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CCRC Clean Combustion Research Center

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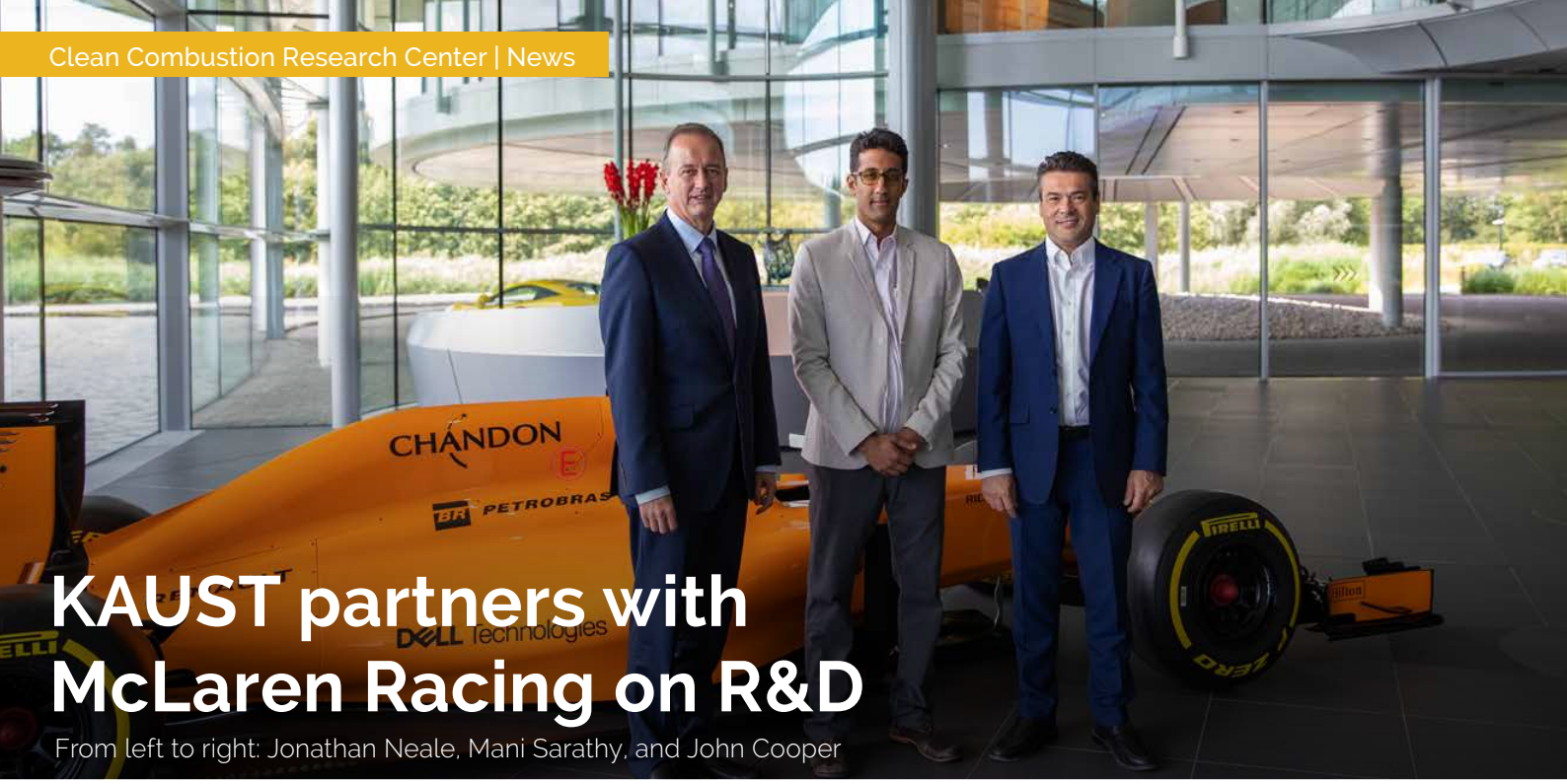


KAUST partners with McLaren Racing on R&D

From left to right: Jonathan Neale, Mani Sarathy, and John Cooper

McLaren Racing and KAUST signed a five-year research and development (R&D) agreement focused on extreme performance technology. The partnership aims to advance research in the areas of computational fluid dynamics (CFD), machine learning, fuels and lubricants, advanced mathematics and sensors and electronics.

