April 15, 2024

To Whom It May Concern:

Pursuant to a fatal incident on March 8, 2024, Fluid Wings was informed that the GCAA and Skydive Dubai would ground all parachutes due to multiple line failures. Our engineer, Mr. Scott Roberts, MSCE, P.E., compiled a list of reported incidents and inspected the accident parachute and several other parachute lines.

DOCUMENT REVIEW

- Basic Performance Design, and Construction of Ram Air Inflated Gliding Parachute Wings, Manley C. Butler Jr., April 1986.
- The Aerodynamics of Parachutes, DJ Cockrel, NATO AGARD-AG-295, 1986.
- https://parachutist.com/Article/Know-Your-Lines
- https://www.skydivemag.com/new/gear-wisdom-line-sets/
- https://www.fluidwings.com/_files/ugd/5a932f_05ae884b12ba4c8d9e78150d0c72c044.pdf

BACKGROUND INFORMATION

We were able to discern approximately 5 incidents of broken lines on our high-performance parachutes referenced by Skydive Dubai over roughly the last 5 years (2020-2024). The line breaks were isolated to 3 wing models and in various sizes. The line breaks were in multiple different locations but predominantly located on the center A-lines at the cascade or at the bottom of the line. It appears that the majority of the failures occurred on opening. The several line types included (300 lb - 400 lb) line types.

The vast majority of the line that Fluid Wings uses on high-performance wings is a 300-400lb Vectran supplied by CSR, Inc. This material is a 12-strand-coated Vectran filament that CSR obtained from Kuraray.

Following is a list of the incidents and data obtained (personal information redacted for privacy).

Pilot	Date	Locaiton	Event	Serial Number	Material Tracking	Tensile Capacity (lb)	Date Lineset Produced	Line Tensile Test (lb)	Slider	Jumps on lines	Wind Loading	Condition
[redacted]	3/8/24	Dubai	A2 both sides broke in flight-one possible visible break reported before landing	AW2 79-00043	190-014	400	10/30/23	569.8	Removable	275	3	SEVERE VISIBLE WEAR Unairworthy
[redacted]	1/18/24	Dubai	A2 Line Broke In flight @ A-B cascade upper portion of the line.	HK2 69-00102	300-PF260	300	5/26/21	428	Removable	221	3.8	Unairworthy
[redacted]	unknown	Dubai	Line Broke on opening	HK2 69-0230	400-0255	400	8/2/23	546	unknown	unknown	unknown	unknown
[redacted]	2/10/20	Maldives- with reported jumps in Dubai prior to the maldives event.	Lines broke at 1800 ft	HKT 67-00040	PF205	400	7/12/18	478	Removable	250-Per Pilot email 2/10/2020	2.8	VISIBLE WEAR - CLEARLY Unairworthy
[redacted]	4/1/23	Dubai	It was HKT-67 wl-2.9 200 jumps on the lineset A-line right side. Right after the finger trap ends Multiple rotation turn . Was broken in the beginning of recovery	HKt67-00102	PF345	400	9/12/19	463	removable	200 per owner	2.9	No Documentation-lines disposed of after re-line

INVESTIGATIONS

We were able to physically investigate the lines on 3 out of 5 of the line sets. Information on each one is as follows.

AW 2 79-00043 - Investigated 4/5/24

The following information was obtained from a telephone interview with the owner of the parachute after the accident:

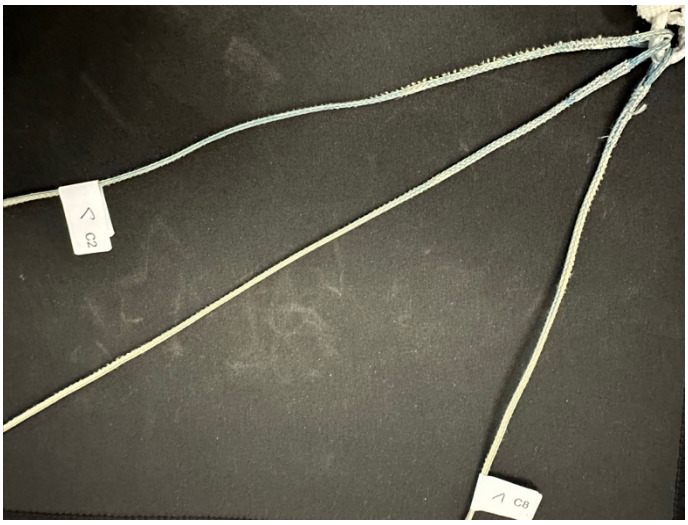
- The parachute was on loan to the jumper since January 11, 2024, as his parachute had worn lines and was no longer airworthy.
- The parachute had approximately 50 jumps on the lines when supplied to the jumper.
- Between January 11, 2024, and the date of the accident, the jumper performed approximately an additional 225 jumps on the lines.

