Robotic Ultra-Sensitive Chemical Monitoring System for Human Safety

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Abstract

The Integrated Cavity Output Spectroscopy (ICOS) instrument is designed to detect miniscule leaks in natural gas plants. The ICOS instrument can be deployed on unmanned robotic systems allowing it to accurately record chemical discharge without risking human exposure. The vibrational stresses experienced by the instrument must be minimized to protect its sensitive components. To solve this problem a testing framework was created to determine the ideal housing solution. By collecting the necessary data, the parameters in which the instrument can operate reliably will be determined. From the results, a specification for dampeners will be created to minimize vibration effect. The document will also serve as a guideline for further analysis.

Figure 1. ICOS and Rover virtual build

Introduction

Figure 2. ICOS Instrument

A newly developed mobile ultra-sensitive Integrated Cavity Output Spectroscopy (ICOS) system is used by the Jet Propulsion Laboratory to detect harmful trace gases in the environment. The prototype must be ruggedized to withstand the stresses of operation before being deployed. A computer model was used to simulate these stresses on the instrument's housing and a mock-up of the instrument was built to replicate the effects of vibration on the vehicle, platform and the system.

Methods and Materials

Data Logger and Laser Detector The mock-up of the ICOS instrument was mounted to the Traxxas TR-4 rover. This rover performed trial runs over various forms of terrain. A mounted data logger was used to collect vibrational data. A laser linearity detector located in the mock-up cavity recorded the mechanical robustness of the laser system.

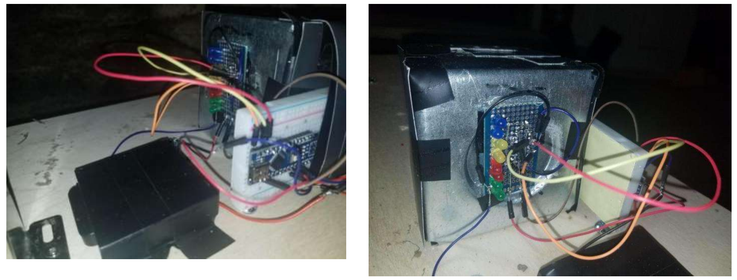


Figure 3. Laser Detector System

ANSYS Modeling ANSYS software was used to simulate deformation and vibrational stress on the ICOS instrument through Solidworks models. By applying Modal Mesh Analysis in conjunction with Random Vibrational Analysis we were able to obtain power spectral density curves and resonance frequencies, as shown below, of the sensor and its individual components. Through shock and impact testing we were able to determine weakpoints within the structure. These simulations were used to determine the overall integrity and robustness of the ICOS instrument.

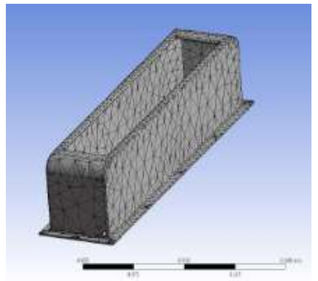


Figure 4. Meshed housing model in Modal Analysis

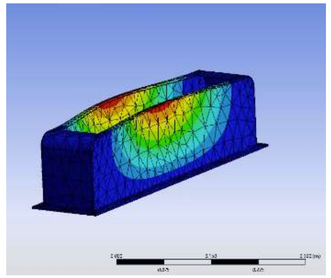
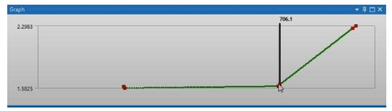


Figure 5. Displacement deformation simulation of ICOS housing

Discussion/Results

Successful recording of vibration frequencies over smooth, gravel terrain and stairs, using the data logger is shown on figure 7. Through ANSYS simulations we were able to develop an understanding of the harmonics of many components within the ICOS instrument. Our analysis was able to identify several key weaknesses such as the pump component, laser cavity and housing. Housing deformation data is shown on figure 6.



Tabular Data

	Frequency [Hz]	Displacement [(m²)/Hz]
1	306.99	1.5979
2	308.49	1.5825
3	699.65	1.5999
4	706.1	1.6183
5	1039.8	2.2644
6	1058.5	2.2983

Figure 6. ANSYS displacement deformation results of ICOS housing

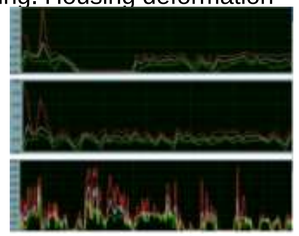


Figure 7. From top to bottom: accelerometer data of rover going over, paved, gravel and stair terrains

Conclusions

Applied vibration test plan shows ability to successfully measure vibration frequencies. ICOS replica and platform provides possible scenario for actual instrument. The platform did become loose due to the vibrations and would need dampening. ANSYS simulation indicated vulnerable points in ICOS cavity and housing through computer modeling.

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