Fall 2021 Technical Report

Cornell Rocketry Team
Motor Mount Stress Test
Structures Subteam

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Summary

1 Technical Report

1.1 System Function and Overview

The primary function of this stress test is to determine whether or not the rocket's fiberglass airframe can withstand the launch thrust force that is applied to the motor mount at the onset of and during flight. It is crucial that the thurst force does not cause fracturing of the motor mount + airframe connection, as this would result in extreme hazards as well as contribute to a mission failure. The secondary function of the stress test is to determine the maximum force that the motor mount and airframe can withstand before fracturing takes place. The success of this test is necessary in ensuring certain safety pre-requisites are met for the rocket's flight during testing and competition.

This testing system acts as the parent for the entire launch vehicle – its results directly impact any subsystem that interacts with or is housed in the airframe. Therefore, the children of this system are all other airframe-integrated systems.

The testing of this system takes place in Cornell University's Bovay Lab on a hydraulic press. Due to the press used, there is a constraint on the test whereby the maximum possible force that can be applied is 5000 lbs.

1.2 Images of Design and Assembled System

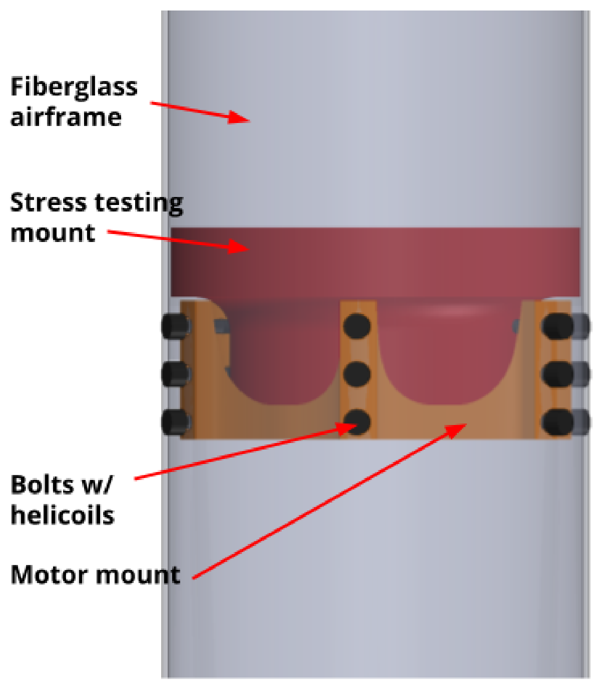


Figure 1: **Testing Assembly CAD (view 1)**

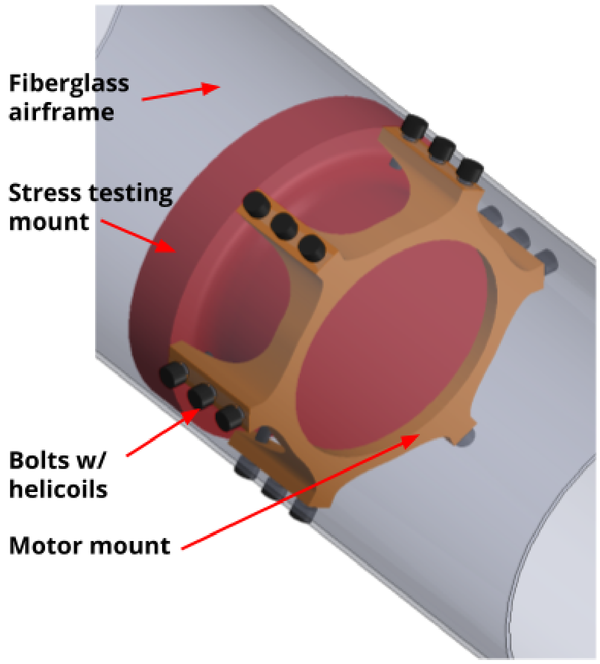


Figure 2: **Testing Assembly CAD (view 2)**

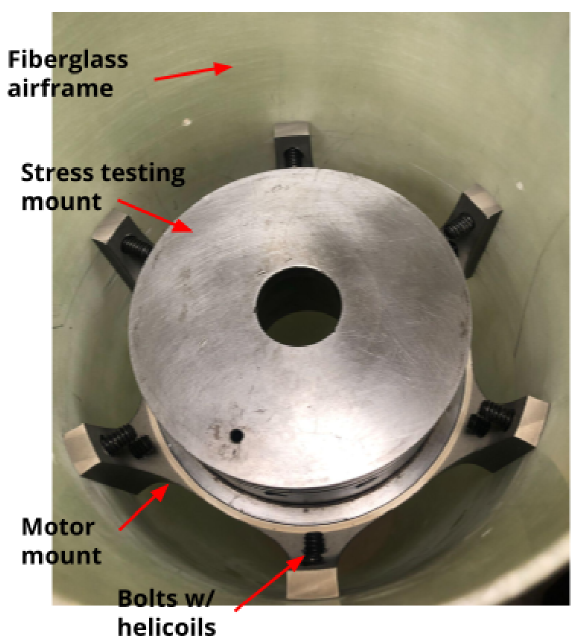


Figure 3: **Assembled Testing Configuration (view 1)**

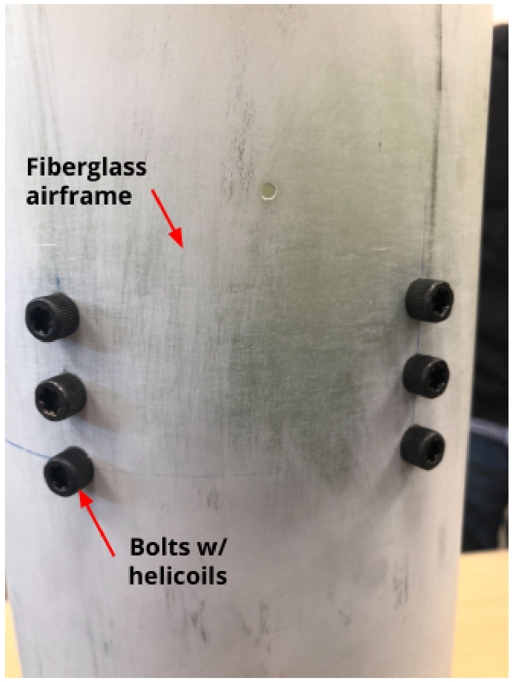


Figure 4: **Assembled Testing Configuration (view 2)**

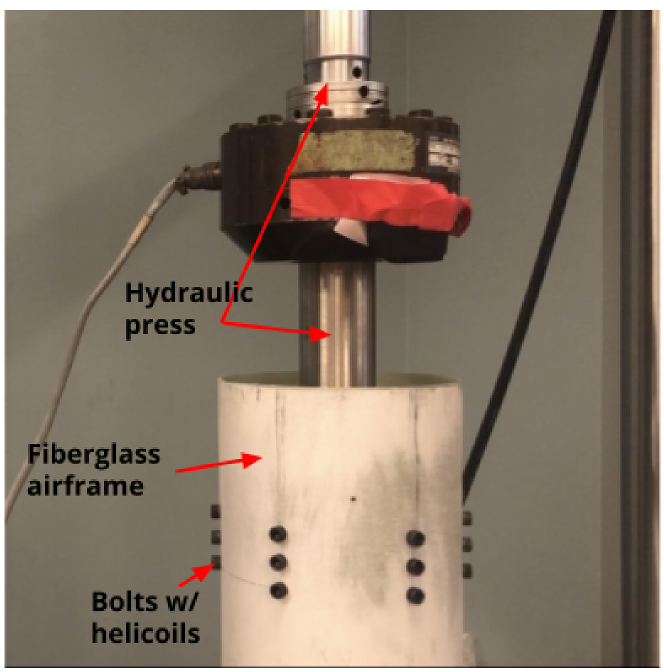


Figure 5: **Mounted Testing Configuration**

1.3 Requirements

Due to the nature of this system being a testing assembly, and not a part of the launch vehicle, there are few requirements for the motor mount test in addition to fulfilling the test's goals previously outlined. The only requirement that must be followed occurs during the assembly of the testing mount, where:

1. FUNC 3. All components on the LV that interface with the airframe shall have at least .005" clearance with the ID of the airframe.

