DESIGN, SIMULATION AND DEVELOPMENT OF TWO AXES GIMBAL FOR MICRO ARIAL VEHICLE

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Abstract- This paper presents the design, simulation and development of two axes gimbal for holding and controlling the position of camera in Micro Arial vehicle. There are wide ranges of applications of gimbal but here it is used to stabilize the camera position which is used to capture the image or to record the video of target. The gimbal mechanism will keep the camera towards target position by compensating the disturbances and vibrations caused by MAV while tracking target. When the MAV is navigating with a bank by any angle the gimbal rotates with help of servo motors to keep the camera remain focused on the target. To track any object we need to locate three coordinates(x, y, and z) of any object, so to reach the target camera position is adjusted along the three axes named as roll, pitch and yaw axes. In gimbal the camera position is adjusted using three servo motors along the above mentioned three axes. Here positional encoders are used as the feedback element to measure and stabilize the orientation of gimbal. This model is designed and simulated in solid works software. The various parameters involved in design, simulation and results are discussed in the paper.

Keywords- Design, Gimbal, MAV, Solid Works.

I. INTRODUCTION

Gimbals are mainly used to keep the objects stationary about a particular axis or multiple axes .For example in olden days Gimbals were used to keep the food or liquids stationary in ships irrespective of the movement of ship in roll or yaw or pitch axis due to the tides in sea. Like this there are wide ranges of applications of gimbal and one of the applications is to track the object using camera in Micro air vehicle (MAV). Gimbals are classified into three types based on number of axes about which object is stabilized, they are

1. Single axis gimbal
2. Two axes gimbal
3. Three axes gimbal

Applications of gimbal include inertial navigation, Rocket engines, Photography and imaging, Film and video. Two servo motors are used to stabilize the position of camera in yaw and pitch axes thus it comes under the category of two axes gimbal with brief specifications as listed in Table 1.

A Micro Air Vehicle or micro aerial vehicle is comes under the category of unmanned aerial vehicle (UAV) and has size restriction. To minimize over all weight of MAV by reducing payload it is advised to manufacture a gimbal with lightweight materials such as fiber or acrylic or aluminum [1, 2, 3].

Various applications of MAV include Forestry, Wildlife surveys, Power-line inspection, Real-estate aerial, Photography, Communications relay, Traffic monitoring, Border surveillance, Fire and rescue operations, Biological or chemical agent sensing[2].

II. PROTOTYPE

The main objective of the project is to design a test system with 2-degrees of freedom, where all DOF'S are rotations in a coordinate system Y-Z connected with an aerial platform [4].

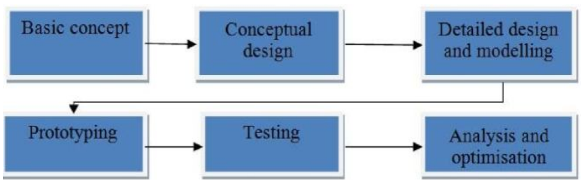

Fig1: Design process

Fig 1 depicts the design process for producing gimbal, first step involves the basic need of gimbal, here gimbal is used to operate camera in yaw and pitch axis of MAV. Weight of the camera is 90 grams as mentioned in table2.second step involves rough idea of the product and third step involves design and modeling of product with complete specifications. After design, prototype is developed for testing process, and after the test if results are close to design then a gimbal is developed for using in MAV. If results are not close to design go to step3 make modifications and follow the same procedure as stated above to produce a gimbal of required functionality.

III. SERVO MOTOR SPECIFICATIONS

PARAMETER	VALUE
BRAND	EMAX
MATERIAL	ABS
OPERATING VOLTAGE	4.8-6.0 [volt]
TORQUE, EFFECTIVE	1.5-1.8 [kg/cm]
PRODUCT WEIGHT	9.2 [grams]
SPEED	0.10second/60 degrees4.8 [V]. 0.12second/60 degree 6.0[V]

Table1. Specifications of servo motor

IV. COMPONENTS AND ASSEMBLY OF GIMBAL.

Following components were used in making the assembly of two axes gimbal. With acrylic as the material all products are produced using turning and milling operations. The set of components used are enclosure, supporting structure, bolt and nuts, screws, servo motors along with servo mounts as shown in fig 2. Supporting structure has two grooves one is at top and another one is at right side to fix servo motors using screw, bolt and nuts.

