µHoubolt Ground Recovery Test Protocol

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TEST BY
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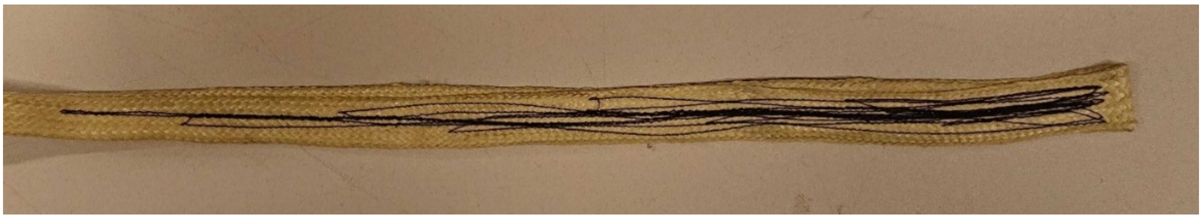
TESTTYPE	Recovery System, Shock Absorber and Clean Separation
TESTGOAL	Verification of significant shock reduction on main chute lines and assurance of clean separation of newly manufactured recovery system
CHANGES	• Shock-absorbers sewn into main chute lines • Reinforcement of chute line mounting points with aluminium to ensure better distribution of the line shock and pressure on the GFRP main plate of the recovery system.
FAILS AND LEARNINGS	• Main chute line failure during test flight. • Crap-Band absorbers not strong enough to absorb impact of vehicle • Different wind conditions in different altitudes can lead to differing vehicle velocities at the point of chute ejection. • Shock absorbers have a very high impact on the maximum load the equipment experiences.
ADDITIONAL INFO	The design of our recovery system was tested in flight two times before: 1. A mock-up rocket (steel tube equipped with original nosecone and recovery system propelled by a solid fuel motor). The test was successful, the nosecone separated cleanly, and the full system was recovered using the two-stage chute system 2. Fully configured test flight. In this case the nosecone also separated cleanly, and the drogue was ejected, however, due to a higher velocity of the vehicle than in the previous test, the shock on the lines of the main chute upon deployment stressed them to much and led to a subsequent failure of mentioned lines, which lead to a ballistic landing of the overall system.

Test summary

The shock absorbers consist of a cord, which is sewn into the main chute lines as shown below. The working principle of this absorber is, that the individual cords break when the load caused by the deceleration of the vehicle hits the line and by that dissipate energy which would fully be transmitted into the vehicle structure without them.



Tests were conducted by dropping a mass, connected to the line on the one end, from a height of approximately two meters.

Multiple tests were conducted:

1. No absorbers as a reference.
2. Line with moderate sewing tightness of absorber cords.
3. Line with high sewing tightness of absorber cords.

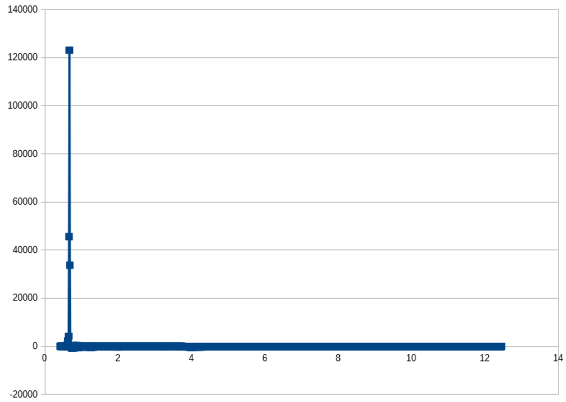
NO ABSORBERS

The test setup was dropped from a height of approximately two meters multiple times with increasing masses until the line broke. This took place at a total mass of 5kg. Subsequent tests were conducted with this mass.

Assuming that in the test setup, which was mounted onto a steel beam on top and is therefore very rigid, the mass needs around 20 cm to decelerate from a speed of approximately 6 m/s after 2 m free fall, the acceleration acting on the system is of around 90 m/s².

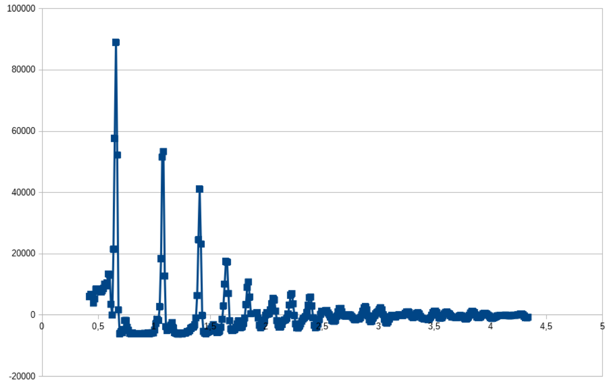
Comparing this to simulation results which yield a maximum acceleration of around 80 m/s² during main parachute deployment, whilst the vehicle at that point has a mass of around 10 kg, it becomes clear that a sufficient shock absorbing mechanism must at least mitigate the shock by a factor of 0.5 to ensure safe operation.

The load cell measured a maximum load 120 kg for this test. The values on the plot axis are shown in grams.



