FILAMENT FORMATION DUE TO PHOTOSPHERIC SHEAR

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INTRODUCTION

Recently, Wu et al. (1983, 1986) have developed a three-dimensional, time-dependent axisymmetric ideal magnetohydrodynamic (MHD) model which has been used to study lower solar atmospheric responses due to photospheric motion. They have shown that various observed solar features can be formed from these numerical simulation experiments. In this short note, we shall report some work currently in progress which has resulted from a specific numerical simulation experiment. These results may elucidate the possible physical mechanism of formation of filament.

NUMERICAL RESULTS

The initial state for this ideal MHD model is an isothermal ($T = 10^5$ K) in hydrostatic equilibrium ($n = 10^{10}$ cm^{-3}); and permeated by a dipole potential magnetic field that has a strength of 8 Gauss at the photospheric level (i.e., x-z plane) which gives a plasma beta being 0.14. With this initial equilibrium state, we introduce a spatially-distributed sine curve type of shear motion (i.e., in the x-z plane). The shear speed is zero at the neutral line and is a maximum (1.0 km s^{-1}) at the edge of the magnetic arcade. The evolution of the magnetic field configuration due to this prescribed shear motion is shown in Figure 1. The corresponding induced current distribution is shown in Figure 2a,b for several times at two specific heights (y = 1,500, 2,500 km) and distributed over a relatively small (8,000 km) scale in the horizontal direction (x-axis). Also, the induced current distribution as a function of altitude at a horizontal position of 2,500 km from the neutral line is shown in Figure 2c. The corresponding plasma properties (i.e. density and temperature) at a specific height and horizontal position are given in Figure 3. To summarize these results, we make the following observations;

(a) Figure 1 shows that the field lines have orderly changes up to 2,000 s after introduction of the shear motion in the x-z plane. A drastic deformation of magnetic field topology occurs during the interval between 2,000 s and 2,500 s.
Physically, this result shows that some of the field lines collapsed to form a current sheet (Figure 1). The appearance of a high density region is coincident with the current sheet; it further shows that the outer edge of the magnetic field has locally been pushed open.

(b) A further, specific, comment may be made about the current sheet. From Figure 2, we can identify the location at t = 2,500 s, of the maximum current density (~10^3 Amp km^{-2}). Specifically, this peak is located at 3,500 km from the neutral line and within the height interval between 1,500 km and 2,500 km.

(c) The density and temperature plots in this region (Figure 3) show that the density has been enhanced 30% ~ 40% and temperature has decreased ~20%. Based on these physical properties, we suggest that the shear motion induced a region which is characterized by a high current plasma density, high density and low temperature. This combination of physical parameters contains all the characteristics for a filament. Since the MHD model for this simulation incorporates ideal MHD theory, we may conclude that the filament could be formed by a plasma pinch effect. Details of this simulation will be given by Wu (1986).

ACKNOWLEDGEMENT

This work is supported by a NAGA Headquarters Grant NAGW-9, NASA/MSFC Grant NAG8-053, and NASA/MSFC Contract (NAS8-33526).

REFERENCES

Wu, S. T., Y. Q. Hu, Y. Nakagawa and E. Tandberg-Hanssen, "Induced Mass and Wave Motions in the Lower Solar Atmosphere. I. Effects of Shear Motion of Flux Tubes", Ap. J. 266, 866-881, 1983.

Wu, S. T., Y. Q. Hu, Y. Nakagawa and E. Tandberg-Hanssen, "Induced Mass and Wave Motions in the Lower Solar Atmosphere II. Effects of Converging and Diverging Photospheric Motions", Ap. J., 1986 (in press).

Wu, S. T., "Magnetohydrodynamic (MHD) Modelling of Solar Active Phenomena Via Numerical Methods" Solar Physics, 1986 (submitted).