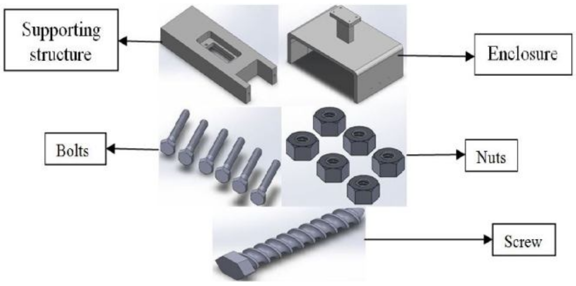

Fig 2: Individual components

Fig 3 shows the assembled Gimbal using the components shown in figure2.

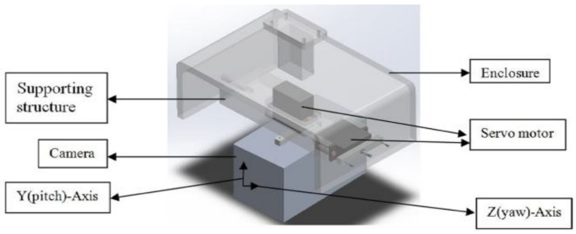

Fig 3. Complete assembly

V.WORKING

As shown in fig 3, there are two servo motors one is right and another is top side of supporting structure. One motor is firmly fixed to right side of supporting structure and then to enclosure with the help of screws and servo mounts, and it is named as right side motor [2]. Left side of structure is supported by one more screw through enclosure. Thus when this motor rotates whole structure rotates and causes movement of camera in pitch axis (Y-axis). Another motor fixed in the groove at the top of the supporting structure with the help of bolt and nuts. The shaft of this motor is attached to camera with the help of servo mounts, bolt and nuts, thin sheet. Thus when this motor rotates, camera oscillates in yaw axis (Z-axis).This adjustment of camera in pitch and yaw axis depends on vehicle turn and vibrations involved in MAV during its flying.

VI. RESULTS AND DISCUSSIONS

A. Theoretical results:
As the assembly of gimbal involves use of screws, bolt and nuts and these are directly acted upon by a torque and load while operating, the failure of these objects need to be discussed while operating. As shown in Table 2, specifications of servo motor maximum torque acting on the screw at 6.0 voltage is 1.8 kg-cm (0.17658 N-m). To know the failure of this screw stress analysis is done in Ansys work bench software or simulation tool within solid works and results were posted in following figures.

List of loads acting on screw and bolt

PART	WEIGHT [grams]
Servo motor(2No)	18.4
Camera	90
Gimbal	30
Total weight	138.4

Table 2: List of loads

This total load of 138.4 grams is supported by one screw and three bolts. So to know the failure of this bolts this load is divided into four equal parts and treated as uniformly distributed load (UDL), screws and nuts are treated as cantilever beams.

Here bolts and nuts are under bending moment, so formula as in (1) for calculating the maximum bending stress induced in cantilever beam when acted upon by UDL is

$$\text{Bending moment,} \quad M = \frac{(wl)\times l}{2} \text{ N-m.} \quad (1)$$

Where wl = total load on screw or bolt.

$$wl = \frac{138.4}{4}$$

$$= 34.6 \text{ grams}$$

$$= \frac{34.6\times 9.81}{1000} \text{ N}$$

$$wl = 0.339426 \text{ N}$$

l = length of the screw.

l = 10 mm

By substituting the above values in "equation (1)," we get

$$M = \frac{0.33942\times 10}{1000\times 2}$$

$$M = 0.0016971 \text{ N-m}$$

As the screw is acted upon by both torque and bending moment it is necessary to determine maximum normal and shear stresses from "Equation (2)," Maximum normal stress,

$$F_{b\,(max)} = \frac{16}{\pi \times D^3}\left[M + \sqrt{M^2 + T^2}\right] .(2)$$

Where M	=	Bending moment
	=	0.0016971 N-m
T	=	Twisting moment or torque
	=	0.17658 N-m
D	=	Diameter of screw
	=	2×10^{-3} m

By substituting the values in "equation (2)," we get,

$F_{b\,(max)}$ =

$$\frac{16}{\pi \times 2^3 \times 10^{-9}}\left[0.0016971 + \sqrt{0.0016971^2 + 0.17658^2}\right]$$

