# VDE Simulation of the Snowflake Divertor Configuration in HL-2M

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1. ***Introduction.*** The vertical displacement event (VDE) is one of essential issues for vertically-elongated tokamaks. Thermal and electromagnetic loads during VDE are severe damage to in-vessel components of tokamaks. Estimating the magnitude of these loads is necessary for an engineering design. HL-2M is a vertically-elongated tokamak under construction, which will achieves advanced divertor configurations, such as the snowflake divertor. In this paper, the VDE under snowflake divertor configuration in HL-2M is investigated by DINA code [1-3].

2. ***Model.*** In HL-2M [4] model, sixteen PF coils, one CS coil as well as eighty-eight magnetic probes and fifty-two loops are installed. The vacuum vessel (VV) is divided into two hundred and ninety filaments. Divertor target plates are created by the limiter module. The computation domain covering 0.9~2.6m on the major radius direction R and -1.5~1.5m on the vertical direction Z is divided into 8385 grid elements. The geometry of HL-2M model for DINA code is shown in Fig. 1.

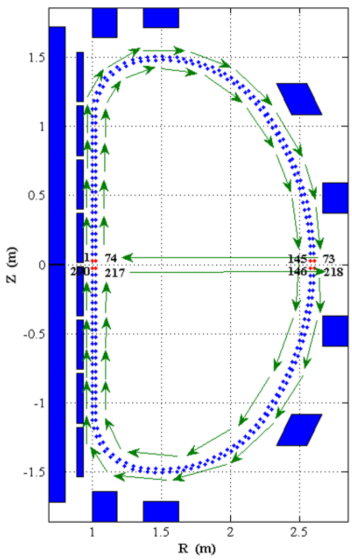


Figure 1. The geometry of HL-2M model for DINA

3. ***VDE away from null-points.*** The snowflake divertor configuration [5] has a larger poloidal weak field around the two null points than the standard one. In order to investigate the effect from the poloidal weak field when plasma moves away from null-points, a lower single-null snowflake configuration with upward VDE is simulated. Then it is compared to the

case of a lower single-null standard configuration with same main plasma parameters shown in Fig. 2. During the simulation, in the case of the feedback system fails, the plasma uncontrollably move upward duo to small perturbations of plasma parameters, evolving into an upper single-null standard divertor configuration. When the plasma column contacts divertor baffles, a limiter configuration forms. Then the thermal quench (TQ) and current quench (CQ) occur almost at the same time. The duration of current quench is 13.5 milliseconds and the peak of normalized poloidal halo current reaches 33.7 percent. By comparing with VDE of the standard divertor configuration, we found no obvious difference between the two VDE cases. This can also be reflected by evolution of these main plasma parameters shown in Fig. 3. Thus it seems that the lower poloidal weak field of the snowflake configuration plays an unimportant role when plasma moves upward.

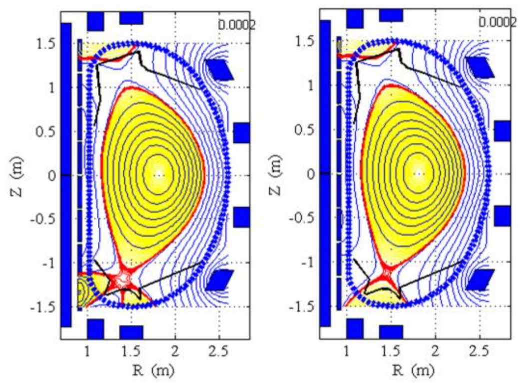


Fig. 2. The lower single-mull snowflake divertor configuration (left) and standard divertor configuration (right) in the flat phase of discharge.

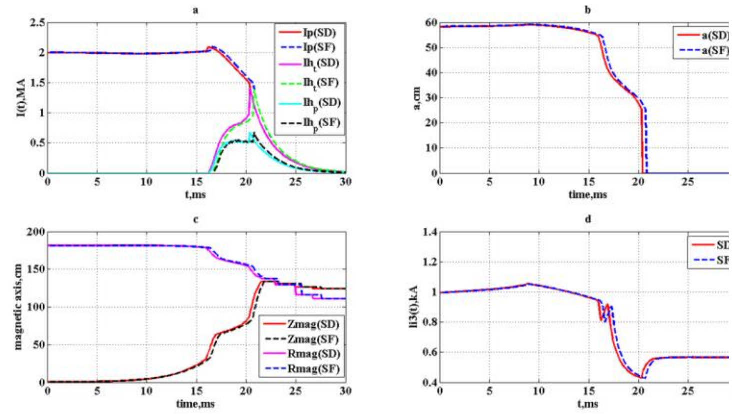


Fig. 3. Evolution of main plasma parameters: plasma current (a), halo current (a), the minor radius (b), the magnetic axis (c), the internal inductance (d).

4. ***VDE towards null-points.*** HL-2M has symmetrical poloidal field coils system and has the ability to generate double-null configurations. A double-null snowflake divertor configuration with upward VDE is simulated to investigate VDE towards null- points. Based on the analyzed result of part 3, effect from the poloidal weak field around lower null-points can be excluded. Here we still use the double-null standard

configuration with same main plasma parameters to compare as shown in Fig. 4. The change of the last closed flux surface (LCFS) under the snowflake VDE per 0.1 millisecond during the VDE is shown in Fig. 5. During the simulation of snowflake VDE, although the vertical instability still develops before the TQ, the upper poloidal

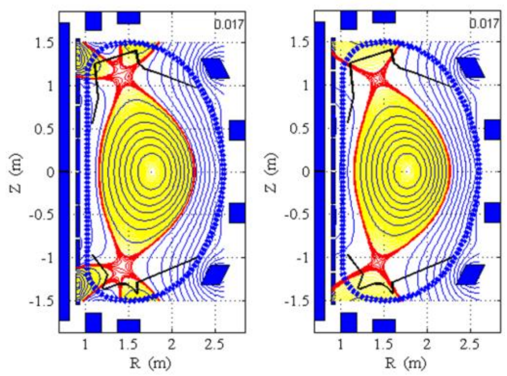


Fig. 4. The double-null snowflake divertor configuration (left) and standard divertor configuration in the flat phase of discharge.