However, the success/failure of this test acts as a verification plan for other system-level requirements for the rocket. The following system requirements are verified with this motor mount test:

1. The motor mount shall fully withstand the 1.5x motor maximum force output.
2. STR 17. The motor mounts shall constrain the motor during launch and recovery.
3. PERF 4. All components shall be qualified by test to 1.25x limit load.

1.4 Design

1.4.1 Testing Design

With the primary goal of this test being to ensure the airframe can withstand the rocket's initial thrust, it is crucial to design the test such that it replicates this actual environment as much as possible. Upon the motor's initial firing, a thrust force of $\approx$ 1100 pounds is applied downward against the bottom motor mount in a time of $\approx$ 50 milleseconds. Therefore, during the motor mount test, the force will be applied in a near-identical time frame. A rapid application of force is a better representation of the thrust than slowly applying force to the testing assembly until 1100 pounds is reached.

For the secondary goal of the test, which is to determine the breaking point of the airframe (ie; at what thrust will the motor mount fail?), the slower incremental increase in force will be applied until failure. Although this does not replicate the thrust environment as much as the previous test, it allows for a more accurate reading of the breaking point due to its slow increase in force application. From these considerations came the following two (2) test designs:

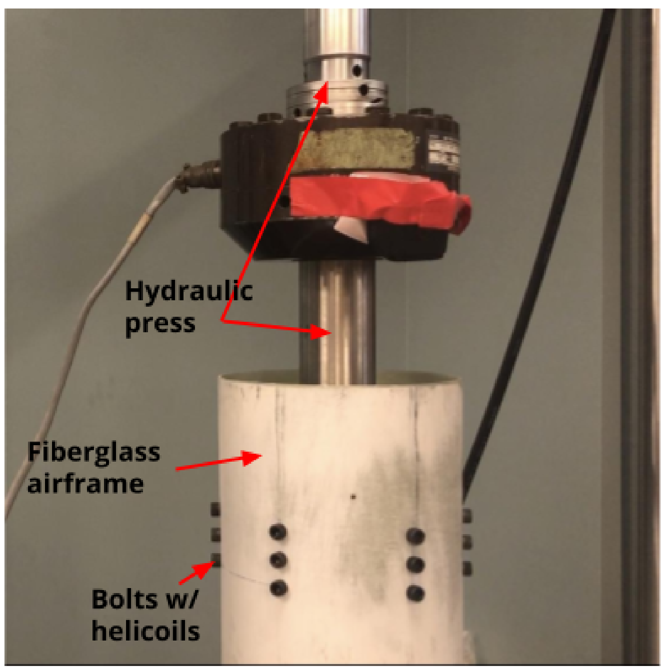
1. Simulating thrust. Initial force of 30 lbs applied. Increase thrust at maximum rate (constrained by the machinery) until 1100 lbs reached. Guaranteed to be <500 ms.
2. Until fracture. Initial force of 30 lbs applied. Increase thrust at slow rate until failure or maximum applicable load reached. Maximum force allowed by press $\approx$ 5000 lbs.

1.4.2 Material and Assembly Design

In building and designing the components of the motor mount testing assembly, the primary consideration is similarity to the launch vehicle. Ideally, the motor mount test should be done on the motor mount that will be used during flight. Using the exact to-be-used motor mount is not an option (not yet manufactured), however, a previous year's motor mount that was previously machined could be used. The similarities between this mount and the launch vehicle motor mount are marginal. The airframe used in the motor mount test is the same type and diameter fiberglass that is used in the launch vehicle, as are the bolts and helicoils used to secure the motor mount to the airframe. Creating the assembly with this high degree of similarity to the launch vehicle allows for the test to be as realistic a representation of the launch vehicle as possible.

1.5 Testing

On November 23, the testing assembly was mounted in Bovay Lab and the tests were completed. The assembly during testing appeared as it does in Figure 5, which is repeated below:



The conclusions made from testing are:

1. The motor mount and airframe withstand the full thrust force without fracture or visible physical changes.
2. The motor mount and airframe withstand roughly 5000 lbs force without fracture. No maximum

The following section, "Analysis" will discuss, analyze, and interpret the data collected during tests.