"This partnership underlines our commitment to supporting global STEM advancements," said Jonathan Neale, chief operations officer of McLaren Group. "KAUST is a leading research and education institution in these fields and mirrors our core values. McLaren Racing is part of a world-leading technology group of companies and is engaged in Formula 1 across the globe. Together with KAUST, we can push science and technology in our mutual interest areas to new limits."

Less than 10 years after the University's establishment in 2009, KAUST has produced promising solutions in the areas of extreme performance technology, with scientists at the University working on research, engineering and innovation challenges that impact Saudi Arabia and the world.

"Our collaboration with McLaren will motivate KAUST students, researchers and faculty members to solve real-world problems in the fast-paced and technologically demanding environment of Formula 1 racing," said Jean Frechet, KAUST senior vice president for Research, Innovation and Economic Development. "Researchers in the Clean Combustion Research Center have already been developing fundamental experimental and numerical capabilities that can be readily applied to Formula 1 cars. Developing capabilities to measure and simulate the extreme conditions in a Formula 1 will inspire innovations that can be used in many other applications important to Saudi Arabia and internationally."

The collaborative learning environment for knowledge transfer across multiple research areas is also an important feature of McLaren Group and its fellow subsidiary companies.

"The partnership is a symbol of international collaboration between two of the world's leading science and technology organizations. We are looking forward to McLaren and KAUST working together to create the technology and innovation of tomorrow," said John Cooper, chief business officer of McLaren Racing.

The R&D collaboration will also open new doors to talent development for KAUST graduate students through research, internships, engineering forums and other opportunities to expand knowledge and skills for the future marketplace.

"McLaren's expertise both on and off the track makes them a perfect partner for KAUST. The Clean Combustion Research Center is creating sustainable mobility solutions for tomorrow's world. Working with McLaren will enable us to get even closer to achieving that goal," said Mani Sarathy, associate director of the KAUST Clean Combustion Research Center. "Formula 1 cars are essentially a testing ground for our technology, so the potential for translating scientific discoveries to real-world solutions is significant."

The core of the University's input into the partnership is focused on goal-oriented fundamental scientific research.

"To engineer technology for such an extreme environment—which a Formula 1 car is—we really need to do better science," Sarathy said. "Our scientists have to develop new experimental methods and new types of mathematical models. We need to train our students to understand more about very complex systems."

"The Formula 1 vehicle is a laboratory we don't have at KAUST. It's a real-world laboratory. It's a place where we can develop new types of fuels [and] new combustion concepts as well as new types of sensors and computer algorithms," he continued.

- By Meres J. Weche
Originally published in KAUST News Website

From left to right: Karl Chatelain, Aamir Farooq and Yedhu Krishna

Interview with Prof. Aamir Farooq

Professor Aamir Farooq is a senior faculty member at the Clean Combustion Research Center. He joined KAUST before the inauguration of the Center, in 2010; and he was appointed assistant professor immediately after obtaining his Ph.D. from Stanford University. After six years of performing high-quality research, Prof. Farooq was appointed associate professor in 2016.

Prof. Farooq's research group has pioneered the application of quantum-cascade-laser (QCL) based mid-IR diagnostics to combustion and chemical kinetics; they devised novel sensors based on chirped-pulse and cavity-enhanced strategies. He has also carried out autoignition and reaction rate measurements on a wide variety of fuels and fuel surrogates. All this remarkable work has resulted in publication of nearly 100 journal papers in six years. Amir has received numerous visiting professor fellowship awards, as well as a recognized Distinguished Co-authored Paper from the Combustion Institute and--this year--one of his papers was selected for the cover image on the October issue of Sustainable Energy & Fuels (see Paper Spotlight in this newsletter).

Alumni of Prof. Farooq's group have pursued academic careers as post-docs or faculty in top universities--UW Madison, RWTH Aachen, University of Orleans and NUST, others have been attracted to industry, including Saudi Aramco. In his search for alternative fuels, such as ammonia as a hydrogen carrier, and unconventional blends of natural gas, Farooq's work has been integrated into "Kingdom's Vision 2030". Another research objective has been the development of advanced laser-based sensors for detecting methane and other pollutants.

