

ا Clean Combustion sity of Research Center

Issue 8 | Summer 2022

KAUST CLEAN COMBUSTION RESEARCH CENTER (CCRC) NEWSLETTER

Cover Image by Ayman Elbaz: Double swirl burner with dual fuels Ammonia and Methane



A NOTE From the Editor



I Combustion science is as relevant today as it was a century ago." This statement was emphasized by the CCRC's newly formed industry advisory board at a meeting in March. The board has representatives from major Saudi industries, international industry players, and government representatives who support

the Center's approach of conducting combustion research across the TRL scale target mobility, power to generation, mineral processing, petrochemicals. and The Center's approach, activities and strategic direction are in-line with KAUST's vision to support curiosity-driven research with impact.

In this newsletter, we report on the uODS project as an example of how our targeted research and innovation have resulted in new technology that we are deploying at a pilot scale. We also report on the new FLEET initiative to tackle research challenges related to land, marine and air transport focusing on fuels and lubricants, and their efficient utilization as part of the decarbonization drive. The FLEET consortia was initiated by two leading

"Combustion science is as relevant today as it was a century ago."____

Faculty in our Center, Prof. Mani Sarathy and Prof. Aamir Farooq. Mani and Aamir have been members of CCRC for more than 10 years and are awardwinning and globally-recognized researchers. We are very pleased to add that both Mani and Aamir have been promoted to full Professors lately, and we profile them both in this edition.

> As we gear up to the first faceto-face international combustion symposium since Dublin, in July, one cannot but reflect on the ingenuity of all the scientists and researchers that helped the world deal with the pandemic threat. This same ingenuity and inventiveness in combustion research are already

helping the world overcome the threat of climate change. As a Center and as a community we have much to contribute in addressing this challenge through the multifaceted approach we have been developing, for both the transitional and the longterm horizons. To learn more about our activities and connect with us, visit our website and subscribe to the CCRC's social media channels

Bassam Dally

Professor of Mechanical Engineering Clean Combustion Research Center



CCRC Prof Bassam Daly was a panelist in the inaugural session of Saudi Youth for Sustainability here at KAUST. Up for discussion was the importance of sustainable growth of the economy and the role of technology to reduce the impact of energy generation on the environment.

Inside this Issue

Faculty Updates	2
Faculty Spotlight	5
Research Updates	4
Featured Alumni	1 5
Upcoming Events	15
	16

FACULTY UPDATES

Two prominent CCRC faculty members are promoted



Professor of Mechanical Engineering Aamir Farooq and Professor of Chemical Engineering Mani Sarathy

There is no question that humanity's future is intrinsically linked to our continued acceptance and development of alternative fuels and technologies. With increasing energy needs, pressure to limit greenhouse gas emissions, and provide cleaner, more efficient fuels all while harnessing sustainable forms of energy borne from our surrounding environment, the need to embrace renewable energy in all of its guises over the coming decades will become paramount.

According to the International Energy Agency, "global renewable energy capacity will rise more than 60% from 2020 levels by 2026 and account for nearly 95% of all worldwide power capacity growth in that time."

As a leading hub of innovation in the Kingdom and worldwide, KAUST is constantly seeking ways to develop research and technologies that lead to societal progress both locally and globally. Research and technologies that boost the University's strategic initiatives centered on energy, water, food, health, the environment, and artificial intelligence, among others. Each year, this vision is realized through the pioneering research activities and excellence of its diverse, multinational Faculty and staff.

Achieving excellence in greener fuels and reducing pollution

KAUST recently acknowledged its progress in sustainable fuel technologies by promoting prominent PSE faculty to the rank of full professor. Two of the Professors promoted are from the Clean Combustion Research Center (CCRC). Associate Professor of Mechanical Engineering Aamir Farooq and Associate Professor of Chemical Engineering Mani Sarathy.