1.6 Analysis

1.6.1 Code

The following Python script was used to cipher through the data collected during testing and convert them into the line graphs seen in Figures 6 and 7 that will be later shown.

```
import pandas as pd
from matplotlib.pyplot import *


thrusttest = pd.read_excel("MotorMountTest.xlsx", sheet_name="ThrustTest")
maxforcetest = pd.read_excel("MotorMountTest.xlsx", sheet_name="MaxForceTest")


data_thrusttest= []
data_maxforcetest = []


for r in range(len(thrusttest)):
  x = (thrusttest.iloc[r][1])
  y = (thrusttest.iloc[r][2])
  data_thrusttest.append([x,y])

for r in range(len(maxforcetest)):
  x = (maxforcetest.iloc[r][1])
  y = (maxforcetest.iloc[r][2])
  data_maxforcetest.append([x,y])


df_thrust = pd.DataFrame(data_thrusttest, columns = ["Load (lbs)", "Displacement
    (in)"])
df_maxforce = pd.DataFrame(data_maxforcetest, columns = ["Displacement (in)",
    "Load (lbs)"])


#Drawing the plots (Scatter Plot)
plott1 = df_thrust.plot.scatter(x="Load (lbs)", y='Displacement (in)',
  title= "Displacement of Motor Mount with Increasing Load")
plott2 = df_maxforce.plot.scatter(x="Displacement (in)", y="Load (lbs)",
  title= "Applied Load With Increasing Displacement")

savefig("insert name here")
```

1.6.2 Data Analysis – Graphs

Using the above script, the following line graphs were created to represent the two tests:

