

جامعة الملك عبدالله للعلوم والتقنية King Abdullah University of Science and Technology Issue 7 | Spring 2022



# KAUST CLEAN COMBUSTION RESEARCH CENTER (CCRC) NEWSLETTER

### Cover Image

Pre-chamber engine simulation - full cycle simulation performed on the Supercomputer Shaheen II at KAUST.

ccrc.kaust.edu.sa

## A NOTE From the Editor



In this first edition for 2022, we highlight our activities such as improving engine efficiency, ammonia combustion and desulfurization of oil using uODS, our groundbreaking technology. We also talk to Prof. Deanna Lacoste about her career and research, and celebrate our alumni Wesley and Sally.

'Combustion is not the problem and electrification is not the only solution', is a sentence I find myself repeating many times these days. Of course, it is not the process of combustion that is causing climate change but rather the burning of fossil fuels that has caused the carbon imbalance in the atmosphere. One of the leading strategies to mitigate this effect is to find a balance through the carbon circularity approach which requires reducing, reusing, recycling and removing carbon from our activities and the atmosphere.

Such an approach requires the improvement in the efficiency of existing processes, fuel switching

and CO2 capture, utilization and storage. All such objectives require research and development in thermal processes which often rely heavily on combustion. Furthermore, the majority of renewable technologies rely on metals that need to be mined and reduced mostly through high temperature processes that utilize combustion as well. One can argue that combustion research is one of the most critical fields for the decarbonization efforts, as we develop new technologies that are lower in carbon intensity.

We at the CCRC continue our basic science and translational research in combustion, alternative fuels, CO2 capture, energy convergence and integration with renewables. We invite you all to visit our website and to learn more about our activities.

Bassam Dally Editor of CCRC Newsletter Professor of Mechanical Engineering Clean Combustion Research Center



An infographic representation of KAUST's Circular Carbon initiatives

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### COMMENCEMENT 2021

# KAUST recognized the graduating class of 2021 as part of its 12th commencement ceremony.

On December 17, KAUST recognized the graduating class of 2021 as part of its 12th Commencement ceremony.

This year's ceremony honored 148 master's degree graduates (95 male/53 female) and 86 Ph.D. graduates (59 male/27 female) from KAUST's three

divisions and various programs. Among the 234 graduates, 93 are from Saudi Arabia (57 male/36 female).

From the Clean Combustion Research Center, 8 Ph.D. graduates and 18 master's degree graduates were commemorated.



CCRC Ph.D. graduates present at the commencement ceremony.

## Ph.D. Graduates

- Tsu-Fang Hong, Taiwan, Chemical Engineering, advised by Prof. Mani Sarathy
- Can Shao, China, Mechanical Engineering, advised by Prof. Mani Sarathy
- Dapeng Liu, China, Mechanical Engineering, advised by Prof. Aamir Farooq
- Farha Khan, India, Mechanical Engineering, advised by Prof. William L. Roberts
- Miguel Figueroa Labastida, Mexico, Mechanical Engineering, advised by prof. Aamir Farooq
- Paolo Guida, Canada, Mechanical Engineering, advised by Prof. William L. Roberts
- Wonsik Song, South Korea, Mechanical
   Engineering, advised by Prof. Hong G. Im
- Yu Jeong Kim, South Korea, Mechanical Engineering, advised by Prof. Hong G. Im

## **MS Graduates**

### **MECHANICAL ENGINEERING**

- Ahmad Aiman A. Tashkandi, Saudi Arabia
- Azat Amiralin, Kazakhstan
- ▶ Faisal Ahmed S. Alsayed, Saudi Arabia
- ▷ Ghufran Salem S. Alkhamis, Saudi Arabia
- ▶ Ibraheem A. Alsheikh, Saudi Arabia
- ▶ Jonathan Allen Peterson, USA
- ▶ Jordan Nunes Figueiredo, Brazil
- ▶ Khalid Abdullah M. Algashgari, Saudi Arabia
- ▶ Lujain I. A. Fatta, Saudi Arabia
- ▶ Mohammed O. A. Andejani, Saudi Arabia
- ▶ Mohammed Bo Khamseen, Saudi Arabia
- ▷ Sarvarkhodzha Nematulloev, Russia
- ▶ Tougeer Anwar Kashif, India
- ▷ Zeinab H. Al Hadi, Lebanon

