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Department of Mechanical Engineering

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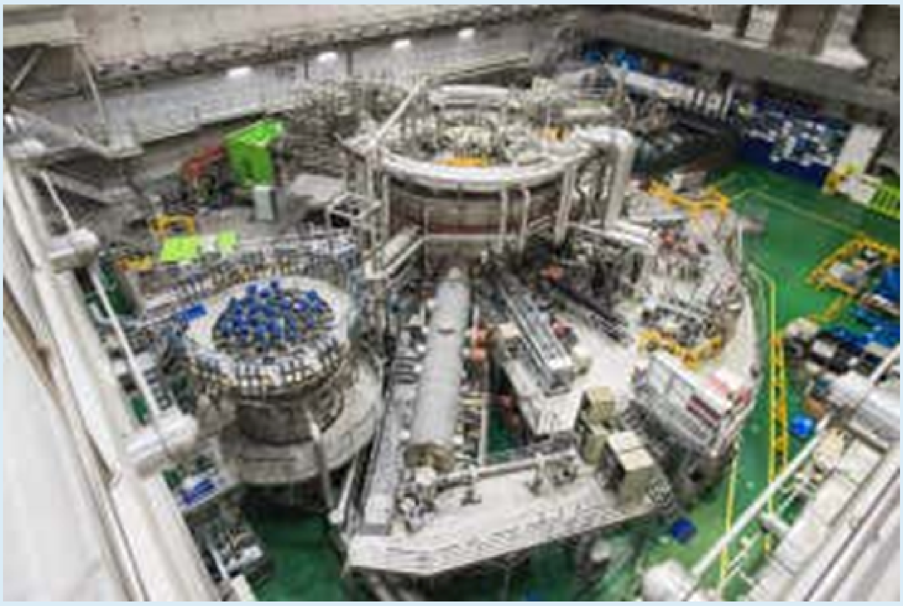
Breakthrough in Nuclear Fusion Technology



A nuclear fusion reaction has lasted for 30 seconds at temperatures in excess of 100 million°C. While the duration and temperature alone aren't records, the simultaneous achievement of heat and stability brings us a step closer to a viable fusion reactor – as long as the technique used can be scaled up.Most scientists agree that viable fusion power is still decades away, but the incremental advances in understanding and results keep coming. An experiment conducted in 2021 created a reaction energetic enough to be self-sustaining, conceptual designs for a commercial reactor are being drawn up, while work continues on the large ITER experimental fusion reactor in France.

Now Yong-Su Na at Seoul National University in South Korea and his colleagues have succeeded in running a reaction at the extremely high temperatures that will be required for a viable reactor, and keeping the hot, ionised state of matter that is created within the device stable for 30 seconds.Controlling this so-called plasma is vital. If it touches the walls of the reactor, it rapidly cools, stifling the reaction and causing significant damage to the chamber that holds it. Researchers normally use various shapes of magnetic fields to contain the plasma – some use an edge transport barrier (ETB), which sculpts plasma with a sharp cut-off in pressure near to the reactor wall, a state that stops heat and plasma escaping. Others use an internal transport barrier (ITB) that creates higher pressure nearer the centre of the plasma. But both can create instability.

Na's team used a modified ITB technique at the Korea Superconducting Tokamak Advanced Research (KSTAR) device, achieving a much lower plasma density. Their approach seems to boost temperatures at the core of the plasma and lower them at the edge, which will probably extend the lifespan of reactor components.Na says that low density was key, and that "fast" or more energetic ions at the core of the plasma – so-called fast-ion-regulated enhancement (FIRE) – are integral to stability. But the team doesn't yet fully understand the mechanisms involved.

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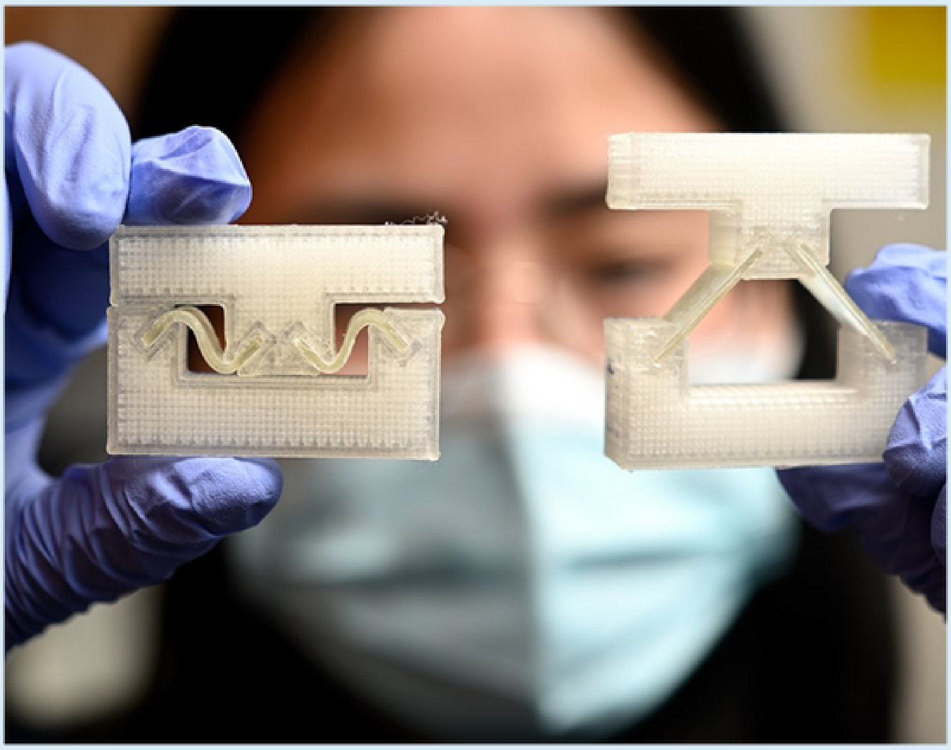
The reaction was stopped after 30 seconds only because of limitations with hardware, and longer periods should be possible in future. KSTAR has now shut down for upgrades, with carbon components on the wall of the reactor being replaced with tungsten, which Na says will improve the reproducibility of experiments.

