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Minimum spatial scale for maintaining vigorous magnetic reconnection

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Magnetic reconnection drives the fast release of magnetic energy in explosive events such as magnetic substorms in the Earth's magnetosphere and flares in the solar corona. On the large scale, reconnection is an MHD-scale process but its rate is controlled by the compact electron diffusion region (EDR), where electrons are not magnetized. Recent kinetic simulations have revealed the structure of EDR in a quasi-steady reconnection rate. In some works, it is suggested that an elongated electron jet in the outflow region does not affect the reconnection rate. However, it is not clear the spatial scale for determining the rate. We find that the minimum spatial scale for maintaining magnetic reconnection by using kinetic simulations on periodic and reflective wall boundary conditions. On the periodic condition, an outflow jet extends a large distance downstream from the X-line with the fast rate of reconnection. However, the influence of periodicity shortens the jet to a narrow structure though the rate of reconnection is still fast. This structure is the minimum spatial scale for maintaining magnetic reconnection. On the other hand, asymmetric reconnection is performed on the reflective wall condition to lead a slow motion of the diffusion region away from the wall, the so called 'X-line retreat.' During the retreat motion an outflow jet is blocked by the wall though the rate of reconnection is maintained. The structure of the blocked jet is very similar to the minimum spatial scale on the periodic condition. We quantitatively show the minimum structure for maintaining magnetic reconnection by comparing the result on these periodic and reflective conditions. We also find the minimum structure is independent of domain sizes but gets smaller with decreasing electron mass.

Keywords: magnetic reconnection, electron diffusion region