#### CHEMICAL ENGINEERING

- ▷ Ana Luiza Slama de Freitas, Brazil,
- ▷ Carolina Arias Gallego, Colombia,
- ▶ Juan Camilo Giraldo Delgado, Colombia,
- ▶ Andres Felipe Cardenas Alvarez, Colombia,

Congratulations to the entire class of 2021 on your achievement! The Clean Combustion Research Center wishes you all the best in your future endeavors.



CCRC M.S. graduates present at the commencement ceremony.

### FACULTY UPDATES

# William L. Roberts, Thibault Guiberti, and co-authors win the 2020 Gaydon Award



A collaborative paper between the Engineering Department at the University of Cambridge and Clean Combustion Research Center, KAUST has won the 2020 Gaydon Award!

The Gaydon Award, named in honor of Prof. A. G. Gaydon, FRS, is granted to a full paper, with at least one British Section member as an author and published and accepted for oral presentation in the Proceedings of the International Symposium. The paper should also make the most significant contribution to combustion research.

"Very honored and humbled to learn that our paper has been selected for the 2020 Gaydon Award by the Combustion Institute (British Section). This award recognizes the paper with the most significant contribution from the United Kingdom to the most recent International Symposium on Combustion." stated Dr. Aaron Skiba, who was a Research Associate at the University of Cambridge.

I am very grateful to my co-authors (Thibault Guiberti, Wesley Boyette, William Roberts, and Epaminondas Mastorakos) for their time and assistance with this work, it certainly would not have been possible without them. Additionally, I am thankful for the extraordinary opportunity to A. W. Skiba, T. F. Guiberti, W. R. Boyette, W. L. Roberts, and E. Mastorakos On the bi-stable nature of turbulent premixed bluff-body stabilized flames at elevated pressure and near lean blow-off" Proc. Comb. Inst. 38, 2853-2860, (2021)



Scan QR or click here to read the paper

have spent time conducting research at the Clean Combustion Research Center (CCRC) at KAUST (King Abdullah University of Science and Technology)." he added.

"This award is a testament to the added value of collaborative research, and we are proud to share it with our colleagues from the University of Cambridge." stated Thibault Guiberti, Assistant Research Professor at CCRC.

"Findings from this study refined our understanding on conditions leading to the undesirable extinction of flames in gas turbine combustors for power or propulsion. Specifically, we used CCRC's bespoke high-pressure combustion duct to scrutinize flame extinction events at elevated pressure and under extreme turbulence, typical of what is found in practical combustors, which had not been achieved before.", he further shared.

# Thibault Guiberti wins "Best Presentation Award for Young Researcher"!



Thibault Guiberti, Assistant Research Professor at CCRC, received the Best Presentation Award for Young Researcher at the 18th International Conference on Flow Dynamics held on October 27-29, 2021 in Sendai, Japan. It was awarded in recognition of the quality of content and oral presentation at the conference for his paper 'Quantitative Measurements in Ammonia-Hydrogen Turbulent Jet Flames at Elevated Pressure'.

His research team includes postdoctoral fellows Guoqing Wang and Chaobo Yang, Ph.D. student Hao Tang, Assistant Professor Gaetano Magnotti, and Professor William L. Roberts.

The team developed a new laser technique to measure qualitatively the concentration of nitric oxide (NO) in turbulent flames of ammonia. The feasibility of this new technique was demonstrated by CCRC in an ammonia-hydrogen turbulent jet flame at elevated pressure. This also helped generate a unique, high-fidelity database for future combustion model validation.

The International Conference on Flow Dynamics explores new horizons in science and technology in flow dynamics by discussing and exchanging information related to the most advanced scientific fields and cutting-edge technologies. ICFD is recognized by researchers and engineers worldwide as one of the largest and most important international conferences in the field of Flow Dynamics. It plays an important role in promoting international research collaborations. The ICFD2021 focused on energy-related topics, such as clean energy, hydrogen energy, and natural energy.

