Research Project: Nano particle reinforced composites for critical infrastructure protection

Research Topic: Impact and energy absorption

Problem

The DYNATUP Model 8250 instrumented impact test machine was specifically designed for applications requiring low to medium energies and velocities up to 30 mph. The system is available at the University of Mississippi and used in this project for evaluating the impact resistance of various construction materials.

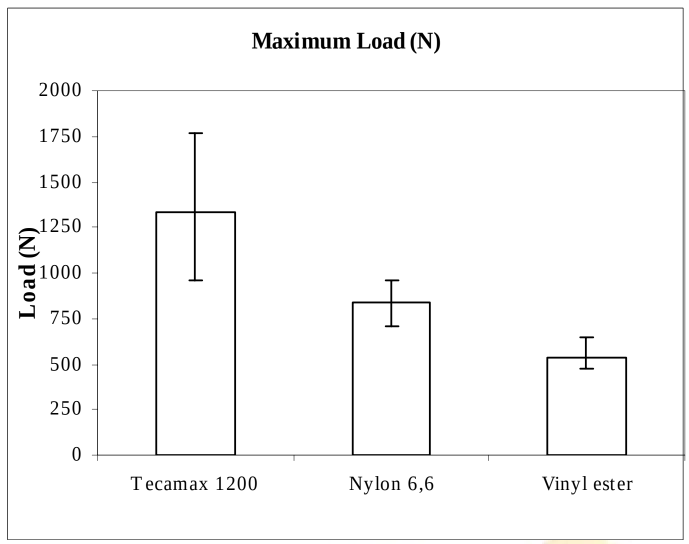
Approach

Flexible soft materials that can undergo energy-absorbing molecular rearrangements during deformation are tough, but also compliant. In contrast, rigid hard materials are stiff but also very brittle having little ability to absorb energy, so their toughness is low. To be strong and tough, a material must be able to absorb a large amount of energy during mechanical deformation, and also maintain its stiffness.

Nanotechnology layering concepts makes it possible to achieve this desirable combination of mechanical properties, with stiffness significantly higher than composites previously fabricated from similar materials using conventional methods. Nanoscale structures such as nanoparticles and nanolayers have very high surface-to-volume ratios, making them ideal for use in composite materials and structures. Nanostructure ceramics are often both harder and less brittle than same materials made on the scale of microns, which are 1,000 times larger than nanometers, but still barely visible to the human eye. For example, adding certain inorganic clays to rubber dramatically improves the lifetime and wear properties of tires because the nanometer-sized clay particles bind to the ends of the polymer molecules, which are “molecular strings” preventing them from unraveling. Dramatic improvements in the properties of this composite material (part rubber and part clay) are reported, demonstrating the potential of nanotechnology as it is rationally applied to more complex systems.

For fibrous composites, an ‘ultra thin’ elastomeric resilient coating applied to the fibers has been found to achieve both structural stiffness and high energy absorption, contributed by tougher fiber pull out and interfacial bonding. Nano ceramic particle layered inserts were observed to confine impact load distributions to smaller areas along with a high rate of energy dissipation, providing higher strength, toughness and ductility with improved damping.

Impact can be broadly classified into two categories, low velocity and high velocity (ballistic) impact. In the latter technique, complete penetration of the projectile into the sample is expected with the generation of compressive, shear and Rayleigh waves from the point of impact. In such cases, the velocity of the impactor is typically greater than 10 m/s (22.4 mph), with the resulting damage being highly localized near the point of impact. The high pressures of short duration applied during explosions can introduce significant permanent deformations and damage the core in transverse directions. On the other hand, in low-velocity impact (lower than 10 m/s), the stress wave effects are minimal and the behavior can be considered to be quasi-static. Pendulum, falling or drop weight impact tests are typically used for characterizing materials under such impact conditions. The DYNATUP Model 8250 instrumented impact test machine is widely used by major materials producers and processors in the automotive, aerospace, electronics and packaging industries.



Findings

Figure below shows the superior impact response of TECAMAX® 1200, a novel rigid rod thermoplastic Self-Reinforced Polymer (SRP), compared to the more conventional nylon 6,6 and vinyl ester resin systems.

Impact

Research conducted on this project will impact the development of composite materials technology in naval ships, homeland security and civil-infrastructure areas.

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