



FEATURED LECTURE - Decarbonization

PLENARY LECTURE BY PROF. ZUOHUA HUANG

Wednesday morning, we had the honor to attend the Plenary Lecture by Prof. **Zuohua Huang** (Xi'an Jiaotong University, China) on fuel blend combustion for decarbonization. Very deep insights were provided into the effect and opportunities of mixing hydrogen, ammonia and hydrocarbon-based fuels to enhance combustion properties, reduce emissions as well as for better adaptation to existing combustion devices.

After the talk, we stopped Prof. Huang to ask him some questions...



Could you provide some suggestions on how to promote the translation of fundamental combustion research into applied fields?


Fundamental combustion research stems from practical problems in applied fields. Solving these issues requires understanding of their underlying mechanisms. For instance, it is important to understand why engine combustion is closely related to flow and chemistry, why optical diagnostics support fuel-air mixing and complete engine combustion, and why engine knocking is strongly influenced by fuel chemistry. *My career began with studying internal combustion engines for my Master's and PhD, focusing on both spark ignition and compression ignition engines.* This experience highlighted many phenomena that were difficult to understand, leading me to *pursue fundamental combustion research for deeper insights.* Applied research drives fundamental studies, and *a better understanding of fundamental principles enhances applied work.* This upstream-downstream relationship ensures productive and impactful research.

How to consistently conduct innovative work throughout your career?

Consistently conducting innovative work requires a long-term strategy, not chasing hot topics. Hot topics offer short-term gains but lack lasting impact. A focused, *long-term approach helps overcome challenges and achieve continuous progress.* Experts in combustion fields build their reputations through years of dedicated work. By setting clear goals and persistently working towards them, researchers can achieve deep expertise and leave a lasting mark. Young scholars should thoughtfully plan their careers, aiming to become experts in specific areas.

*Prof. Zuohua Huang (Middle) with Session Chairs
Prof. Hideaki Kobayashi (Left) and Katharina Kohse-Höinghaus (Right).*







Milan 2024
CI'S 40th
INTERNATIONAL SYMPOSIUM
Emphasizing Energy Transition
25th - 28th JULY 2024

5.1 HCNG Engine

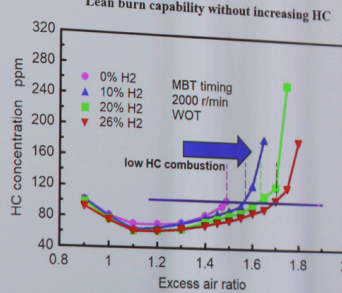
Low HC and NOx achieve in HCNG engine

Low cyclic variation lean burn combustion





Lean burn capability without increasing HC



HC concentration ppm

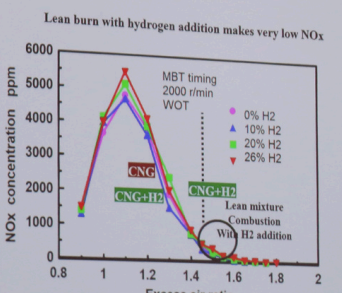
Excess air ratio

Legend: 0% H2 (circle), 10% H2 (triangle), 20% H2 (square), 26% H2 (inverted triangle)

MBT timing
2000 r/min
WOT

low HC combustion

Lean burn with hydrogen addition makes very low NOx



NOx concentration ppm

Excess air ratio

Legend: 0% H2 (circle), 10% H2 (triangle), 20% H2 (square), 26% H2 (inverted triangle)

MBT timing
2000 r/min
WOT

Prof. Zuohua Huang delivers his Plenary Lecture!



SCIENTIFIC HIGHLIGHTS from INDUSTRY

GREAT EXCHANGES AT TODAY'S INDUSTRY SESSIONS!

Wednesday was industry day! In the morning, in parallel to the “regular” colloquia, two industry sessions were held. Invited speakers included Drs. **Alessandro Della Rocca** (Tenova, Italy), **Francesco Di Sabatino**, (SwRI, U.S.), **Louis A. Gritzso** (FM Global, U.S.), **Harri Kytömaa** (Exponent, U.S.), **Keigo Matsumoto** (Mitsubishi Heavy Industries Ltd., Japan), **Paul Papas** (RTX Technology Research Center, U.S.), **Venke Sankaran** (AFRL, U.S.), **Saumitra Saxena** (KAUST, Saudi Arabia), and Prof. **James Turner** (CCRC, KAUST, Saudi Arabia). They covered a variety of topics from an applied perspective, from wildfires and Li-ion battery fires in aviation, to plastic waste valorization, propulsion, and hydrogen safety.