Scan QR code of click here to read the full paper.



### Faculty Spotlight: Deanna Lacoste



Hello Deanna, thank you for agreeing to be interviewed for the CCRC Newsletter. Can we start by asking you about your academic journey and how did you end up at KAUST?

Hello Bassam, thanks for inviting me. I got my MS and Ph.D. degrees from the University of Poitiers, in France. My Ph.D. thesis was on spark ignition of stratified mixtures. After two years of postdoc at Ecole Centrale Paris (now CentraleSupelec), I became a CNRS research engineer in the same institution. Ten years later, I wanted to change my working environment and I moved for short periods in different institutions, including the University of Tokyo and TU Berlin.

In 2013, I saw a presentation by Suk Ho Chung in a workshop on plasma-assisted combustion. He briefly presented KAUST and it sounded amazing. I decided to apply and I joined the CCRC in 2014. You were promoted to an Associate Professor this year, congratulations!! What did this experience teach you that you are happy to share with junior faculty who are going through the process?

Thank you! What I learned is that if you want to be promoted, people must know you. Both at KAUST and internationally, people should know what you are doing and what your core expertise is. Publishing papers and presenting at conferences is not enough, it is necessary to meet and talk. This shift from focusing on my research to spending a large fraction of my time engaging with people in commissions, in meetings, in seminars, in lab visits all over the world, was a key point for me.

## Can you tell us about your research interest now and into the future?

I am interested in plasma-assisted combustion, with a special focus on the control of flame dynamics

and on the enhancement of detonations. I am also curious about other applications of nonequilibrium plasmas at atmospheric pressure, such as plasma for the synthesis of nanomaterials, plasma for ore melting, or plasma for biological applications. I think that in the future, I will be developing more of these aspects of my research.

Research and development of energy technology are essential for the circular carbon economy and for ensuring a sustainable future. Can you tell us how your research fits into these initiatives and global direction?

My research mainly focuses on improving the efficiency of energy conversion systems. This is one of the essential aspects of the circular carbon economy. I am also working on waste heat recovery and the combustion of carbon-free fuels such as hydrogen and ammonia. All of these research themes fit into reducing the amount of carbon dioxide released into the atmosphere.

#### You are due to deliver a Keynote Lecture at the upcoming International Symposium on Combustion in Vancouver in July this year. Can you give us a snippet of what you will be talking about?

I will be talking about plasma-assisted combustion, of course! I sincerely thank Bénédicte Cuenot and Nils Hansen for this opportunity. It is the first time that plasma-assisted combustion will be presented in a plenary lecture at the International Symposium on Combustion (I checked) and I am super excited. I hope that I will be a good advocate of the great research that has been done in this field. I will just dedicate the last part of my talk to what has been keeping me busy for the last 10 years: the control of thermoacoustic instabilities by non-equilibrium plasma discharges.

# Can you tell us about your involvement in the Women in Science, Engineering, and Research, WISER conference series?

For the second time, my colleagues Niveen Khashab, Suzana Nunes, and I are organizing a KAUST workshop for Women in Science, Engineering, and Research around the International Women's Day, on March 8. This hybrid event will bring together female scientists, at various stages of their career, from all over the world, talking about their professional journey. The theme of this year is "Understand", which stands for understanding why there are so few women in STEM (about 30%) and understanding why women in STEM don't have the same career as men (less than 5% in university upper management, for example). To learn more about these two points, we have invited experts in gender equity as well as key persons from KAUST HR, PSE division, and KAUST School. I am sure that we will have exciting discussions.

## What would you tell a young student who is about to start their studies in combustion?

Don't believe in social media! Combustion science is not dying. It has never been so vibrant and innovative. With the challenges of global warming and growing of the energy demand, we need smart and innovative solutions. There is an emergency and combustion systems must evolve quickly. To help this transition, the combustion community is working hard and we need fresh minds to help us.