= 113.49 Mpa

Minimum normal stress,

$$F_{b(min)} = \frac{16}{\pi \times D^3}\left[M - \sqrt{M^2 + T^2}\right] .(3)$$

By substituting the values in "equation (3)," we get,

$F_{b\,(min)}$ =

$$\frac{16}{\pi \times 2^3 \times 10^{-9}}\left[0.00169713 - \sqrt{0.0016971^2 + 0.17658^2}\right]$$

= -111.85 Mpa

Maximum shear stress,

$$\tau_{\,(Max)} = \frac{F_{b(max)} - F_{b(min)}}{2} \ . (4)$$

By substituting $F_{b(max)}$ and $F_{b(min)}$ in "equation (4)," we get

$$= \frac{113.49 - (-111.85)}{2}$$

$\tau_{\,(Max)}$ = 112.67 Mpa

From the above results it is observed that maximum stress induced in screw is 113.49 Mpa and maximum shear stress is 112.67 Mpa, both this values are lower than yield strength of screw material (stainless steel) whose value is 172.339 Mpa.

B. Simulation results

Figure 4 shows the stress analysis of screw when it is acted upon by both torque and bending moment. Sequence of images explains the application of torque and UDL on screw, stress, strain, displacement of screw. The maximum stress, strain, and displacement induced in the screw is 90.25 Mpa, 8.103×10-7, 2.719×10-7bmm. observing the results, both theoretical and practical it can be conclude that screw and bolts are in safe condition under bending and torsion load.

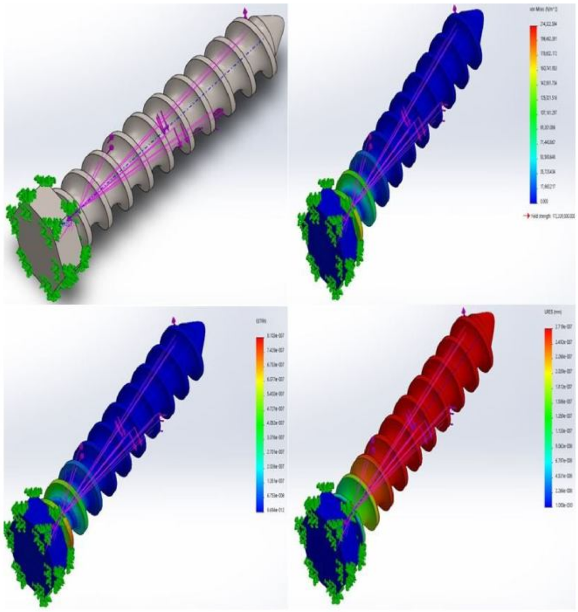

Fig 4. Stress analysis of screw when it acted upon by bothtorque and bending moment.

VII. TYPICAL INTEGRATION OF GIMBAL WITH MAV SYSTEM

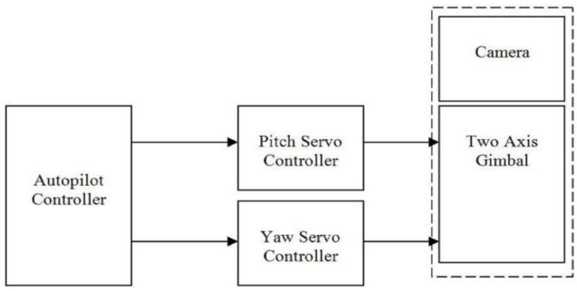

Fig 5. Typical integration of Gimbal with Autopilot

Fig 5 shows the typical integration of Gimbal with Camera to the Autopilot system of the Micro Air Vehicle. Camera is mechanically integrated with the Gimbal and the whole assembly is integrated on to the MAV. Gimbal axis is controlled by two electrical servo motors driven by the respective controllers. However the control signals for the servo controllers are driven by the Autopilot in synchronization with the image processing system.

CONCLUSION

As a summary two axes gimbal is designed, simulated and developed for positioning the camera in MAV which can be used for tracking a particular object or any other applications of MAV. This design can be used to handle various camera sizes but selection of servo motor depends on weight of camera that has been used for tracking purpose. Further research and development must be done to bring out better design and also to develop three axes gimbal so that complete details of objects can be find out.

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