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New method to test materials can aid national defense

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A report on research exploring ways to characterize the internal structure, properties and behavior of advanced materials used in challenging Department of Defense operations has won three Arizona State University engineers the 2012 Best Paper Award from the *Journal of Aerospace Engineering*.

The paper's co-authors are professor Aditi Chattopadhyay, assistant research professor Masoud Yekani Fard and assistant research scientist Yingtao Liu. Each is on the faculty of the School for Engineering of Matter, Transport and Energy, one of ASU's Ira A. Fulton Schools of Engineering.

The award will be formally presented to Chattopadhyay at the next Earth and Space Conference organized by the Aerospace Division of the American Society of Civil Engineers.

The winning paper, "Analytical Solution for Flexural Response of Epoxy Resin Materials," is based on a chapter of Yekani Fard's doctoral thesis on a three-year project funded by the Army Research Office involving studies of the high-velocity impact resistance of composite materials.

The Army is interested in specific applications of the materials research for aircraft and aerospace systems, weapons and defense systems, and ground transportation resources that would be exposed to high-impact situations on the battlefield. The same kinds of composite materials are also commonly used in bridges and tunnels, and in marine and offshore structures, as well as in automobile bumpers and panels, and in consumer products such as tennis racquets.

The researchers are looking at how the various material components in the composites behave to better understand how the materials will hold up under high- impact pressures.

"The Army is using composites in mission-critical systems," Chattopadhyay says. "They need to know if a material is strong enough to withstand the sort of impact it is expected to go through." That requires a focus on the epoxies that essentially are the "glue" that holds together the various materials in a composite.

"In most of the applications, it is the epoxy that is the dominant factor in the behavior of the whole structure," Yekani Fard explains.

The leading method to predict epoxy resin behavior has been an empirical approach called the Weibull model. The researchers say the effectiveness of the model depends entirely on conducting a high number of experiments, and the method has a significant margin of error.

These factors make the Weibull model not only expensive and inaccurate to a certain degree, but it cannot be applied universally to different epoxy resins, and instead must be repeated for the assessment of each individual material.

The inefficiency of the Weibull model and the prevalent use of epoxy resin in composites creates a strong need for accurate understanding of the behavior under variable loading, or changing pressure and stress. The team's award-winning paper details development of a new modeling method to produce a more reliable prediction of the capabilities of various epoxy resins.

The team developed an approach that can be applied not only to all epoxy resins, but to multiple semi-brittle materials. The method uses basic physics concepts of push-and-pull deformations in and out of a material plane, and classifies the similarities and differences in the material's response.

"We were able to develop a methodology with formulations that are extensive, but the fundamentals are simple physics, which allows use in different applications," Yekani Fard says.

The new method, for instance, allows for more reliable testing to predict the behavior and strength of materials such as bone cements – substances commonly used to hold implants in bone in procedures such as hip replacement and knee replacement surgeries. The composites that make up such cements contain semi-brittle materials similar to the materials used in military applications.

The Army Research Office also funded a series of experiments to gather data and research literature used to develop the model. Once the model was developed, it was tested for accuracy on different types of structures.

"This model adds to the knowledge of scientists and engineers in understanding how a material behaves both fundamentally and in different types of structures," Yekani Fard says.

Provided by Arizona State University

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