Safety Investigation Brief

Microlight Windscreen Failure

Summary of occurrence

On 29 March 2018, the pilot and passenger departed Thames Aerodrome for a scenic flight to the east coast. Having been flying for approximately 40 minutes, heading back to Thames Aerodrome, the pilot flew the aircraft over the open mine to the north of the town of Waihi (Refer Figure 1). While both occupants were viewing the open mine at approximately 1600 feet above mean sea level, and at a speed of 80 knots, the windscreen failed catastrophically.

The sudden inflow of air caused both cabin doors to come open and aerodynamic control became compromised. The pilot elected to make a forced landing onto open ground to the south of the town. While a successful approach was made to the chosen farm paddock, following touch down the aircraft bounced and was inverted, injuring the occupants (Refer Figure 2). Emergency services attend and provided assistance.

When interviewed regarding the incident the pilot reported a possible collision with a drone. Examination of the aircraft and searches of the area of the mine have found no evidence of a drone.

During the examination of the aircraft it was found that there was discolouration of the plastic polymer windscreen in the form of yellowing from original clear. Subsequent laboratory examination of recovered chards and sections from the windscreen, identified evidence of Ultra Violet (UV) degradation to the upper areas of the exterior surface (refer Appendix A). UV degradation can affect the polymer bonding properties which can result in sudden failures.

Due to the high UV levels in New Zealand that can adversely degraded plastic polymers, it is recommended that aircraft are stored in a suitable building or a material cover is placed over the windows. Thorough pre-flight inspections could identify the emergence of discolouration or other defects of the aircraft transparencies. The use of cleaning materials should also be carried out in accordance with the manufacture's requirements. Any defects noted should be discussed with a suitably qualified maintenance provider.

Administrative information

Aircraft manufacturer and model		Aeroprakt Limited, A-22LS, Ser. No 198
Engine manufacturer and model		Bombardier-Rotax 912 ULS
Registration		ZK-LFD
Location of incident		Near Waihi,
Date and time of incident		29/03/18, 1510 hours
Flight rules applying		Private
		Visual (VFR)
Occurrence number		18/1472
Injuries	Crew	One- Head injury and bruising
	Passengers	One- Bruising
	Others	Nil

Pilot information

Age and gender		Male
Pilot licences		RAANZ
Pilot ratings		Fixed wing, piston engine
Flying experience (hours)	Total helicopter	Not Applicable
	Total fixed wing	350 approx.
	With this aircraft type	N/K
	In last 7 days	N/K
	In last 90 days	N/K
	In last 12 months	N/K

Meteorological information and flight plan

Conditions at incident site	Wind (knots)	10
	Visibility (metres)	Over 10000
	Cloud (descriptor)	Few – Scattered – **Broken** – Overcast
	Pressure (hPa)	Not Available
	Temperature (°C)	Not Available
Departure point		Thames
Destination		Thames

Wreckage and impact information

Aircraft damage	Extensive	
Aircraft fire	No fire ☒	
ELT activated?	Not installed	No ☒
ELT signal received by Rescue Coordination Centre (RCC)		No ☒
Aircraft recovered?	Yes ☒	
Location	37º 24 51.1'S 175º 50 50.0'E	

Figure 1. Modified Google® Earth image showing incident and accident locations.

Figure 2. Image of aircraft at accident site (Source: Police)

About the CAA

New Zealand's legislative mandate to investigate an accident or incident are prescribed in the Transport Accident Investigation Commission Act 1990 (the TAIC Act) and Civil Aviation Act 1990 (the Act).

Following notification of an accident or incident, TAIC may conduct an investigation. CAA may also investigate subject to Section 72B(2)(d) of the Act which prescribes the following:

> **72B Functions of Authority**
>
> (2) The Authority has the following functions:
>
> (d) To investigate and review civil aviation accidents and incidents in its capacity as the responsible safety and security authority, subject to the limitations set out in section 14(3) of the Transport Accident Investigation Commission Act 1990

The purpose of a CAA safety investigation is to determine the circumstances and identify contributory factors of an accident or incident with the purpose of minimising or reducing the risk to an acceptable level of a similar occurrence arising in the future. The safety investigation does not seek to ascribe responsibility to any person but to establish the contributory factors of the accident or incident based on the balance of probability.

