Miniature Piezoelectric Macro-Mass Balance

This system can be used to verify the mass of multiple samples in pharmaceutical and food-processing applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

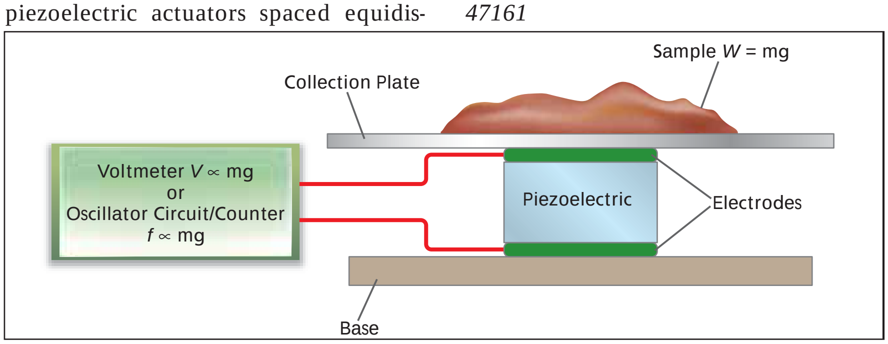
Mass balances usually use a strain gauge that requires an impedance measurement and is susceptible to noise and thermal drift. A piezoelectric balance can be used to measure mass directly by monitoring the voltage developed across the piezoelectric balance, which is linear with weight or it can be used in resonance to produce a frequency change proportional to the mass change (see figure). The piezoelectric actuator/balance is swept in frequency through its fundamental resonance. If a small mass is added to the balance, the resonance frequency shifts down in proportion to the mass. By monitoring the frequency shift, the mass can be determined.

This design allows for two independent measurements of mass. Additionally, more than one sample can be verified because this invention allows for each sample to be transported away from the measuring device upon completion of the measurement, if required.

A piezoelectric actuator, or many piezoelectric actuators, was placed between the collection plate of the sampling system and the support structure. As the sample mass is added to the plate, the piezoelectrics are stressed, causing them to produce a voltage that is proportional to the mass and acceleration. In addition, a change in mass Δm produces a change in the resonance frequency with Δf proportional to Δm. In a microgravity environment, the spacecraft could be accelerated to produce a force on the piezoelectric actuator that would produce a voltage proportional to the mass and acceleration. Alternatively, the acceleration could be used to force the mass on the plate, and the inertial effects of the mass on the plate would produce a shift in the resonance frequency with the change in frequency related to the mass change.

Three prototypes of the mass balance mechanism were developed. These macro-mass balances each consist of a solid base and an APA 60 Cedrat flextensional piezoelectric actuator supporting a measuring plate. A similar structure with 3 APA 120 Cedrat flextensional piezoelectric actuators spaced equidistantly at 120° supporting the plate and a softer macro balance with an APA 150 actuator/sensor were developed. These flextensional actuators were chosen because they increase the sensitivity of the actuator to stress, allow the piezoelectric to be pre-stressed, and the piezoelectric element is a stacked multilayer actuator, which has a considerably lower input impedance than a monolithic element that allows for common instruments (e.g., input impedance of 10 megohms) to measure the voltage without rapidly discharging the charge/voltage on the piezoelectric actuator.

This work was done by Stewart Sherrit, Ashitey Trebi-Ollennu, Robert G. Bonitz, and Yoseph Bar-Cohen of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47161



There are **Two Methods of Measuring Mass**: A direct method uses a voltmeter; an indirect method uses an oscillator circuit/counter.

Acoustic Liner for Turbomachinery Applications

This acoustic liner reduces turbomachinery noise of aircraft.

John H. Glenn Research Center, Cleveland, Ohio

The purpose of this innovation is to reduce aircraft noise in the communities surrounding airports by significantly attenuating the noise generated by the turbomachinery, and enhancing safety by providing a containment barrier for a blade failure. Acoustic liners are used in today's turbofan engines to reduce noise. The amount of noise reduction from an acoustic liner is a function of the treatment area, the liner design, and the material properties, and limited by the constraints of the nacelle or casement design. It is desirable to increase the effective area of the acoustic treatment to increase noise suppression. Modern turbofan engines use "wide-chord" rotor blades, which means there is considerable treatment area available over the rotor tip.

