VAISALA

WHITE PAPER

Vaisala Radiosonde RS41 Unwinder with BioTwine™

The first part of this document describes the Vaisala BioTwine™ material and provides evidence of its biodegradability in different environments. The second part of this document shows that sounding parameters that are potentially sensitive to string material and unwinder design change had no statistical differences, and that therefore the measurement accuracy of the RS41 radiosonde is not affected by the change in string material. All specifications and previously-published performance white papers therefore still apply.

1 Introduction

Biodegradable Vaisala BioTwine™

Vaisala BioTwine™ is biodegradable twine that reduces micro-plastics originating from soundings operations after service.

Vaisala BioTwine™ is a cellulose-based fiber. The material is biodegradable and compostable. In biodegradation, oxidation and hydrolysis start breaking the polymer chains of the Vaisala BioTwine™, which then changes to enzymatic cleaving by different microorganisms. The resulting small sugar molecules are then used in the microorganisms' metabolism. No microplastics are formed during the degradation. In manufacturing, the fibers are produced in a closed process where 99% of organic solvent can be recovered and reused.

Table 1 (below) summarizes the comparison between different string materials' mechanical properties, both initial and after service. In various tests there were sample-pairs exposed for a comparison.

Tests were carried out in different environments and they show that Vaisala BioTwine™ loses strength in terrain, compost, freshwater and marine environments remarkably faster than other currently deployed string materials, like cotton or polypropylene (PP).

In Table 1, the first row "Dry" shows the tested string strengths at the beginning of the test. The tensile strength of Vaisala BioTwine™ is ~540 MPa (measured in standard climate room), which is equal to ~8.5 kg. Polypropylene (PP) and cotton string strengths correspond to the level currently in operational use, being about 11.5 kg.

Material	Cotton (kg)	PP (kg)	BioTwine (kg)
Dry	11.63	11.54	8.48
Wet	13.74	9.24	7.03
Terrain 7 months	7.55	N/A	1.91
Compost 5 months	N/A	6.87	1.26
Freshwater 5 months	N/A	5.77	2.12
Baltic Sea 1 month	7.20	N/A	1.86
Baltic Sea 8 months	3.01	N/A	0.46

Table 1. *Mechanical results of high-quality cotton string, traditional polypropylene string (PP) and Vaisala BioTwine™*

When wetted, Vaisala BioTwine™ and polypropylene (PP) string strength decreases, whereas cotton string strength increases. The results are presented in the row "Wet".

In a terrain environment test with a duration of 7 months, Vaisala BioTwine™ strength was reduced to 1.91 kg, in comparison with cotton strength 7.55 kg.

In a home compost test with a duration of 5 months, Vaisala BioTwine™ strength was reduced to 1.26 kg, in comparison with polypropylene strength 6.87 kg. The compost test gave an estimation of 8 months to reach complete disintegration for Vaisala BioTwine™. Polypropylene string loses its strength gradually in compost, but does not biodegrade.

The freshwater test was carried out in a cold climate (T <5 °C). In the test with a duration of 5 months, Vaisala BioTwine™ strength was reduced to 2.12 kg, in comparison with polypropylene strength 5.77 kg. The estimated complete degradation of Vaisala BioTwine™ takes about 14 months in freshwater. Polypropylene string loses its strength gradually in freshwater, but does not biodegrade.

The marine test was performed in the Baltic Sea, which has a low salt concentration compared to that of the oceans with 35 ‰. The first test samples after 1 month of soaking gave string strength results of 1.86 kg for Vaisala BioTwine™ and 7.2 kg for cotton. The results for samples after an 8-month period were 0.46 kg and 3.01 kg respectively. Based on the results, the estimated time for complete degradation of Vaisala BioTwine™ is slightly over 9 months in the Baltic Sea.

The salt concentration in the Baltic Sea is just a fraction of the typical ocean salt concentration. Therefore, if the BioTwine lands in salty ocean, for example the Pacific Ocean, the complete disintegration time can be faster than in the test. The biodegradation process is accelerated due to salt which acts as an electron acceptor for microorganisms. However, some marine environments can also have very slow biodegradation processes since they lack the nutrients needed by microorganisms.

Note that the estimated times for complete biodegradation are rough predictions and in practice the rate can vary significantly during the process depending on the environmental conditions. However, the results mean that Vaisala BioTwine™ is already weak long before complete disintegration is reached, and it breaks when slight force is applied.

