National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Mechanical and Fluid Systems

Shape Memory Alloy Tubular Structure

Revolutionary Technology Eliminates Pneumatic Tire Risks

Innovators at NASA's Glenn Research Center (GRC) have developed a next-generation, non-pneumatic, compliant tire structure based on shape memory alloy (SMA) elements. This new structure builds upon previous work related to airless tires that were designed for rovers used in planetary exploration. The use of SMAs capable of undergoing high strain as load bearing components results in a tubular structure that can withstand excessive deformation without permanent damage. These structures are capable of performing similarly to traditional pneumatic tires but with no risk of puncture or loss of tire pressure. The new technology is an extension of previous nonpneumatic metal-mesh tire designs developed at GRC, but with a structural pattern that improves manufacturability and offers design flexibility for customization. The innovation has been prototyped for use as a bicycle tire, but this SMA structure can be used in a wide range of applications including, off-road vehicles, aircraft landing gear, military ground vehicles, agricultural machinery, seals, and energy absorbers.

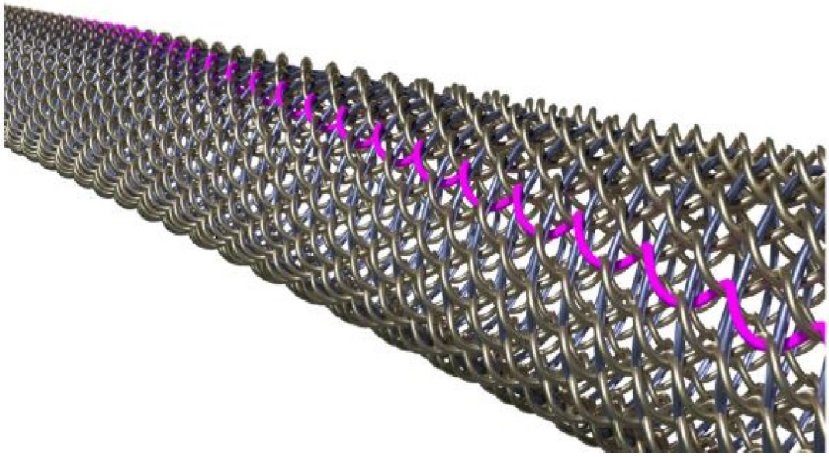
BENEFITS

- Safe, reliable, and high-strength: the airless SMA structure eliminates the possibility of puncture failure and can withstand excessive deformation (more than 30x that of traditional materials)
- Design flexibility: customization of structural performance characteristics can result in optimized performance that conventional pneumatic tires cannot achieve
- Improved manufacturability: the structure is more simple to build than previous designs and is scalable for a variety of applications
- Reengineering opportunities: the SMA structure provides the potential to redesign wheel and braking systems, seals, and energy absorption components that may offer advantages over conventional systems

THE TECHNOLOGY

The Glenn technology utilizes SMA structural elements (wires and springs) interlocked via a unique layering pattern, allowing the structure to take on tubular geometries while exhibiting the same ride performance as traditional tires. Though previous tires have used SMA elements as load-carrying members, this new design offers an improved structural pattern - consisting of two layers of SMA elements. The primary layer is a single wire shape set into a coil and wrapped circumferentially around a wheel, which sets the overall tire geometry and provides added strength in the radial and axial directions. The secondary layer consists of smaller SMA springs interlocked with each other as well as the primary coil, acting as a sheath that sets the coil spacing and provides the necessary shear stiffness.

SMAs are superelastic in nature and can take up to 8% effective reversible strain without yielding. The SMAs can handle up to 30x more strain, allowing the tire structure to undergo high levels of deformation without permanent damage. Because these tires do not rely on air, the risks associated with a flat tire are eliminated, and tire stiffness never varies (the tires never run 'under-inflated'). Furthermore, this airless tire design may enable the redesigning of wheel and braking systems. The first bicycle tire prototype was estimated to have a tire stiffness comparable to a road bike tire inflated to 75 psi, but with improved lateral and shear stiffness. By varying the SMA wire geometry, a wide range of tire sizes and stiffnesses is achievable. Rubber tread surfaces may be attached to the outside of the SMA tire for sufficient traction on a variety of terrain.



Above is a graphical representation of the two-layer SMA structure.

APPLICATIONS

The technology has several potential applications:

- Vehicle tires aircraft, agricultural machinery, off-road vehicles, trucks, motorcycles, automobiles, bicycles, etc.
- Energy absorbers: sports helmets, military equipment, etc.
- Seals and couplings
- Compliant connectors
- Biomedical

PUBLICATIONS

Patent No: 11,912,078

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