ME 400: Project & Thesis

Design & Simulation of an Alpha Type Stirling Engine

Accomplished by:

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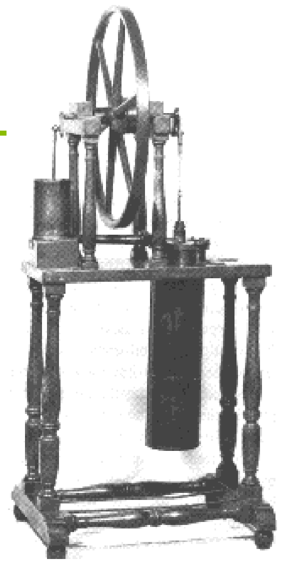
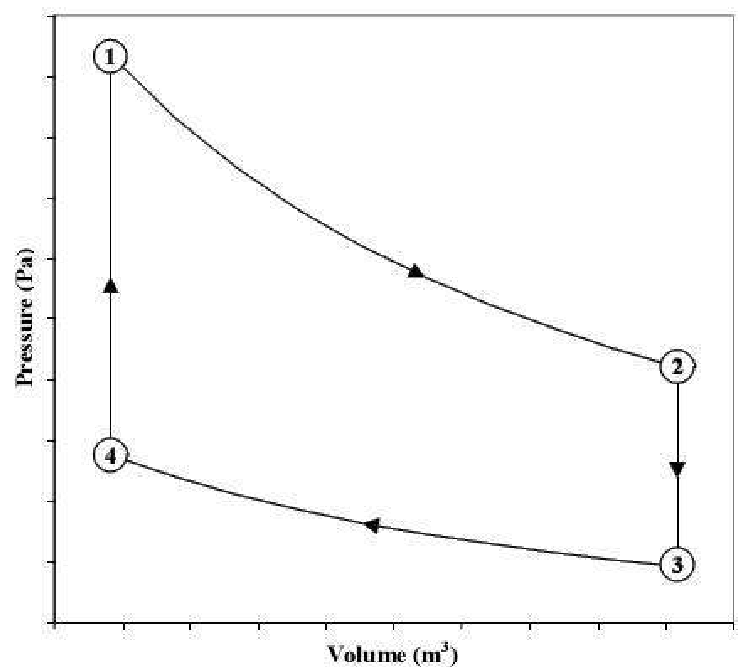
Stirling Cycle



Reverend Dr. Robert Stirling (Patented in 1816)

Thermodynamic Processes –

- Isothermal Expansion
- Isochoric Displacement
- Isothermal Compression
- Isochoric Displacement



