Numerical Experiment of Emergence of Kink-unstable Flux Tube to Understand Formation of Delta-sunspots

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The so-called "delta-sunspots" are known to be among the most flare-productive active regions in the solar atmosphere. Observations show that a fraction of the delta-sunspots emerge with strong magnetic shear and with polarity orientations not following the Hale-polarity rule obeyed by the majority of active regions. To understand the observed evolution of these active regions, MHD simulations have been carried out in which a subsurface twisted kink-unstable flux tube emerges from the convection zone into the solar atmosphere. From the simulations, unlike the previous expectations based on the rigid emergence of a knotted tube, we found that a kinked tube can form a complex photospheric magnetic structure during the emergence. The photospheric magnetic polarities exhibit rotational motion and their evolution is coupled to coronal field conditions (rapid expansion and possibly reconnection). We identified that the spot rotation is driven by the torque arising from the mismatch in twist between the coronal part and parent flux tubes. On the basis of the idealized numerical experiments, we will discuss the complex magnetic field evolution and the energy transport process. This study would be important for understanding the formation of delta-sunspots with complex structures.