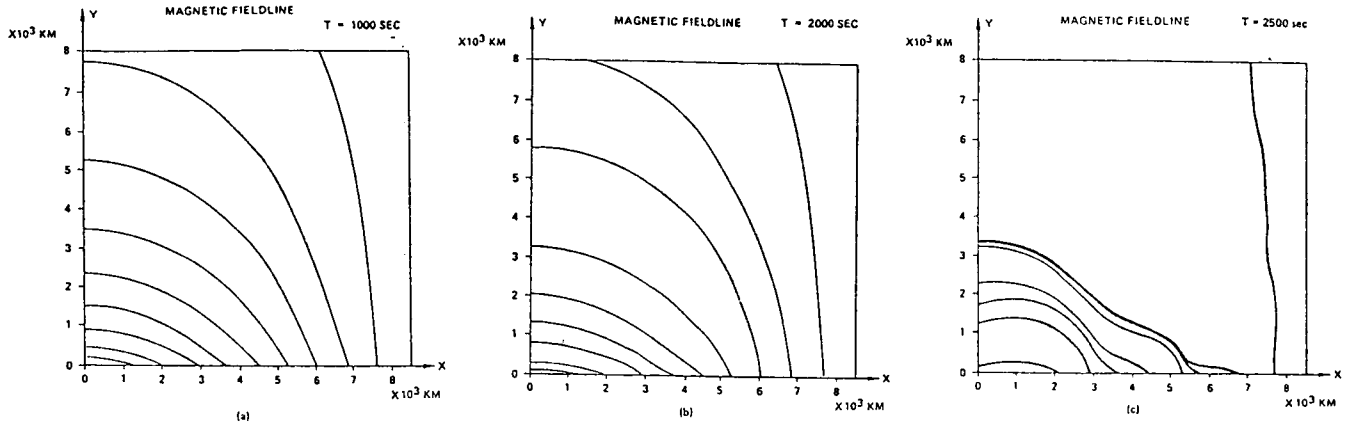

Figure 1. Computed evolution of magnetic field lines due to photospheric shear.

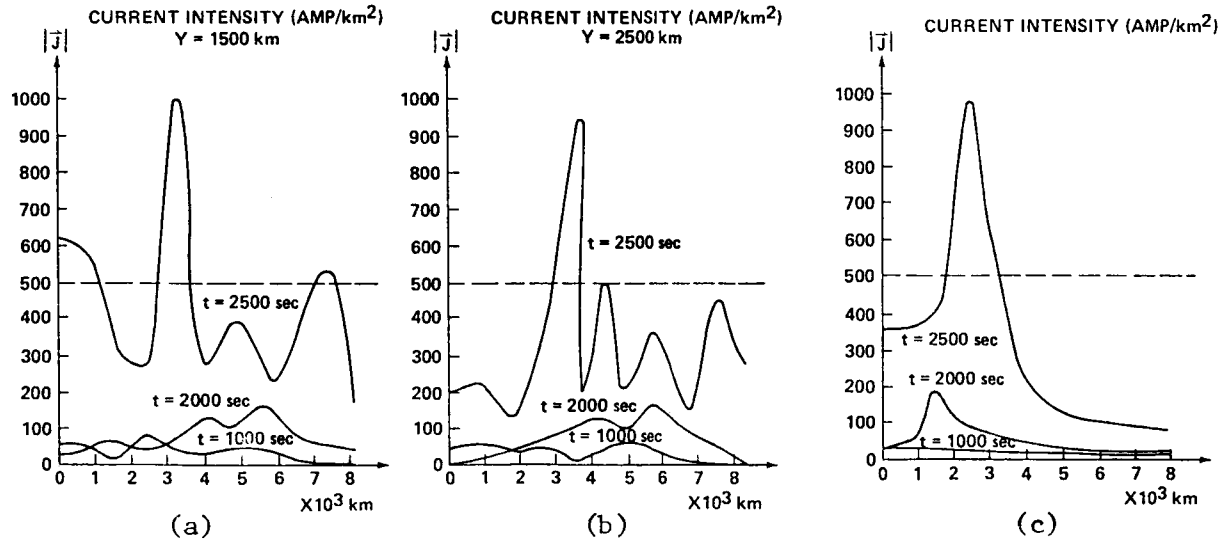

Figure 2. Computed indueced current intensity vs horizontal axis at two specific heights (i.e., y = 1,500 km and 2,500 km; 2a, 2b) and vs height at a specific horizontal position (x = 2,500 km) with several times (1,000 s, 2,000 s, and 2,500 s).