The lower A8 and upper D5 (pilot right-hand side) were removed and sent to our Utah facility for testing. The results are as follows:

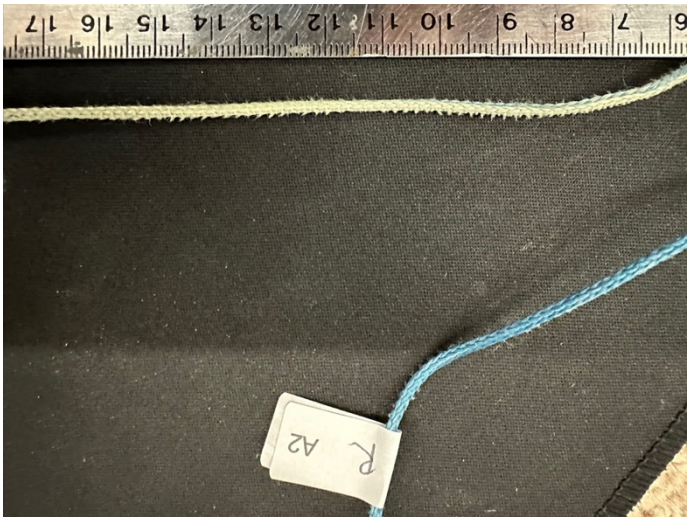
- A8R - 247 lb.
- D5R - 395 lb.

The lower A8 and upper D5 (pilot left-hand side) were removed, and tensile capacity was tested in our Florida facility at the time of the examination. The results are as follows:

- A8L - 273.5 lb.
- D5L - 421.0 lb.

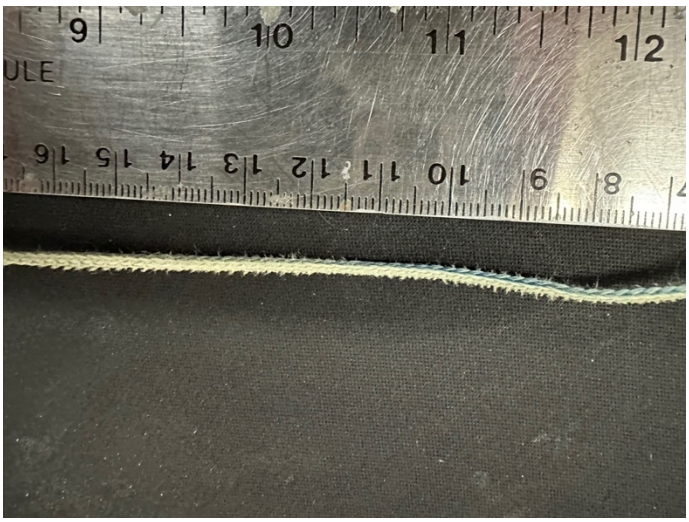


Photograph 1: Lower portions of lines.

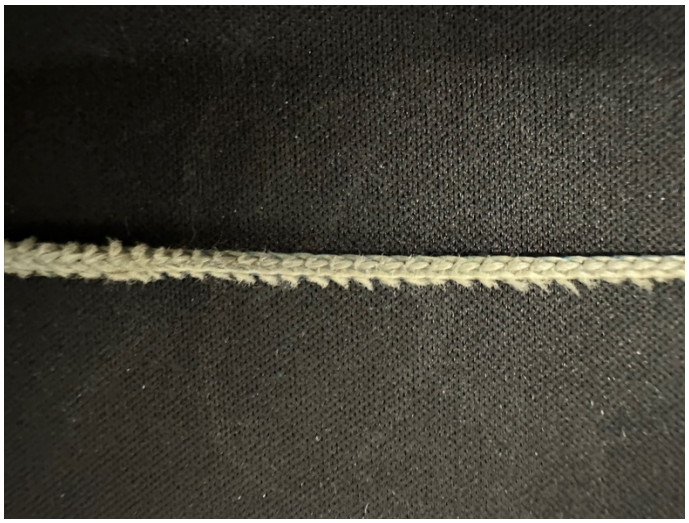


Photograph 2: Lower portions of lines.