Figure 1 (below) shows that the Baltic Sea experiment affects the biodegradable twine materials similarly. The difference is in the disintegration rate, which is clearly faster in the case of Vaisala BioTwine™. This fast decrease in tensile strength is caused by unaligned filaments in the twine. During the experiment, the individual filaments have moved and loosened up the twine structure.

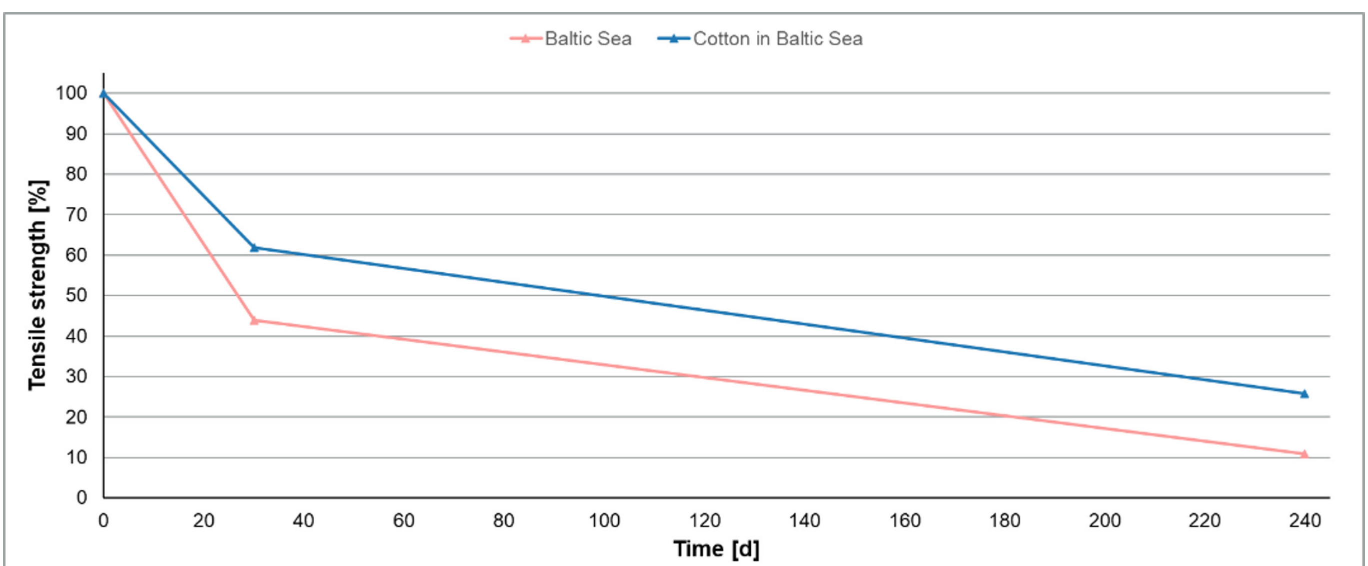

Figure 1. *Biodegradation experiment conducted in the Baltic Sea with Vaisala BioTwine™ and Cotton. Experiment lasted 240 days.*

Change from PP-string to Vaisala BioTwine™

RS41 design and infrastructure set the style and dimensions for the string change. The shape of the unwinder body is the same but dimensions differ for the current unwinder. The new dimensions provide more space for the twine. This ensures compatibility with the current Vaisala AUTOSONDE AS41 and AS15 without any modifications. The new dimensions do not require any changes to the sounding equipment either. The Vaisala BioTwine™ version and the PP-string version are set side by side in Figure 2 (below). From the operator's point of view, the change is visible, but the operation remains simple and user-friendly.

Table 2 (below) lists the properties of traditional PP-string and Vaisala BioTwine™. In sounding operations, the lower unwinding speed of Vaisala BioTwine™ is beneficial, especially in windy conditions.

