Plasma-Enhanced Combustion of Methane and Hydrogen in Piston Engine Applications

Travis Riggs, Aimee Ortiz-Ramirez, Joshua Tobar Lam, Mariano Rubio and Boxin Zhang.
Citrus College, 2023 Summer Research Experience

Abstract

When burning fuels such as hydrogen or methane, traditional automotive spark ignition just doesn't cut it. To properly ignite these fuels we adopted a nanosecond pulsed transient plasma ignition system. This allowed us to create plasma to ignite the fuel without creating the excess heat that we see form spark ignition. The more heat inside of the combustion chamber the more harmful emissions are created. While conducting our research we experimented with several different fuels and styles of ignition which gave us a lot of unique results but ultimately we found that we achieved our most promising results using the NPTP ignition with pure hydrogen fuel.

Introduction & Background

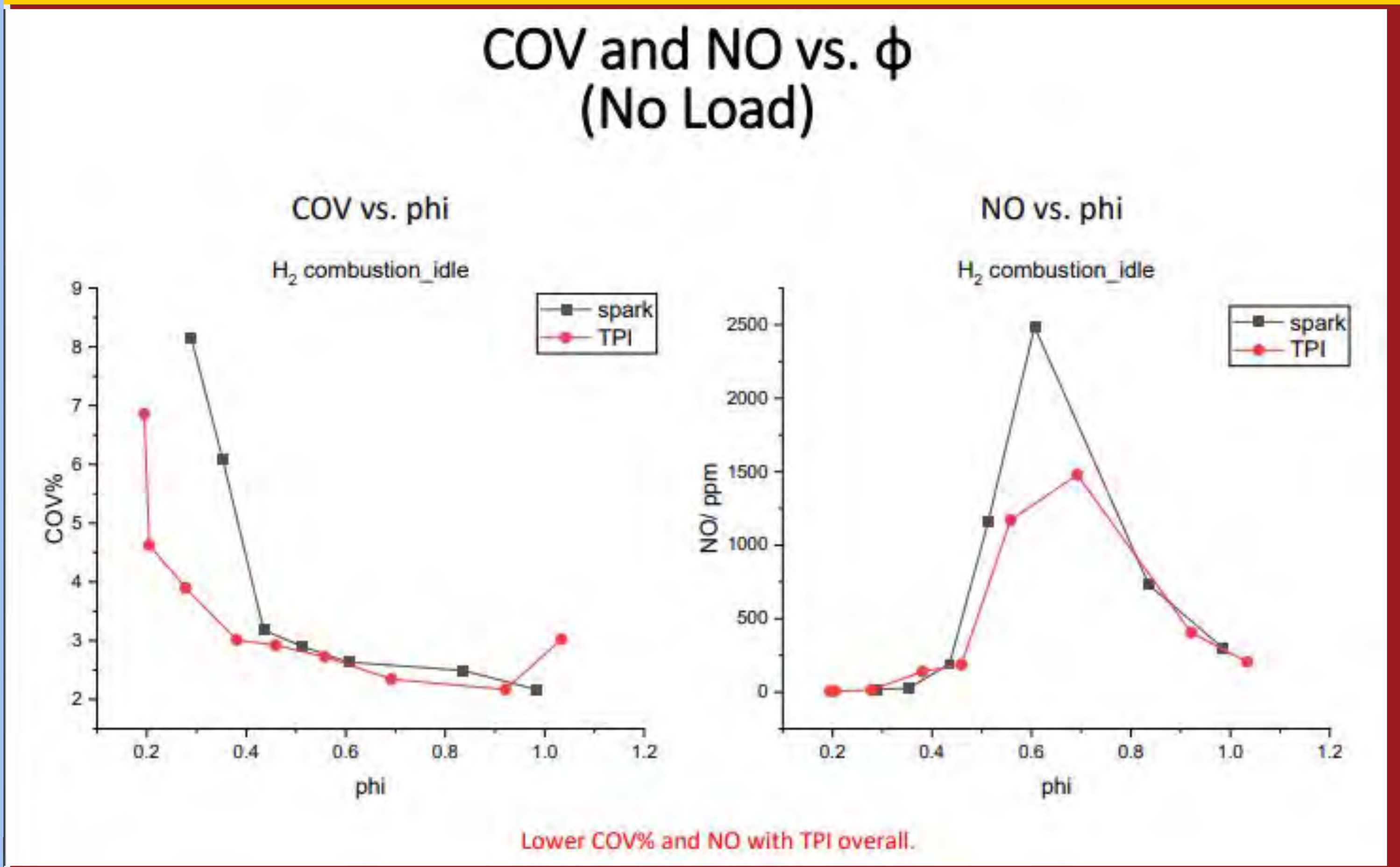
Nanosecond high voltage pulses can generate a transient plasma that can aid in the combustion efficiency of fuel-air mixtures at high lean levels. Carbon-based fuels ignited under conventional spark (thermal) ignition have a weak thermal combustion reaction which contributes to global warming. Nanosecond Pulsed Transient Plasma (NPTP) has the capability to thermally accelerate combustion through molecule dissociation via electron impact thus increasing propagation reactions.