Turbofan engines require containment over the rotors for protection from blade failure. Traditional methods use a material wrap such as Kevlar integrated with rub strips and sometimes metal layers (sandwiches). It is possible to substitute the soft rub-strip material with an open-cell metallic foam that provides noise-reduction benefits and a sacrificial material in the first layer of the containment system.

An open-cell foam was evaluated that behaves like a bulk acoustic liner, serves as a tip rub strip, and can be integrated with a rotor containment system. Foams can be integrated with the fan-containment system to provide sufficient safety margins and increased noise attenuation. The major innovation is the integration of the foam with the containment.

The uniqueness of the innovation is the ability to reduce turbomachinery noise for aircraft engine applications while providing sufficient blade containment and minimal (if any) aerodynamic penalty. The innovation can be applied to compressors, turbines, and fans. Space is usually limited over the rotors due to the need for containment systems. The innovation replaces the first layer of the containment system with a foam that behaves like an acoustic bulk liner. The material properties of the foam can be tailored for temperature, density, porosity, and weight to suit the application. Existing turbofan engines do not use acoustic treatment placed directly over the rotor. The innovation enables this due to the foam behaving like a rub strip and an acoustic liner. Full-scale testing of production turbofan engine resulted in 5-dB total attenuation.

This innovation can be applied to other turbomachinery where noise reduction is needed from the rotors; for example, ground power systems, cooling / ventilating fans, and ducted propellers.

This work was done by Dennis L. Huff and Daniel L. Sutliff of Glenn Research Center; Michael G. Jones of Langley Research Center; and Mohan G. Hebsur of the Ohio Space Institute.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: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18438-1.

Metering Gas Strut for Separating Rocket Stages

Marshall Space Flight Center, Alabama

A proposed gas strut system would separate a liquid-fueled second rocket stage from a solid-fueled first stage using an array of pre-charged struts. The strut would be a piston-and-cylinder mechanism containing a compressed gas. Adiabatic expansion of the gas would drive the extension of the strut. The strut is designed to produce a force-versus-time profile, chosen to prevent agitation of the liquid fuel, in which the force would increase from an initial low value to a peak value, then decay toward the end of the stroke.

The strut would include a piston chamber and a storage chamber. The piston chamber would initially contain gas at a low pressure to provide the initial low separation force. The storage chamber would contain gas at a higher pressure. The piston would include a longitudinal metering rod containing an array of small holes, sized to restrict the flow gas between the chambers, that would initially not be exposed to the interior of the piston chamber. During subsequent expansion, the piston motion would open more of the metering holes between the storage and piston chambers, thereby increasing the flow of gas into the piston chamber to produce the desired buildup of force.

This work was done by Brian Floyd of Integrated Concepts Research Corp. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32660-1.

Large-Flow-Area Flow-Selective Liquid / Gas Separator

A two-phase flow separator for fuel cells operates between 2 and 10 kW in multi-g environments.

Lyndon B. Johnson Space Center, Houston, Texas

This liquid / gas separator provides the basis for a first stage of a fuel cell product water / oxygen gas phase separator. It can separate liquid and gas in bulk in multiple gravity environments. The system separates fuel cell product water entrained with circulating oxygen gas from the outlet of a fuel cell stack before allowing the gas to return to the fuel cell stack inlet. Additional makeup oxygen gas is added either before or after the separator to account for the gas consumed in the fuel cell power plant. A large volume is provided upstream of porous material in the separator to allow for the collection of water that does not exit the separator with the outgoing oxygen gas. The water then can be removed as it continues to collect, so that the accumulation of water does not impede the separating action of the device.

The system is designed with a series of tubes of the porous material configured into a shell-and-tube heat exchanger configuration. The two-phase fluid stream to be separated enters the shell-side portion of the device. Gas flows to the center passages of the tubes through the porous material and is then routed to a common volume at the end of the tubes by simple pressure difference from a pumping device. Gas flows through the porous material of the tubes with greater ease as a function of the ratio of the dynamic viscosity of the water and gas. By careful selection of the dimensions of the tubes (wall thickness, porosity, diameter, length of the tubes, number of the tubes, and tube-to-tube spacing in the shell volume) a suitable design can be made to match the magnitude of water and gas flow, developed pressures from the oxygen reactant pumping device, and required residual water inventory for the shell-side volume.

The system design has the flexibility to be configured in a few different ways. Special configurations of the tube geometry could aid the operation of the re-