What type of research has attracted you?
After my undergraduate degree in ME, I started working in industry, as I had planned. In two years, I worked at two very different companies in very different roles, and at both jobs I came to the same conclusion: industrial jobs are exciting at first, but they soon become uninspiring. That's when I decided to investigate graduate schools, recalling that the best time of my undergraduate career was in my final year, working on selective laser sintering.

How did you select your field?
I had been attracted to lasers since high school and my early years as un undergrad. At Stanford, I flirted with MEMS but soon found it unsuited to my interests; then I joined Prof. Hanson's group at Stanford, specializing in applying laser-based diagnostics to combustion. From there on, I never looked back and lasers have continued to inspire me every day.

What is the future of diagnostics in combustion research?
Future combustion systems will be operated under extreme conditions to enhance the efficiency of combustion and reduce emissions. Development and improvement of these systems will rely heavily on in-situ laser diagnostic techniques. We need advanced laser diagnostics for laboratory studies, but also field-deployable laser sensors that can be used for feedback control and dynamic optimization.

How important are collaborations with industrial partners?
As engineers and scientists, it is very important to maintain a close link with industrial partners to promote research on industrially-relevant topics. Industry and academia can greatly accelerate innovation and development by collaboration. In this context, CCRC has been fortunate to collaborate with many industries, including Saudi Aramco, GE, SABIC, and McLaren.

What would you say to young students who are attracted to combustion or laser diagnostics?
The challenges of the modern world are highly complex, and to address them, interdisciplinary skills are extremely important. Students in my laboratory need to be grounded in the fundamentals of ME, as well as optics, spectroscopy, shock wave physics and chemistry. Solving the current challenges in combustion is more stimulating than ever.

Paper Spotlight

Glycerol carbonate as a fuel additive for a sustainable future

A recent study by a group of CCRC researchers led by Prof. Amir Farooq proves that glycerol carbonate (GC) has great potential as a fuel, or a fuel additive, for cleaner combustion. The resulting paper was introduced on the cover of Sustainable Energy and Fuels where it was published this year.

Global warming and diminishing oil reserves have forced the research community and policymakers around the world to demand a shift from conventional fossil fuels to renewable sources like biodiesels, renewable bio-driven fuels, derived from vegetable oils and animal fats, and considered to be bio-degradable, non-toxic and environmentally friendly.

Aamir Farooq and Ahfaz Ahmed in the shock tube lab

Crude glycerol, of about 10–20% by volume, exists as a byproduct in biodiesel production. Increasing demand for biodiesel fuels has led to a substantial increase in the supply of glycerol in the global market and a correspondingly dramatic fall in the price of glycerol, warranting alternative uses of glycerol. One potential way to deal with the crude glycerol overflow is to convert it to GC for use as a fuel or fuel additive. Recent work in this direction by a group of CCRC researchers was published in Sustainable Energy and Fuels.

According to Prof. Aamir Farooq, "Researchers have tried to utilize glycerol for combustion applications but found that its extremely high viscosity makes it quite unsuitable. This motivated us to explore derivatives of glycerol; and GC turned out to have very high potential as a fuel additive. As a first step, a fundamental study was made to understand the pyrolysis of GC."

In this work, the authors explored possible reaction pathways in the initial stage of GC pyrolysis. Ab initio/RRKM-master equation methods were employed to differentiate various reaction pathways and find the pressure- and temperature-dependence of the major channels. It was found that glycerol carbonate decomposes almost exclusively to produce CO_2 and 3-hydroxypropanal over 800 – 2000 K, and the radical forming channels are unimportant. Since 3-hydroxypropanal is one of the main products of GC decomposition, and aldehydes are known to have a very high impact on soot reduction, it may be concluded that GC has great potential for cleaner combustion as a fuel additive. According to Prof. Farooq, GC could replace up to 20 or 30% of hydrocarbon fuel when used as an octane booster in low-octane fuels, like naphtha.

This research was performed in collaboration with the University of Miskolc in Hungary, and funded by King Abdullah University of Science and Technology, the European Union and the Hungarian State. The work was well-accepted and selected as the cover image in the October 2018 issue of SE&F journal.