Materials & Methods

Transit Plasma System (TPS), Hydrogen, Methane, and Ammonia, Firman T08071 generator, Horiba, Load Bank and Voltage Transformer, Hall-effect sensor, Data acquisition device, intake vacuum sensor, Throttle position sensor.

Focused on two methods to find leaner fuel rates using the TPS system and the Conventional Spark. For all fuel alternatives. Find lowest flow rate for conventional at no load before stalling and repeat with TPS. Find highest flow rate for conventional at no load before exceeding RPM limit and repeat with TPS. Revisit all flow rates but apply max load according to flow rate. Looking to load the generator up to 1.000 kW if possible.

Results



Indicated Work

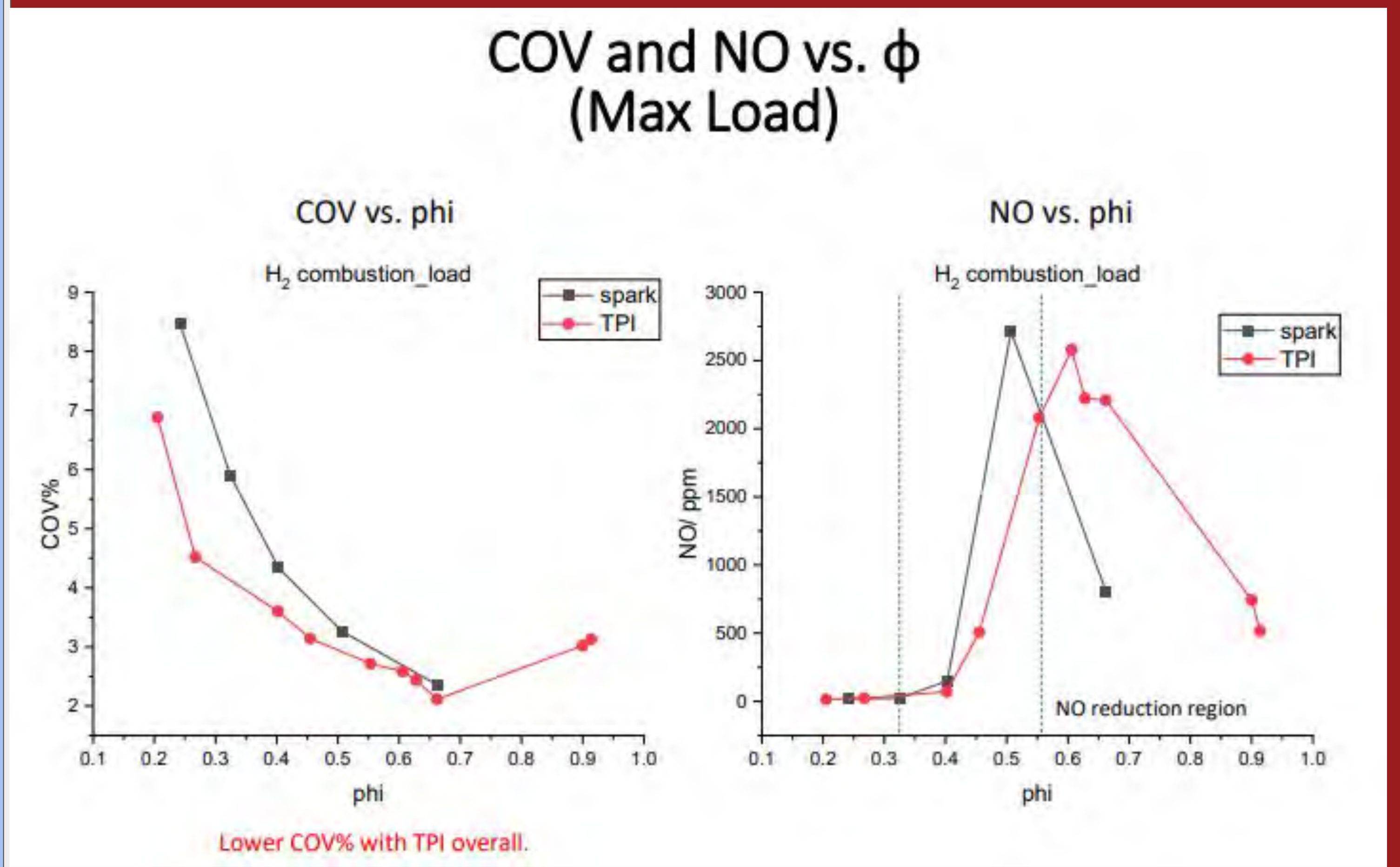
$$W_{c,i} = \oint p\, dV$$

Indicated Power

$$P_i = \frac{W_{c,i} N}{n_R}$$

Indicated Mean Effective Pressure

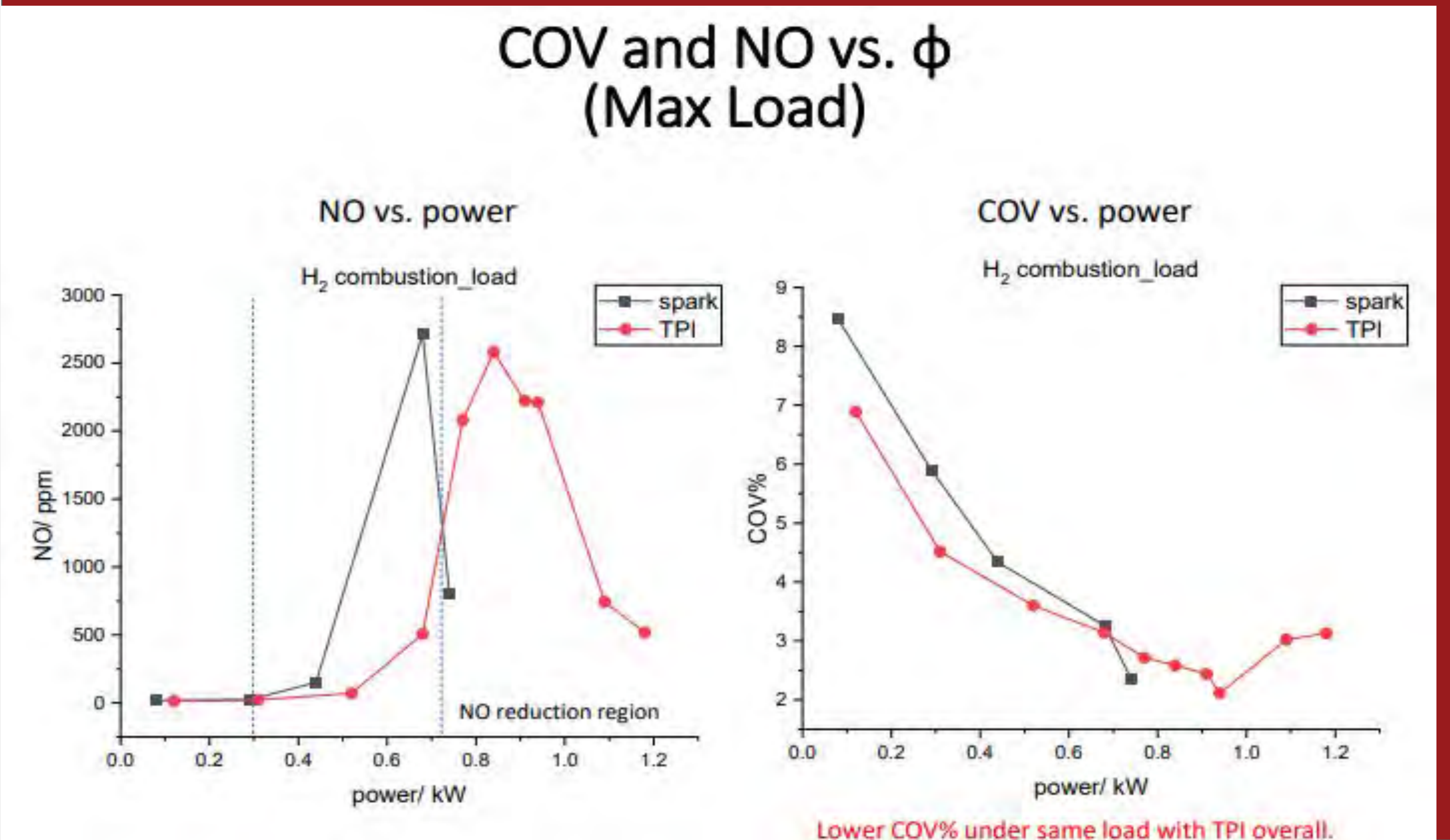
$$mep = \frac{P n_R}{V_d N}$$

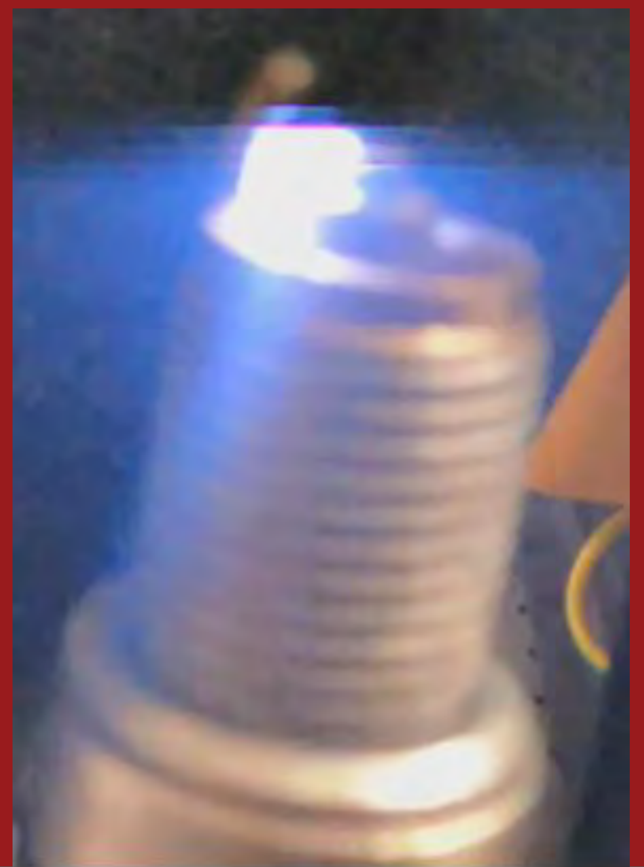


Phi:EQR determined by O2 measurement in the exhaust.