Interviewed by Bassam Dally, Editor of CCRC Newsletter Professor of Mechanical Engineering Clean Combustion Research Center, KAUST.

### Sustainability Seminar Series | Powering a Green Future



On February 15, 2022, Prof. Bassam Dally was hosted by Students for Sustainability at KAUST as a guest speaker in the Sustainability Seminar Series. Prof Dally's talk was titled: "*Powering a Green Future from Aspirations to Reality*"

In his talk, Prof. Dally discussed the widening gap between the aspirational targets of carbon neutrality by 2050, and reality on the ground. He showed evidence that with current policies and commitments; we are unlikely to meet the intended target of limiting the temperature rise to less than 2°C by the end of the century. He talked

about current impediments and constraints, and discussed measures to overcome them. He then proposed the concept of integrated solutions for cost-effective decarbonization and gave examples where major gains can be achieved using existing technologies in areas such as natural gas leakage, cement production and the iron and steel industry. These three sectors are responsible for a ~20% of the total CO2 equivalent emission worldwide. Paying special attention to these industries can bring tangible addition to the ongoing decarbonization strategies worldwide. To listen to his talk please, scan the barcode below or click on this link.

The event was moderated by KAUST student, and member of S-Square, Tanaallah A. Alqurshi and is supported by Graduate Events & Recreation and the Head of KAUST Sustainability, Dr. Ana Margarida Costa.

Scan QR or click here to view recording.



### Combustion Webinar | Prof. Hong G. Im

On March 16, 2022, Prof. Hong G. Im presented a talk at the Combustion Webinar Series led by Prof. Yiguang Ju of Princeton University.

#### His talk was titled: "High Fidelity Simulations of Hydrogen and Ammonia Turbulent Premixed Flames: Phy. Charac. & Modeling"

In his talk Prof. Im provided an overview of recent studies at KAUST using direct numerical simulations to reveal local structures and statistical characteristics of turbulent premixed flames at a wide range of relevant physical parameters. The use of simulation data to provide insights into turbulent combustion



modeling implication and recent developments in accelerated simulations using GPU and machine learning were also discussed.

Scan QR or click here to view recording.



### FEATURED ALUMNI

## Sally Homsey

### Wesley Boyette



**Program:** Ph.D. Student (Spring 2021) **PI:** Prof. Robert W. Dibble & Prof. William L. Roberts **Current Position:** Senior Engineer Support Contractor, National Energy Technology Laboratory, U.S.A.

"I joined KAUST in 2015, a year after Wesley and I were married. My Ph.D. research mainly focused on carbon capture by calcium looping. More specifically, I investigated the potential of using local limestones for SO2 and CO2 co-capture from heavy fuel oil-fired power plants. KAUST is where I became a member of the scientific community working on technologies that combat climate change. Wesley and my first home together, where we adopted our two cats. We met many wonderful people who we hope will be lifelong friends.

I am currently a senior engineer support contractor at the National Energy Technology Laboratory in Pittsburgh, Pennsylvania, U.S.A., where I lead a team assessing post-combustion carbon capture technologies through techno-economic analysis."



Program: Ph.D. Student (Fall 2018)
PI: Prof. William L. Roberts
Current Position: Postdoctoral Scholar,
Department of Mechanical and Aerospace
Engineering, Ohio State University

"Having completed a Master's degree with Prof. Roberts at North Carolina State University, I was given the opportunity to be one of his first Ph.D. students at the CCRC. I was lucky to be joined by my wife Sally, who started her Ph.D. a couple of years later. My project was to help establish the high-pressure combustion laboratory and design a unique pressurized vessel for studying turbulent jet flames. I will always cherish my time at KAUST, the exciting research I was able to conduct there, and the talented researchers with whom I collaborated.

After leaving KAUST, I continued my combustion research as a Postdoctoral Scholar at Ohio State University, where I am investigating high-pressure spray flames, novel soot diagnostics, and the challenges of operating gas turbine engines on fuels with high hydrogen content."