Future work by this group will focus on the experimental study of pyrolysis and oxidation of GC, as well as its blends with conventional fuels in a shock tube, a rapid compression machine and a jet-stirred reactor. "As the next step, feasibility studies using GC as a fuel, or in fuel blends for combustion applications, are currently underway." says Dr. Binod R. Giri, a member of the research group.

The researchers are currently in the process of running homogeneous charge compression ignition (HCCI) engine experiments on blends of GC with low-octane gasoline fuels.

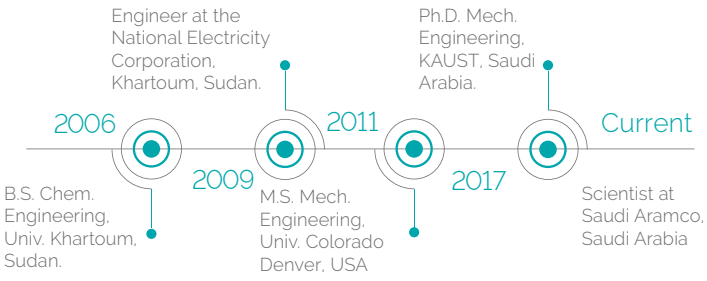
Reference

Glycerol carbonate as a fuel additive for a sustainable future
M. Szőri,a B. R. Giri, Z. Wang, A. E. Dawood, B. Viskolcza and A. Farooq
Sustainable Energy Fuels, 2018,2, 2171-2178

CCRC Ph.D. graduates 2017 – 2018

Over the last academic year, 15 students from the Clean Combustion Research Center were awarded a Ph.D. degree. After four, five, and even six years of work and study at KAUST, what have they attained and how has a Ph.D. from KAUST enhanced their lives? Here are the achievements of just a few of our graduates:

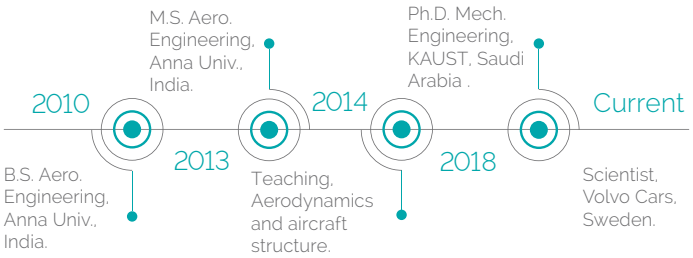
Ahmed Abdelgadir



Ahmed Abdelgadir is a talented Sudanese engineer and a recent graduate of KAUST. In 2006 he received his bachelor's degree in chemical engineering from the University of Khartoum. After graduation, he joined the National Electricity Corporation in Khartoum, for three years. Ahmed said, "I always had a passion to pursue my education so I moved to the U.S. to attend the University of Colorado, in Denver".

In 2011 he received the master's degree in mechanical engineering from U.C. and joined the Clean Combustion Research Center at KAUST to earn a Ph.D., which he attained in 2017. "Since I joined KAUST my goal has been to start a career in industry", said Ahmed. "Through collaborations and conferences, the CCRC helped me to build a network, and make connections at one of the biggest companies in the world--Saudi Aramco. Being a part of the CCRC encouraged my intellectual growth and equipped me with the tools and skills to fit into an industrial environment. The challenges I faced during my Ph.D., the diversity of the people at CCRC, and the proficiency I gained--all paved the way for success in my new position. And best of all," he smiled, "at CCRC I met my lovely wife!"

Mohammed Jassim

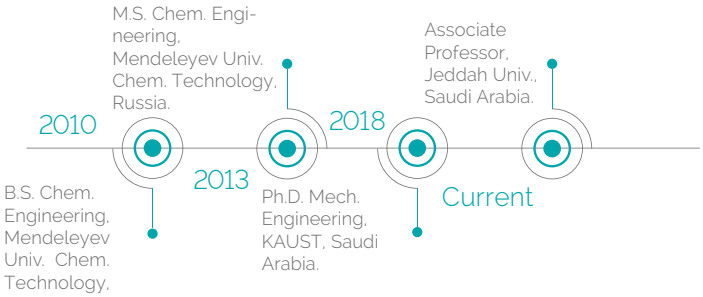


Mohammed Jassim is one of the CCRC's students who received his PhD in 2018. He began his undergraduate studies at Anna University in India, where he received his bachelor's degree in aeronautical engineering, in 2010. Three years later, Anna University awarded him a master's degree in the same field. Before joining KAUST in 2014, Mohammed took an opportunity to experience teaching aerodynamics and aircraft structures.