Additional Comment(s) (If Applicable): Note severe abrasion and wear.

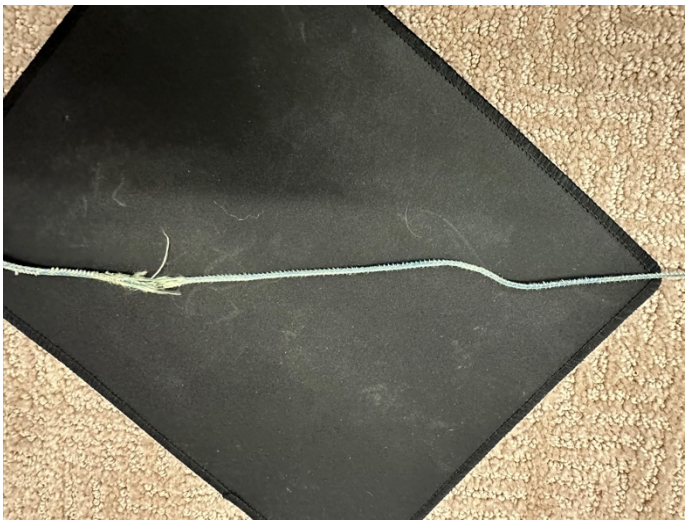


Photograph 3: Severe wear on lines.

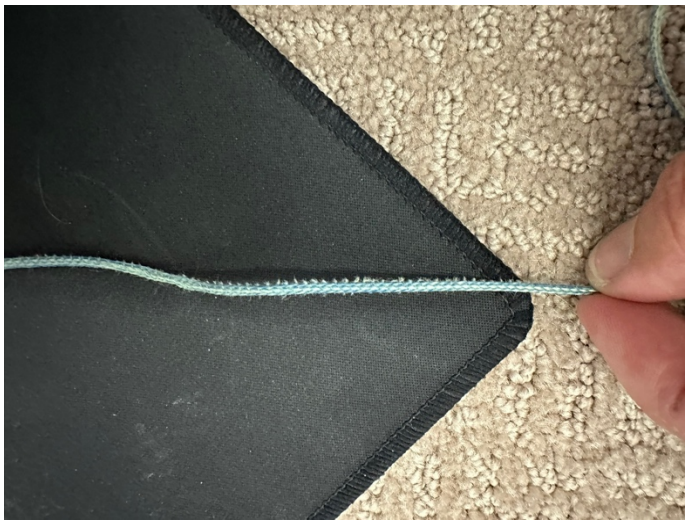


Photograph 4: Lower portions of lines.

Additional Comment(s) (If Applicable): Note severe abrasion and wear.

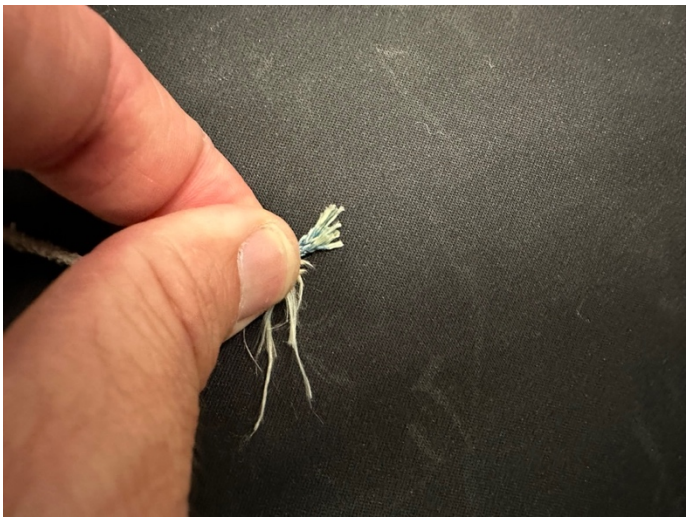


Photograph 5: View of broken line.



