Simulation Study of Non- Linear Explosive behavior of Single/Double Tearing Modes

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Abstract

Through computer simulations, now it is possible to analyze the fast evolving dynamics of magnetic reconnection. This research study is mainly focused on the non-linear dynamics of double tearing mode (DTM) and the single tearing mode. Numerical simulations of the reduced two field magneto-hydrodynamics (MHD) equations in slab geometry are performed. During the non-linear analysis of DTM, an explosive increase in the growth rate of DTM is observed for some specific values of Ly. Simulation results show that this explosive growth of DTM is due to the generation of fast growing secondary instability.

The same procedure is applied to investigate the non-linear dynamics of the single tearing mode (STM). It is found that for sufficiently large values of the instability parameter Δ′ and low resistivity, the X-point of the island collapse and Secondary Island is formed. The effect of this secondary island on the kinetic flow and current modification is also investigated. However, some of the simulation results are yet to be explained in physical terms.

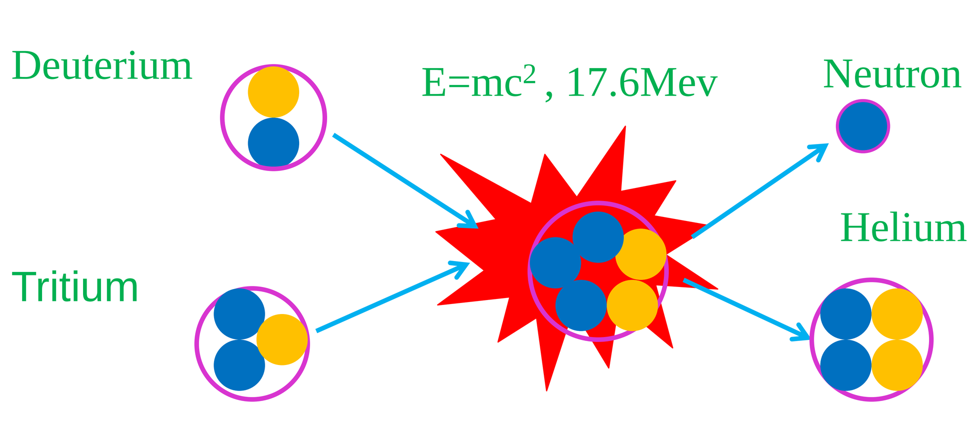
Introduction

Is there any perfect energy source?[1]

- ✓ Free of CO_2 emission
- ✓ No long living radioactive waste
- ✓ An inexhaustible fuel to burn
- ✓ No risk of a severe accident

The answer is "yes" and that is "Nuclear Fusion".

What is Nuclear Fusion?