A CAA safety investigation seeks to provide the Director of the CAA with the information required to assess which, if any, risk-based regulatory intervention tools may be required to attain CAA safety objectives.

About this safety investigation brief

The purpose of this brief is to identify to the aviation community:

- what happened
- factors contributing to the accident
- any relevant safety messages.

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PPS Group Technical Memorandum

C1441 ZK LFD Windscreen Investigation

17 July 2018

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Ph (09) 445-5902 Fax (09) 445-5890

File Ref:	3739/1816	Contact Ph No:	(09) 446 - 1831
Work Stream No:	E1816	DTelN	397 - 8231
Work Requested:	Chemical and mechanical analysis of failed windscreen to identify potential failure mechanisms.		
Task Reference:	Email: Ryan Brookes (r.brookes@dta.mil.nz) to Paul Breuilly (Paul.Breuilly@caa.govt.nz), *Inspection and testing of failed microlight windscreen*, 24/04/18		
Report to:	Mr Paul Breuilly – Civil Aviation Authority		

Introduction

1. The Civil Aviation Authority (CAA) asked DTA to investigate the material properties of a microlight windscreen that had been involved in a serious accident. (ZK-LFD). Samples of the damaged windscreen were sent to DTA for analysis to determine the state of the material and whether there was any relationship to the yellow appearance and a decrease in mechanical performance.

Material Identification

2. Identification of the material was undertaken using pyrolysis gas chromatography with mass spectroscopy (Py-GC-MS). A definitive result could not be obtained using the polymer library supplied with the instrument. The closest match (71%) was to PCT (Polycyclohexylenedimethylene terephthalate) a polymer that is similar to PET (polyethylene terephthalate). This suggests that the material is either PETG, a copolymer of PET that includes some cyclohexane dimethanol in the polymer backbone, or a blend of PET and PCT. PETG is not present in the pyrolysis software library.

3. Fourier transform infrared (FTIR) was also used to identify the windscreen material. The best matched result in the reference library was PET at 84%. A match of only 68% was obtained to the PETG reference. A reference for PTC was not present in the FTIR spectral library.

4. Additional testing would be required to conclusively identify the material. Differential scanning calorimetry (DSC) could be used to determine whether the material is a copolymer or polymer blend by detecting the presence of more than one melting point. Reference samples of PETG or PCT could also be obtained analysed be Py-GC-MS and FTIR.

Environmental Degradation of PET

5. PET is subject to degradation in the environment primarily from exposure to UV light. Although the windscreen material is not pure PET the degradation mechanisms cited below are still relevant to a large part of the polymer.

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6. UV light breaks bonds within the polymer chain which results in shorter polymer chains, loss of material and creates reactive chemical groups. These reactive groups can create crosslinks between polymer chains, making the material more brittle. Some of the compounds formed from these reactive groups are coloured and cause the material to yellow. UV degradation is localised to the surface (up to 1 μm) of the polymer where the light in the UV wavelengths are strongly absorbed by PET [1].Accelerated weathering techniques suggest that prolonged UV exposure will reduce the tensile strength of PET [2], however it is difficult to make a direct comparison of accelerated results to real world weathering rates.

7. FTIR using an attenuated total reflectance (ATR) accessory is ideal for observing UV degradation in polymers as the technique only involves light that is reflected from the first few micro meters of the sample surface. UV degradation creates a number of new compounds that contain carbonyl bonds (which strongly absorb in the infrared) and analysis of this region can show the presence of these compounds and the reduction of the amount of original material. For PET the terephthalate carbonyl peak at 1713cm^{-1} is reduced [3] as it is converted to other compounds which also cause this peak to broaden.

Analysis of Samples

8. Samples of the damaged windscreen were provided from different location on the windscreen as indicated in Figure 1 below. Duplicate subsamples were taken from each location as well as from a selection of additional windscreen fragments whose original locations were unknown.