Photograph 6: Lower portions of lines.

Additional Comment(s) (If Applicable): Note severe abrasion and wear.

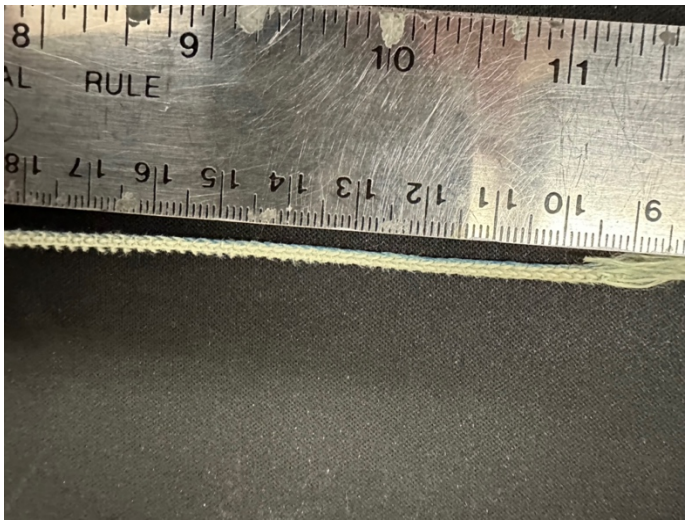


Photograph 7: View of angled cut at failed line.

Photograph 8: View of wear at upper portion of lines.

Additional Comment(s) (If Applicable): Note severe abrasion and wear.

Photograph 9: View of dirt and debris on slider.



Photograph 10: View of wear on lower portion of line.

Additional Comment(s) (If Applicable): Note severe abrasion and wear.

Photograph 11: View of parachute.

Photograph 12: View of lines on card as delivered.

Additional Comment(s) (If Applicable): Note severe abrasion and wear.

The evidence observed on the examination of the subject incident parachute (AIRWOLF2 79-00043) indicates that the condition of the lines would be considered severely worn and thus unairworthy. The severe wear is the result of prolonged use in a harsh environment.

ADDITIONAL TESTING:

We obtained tensile testing results for the line from the line manufacturer. The particular batch in question was tested before shipping to Fluid Wings, and test results are summarized below:

- Sample 1 - 598 lb. at 4.3% elongation
- Sample 2 - 569.8 lb. at 4.6% elongation
- Sample 3 - 596.2 lb. at 4.8% elongation

Tensile testing of spliced and bar-tacked specimens from the same spool at Fluid Wings were noted as follows:

- Sample 1 - 473 lb. at 6.8% elongation
- Sample 2 - 483 lb. at 7% elongation
- Sample 3 - 486.5 lb. at 6.6% elongation
- Sample 4 - 478 lb. at 6.3% elongation
- Sample 5 - 486.5 lb. at 7.3% elongation

It should be noted that the samples typically fail at lower values as the splicing and bar tack reduce the load capacity of the material.

The nominal strength of the lines is approximately 400 lb. All of the line materials were noted to be within the acceptable ranges for tensile capacity.