Both industry sessions were quite packed; attendees were very enthusiastic. Some were even impatiently waiting to get in and catch a glimpse of the speakers! The feedback of all attendees was extremely positive, especially about how the speakers targeted their presentations to guide future academic research tasks to solving practical problems at the industrial scale (basically the usual question from academia to industrial partners “what do you want from us”- often unanswered). For instance, Prof. James Turner provided an excellent description of engine problems, which can be useful to the whole community, while Dr. Venke Sankaran gave insights into practical problems for aerospace combustion applications.

During the coffee break, attendees enthusiastically commented on the industry sessions!

Alessandro Pegurri (PhD student at Politecnico di Milano, Italy)

“I really enjoyed the presentation of Lou Gritzso during the first industry session on wildfires - he made such a complex topic so compelling and accessible to non-experts too! At the same time, he gave deep insights into different aspects contributing to the dynamics of the wildfires, such as combustion chemistry, flame physics and dynamics, risk management, and environmental aspects.”

Ken Brezinsky (Prof. at UIC, Chicago, U.S.)

“I was impressed by the talk of Alessandro Della Rocca during the industry session - he was a very good speaker, compelling, described problems, and made me wonder what we combustion people can do for the metal industry and why we don't have a better relationship with them, since they do have engineering problems we could deal with.

Conversely, I have some comments on the Panel session from Tuesday afternoon - I would expect that young people go to a past, present and future presentation to pursue direction for the next 15 years. However, presentations were too general and without concrete specifics that a young person could yield to - so more like motivational rather than directional talks.”



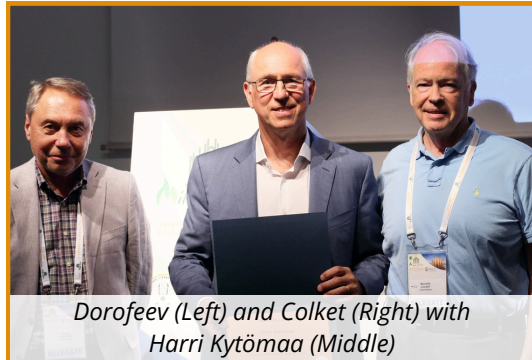
Alessandro Della Rocca delivers his talk!



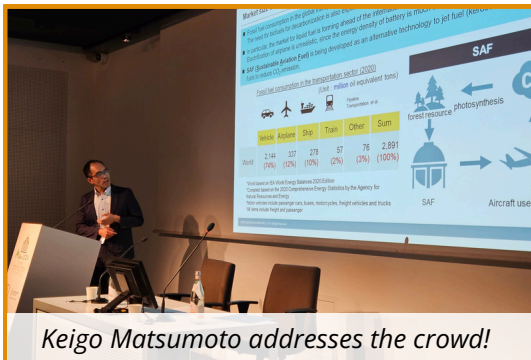
Francesco Di Sabatino presents his work!



Session Chairs Sergey Dorofeev (Left), and Meredith Colket (Right), with Louis Gritzko (Middle)



Dorofeev (Left) and Colket (Right) with Harri Kytömaa (Middle)



Keigo Matsumoto addresses the crowd!



Dorofeev (Left) and Colket (Right) with Paul Papas (Middle)



Venke Sankaran talks future R&D needs in aerospace propulsion!



Dorofeev (Left) and Colket (Right) with Saumitra Saxena (Middle)



Session Chair Uwe Riedel (Right) with James Turner (Left)

A LIVELY INDUSTRY ROUNDTABLE!

Wednesday's Special Industry Roundtable on "Hydrogen as an energy vector" attracted a large audience. A proper representation of the different industries made the roundtable particularly interesting, on top of which Dr. **Max Schoenfisch** from the IEA (France) gave a very clear outlook. Surprisingly, by 2040, on an annual average, the *share of hydrogen for thermal power generation will be close to zero(!)*, while it can account for up to almost 20% in peak situations. Hence, for thermal power, hydrogen will fit the market for capacity purposes only, such that the upfront investment costs will have to be kept low... A second important point to consider is that the transition will happen in the lifetime of many existing plants, such that *retrofitting* will become a primary design criterion. After this enlightening introduction, the participants gave an account on how each industry is tackling the transition towards hydrogen as a fuel through three statements each.

Andrea Baio (EAS Pyronics Int., Italy) stated that for the high temperature furnace industry the real main issue - already highlighted at several occasions during the Symposium - is the massive amount of hydrogen required. Without supply security, investments in infrastructure will be difficult to justify. For lower temperature applications, other technologies are available (e.g., FGR).

Christian Romano (Baker Hughes, Italy) showed a promising roadmap for stationary gas turbines with on-going programmes aiming at qualifying low NOx 100% hydrogen firing and full NG-H2 flexibility by 2026. Here again, challenges behind combustion chemistry include safety, piping, and certifications.