MODERATE SEWING TIGHTNESS

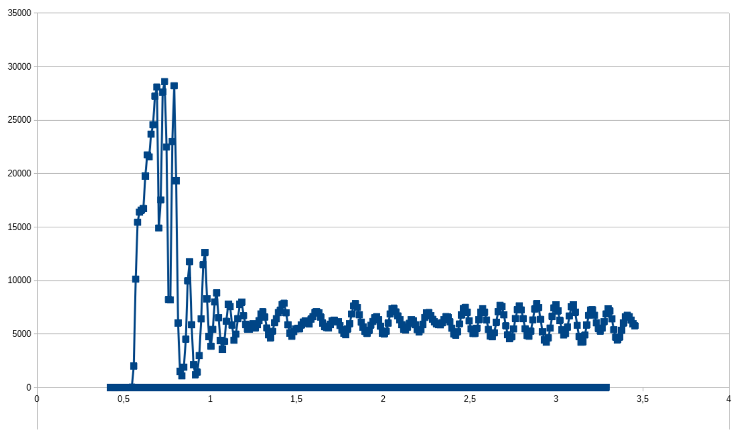
The moderate sewing tightness absorber reduced the shock load on the line around 90 kg as it can be seen in below figure.



The moderate sewing tightness was certainly not enough to properly absorb the shock acting on the vehicle, therefore sewing tightness was further increased.

INCREASED SEWING TIGHTNESS

The last test with increased sewing tightness reduced the shock load further to below 30 kg as shown in the next figure.

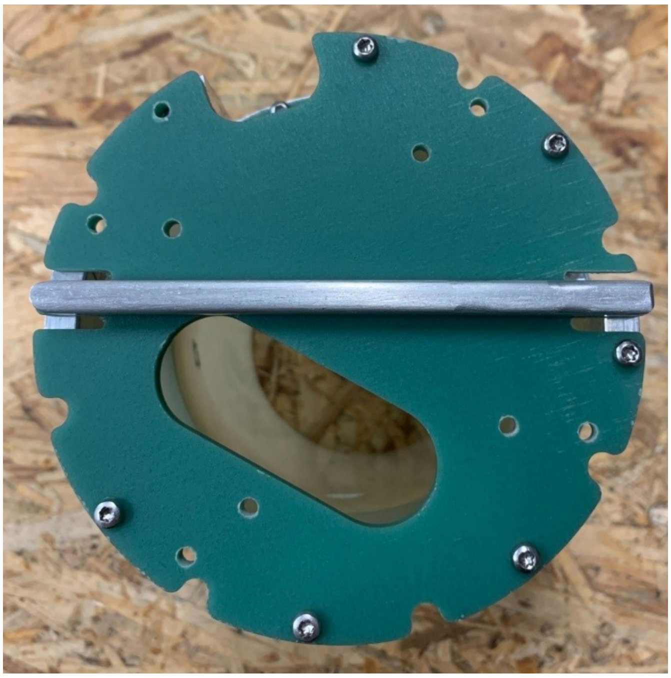


It is also clearly visible, that the shock time was spread out to a longer duration, which further reduces the load on the system. This was reached by a special sewing pattern which ensures that the absorber first breaks in less robust regions and later gradually increases the load. A sketch of the sewing pattern which has shown to yield best results after some iterations is shown below.

The used shock absorber, in combination with the test setup consisting of mass and load cell is shown in the following figure. The disintegration of the absorber cords is clearly visible.

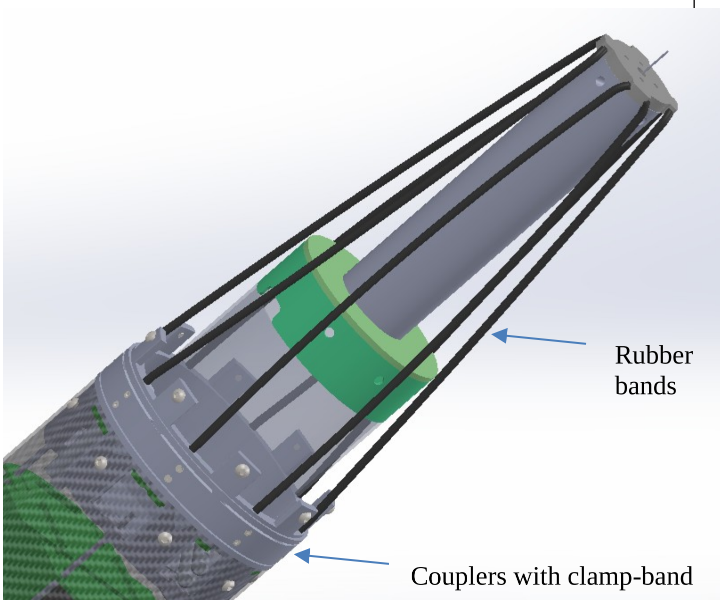
As the results from simulations and tests yielded higher values than expected, also the chute mountings were reinforced to ensure safe operation during future deployments.

The aluminium beam on the mounting points which reinforces the GFRP mountings and distributes the parachute load onto a greater area of the recovery base plate is shown in the following picture. For orientation, note that if this part would be inside the vehicle, the shown picture would be taken from the side of the engine towards the nosecone. The lines are mounted on the left and right of the aluminium bar.



Lastly, it was tested if the newly manufactured deployment system, whose design was not modified since previous tests apart from the shock absorbers and the base plate reinforcement, separates the nosecone in a clean way from the vehicle.

During ascent, the nosecone is mounted to the main airframe by couplers, which are held together by a sheet-metal clamp-band. On first stage recovery deployment, a line which holds the clamp-band together is cut open, which leads to the clamp-band falling off. The nosecone is pre-loaded by rubber bands, which push it away from the main vehicle during deployment.



The used line cutters during flight are human rated, expensive and testing the electronic control of them is in the scope of electronics testing. Therefore, the clamp-band line was cut manually, and a clean separation of nosecone and couplers was verified.

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