FACULTY SPOTLIGHT KAUST Professor Aamir Farooq

s the world moves toward new vehicle technologies and more sustainable modes of transport, optimizing engine efficiency and minimizing emissions is a key research drive of **KAUST Professor Aamir Farooq** and his colleagues in the CCRC. Researchers at the center aim to develop greener and more efficient fuels with the long-term goal of providing less polluting, better performing, and easier to transport and store fuels.

Professor Farooq's main research interests are in the areas of fuel chemistry, precision spectroscopy, and laser-based sensors. He is the principal investigator of the Chemical Kinetics and Laser Sensors Laboratory which utilizes shock waves to reach extremely high temperatures and pressures. He develops laserbased gas sensors for environment-monitoring, process optimization and biomedical applications. He has recently exploited machine-learning methods in multispecies sensing and fuel property predictions.

In response to his promotion Professor Farooq said, "I am very pleased to have reached this important milestone in my academic journey. I joined KAUST in 2010 as an Assistant Professor, fresh from my PhD at Stanford University. The unique research environment at KAUST enabled me to pursue my dreams. I am grateful to my colleagues in CCRC and Mechanical Engineering, and in particular to my group members for their collaboration and contribution."



CCRC Professor Aamir Faroog

The Air Pollution Epidemic by Professor Aamir Farooq Originally published in AWE International Magazine <u>Scan QR or click here to read the</u> article



FACULTY SPOTLIGHT KAUST Professor Mani Sarathy



N ow over a century old, combustion engine technology continues to be refined and improved upon. The design and operation of transportation fuels and their specific physical and chemical kinetic properties remain at the forefront of Professor Mani Sarathy's research into thoroughly understanding and improving sustainable fuel technologies. Sarathy leads the KAUST-McLaren partnership on extreme performance technologies, including sustainable Formula 1 fuel design. He is also Senior Manager for Technology and Innovation at ENOWA. NEOM Hydrogen, where he works on developing renewable hydrogen projects at scale.

Professor Sarathy's research focuses on developing sustainable energy technologies with minimal environmental impact. He is particularly interested in simulating the combustion chemistry of transportation fuels and hydrogen in fuel cells. The Associate Director of the KAUST CCRC also develops chemical kinetic models that can be used in energy systems to simulate fuel combustion and pollutant formation. Throughout his career, Sarathy has approached combustion science from a variety of perspectives. This has been achieved through research into the fundamental chemistry and physics of fuel combustion, exploring alternative fuel sources, and working with atmospheric scientists to understand the impact of exhaust emissions on the atmosphere. He has recently investigated harnessing the capabilities of artificial intelligence and machine learning.

In response to his promotion Professor Sarathy said, "When I joined KAUST 10 years ago, the leadership told me that the future reputation and image of KAUST would depend on the success of its young Faculty members. My wife, family, and colleagues have supported me to work hard and perform at my best, so that it contributes to the success of KAUST and the Kingdom. I am grateful to be part of such an inspirational institution blessed by the vision of the late King Abdullah."

DEANS AWARD

Mechanical Engineering Program



Recently the Mechanical Engineering Program celebrated the 15 students who received the Dean's Award 2022. Nine of the awardees are from Clean Combustion Research Center.

The students were selected based on their academic and research accomplishment. Each student received their award certificate from Professor Ravi Samtaney (Dean PSE) and Professor Aamir Farooq (Program Chair ME). The award also includes a one-time \$2500 cash prize.

Congratulations to our CCRC ME awardees!

- Emad AL Ibrahim Hao Shi Kiran Yalamanchi Mhanna Mhanna Ponnya Hlaing
- Erica Quadarella Hao Tang Lorenzo Angelilli Mickael Silva

"I feel honored and grateful to receive this award, it is a great motivation towards improvement. This would not have been possible without the help and guidance of my colleagues and Professor", says Ph.D. Student Mhanna Mhanna, who joined the center in 2017 and was the member of SAC (Student Advisory Committee) from 2020 to 2021.



