can be derived, using the present model as a basis, following a mechanics-of-materials approach or other suitable approach. The present constitutive model, in combination with classical lamination theory, has been incorporated into a finite-element mathematical model and computer code to enable modeling of static and dynamic responses of panel-type SMAHC structures subjected to static and dynamic thermal and mechanical loads. Loads that have been considered include acoustic pressures, acceleration forces, and concentrated forces. Phenomena that have been investigated include control of thermal buckling, thermal post-buckling, random vibration, and acoustic transmission/radiation responses of structures under constrained recovery. The constitutive model and structural response formulation have been validated against experimental measurements of thermal buckling/post-buckling and random vibration responses.

This work was done by Travis L. Turner of **Langley Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.techbriefs.com/tsp*** *under the Materials category.*
LAR-16274

Liquid-Crystal Thermosets, a New Generation of High-Performance Liquid-Crystal Polymers

Liquid-crystal polymers can now be used as resins in textile composites.

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One of the major challenges for NASA's next-generation reusable-launch-vehicle (RLV) program is the design of a cryogenic lightweight composite fuel tank. Potential matrix resin systems need to exhibit a low coefficient of thermal expansion (CTE), good mechanical strength, and excellent barrier properties at cryogenic temperatures under load. In addition, the resin system needs to be processable by a variety of non-autoclavable techniques, such as vacuum-bag curing, resin-transfer molding (RTM), vacuum-assisted resin-transfer molding (VaRTM), resin-film infusion (RFI), pultrusion, and advanced tow placement (ATP).

To meet these requirements, the Advanced Materials and Processing Branch (AMPB) at NASA Langley Research Center developed a new family of wholly aromatic liquid-crystal oligomers that can be processed and thermally cross-linked while maintaining their liquid-crystal order. All the monomers were polymerized in the presence of a cross-linkable unit by use of an environmentally benign melt-condensation technique. This method does not require hazardous solvents, and the only side product is acetic acid. The final product can be obtained as a powder or granulate and has an infinite shelf life. The obtained oligomers melt into a nematic phase and do not exhibit isotropization temperatures greater than the temperatures of decomposition ($T_i > T_{dec}$). Three aromatic formulations were designed and tested and included esters, ester-amides, and ester-imides.

One of the major advantages of this invention, named LaRC-LCR or Langley Research Center-Liquid Crystal Resin, is the ability to control a variety of resin characteristics, such as melting temperature, viscosity, and the cross-link density of the final part. Depending on the formulation, oligomers can be prepared with melt viscosities in the range of 10–10,000 poise (100 rad/s), which can easily be melt-processed using a variety of composite-processing techniques. This capability provides NASA with custom-made matrix resins that meet the required processing conditions for the fabrication of textile composites. Once the resin is in place, the temperature is raised to 375 °C and the oligomers are cross-linked into a high-glass-transition-temperature (T_g) nematic network without releasing volatiles. The mechanical properties of the fully cross-linked, composite articles are comparable to typical composites based on commercially available epoxy resins.

LaRC-LCR can also be used in thermoforming techniques where short holding times are desired. The resin can be used to spin fibers, extrude thin films and sheets, or injection mold complex parts. Although LaRC-LCR has been developed to meet NASA's needs towards the development of a next-generation launch vehicle, other applications can be envisioned as well. The thermal and mechanical behavior of this material are ideally suited for electronic applications and may find use in flexible circuits, chip housings, and flip-chip underfills. Another area where thermal stability and chemical resistance are highly desirable is the automotive industry. Distributor caps, fuel tanks, air-intake manifolds, rocker covers, and ignition systems are among the potential applications. The low viscosity of this resin makes this material ideal for coating applications as well. Fine powders have been used in plasma-spray applications, and well-defined thin coatings were obtained. LaRC-LCR can also be used as an adhesive. Lap-shear values of 3,435 psi (22,683 kPa) were easily obtained. In contrast, these values are ≈20 times higher than those observed in commercially available LCP resins.

This work was done by Theo Dingemans, Erik Weiser, Tan Hou, Brian Jensen, and Terry StClair at **Langley Research Center** *and funded under NASA's Reusable Launch Vehicle (RLV) research program.*

This invention is owned by NASA, and a patent application has been filed. An exclusive license for its commercial development has been granted to TICONA Inc. (Summit, NJ). For further information, contact Diane Hope at the Technology Commercialization Program Office (TCPO), NASA Langley Research Center, 3 Langley Boulevard, Mail Stop 200, Hampton, VA 23681-2199. E-mail: d.l.hope@larc.nasa.gov.
LAR-16079

Several Products made from LaRC-LCR include films, plaques, foams, uniaxial carbon-fiber prepregs, and carbon-fiber composites.