REEF Subsonic WT Articulating Robotic Arm

[1]

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Table of Contents

Table of Figures

Table of Tables

Abstract

The goal of the REEF WT Articulating Robotic Arm project is to create a robotic arm capable of mounting, pitching, and yawing a specimen during operation of the wind tunnel. During operation, the mounting mechanism must keep the specimen in the center of the $42in^2$ test section. The previous arm for the wind tunnel was relocated to another research facility, and a new one is required to carry out further testing of specimens. A sting mount will be utilized in order to minimize flow disruption around the specimen. The joints and base of the arm will be moved using stepper motors. Per the sponsor's request, the material for the arm will be comprised mostly of 8020. Measurements of the tunnel have been given. The next steps include creating a schedule and drafting design ideas for the mounting mechanism.

1 Introduction

1.1 Objective and Background

The objective of this project is to create a mechanism to mount a specimen in the center of the wind tunnel test area. This mechanism must be able to adjust the pitch and yaw of the specimen while the wind tunnel is operational. The building material was specified to be 8020 by the sponsor. A servo control unit will be provided to be programmed with the purchased stepper motors and the user interface. These stepper motors will be the source of movement for the mechanism. The wind tunnel has a maximum speed of 22 m/s, or approximately 50 mph, with a $42in^2$ test section. A sting mount will be used to hold the specimen in place. Multiple mechanisms of this type exist. The background analyzes a few different mounting types used for research in large wind tunnels.

1.2 Problems

Numerous problems remain to be solved in this project. First, a design must be created in order to best adjust orientation of the specimen while keeping it located in the center of the test section. The team will have to decide on an angle of attack as well as design the mechanism to move the specimen in pitch and yaw. Second, forces from the wind tunnel must be analyzed in order to build a structure that can withstand maximum speeds. A high factor of safety will be used for this design portion, so that the integrity of the structure is ensured. Third, a force reducing mechanism such as a gearbox or chain drive must be designed in order to move the mounting mechanism during wind tunnel operation. This will also incorporate the force analysis on the tunnel. The final problem lies in pricing. Given a material, motor type, and size constraints, a design must be formulated to keep within the budgeted $2000.

2 Project Definition

2.1 Background research

Wind tunnels have proven to be a cost effective means to test an aerodynamic design in a controlled environment. Small scale aircraft models will have the same drag, life, and side force coefficients as full scale aircraft in flight. In order to properly test an object in a wind tunnel, a device must be constructed to hold the model in place and measure the forces acting on it. Depending on the desired data, model size, and wind tunnel test section, the mount could be very robust, or be very discreet to reduce impact on the acquired data. There are several types of mounts that have been developed for wind tunnel testing. Four commonly used mounts are single strut, two strut, three strut, and sting mounts[2] as shown in figure 1.

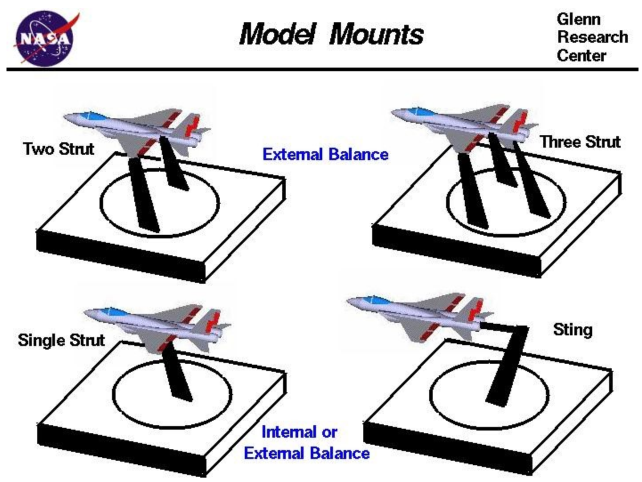

Figure 1: Model Mounts[2]

Per suggestion of our sponsor, the mount we will utilize is a sting mount. The benefit of the sting mount is there is little areodynamic interference until the flow reaches the wake. This means the lift and side forces will be unaffected, however, the drag force will be slightly impacted by the mount geometry itself. Sting mounts also provide an easy method to run wires or tubes through the mount and to the control room.

Sting mounts are very versitile and have the benefit of providing internal or external balance testing. With internal testing, strain gages are placed within the sting assembily inside the aircraft model.

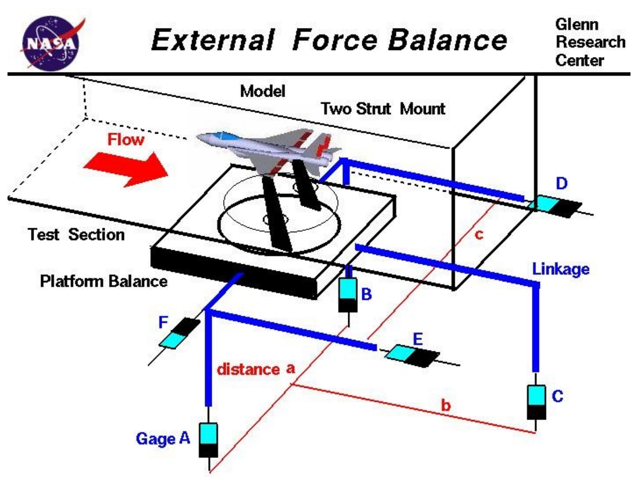

Figure 2: External Force Balance[4]

These strain gages will measure the forces and moments acting on the model. The lift, drag, and pitch can be determined. However, the side forces (roll or yaw) can not be determined with internal balance testing[3]. In order to measure the side forces, the mount must be able to preform an external balance. The external balance encorporates mulitple strain gages within the base of the model itself. In figure 2, boxes A through F represent the different strain gages within the base of the mount. These gages measure six different components, lift, drag, and side forces, as well as pitch, yaw, and roll moments[4].

