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Mechanical Design of Inertially Stabilized Platform for Unmanned Aerial Vehicle

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Abstract:

Unmanned Aerial Vehicles are subjected to many disturbances with different vibration frequencies that affect their positioning and pointing capabilities. This often causes issues in applications requiring line of sight (LOS) communication. Therefore, a gimbal system is required to stabilize the payload mounted on the Unmanned Aerial Vehicle and thereby increase its pointing capabilities. Gimbal design consists mainly of the mechanical design of the gimbal and control electronics, which include processing inputs from sensors and controlling the gimbal's actuator. These mechanical and electrical design systems are to be designed to satisfy the detailed requirements, i.e., size, weight, payload, pointing range, accuracy, etc.[1]

Keywords **—**Gimbal, Unmanned Aerial Vehicle (UAV), line of sight(LOS), Payload, Analysis

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I. INTRODUCTION

Numerous instruments are targeted and stabilized using inertially stabilized platforms (ISP). These can include infrared and optical cameras used for civilian or military purposes, such as target tracking, telescope pointing, and image capturing, where the instrument's line of sight (LOS) must be held constant and oriented in a specific direction.[2] This is considerably more important if the instrument is mounted on a moving base, such as a land vehicle, aircraft, helicopter, or ship that is in motion or is subject to environmental vibrations.

A gimbal is a pivoting support that allows an object to rotate about an axis. A system of three gimbals, each mounted on the other with orthogonal pivot axes, can isolate an object mounted on the innermost gimbal from the rotation of its support (e.g., vertical in the first animation). For instance, gyroscopes, shipboard compasses, stoves, and even drink holders generally use gimbals to maintain things upright relative, to the horizon despite the pitching and rolling of the ship.[2]

Gerolamo Cardano (1501–1576), an Italian mathematician and physicist, meticulously detailed the gimbal suspension used for suspending compasses and similar instruments. However, Cardano neither invented nor claimed to have invented the gimbal. Philo of Byzantium described the device for the first time in the third century B.C., while some current authors believe it may not have a single recognized inventor.[2]

Unmanned aerial vehicles (UAVs), sometimes known as drones, are aircraft that lack a human pilot, crew, or passengers. UAVs are part of an unmanned aircraft system (UAS), which also includes a ground-based controller and a communications system with the UAV. The flight of UAVs may be controlled remotely by a human operator, as remotely-piloted aircraft (RPA), or with varying degrees of autonomy, such as autopilot assistance, up to the point where there is no provision for human involvement.[1]

UAVs were initially developed for military duties that were too "boring, unclean, or dangerous" for people. By the turn of the twenty-first century, they had become indispensable assets for most forces. As control technology improved and costs decreased, their employment in non-military applications increased. These include forest fire monitoring, aerial photography, product deliveries, agribusiness, law enforcement and surveillance, infrastructure inspections, entertainment, science, smuggling, and racing drones.[1]

II. MECHANICAL DESIGN

Gimbal is the system used to prevent shaking, one of the biggest problems in vibration. Figure 1 illustrates a simple block diagram of the gimbal assembly. There are two or three gimbal engines on the systems that aim to prevent or eliminate vibration. The basic logic of this system, which can minimize the vibration in payload devices, is to create a reverse motion in the opposite direction of the vibration. This reverse motion is provided by the Inertial Measuring Unit (IMU) Sensor, which is placed on the payload. The IMU Sensor detects the movements and reports motion to three brushless servo motors aligned with the payload. The sensor detects the relative position of the payload according to the ground. Based on the predetermined optimum position, how much the optimum position defined in each movement of the payload deteriorates is detected. The main aim is to protect this optimum position. The information received from the sensor is processed on the electronic board and transmitted as a command to the brushless servo motors, which provide smooth motion. Thus, the brushless servo motor that produces the opposite movement of the payload. [3]
Thanks to the Three-Axis Gimbal, in unmanned armed vehicles used in the defense industry, payload mounted at the barrel level can produce smooth going, which helps to achieve accurate targeting and perfect goal. [3]
This study presents a three-axis gimbal system with a PID controller as the general control system. In the second chapter, the components of the moving platform system are detailed. The values are read from the sensor in the third chapter, and the control system is filtered. Finally, in the fourth chapter, proposals and conclusions are submitted.