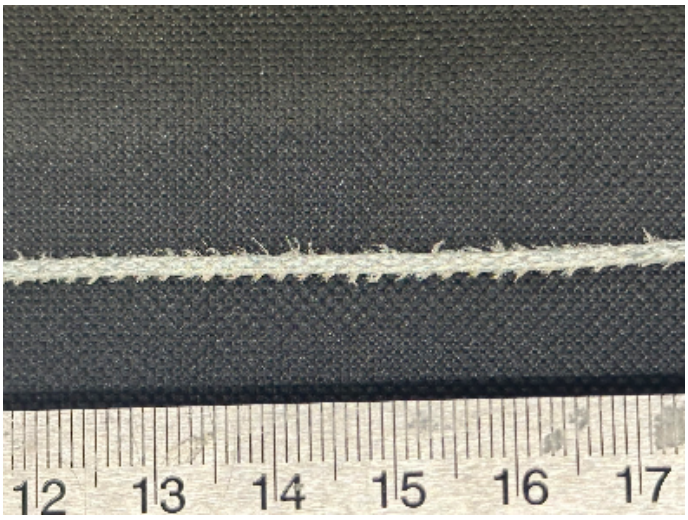
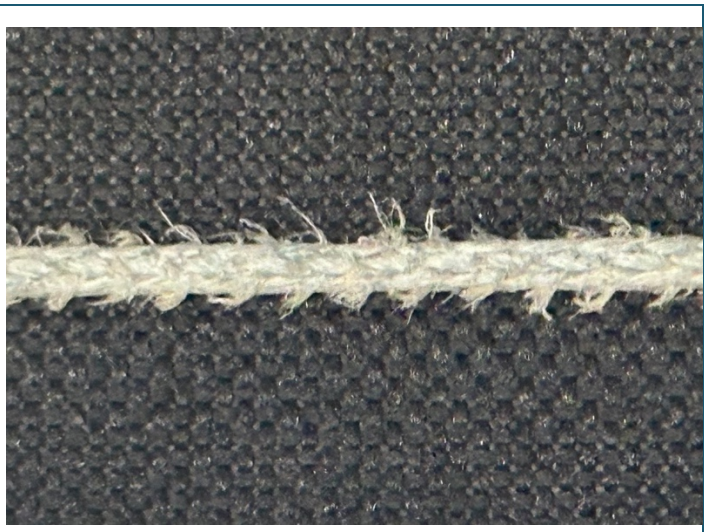
HK2 69-00102 - Examined 3/27/24

The lines were a 300lb line set from 2021. The lower A and upper D were removed, and tensile capacity was tested in the Florida Facility at the time of the examination. The results are as follows:

- A - 168 lb.
- D - 288 lb.

It should be noted that these lines are ultra-thin lines used for competition canopy piloting and are not suitable for terminal deployments. The owner reported:

"I checked them and the wear is as shown in the release. As in I definitely should have checked them more often and changed them before the point they were at."

<table>
<tr><td> 
</td><td>  </td></tr>
<tr><td>Photograph 13: View of wear on lines.</td><td>Photograph 14: Close up view of broken strands on the line.</td></tr>
<tr><td colspan="2">Additional Comment(s) (If Applicable): Note severe abrasion broken strands and wear.</td></tr>
</table>

HKT 67-00040 - Examined February 2020

The lines were a 400lb line set from 2018. The lower A and upper D were removed, and tensile capacity was tested in the Florida Facility at the time of the examination. The results are as follows:

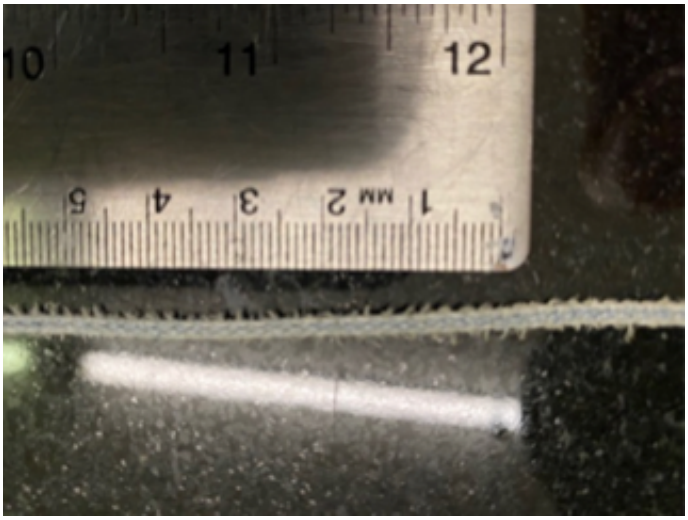
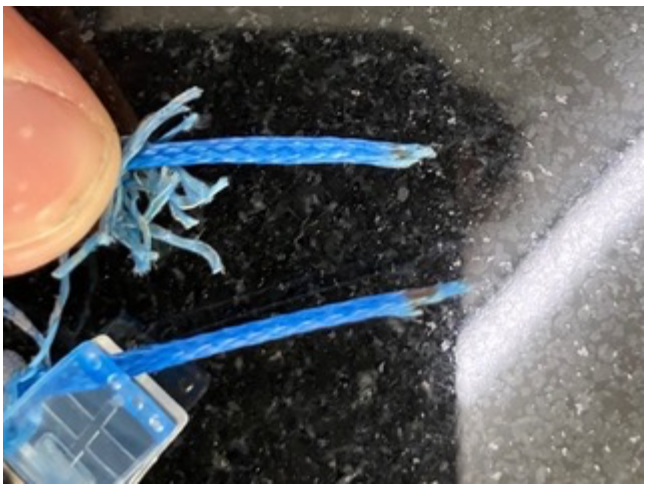
- A - 207 lb.
- D - 417 lb.