From left to right: Dean Ravi Samtaney, Mhanna Mhanna, Associate Professor and Program Chair ME Aamir Farooq

6

RESEARCH UPDATES

Initiating FLEET to decarbonize transportation sector



CCRC Professore Aamir Faroooq presents to guests and partners at the launch of FLEET

ransportation is never only about how we move people; it is primarily how we move goods. According to the UN: by 2030 there will be over one billion more people on the planet, and the demands on transportation will only increase. Freight volume is expected to grow by more than 70%. Maritime transportation accounts for as much as 80% of the world's merchandise in volume handled by ports. Aviation may still be recovering from the effects of the pandemic, but the expectation is that by mid-2030s no fewer than 200,000 commercial flights per day are expected to take off and land around the world and so far, efforts have been insufficient to generate the scale and focus to transform the world's mobility.

To advance sustainability within the mobility

sector King Abdullah University of Science and Technology (KAUST) and the Oil Sustainability Program recently launched the FLEET Consortium. The Consortium plans to develop innovative fuels, lubricants, and efficient engine technologies and, in the words of Prof. Bill Roberts, Director of the Clean Combustion Research Center (CCRC), "represents a wonderful opportunity for KAUST and the CCRC to provide impactful solutions to greenhouse gas emissions across the entire mobility sector, both for the Kingdom and globally." It is the CCRC that initiated FLEET.

During the official launch, KAUST President Tony Chan said in his speech, "the goal of FLEET is very much aligned with our institutional priorities. Improving environmental and economic competitiveness of the transportation sector is a



KAUST President Tony Chan at the launch of FLEET

goal we share with the industry and government sector, and the partnership with our FLEET members is essential for success."

Through the FLEET platform, Program Director, Mohammad Al Tayyar explained, "The Oil Sustainability Program with its partners, aims to address and innovatively transform the global transportation sector through three main approaches: fuel enhancement, engine development, and engine exhaust to reduce CO2 emissions."

FLEET'S ORIGIN AND STRUCTURE

FLEET is being led by the CCRC's Prof. Mani Sarathy and Prof. Aamir Farooq in collaboration with OSP. As Prof. Mani explained, "in early 2021, the structure of the consortium and its founding members were carefully considered by KAUST and OSP. It was clear to both parties that this consortium model would impact sustainable transportation research by bringing together leading research institutes, industry leaders, and government stakeholder."

Furthermore Prof. Farooq added, "FLEET Members stand to gain a higher return on their R&D through the consortium compared to direct R&D funding. They will be involved in several innovative research projects, participate in research roundtable sessions with leading industry players, and be able to develop human capital technical know-how. Eventually, these research projects are expected to be piloted and commercialized by FLEET members."





Photo of FLEET consortium members during the welcome dinner at KAUST

FLEET PROJECTS and PARTNERS

CURRENT PROJECTS

FLEET is already working on six projects. Commenting on these Mansour Al-Zahrani, the GM of Maintenance and Scheduling at SAPTCO noted that, "Three projects out of six provide technology solutions to carbon emissions in the transportation industry."

FLEET's 2022-2023 projects:

MtG Refinery

Evaluate the technical feasibility of feeding a refinery with green methanol to produce gasoline using standard refinery equipment and a techno-economic assessment in the European context.

MtG, EtG and their Blends

Experimental and modelling investigation of MtG, EtG, and their blends with renewable and petroleum-derived additives – includes ignition studies and vehicle testing

LCA of PEM Fuel Cell Vehicles

To explore the decarbonization potential of using grey and blue hydrogen in PEM fuel cell vehicles in Saudi Arabia by comparing life-cycle emissions of diesel engine, electric vehicles and PEM fuel cell vehicles for heavyduty transportation

1-D Fuel Cell Modelling

Modelling of PEM fuel cell to relate cell voltage to pressure, temperature, gas diffusion layer morphology, platinum type, ionomer molecular structure, and impurities

