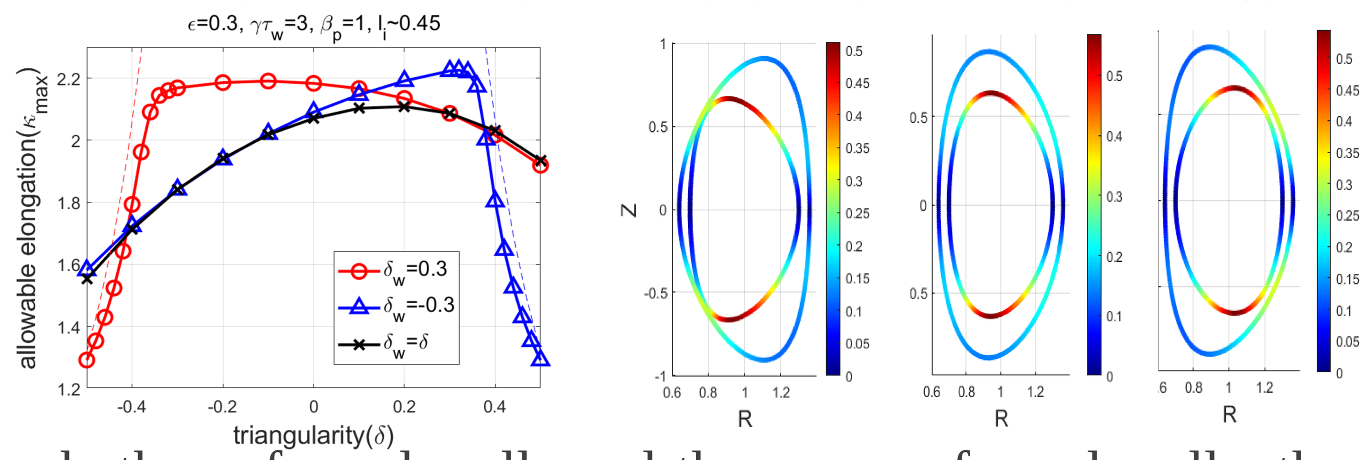
where $\psi, \hat{\psi}, \hat{\hat{\psi}}$ are the perturbed poloidal fluxes due to the RWM in the plasma region, the inner and the outer vacuum region.



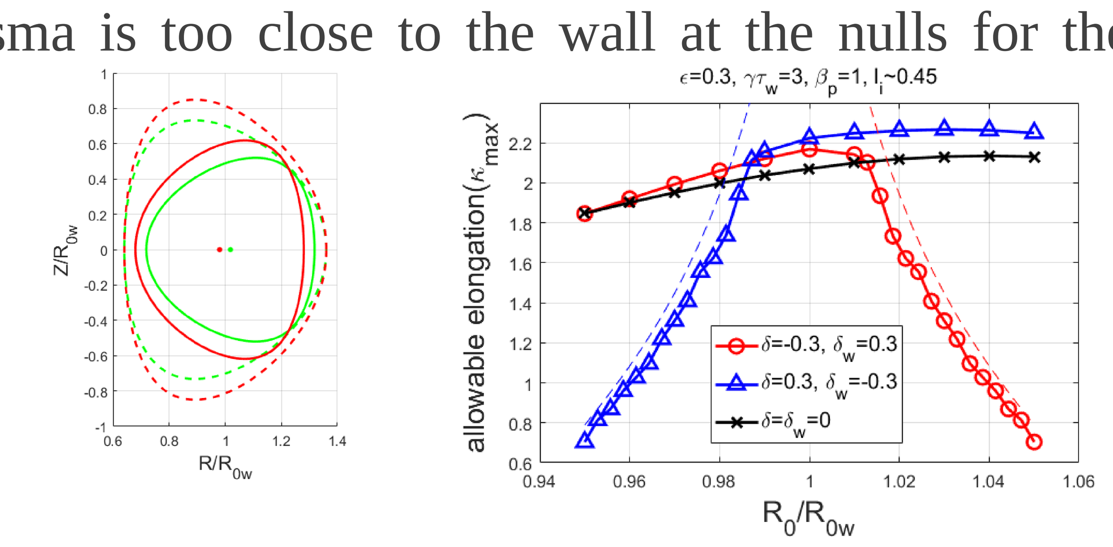
-With the negative triangularity, the κ_{max} decreases as the β_p increase for the negative triangularity, while increases for the positive one. The plasma contribution δW_F increase almost proportionally by the increased β_p, while it is reversed for the negative (MHD Equilibrium effects).

Wall effects on the n=0 RWM

- The maximum elongation against n=0 RWM is simulated in AVSTAB
- The non-conformal wall can be more stable for the n=0 RWM mode



- For both conformal walls and the non-conformal walls, the small move of the plasma center toward the low field side results in more stabilization.
- The large move toward any directions can degrade the stabilization, when the plasma is too close to the wall at the nulls for the opposite triangularity.



CONCLUSION

- The higher poloidal beta provides more instability of RWM for the negative triangular plasma, derived from the increased Shafranov shift and the elongations of the inner flux surfaces of the MHD equilibrium.
- In spite of the misalignment between the plasma and wall boundaries, the different triangularity of the plasma and wall can cause more stabilization.
- The effect has the optimal degree of the difference of non-conformality.
- When the plasma is too close to the wall at the nulls for the opposite triangularity, the strong instability occurs

ACKNOWLEDGEMENTS / REFERENCES

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