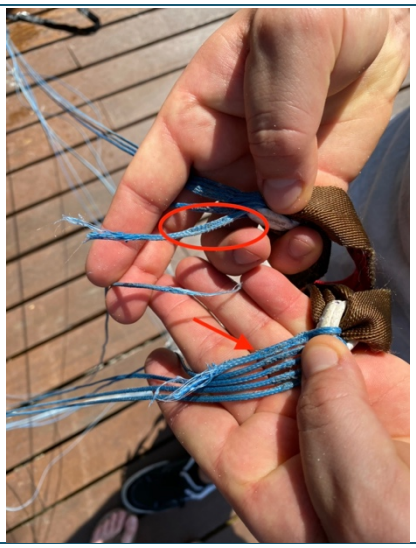
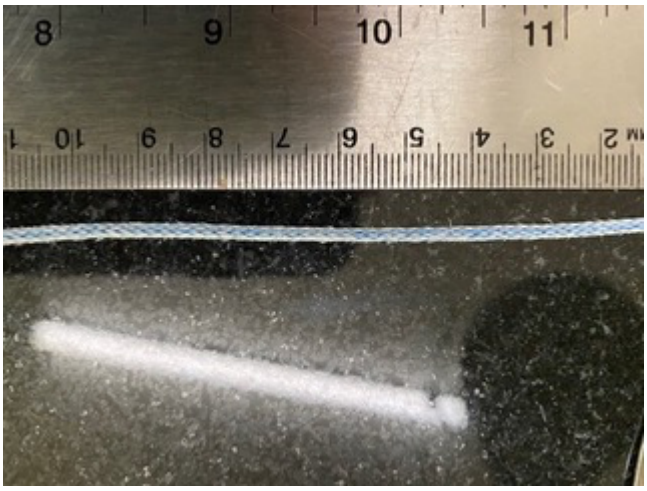
It should be noted that this occurred in 2020 on a line set that appears to have been over 2 years old.

The owner has inconsistencies in the information he provides to multiple sources. In his email provided to the GCAA, he reports 100-150 jumps. In an email to Fluid Wings LLC circa February 10, 2020, he reported that the lines had up to 250 jumps.

We are willing to release the email transcripts from this customer upon request.

Photographs from line set investigation circa Feb 2020.

<table>
<tr><td> 
</td><td>  </td></tr>
<tr><td>Photograph 15: View of wear on lines.</td><td>Photograph 16: View of line cut at angle on interior of splice.</td></tr>
<tr><td colspan="2">Additional Comment(s) (If Applicable): Note severe abrasion and wear on the left photo of the lines. Also note that the line set was deconstructed to verify that the cuts were made at angles.</td></tr>
</table>

	
Photograph 17: View of wear on that jumper has included with several posts.	**Photograph 18:** View of line condition at upper portion of the lines.
Additional Comment(s) (If Applicable): Note wear in the lower portion of the lines at location of slider and condition at upper lines with less abrasion.	

DISCUSSION

The primary measurable parameter to ensure the quality of parachute lines is determined by tensile strength. The tensile strength is determined by the line material and braid and is tested many times prior to use. Fluid Wings LLC maintains test records for all lines we use and can trace the materials to individual parachutes based on our TSO approved quality system. We require that lines be built to very tight tolerances, perhaps the tightest in the industry (typically +/- 3mm) for the uninstalled measurements. All lines to be spliced are required to be cut at oblique angles to minimize stress concentrations, as a standard practice.