Figure 2. *Unwinder with BioTwine™ (on the right) and unwinder with PP-string (on the left).*

	Vaisala BioTwine™	PP-string
Material of the string	Cellulose based	Non-UV treated polypropylene
String diameter	0.9 mm	0.7 mm
Length of the string	55 m	55 m
Strength (pull)	<95 N	<115 N
String weight / total unwinder weight	16 g / 31 g	9.3 g / 25 g
Lower flange diameter in unwinder body	66.5 mm	66.5 mm
Unwinding speed	0.26 m/s	0.35 m/s

Table 2. *Comparison between unwinders with Vaisala BioTwine™ and PP-string*

2 Comparison data

The following chapter presents the comparison data of Vaisala BioTwine™ against PP-string unwinders. Sounding parameters that are potentially sensitive to string material and unwinder design were analyzed from soundings done at several sites by 2 pilot customers. The number of Vaisala BioTwine™ test soundings was 75 and 40, respectively, and a similar set of alternating reference soundings were performed with the PP-string unwinder. The test sites represented conditions of tropical and mid-latitude climate. The following box-plot graphs present the analysis results.

Interpretation of box-plot graphs

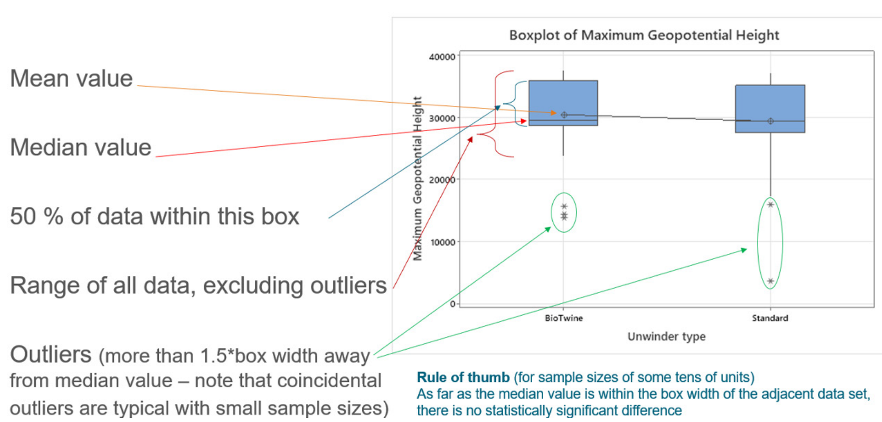

Figure 3. *Interpretation of box-plot graphs*

Ascent rate

In the test soundings performed, a slightly lower mean ascent rate was achieved with the Vaisala BioTwine™ unwinders at both campaigns, see Figure 4 (below). However, the difference of means was less than 0.2 m/s in the first campaign and, using 95 % confidence interval, no statistically significant difference was observed in the second.

The nozzle lift, defined by the amount of gas used in the filling of the balloon, naturally affects both the ascent rate and the reached geopotential height. The results of ascent rate and maximum geopotential height mean differences, the latter presented further below, give some indication of a minor difference in mean nozzle lift as the 2 unwinder types were used.

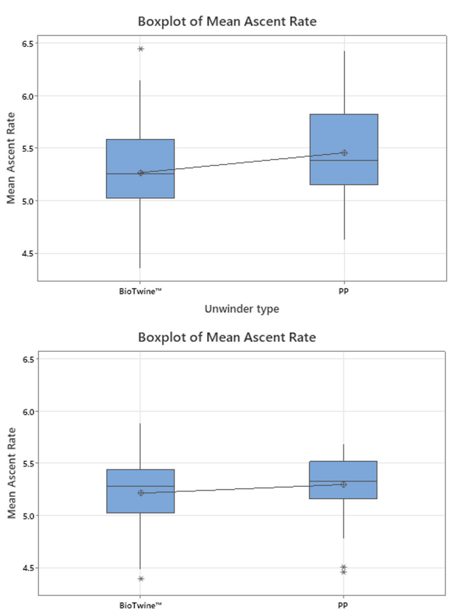

Figure 4. *Descriptive statistics and the related differences in the mean ascent rate [m/s], Vaisala BioTwine™ unwinder against unwinder with PP-string, at the 2 sounding campaigns.*

Ascent rate noise

In this analysis, the ascent rate noise was calculated by averaging the standard deviations of consecutive 100 sec long data sets above the altitude of 8 km [m/s]. Looking at the results of Figure 5 (right), it can be inferred that a marginally lower ascent rate noise is achieved with the new Vaisala BioTwine™ unwinder. The absolute differences in both campaigns were relatively small but just enough to exceed the statistical 95 % confidence level for a significant difference.

