tion of the algorithm is in creating the sliding mode in the observer system implemented as software. Once the sliding mode starts in the system, the equivalent value of the discontinuous function in sliding mode can be obtained by filtering out the high-frequency chattering component. In control theory, "observers" are dynamic algorithms for the online estimation of the current state of a dynamic system by measurements of an output of the system. Classical linear observers can provide optimal estimates of a system state in case of uncertainty modeled by white noise. For nonlinear cases, the theory of nonlinear observers has been developed and its success is mainly due to the sliding mode approach.

Using the mathematical theory of variable structure systems with sliding modes, the observer algorithm is designed in such a way that it steers the output of the model to the output of the system obtained via a variety of sensors, in spite of possible mismatches between the assumed model and actual system. The unique properties of sliding mode control allow not only control of the model internal states to the states of the real-life system, but also identification of the disturbance or anomaly that may occur.

This work was done by Wanda M. Solano of Stennis Space Center and Sergey V. Drakunov of Embry-Riddle Aeronautical University. For more information, call the Innovative Partnerships Office at 228-688-1929. SSC-00369

Absolute Position of Targets Measured Through a Chamber Window Using Lidar Metrology Systems

This technique can be used to measure objects in thermal-vacuum chamber test environments, in furnaces used to forge items for manufacturing, and for measuring chemically volatile or radioactive materials through a window.

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Lidar is a useful tool for taking metrology measurements without the need for physical contact with the parts under test. Lidar instruments are aimed at a target using azimuth and elevation stages, then focus a beam of coherent, frequency modulated laser energy onto the target, such as the surface of a mechanical structure. Energy from the reflected beam is mixed with an optical reference signal that travels in a fiber path internal to the instrument, and the range to the target is calculated based on the difference in the frequency of the returned and reference signals. In cases when the parts are in extreme environments, additional steps need to be taken to separate the operator and lidar from that environment. A model has been developed that accurately reduces the lidar data to an absolute position and accounts for the three media in the testbed — air, fused silica, and vacuum — but the approach can be adapted for any environment or material.

The accuracy of laser metrology measurements depends upon knowing the parameters of the media through which the measurement beam travels. Under normal conditions, this means knowledge of the temperature, pressure, and humidity of the air in the measurement volume. In the past, chamber windows have been used to separate the measuring device from the extreme environment within the chamber and still permit optical measurement, but, so far, only relative changes have been diagnosed. The ability to make accurate measurements through a window presents a challenge as there are a number of factors to consider.

In the case of the lidar, the window will increase the time-of-flight of the laser beam causing a ranging error, and refract the direction of the beam causing angular positioning errors. In addition, differences in pressure, temperature, and humidity on each side of the window will cause slight atmospheric index changes and induce deformation and a refractive index gradient within the window. Also, since the window is a dispersive media, the effect of both phase and group indices have to be considered. Taking all these factors into account, a method was developed to measure targets through multiple regions of different materials and produce results that are absolute measurements of target position in three-dimensional space, rather than simply relative position.

The environment in which the lidar measurements are taken must be broken down into separate regions of interest and each region solved for separately. In this case, there were three regions of interest: air, fused silica, and vacuum. The angular position of the target inside the chamber is solved using only phase index and phase velocity, while the ranging effects due to travel from air to glass to vacuum/air are solved with group index and group velocity. When all parameters are solved simultaneously, an absolute knowledge of the position of each target within an environmental chamber can be derived.

Novel features of this innovation include measuring absolute position of targets through multiple dispersive and non-dispersive media, deconstruction of lidar raw data from a commercial off-the-shelf unit into reworkable parameters, and use of group velocities to reduce range data. Measurement of structures within a vacuum chamber or other harsh environment, such as a furnace, may now be measured as easily as if they were in an ambient laboratory. This analysis permits transformation of the raw data into absolute spatial units (e.g., mm).

This technique has also been extended to laser tracker, theodolite, and cathetometer measurements through refractive media.

This work was done by David Kubalak, Theodore Hadjimichael, and Raymond Ohl of Goddard Space Flight Center; Anthony Slotwinski of Nikon Metrology; Randal Telfer of Orbital Sciences Corp.; and Joseph Hayden of Sigma Space Corp. Further information is contained in a TSP (see page 1). GSC-16192-1