Undergraduate engineers advance shock wave mitigation research

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Professor Veronica Eliasson. Credit: UC San Diego

A team of undergraduate engineers at UC San Diego has discovered a method that could make materials more resilient against massive shocks such as earthquakes or explosions. The students, conducting research in the structural engineering lab of Professor Veronica Eliasson, used a shock tube to generate powerful explosions within the tube—at Mach 1.2 to be exact, meaning faster than the speed of sound. They then used an ultra high-speed camera to capture and analyze how materials with certain patterns fared.

Previous research from Eliasson's lab had shown that obstacles laid out in a logarithmic spiral—picture a Nautilus shell spiraling around and around—were better able to diminish the energy of a shock wave and reduce overall damage than when arranged in other patterns. The students took that a step further, testing whether cutting three grooves into each side of their rectangular obstacle materials would be an even better attenuator of the shock when compared with similar obstacles laid out in a logarithmic spiral but with no grooves.

They found that these grooves did indeed diminish the impacts of what's called the reflected shock wave—once the initial wave has hit the spiral of obstacles and bounced back. Results were inconclusive for the initial transmitted shock wave. The undergraduate students reported their findings in the journal *Multiscale and Multidisciplinary Modeling, Experiments and Design*.

"This research can be used in military applications and civil applications too, to design materials and buildings to better withstand high-intensity blasts," said Christina Scafidi, one of the authors of the paper and a 2019 structural engineering graduate.

Scafidi is interning for DCI Engineers in San Diego this summer before returning to the Jacobs School of Engineering to earn a master's in structural engineering this fall.

"The coal industry has had many fatal accidents and we believe this research presents a strong case for protecting the workers from blast waves that can easily propagate throughout an entire coal mine," added Alexander Ivanov, a recent aerospace engineering graduate and co-author of the paper. "If the entire wall of the coal mine could be lined with these solid geometric obstacles, it could provide a cheap way to protect all of the workers in the mine."

Ivanov, Scafidi, Nicolas Fassardi and Tal Shemen, all undergraduate engineering students who graduated in June, had to meticulously arrange the shock wave experiments, making sure that not only the materials were aligned correctly and the tube pressurized exactly right, but also ensuring that the mirror and lens system they used to capture the results on the high-speed camera was in place, too.

The students would head into lab early in the morning to try and run their experiments with as few people in the building as possible.

"Every day we'd get to lab really early because

using the shock tube was quite loud—it creates this reverberation that is loud even with ear protection on," Scafidi said. "So we'd run tests before most people came in."

Some of the students—like Scafidi and Fassardi—had hoped to get involved in research as undergraduates, although neither expected they'd be able to do so as sophomores, which is when they started working in Eliasson's lab.

"I planned on getting involved in research as an undergrad but this opportunity came sooner than I had expected, as I still had two years left of my undergrad and thought that I would be a better research candidate the following year," said Fassardi, an aerospace engineering student. "However this opportunity was perfect because our paper was published just two weeks after graduating college!"

Fassardi will be working for Lockheed Martin Space in Sunnyvale starting in August.

"I wanted to join a lab but I didn't know that majoring in structural engineering you had so many options," Scafidi said. "I thought it would be mostly civil design. So joining Eliasson's lab showed me you can tailor your degree toward so many other things—shock wave research, structural health monitoring. I can use what I learned in her lab throughout my career."

For Ivanov, who hadn't planned on doing research, the experience was challenging, rewarding, and ultimately influential—he credits working in Eliasson's lab with his decision to pursue a graduate degree. He'll return to UC San Diego in the fall to work toward a master's degree in mechanical and aerospace engineering.

More information: Alexander Ivanov et al, Shock wave attenuation using rigid obstacles with large- and small-scale geometrical features, *Multiscale and Multidisciplinary Modeling, Experiments and Design* (2019). DOI: 10.1007/s41939-019-00053-2

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