New Institute at USC to Target Marine Diesel Emissions Through Research Into Advanced Combustion Technology; Investigation of Transient Plasma Ignition

25 February 2010

Kenneth Koo, group chairman and CEO of Hong Kong-based Tai Chong Cheang Steamship Co., has pledged up to $4.1 million to fund a research program at the University of Southern California (USC) to improve combustion efficiency in marine diesel engines and thereby reduce emissions.

Koo will work with the USC Viterbi School of Engineering to establish the TCC Institute for Emissions Reduction From Marine Diesel Engines. USC has proposed a five-year research plan that will proceed along two paths: a combustion study that will compare and measure differences in conventional diesel engine combustion and diesel engine combustion assisted by transient plasma ignition; and a nano-second pulsed power study that will develop lab-scale prototype transient plasma ignition equipment to achieve more complete combustion in diesel engine cylinders that can then be scaled up for evaluation on full-size engines.

Vinay Patwardhan, the company’s director of group planning and development and a merchant ship captain, noted that the design and method of operation of large diesel engines is virtually unchanged from 100 years ago.

Combustion efficiency is only about 50 percent. We believe a huge improvement approaching complete combustion can be attained with transient plasma ignition, and we intend for USC to conduct research to develop prototype technology that could be truly revolutionary.

—Vinay Patwardhan

Transient plasma discharge (also called pulsed corona discharge), is the transient phase of spark discharge before arc formation. According to researchers at USC, the transient phase lasts 10-100 nanoseconds while the remainder of the spark discharge (arc and glow discharge) takes microseconds or even milliseconds.

Experiments have shown that for flame ignition, the transient plasma phase is more efficient than the arc and glow discharge phases—94% of the transient phase discharge energy goes to plasma, which leads to flame ignition. In the arc and glow discharge phases, only 50% (arc) or 30% (glow) of the energy goes to plasma; 45% (arc) or 70% (glow) of the energy is dissipated in electrode heating.

Transient plasma discharge can readily ignite flame at many points (tens to hundreds) simultaneously, while conventional spark ignition has only one discharge channel. Multi-site ignition can greatly increase the burning rate and decrease heat loss to the chamber walls, boosting thermal efficiency and facilitating lean fuel burning. Transient plasma ignition has a higher thermal efficiency as a result of the higher electron energy, which provides a better match with the ionization and dissociation energy of many molecules, with less radiative and conductive heat loss.

The first phase of research will be conducted at USC, with the goal of producing lab-scale prototype technology that can be scaled up for eventual testing in full-size engines.

Koo intends to engage engine manufacturers and shipping owners around the world to commercialize and fully implement the technology. USC Viterbi School of Engineering professors Fokion Egolfopoulos and Martin Gundersen will be the principal investigators.
Our goal is to reverse, recover and reduce greenhouse gas emissions while also conserving fuel and reducing emissions harmful to health and the environment. I believe we have a responsibility to be good stewards of the environment, and we are willing to do our part to reduce the impact on climate change caused by our ships.

—Kenneth Koo

Resources

- Pulsed Power Group at USC (Gundersen)
- Combustion and Fuels Research Laboratory at USC (Egolfopoulos)

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Comments

This seems similar in concept to HCCI. Marine engines are a good place to develop these technologies, since these engines operate primarily at steady state and do not need to respond rapidly to changing power demand, as auto engines do. This technology could be transferred to range extender gensets for serial hybrids, since they also operate in steady state mode.

Posted by: fred schumacher | February 25, 2010 at 05:01 AM

Yes, a much lighter, cleaner running, more efficient, diesel range extender could be an advantage for various size PHEVs.

What would be the net advantages over recent 2 or 3 cyls improved gasoline ICE range extender?

Posted by: HarveyD | February 25, 2010 at 08:36 AM

We could see HCCI in range extended vehicles. There are lots of options when you control the load profile in an engine/alternator and the batteries and motor handle the transient loads.

