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Collisionless Magnetic Reconnection and Dynamo Processes in a Spatially Rotating Magnetic Field

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Spatially rotating magnetic fields have been observed in the solar wind and in the Earth's magnetopause as well as in reversed field pinch (RFP) devices. Such field configurations have a similarity with extended current layers having a spatially varying plasma pressure instead of the spatially varying guide field. It is thus expected that magnetic reconnection may take place in a rotating magnetic field no less than in an extended current layer. We have investigated the spontaneous evolution of a collisionless plasma system embedding a rotating magnetic field with a two-and-a-half-dimensional electromagnetic particle-in-cell (PIC) simulation. It is found that a magnetic-flux-reducing diffusion phase and a magnetic-flux-increasing dynamo phase are alternating with a certain period. The temperature of the system also varies with the same period, showing a similarity to sawtooth oscillations in tokamaks. We have shown that a modified theory of sawtooth oscillations can explain the periodic behavior observed in the simulation. A strong guide field distorts the current layer as was observed in laboratory experiments. This distortion is smoothed out as magnetic islands fade away by the O-line diffusion, but is soon strengthened by the growth of magnetic islands. These processes are all repeating with a fixed period. Our results suggest that a rotating magnetic field configuration continuously undergoes deformation and relaxation in a short time-scale although it might look rather steady in a long-term view.