AN ENERGY STORAGE MECHANISM FOR A SOLAR FLARE BY SHEARING THE MAGNETIC FIELD

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ABSTRACT. The complete set of MHD equations is solved by numerical calculation. The aim is to study the energy storage mechanism of a solar flare by shearing the magnetic field. Results show that the magnetic energy is stored in local regions and is large enough to explain a big solar flare.

Gold et al. suggested that the energy is stored by twisting a magnetic flux tube and Liu et al. Showed quantitatively their evolution. Tanaka et al. gave the energy stored in the sheared linear force-free field. We deal with the non-linear coupling effects between the flow field and magnetic field and obtain the quantitative relationship for their dynamical evolution.

The ideal MHD equations can be written as follows:

$$\begin{cases} \dfrac{\partial \rho_*}{\partial t} + \nabla\cdot(\rho_* \bar{v}_*) = 0, & (1) \\ \rho_*\left[\dfrac{\partial \bar{v}_*}{\partial t} + (\bar{v}_*\cdot\nabla)\bar{v}_*\right] = -\nabla p_* + \dfrac{1}{4\pi}(\nabla\times\bar{B}_*)\times\bar{B}_* + \rho_*\bar{g}, & (2) \\ \dfrac{\partial \bar{B}_*}{\partial t} = \nabla\times(\bar{v}_*\times\bar{B}_*), & (3) \\ \nabla\cdot\bar{B}_* = 0, & (4) \\ p_* = \kappa\rho_*^{\gamma}. & (5) \end{cases}$$

Here the two-dimensional three-component problem is studied by means of numerical methods.

The initial magnetic field satisfies equilibrium equation:

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = 0. \qquad (6)$$

J.-P. Swings (ed.), Highlights of Astronomy, 767–768.
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https://doi.org/10.1017/S1539299600007280 Published online by Cambridge University Press

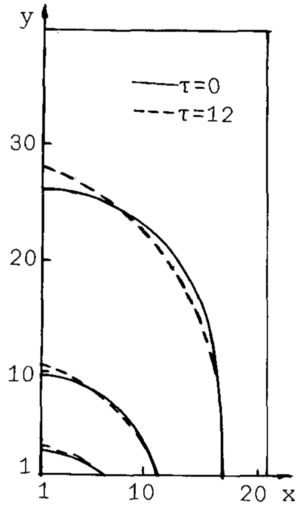
One of the lower boundary condition is the shear velocity of plasma at the bottom of solar atmosphere which we write in the form

$$w = 2w_4 x(x^2-1)[-w_1(x^2-1) + 2]e^{-w_1 x^2} \quad \text{on } y=0. \tag{7}$$

The other boundary conditions are based on projected characteristic equations by using characteristic theory (Liu).

The computational configuration of the magnetic field is given in Fig. 1. Correlations between magnetic energy and time are presented in Fig. 2 where Δw_B means the total magnetic energy growth ratio.

The arched bipolar magnetic configuration obtained by numerical calculation is consistent with results observed. Fig. 2 shows that the magnetic energy of horizontal magnetic field component reaches 1.9×10^{32} erg at 650 sec. The total magnetic energy growth ratio reaches 3.1% at 650 sec.. The net increase of magnetic energy may be on the order of 3.7×10^{32} erg during a day if it increases at the same rate as before. This huge magnetic energy storage in local active regions of the solar atmosphere can be considered as a source of the explosion for a big flare.



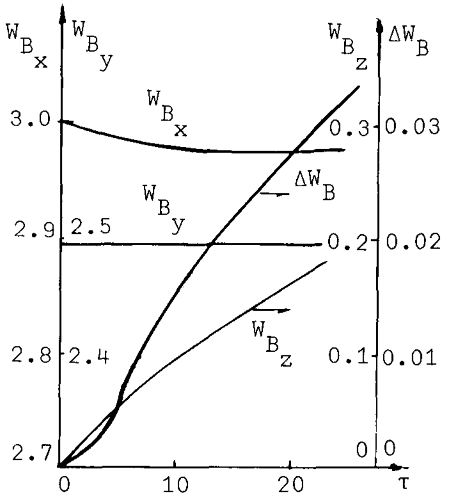


Fig. 1 The computational configurations of the magnetic field at τ=0(solid) and at τ=12 (dashed).

Fig. 2 Magnetic energy versus time.

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https://doi.org/10.1017/S1539299600007280 Published online by Cambridge University Press