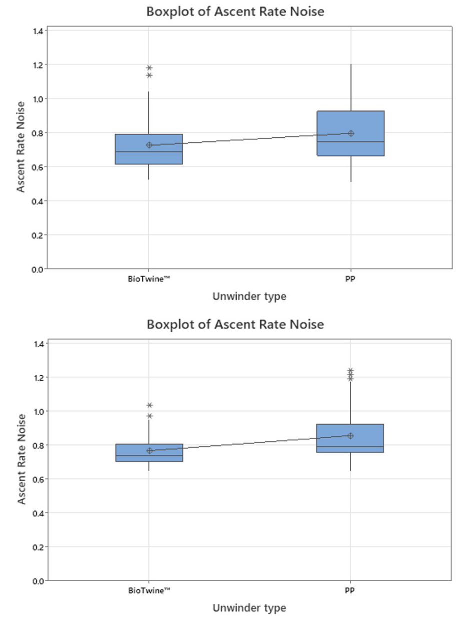

Figure 5. *Descriptive statistics and the related differences in the ascent rate noise [m/s], Vaisala BioTwine™ unwinder against unwinder with PP-string, at the 2 sounding campaigns.*

Maximum geopotential height

When looking at the data of reached geopotential height in the soundings, it seems that the soundings with Vaisala BioTwine™ would have gained slightly higher maximum heights, see Figure 6 (below). However, no statistically significant difference between the Vaisala BioTwine™ and PP-string unwinder is found when a 95 % confidence interval is applied.

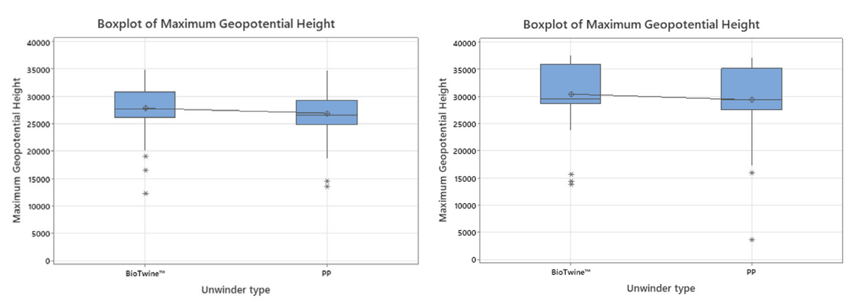

Figure 6. *Descriptive statistics and the related differences in the reached maximum geopotential height [m], Vaisala BioTwine™ unwinder against unwinder with PP-string, at the 2 sounding campaigns.*

Valid telemetry

It is very unlikely that string material has an effect on telemetry, but for the sake of certainty the matter was confirmed from the data. As Figure 7 shows, the quality of telemetry was close to 100 % in both test campaigns and no significant difference was observed between Vaisala BioTwine™ and PP-string unwinder.

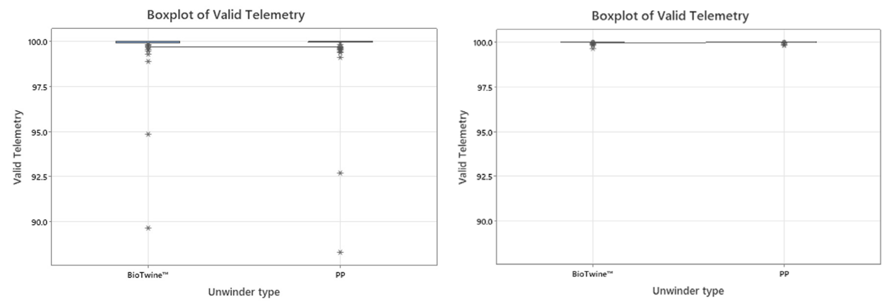

Figure 7. *Descriptive statistics and the related differences in the valid telemetry data [%], Vaisala BioTwine™ unwinder against unwinder with PP-string, at the 2 sounding campaigns.*

3 Summary

Regarding sounding operations and radiosonde measurement performance, the string change applied to RS41 radiosonde does not involve any changes; sounding operations remain the same, extremely simple and user-friendly, and all specifications and previously published performance white papers fully apply.

However, this is a significant change from the environmental point of view. Vaisala BioTwine™ degrades faster than other string materials used in unwinders without forming any microplastics.

The option of using Vaisala BioTwine™ is also communicated in www.vaisala.com, having no effect on RS41 data continuity.

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