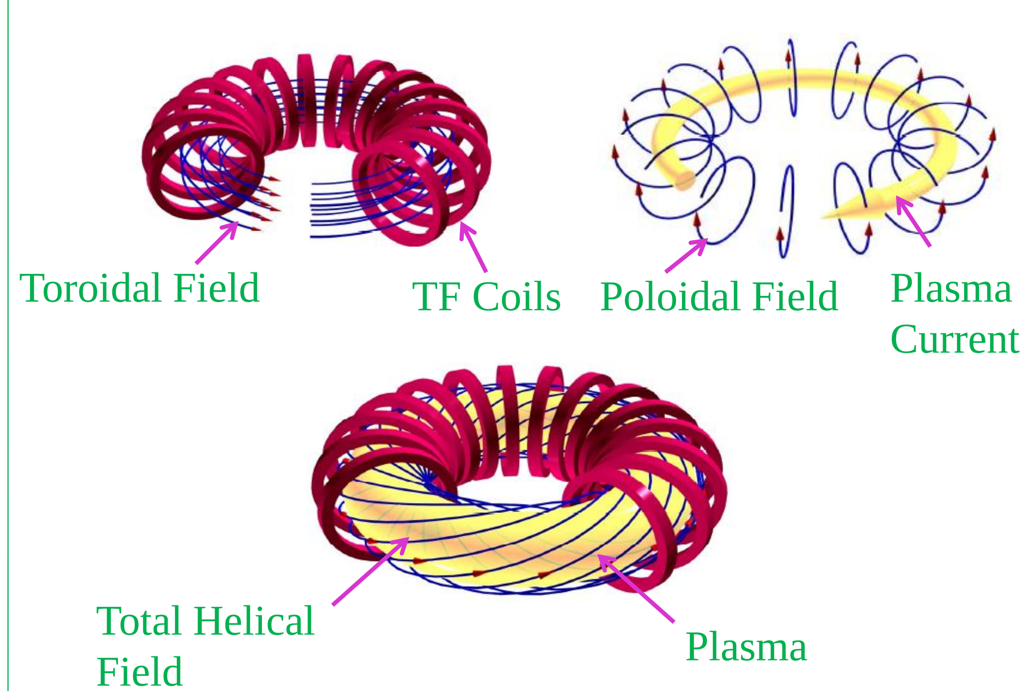


Out of 17.6Mev of energy, neutron takes 14.1Mev and 3.5Mev goes to α-particle

How to realize the dream of fusion energy true ?

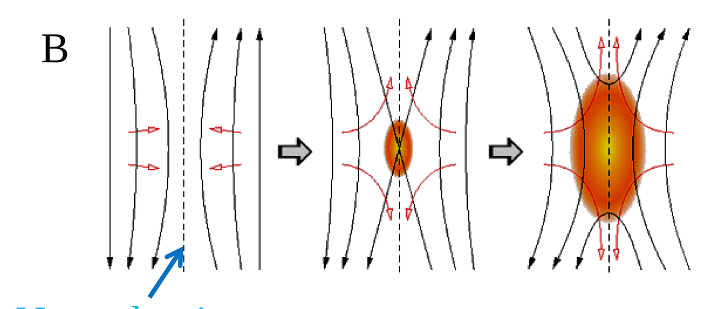
In order to make the fusion energy possible, the concept of "Tokamak" is introduced. It is a fusion device, which make use of the magnetic fields to confine the hot plasma.

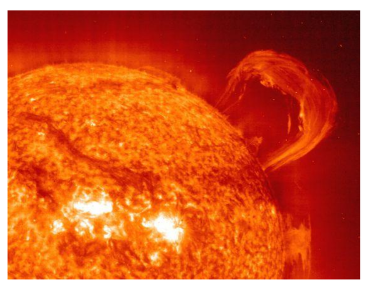
Basic Tokamak Geometry:



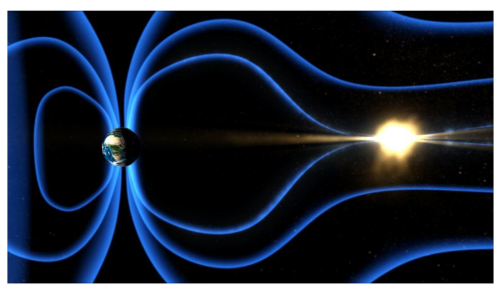
Magnetic Reconnection[2, 3]

A non-zero resistivity η of plasma allows the topology of the magnetic field to change near a neutral point . This process of breaking and reconnecting of the oppositely moving field lines is known as magnetic reconnection[2, 3]. Examples of reconnection in nature are solar flares and reconnection in earth's magneto-tail.





Solar flares



Magnetic reconnection in Earth's Magneto-tail

Tearing Instability:

Tearing mode is spontaneous (i.e., non-driven) magnetic reconnectin in the presence of a strong magnetic field (guide field). Tearing mode is unstable only if the instability parameter is positive, i.e. $\Delta' = \frac{\psi_1'(+0) - \psi_1'(-0)}{\psi_1(0)} > 0$

As a result of tearing instability we get the modified magnetic field configuration, called the magnetic island.