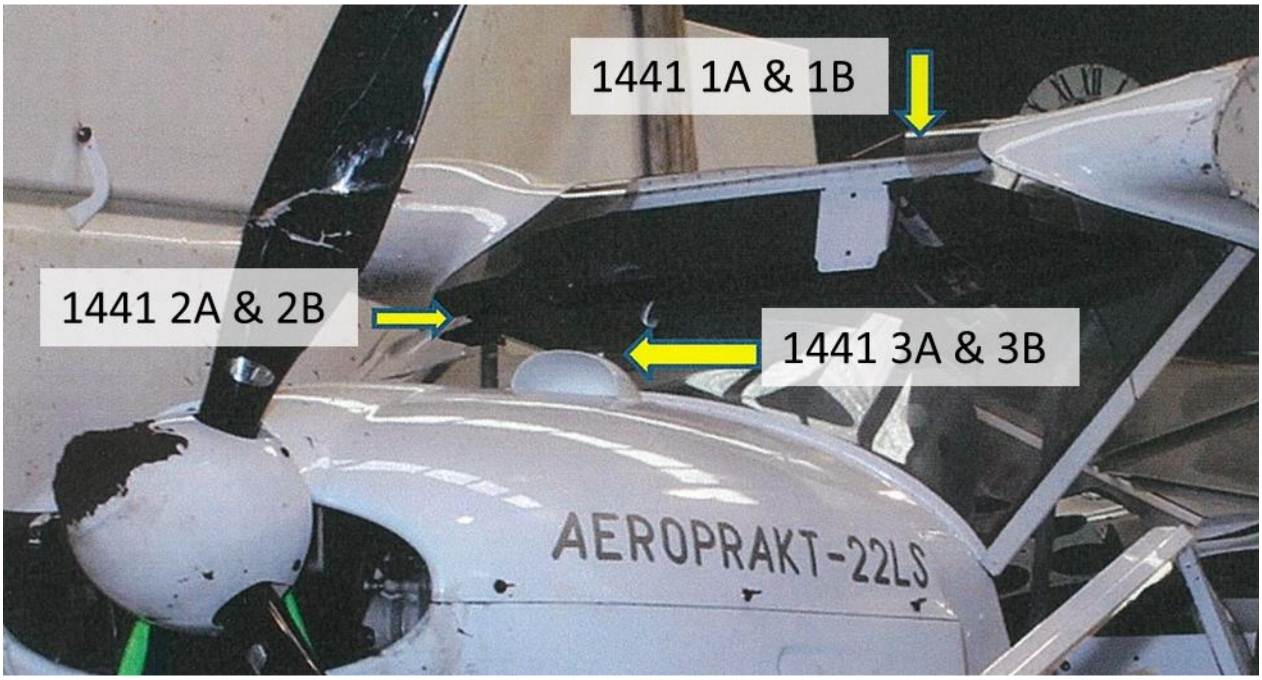

Figure 1: Locations of known windscreen samples as indicate by yellow arrows along with corresponding DTA sample numbers (image provided by CAA).

Yellowing

9. A selection of windscreen fragments from unknown locations were selected visually to give a range from high to minimal yellowing. These fragments were then analysed along with the samples from known locations using a UV Visible spectrophotometer to determine the degree of yellowing of each sample. Results showing the yellowness index values for each sample are shown in table 1 below. The higher the

yellowness index the greater the degree of yellowing in the sample. From the known sample locations it appears that the samples increase in yellowness from bottom to top of the windscreen.

Table 1: Yellowness index of windscreen samples and locations where known.

Sample ID	Windscreen Location	Yellowness Index*
1441 3A	Lower	1.37
1441 7A	Unknown	1.48
1441 7B	Unknown	1.54
1441 3B	Lower	1.65
1441 4A	Unknown	2.27
1441 4B	Unknown	2.34
1441 6A	Unknown	2.7
1441 6B	Unknown	2.77
1441 2B	Middle	3.18
1441 2A	Middle	3.56
1441 5B	Unknown	4.5
1441 5A	Unknown	4.59
1441 1B	Upper	4.6
1441 1A	Upper	5.6

*Derived using the UVPC Colour Analysis Software v3.10 from Shimadzu

FTIR Analysis

10. During FTIR analysis it was noted that each sample had one side that showed evidence of degradation and one side that did not. As the exact orientation of each fragment was not known it has been assumed that the side showing no degradation was the interior surface.