Tensile Capacity:

The failure of a line may be expected when the applied load exceeds the tensile capacity applied to it. Parachute lines are subject to wear, and their strength will generally decline with increased age and wear. It should be noted that the lines with the least visible wear (still notable wear) were essentially still at nominal strength.

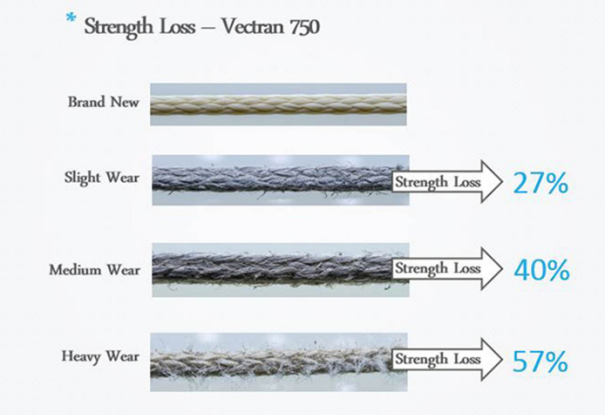
Basic Performance Design, and Construction of Ram Air Inflated Gliding Parachute Wings, Manley C. Butler Jr., April 1986 recommends a safety factor of 5:1 for line strength. In practice, Fluid Wings prefers to design for values that exceed the 5:1 margin.

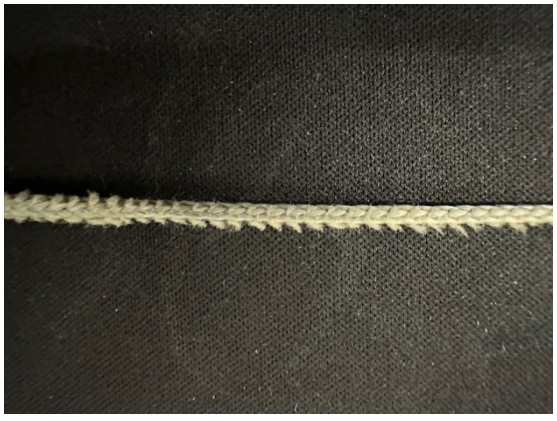
In Basic Performance Design, and Construction of Ram Air Inflated Gliding Parachute Wings, Manley C. Butler Jr., further notes: *"Many canopies seem to break the center A-lines most often followed by the control lines"*. It should be noted that this was published in 1986, approximately 38 years prior to this report at the time of writing. The noted failure of the center A lines would be consistent with these findings.

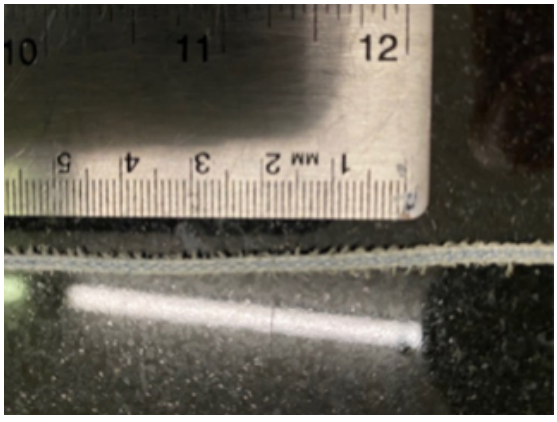
It should be noted that publicly available information (not just Fluid Wings) repeatedly states that jump numbers are not an appropriate method of determining line conditions.

Line wear:

The following images are taken from: https://parachutist.com/Article/Know-Your-Lines







(Photographs previously noted in the observations section for reference purposes)

It should be noted that the wear conditions noted in the observed parachutes were generally worse than in the heavy wear category in the aforementioned article.

In areas with no visible wear, we noted tensile strength to be at approximately the nominal capacity. In the areas of the wing where maximum wear would be expected to occur (lower portion of the lines where the slider is rapidly flapping), the lines were in the range of 56% of their original capacity as taken by the average of the splices testing values on the spool that line set was manufactured from. The line tensile strengths on the lower portion of the parachute were severely compromised by long-term visible wear.

