HARMLES - Dry lubricated Harmonic Drives

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Abstract

The technology is a novel solid lubricated harmonic drive gear developed by the FP7 funded HARMLES consortium. An existing liquid lubricated Harmonic Drive® (HD) gear has been modified to operate using a dry lubrication design. This type of design removes the need for additional lubricants. A WC-MoSx coating has been adapted for the Harmonic Drive gears and a demonstrator unit has been tested under both space and terrestrial conditions.

Description

Harmonic Drive gears have been used for more than four decades for applications in space. This gear principle was originally developed for space applications including both satellites and planetary exploration.

Harmonic Drive® gears are based on the principle that a flexible element is used to transmit torque, which offers the advantages of low or zero backlash in combination with excellent precision. The large gear ratio in combination with the ability of zero stick-slip movement at slow speeds makes them an excellent choice for space applications: a small actuator motor (i.e. low mass and low power consumption) may be used to move large components like antennas or solar panels.

One current drawback of these drives is that they need liquid lubricants (including greases) in order to satisfy the operational requirements. However due to vacuum and temperature conditions in space, liquid lubricants and greases bear the risk of outgassing and evaporation, leading to operational problems for the gears themselves as well as deposition of outgassed material on critical structures. These issues have led to a demand for dry lubricated gears. The technology covers extended temperature ranges and applications with critical items located close to the gears, such as optics or telescopes.

HarmLES has aimed to provide a solution to this issue by increasing the accessible lifetime of this type of component by developing a new Harmonic Drive® gear type for solid lubrication. An integrated approach was chosen considering materials, coatings and gear design. Besides the development of a proper coating, a major aim of the project was to optimize the geometry of the Harmonic - Drive® gear, especially towards the needs of solid lubrication for space applications. Based on

requirements raised by potential end-users, the Harmonic Drive® gear was re-designed and a new gear type called ZirconLine (size 20 with ratio 100) has been developed. Modifications introduced to the gear, have decreased the contact stresses and the sliding path within the toothing.

A gear prototype has been manufactured. The characteristics of the gear are in line with the requirements raised by the end users, which were mainly zero backlash, a defined minimum stiffness and a Transmission Accuracy better than 60 arcsecs. The achieved endurance in vacuum was increased significantly from a few-hundred output revolutions to more than 17,500 revolutions (which was the in-service lifetime objective for this technology).

Vacuum endurance tests were confirmed by post-test inspection of the gear. The gear stiffness after the test is identical to the initial pre-test value. The visual appearance of the teeth was found to be in very good condition after the test, underlining the huge enhancement over existing systems.

Alongside the re-design, the success was also based on a new composite coating based on a WC-interlayer plus a solid lubricant top-layer using a reinforced MoS2. The composite coating showed superior lifetime compared to standard MoS2 coatings. The coating process has been adopted for gear components – gear teeth and wave generator (WG) bearing.

Innovations and advantages of the offer

HarmLES has developed the first solid lubricated Harmonic Drive® gears with zero backlash and high gear stiffness to provide reasonable endurance. The technology exhibits the following:

- Lifetimes of up to 20.000 output revolutions were achieved in vacuum testing at 4Nm
- The efficiency of the gear during the vacuum endurance measurements was almost completely stable throughout the whole test, a much superior performance when compared to grease lubricated HDs.

Application

Current and future potential applications for dry lubricant harmonic drives include:

- Aerospace: Solar Array Drives, Antenna Pointing, Valve Actuators, Lunar and Interplanetary Rovers
- Robotics: Industrial, Semiconductor & Flat Panel, Humanoid, Mobile Robots
- Medical: Surgical Robots, Medical Imaging, Therapeutic, Prosthetics, Exoskeletons, Lab Automation
- Defence: Unmanned Vehicles, Remote Weapon Stations, Antenna Pointing
- Machine Tool: Milling Head, Tool Changer, Rotary Table, Grinding, B & C Axis
- Cryogenics (coating related)

Comments on the technology by the broker

This technology has a good space heritage and work has started to investigate its use in spin off applications. The technology is suitable for numerous space applications, as well as offering potential for uptake in a range of non-space sectors. The technology has undergone an extensive testing campaign and the knowledge and results developed within HARMLES is based on hundreds of measurements in a variety of extreme environments.

Description of Space Heritage

Coatings have been tested in orbit at TriboLAB, in the International Space Station (ISS). TriboLAB is a tribology laboratory installed in the EuTEF (European Technology Exposure Facility), fixed to Columbus laboratory from ESA. Launch date: Feb 2008 STS-122 delivered the Columbus European Laboratory Module.

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