Computation of Ideal Magneto-Hydrodynamic Equilibrium of PASEO

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GOALS

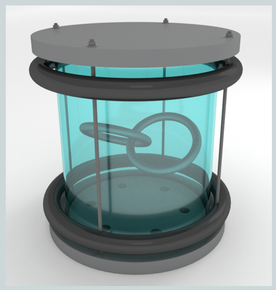
- Determine the ideal Magneto-Hydrodynamic (MHD) equilibrium of The Princeton Adaptable Stellarator for Education and Outreach (PASEO)
- Develop a software stack in order to rapidly solve for ideal MHD equilibrium using VMEC

INTRODUCTION

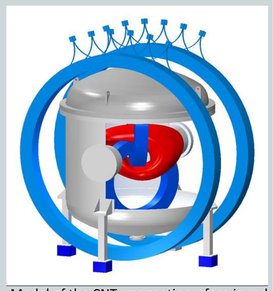
- A stellarator is a plasma confinement device that implements electromagnetic coils with no need for toroidal current drive in the plasma
- PASEO is a table top stellarator currently being developed by PPPL in order to facilitate public demonstrations of stellarator physics as well as support graduate/undergraduate experiments
- Ideal MHD equilibrium ensures on a macroscopic level that a plasma can be confined by a magnetic field. This is important in order to optimize the magnetic surface for both public demonstrations and experiments.

PHYSICAL DESIGN

- Highly adjustable design that allows for easy adjustment of the angle between interlocking coils and distance between poloidal coils.
- PASEO's design is based off of the experimental nature of the Columbia Non-Neutral Torus (CNT) as well as the visually engaging Mini-CNT
- Two interlocking coils : radius 0.10 m
- Two poloidal field coils : radius 0.25 m
- Vacuum chamber made of borosilicate glass with expected operational pressures of between (0.1-10.0) mTorr
- Currents of coils up to 2,000 amp-turns

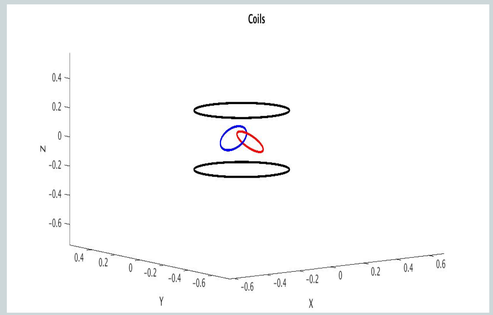


Model of PASEO, via Jared Carlson



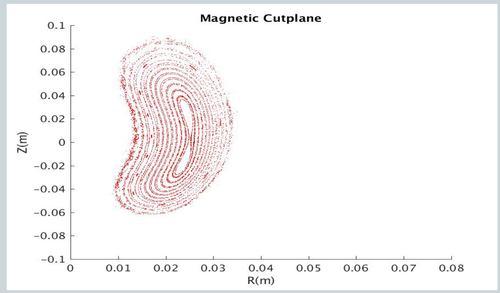
Model of the CNT, magnetic surface in red

CODE INTEGRATION



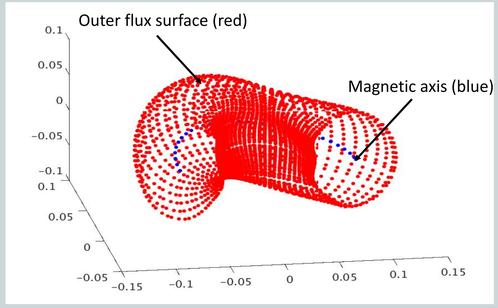
MAKEGRID

- The coil configuration is represented as a filament file generated via a MATLAB script. This filament file is the used as input to the MAKEGRID code.
- Using the Biot-Savart law the code calculates the magnetic field data on an R-Z grid