High-performance parachutes are configured for high-speed landings and extreme flight maneuverability. The lines are a source of drag, and as such, minimizing line diameter/area is a desirable condition for these types of wings. Furthermore, the addition of thicker lines has been shown to increase the chances of some types of deployment malfunctions (e.g., tension knots). High-performance parachutes configured with small diameter lines are for pilots who want less drag and who must be willing to get frequent relines in exchange for higher performance.

The subject parachute lines exhibited visible wear in a manner that the tensile capacity could reasonably be expected to be significantly reduced based on previously mentioned publicly available line wear information. Furthermore, the noted failure is consistent with failure patterns described in published literature. Therefore, we may conclude that the lines did not fail in an abnormal manner when their wear state is taken into consideration.

It should be noted that numerous publicly available sources indicate that sandy environments will reduce the life expectancy of a parachute line. The Skydive Dubai environment presents several hazards, including sand and dust, that can reduce the lifespan of a line.

Inspections:

Generally, a main parachute has no formal airworthiness requirements. We are unaware of any formal requirements for the inspection of main parachutes at international drop zones or the parachute packing operations in Dubai.

In the United States, the following requirements are in place for packing a main parachute, presumably to allow for an inspection of the gear by a qualified rigger or the user. The requirements of packing a parachute are governed by FAR *105.43 Use of single-harness, dual-parachute systems:*

> *"(a) The main parachute must have been packed within 180 days before the date of its use by a certificated parachute rigger, the person making the next jump with that parachute, or a non-certificated person under the direct supervision of a certificated parachute rigger."*

It is generally accepted practice that the pilot of an aircraft is responsible for the determination of airworthiness. In the United States, the FAA requires:

> *FAR 91.7(a) requires that "no person may operate a civil aircraft unless it is in an airworthy condition." Subsection (b) of the same section provides that the pilot in command [PIC] of an aircraft is responsible for determining that the aircraft is in a condition for safe flight, and that the PIC must discontinue the flight when the aircraft encounters unairworthy mechanical, electrical, or structural conditions.*

While a main parachute is not a certified aircraft, and there are no requirements for periodic inspection by a rigger or mechanic, the pilot would be the sole person who could be expected to make an airworthiness decision. Therefore, we may conclude that the generally accepted practice of preflight inspections and the determination of airworthiness would be the sole responsibility of the parachute pilot.

Given the condition of the lines observed on the subject parachute and the information generally available, the determination of the unairworthy condition lines should have been apparent upon a proper preflight inspection of the gear for each parachute we have examined.

<u>Incident Reporting:</u>
The anecdotal data provided on some of the parachutes with line failures was noted to vary widely in reliability and contain incorrect information.

The information being circulated appears to have no discernible effort to verify the veracity of statements.

Fluid Wings was not contacted by any dropzone at any point to verify information.

That is understandable given the emotional nature of such an event (fatal incident), but rumor and conjecture can work against efforts to identify or solve potential safety issues.

<u>Common Factor Analysis:</u>

We have performed a forensic analysis of 3 out of 5 of the reported line failures in Dubai. Investigations all yielded several commonalities:

1. The lines all exhibited visually detectable severe wear.

2. All of the wings we were able to investigate or observe photographs of, all report (at some point in time) jumps in excess of 200 jumps (average of over 230).

3. Another commonality appears to be their use in the Skydive Dubai environment. This location is known to be extremely abrasive on lines (noted by multiple other wing manufacturers).

4. In each case, the wear is very visible and visually discernible and should have been detected with a thorough preflight inspection.

External factors may be interfering with preflight inspections. A careful analysis of operations should be performed to determine where or if the process may be improved. Pilots should be encouraged to adhere to a safe maintenance schedule.

CONCLUSIONS

Based upon our review of all available information to date, the following is a summary of our findings:

1. The evidence observed on the examination of the subject parachutes indicates that the condition of the lines would be considered unairworthy and severely worn. The severe wear is the result of use in a harsh environment.

2. No material deficiencies with the lines were identified.

3. No manufacturing deficiencies with the investigated lines were identified.

4. The location of the observed failure (Center A2-lines) would be considered a normally expected failure mode for severely worn lines that were deteriorated from excessive use.