The role of η-quenching in MHD flux transport dynamo

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“Flux-transport dynamo” (FTD), which is one model of the solar dynamos, succeeded to reproduce the basic solar cycle features. However, most of FTD studies have addressed the time-development of the magnetic field in a purely kinematic regime. In a kinematic regime, the fluid velocity is given from observation or other theories, so only magnetic induction equation is solved. On the other hand, in a non-kinematic (or MHD) regime, both of magnetic field and fluid velocity field are computed by solving magnetic induction equation and Navier-Stokes equation. So this regime allows for the feedback of the Lorentz force on fluid velocity field. Rempel (2006) conducted FTD simulation in a non-kinematic regime and showed FTD model worked successfully even if strong feedback on fluid velocity existed.

Here we address FTD simulation based on the model of Rempel (2006) and includes “η-quenching”, which is not considered in Rempel (2006). It is known that the turbulent magnetic diffusivity used in the solar dynamos is quenched by the existence of strong magnetic fields. This phenomenon is called as η-quenching. And η-quenching can be a powerful mechanism for amplifying magnetic fields (Gilman & Rempel, 2005). The following presents the reasons why we include the effect of η-quenching. One reason is that the maximum magnetic field strength is around 15 kG in Rempel (2006), though rising flux tube simulation (Weber et al., 2011) concluded that magnetic flux tubes forming sunspots should have field strengths around 40-50 kG. The other reason is that no study has investigated the role of η-quenching in a non-kinematic FTD model. Stronger magnetic fields amplified by η-quenching result in stronger feedback to fluid velocity. To investigate this effect, we need to conduct a non-kinematic dynamo simulation in which both of velocity fields and magnetic fields are computed.

We find that η-quenching can amplify magnetic fields even in a non-kinematic regime and the maximum magnetic field strength can be up to around 2 times larger than the case without the effect of η-quenching. However, this amplification leads to the significant feedback to fluid velocity. This feedback makes the amplitude of temporal variations of the solar rotation rate, which is known as torsional oscillations, too large to be consistent with observation.

