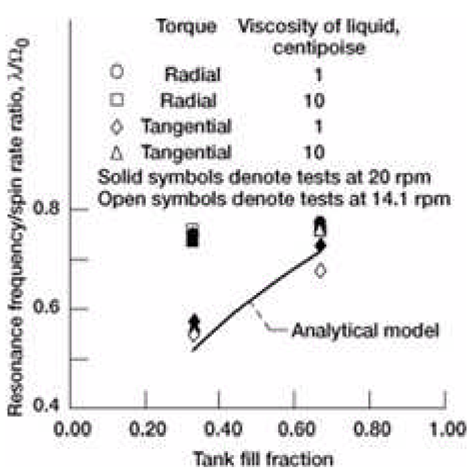
Results of Liquid Motion Experiment Analyzed

About half of all scientific and commercial spacecraft spin during some part of their mission. Although spinning has many benefits (increasing stability, controlling the location of liquid propellants, and distributing solar heat loads), it also creates problems because a precession (or wobble) motion is unavoidable. For modern spacecraft, by far the largest source of wobble is energy dissipation in the liquid of partially filled tanks. The liquid's energy dissipation cannot, however, be quantified adequately by any ground test. Current analytical models are also inadequate because fundamental data on fluid motion in low gravity are needed to validate them. Consequently, spacecraft attitude-control systems are designed and operated very conservatively. Nonetheless, spacecraft often still perform poorly in orbit, and some have been lost because of a rapid increase of the wobble rate. The Liquid Motion Experiment (LME) was designed to provide spacecraft designers accurate data on the wobble dynamics of spacecraft that contain large quantities of mobile liquids. LME, which was flown on the space shuttle mission STS-84, was built under contract to the NASA Lewis Research Center by the Southwest Research Institute of San Antonio, Texas. Major accomplishments for 1998 include reduction of the flight data and publication of the experimental results.

LME was essentially a spin table that created a realistic nutation motion of scale-model tanks containing liquid. Two spherical and two cylindrical transparent tanks were tested simultaneously, and three sets of such tanks were employed to vary liquid viscosity, fill level, and propellant management device (PMD) design. All the tanks were approximately 4.5 in. in diameter. The primary test measurements were the radial and tangential torques exerted on the tanks by the liquid. These torques could not be measured on the ground because of the masking effects of gravity.



Resonant frequencies for bare cylindrical tanks at high spin rates (20 and 14.1 rpm spin).

Liquid resonant frequencies and viscous damping coefficients were determined by sine sweep tests. The observed resonance frequencies for cylindrical tanks depended on the fill level. These frequencies were in the range of 0.73 to 0.78 times the spin rate for resonances about the radial axis and were in the range of 0.55 to 75 times the spin rate for resonances about the tangential axis. The available analytical model predicted only one resonance for a given fill level, and this prediction agreed rather closely with the tangential axis resonance frequencies observed in the tests. The resonances for the spherical tanks, which were in the range of 0.74 to 77 times the spin rate, did not vary significantly between the tangential and radial axes. The PMD's sometimes enhanced the resonances and energy dissipation rates and sometimes decreased them. This inconsistency points out our need to better understand the effects of PMD on liquid motion as a function of PMD and tank design. Energy dissipation rates were determined by sine dwell tests. The LME energy dissipation rates varied from 0.3 to 0.5 times the estimates obtained from previous ground tests and spacecraft flight data.

Find out more. http://space-power.grc.nasa.gov/ppo/projects/lme/

Bibliography

Chato, D.J., et al.: Liquid Motion Experiment Flight Test Results. NASA TM-1998-208479, 1998.

Deffenbaugh, D.M.; Dodge, F.T.; and Green, S.T.: Liquid Motion in a Rotating Tank Experiment (LME). NASA CR-1998-208667, 1998.

Lewis contacts: David J. Chato, (216) 977-7488, David.Chato@grc.nasa.gov
Authors: David J. Chato
Headquarters program office: OSS
Programs/Projects: Microgravity Science, HEDS, In-STEP, Space Transportation R&T