Engine Characteristics & Applications

Multi Fuel Capability

Quiet Operation

Flat Part Load Characteristics

Low Pollutant Emissions

Low Cycle Torque Variation

Higher Manufacturing Cost

Lower Seal Reliability

Complex Control System

CHP Applications

Stirling Cryocoolers

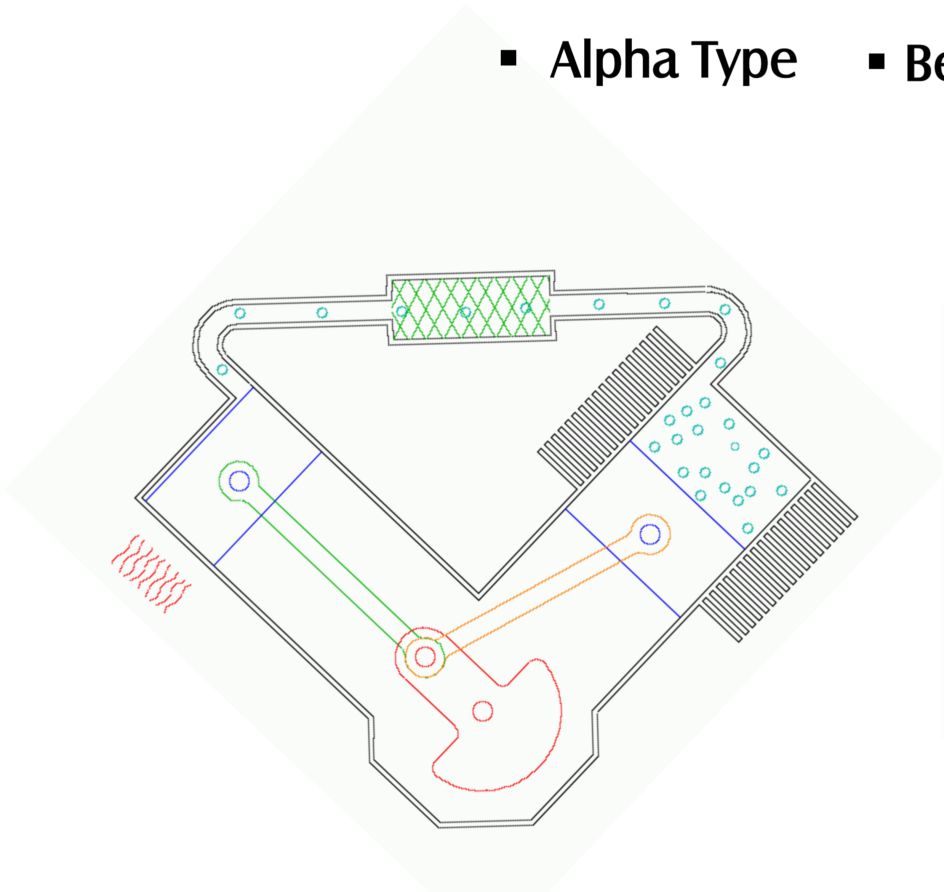
Nuclear Power

Geothermal Energy

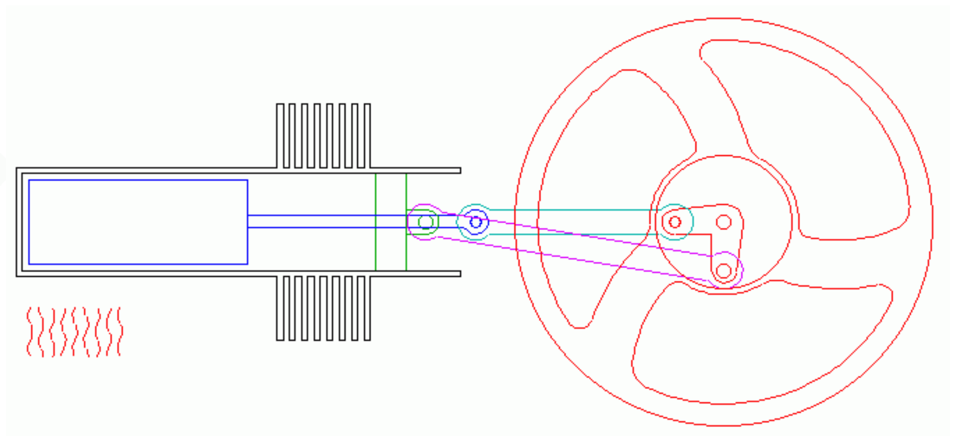
LTD Engines

Classification

- Alpha Type
- Beta Type
- Gamma Type



α configuration



β configuration

Design Criteria

Design Working Temperatures: T_h 150ºC T_c 25ºC

η_{carnot} 30 %

Design Heat Input: 200W

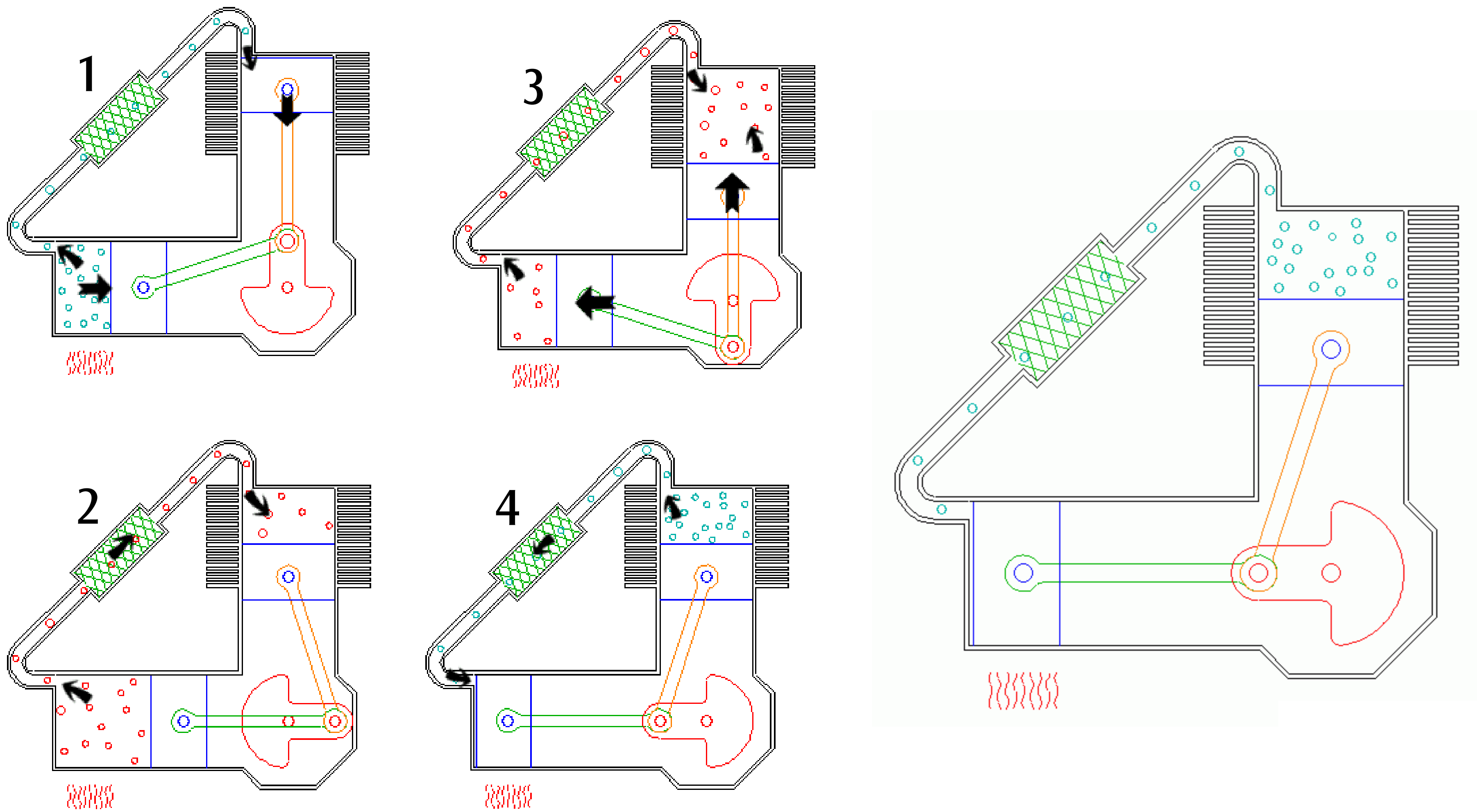
Power Output (Indicated): 60W

- Inadequate Design Info.
- Unavailability of Ready Made Parts
- Material Limitations
- Machining Limitations

Initial Experimentation

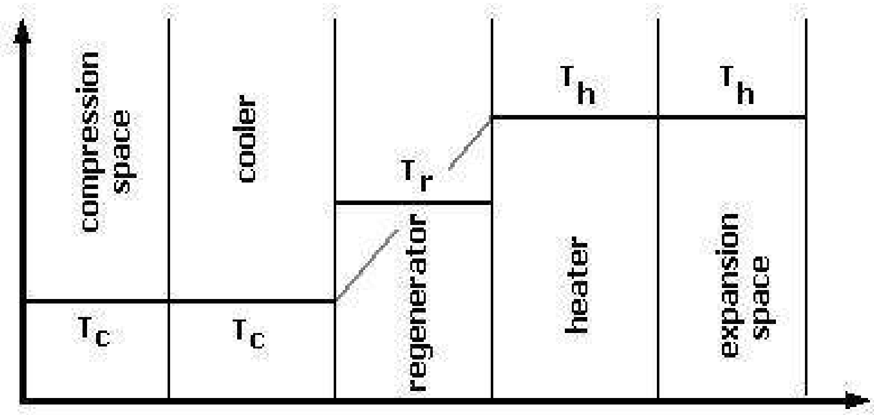
Experimentation Video

Alpha Type Stirling Engine

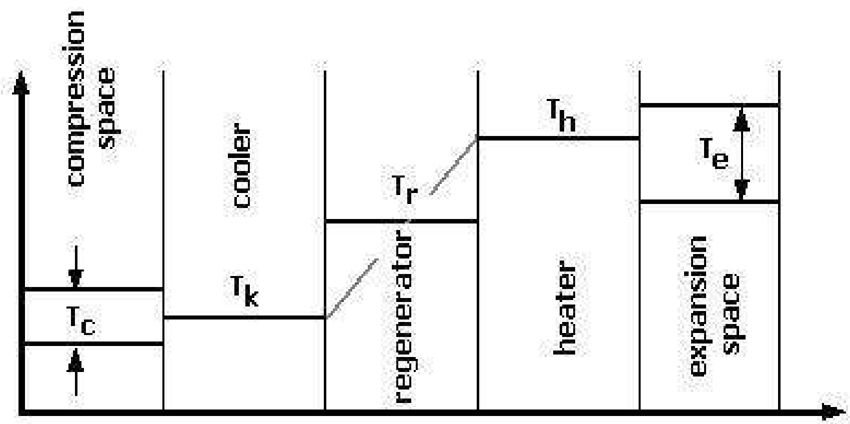


Mathematical Modeling

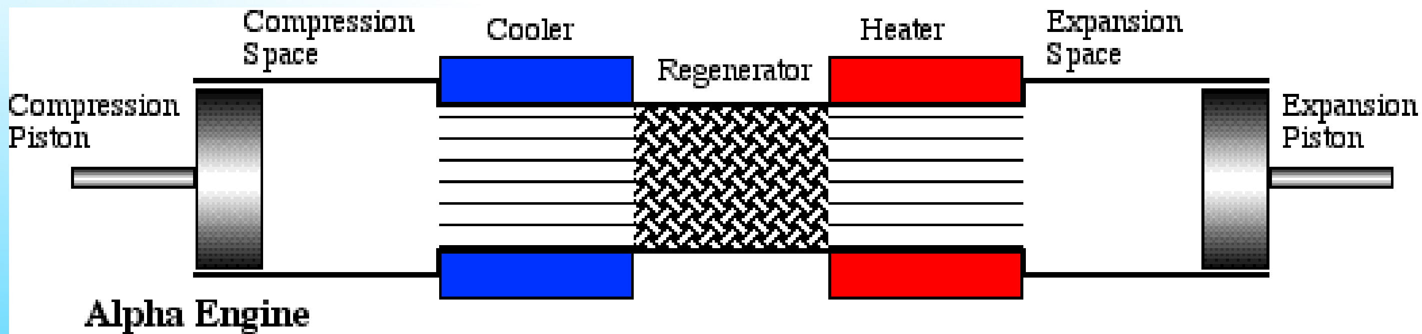
- First Order
- Second Order
- Third Order



- Isothermal
- Adiabatic



Mathematical Modeling (contd.)