After graduating in 2018, he said "The CCRC gave me a new approach to life. I had a kind of brain freeze--I was very shy with new people. Professor Hong Im was a big help in overcoming the problem", he explained. "For example, in my first Skype interview, I couldn't express myself confidently and the discussion became frozen; but after a friendly phone conversation with Professor Im, I had a job offer."

During his Ph.D. studies, Mohammed mainly performed modeling and simulations. "Access to the supercomputers at KAUST is a powerful tool that transforms CCRC modelers into the most gifted students in pursuit of a Ph.D." He added, "Professor Im, trained me and brought out my best; he transformed me from a shy guy into Dr. Mohammed Jaasim."

Adamu Alfazazi



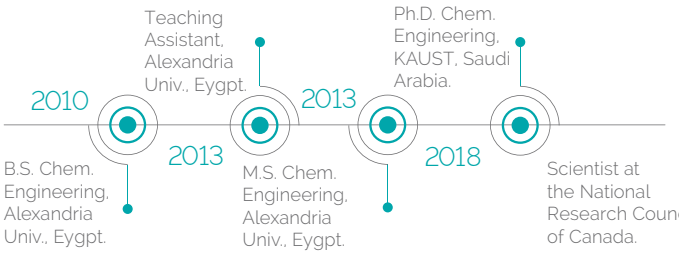
Before joining KAUST, Adamu received both his bachelor and master's degrees from the Mendeleyev University of Chemical Technology in Moscow.

During his Ph.D. studies, his research focused on auto-ignition chemistry of classical and alternative fuels in non-premixed systems. After graduation in 2018, he became an Associate Professor at Jeddah University, where he intends to continue his research in combustion, with a gradual shift towards chemical engineering-related topics like catalysis, or oil and gas purification.

Adamu said, "CCRC helped me improve my mentorship skills by giving me the opportunity to co-supervise several masters and invited students." He added: "Professor Sarathy advised me in the writing of research proposals, which will certainly help going forward in my academic career; and several CCRC friends have been a positive impact in my life.

Prof. Deanna Lacoste was an inspiration, helping students with their CVs, advising and looking out for career opportunities for them. I'll carry her positive attitude with me and share it with my colleagues, friends, and future students."

Nour Atef



Nour is a notable alumni who received her Ph.D. at KAUST in 2018. She achieved her bachelor's degree in chemical engineering at Alexandria University, in Egypt, ranking second in her graduating class. She remained at A.U. for her master's degree, where she was a teaching assistant, completing nearly 2400 hours of teaching.

After joining KAUST, she worked on numerical investigation of gasoline compression ignition engines by developing kinetic models for understanding the combustion chemistry of various fuel components. She also conducted 3D CFD simulations for engines to validate models and investigate the behavior of fuels under various engine conditions.

Nour is currently a Research Associate at the National Research Council of Canada, where she is still developing kinetic models for pyrolysis and combustion.

She expressed her gratitude to CCRC: "I received the exposure I needed for the next step in my career; and the friendly, competitive environment triggered my passion for research and increased my self-confidence. The diversity at CCRC introduced me to different cultures, affecting my understanding and my world view. Now I feel it's my duty, as well as my pleasure, to spread the word about CCRC."

CCRC Graduate Students 2018

Ossama Manna
Nationality: Egyptian
Advisor: Prof. William Roberts
Ph.D. Title: Structure and burning characteristics of laminar and turbulent premixed flames at elevated pressures.

Fethi Khaled
Nationality: Tunisian
Advisor: Prof. Aamir Farooq
Ph.D. Title: A study of the kinetics of fuels: Ignition delay time correlation and reaction with hydroxyl radicals.

Mohanned Ali Al-Khodaier
Nationality: Saudi Arabian
Advisor: Prof. Mani Sarathy
Ph.D. Title: Energetic strained molecules as future octane boosters: Theoretical and experimental study.