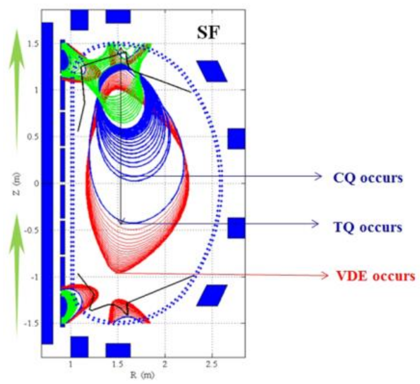


Fig. 5. Change of the LCFS of snowflake divertor configuration during VDE.

weak field may partly slow down the development. Under this effect, the vertical movement velocity of the plasma column before the TQ is slower than the case of standard VDE. During the TQ, sudden large perturbations of plasma parameters cause the velocity reaches a peak. After that the vertical instability is restrained duo to the energy release and the effect from upper divertor baffles as shown in Fig. 6. As the safety factor decreases during the CQ, the core plasma becomes more and more unstable, and finally the current decay rate suddenly reaches a peak. This will give rise to the spike of halo current. By the comparison, it is found value of the normalized poloidal halo current peak under snowflake VDE reaches 51.3 percent, which is 30 percent larger than the case of standard. Meanwhile a shorter duration of

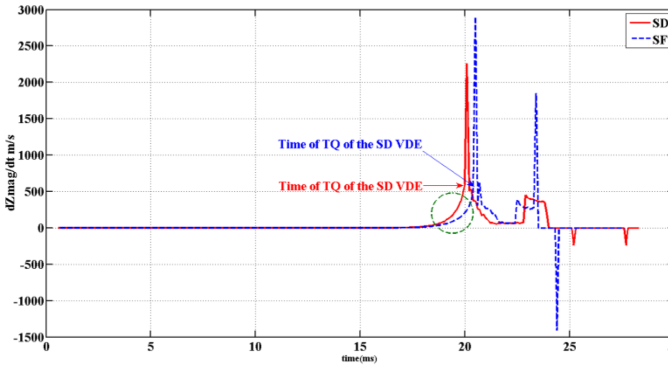


Fig. 6. Time trace of the velocity: standard (red) and snowflake (blue).

the CQ, about 7.4 milliseconds, is also obtained under snowflake VDE shown in Fig. 7.

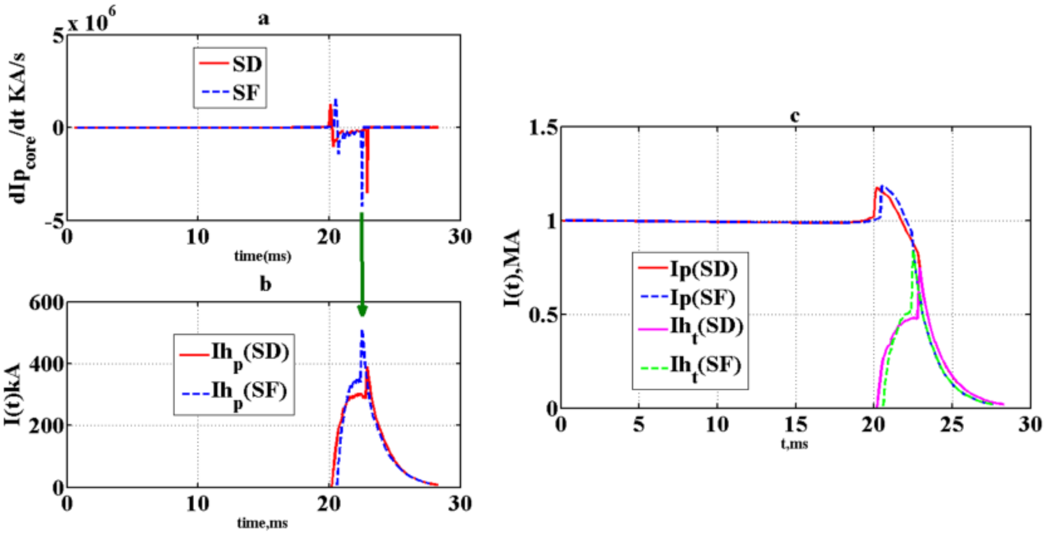


Fig. 7. (a) Evolution of the core plasma decay rate, (b) evolution of the poloidal halo current, (c) evolution of the total plasma current and toroidal current.

5. ***Summary.*** Simulation results show that the magnetic configuration on the plasma movement direction actually influences the process of VDE. For the case towards null-points, comparing with the standard, vertical velocity of the snowflake VDE is slower duo to the effect from the poloidal weak field around two null-points. This may be beneficial for control. But the higher peak of normalized poloidal halo current and shorter duration of the CQ may give rise to larger electromagnetic force on in-vessel components. This should be focused on the tokamak engineering design.

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## *References*

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