Final Year Project 2011
Lebanese Linear Plasma Device

Ralph Ghazal
Nareg Oughourlian
Michel Al Haddad
Michael Haddad

A Collaboration between the
Mechanical Engineering and the Physics Departments
Harvesting Energy From Nuclear Fusion

• Nuclear fusion happens when multiple nuclei having the same charge fuse together and form a heavier atom
• The difference in mass between the reactants and the products will be the energy we wish to harvest

Great Advantages

• Vast Fuel Supply
• No risk of a nuclear accident
• No air pollution or CO2 generation
• Low nuclear waste
Tokamak, a Fusion Test Reactor

Pump down phase: air is pumped out the vacuum chamber to reach a high vacuum.

- Gas (in this case it’s hydrogen) is pumped into the vacuum chamber.

- An electric pulse ionizes the gas.

- Once the ionized particles are near enough to each other, the atomic force takes over and fuses the two molecules into a new one, releasing large amounts of energy in the process.
Problem Approach Outline

• Decide on the Configurations of the design, and draw the entire linear device on a design software

• Design the support structure, with an in-depth analysis of the stresses and mechanical properties that will be required

• Design the configuration of the pumping system and pressure control inside the vessel

• Design the configurations of the magnetic coils to produce the desired magnetic field
Designing the Vessel of LLPD

- We proceeded to draw the entire machine on the CAD software PRO-E.
- Identify the equipments needed for the three configurations discussed hereafter.
- Process to an inventory of the existing vacuum chamber sections.
- Draw the existing chamber sections on PRO-E.
- Identify and order the missing components.

Design 1: Centered source region and long (L= 3.04 m)
Design 2: Centered source region and short (L= 2.35 m)

Design 3: Edge source region and long (L=3.30 m)
Support Structure design

- Weight distribution
- Design specifications
- CAD model
- Fabrication
Design Specifications and Calculations

- Theoretical CAD drawings
- Safety Factor
- Market restrictions
- Stress analysis and calculations
- Sizing of the different components
Weight Distribution

Weight distribution along the system to be supported

Weight Distribution (Kg)
CAD drawings

PRO-Engineering software

3D model of the parts to be assembled
I-Beam sizing

\[ \sum \vec{F} = 0 \]
\[ \sum \vec{M} = 0 \]

- Find R1 R2 R3
- Consider R1 and R2 for simplicity
- Shear and moment diagram
- Maximum moment \( M_{\text{max}} = 356.4 \text{ N.m} \)

\[ \sigma = \frac{Mc}{I} \quad \text{given} \quad Sy = 250 \text{ Mpa} \]

\[ n_d = \frac{Sy}{\sigma} = 66 \]
Leg sizing

\[ \frac{F}{A} = \sigma = 435 \text{ N} \]

\[ n_d = \frac{S y}{\sigma} = 531 \]

S = 8 cm
s = 6 cm
Middle plate sizing

\[ \sum \vec{F} = 0 \]
\[ \sum \vec{M} = 0 \]

- Find Weight
- Shear and moment diagram
- Maximum moment given \( S_y \)

\[
\sigma = \frac{Mc}{I} = 0.470 \, MPa
\]

\[
n_d = \frac{S_y}{\sigma} = 153
\]
CAD drawings

PRO-Engineering software

3D model of the parts to be assembled
CAD drawings (2)

System Inventory:

2 H or I beams

6 main legs
CAD drawings (3)

Transverse leg supports

Longitudinal leg supports
CAD drawings (4)

Cross bars

S clamps
CAD drawings (5)

Wooden arm

Upper clamp
Fabrication shop

- Material HEA 100

Building the actual device at the fabrication shop

Structure delivered to AUB on Friday 27 Mai 2011.
The pumping system
Pumping System diagram version 3

Legend:
- Direct connection (no pipe needed)
- Stainless Steel Connection pipe
- Analog thermal Conductivity gauge
- Analog Ionization gauge

Hydrogen Tank
Pressure Reducer
Flow controller
Vacuum Chamber
Flow controller
Hydrogen Tank

Butterfly valve
T-connection
Reducer
High vacuum Turbo pump

CF 8 in
Gate valve
CF 8 in

CF 8 in
CF 10 in

CF 8 in
KF 1 in
Automatic Switch Valve

CF 10 in

KF 1 in
Oil Trap

D = 1 in.

Rotary vane Pump
Pumps Choice: Viscous flow

• Roughing pumps are perfect for this regime
• When deciding on a vacuum pump we have taken into account several factors:
  o Possible oil contamination of the vacuum chamber
  o Vibrations produced by the pump
  o Most importantly: absolute pressure reached

• System’s specifications:
  o Base pressure $10^{-7}$ Torrs
  o Operating pressure $10^{-3}$ Torrs
Magnetic Coils - Concept

- Surrounding the vacuum chamber, a Magnetic Field is created by a set of magnetic coils mounted on the main support.

- Coils are used to confine the plasma.

- Magnetic Field: $B_{\text{max}} = 1000$ Gauss & $I_{\text{max}} = 500$ A

- We can determine the length needed for each coil $L=32.04$ m

- Each coil is 2x16 turns

- Coils are to be designed from copper wires and a cooling system to ensure continuous operation.

- Two alternative for design:
  - having the coils in series or coils in parallel
  - Water cooling can be from inside or from outside
Magnetic Coils – with External cooling

- Coil box is made of Aluminum
- Dimensions:
  - Height: 8 cm
  - Length & width: 90 cm
- Design:
  - 2 Water inlets on the Front
  - 1 Water outlet on the Back
- 1 Coil I/O on the Front
- Upper and lower plate are linked by a cylindrical plate
- Inside the coil box we have 8 similar plates
- These plates are designed to:
  - allow the coil to loop 24 mesh
  - Allow water to circulate
Magnetic Coils - with internal cooling

- We used copper wires to form coils.
- Each coil should provide about 450 Gauss.
- Each 2-3 coils are hooked in parallel and supplied by one generator.

**Some calculations:**

- $Q_{\text{box}} = 1725$ W.
- 15 coil boxes.
- $Q_{\text{max}} = 25875$ W.
- $m(\dot{)} = \frac{Q}{C_p \Delta T} = 618.82$ grams/sec
- $V(\dot{)} = 37.1292$ L/min or Lpm
Pictures of Copper wire used
Conclusion

• One of it kind in the region, and unique properties worldwide.

• Adaptable design.

• Enabled AUB and Lebanon to partake in the global effort for fusion development.

• Delivered to AUB as we speak!
THANK YOU