

A Novel Approach to Vibration Isolation in Small, Unmanned Aerial Vehicles

MAJ Christopher L. Reitsma, Instructor, USMA, chris.reitsma@usma.edu

Extended Abstract—Since the beginning of the War on Terrorism with deployments to Afghanistan and Iraq, the proliferation of robots, large and small, continues to expand and grow as essential elements to units in those forward-deployed areas. Robotic companies have developed an array of Unmanned Ground Vehicles (UGV) that are soldier transportable, while Unmanned Aerial Vehicles (UAV) continue to be limited to airplane-type configurations. In an urban environment, the use of a Raven or similar UAV provides a large or top-down, aerial view with little capability of a static, localized or ground-view perspective, i.e. observation into a second floor window or an area inaccessible by ground. Helicopter-type configurations lag years behind in concept, development and implementation because of cost, propulsion, sensors and miniaturization. Many Micro Air Vehicles (MAV) have been developed and tested, but none have been put into production. While there are many radio-controlled helicopters that would suffice in capabilities, they require a skilled radio control (RC) pilot. Many companies are developing RC-type helicopters, but sensor packages, endurance and video surveillance requirements can quickly exceed payload capabilities. Large aerial systems can use larger, gyroscopic accelerometers because they have the power and payload while small systems cannot. State-of-the-art accelerometers are small, light-weight and require little power, but they are extremely susceptible to vibration. Many vibration isolators currently in use—spring, rubber or elastomeric—add significant weight to dampen low harmonic frequencies.

The author proposes the use of a foam-type isolator, Tempur-pedic® foam, to reduce high-frequency vibration imparted onto electrical accelerometers from a quad-propeller system. As demonstrated in a TV commercial, a mattress-sized piece of the foam could negate low frequency vibrations, but would it significantly reduce higher frequencies used in RC helicopters? A quad-propeller system is beneficial in that it provides static propeller orientation and full electrical control while a single-propeller system requires a combination of mechanical and electrical control. Using an RC toy as a platform, the author used a BASIC Stamp2p installed on a Board of Education (BOE) and a MEMSIC 2125 dual-axis accelerometer mounted on the BOE. The BOE was either mounted directly onto the system or on a 3"x4"x1" piece of foam. The Stamp2p controlled the DC motors by TTL utilizing a power MOSFET circuit for each motor. The program created a PWM signal to control the duty cycle for each motor. The program extracted accelerometer readings from a 50 to 100% duty cycle with 50 iterations at each setting. Less than 50% was unnecessary because the vehicle would be in a non-flying profile under any power or load conditions. Instead of the 12 volts nominally rated for the DC motors, the voltage was reduced to six volts for analysis to prevent the system from flying and thus impart additional movement and vibration error. For analysis and comparison, measurement results from all four propellers operating simultaneously provided the desired effect of normal operation of the aerial system.

Other designers have tested various types of materials—springs, silicone gel, neoprene and rubber—to reduce vibration transmission along one axis. These devices typically weigh more because of material density and mounting hardware. For applications in a small aerial platform, excess weight is a significant concern requiring compensation through the reduction of battery size or removal of other system components. For small UAVs, a foam-type isolation system is a better choice in terms of weight and vibration isolation for multiple axes.

Because the foam is lightweight, elastomeric and has memory, its use can provide significant complementary advantages for aerial vehicles. The foam can encapsulate sensors and

mount in a cavity or on an external component, similar to the test system discussed in this paper. Depending on the packaging of the sensor, the foam can also act as insulation, structural protection or an additional, structural component. Of note, the size and the amount of compression of the foam affect the amount of vibration isolation. While a larger piece of foam can further reduce vibration transmission, compression of the foam to fit within a cavity of a UAV can reduce the desired benefit. Consequently, the size and shape of the foam must be designed for its system.

During testing, the foam provided a 53% (pitch) and 61% (roll) overall reduction in the axes over the range of vibration measurements as compared to the stationary value. The differences between axes can be attributed to the sensor not being mounted at the origin of the foam or system because of the structural configuration of the system. This small piece of foam yielded remarkable results for this type of accelerometer. Moreover, the foam provided a 65% (pitch) and 60% (roll) improvement based on the averages for each speed setting. Furthermore, this demonstrated that the average of multiple measurements with a small variance can yield the desired measurement. The cost associated with additional measurements is additional time which reduces a system's response time to apply flight corrections. The foam can reduce the number of iterations and time required for acceptable measurements. Since the foam is nonsymmetrical, additional tests verified that an increase in foam transmission length corresponded to an increase in vibration reduction.

While this foam was designed for larger applications and lower frequencies of vibration, these tests demonstrate that it is useful in small, high-frequency devices such as a semi-autonomous aerial reconnaissance robotic platform. The foam reduces the amount of vibration, and hence the error of measured values, which reduces the number of iterations for an average to yield accurate results for an aerial platform in this configuration. Utilization of foam in this system has resulted in reduced weight, power requirements and response time for accurate sensor data. Future tests will incorporate iterative sensor analysis, higher power settings, flight tests and additional accelerometers.

MAJ Chris Reitsma
 601 Thayer Road
 D/EE&CS
 West Point, NY 10996
 845-938-5607 (office)
 845-938-5956 (fax)

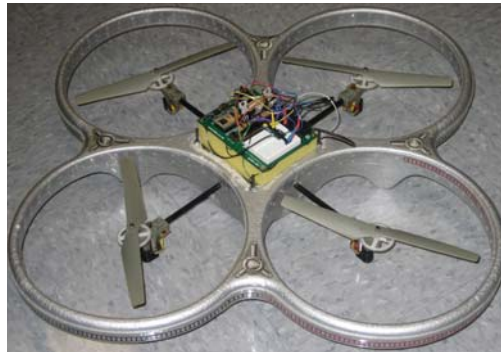


Figure 1. Testing Platform

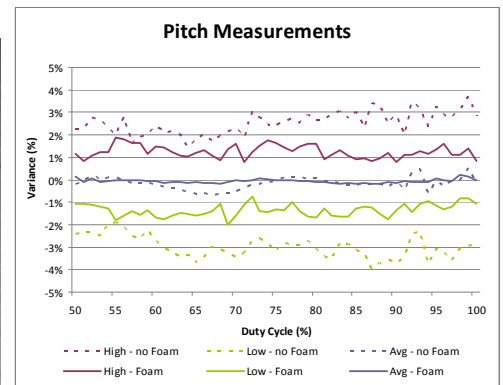


Figure 2. Pitch Variance versus Duty Cycle