Then came a highly expected application: hydrogen for aviation gas turbines, represented by Dr. **Ruud Eggels** (Rolls Royce, Germany). For aviation, recent programmes at Rolls Royce have looked into the use of hydrogen in annular type combustors with planned engine ground test in 2025. RQL combustor technology is seen as the fastest way to adapt hydrogen by using existing mature systems. Surprisingly, measured NOx were not necessarily higher than with kerosene which, without being fully explained, is rather encouraging. The on-board supply chain of hydrogen (pumps, metering, tank systems, etc.) is in fact the biggest bottleneck. At ground level, both infrastructure and regulations are non-existent.

The last speaker was Dr. **Toshiro Fujimori** (IHI Corporation, Japan) who highlighted the huge efforts of IHI in Japan to materialize ammonia power generation to reduce CO2 emissions. For instance, in the marine sector a 2 MW engine with 80% ammonia firing will be demonstrated in the Tokyo Bay. Amongst the challenges, Toshiro mentioned the need for N2O after-treatment, 100% ammonia firing, and lower primary NOx formation. A transition step in the decarbonization of existing coal assets has been achieved by co-firing up to 20% ammonia, with equal NOx performance. 20% is not large in itself, but in a 1 GW power plant it still corresponds to 1 Mt CO2 reduction at low retrofit costs, and therefore a convincing transition effort.

In addition to supply, *cost* of hydrogen is obviously a barrier to the penetration in the power market. It was reminded that blue hydrogen (i.e. from steam reforming of natural gas with CCS) by far produces the cheapest hydrogen, and will be so for a long time.



MEET THE ROUNDTABLE MODERATOR

DR. ARVIND RAO - HOW DID IT GO?

Let's meet the moderator of the first Industry Roundtable, Prof. **Arvind Gangoli Rao**, from the faculty of Aerospace Engineering at Delft University of Technology. After the roundtable, we stopped him to ask him his perspective on the discussion and more insights into his own career.

What are your impressions and highlights from today's discussion?

I found it fascinating to see how different parts of the world are adopting various fuels. Europe is focusing more on hydrogen, while Japan is pushing ahead with ammonia. The US might go with Sustainable Aviation Fuel (SAF) or other alternatives.

Different fuels are suited to different applications. For high-temperature processes, hydrogen is ideal, whereas SAF is more suitable for aviation. Ammonia, however, doesn't seem viable for aviation. This diversity highlights the need for extensive research across various areas, although it also brings a significant level of uncertainty to the global energy transition.

In your perspective, which guidelines do you suggest to follow for an effective energy transition?

Firstly, we should not forget about current assets and the *importance of increasing efficiency in existing systems*. Additionally, using even small quantities of hydrogen can significantly reduce pollutant emissions in many cases. Hydrogen comes in various "colors," but for combustion purposes, the color doesn't matter. We can start with blue hydrogen, which might not be as green but is still a viable starting point. Ammonia can also play a role alongside hydrogen. In the energy transition, we need to take action now. Maybe we will not succeed in this, but I think that we needed this kind of attitude in the energy transition

Since you started in the combustion field and aircraft propulsion, how have these sectors evolved through the years?

As an aerospace engineer, I feel this is the best period of my career. When I graduated, the focus was solely on reducing costs in aviation to make money, with efficiency being important only for cost-effectiveness. CO2 reduction was merely a byproduct of cost-cutting measures. Today, we are discussing radical changes, such as different aircraft architectures, hybrid and electric propulsion, new combustion systems, and various fuels like hydrogen and SAF. Now, we are exploring a wide range of possibilities. It's a thrilling and transformative time!





From L to R: Industry Roundtable moderator Prof. Dr. Arvind Gangoli Rao, with panelists Dr. Max Schoenfisch, Andrea Balo, Cristian Romano, Dr. Ruud Eggels, Dr. Toshiro Fujimori

Statement 1

Thermal power plants using hydrogen or hydrogen-based fuels could be important providers of secure capacity in net zero electricity systems

H2 as an energy vector for heat & power

Average power supply mix across the year and in peak-100 hours in Europe in 2050

Category	Annual (%)	Peak (%)
Other	~10	~10
Battery storage	~10	~10
Hydro	~10	~10
Thermal	~10	~10
Wind	~10	~10
Solar PV	~10	~10

Our Industry Roundtable panelists deliver some insights.