Ideal Gas Equation: PV = mRT

Working Fluid: air

Initial Pressurization: none

Total System Mass: Constant

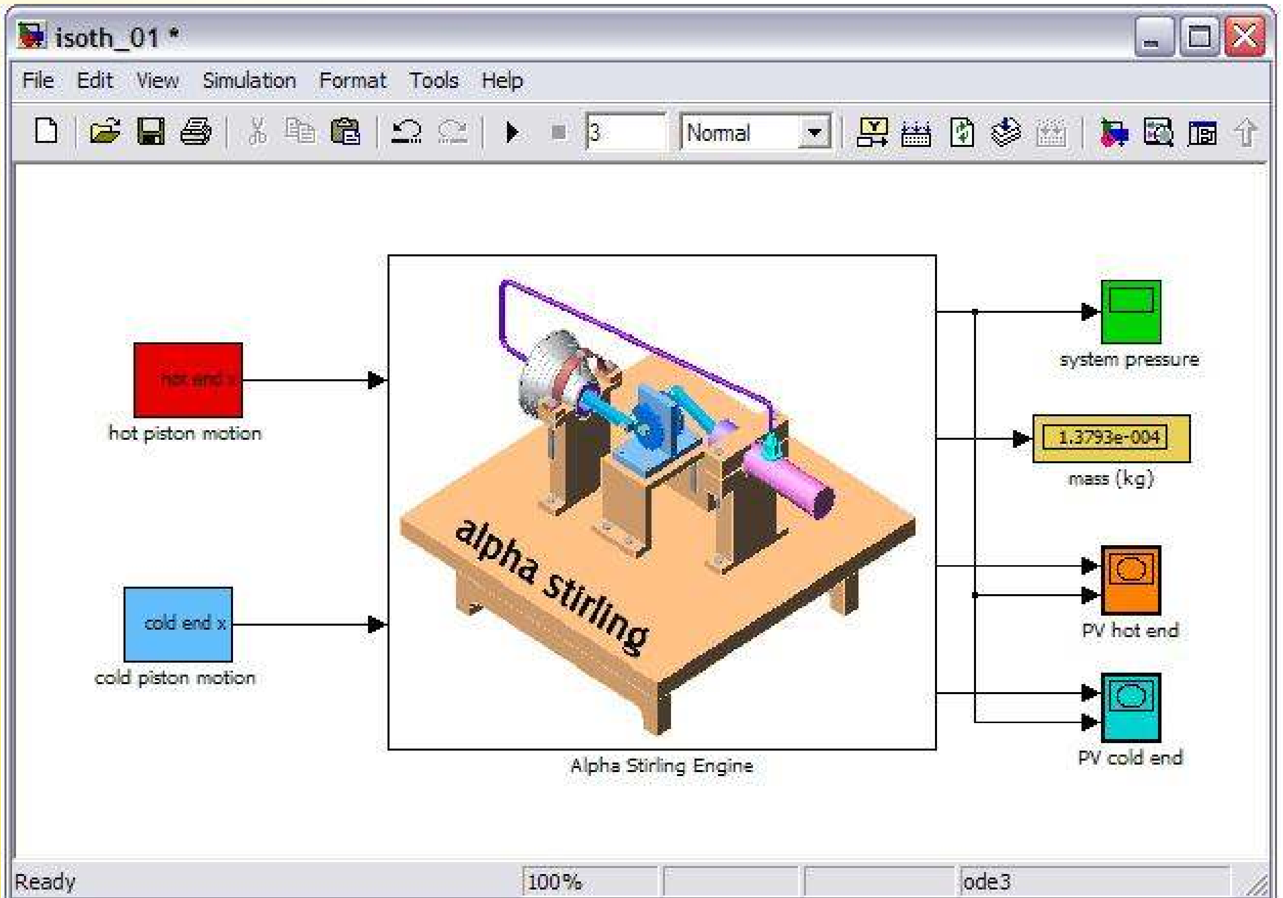
Piston Motion: sinusoidal

Regenerator Temp: T_h

At t = 0: $M = P (V_h / T_h + V_t / T_r + V_r / T_r + V_c / T_c) / R$

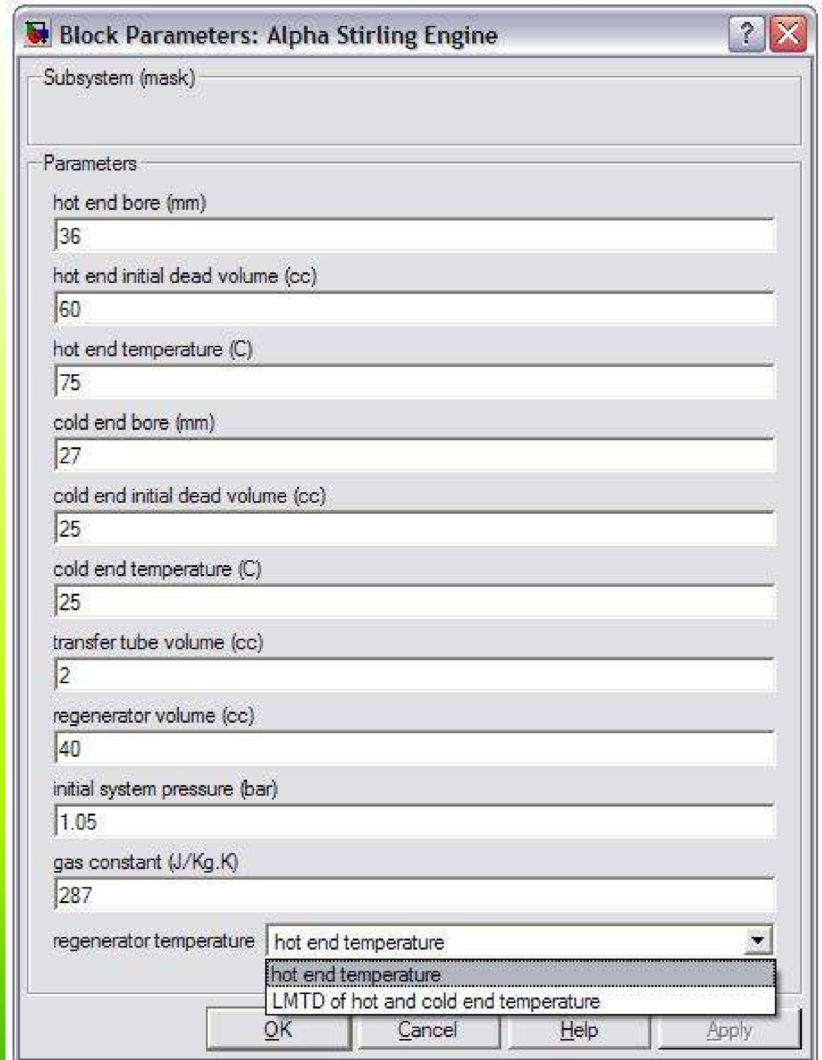
System Pressure: $P = MR / (V_h / T_h + V_t / T_r + V_r / T_r + V_c / T_c)$