### **RESEARCH UPDATES**

### **CCRC Startup signs MoU with Luberef**



William L. Roberts, Director, CCRC and Tareq Alnuaim, President and CEO of Luberef signing the MoU

At KAUST's Clean Combustion Research Center (CCRC) a startup is being lifted to new heights with their new partnership with Saudi Aramco Base Oil Company - Luberef.

Emerging Solutions Commercial Company. LLC, trading as uODS, is a company formed to commercialize KAUST intellectual property to remove harmful sulfur from hydrocarbons.

The MoU was signed on 19, January 2022 with Luberef agreeing to support them in the development and deployment of their technology.

"This spin out and the resulting MoU with Luberef is a great example of translating the fundamental research done in our labs, with a team of international collaborators, into a scaleable and economically-viable process to meet a critical real-world need," stated William Roberts, Professor and President, uODS

The uODS process is built upon basic research in sonochemistry pioneered at the CCRC. The process reduces sulfur in marine fuels, meeting IMO2020

regulations, without the need to consume valuable hydrogen. Additionally the process is able to operate at low temperatures and atmospheric pressure.

"Demonstrating the uODS technology at scale will be a major milestone achievement for the kingdom's efforts to drive the industry to achieve environmental excellence, and ensure that oil has a more sustainable future", said Mark Brown, CEO, uODS.

The uODS process core is in the ultrasonicallyinduced cavitation. Sound waves propagate into the liquid creating microscopic cavitation bubbles that eventually collapse, leading to high mixing and hot spots.

"We realized that the key to creating a commercially viable process was the fluid dynamics of the system. Modelling the entire process, from a single bubble to the whole reactor, enabled accurate control over the process and improved yield", added Paolo Guida, CTO, uODS. FUELCOM3 project, a strong partnership with Saudi Aramco to support research on sustainable transportation



The FUELCOM Team at its inaugural meeting.

The FUELCOM projects materialize more than a decade of strategic partnership between Saudi Aramco Transport Technologies R&D Division and KAUST's Clean Combustion Research Center (CCRC). In the earlier phase, the project was instrumental in developing fundamental research capabilities in modeling and experimental facilities, which have led to advances in fuel characterization, chemical kinetic models, optical and metal engine test cells, and computational simulations to predict engine performance. This has led to more practically relevant collaborations with new OEM co-partners such as Volvo trucks and Hyundai Motor Company (HMC). The project has also been highly productive with more than 230 publications in major journals and 6500 citations, building the reputation of FUELCOM as a unique research model where fundamental understanding in the university laboratories can be translated into real life applications.

In the later phase of FUELCOM since 2019, the project team have been investigating two new engine technologies: (i) high pressure isobaric combustion to achieve higher efficiency Diesel engines, and (ii) pre-chamber combustion (PCC) to enable ultra-lean combustion engines

for higher efficiency and lower emissions. The synergistic experimental and computational studies demonstrated that the isobaric combustion shows great promises as fuel-flexible engines with efficiencies higher than 55%. The narrow throat pre-chamber concept is also unique as an easy drop-in option for existing heavy duty truck engines, allowing an immediate impact on reducing carbon footprint.

As the Kingdom of Saudi Arabia and the world is accelerating into circular carbon economy, the present FUELCOM3 project is focusing on hydrogen as a strategic future fuel for transporation. Several hydrogen internal combustion technologies on both car and truck engines are being explored, by utilizing advanced injection strategies to achieve extreme lean combustion for low NOx emissions. The comprehensive work package ranges from concept design, engine simulation/optimization, to engine experiments. The performance of our concepts are assessed against other competing technologies, such as fuel cells and battery electric vehicles, through a rigorous life cycle assessment (LCA) on a well-to-wheel (WtW) basis.

### EVENTS

### 13th Asia-Pacific Conference on Combustion (ASPACC)

The Saudi Arabian Section of the Combustion Institute (SASCI), jointly with Khalifa University, organized the 13th Asia-Pacific Conference on Combustion (ASPACC), on December 5-9, 2021, at the Abu Dhabi National Exhibition Centre (ADNEC), Abu Dhabi, United Arab Emirates.