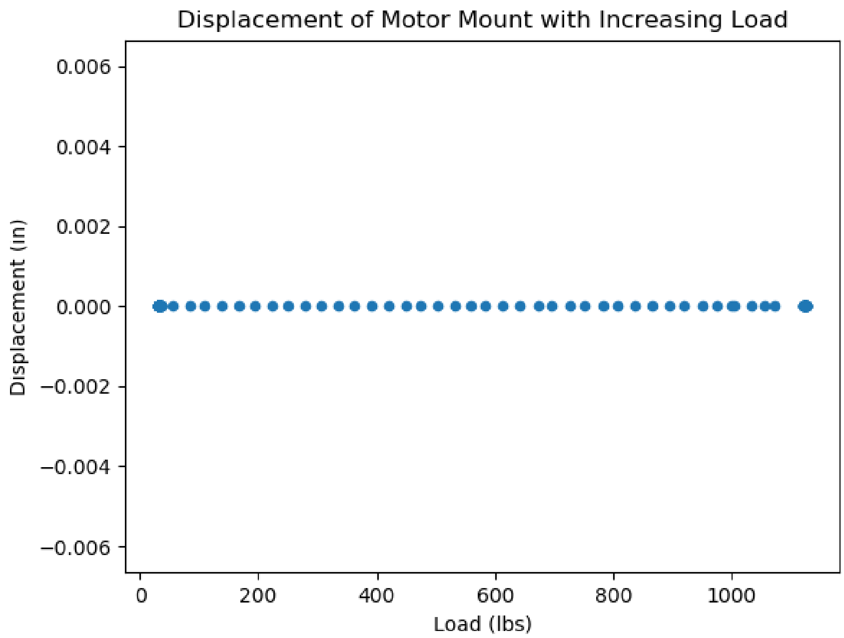


Figure 6: **Displacement of Motor Mount with Increasing Load**

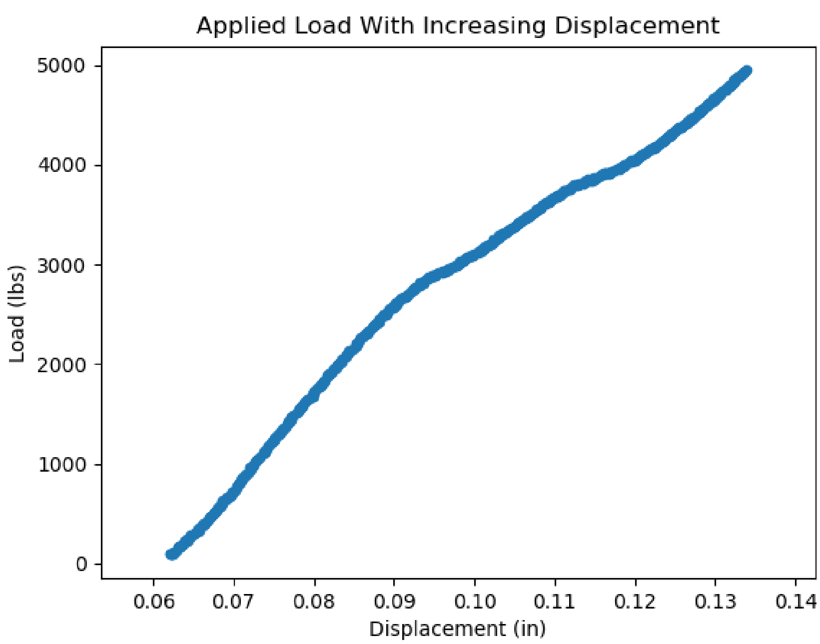


Figure 7: **Applied Load with Increasing Displacement**

1.6.3 Data Analysis – Continued

Results from the primary test – determining if the motor mount can withstand the thrust force – are seen in Figure 6. Though not displayed in this graph, the applied force increased from 32 lbs to 1126 lbs (ie; the thrust force) in $\approx$ 300 ms. Throughout this increase in force, and after maintaining an applied force of 1126 lbs on the motor mount for 10 additional seconds, the motor mount experienced 0 (0.000) inches of displacement. Furthermore, no bolts had any shifts in location. The assembly did not move. From this combination of both visual and numerical feedback, it can be determined that the motor mount and airframe can properly withstand the thrust force.

Results from the secondary test – determining the breaking point of the motor mount and airframe – are seen in Figure 7. With the hydraulic press being operated in "displacement mode", displacement of the press is increased, and therefore so long as the motor mount does not fail, the applied load increases as well. Over the course of this test, the motor mount and airframe did not budge (ie; steadily increasing displacement), and the applied force reached 4945.00 lbs before the press reached its maximum allowable applied force. So, no true breaking point of the motor mount or airframe was determined – although it is known to be larger than 4945.00 lbs.

Interesting to note, however, are the two "slips" that can be noticed in Figure 7. These changes from the steadily increasing rate of displacement take place at roughly 3000 and 4000 lbs force applied. Though the motor mount and airframe remained intact and without fracture, as we see in figure 8 below, the bolts appear to have ever-so-slightly shifted. Therefore, it is believed that at these levels of applied force, the bolts began to "dig in" to the airframe more. This causes no foreseeable danger to the airframe, however it shows that the bolts begin to move with high forces applied, and that at some point a break is inevitable.

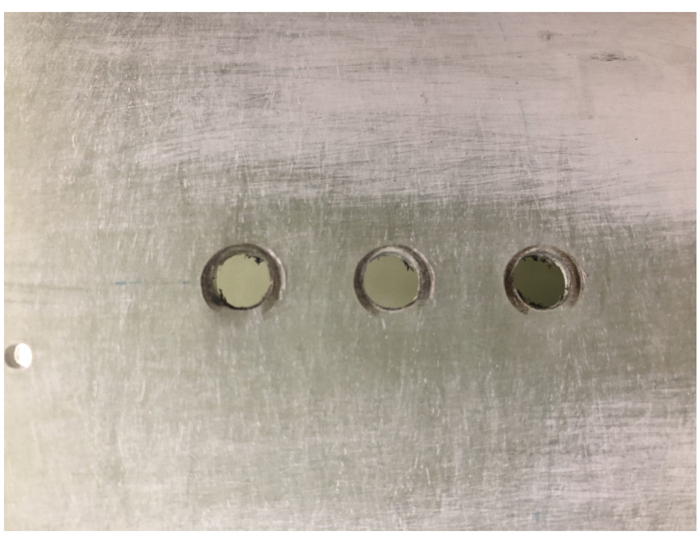


Figure 8: **Bolt Holes After Testing**

1.6.4 Key Takeaways

1. The motor mount and airframe can withstand the thrust force.
2. The motor mount and airframe can withstand > 4945 lbs, with an unknown breaking point.

1.7 Supply Chain

The vast majority of parts required for this testing assembly did not need to be ordered and were already in the CRT project team space. An additional order of McMaster heli-coils was made, which was promptly delivered and utilized. Bovay Lab provided access to their resources free of charge, allowing for this project to be extremely low cost.