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Design of a Constant Volume Combustion Chamber

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DESIGN OF A CONSTANT VOLUME COMBUSTION CHAMBER FOR FUEL INJECTION ANALYSIS

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Abstract:

- Fuel injection is studied because the performance, low level of emissions, and noise of a diesel engine is directly influenced by the fuel injection system
- The constant volume combustion chamber (CVCC) provides the optimal controlled environment for injection spray analysis
- The CVCC is required to meet all guidelines defined by the state of Maine for pressure vessel certification

Project Goals:

- Create a CVCC with optical access to analyze fuel injection
- Record slow-motion video of a fuel injection event
- Use telemetry data and motion analysis software to deduce scientific data
- Acquire the following data: fuel injection speed, spray cone angle, droplet size as a function of spray penetration, mean droplet size, spray density mapping, flame front of combustion

Design of Chamber

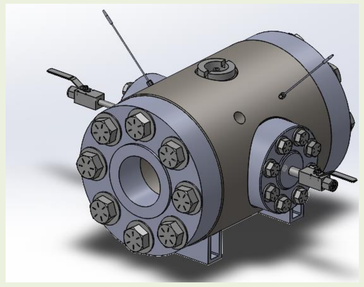
Required Instrumentation

- Single hole injector
- Spark plugs
- Thermocouple
- Hydrostatic port
- Pressure transducer

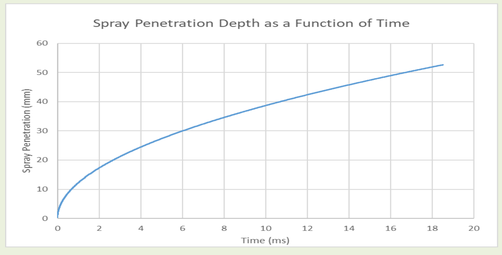
Injector Adapter

Key Features

- Injector Tip Placement
- Provides Proper Seal of the Injector
- Creates Chamber Adaptability



Injector Spray Calculations



$$Spray\ Distance[mm] = 3.07 * \left(\frac{\Delta P_{Chamber}}{\rho_{Diesel}}\right)^{0.25} * (Time * Dia_{Injector})^{0.5} * \left(\frac{294}{Temp_{Gas}}\right)^{0.25}$$

Chamber Operating Conditions

Combustion Event 1 (H_2 Pre-burn)	
Temperature Inside Chamber	Chamber Pressure
400 (K)	500 (PSI)

Combustion Event 2 (Injection Event)	
Temperature Inside Chamber	Chamber Pressure
1200 (K)	1500 (PSI)

Schlieren Optics Design

Schlieren photography is a method of visualizing the refractivity differences of a transparent inhomogeneous medium. The inhomogeneous media refracts light proportional to their gradients of refractive index in the x-y plane, producing angular ray deflection angles of ε.

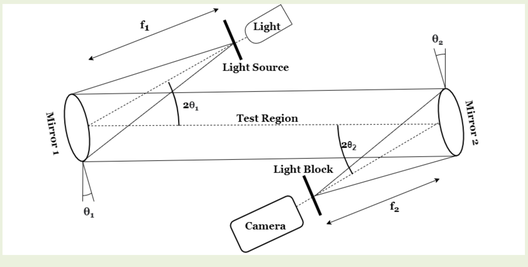
$$\varepsilon_x = \frac{1}{n}\int \frac{\partial n}{\partial x}\partial z\,, \qquad \varepsilon_y = \frac{1}{n}\int \frac{\partial n}{\partial y}\partial z$$

Key Features

- Designed to fit around CVCC
- Testing region over 2 times focal length
- Coma aberration eliminated
- Astigmatism aberration minimized

Schlieren Optical Setup

Z-type Herschelian Schlieren Setup

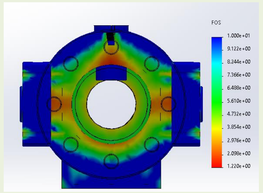


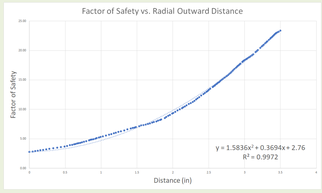
Final Setup Dimensions				
θ_1 (deg.)	θ_2(deg.)	f_1 (in.)	f_2 (in.)	Center Distance (in)
5.9	5.9	49	49	104

Constant Volume Combustion Chamber Stress Analysis

Key Chamber Safety Features

- All chamber components designed to ASME B16.5 standard
- Typical factor of safety for a pressure vessel is between 3 and 6
- Optimal depth of thread engagement for bolted connections ensure a factor of safety greater than 5

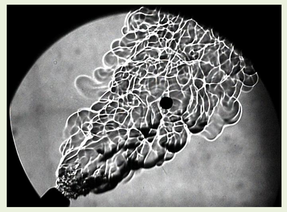




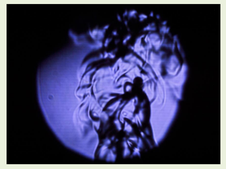
Finite Element Analysis Conditions		
Temperature	Pressure	Mesh Type
400 (K)	2000 (PSI)	Curvature Based Mesh

Schlieren Results

iX-Camera Testing



Point Source



Extended Light Source

Point Source:

- 400 µm pinhole source
- 800 µm pinhole block
- Infinite focus
- Infinite sensitivity
- Zero measuring range
- Analytical data not measurable
- Not useful for this project

Extended Light Source:

- 1 x 5 mm rectangular slit
- Adjustable razorblade cut off
- Graduated measuring range
- Useful for analysis

Future Work

Optics

- Planar-laser induced fluorescence (PLIF) integration
- Purchase an optical table/rail system
- Use manual positioning stages
- Use a focusing lens for the lighting system in conjunction with a diffuser

Constant Volume Combustion Chamber

- Purchase viewing flanges
- Seek quotes for chamber components
- Purchase stand for CVCC
- Design fuel delivery system

Acknowledgements

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References

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