ASPACC has established its place as a major forum to disseminate and exchange cuttingedge activities on fundamental and applied combustion research. The world is rapidly changing towards sustainable energy and environment by utilizing alternative and renewable sources. The combustion research community plays a vital role in this through clean and efficient utilization of conventional and future fuels by deploying state-of-the-art computational and experimental techniques. Chaired by Hong G. Im, Chairman of SASCI, and Professor of Mechanical Engineering at KAUST, the event was a huge success. Despite numerous challenges due to the pandemic restrictions, the ASPACC had seven keynote presentations, over two hundred contributing papers, and a special industry session with six panelists.

Many new ideas that will pave the way to the future direction of combustion research were shared both in person and virtually by the attendees at the conference. It became evident that the state-of-the-art combustion technology for conventional and renewable fuels will serve as a backbone in achieving global energy sustainability with minimal carbon footprint at scale, for both short and long term.



### Ammonia Combustion Meeting, 2022

The Clean Combustion Research Center was honored to host the first hybrid Ammonia Combustion Meeting (ACM) on February 10, 2022. The ACM is an exclusive meeting where experts from academia and industry come together to discuss different aspects of ammonia combustion in the field and highlight the key challenges for the community to tackle.

This meeting was co-organized by a team of experts from around the globe including Mara De Joannon, STEMS-CNR; Matthew Dunn, University of Sydney; Andrea Gruber, SINTEF; Akihiro Hayakawa, Tohoku University; Gaetano Magnotti, KAUST; Agustin Valera Medina, Cardiff University; and Christine Rousselle, University of Orléans.

Topics discussed included ammonia oxidation kinetics, laminar flames and fundamental combustion properties, canonical turbulent flames, MILD combustion, laboratory-scale industrial burners, and internal combustion engines.

#### SPEAKER AND TALK DETAILS:

- Hideaki Kobayashi, Tohoku University Challenges and perspectives of ammonia combustion for carbon neutrality
- Robert Barlow, Barlow Combustion Research Canonical NH3/H2/N2-air turbulent flames: stateof-the-art and future challenges
- Youngmin Woo, Korea Institute of Energy Research

Ammonia fuel application in a conventional vehicle

- Toshiyuki Suda, IHI corporation
   Progress of fuel ammonia utilization in power sector
- Albert Lanser, Duiker Combustion Engineers
   Experiences with Industrial applications for ammonia combustion
- Mani Sarathy, KAUST
   Chemical kinetics of ammonia combustion



- Pino Sabia, STEMS-CNR, Naples
   MILD Combustion and Ammonia Oxidation: State of Art and Future Challenges
- Yuyang Li, Shangai Jiao Tong University Enhancement of ammonia combustion: Co-firing, oxygen enrichment and partial cracking
- Christine Mounaïm–Rousselle, University of Orléans

Combustion mode in Ammonia fueled engines: state-of-the-art and future challenges

 Davide Ferri, Paul Scherrer Institute
 Ammonia fueled engines: perspectives on catalytic emission control

Scan QR or click here to see all recorded talks.



### Meet the 2022 CCRC Student Advisory Committee (SAC)



From left to right: Mohammed A. Almomtan (President), Christopher B. Wagstaff (Students' Mentor), Lorenzo Angelilli (Secretary), Jordan N. Figueiredo, Zeinab Al Hadi (Members)

The Student Advisory Committee (SAC) aims to represent the CCRC student body to the CCRC administration, staff and faculty members.

Every year, CCRC students are elected to constitute the SAC to represent and keep CCRC an exemplary center at KAUST.

Some of the SAC's core objectives include creating a better environment for the students to excel, defending student privileges, being involved in decisions related to CCRC students, representing CCRC students' opinions, improving and integrating students' academic and social experiences, and encouraging students to constantly improve the CCRC environment.

This years committee includes: **President:** Mohammed Almomtan **Secretary:** Lorenzo Angelilli **Students' mentor:** Christopher Wagstaff **Members:** Zeinab Al Hadi and Jordan Figueiredo

KAUST RESEARCH CONFERENCE Hydrogen-Based Mobility and Power October 23-26, 2022

NEW DATES