Computer Simulation



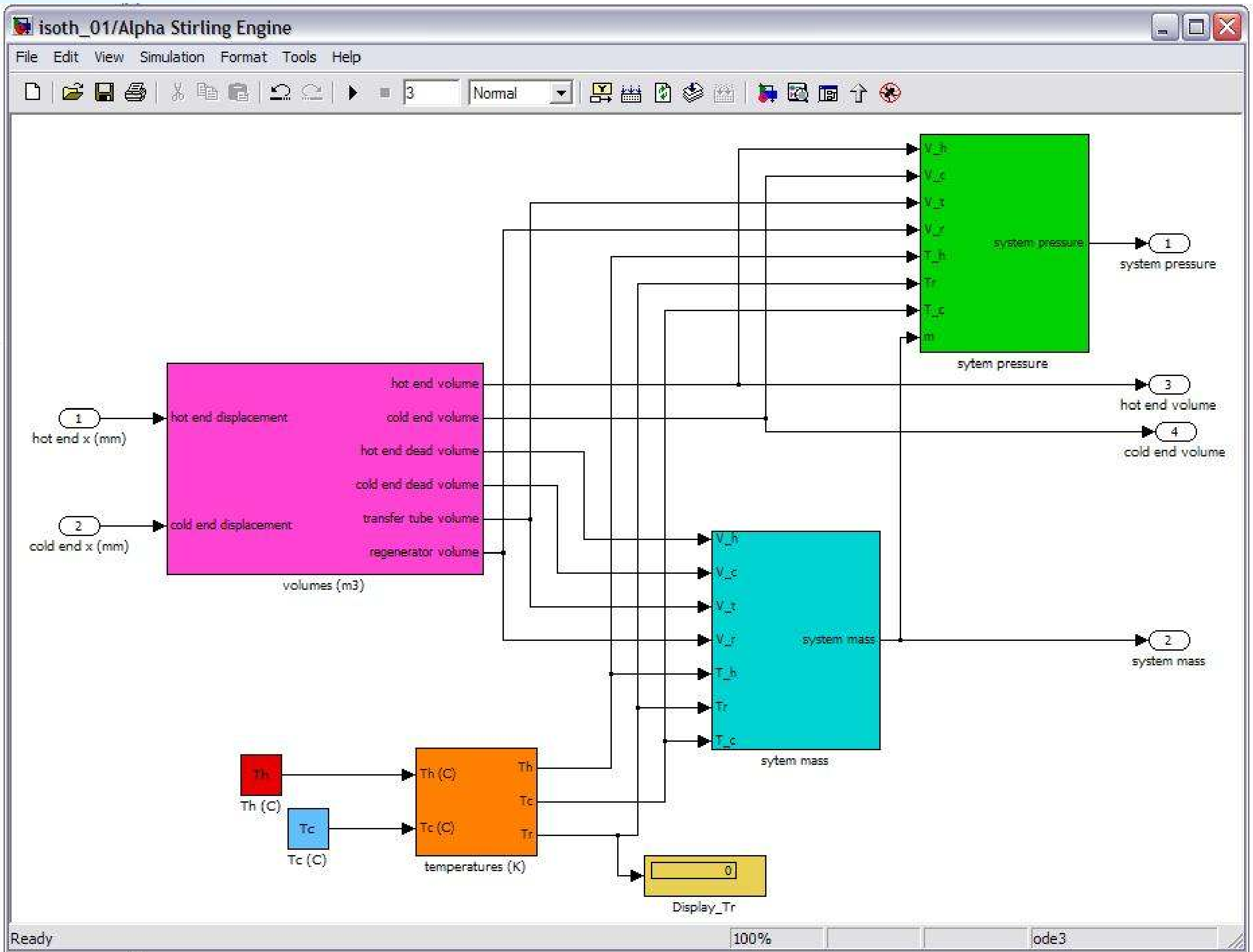
- SIMULINK Model
- Masked System
- Time Dependency
- Conversion of θ to t

Computer Simulation (contd.)



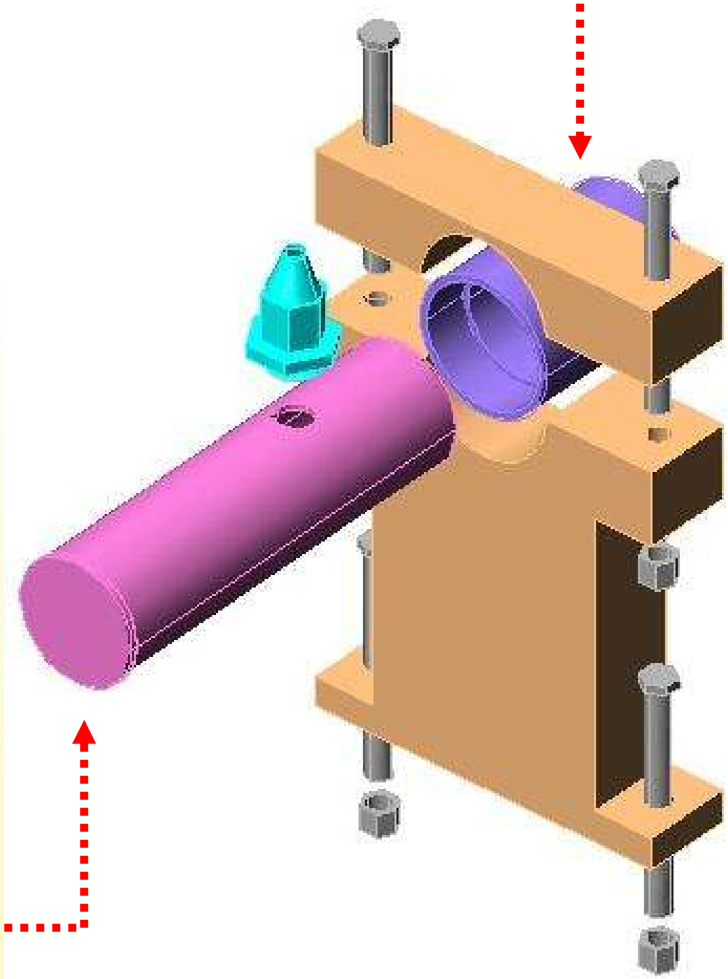
- Basic User Interface
- Dimensional Variables
- System Initialization

Computer Simulation (contd.)



Fabrication Stage

Hot End:

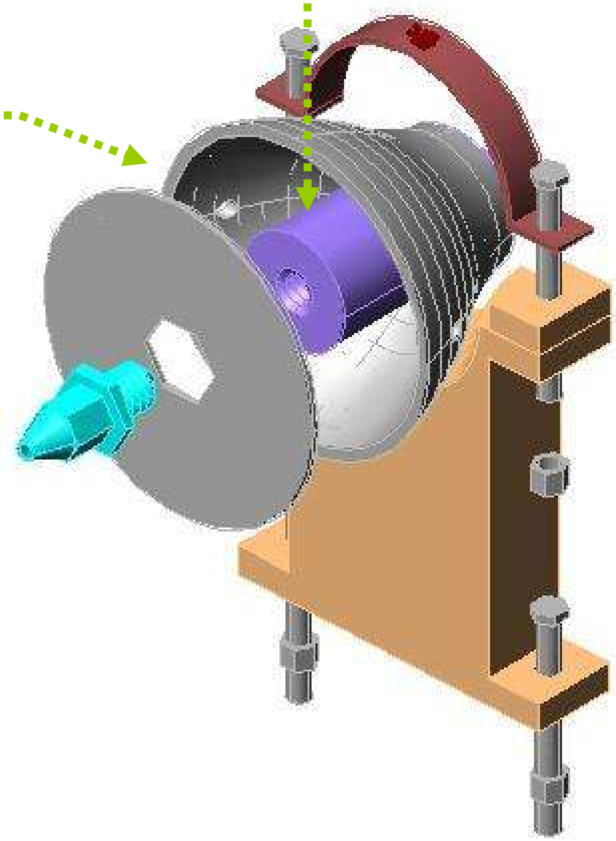


- Cylinder with inner groove
- Dead Volume for Heating

Fabrication Stage (contd.)