FIELDLINES

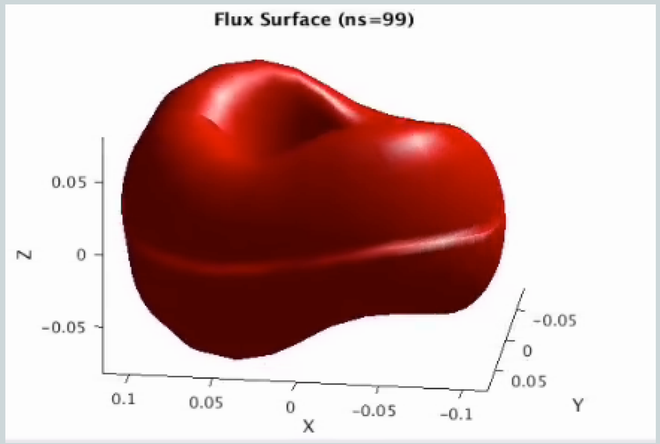
- The output of the MAKEGRID code is then used as input to the FIELDLINES code which follows field lines about a toroidal domain
- A differential equation can therefore be constructed as a function of toroidal angle which is solved using the Runge-Kutta method



DESCUR

- VMEC requires a starting guess for the magnetic axis and plasma boundary represented as set of Fourier harmonics
- A MATLAB script was developed by taking the output of the FIELDLINE code and cutting the outer flux surface into a set number of phi planes along with the magnetic axis
- These R-phi-Z points are then used as input to calculate the Last Closed Magnetic Flux surface in terms of Fourier coefficients

VMEC (Variatonal Moment Equilibrium Code)



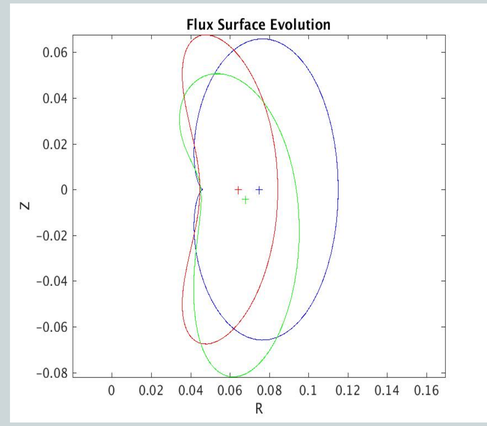
Last closed magnetic flux surface with plasma introduced

Force Balance Equations

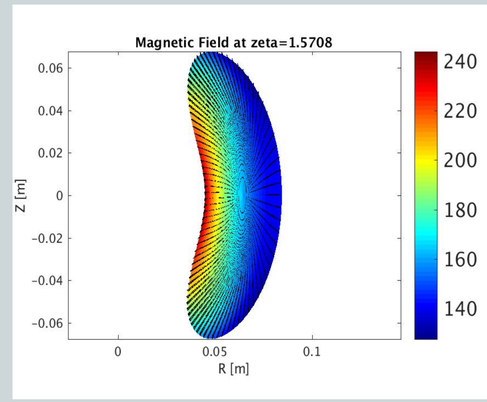
$$F = -j \times B + \nabla p = 0$$
$$\nabla \times B = \mu o j$$
$$\nabla \cdot B = 0$$

- VMEC solves the above force balance equations in three dimensions about a toroidal domain by using a varational method to find the minimum energy
- VMEC is controlled via a Fortran name list with notable inputs being pressure, current/IOTA, magnetic axis, plasma boundary, and runtime parameters

VISUALIZATIONS OF VMEC OUTPUT



Cross sections of the last closed magnetic flux surface at varying toroidal angles



Strength of the magnetic field at a specified cross section

Future Work

- Experiment with different pressure profiles and coil configurations using VMEC in order to optimize PASEO's magnetic surfaces
- Implementing a virtual reality application that allows for the visualization of magnetic surfaces generated by PASEO's highly adjustable design could prove useful in accomplish PASEO's mission of public outreach
- Designing demonstrations to take advantage of PASEO's adjustable and visually engaging nature

References and Acknowledgments

1. Strumberger, E. and Holzl, M., Laboratory Report IPP 5/113, Garching 2005. http://www.ipp.mpg.de/~mhoelzl/Ippreport_5_113.pdf
2. Carlson J., Previous work on PASEO
3. Lazerson S., matlabVMEC package

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