Posted by: SJC | February 25, 2010 at 11:59 AM

This plasma discharge technology can improve spark ignition engines when operate in very lean combustion, but I don't see how it can improve Diesel engines, which are ignited by a spray of fuel into very hot air. This spray of fuel ignites in a wide burst pattern just as good or even better than plasma discharge. Large marine diesel engines operate quite close to the theoretical efficiency for diesel cycle, and it is difficult to improve on this efficiency.

Posted by: Roger Pham | February 25, 2010 at 01:23 PM
Roger it is not so easy to see how a plasma can crack the globous nut of unburnt
diesel, but we know for fact that various fuel additives: lpg, ng H2 and ethanol
(water emulsion?) can have this beneficial affect.

The injectors on bunker and heavy crude burners must be rather loose tolerance
and this in combination with volumous combustion chambers cannot be optimal
environment for oxidation.

Surprising to me that the efficiencies are as high as they are (by reputation).

Could this be a reflection of the severity of small displacement inefficiency rather
than any leaning toward theoretical maxims?

The way they multiple path plasma is described, I can concieve that especially in
the large capacity engines envisioned, this could be a similar effect to high
pressure spay directed pintle(s).

I don't quite understand the layman's difference in descriptor between a plasma
'electrode' and spark plug other than convention.
I.E. a fancy spark plug(s) That I.E. don't fit or function exactly as conventional.

Posted by: Arnold | February 26, 2010 at 01:21 AM

This is a tough undertaking.

OGV marine diesels are really very efficient. They have thermal efficiencies
hovering around 50%, which is unheard of in any internal combustion engine.

Trying to improve them further using PCCI concepts, Premixed, Charge
Compression Ignition, may or may not lead to much, perhaps augmented with
some HCCI too.

But such is the nature of incremental technological improvement. Over time the
little advances accumulate, and become large.

Posted by: Stan Peterson | February 26, 2010 at 09:10 AM

@Arnold,
To 'crack the globous nut of unburnt diesel,' what must be done is a lot of
turbulent and prolongation of the delayed ignition phase in order for the fuel to
vaporize and mix with air for complete combustion. Thankfully, large marine diesel
engines run quite slowly, at only a few hundred rpm, so there is a lot more time
for vaporization and combustion than in a truck diesel running at 1500 rpm. Better
fuel vaporization can be achieved by using multiple fuel injectors simultaneously
in a large-bore engine, so that the fuel droplets can be smaller and do not have to
travel a long distance from the center of the cylinder to the periphery. The bunker
fuel is pre-heated prior to injection to lower the viscosity of the fuel in order to
form smaller droplets.

I still don't see the role of plasma ignition in a diesel engine. It would be better to
use multiple injectors in order to achieve better fuel-air mixing and ignition at
multiple points in a large-bore engine, plus the use of swirl motion on the air
intake to allow for better mixing. Once ignition takes place at every location that
fuel is injected in a diesel engine, combustion is vigorous and quite complete
where there is enough oxygen available for combustion. Better fuel-air mixing is
the key here, not plasma ignition.

Posted by: Roger Pham | February 26, 2010 at 10:17 PM

Roger,

I am speculating, but I suggest that:

There has been lots of work done under the rubric of PCCI and HCCI that does
tend to indicate that a partial OTTO, partial Diesel, cycle engine, can be more
efficient than either, alone.

I suspect this may be an attempt to create a supercritical and/or partially ionized
fuel state in the cylinder prior to ignition.

Through a combination of bunker fuel pre-heat, using exhaust gas heating, for
waste heat recovery, together with better fuel premixing, utilizing multi-point and
multi-cycle injection, as you suggest, along with partial fuel charge ionization, via plasma ionization, the ignition conditions are optimized.

Then the ignition can proceed uniformly and homogeneously in the cylinder very rapidly, and hence more efficiently, without transferring lots of waste heat to the cylinder walls.

Posted by: Stan Peterson | March 05, 2010 at 06:22 PM

Agree with you, Stan.

Posted by: Roger Pham | March 09, 2010 at 11:18 AM

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