NASAfacts

Space Technology
Game Changing Development
Bulk Metallic Glass Gears

NASA is developing technologies that will allow exploration of promising places in the solar system ranging from the Moon to Mars to icy worlds such as the moon of Jupiter, Europa. These locations have extreme environments that require landers and rovers to operate at temperatures below –150 °C. To put that in perspective, the lowest observed temperature on any location on Earth's surface was –97.8 °C (–144 °F) in small topographic basins near the East Antarctic ice divide.

More science can be accomplished on icy body missions, like those to Europa, if spacecraft hardware can operate without power consuming heaters. Researchers are developing unheated gearboxes to operate in these environments using bulk metallic glass (BMG) alloys invented at NASA specifically for this application. Gearboxes developed with the BMG technology must be capable of operating at surface temperatures of –173 °C (–280 °F).

The composition and amorphous atomic structure of these BMG alloys make them tougher than ceramics and twice as strong as steel, with better elastic properties than either. A gearbox is a mechanical system that uses gears and gear trains to provide speed and torque from a rotating power source to another device, like a car's transmission adapts engine output to drive the wheels. Combined with greater wear and corrosion resistance, these alloys are promising gearbox component materials.

Steel **Amorphous metal**

Amorphous metal can be cast into the final shape with no post-casting finishing steps required. Precise teeth shapes can be incorporated into the mold and replicated near-perfectly into the castings. Certain alloys of amorphous metal (metallic glass) also have extremely good elastic, contact stress, and galling properties for this application.

The BMG Gears project within NASA's Space Technology's Game Changing Development Program (GCD) plans to demonstrate capabilities of custom BMG alloys in heaterless planetary and strain-wave gearbox configurations. Enabled by the materials working in extreme cold environments, mechanisms such as these could increase science return by reducing power consumption, mass, system complexity, and operational constraints. Applied to a Mars Curiosity type rover, for example, this technology would enable nighttime operations during winter while saving 950 watt-hours per day; enough to run the remote sensing mast while moving. The additional benefit of ~7 kg in heaterless mass savings could allow another instrument to fly.

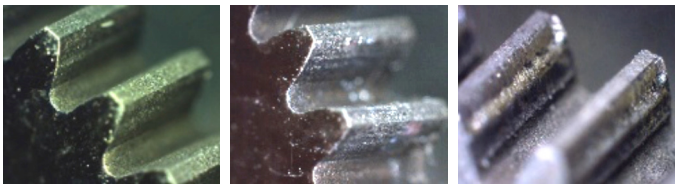
Currently there are no materials specifications available that define acceptable ranges for the constituent components and minor elements in the BMGs that enable these gearboxes. NASA is working closely with industry to develop those specifications and mature a supply chain for the BMG alloys. An important benefit of using BMG alloys is that components can be directly molded from the material and the supply chain for gearbox components in this manner is being similarly matured.

Recently, a heaterless planetary gearbox comprised of copper- and zirconium-based BMG gear components operating at and below –173 °C has been demonstrated. These results follow a prior demonstration of the same BMG alloy tested in a dry lubricated hybrid gearbox. Using a steel drive gear and BMG planet gears, this gearbox configuration ran 75 percent longer than a dry lubricated all-steel gearbox (14 million revolutions versus 8 million revolutions). Researchers are now determining the operational limits and mechanical fatigue properties needed for design rules and guidelines for BMG alloy use. Additionally, resilience to launch, entry, descent and landing loads, and pryoshock events will be demonstrated by dynamics testing the current point design.

The BMG Gears project seeks to advance the technology to a technology readiness level (TRL) of six for mission demonstration opportunities and project infusion. The project will mature a cryo-capable BMG-based planetary gearbox with demonstrated performance exceeding current products. The technological advance will enable operating mobility systems through the Lunar night and offers potential to a Europa Lander mission that includes actuators or mechanisms without additional power requirements for gearboxes heating. This means increased science return through increased mission life or instrumentation.

GCD is part of NASA's Space Technology Mission Directorate. The GCD Program aims to advance exploratory concepts and deliver technology solutions that enable new capabilities or radically alter current approaches.

For more information about GCD, please visit http://gameon.nasa.gov/



Nominal BMG gear | **BMG gear after 3 hr wear** | **Steel gear after 3 hr wear**

More than 3 million cycles were achieved at less than –100 °C with dry lubricated hybrid gearbox.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

www.nasa.gov

CL#19-1976