Space Robotic Force Moment Sensing: Boundary Condition Influences

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ABSTRACT

A non-linear concept for a space robotic force moment sensor (FMS) which reduces the problems of boundary conditions and thermal strains, is presented.. A 3 degree of freedom (dof) version has been built and partially tested to investigate the feasibility of several novel mechanical approaches to address force moment sensing issues which have plagued space robotic applications to date.

The sensor concept is based on a non-linear system which allows for transduction based on frequency shift rather than amplitude measurement. The non-linearity is one which stiffens under increasing load level.

There have been a number of force moment sensors built for space which have not achieved all of their design goals, Ma and Martin [1] allude to the difficulties of space robotic FMS. JPL (Jet Propulsion Laboratory) built one which flew as part of an SRMS (shuttle remote manipulator) space shuttle mission on STS-62 [2]. CSA (Canadian Space Agency) has a pair of FMS sensors on SSRMS. The Japanese Space Agency flew one on their mission ETS-7 [3,4,5]. In all of these cases, the sensors were limited by their thermal sensitivities. In the case of the SSRMS (space station remote manipulator system) sensor, sufficient thermal measurements were taken to largely compensate for the temperature issue, but the sensor design was stiff enough that the local flexing of the interface flanges caused errors. Apparently that influence has now been successfully calibrated out of the system as well, with extensive on-orbit testing.

We have been working on a force moment sensing concept for a number of years, based on frequency shift as a transduction approach. This approach has allowed us to utilize piezoceramic's, even in low frequency space robotic applications (0-20 Hz). The drift problems which result from using time domain, amplitude measurements in low frequency applications are well considered. The models and physical manifestations associated with '1/f Noise' have been extensively reviewed [6].

Table 1 presents our initial test and analytical work on boundary condition influences and thermal gradients.

Figure 1 presents the 3 dof force and moment sensor breadboard. The presence of the pin-ended struts in the load path create the stiffening non-linearity. An applied load results in a change in mechanical system frequency. The segmentally poled ceramic cylinder in the centre is directly in the sensor load path. The ceramic cylinder is electrically driven to excite the mechanical system frequency, the electronics and signal processing software then identifies the frequency. This combination of simple modal analysis with piezoceramic characteristic provides a novel method of determining static to 20 Hz applied forces, for multiple dofs.

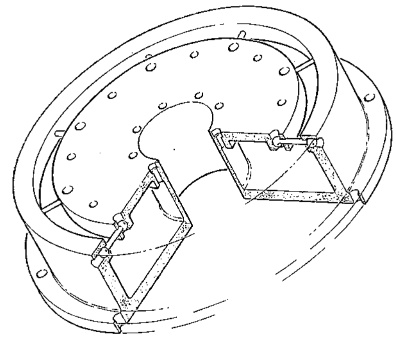

Figure 1 FMS Configuration

Table 1 - Modal Frequencies

Mode	Test Frequency	FE Freq. pinned boundary	FE Freq, pinned boundary, thermal gradient	FE Freq, fixed boundary
1	250.	261.133	267.875	279.618
2	302	333.942	339.751	336.213
3		334.086	349.000	336.356
4	440*	401.089	410.081	401.090
5	600	694.466	696.589	706.013
6	950*	922.296	925.844	922.394
7		923.979	927.665	924.076
9	1377	1269.946	1270.811	1295.048
10		1270.012	1272.142	1295.122
11	1547	1570.130	1570.137	1696.042
12		1759.525	1759.625	2122.772
13		1759.544	1759.775	2122.782
14	1900*	1977.265	1978.980	1977.385
15		1979.657	1981.246	1979.776

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