Increasing Engine Efficiency through Extreme Compression
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**Motivation**

One of the most substantial loss mechanisms in current, simple-cycle, unthrottled, reactive engines is combustion irreversibility. A large fraction (~20%) of the energy of the fuel resource can be destroyed during the combustion process. The goal of this project is to substantially reduce the combustion irreversibility thereby increasing the overall efficiency.

**Experimental Design**

We have designed an experimental apparatus to study the feasibility of achieving reduced combustion irreversibility by performing the reaction at high internal energies. The apparatus contains:

- A fast (~20 ms opening time) air-driven poppet valve to allow repeatable, controllable introduction of driver air to cylinder
- A free-piston architecture that allows for high piston speeds
- An ~2.5 m long cylinder bore to achieve low surface to volume ratios at TDC, reducing the effects of heat transfer
- A high-pressure combustor attached to the end of the cylinder to withstand the high pressures at TDC
- A sapphire window port for optical access to combustion

**Premixed-Charge Combustion Strategies**

Engine operation near stoichiometric conditions is desirable because a common peak efficiency is observed to be 57%. This value is higher relative to the one of the most substantial loss mechanisms in current, simple-cycle, ideal limit than data previously obtained from direct injection of diesel fuel experiments.

- Direct injection methods typically require lean operation in order to avoid considerable soot production, due to the difficulty of rapid mixing. A combustion irreversibility thereby increasing the overall efficiency.

**Gaseous Emissions Sampling System**

The ability to measure concentrations of NO\(_x\), CO, CO\(_2\), O\(_2\), and unburned hydrocarbons has recently been added. The cylinder walls are electrically heated to 90 °C to prevent water and HC condensation.

At a compression ratio of 200:1, the work lost due to combustion irreversibility can be reduced to one-half that of the 10:1 compression ratio case.

**Efficiency and Emissions Data**

The premixed-methane-air mixture is combusted over a range of compression ratios to investigate the effect on indicated efficiency. The peak efficiency is observed to be 57%. This value is higher relative to the ideal limit than data previously obtained from direct injection of diesel fuel experiments.

**Emissions Data Obtained from Intercooling Autoignition Delay Strategy**

Gaseous emission measurements are made with a gas analyzer. It is noted that due to the ignition phasing strategy, the peak temperature is relatively constant across the range of compression ratios. Hence, there is an independence of compression ratio and NO\(_x\) formation.

**Future Work**

Now that the benefits of extreme compression have been experimentally demonstrated, the focus will shift to the formation of soot within the context of diesel-style direct injection combustion. This eliminates the autoignition-phasing challenges, albeit understood and manageable, and allows for a further investigation of extreme compression with liquid fuels. The topic presently being researched involves the addition of oxygen-carrying species to the fuel, which when subject to the extreme internal energy imposed by the high compression ratio device may result in a different chemical pathway that avoids the formation of soot completely.

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