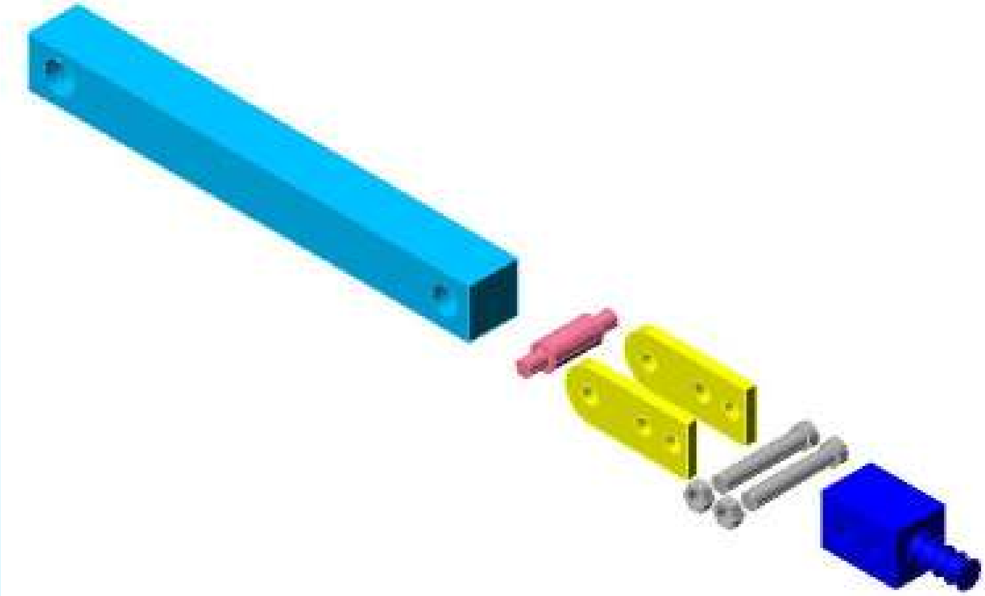
Cold End:

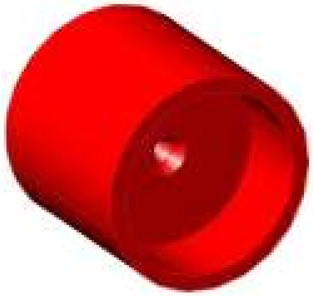
- Cylinder with thread
- Water Jacket



Fabrication Stage (contd.)

Piston & Connecting Rod:

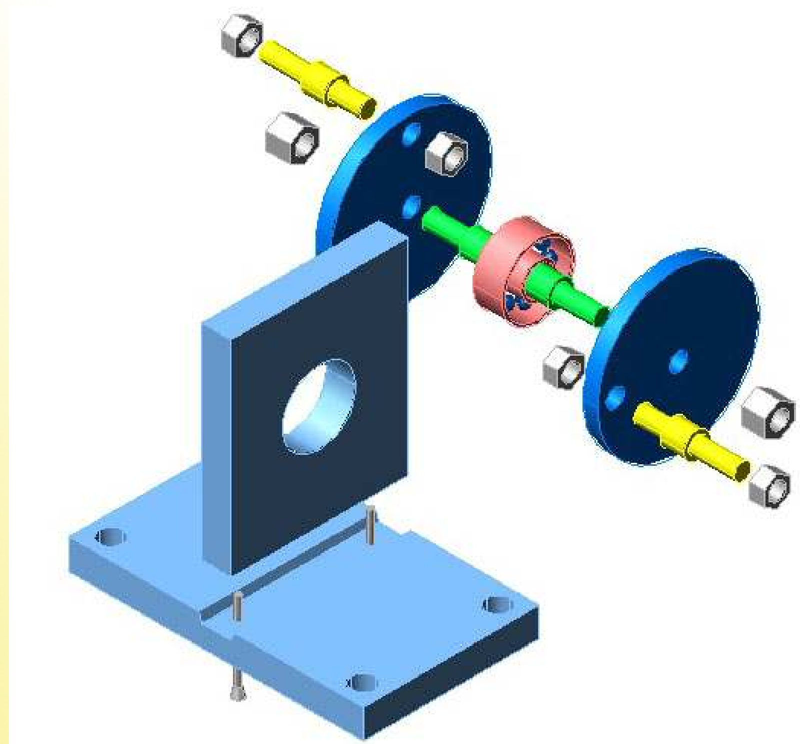




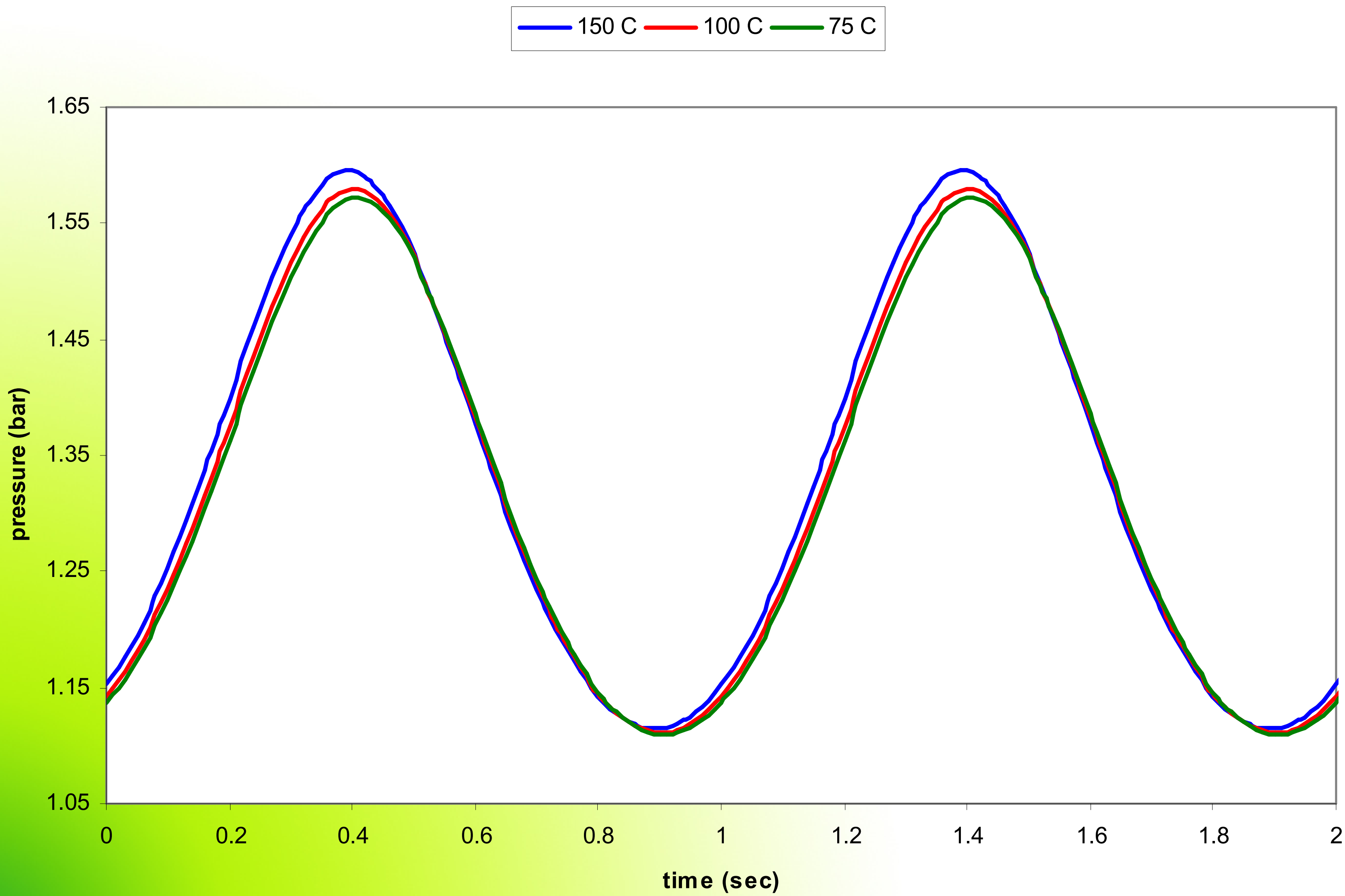
Fabrication Stage (contd.)