Simulation Model

Our simulation model is based on 2-field reduced MHD equations in slab geometry;

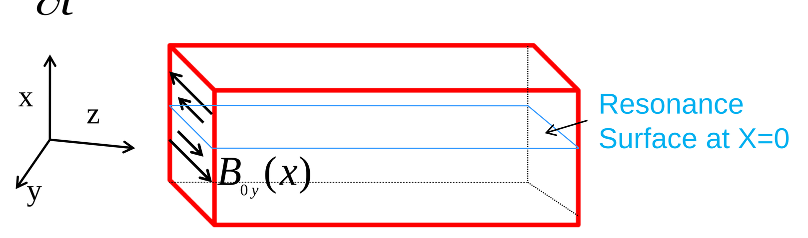
$$\frac{\partial \psi}{\partial t} = -[\phi, \psi] + \frac{1}{S}\nabla^2 \psi$$

$$\frac{\partial (\nabla^2 \phi)}{\partial t} = -[\phi, \nabla^2 \phi] + [\psi, \nabla^2 \psi]$$

Here, ψ is the flux function and φ is flow function

x-direction: Finite difference method

y - direction: Fourier Decomposition

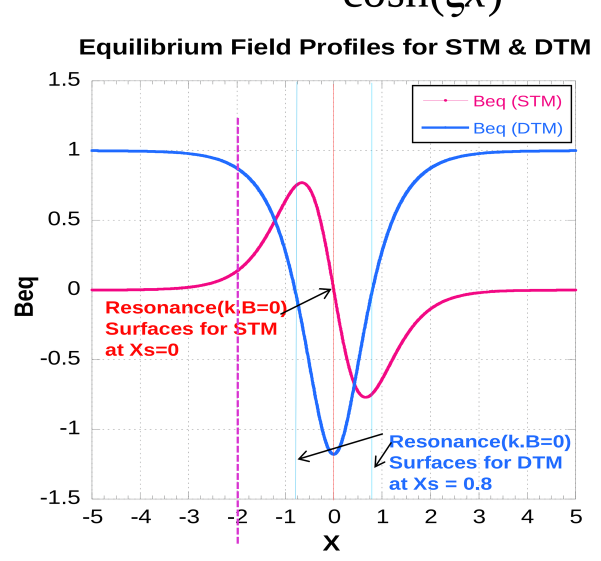


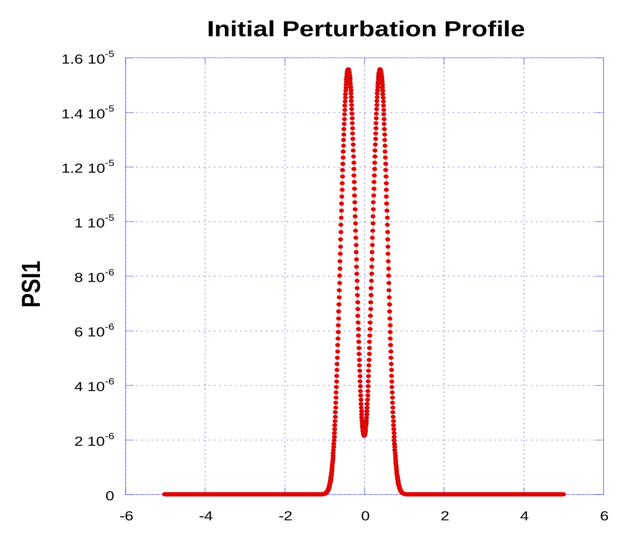
Simulation Geometry: Slab geometry is used;

Where, the equilibrium field is along y-axis and perturbation is applied along x-axis.

Equilibrium profile for Double Tearing Mode (DTM) and STM are given below [4].

For DTM: $B_{0y}(x) = 1 - \frac{(1+B_c)}{\cosh(\xi x)}$ and for STM: $B_{0y}(x) = -2\text{sec}h^2(x)\tanh(x)$