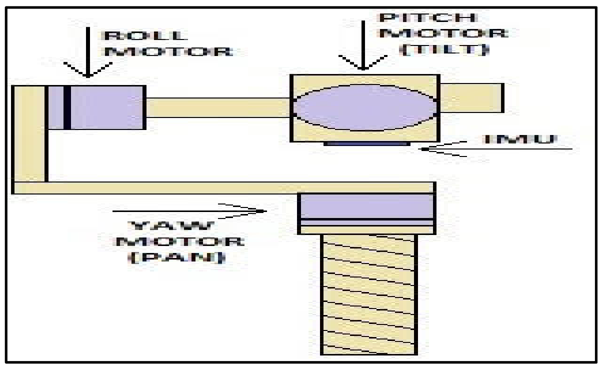

Figure 1 Gimbal block diagram[3]

The frame carrying the system should be enduring enough to carry the camera and light enough to provide ease of use. Carbon fiber pipe is the material qualified for the conditions that we are looking for.A six-axis IMU sensor card (often used in multicopter and robotic projects) with a three-axis gyroscope and a three-axis angular accelerometer is often needed to detect camera movements. Thus, we can obtain information such as orientation, speed, and position from a single unit.[3]

The three axes mentioned in the Three-Axis Gimbal are shown in Figure 2. These three axes are called pan, roll, and tilt, which carry the same name as the axes of the movement of a plane. In order to absorb the unwanted movements of these three axes, three separate brushless servo motors are mounted on these axes corresponding to the payload. The brushless servo motor mounted on the pitch axis absorbs the unwanted up-down movement of the payload, undesired right-left motion is absorbed by the brushless servo motor camera lens mounted on the yaw axis, and undesired rolling motion from one edge to the other is absorbed by the brushless servo motor mounted on the roll axis. There is no absorption in the sudden and involuntary turns toward the right or left.[4]

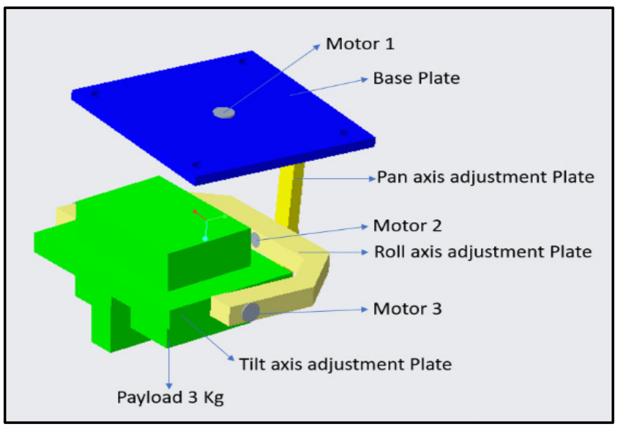

Figure 2 Three-Axis of Gimbal with component

III. EXPERIMENTS & ANALYSIS

For analysis and experiment, we used Autodesk inventor. At the same time,we are doing a stress analysis of the gimbal. The following results we get.

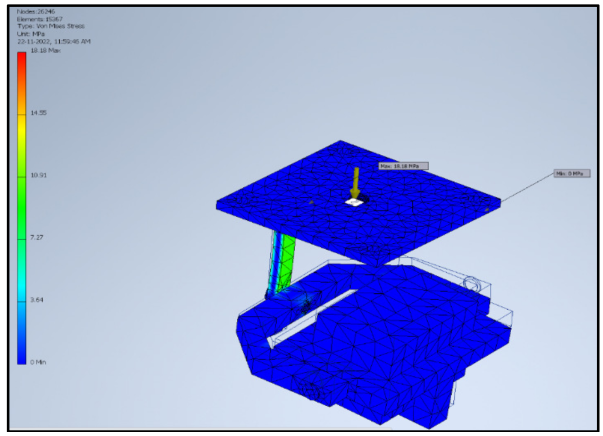

Figure 3 Von Mises Stress (Max = 18.18 MPa)

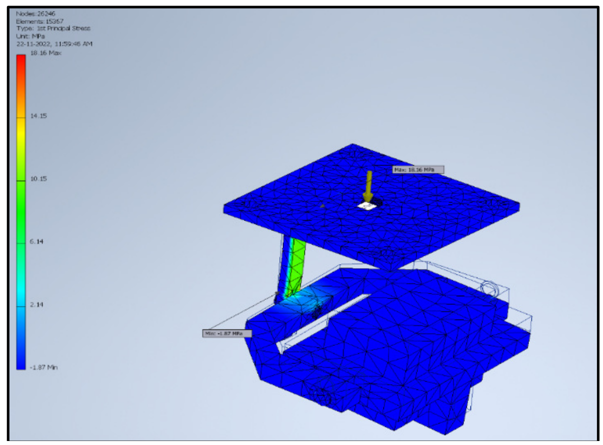

Figure 4 Principal Stress (Max = 18.16 MPa)

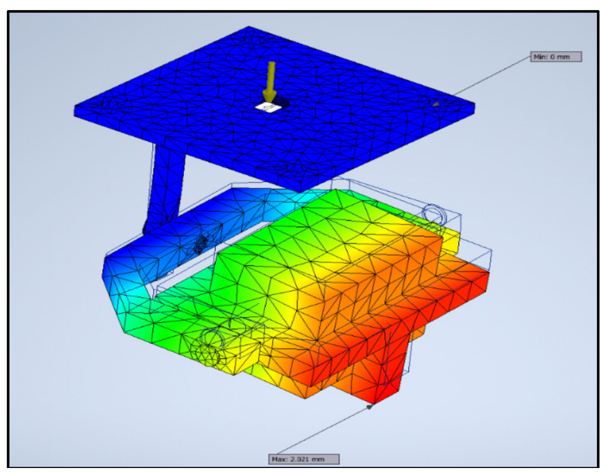

Figure 5 Displacement (Max = 2.021 mm)

IV. RESULTS

While doing analysis, we observed that the displacement is only 2 mm in figure 5 and the stress analysis is also minimum in figure 6.