Crank & Flywheel:

- Generates Sinusoidal Piston Motion
- 90º Phase Angle

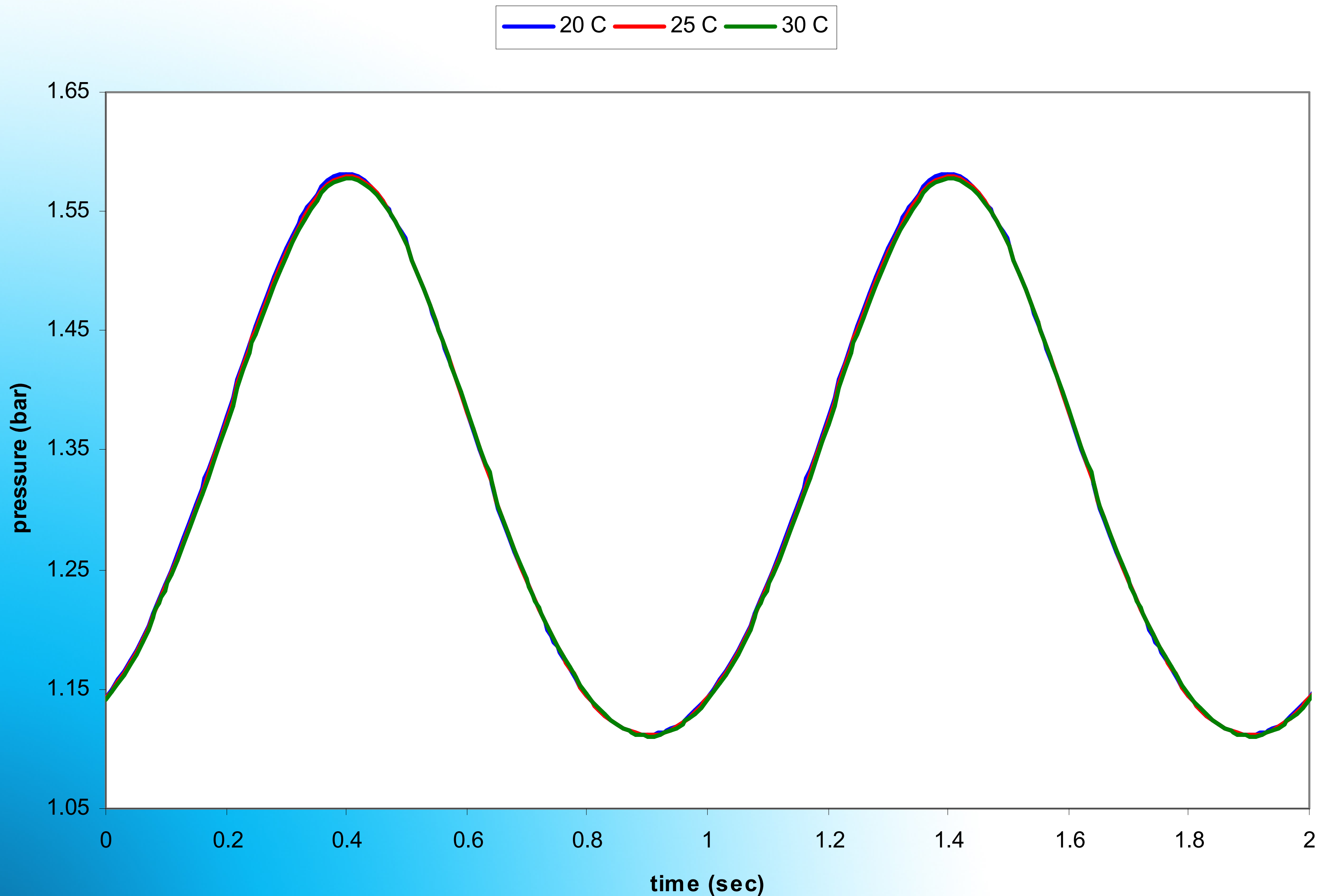


Result Analysis



Plot : variation of system pressure with time (crank angle) and hot end temperature

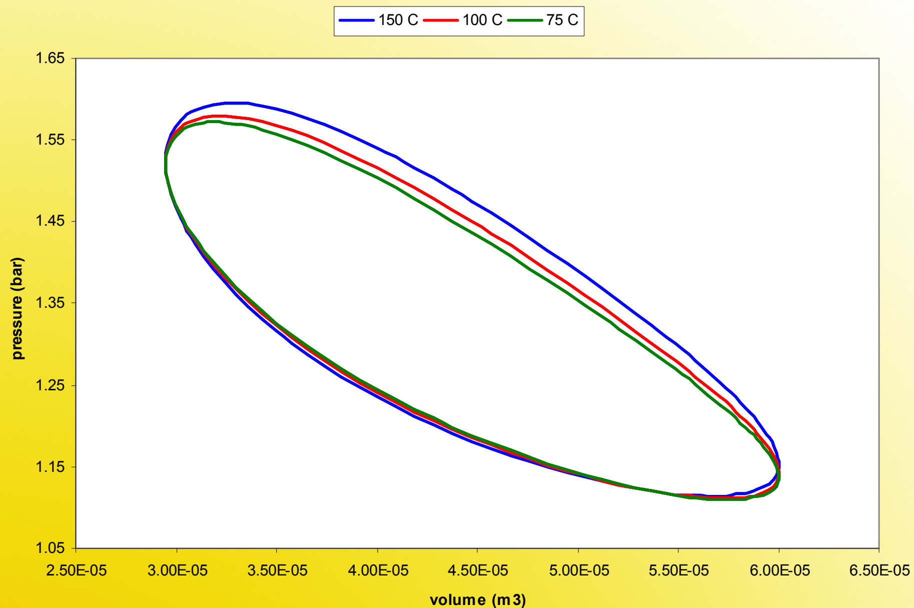
Result Analysis (contd.)



Plot : variation of system pressure with time (crank angle) and cold end temperature

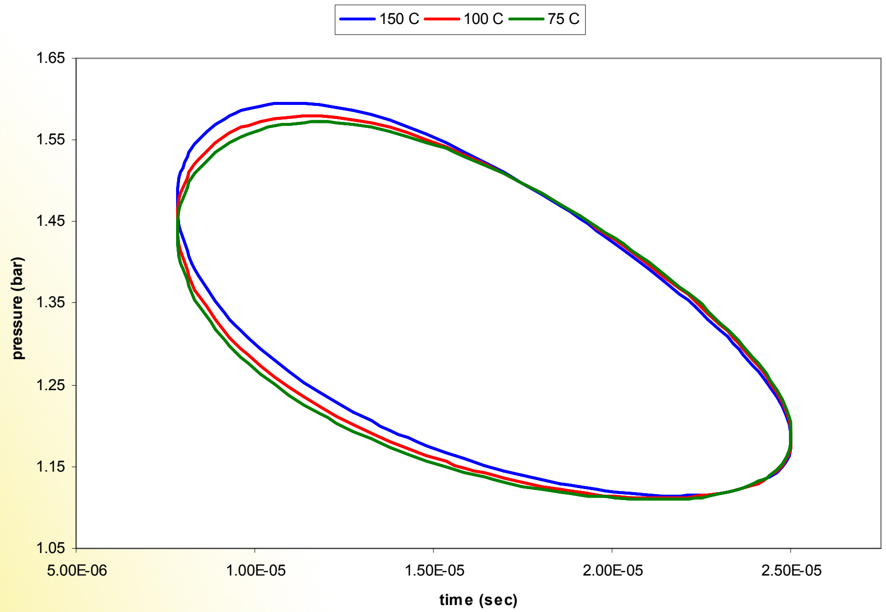
Result Analysis (contd.)