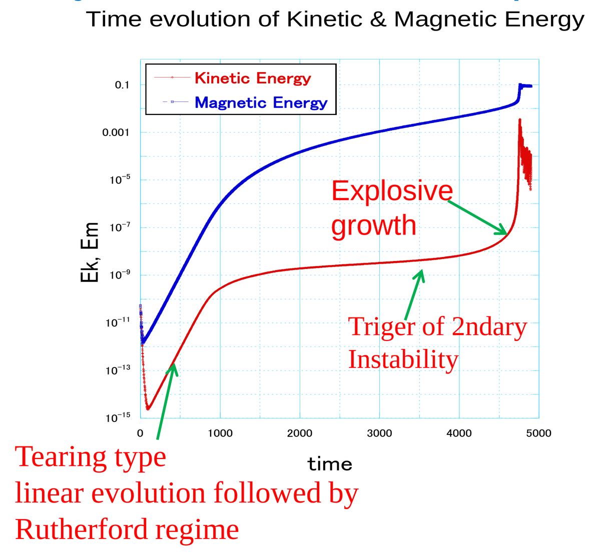


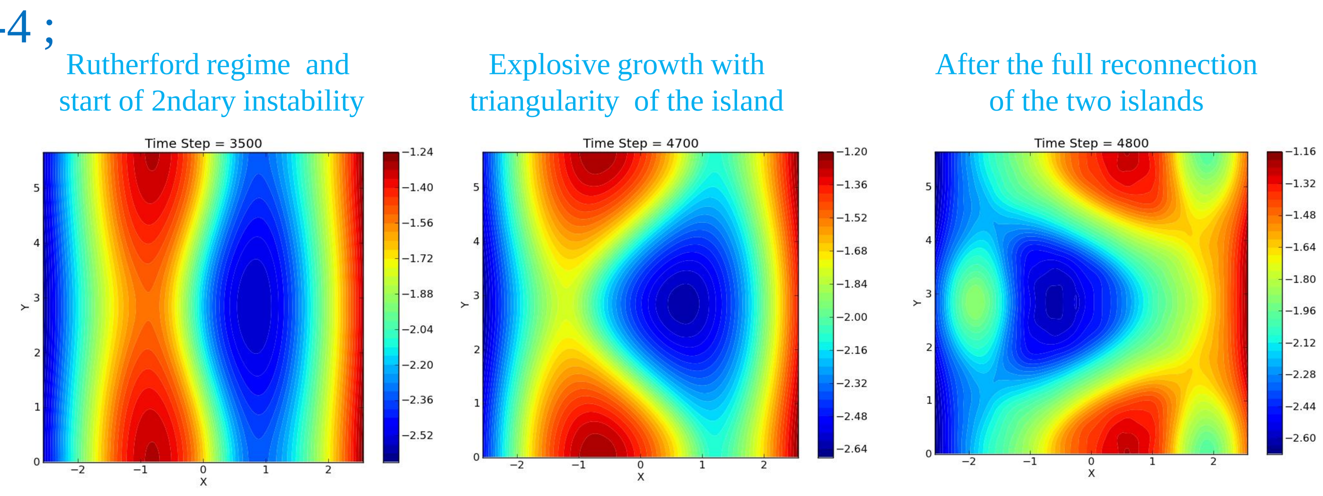


Results

Non-Linear Simulation of DTM: Explosive growth of secondary Instability;

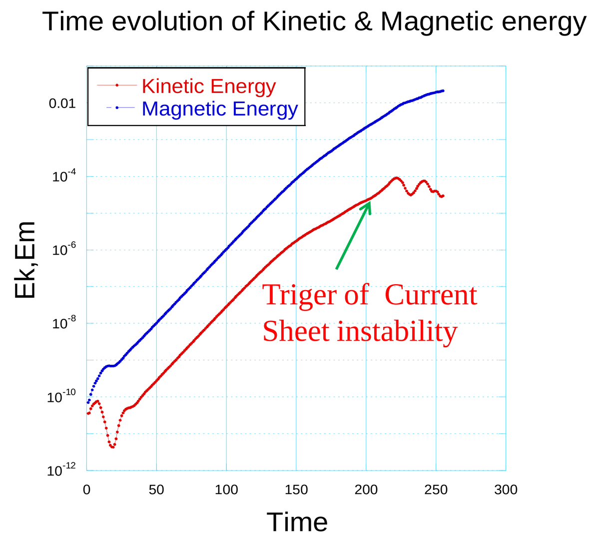
Ly = 0.9, Xs = 0.8 and η=1.E-4 ;