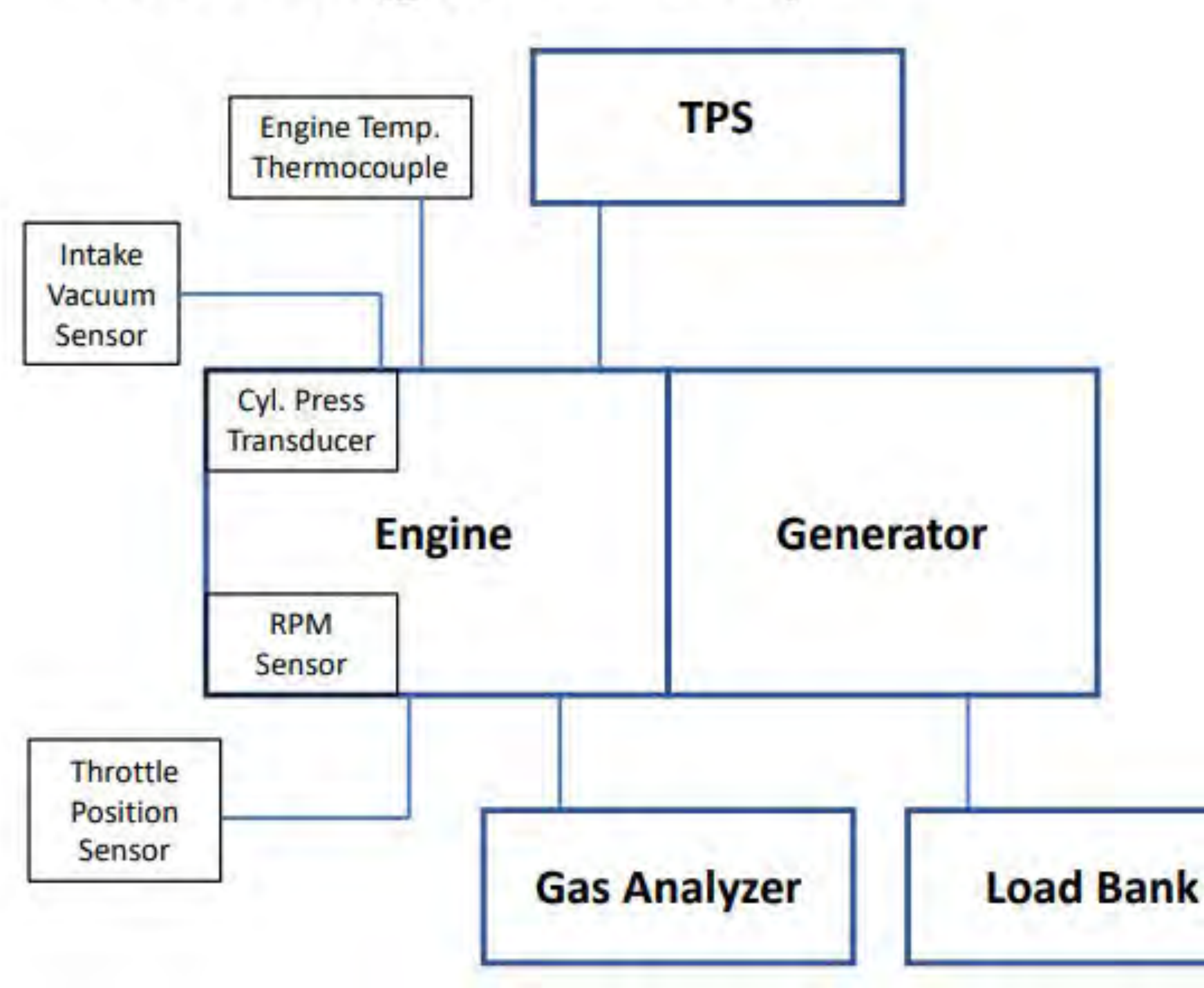
CoV:Coefficient of Variation of Indicated Mean Effective Pressure calculated based on IMEP obtained. Cylinder pressure must be measured to determine IMEP.