Lee Margetts at the University of Manchester, UK, says that the physics of fusion reactors is becoming well understood, but that there are technical hurdles to overcome before a working power plant can be built. Part of that will be developing methods to withdraw heat from the reactor and use it to generate electrical current.Brian Appelbe at Imperial College London agrees that the scientific challenges left in fusion research should be achievable, and that FIRE is a step forwards, but that commercialisation will be difficult.

"The magnetic confinement fusion approach has got a pretty long history of evolving to solve the next problem that it comes up against," he says. "But the thing that makes me kind of nervous, or uncertain, is the engineering challenges of actually building an economical power plant based on this."

Shock-Absorbing Metamaterial Holds Promise for Impact Protection



Metals and plastics are typically the materials used to absorb energy in high-impact situations—for example, car bumpers or helmets. However, these materials typically do not perform well at higher speeds, are heavy, and are not reusable.To improve this situation, a team of Johns Hopkins University researchers led by Sung Hoon Kang, assistant professor in the department of mechanical engineering and Hopkins Extreme Materials Institute, investigated materials that could deliver greater energy absorption at higher speeds of impact, while being lighter weight and also reusable. They focused on liquid crystal elastomers (LCEs), which have ideal material characteristics for this application.

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LCEs, while softer than typical elastomers at static conditions, transform into hard, shock-absorbing plastics at higher speeds of impact. The foam-based LCE material the team developed is lighter than metal, displays better energy absorption at higher impact speeds, and can be reused. Commercial applications abound, such as helmets, body armor, and automobile and aerospace parts.To date, high-energy-absorbing LCEs have been used mainly in actuators and robotics. Kang harnessed the energy dissipation capabilities of LCEs by designing foam-like, multilayered structures that amplify the energy dissipation density upon impact.

The viscoelastic behavior of the LCE causes the energy absorption to increase with strain rate, according to a power-law relationship, which can be modulated by changing the degree of mesogen alignment and the loading direction relative to the director.

“Introducing the foam-like geometry and stacking them allowed us to have a synergy between material and geometry, thus achieving a much higher energy absorption density compared with that of a bulk material,” Kang said. “We were also not expecting the power-law relation between energy absorption density and strain rate so that the energy absorption density showed orders of magnitude increase at an impact regime.”

In addition, the vertical stacking of LCE units caused nonuniform buckling due to viscoelasticity of LCE, which produced additional viscous dissipation and further increased the energy absorption density. This synergistic interaction between viscoelastic dissipation and snap-through buckling also caused the energy absorption density to increase with the number of layers.

The enhancement of the energy absorption density caused by the vertical stacking of foam-like geometries suggests that if we scale down the foam-like geometry, we can have a large increase in energy absorption using the same amount of a material.Experiments showed the material withstood strikes from objects weighing about 4 to 15 pounds, coming at speeds of up to about 22 miles per hour. The tests were limited to 22 miles per hour due to limits of the testing machines, but the team is confident the padding could safely absorb even greater impacts.

For this experiment, Kang used LCE as a beam material for a simple 1D metastructure. Greater enhancement of energy absorption is expected through systematic structural designs in the future.Kang’s team is currently assessing other mechanisms for improving the material’s strength and energy absorption capability. The researchers have already received several inquiries from helmet companies and are exploring collaboration with industries to design, fabricate, and test next-generation lightweight energy-absorbing materials for various applications, including automotive and aerospace parts and personal protections.

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Department News

Congratulations

Naveen Krishna of 2016-20 batch of Mechanical Engineering, has been awarded the prestigious Commonwealth Scholarship. He is among the nine awardees from across the globe who received the Commonwealth Warwick Scholarship 2022-23. He will be studying MSc Humanitarian Engineering at University of Warwick in the United Kingdom. The United Kingdom Commonwealth Scholarship will cover full tuition fees, to-and-fro travel, thesis grant, visa expenses and also provide monthly stipend, worth over Rs. 40 lakhs, during the 12 months master's programme and research to be undertaken at Warwick from September 2022.

Congratulations to Mr. Sreehari S and Ms. Aswathy Ramesh for sharing the top position in the 2022B.Techbatch by securing a cumulative GPA of 9.00.

Congratulations to Mr. AbinShaji, Mr. Akshay C and Mr. Aravind Satheesh for getting placed in Mahindra and Mahindra in a placement drive conducted as part of the SAE BAJA 2022 India. SAE BAJA India is a collegiate design series competition run by the Society of Automotive Engineers India, whereteams comprising of students from universities all over the country design and build small off-road cars.

In addition to the above three students, 15 other students got offers from top companies like Capgemini, L&T, Cognizant Technology Services, Tata Consultancy Services, Infosys etc. Congratulations to all the students who got job offers.

Congratulations to team ASTRA for winning second position in the durability event and the validation event held as part of the prestigious SAE BAJA 2022 at Pithampur, Madhya Pradesh (5 – 10 April 2022). 138 teams from across the country had registered for the event. BAJA is an inter-collegiate event organized by SAE to provide SAE student members with a challenging project that involves design, planning, manufacturing, marketing and racing an All Terrain Vehicle (ATV).