



### **Wireless Inductive Power Device Suppresses Blade Vibrations**

**The aerospace and electric power generation industries could benefit from this technology.**

*John H. Glenn Research Center, Cleveland, Ohio*

Vibration in turbomachinery can cause blade failures and leads to the use of heavier, thicker blades that result in lower aerodynamic efficiency and increased noise. Metal and/or composite fatigue in the blades of jet engines has resulted in blade destruction and loss of lives. Techniques for suppressing low-frequency blade vibration, such as “tuned circuit resistive dissipation of vibratory energy,” or simply “passive damping,” can require electronics incorporating coils of unwieldy dimensions and adding unwanted weight to the rotor. Other approaches, using vibration-dampening devices or damping material, could add undesirable weight to the blades or hub, making them less efficient.

A wireless inductive power device (WIPD) was designed, fabricated, and developed for use in the NASA Glenn’s “Dynamic Spin Rig” (DSR) facility. The DSR is used to simulate the functionality of turbomachinery. The relatively small and lightweight device [10 lb (≈4.5 kg)] replaces the existing venerable and bulky slip-ring. The goal is the eventual integration of this technology into actual turbomachinery such as jet engines or electric power generators, wherein the device will facilitate the suppression of potentially

destructive vibrations in fan blades. This technology obviates slip rings, which require cooling and can prove unreliable or be problematic over time.

The WIPD consists of two parts: a remote element, which is positioned on the rotor and provides up to 100 W of electrical power to thin, lightweight piezoelectric patches strategically placed on/in fan blades; and a stationary base unit that wirelessly communicates with the remote unit. The base unit supplies inductive power, and also acts as an input and output corridor for wireless measurement, and active control command to the remote unit.

Efficient engine operation necessitates minimal disturbance to the gas flow across the turbine blades in any effort to moderate blade vibration. This innovation makes it possible to moderate vibration on or in turbomachinery blades by providing 100 W of wireless electrical power and actuation control to thin, lightweight vibration-suppressing piezoelectric patches (eight actuation and eight sensor patches in this prototype, for a total of 16 channels) positioned strategically on the surface of, or within, titanium fan blades, or embedded in composite fan blades. This approach moves significantly closer

to the ultimate integration of “active” vibration suppression technology into jet engines and other turbomachinery devices such as turbine electrical generators used in the power industry.

The novel feature of this device is in its utilization of wireless technology to simultaneously sense and actively control vibration in rotating or stationary turbomachinery blades using piezoelectric patches. In the past, wireless technology was used solely for sensing and diagnostics. This technology, however, will accomplish much more, in terms of simultaneously sensing, suppressing blade vibration, and making it possible for detailed study of vibration impact in turbomachinery blades.

*This work was done by Carlos R. Morrison, Andrew J. Provenza, Benjamin B. Choi, Milind A. Bakhle, James B. Min, George L. Stefko, Kirsten P. Duffy of Glenn Research Center and John Kussmann of MESA Systems Co. and Alan J. Fougere of D-2 Inc. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18601-1.*

### **Safe, Advanced, Adaptable Isolation System Eliminates the Need for Critical Lifts**

**Inflatable isolators are integrated into an aircraft jacking system.**

*Dryden Flight Research Center, Edwards, California*

The Starr Soft Support isolation system incorporates an automatically reconfigurable aircraft jack into NASA’s existing 1-Hertz isolators. This enables an aircraft to float in mid-air without the need for a critical lift during ground vibration testing (GVT), significantly reducing testing risk, time, and costs. Currently incorporating the most advanced technology available, the 60,000-pound-capacity (27-metric-ton) isolation system

is used for weight and measurement tests, control-surface free-play tests, and structural mode interaction tests without the need for any major reconfiguration, often saving days of time and significantly reducing labor costs.

The Starr Soft Support isolation system consists of an aircraft-jacking device with three jacking points, each of which has an individual motor and accommodates up to 20,000 pounds (9 metric tons) for a

total 60,000-pound (27-metric-ton) capacity. The system can be transported to the aircraft by forklift and placed at its jacking points using a pallet jack. The motors power the electric actuators, raising the aircraft above the ground until the landing gear can retract.