Muhammad Umer Waqas
Nationality: Pakistani
Advisor: Prof. Bengt Johansson
Ph.D. Title: Auto-ignition quality of high octane blended fuels in SI, HCCI and CI combustion modes.

Wesley Boyette
Nationality: American
Advisor: Prof. William Roberts
Ph.D. Title: Experiments on turbulent nonpremixed flames at elevated pressures.

Ehson Fawad Nasir
Nationality: Pakistani
Advisor: Prof. Aamir Farooq
Ph.D. Title: Mid-IR laser absorption diagnostics for shock tube and rapid compression machine experiment.

Muhammad Al Abbad
Nationality: Saudi Arabian
Advisor: Prof. Aamir Farooq
Ph.D. Title: Reactivity and ignition delay measurements of petroleum-based fuels, surrogate fuels and biofuels.

Adamu Alfazazi
Nationality: Nigerian
Advisor: Prof. Mani Sarathy
Ph.D. Title: Autoignition chemistry of liquid and gaseous fuels in non-premixed systems.

Ahfaz Ahmed
Nationality: Indian
Advisor: Prof. William Roberts and Prof. Mani Sarathy
Ph.D. Title: First principles-based fuel design: Investigating fuel properties and combustion chemistry,premixed flames at elevated pressures.

Mohammed Jaasim Mubarak Ali
Nationality: Indian
Advisor: Prof. Hong G. Im
Ph.D. Title: Modeling of pre-ignition and super-knock in spark ignition engines.

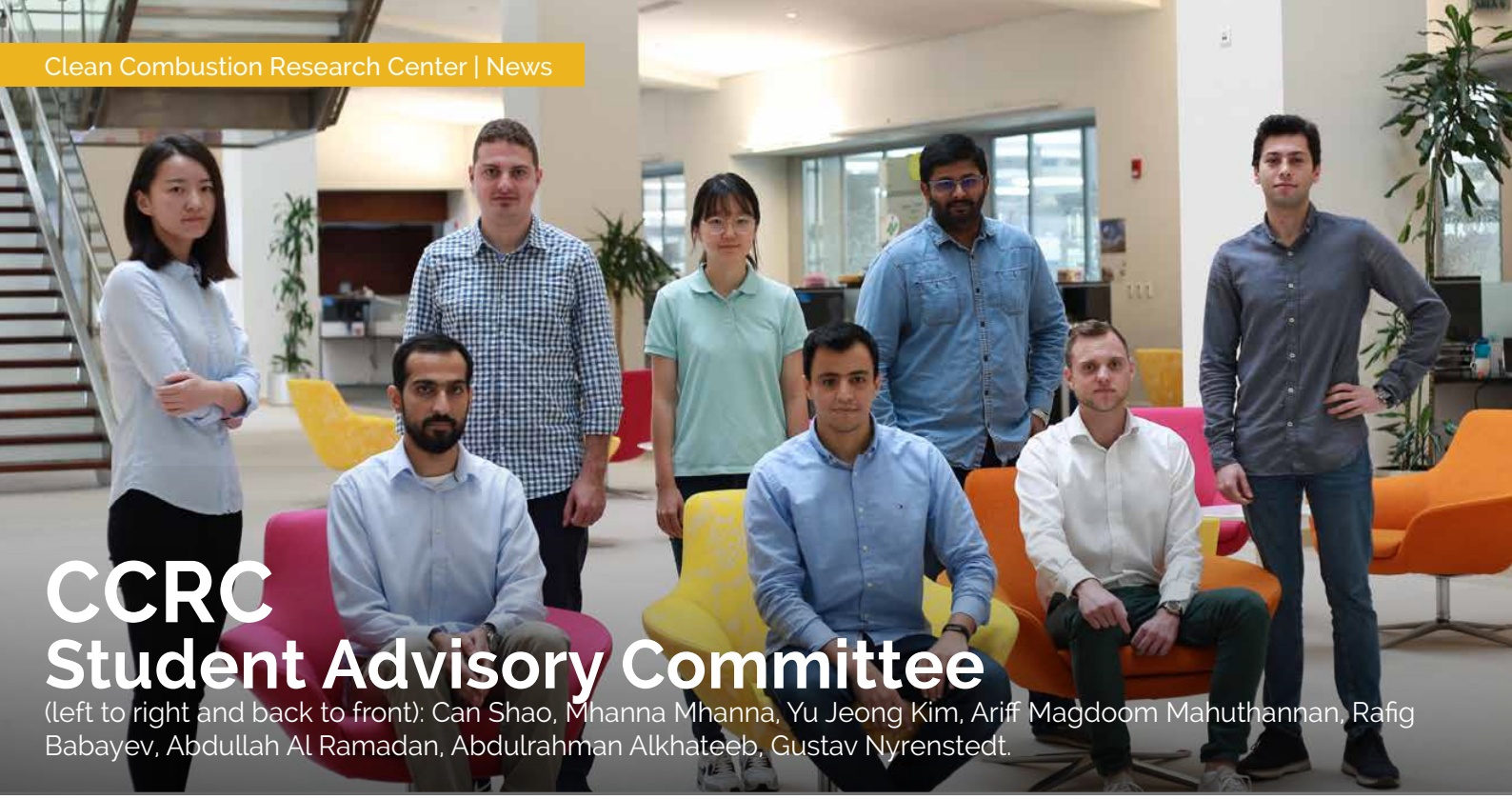
Nimal Naser
Nationality: Indian
Advisor: Prof. Mani Sarathy and Prof. Suk Ho Chung
Ph.D. Title: Autoignition behavior of practical fuels.