Inverted and Closed Joule Cycle for WHR

Utilize waste heat in exhaust gas to drive advanced heat recovery processes for increased efficiency of marine engines



Spray and Combustion Modelling

Develop new numerical tools for predicting spray and combustion behavior under supercritical conditions present in modern marine engines and aviation turbines

A PATHWAY TO A SUSTAINABLE FUTURE – CONNECTING ACADEMIA TO INDUSTRY

FLEET links industry with groundbreaking research centers like the CCRC, and provides a platform for industry to utilize these laboratories to find solutions for challenges specific to them. Advancements in sustainability can then be scaled up more rapidly. By joining, members demonstrate their commitment to developing sustainable transport and mobility solutions. Founding members are Aramco, Hyundai, Toyota, Bahri, Pacific Green Technologies and

FLEET MEMBERS WEIGH IN

"**Bahri** is happy to be a member of the FLEET Consortium, which has taken up some very important projects with aims of improving efficiency in fuels and engines as well as reducing the carbon footprint in the transportation sector. Bahri, being a shipping company and a logistic service provider is a heavy consumer of energy and fuels. Bahri has always been looking at ways to optimize and improve our energy and fuel consumption – both for economic and environmental reasons.

We are highly committed towards meeting sustainability and decarbonization goals of the Kingdom. and the



We believe that the investment into the research and development of the chosen projects by FLEET will surely help define pathways to a sustainable future," said **Abdulaziz Sabri, President – Ship Management at Bahri** and FLEET member.

"Toyota sells vehicles in more than 170 countries where climate, road condition, vehicle usage and energy situation are so diversified. We want to explore various technology options to reduce carbon footprint so that we can offer practical and sustainable solution that matches each country and customer..

FLEET is a great framework to catalyze the efforts and initiatives between academia and industry. We are especially interested in research projects on fuel cell and e-fuel as the Kingdom of Saudi Arabia has strong potential to become a leading producer and exporter of hydrogen," said **Toyota's Kei Fujita, Chief Representative, Middle East and Central Asia Representative Office.**

Yohan Chi, Ph. D, Senior Research Fellow and spokesperson of FLEET member Hyundai said, "Hyundai Motor Company and Kia Corporation (Hyundai Motor Group, collectively) have announced Carbon Neutrality 2045 roadmaps, committing to become carbon neutral in their global products and operations by 2045. Hyundai Motor Group is conducting various R&D activities to minimize greenhouse gas emissions from internal combustion engine (ICE) vehicles, as well as battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV). Hyundai Motor Group looks forward to working closely with FLEET partners toward eco-friendly fuel, and expects to effectively achieve carbon neutrality by significantly reducing carbon emissions through the new eco-friendly engine technology."

The importance and relevance of launching a consortium like FLEET cannot be overstated. **Aramco Head of R&D, Gerard de Nazelle** is confident when he commented: parahrasing Margaret Mead:

"Never doubt that FLEET, a small group of committed scientists and engineers, can change the world – indeed we will, by shaping affordable and sustainable solutions to mobility challenges for billions across the world."

CLEAN COMBUSTION RESEARCH CENTER - ccrc.kaust.edu.sa

RESEARCH UPDATES When Cool Ideas Come Raining Down



Christopher Wagstaff drew inspiration from childhood memory to improve a technique used for low temperature carbon capture.

apturing carbon dioxide (CO2) from flue gases by freezing it to a solid is potentially more cost-effective and efficient than absorption/desorption methods.

"At the heart of our low-temperature carboncapture technology is a spray tower, where very cold liquid is sprayed onto incoming flue gas," says Christopher Wagstaff, Ph.D. candidate at KAUST's Clean Combustion Research Center. "The CO2 in the gas instantly freezes on contact with the liquid, which enables it to be collected. However, to optimize the process, the spray of cold liquid droplets needs to be uniform and consistent, and densely but evenly distributed. Current designs do not achieve this."