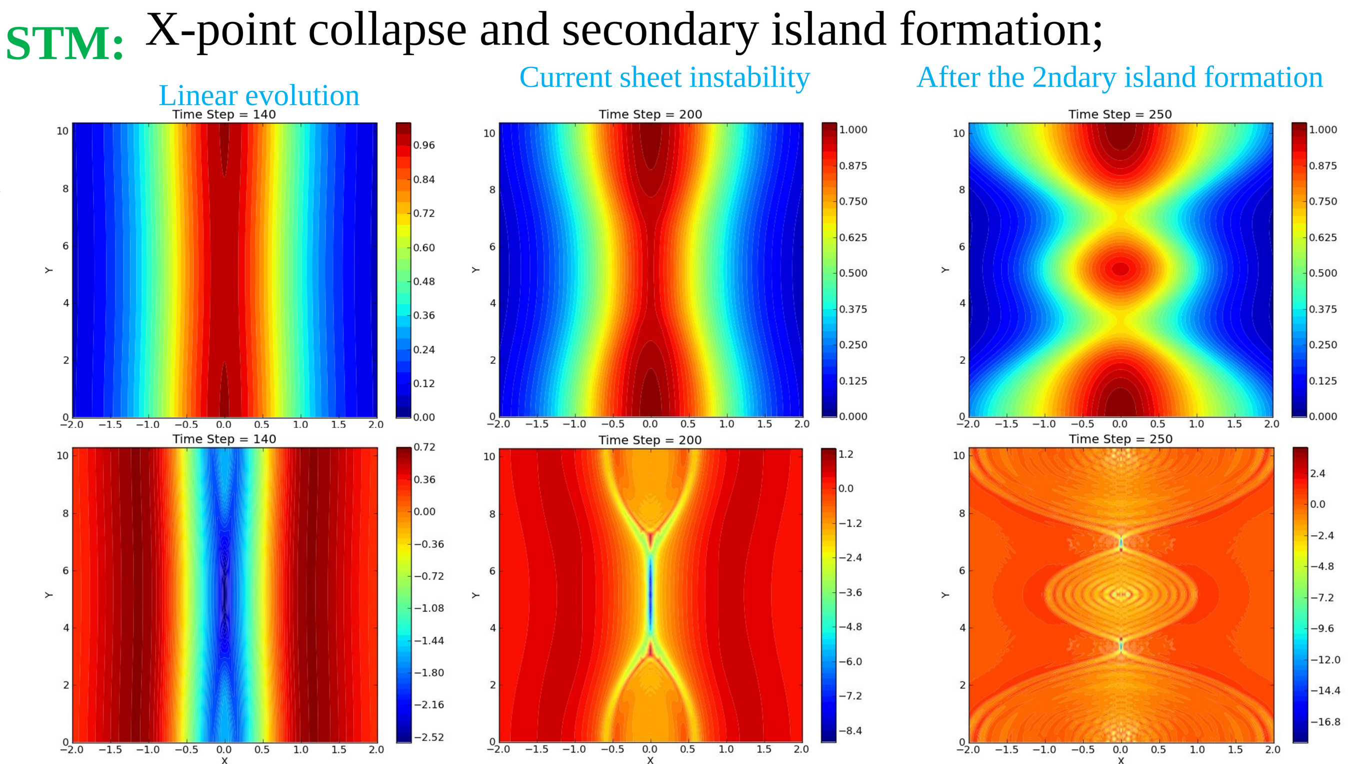




Non-Linear Simulation of STM: X-point collapse and secondary island formation;

Δ′=40.6 and η=2.8E-4:





Conclusions

Two field reduced MHD equations are used to do the linear and non-linear study of double tearing mode (DTM)and single tearing mode(STM). In case of DTM an explosive secondary instability is observed,whereas, for STM formation of secondary island takes place. Now, the aim of our research is to understand the physics of these explosive type secondary instabilities.

References

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[4] Pritchett et-al, "Linear analysis of the DTM",Phys. Fluids, 23(1980).