COFFEE TALKS

COFFEE TALK WITH A COMMERCIAL DIAGNOSTICS SUPPLIER FROM INDUSTRY

Dr. Rob Littlewood and his colleagues have set up shop on behalf of **Dantec Dynamics** in the Exhibition Hall of the Symposium, of course to promote their diagnostic equipment line, but not just for that... In these times of energy transition we were curious about how the *demand in commercial reacting flow instrumentation* has evolved, if at all. Rob first mentions that the newest trend is on volumetric type of measurements in search for ever better characterization of *complex turbulent reacting flows*. But the energy transition has impacted the demand through new opportunities. For example, the combustion systems fueled by hydrogen and the associated avoidance of soot and other gaseous emitters, enable the use of simpler equipment like the *UV sensitive camera without intensifier*. We were then **questioning if the time from lab to commercialization of advanced combustion diagnostics was compatible with rapid transition**. It is in fact often *opportunity driven*, he says. *Sometimes the technique may have existed for a long time in another field*, like "event based camera imaging" used for around 30 years in physics for photon counting applications at pioneering facilities like CERN and other accelerators. But recently, the idea has been adapted to the field of flow measurement. Littlewood adds that *it is difficult to bet on which tools to develop to commercialization as it requires extensive investment*, so it is important for us to come to the Symposium and hear about the trends and uses in the labs.



COFFEE TALKS

WHAT ABOUT LIQUID AMMONIA-FIRED GAS TURBINES?

While the majority of ammonia-oriented papers are focusing on mixtures with other, better reacting fuels to deal with the poor combustion stabilization of ammonia, a group of researchers insist on burning it, not only pure, but in liquid form too! There are actually good reasons to believe that they may be right, as those are the very scientists that pioneered the recent ammonia fueled gas turbine era of the last 10 years. We asked Senior Researchers **Norihiko IKI** and **Yong FAN** (AIST, Japan) if this is a reasonable way to go, and their research studies and testing confirm it. It's a bit complicated of a combustor design, they say, but *it's possible to achieve this with some adapted starting procedures with a slightly cracked mixture, followed by a rapid switch to liquid ammonia*. The main advantage is of course the avoidance of a large continuously operating cracker. And this is a very good argument, as there are already many barriers to overcome to make ammonia a cheap decarbonized fuel, therefore the importance to eliminate any additional technical complexities.

SOCIAL EVENTS - PICNIC AT VILLA ERBA!



DID YOU ENJOY THE LAKE VIEW?

The day started a bit cloudy in Milan, but fortunately the sky opened in the afternoon for the picnic excursion at Lake Como. Several buses left the MiCo at 14:00 for the Villa Erba. On our way to the location, the mountains over Lake Como could already be seen from the bus. Arriving at the Villa, everyone was impressed by the beauty of the place, the palace, in neo renaissance style with vine plants, added a delightful touch. The researchers showed that their abilities go beyond combustion science and participated in multiple sports activities available in the Villa: foot dart was highly popular, together with the cornhole and foot billiard. A part of the group enjoyed the charming town of Cernobbio, and others took their time to stroll around the lake shores, even under an intense sun. Some of the lucky ones went to the pool right close to the lake with a wonderful view. After this pleasant and scorching afternoon, there was nothing better than a cold drink to refresh. Some enjoyed beers, while others stuck to a classic wine and soft drinks. After a whole day of amusement, the barbecue and great food was the perfect way to finish the day. Of course, as we are in Italy, so there was risotto and arancini served along with great mozzarella, cheese and ham. After the meal, the participants enjoyed live music by the lively Boom Boom Brothers, who had everyone dance and sing along. They also thanked Politecnico di Milano and the CI after their show. Indeed, the crowd was cheerful and grateful to them also for playing a few more songs after they had declared that the show was over!

Some feedback from the MZ Events team: They were pleased with how "tidy" and smoothly everything was when it was time to get back to Milan. Also the bus driver was impressed (a reporter just happened to overhear this conversation)!

Some participants - including the relaxed CI President-Elect Prof. Hai Wang - stated that it was the best picnic event they have attended in years! Well done to the organizers, especially Isabella Branca!



Have you ever seen a table football game this big?



What a stunning piece of architecture!

The Boom Boom Brothers put on a show!



The crowd is loving the music!



Another snapshot of the site of the excursion.

Time to eat!



More foot dart fun!



Foot dart was a popular game at picnic!



What is the Symposium Tribune? It's a daily bulletin that will keep you updated on all the key highlights and events happening at the Symposium, including interesting scientific talks and interviews to speakers, organizers, awardees. You will also find opinions from participants, and insights into social events in case you can't make it!

Contributors: Luna Pratali Maffei (POLIMI), Fabiola Citrangolo Destro (LL-CNRS), Lauren Creadore (CUNY), Mario Di Taranto (SINTEF), Ali Elkhazraji (KAUST), Federica Ferraro (TU-Braunschweig), Alexander Konnov (Lund University), Yuyang Li (SJTU), Zhuyin Ren (Tsinghua University), Maria Virginia Manna (STEMS-CNR), Max Schneider (TU Darmstadt), Jungho Sohn (KAIST), Stephen Tse (Rutgers), Augustin Valera-Medina (Cardiff), Draven Marino (The Combustion Institute), Tiziano Faravelli (POLIMI)

Feedback is always welcome, and can be submitted via Telegram: <https://t.me/CombustionSymposium2024/2>