Hot End P-V Diagram



Plot : hot end PV diagram @ different hot end temperatures

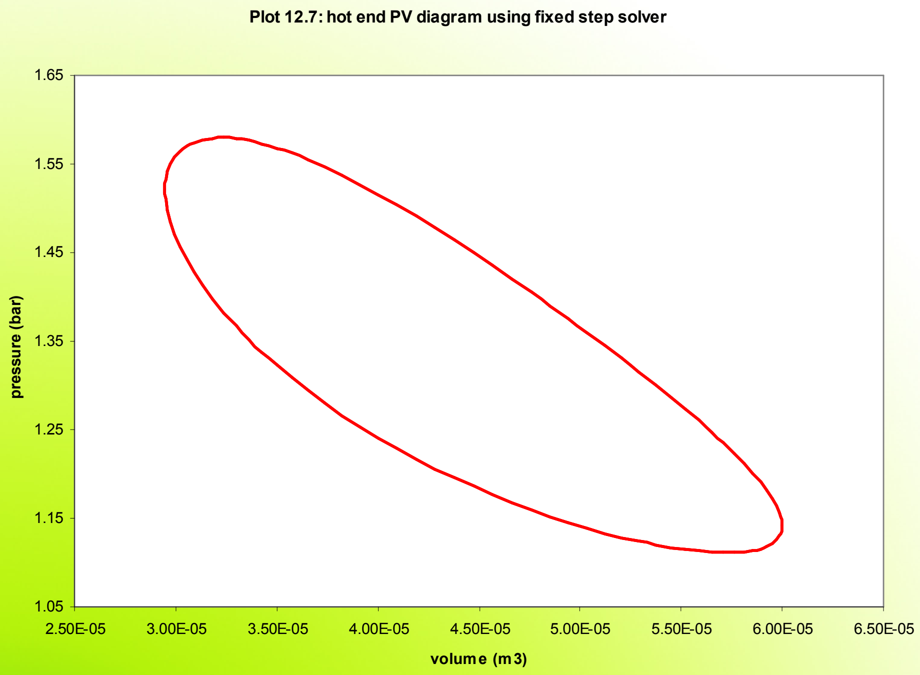
Cold End P-V Diagram

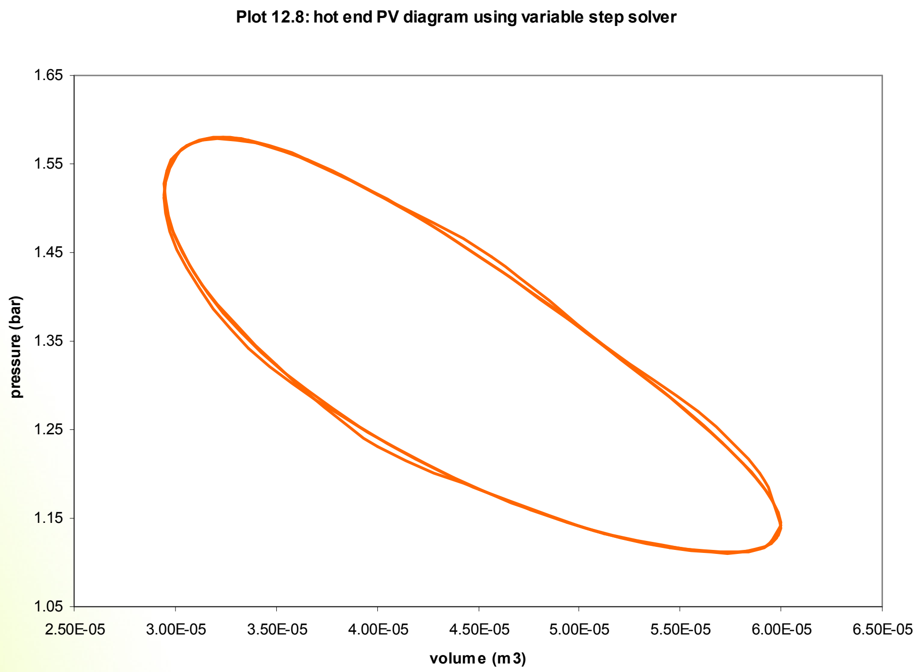


Plot : cold end PV diagram @ different hot end temperatures

Result Analysis (contd.)

Effect of SIMULINK Solver -





ODE3 Solver with Fixed Step

ODE3 Solver with Variable Step

Fundamental Study

Incorporating PI and TI –

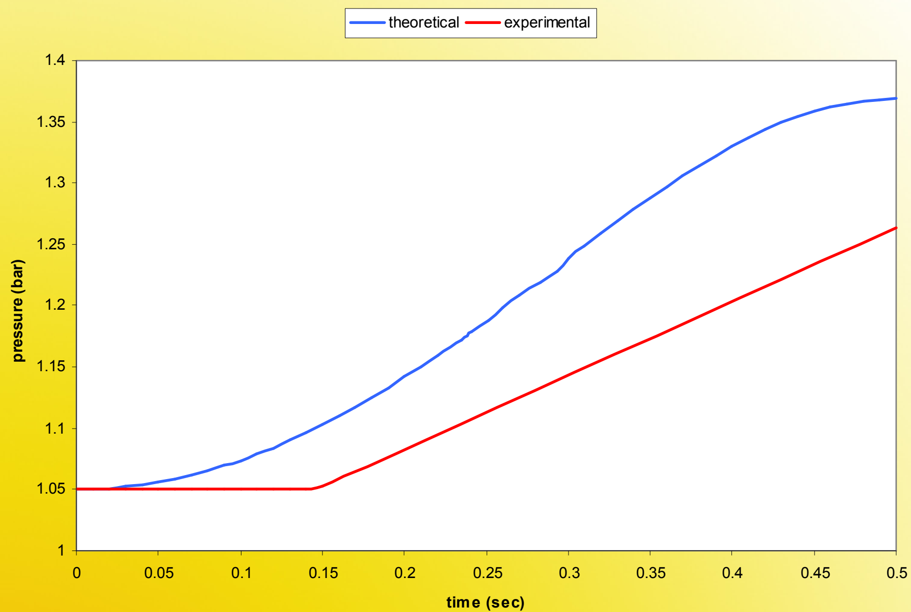
Pressure Gauge

Thermocouple Read-Out

Fundamental Study

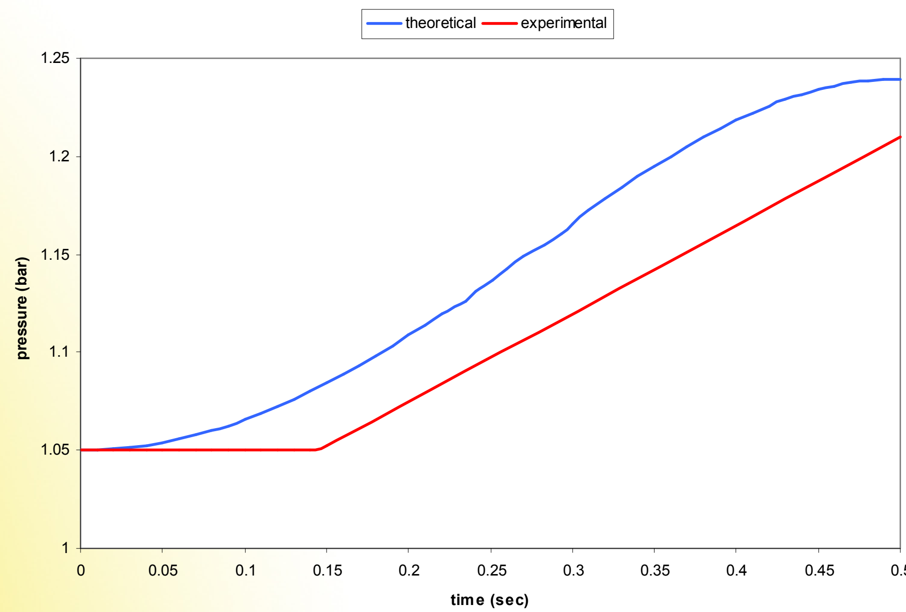
Case – 1: the hot piston is moved manually keeping the cold piston fixed

Case – 2: the cold piston is moved manually keeping the hot piston fixed



Plot : variation of system pressure with time (crank angle) without cold end motion