Inflatable isolators then deploy, enabling the aircraft to float in mid-air, simulating a 1-Hertz free-free boundary condition. Inflatable isolators have been in

use at NASA for years, enabling aircraft to literally float unsupported for highly accurate GVT. These isolators must be placed underneath the aircraft for this to occur. Traditionally, this is achieved by a “critical lift” — a high-risk procedure in which a crane and flexible cord system are used to lift the aircraft. In contrast, the Starr Soft Support isolation system eliminates the need for critical lift by integrating the inflatable isolators into an

aircraft jacking system. The system maintains vertical and horizontal isolating capabilities. The aircraft can be rolled onto the system, jacked up, and then the isolators can be inflated and positioned without any personnel needing to work underneath the aircraft. Also, the system accommodates changes in aircraft configuration, automatically adapting to changes in mass, and it can adjust the height of the isolators in one basic setup.

Dryden personnel used the Starr Soft Support system to successfully perform a GVT on an F-15 being structurally modified by Gulfstream, Dryden’s Gulfstream III used for science research and the crew exploration module and adaptor cone assembly.

*This work was done by Starr Ginn of Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-009-042*

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## **Anti-Rotation Device Releasable by Insertion of a Tool**

*Lyndon B. Johnson Space Center, Houston, Texas*

A drive mechanism enables a socket-type wrench to rotate a shaft and prevents accidental rotation of the shaft when the wrench is not coupled to the shaft. In the original intended application, the shaft would be part of an attachment mechanism on a spacecraft, and the purpose to be served by the drive is to prevent back-driving of the shaft by launch vibrations while enabling an astronaut equipped with the appropriate wrench to actuate the shaft while in orbit. The design could

also be adapted to terrestrial applications in which it is necessary to prevent rotational back-driving. The mechanism includes a gear near the tip of the shaft, and a drive nut that constitutes the tip of the shaft. The gear and drive nut are positioned in a recess in a housing. The recess is sized to receive the wrench socket that mates with the drive nut. Also contained in the housing are four linkages that include pins that are spring-loaded into engagement with the gear to prevent

rotation of the shaft. When the wrench socket is inserted in the recess, it pushes on the linkages in such a manner as to disengage the pins from the gear.

*This work was done by Harry K. Warden and Terro J. Jenkins of The Boeing Co. for Johnson Space Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809.*

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## **A Magnetically Coupled Cryogenic Pump**

**A proof of concept pump is successful.**

*John F. Kennedy Space Center, Florida*

Historically, cryogenic pumps used for propellant loading at Kennedy Space Center (KSC) and other NASA Centers have a bellows mechanical seal and oil bath ball bearings, both of which can be problematic and require high maintenance. Because of the extremely low temperatures, the mechanical seals are made of special materials and design, have wearing surfaces, are subject to improper installation, and commonly are a potential leak path. The ball bearings are non-precision bearings [ABEC-1 (Annular Bearing Engineering Council)] and are lubricated using LOX compatible oil. This oil is compatible with the propellant to prevent explosions, but does not have good lubricating properties. Due to the poor lubricity, it has been a goal of the KSC cryogenics community for the last 15 years to develop a magnetically coupled pump, which would eliminate these two potential issues. A number of projects have been attempted, but none of the pumps was a success.

An off-the-shelf magnetically coupled pump (typically used with corrosive fluids) was procured that has been used for hypergolic service at KSC. The KSC Cryogenics Test Lab (CTL) operated the pump in cryogenic LN<sub>2</sub> “as received” to determine a baseline for modifications required. The pump bushing, bearings, and thrust rings failed, and the pump would not flow liquid (this is a typical failure mode that was experienced in the previous attempts).

Using the knowledge gained over the years designing and building cryogenic pumps, the CTL determined alternative materials that would be suitable for use under the pump design conditions. The CTL procured alternative materials for the bearings (bronze, aluminum bronze, and glass filled PTFE) and machined new bearing bushings, sleeves, and thrust rings. The designed clearances among the bushings, sleeves, thrust rings, case, and case cover were altered once again using experience gained from previous cryogenic

pump rebuilds and designs. The alternative material parts were assembled into the pump, and the pump was successfully operated meeting all expected operating parameters.

Unique pump sub-assembly parts were designed and manufactured by the CTL using specialized materials determined to be superior for cryogenic thermal applications under the pump design conditions. This work is a proof-of-concept/proof-of-operation of the pump only. Other known internal design modifications to the pump should be accomplished for the long-term use of the pump. An upscaled version of this pump, which is under development and testing at the CTL, can be used either for current or future vehicle loading or for vehicle replenishment. Scaling of this pump can be easily accomplished.

*This work was done by Walter Hatfield and Kevin Jumper of John F. Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13434*