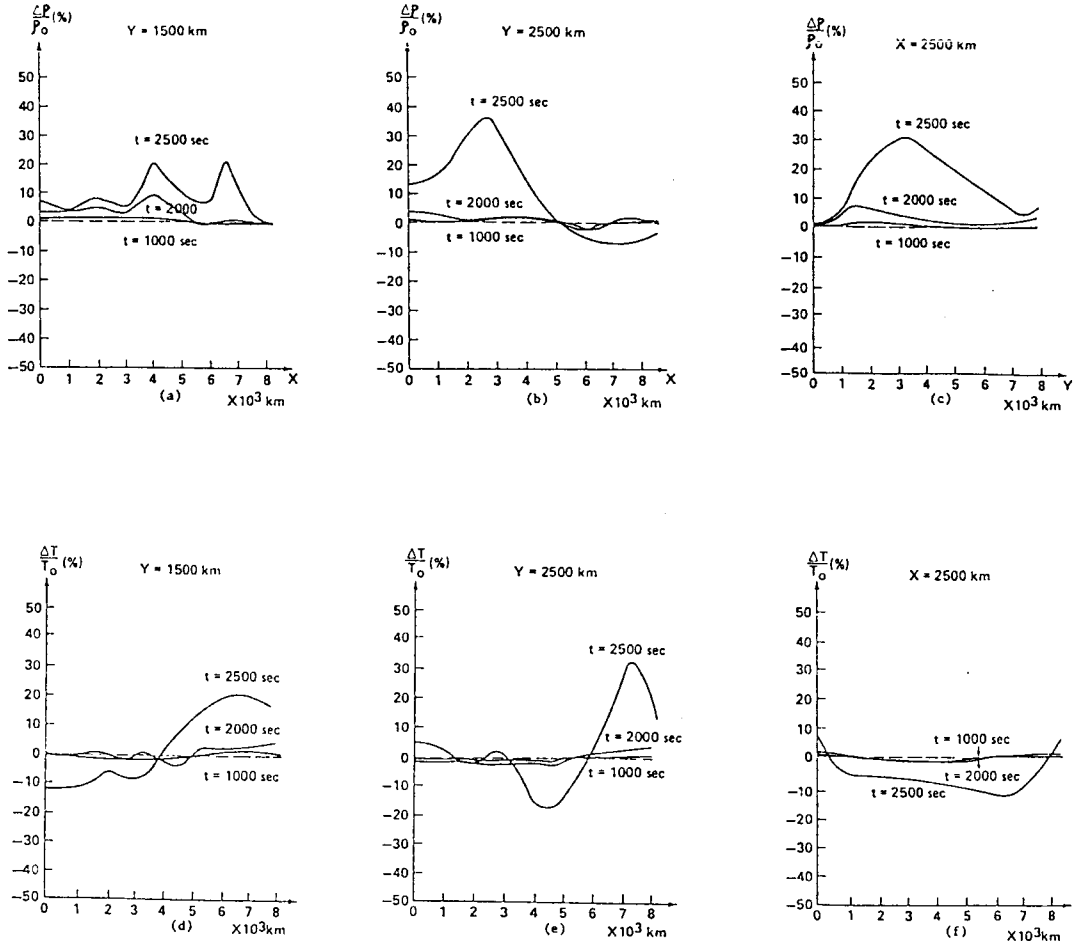

Figure 3. The plasma density (a,b,c) and temperature (e,f,g) distribution as a function of height and horizontal axis at several times (1,000 s, 2,000 s, and 2,500 s).