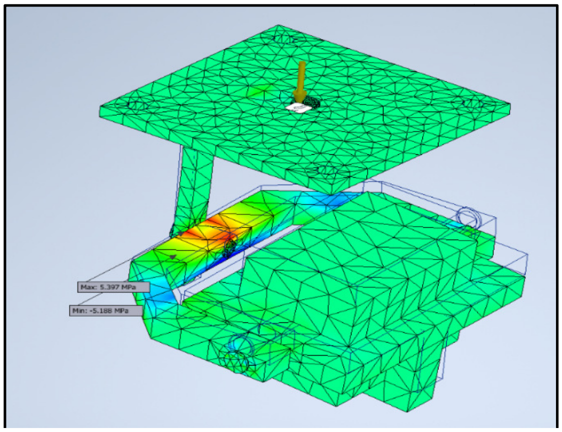

Figure 6 Stress XX (Max = 5.397 MPa)

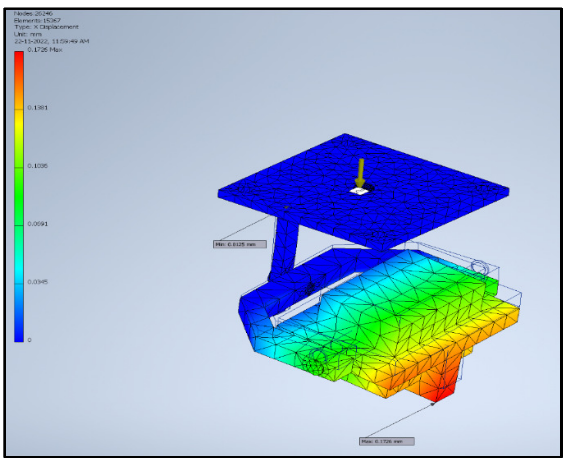

Figure 7 X-axis Displacement (Max = 0.1726 mm)

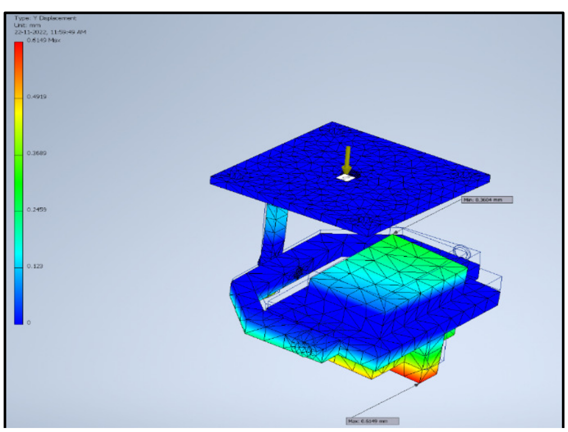

Figure 8 Y axis Displacement (Max = 0.6149 mm)

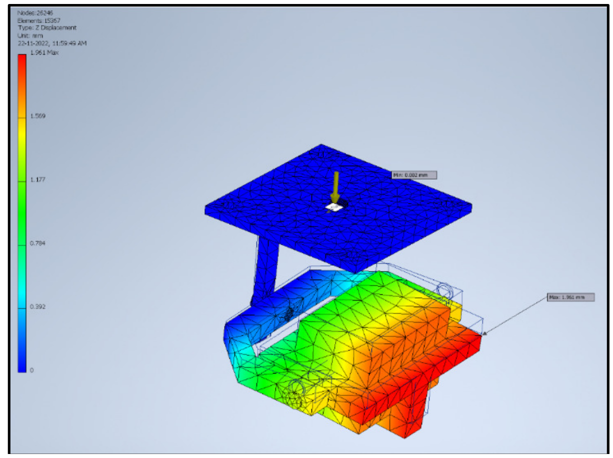

Figure 9 Z axis Displacement (Max = 1.961 mm)

V. CONCLUSION

In this study, a three-axis gimbal system is introduced. Under the mechanical design title, the gimbal system's basic elements are introduced. Brushless servo motors are used in the system as motion providers. A step motor or servo motor may be preferred instead of a brushless one. [3]–[7]

We see and observe that our design efficiently takes care of payloads. The design and development of this gimbal were completed.

This system is being implemented and targeted to be used in military applications within our country.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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