THE QUASI-STATIC EVOLUTION OF MAGNETIC STRUCTURES ON THE SUN AND THEIR TOPOLOGICAL RECONSTRUCTION

Yu.G.MATYUKHIN and V.M.TOMOZOV
664033, Irkutsk 33, P.O.Box 4026,
SibIZMIR, USSR

ABSTRACT. We have considered the problem of quasi-static evolution of a magnetic configuration as it is affected by shear motions at field line footpoints. It is found that, with a certain character of the shear motions at the field line footpoints, topological reconstruction will, by necessity, occur in the magnetic configuration. A pattern of magnetic field lines during the course of configuration restructuring is constructed.

We consider the problem of quasi-static evolution of a magnetic structure on the Sun such as a loop arcade under the action of shear motions of a certain kind of field line footpoints in the photosphere. Equations describing the quasi-static evolution of a magnetic structure are derivable from a system of MHD equations by the method of expansion in small parameter $\alpha^2 = (v/v_A)^2 \ll 1$ (v being the velocity of motions, and v_A, the Alfven velocity, respectively). A 2D-configuration of the magnetic field $\vec{B} = \{\vec{e}_z \times \nabla u, \vec{e}_z B_z(u)\}$ ($\vec{e}_z u = \vec{A}$ being a vector-potential) is considered.

The boundary-value problem (BVP) has the form:

$$\left.\begin{array}{ll} \Delta u = -\lambda f(u) & \partial u/\partial y(y = b) = 0 \\ u/s = g(x) & \partial u/\partial x(|x| = a) = 0 \end{array}\right\} (*)$$

where λ is a parameter, and $f(u)$ is a function related in some way to $B_z(u)$. If $B_z(u)$ is a unique function at a given u, then all solutions of the system (*) for a given λ, possessing a different field topology, will correspond to the same displacement. We specify the function $f(u)$ such that the BVP (*) had in a certain finite range of λ-values three solutions at least. To do this, it suffices to postulate that $f(u) \sim u^s$ and $s > 3$ when $u \to 0$ and, besides, $f(u) = 0$ when $u > u_0$ (Heyvaerts et al., 1980). The BVP (*) was solved by the method of upper and lower solutions (Matyukhin and Tomozov, 1989) using the particular values of the parameters $a = 3$ and $b = 6$ in units of the scale $\ell_0 = 10^9$ cm. Let us now clarify the character of the magnetic

E. R. Priest and V. Krishan (eds.), Basic Plasma Processes on the Sun, 345–346.

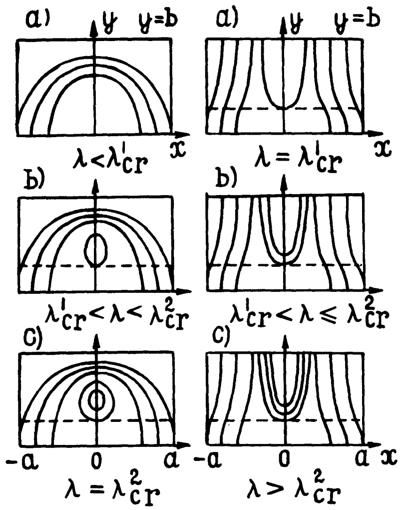

Fig. 1 Fig. 2

field topology for different solutions of the BVP (*). Fig. 1 (a,b, c) shows a typical topology of magnetic field lines for the lower solution of the BVP. From Fig. 1 it is easy to see that, for the entire range of values of the parameter λ in which the lower solution exists, the field lines have a closed topology. In the process of evolution from $\lambda = 0$ to $\lambda = \lambda^2_{cr}$, a "magnetic island" is generated inside the magnetic configuration, i.e., a region of closed field lines unembedded in the photosphere.

The magnetic field line topology for the upper solution as a function of the parameter λ is shown in Fig. 2 (a,b,c). Note that in the above range of variation of the parameter λ all magnetic configurations are open, and inside the field lines embedded in the photosphere there are open field lines with $B_z(u) = 0$ (with a zero shear of the magnetic field). Note that all solutions (upper and lower) describing the closed and open field topologies, are stable to 2D-disturbances which do not alter the problem symmetry along the Z-axis.

In order to describe the evolution of a magnetic configuration, it is necessary to investigate the dependence of the full magnetic energy of the structure on the value of shear (the parameter λ) for a closed and open magnetic structure. This suggests the following scenario of a quasi-static evolution of an arcade (Matyukhin and Tomozov, 1989). Under the action of a shear motion the originally closed equilibrium magnetic structure necessarily evolves to such an equilibrium state that it becomes linearly unstable so that if the value of magnetic field shear reaches $\lambda = \lambda^2_{cr} = 4$, then the magnetic structure ought to reach a new stable equilibrium state with a change in magnetic field topology (from closed to open), with the release of the accumulated free energy of the field.

REFERENCES

Heyvaerts J., Lasry J.M., Schatzman M., and Witomsky G. (1980), Lecture Notes in Mathematics, 782, pp. 160-191.

Matyukhin Yu.G. and Tomozov V.M. (1989), In: AGU Chapman Conference on: Physics of Magnetic Flux Ropes, Extended Abstracts, Hamilton, Bermuda, March 27-31, pp. 146-157.

https://doi.org/10.1017/S0074180900088239 Published online by Cambridge University Press