Wagstaff is working on this challenge under the supervision of KAUST's Bill Roberts. After exploring various concepts with colleagues, Wagstaff came to believe that slight changes to the nozzles or spray patterns wouldn't make much improvement. Then, scrolling through social media one day, Wagstaff came across a group called Weird Secondhand Finds. Someone had shared an image of a rain oil lamp, which Wagstaff instantly recognized from his childhood.

"Family friends had a rain oil lamp, and as a kid, I would gaze at the droplets gliding along the wetted wires while the adults were having a boring conversation," says Wagstaff. "The way the droplets glide is really eye-catching: they move 'mostly' predictably, like water over a waterfall."

Wagstaff realized that this wetted-wires design could improve the spray tower. "Having the droplets slide on wires would make them more uniform in size and evenly and tightly distributed, and they would 'fall' much more slowly than droplets in freefall," he says. By engineering the wires to precisely control the droplets, the team could feasibly harvest more CO2 from flue gas.

"Finding inspiration from seemingly unrelated fields to tackle challenging problems takes a sense of wonder and excitement; Chris has both in spades," says Roberts.

Wagstaff conducted extensive experiments to determine the most compact wire spacing and best orientation to avoid droplets merging, and also examined the surface tension under the input gas counterflow. Initial trials with the wetted wires are showing great promise.

"It is a tricky problem, but if the wetted wire phenomena can be engineered into a practical solution, then it will transform the efficiency and scalability of this system," says Roberts.

"We're working with Saudi companies to demonstrate low-temperature carbon capture," adds Wagstaff. "Actually, wetted wires could have many applications: for instance, distillation and refining processes could benefit from this idea."



Originally published in KAUST Insight. Photos by: Anastasia Serin

RESEARCH UPDATES Scaling Up - From Beaker To Shipping Containers



Lab scale uODS process in KAUST laboratory

hrough their new start-up uODS, the CCRC are making an impact and doing things at scale.

The objective of a current project is to reduce industrial partner Luberef's daily environmental footprint from burning 300 tons of high-sulfur heavy fuel oil at their refinery in Jeddah. Currently, the refinery releases emissions containing large quantities of SOx, which contributes to acid rain, nitrogen oxide (NOx), and exhaust particulate matter (PM).

This week the CCRC and the KAUST startup completed the build and packed up the 25 tons of hardware to be used on-site at Luberef. They will start by test producing 10 tons per day of desulfurized fuel as part of the agreement with Luberef. "They'll run the desulfurized fuel through their boilers, and we'll be able to measure emissions at the stack, showing a reduction of harmful emissions by a factor of seven or more," Prof. William Roberts, CCRC Director said. "At the end of the 8 or 9-week testing phase, the goal is to scale up from there and provide Luberef with the 300 tons they require daily."

It's been four years in the works. The CCRC used several internal funding mechanisms to develop the science, get the patents in process, build a 1-ton/day capacity rig, and most recently, complete the build of the 10-ton/day capacity rig, using shipping containers to ensure it is easily transportable to the site. KAUST Research helped with the funding to take it out of the CCRC's labs in Building 7 and containerize it. Towards the end of last year, uODS tarted negotiating with Luberef in earnest to deal with their emissions problem, a problem that also affects all shipping.

"The idea is you take what you learn from point one ton/day, to one ton/day and then to the 10 ton/day scale. And then design a module that is easily replicated to get the overall capacity needed," explained Roberts. uODS must make 300 tons of fuel to run through the stack at Luberef. They will have to run 24 hours a day, 7 days a week for a month to generate that quantity of desulfurized oil so Luberef can burn the fuel without producing high levels of toxic SO2 and SO3. This same process will be used to remove sulfur from marine fuel oil to meet International Maritime Organization regulations on SOx emissions. There is huge scope for scaling considering a refinery would typically produce as much as 12000 tons a day but as Roberts points out, once you have the process modularized, it is straightforward to scale.