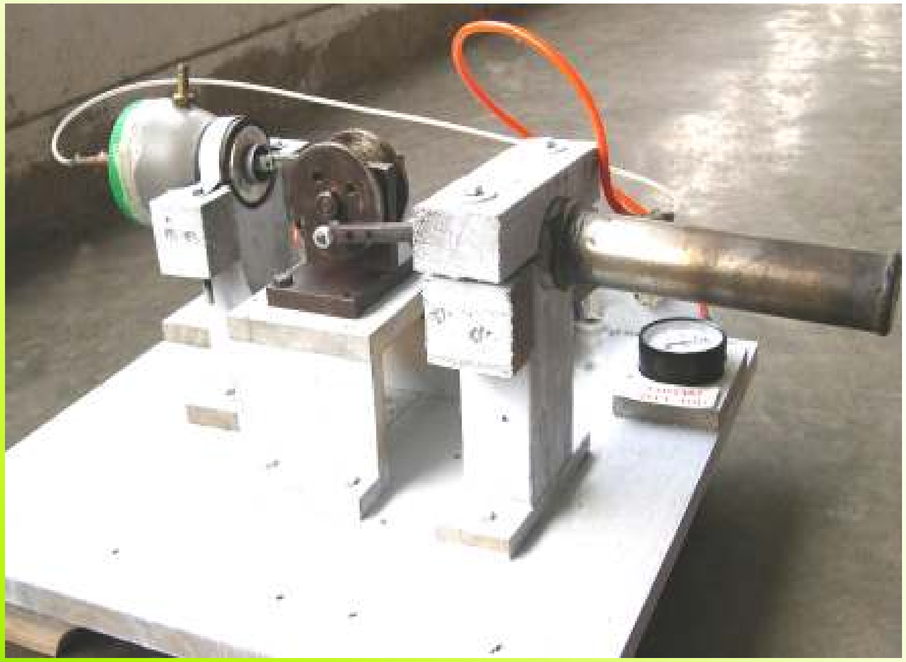
Case - 1

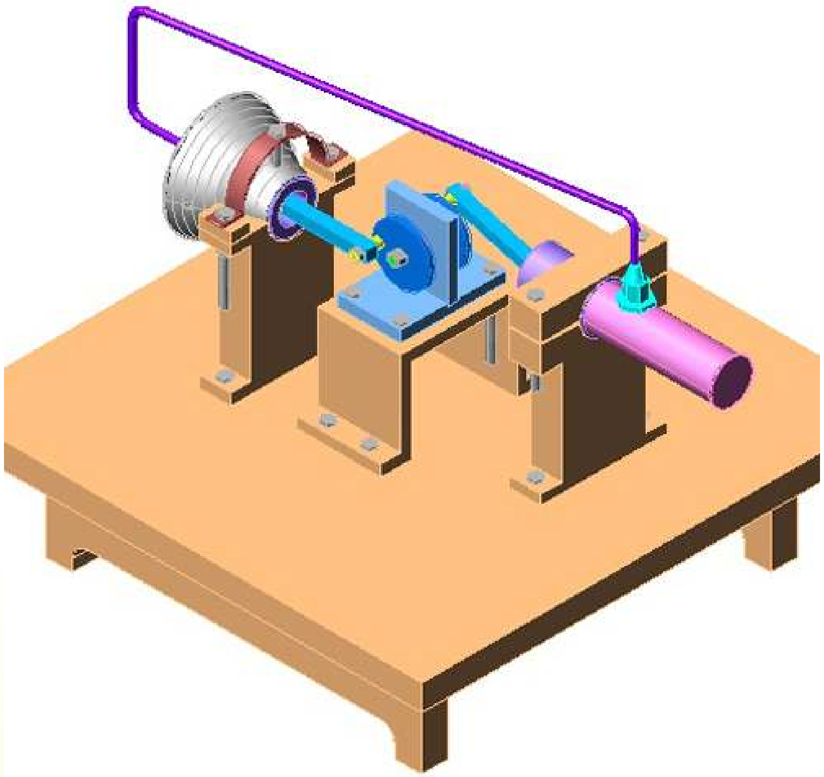


Plot 12.6: variation of system pressure with time (crank angle) without hot end motion

Case - 2

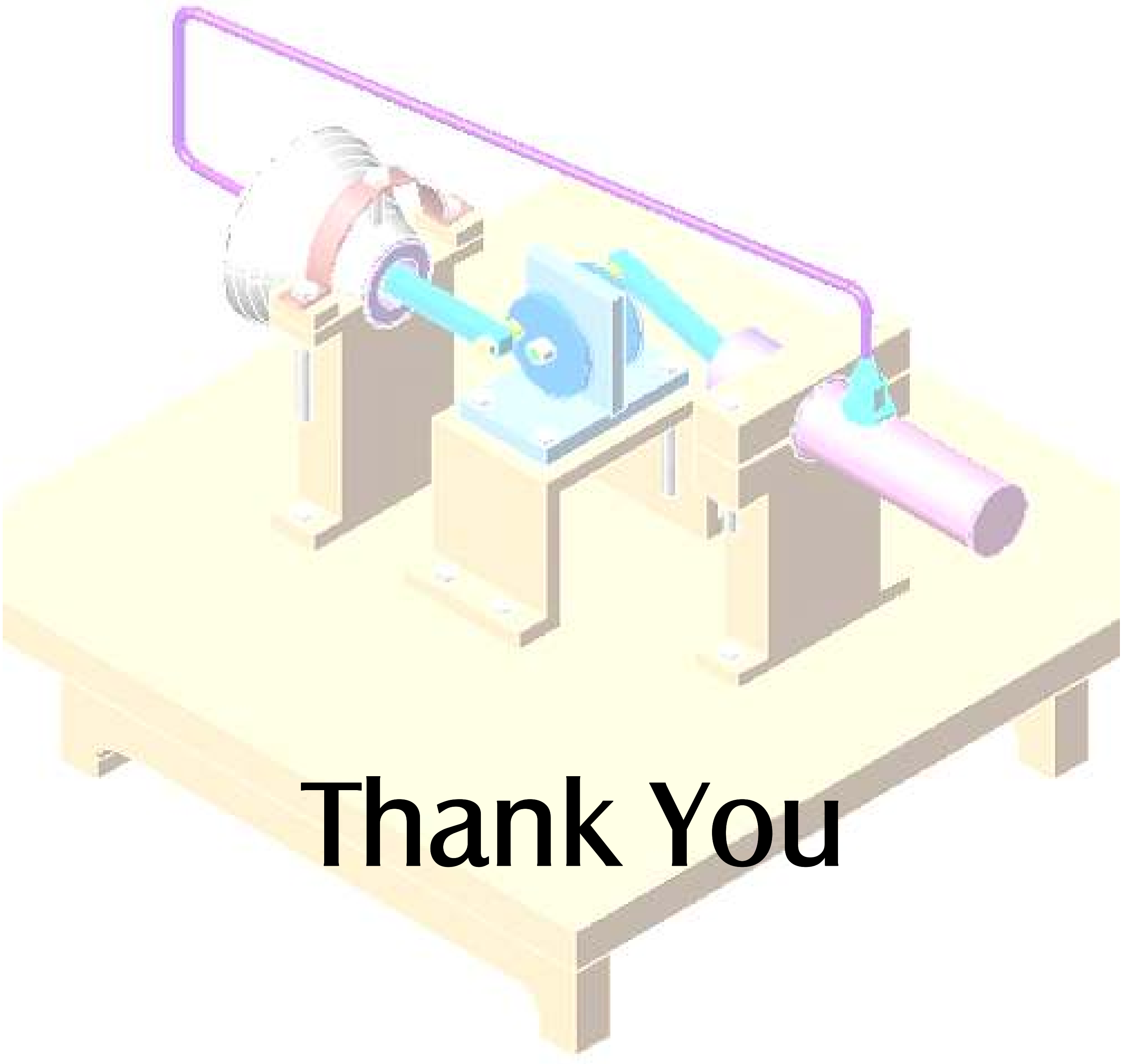
Conclusion





Recommendation

- Incorporation of Quick Heating Arrangement
- Redesigning the Flywheel
- Reduction in Dead Volume
- Incorporation of a Regenerator
- Initial Pressurization
- Working Gas



Thank You