Stefano Luca
Nationality: Italian
Advisor: Prof. Fabrizio Bisetti
Ph.D. Title: Premixed and partial premixed turbulent flames at high Reynolds number.

Nour Atef Elsagan
Nationality: Egyptian
Advisor: Prof. Mani Sarathy
Ph.D. Title: Investigating the effect of physical and chemical properties of gasoline and its surrogates in a gasoline compression ignition (GCI) engine..

Samah Mohamed
Nationality: Sudanese
Advisor: Prof. Mani Sarathy
Ph.D. Title: Simulating low temperature combustion: Thermochemistry, computational kinetics and detailed reaction mechanisms.

Hafiz Amin
Nationality: Pakistani
Advisor: Prof. William Roberts
Ph.D. Title: Investigating soot morphology in counterflow flames at elevated pressures.



CCRC
Student Advisory Committee

(left to right and back to front): Can Shao, Mhanna Mhanna, Yu Jeong Kim, Ariff Magdoom Mahuthannan, Rafig Babayev, Abdullah Al Ramadan, Abdulrahman Alkhateeb, Gustav Nyrenstedt.

The Clean Combustion Research Center at KAUST has recently established a student advisory committee, created to work with the director, associate director, and faculty of CCRC to advise on research, academic and social programs. The committee consists of eight Ph.D. students, Can Shao, Mhanna Mhanna, Yu Jeong Kim, Ariff Magdoom Mahuthannan, Rafig Babayev, Abdullah Al Ramadan, Abdulrahman Alkhateeb, Gustav Nyrenstedt.
Two teams collaborate to achieve academic and research excellence in an atmosphere of cooperative cultural diversification.

The ART Team focuses on academics, research and training to enhance theoretical knowledge and social interaction. The objectives of the Life Team are to improve social relations within the Center and create a family-like working environment. Abdulrahman Alkhateeb, Committee Chair, says "The establishment of a student advisory committee shows the commitment of the Center and its director to the development not only of the facility, but of the human resources necessary to meet a world-class standard."

Upcoming Events

On 27 January, 2019, the Clean Combustion Research Center will open its doors to the brightest engineering and chemistry students worldwide for the second "Clean Combustion Winter School".

During the two-week program, students will learn about the hottest topic in combustion research, by conducting experiments and simulations using state-of-the-art experimental and computation facilities. Daily lectures will complement the research activity providing the necessary background.

VISIT EVENT WEBSITE

Delegates from academia, government laboratories and industry are invited to attend the 2019 conference on Future of Fuel, hosted and organized by the Clean Combustion Research Center (CCRC) at KAUST.

Held from 4 - 7 March, 2019, the conference will focus on three main areas:
1. Positioning Future Fuels
2. Industrial Perspectives on Future Fuels and
3. Academic Challenges in Future Fuels

VISIT EVENT WEBSITE