Need Statement

The sponsor for team 12, the REEF Subsonic WT Articulating Robotic Arm project, is the Air force research lab. Mike Systma is the air force research lab representative for this project. The facility has a subsonic wind tunnel with a test section of 42 in^2. The wind tunnel reaches a maximum speed of 22 meters/second. The existing robotic arm mount was removed and placed in a different wind tunnel. A new robotic arm must be designed in order to mount test specimens. The test specimens must be able to adjust in pitch and yaw within the center of the wind tunnel test section.

Need Statement: There is no mounting mechanism in the wind tunnel to hold the specimen.

2.2 Goal Statement & Objectives

Goal Statement: Design a mounting mechanism in order to mount and adjust test specimen to desired orientations during wind tunnel operation.

Objectives:

- Adjust pitch (angle of attack) of specimen ±75º
- Adjust yaw (side slip) of specimen ±75º
- Must be a mobile mounting mechanism
- Keep specimen in center of test section
- Withstand maximum wind speeds of the tunnel
- Hold specimen still

2.3 Constraints

There are multiple constraints that need to be acknowledged and adhered to for the production of a robotic arm for use in a subsonic wind tunnel. The arm is required to alter the pitch and either the roll or yaw of a given model as it is studied in a wind tunnel, based on parameters inputted by researchers that will be carried out by the mechanism's stepper motors. The power source for the robot would come from a standard wall socket.

The first main constraint is the budget that has been allotted for the project, a total of $2,000, for the procurement of materials and construction of the arm. The major expenditures come from the purchase of stepper motors and encoders, as well as the 8020 building materials for the structure. This material was requested by the sponsor. The most expensive part, the servo controller unit, will be provided by the sponsor. A preemptive break down of the budget is shown in the table below. 8020.net[5] was used by our sponsor to give an approximation of the pricing for the building materials.

Since there is a potential for deformation and even damage to the structure due to the forces produced by the wind tunnel, a high factor of safety is needed. The supporting structure and the arm must be able to withstand the forces produced by the wind tunnel blowing directly onto both, as well as not tip over due to the previously mentioned forces and lift generated due to the model. All of these forces must be accounted for while minimizing the total weight of the system. The structure holding the arm must be able to be moved easily and once in its desired location locked into place, most likely through the use of locking wheels. The vertical position of the model held by the arm needs to be placed in the center of a 42”x42” square inlet; the centroid of the opening being approximately 84” in height.

Table 1: Estimated Budget

Item	**Estimated Costs**
80/20 Frame Structure	$500-$600
Stepper Motor/Encoders	$400
Raw Materials	$200-$300
Shop Time/Fabrication	$200
Total	**$1500**

2.4 Methodology

The first objective of the project will be to visit the site and take measurements needed and evaluate the space for the mounting mechanism. During the site visit, the sponsor will discuss with our group design ideas. Before any further actions can be made, a functional design idea must be created that could theoretically accomplish all of the design constraints established.

Next, dimensioning of the parts must be set. Size and weight of materials must be known in order to do force analysis on individual parts from the mechanism. The mechanism must be designed with a high factor of safety while the tunnel is running at maximum speed. Once force analysis and the design of individual components is completed, drawings must be made.

Finally, once the design and drawings have been set for the mechanism, budget must be discussed. The original design was made with budget kept in mind, but this is the part where pricing is established. Each drawing, motor required, and part must be quoted for pricing in order to fall within the set budget ceiling. If the design exceeds budget, smaller aspects of the design may be changed in order to lower the price. Analysis would be completed again, followed by the same steps. If the design cannot be changed, further funding will come from sponsor.

2.5 Schedule

A Gantt chart will be utilized to present the schedule for this project in the following deliverable.

3 Conclusion

The previous robotic arm used for this wind tunnel was relocated to another research area, and the tunnel can no longer be used to carry out tests without a mounting mechanism. The goal of this project is to creating a mounting mechanism that can also adjust the pitch and yaw of the specimen during wind tunnel operation. During operation, the specimen must remain located in the center of the 42 in^2 test section. It is intended that the mounting mechanism be made with 8020 material per the sponsor's request. The mechanism will also utilize stepper motors with encoders and a servo control unit. Per the sponsor's suggestion, the design will feature a sting mount. This will minimize flow disruption around the test specimen and therefore impact the majority of test results the least.

In the next portion of this project, design ideas must be evaluated. The sponsor will take part in this ideation and invention part. Once a design is formulated, force and weight analysis will be completed. The mechanism must withstand the maximum air speed of 22 m/s while being fully operational. Being able to already define a number of parts required for the project, an approximate budget was created, totaling about $1500 dollars. The excess $500 dollars is a rough estimate but should cover miscellaneous costs.

In the days leading up to the next deliverable due date, the team will hold staff meetings and make a site visit in order to confirm design details and constraints and evaluate progress. A site visit will allow the group to examine the surroundings, see other mounting mechanisms, and take essential measurements for the ideation and invention portion of the project. A schedule will also be formulated within the next two weeks. A Gantt chart will be used to represent the time table of action for this project. The budget will continue to be shaped and evaluated on a weekly basis as the project becomes more defined.

4 References

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