Transient Plasma Plug
300 V at 5 count burst





Test Engine Setup



Conclusions

COV and Phi across various loads revealed that transient plasma ignition lowers COV percentage and nitride oxide traces at no load and max load. The NO reduction region can be explored more with NPTP. By applying NPTP the use of Hydrogen and Methane becomes more efficient. It would be interesting how well gasoline, ethanol, or even Nitromethane act under NPTP conditions.

References

KSME International Journal Vol. 15.No.1,pp.81-87, 2001
Heywood, John B. Internal Combustion Engine Fundamentals. Vol. 2, McGraw-Hill Education, 2018.

Acknowledgements

Collaborators: Citrus College, USC
Team at USC: Mariano Rubio, Boxin Zhang

Alternate Text

Travis Riggs, Joshua Tobar Lam, & and Aimee Ortiz-Ramirez

USC

'Plasma-Enhanced Combustion of Methane and Hydrogen in Piston Engine Applications'

Abstract: When burning fuels such as hydrogen or methane, traditional automotive spark ignition just doesn't cut it. To properly ignite these fuels, we adopted a nanosecond pulsed transient plasma ignition system. This allowed us to create plasma to ignite the fuel without creating the excess heat that we see form spark ignition. The more heat inside of the combustion chamber the more harmful emissions are created. While conducting our research we experimented with several different fuels and styles of ignition which gave us a lot of unique results but ultimately, we found that we achieved our most promising results using the NPTP ignition with pure hydrogen fuel.

Introduction and Back ground: Nanosecond high voltage pulses can generate a transient plasma that can aid in the combustion efficiency of fuel-air mixtures at high lean levels. Carbon-based fuels ignited under conventional spark (thermal) ignition have a weak thermal combustion reaction which contributes to global warming. Nanosecond Pulsed Transient Plasma (NPTP) has the capability to thermally accelerate combustion through molecule dissociation via electron impact thus increasing propagation reactions.

Materials and Methods: Transit Plasma System (TPS), Hydrogen, Methane, and Ammonia, Firman T08071 generator, Horiba, Load Bank and Voltage Transformer, Hall-effect sensor, Data acquisition device, intake vacuum sensor, Throttle position sensor. Focused on two methods to find leaner fuel rates using the TPS system and the Conventional Spark. For all fuel alternatives. Find lowest flow rate for conventional at no load before stalling and repeat with TPS. Find highest flow rate for conventional at no load before exceeding RPM limit and repeat with TPS. Revisit all flow rates but apply max load according to flow rate. Looking to load the generator up to 1.000 kW if possible.

Results: Three tables labeled, "COV and NO vs. Φ (No Load)", "COV and No vs. Φ (Max Load)", "COV and No vs. Φ (Max Load)".

Formulas for "Indicated Work", "Indicated Power", "Indicated Mean Effective Pressure".

"Phi: EQR determined by O2 measurement in the exhaust. CoV: Coefficient of Variation of Indicated Mean Effective Pressure calculated based on IMEP obtained. Cylinder pressure must be measured to determine IMEP.

Picture labeled: "Transient Plasma Plug 300 V at 5 count burst".

Chart labeled: "Test Engine Setup"

Conclusions: COV and Phi across various loads revealed that transient plasma ignition lowers COV percentage and nitride oxide traces at no load and max load. The NO reduction region can be explored more with NPTP. By applying NPTP the use of Hydrogen and Methane becomes more efficient. It would be interesting how well gasoline, ethanol, or even Nitromethane act under NPTP conditions.

References: KSME International Journal Vol. 15. No. 1, pp.81-87, 2001 Heywood, John B. Internal Combustion Engine Fundamentals. Vol. 2, McGraw-Hill Education, 2018.

Acknowledgements: Collaborators: Citrus College, USC Team at USC: Mariano Rubio, Boxin Zhang.