"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." Mark Brown, CEO of uODS commented.

"Luberef is an ideal proving ground for us, and we've learned a lot. We are also going to learn a lot more during the next two months as we try to go from something that would run for an hour or two a day to something that is running 24 hours a day. The outcome of this testing stage is that we need to scale up 30 times, to produce 300 tons a day. The further scaled-up rig will be funded by uODS and built at KAUST. "This is really pushing the scale at which we can operate. It will need to be 30 times larger than the test model." As Roberts said "you can't give up. If it was easy someone else would have done it."



17 FOR THE GOA

13 ACTION

Rigs being loaded up outside Building 7 labs at KAUST headed for Luberef



Photo of personnel from CCRC, uODS and Luberef in front of uODS hardware before its deployment.

FEATURED ALUMNI

Nour Elsagan

Zhandong Wang



PhD 2018
PI: Prof. Mani Sarathy; Combustion and Pyrolysis Chemistry (CPC) Group
Current Position: Research Officer at the National Research Council of Canada

Before coming to KAUST, Nour expected the move would be challenging. To her surprise, she found a nurturing and supportive environment at KAUST, and all the facilities and resources needed to do her research. Once settled in, she was encouraged to participate in international conferences and connect with researchers all over the world. Nour improved her presentation skills and boosted her self-confidence.

While at KAUST, she was aware of the importance of building a professional network, which is how she found her current job. KAUST's multicultural environment also opened her eyes to the diversity in the world which helped her later in adapting to different work environments.

Nour is keen to see the impact of her research in real life in the future. Her definition of success as a researcher during post-graduate studies was initially about publishing papers and getting funds. However, this has been changing for Nour with her goals shifting to improving the lives of people through standardization, regulations, and legislation in her research.



Postdoc and Research Scientist 2018 PI: Prof. Mani Sarathy; Combustion and Pyrolysis Chemistry (CPC) Group Current Position: Professor, University of Science and Technology of China

Zhandong Wang describes KAUST as wonderful and one of the best experiences he ever had. "KAUST was like a paradise where the people are happy with what they are doing," he said.

During his time at CCRC, there was a breakthrough for the autoxidation chemistry in combustion and atmosphere which to this day he is still proud of. Zhandong enjoyed the free environment at CCRC as well as the support of the team. He was inspired by Prof. Mani Sarathy who showed him how to be a good professor, mentor, and a good friend. He won't forget that Mani worked hard to improve Zhandong's first paper at CCRC during the Christmas holidays. The opportunities for cooperation and to attend conferences were important to his career and broadened his research topics and network.

Zhandong won the highly competitive 1000 Talents award in China and is currently doing interesting work related to combustion, atmosphere, and energy conversion. In the next five years, he hopes to contribute to the prosperity of his country.

UPCOMING EVENTS



WWW.SAS-CI.COM

Saudi Arabian Section of the Combustion Institute 12th SASCI Annual Meeting 5-6 October 2022

> TOWARDS NEAR ZERO-CARBON ENERGY AND MOBILITY Abha, Saudi Arabia

SASCI 2022, jointly organized by the Transport Technologies R&D Division of Saudi Aramco and the Clean Combustion Research Center at King Abdullah University of Science and Technology (KAUST)



Research Conference Al for ENERGY

Co-organized by the Clean Combustion Research Center (CCRC) and the AI initiative at KAUST

جامعة الملك عبداللم للعلوم والتقنية King Abdullah University of Setence and Technology

Clean Combustion Research Center March 6-8, 2023 KAUST, Saudi Arabia

ccrc.kaust.edu.sa



جامعة الملك عبدالله للعلوم والتقنية King Abdullah University of Science and Technology Clean Combustion Research Center



Pursuing combustion solutions to global challenges for a changing world

Follow CCRC on social media





CLEAN COMBUSTION RESEARCH CENTER - ccrc.kaust.edu.sa