11. Degradation of the windscreen surface causes a number of changes to be observed in the FTIR spectra of the material. A key area to observe these changes is the region between 1800 - 1600cm^{-1} where the carbonyl peaks in the original material and degradation products strongly absorb the infrared light. Figure 2 shows this region for the exterior surface of each of the samples along with one interior surface for reference. All exterior surfaces show a reduction in the terephthalate peak (from the original material) at 1713cm^{-1} indicating some degradation or loss of this component. Peak broadening due to the formation of new compounds is also seen on the exterior surfaces. The reduction and broadening of the peak t 1713cm^{-1} matches the degradation mechanism described in reference [3] and trends from bottom to top across the windscreen. The exterior surfaces show an increase in absorption at 1628cm^{-1} which also has a trend based on location with the upper areas of the windscreen showing a greater increase than the lower. These results show that significant degradation of the original material has occurred particularly in the upper

sections of the windscreen. It should be noted that this only refers to the first 1- 2 µm of the sample which is only 0.1% of the total thickness of thewindscreen material.

12. The trends mentioned in paragraph 11 above also match well to the yellowness index values in table 1 confirming that the yellowing of the material is likely related to the breakdown of the original polymer material.

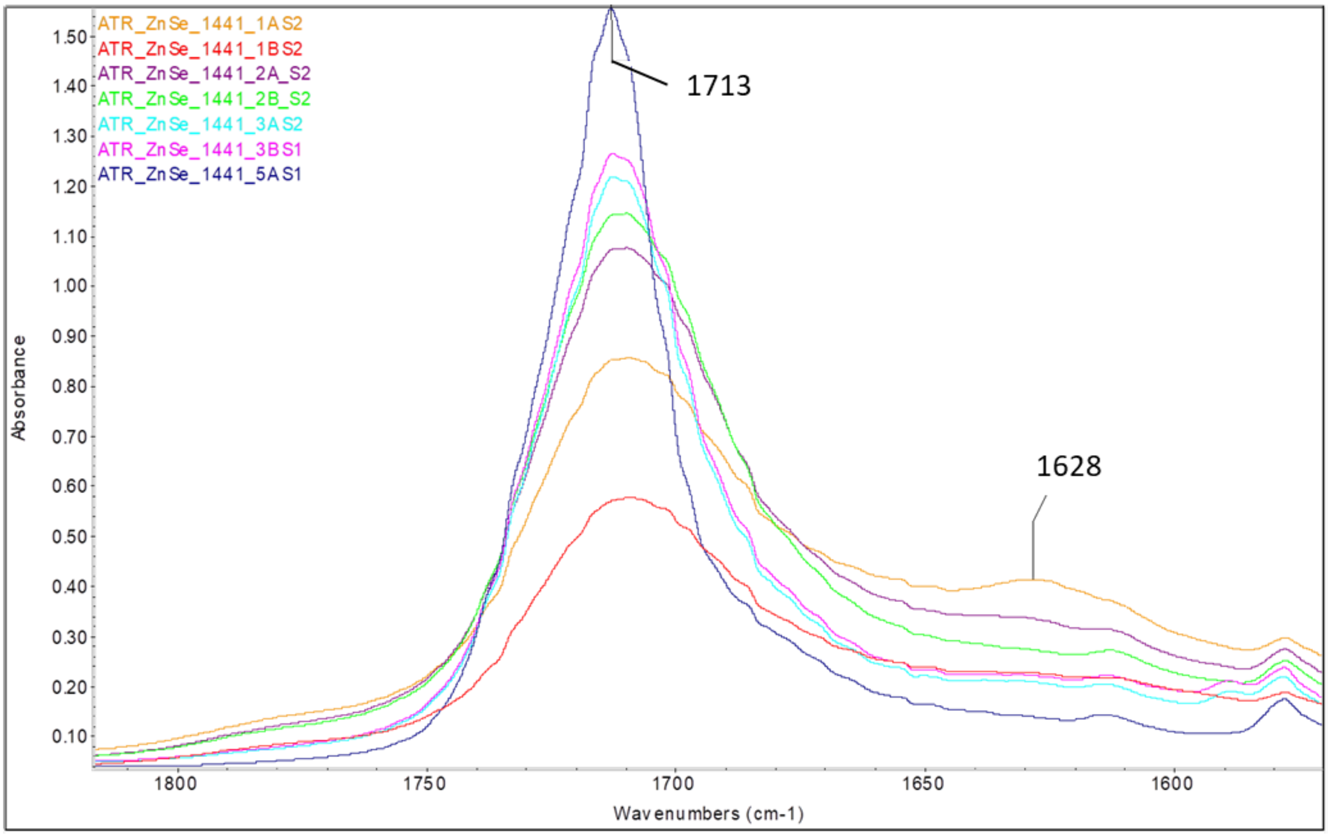

Figure 2 ATR- FTIR results zoomed to the 1800 - 1600cm^{-1}region for exterior surfaces of windscreen sections at different locations showing changes in adsorption at 1713cm^{-1} and 1628 cm^{-1}. Locations are top (1441 1A &1B), middle (1441 2A & 2B) and bottom (1441 3A & 3B). Sample 1441 5A is from the interior surface of the windscreen.

