Force by cross-field current between electrodes on a plasma confined by a
cusp magnetic field

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In a recent experiment (Collins et al., PRL 108, 115001) a plasma confined by a cusp magnetic field was set into rotation by the $j \times B$ force due to a current between electrodes inserted into the edge region of the plasma. The goal of a similar experiment is to create a dynamo in the magnetic field free bulk plasma. In order to find out how much momentum can be transferred to the plasma in such an experiment, we studied the process of plasma acceleration with particle-in-cell simulations resolving the full gyro-motion. The current flow parallel to and across the field lines of the magnetic field, the force on the plasma and the resulting plasma velocity in the direction of $j \times B$ are calculated. A slab model is used with a two-dimensional magnetic field corresponding to a periodic array of alternating magnets. A fixed potential difference is applied to the electrodes which are altogether electrically floating in the plasma. The plasma is uniform in the third dimension which is the direction of $j \times B$ and of the resulting flow. The cusp magnetic field, produced by permanent magnets, decreases strongly with distance from the magnets. While the electrons are mainly following the field lines, the ion gyro radii can be comparable to the gradient lengths of the magnetic and electric fields such that the usual expressions for particle drifts do not apply. The results of the simulations are: With non-emitting electrodes the current is limited to the ion saturation current. With strong electron emission at the cathode a much larger current can flow provided a strong plasma source is supplying enough electron-ion pairs for maintaining the current, since the electrons from the cathode cannot reach the anode. Near the electrodes the current is carried by electrons parallel to the field lines, while the cross-field current is carried by ions. The dependence of the volume integrated force and of the plasma momentum on the position of the electrodes and on the magnetic field parameters is determined.