Air-Bearing Flight Control Simulation

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Introduction

- Controller Validation

- Micro-friction air-bearing sphere used to simulate zero G environment to test Affordable Vehicle Avionics (AVA)

- Counterbalance Design
  ● Data Acquisition:
    ○ Object tracking program for Truth Data system
    ○ Pixhawk
  ● Moment of inertia and drag characterization
Air-Bearing Test Assembly

Counter Balance  Thrusters  Batteries  AVA

Air Bearing Sphere  Position Lasers  Air Tank / Regulator

https://youtu.be/RFO1WkmKmKI
Static and Dynamic Balance - Initial Design

- Mount at CG
- Important for accurate data acquisition.
- Problems: Weights move, deflection, unable to sustain balance
Static and Dynamic Balance - Improved Design

- Structural rigidity increased by implementing four mounting rods as opposed to one.
- Both static and dynamic balance easier to achieve with improved design.
- Smooth travel of ACME beam allow for precise static balancing.
- Second air tank integration allows for sustainable balance about pitch axis during tank discharge.
Deflection

- Deflection of a rotating rod from its axis of rotation affects dynamic balance.

- Overall stiffness of system correlates to deflection due to gravitational acceleration.
Second Air Tank Integration

- Future Design Implementation
- Route quarter inch tube through air-bearing sphere.
- Still allows for easy disassembly.
Creo Center of Gravity Analysis

- Kinematic Multiaxial Balance successfully statically balances the system in the roll axis.
Creo Center of Gravity Analysis

- KMB controls the center of gravity location for static and dynamic balancing.
To have confidence in being to able to simulate actual flight conditions, vehicle moment of inertia, and bearing drag must be accurately characterized on the test rig.

- Aerospace industry approach is used: Inducing pendulum motion.
Moment of Inertia and Drag Characterization

- Vehicle becomes Damped Harmonic Oscillator.
- Small angle approximation
- Least squares curve fit analysis was done to “back out” the unknown coefficients: I and B.
- Small scale validation showed a less than 4% difference between Creo and empirical approach.
- Approach valid for motion about all axis.

\[ I\alpha + B\omega + Mgl \cdot \sin(\theta) = 0 \]

\[ \theta(t) = A_0 \cdot e^{-\frac{B}{2I}t} \cdot \cos\left(\frac{Mgl}{I} - \frac{B^2}{4I^2}t + \phi\right) + at + b \]
Data Acquisition

- Vehicle motion must be tracked accurately on test rig.
- Three separate data collection packages were used:
  - AVA
  - Truth Data
  - Pixhawk
- Positional Data is compared to verify accuracy of vehicle control systems.
Object Tracking Program

- Truth data must be compared to the AVA and Pixhawk data to verify for accuracy.

- Two lasers affixed to vehicle will help verify pitch, yaw, and roll.

- MATLAB program developed to output truth data.
Object Tracking Process

1. Analyzes calibration frames with no object.
2. Prompts user for start time and duration of video.
3. Cuts the video into individual frames to be analyzed.
4. Finds objects in the frames that were introduced since the calibration frame.
5. Builds .xlsx program that will output frame number, time, x-position for each laser, y-position for each laser, pitch calculations, yaw calculations, and roll calculations.
Test Results

- Truth Data system only.
- Vertical line denotes start of test.
- Both x- and y-positions sinusoidal, as anticipated.
- Lower frequency indicates purely pitch and yaw maneuvers.
Test Results (continued)

- Truth data system and Pixhawk.
- Pixhawk and truth data show AVA despins vehicle well.
- AVA attempts to move to null multiple times but does not succeed.
- Pixhawk tracks pitch/yaw accurately while spinning at low rate.
Future Work: The Million Dollar Rocket

UP Aerospace Inc. is working with MSFC to develop an affordable NanoLaunch rocket, called Spyder.

- Numerous companies are pursuing this price range for orbital insertion.
- MSFC’s objective is to enable companies to reach this goal.
- AVA costs approximately $10,000, substantially less than the price of conventional vehicle avionics.
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