Mechanical Characterisation

13. In order to quantify the effect of the UV degradation on the mechanical properties of the windscreen flexure testing (three point bend) was performed. Test specimens of 12.7 x 50 mm were prepared from pieces of the broken windscreen and tested in accordance with ASTM D 790-03. The support span for the testing was 32 mm and the rate of crosshead movement was 8.5 mm/minute giving a rate of straining on the outer surface of 0.1 mm/mm/min.

14. Tests were performed on the most and least yellow specimens. The most yellow specimens, from the top of the windscreen (1441/1a and b) had a slightly different performance at high strain, but there was insignificant difference in maximum flexural stress from the least yellow specimens (1441/7a and b). The stress strain chart for these tests is presented in figure 3

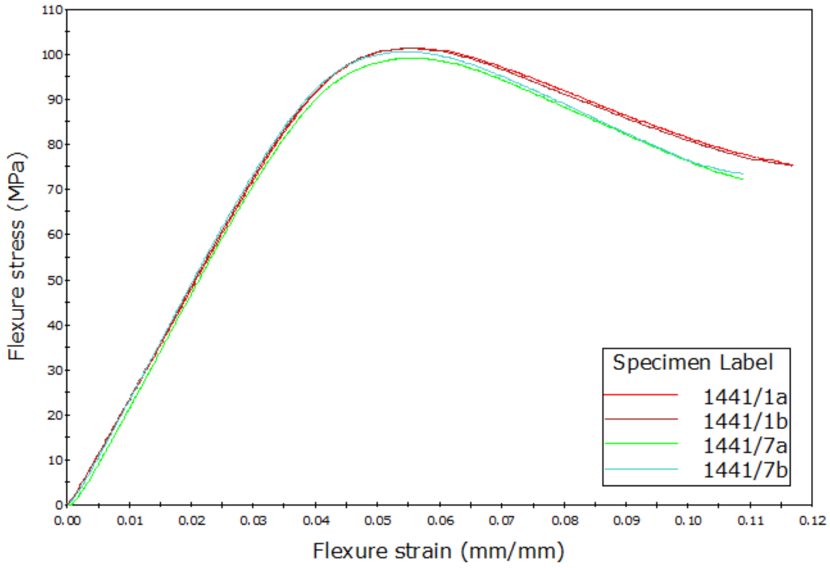

Figure 3. Flexural stress vs strain diagram for the most (1441/1a and b) and least (1441/7a and b) yellow specimens as tested in three point bending.

15. Given the very similar mechanical performance of the specimens with the greatest difference in colouration no further three point bend testing was conducted.

16. Instrumented impact testing with an accelerometer mounted on a swinging hammer may be able to detect differences in impact strength as opposed to flexural strength, but DTA does not have that capability at an appropriate scale for the windscreen material.

Conclusions

17. The material could not be conclusively identified but it is likely to be a PET copolymer or blend. Additional testing or reference samples would be required to fully identify the polymer.

18. The windscreen material does appear to have suffered from UV degradation on its exterior surface and this is more pronounced on the upper areas.

19. UV degradation does not appear to have reduced the flexural stress properties of the windscreen.

20. The extent to which the UV degradation has reduced other mechanical properties of the windscreen has not been established. Additional impact testing of the windscreen sections would show any reduction in this property which may have been most relevant in this incident.

References

[1] B. P., D. M., and W. D. M., "Photochemical degradation of poly(ethylene terephthalate). IV. Surface changes," *J. Appl. Polym. Sci.*, vol. 17, no. 6, pp. 1895–1907.

[2] M. Funabashi *et al.*, "Highly Accelerated Aging Method for Poly(ethylene terephthalate) Film Using Xenon Lamp with Heating System," *J. Polym.*, p. 9, 2016.

[3] G. Abdulkerim, "Degradation Pathway Models of Poly(Ethylene-Terephthalate) Under Accelerated Weathering Exposures," Case Western Reserve University, 2016.

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