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# COMPARISON OF DAMAGE CHARACTERISTICS OF ADHESIVELY BONDED AND RIVET-CONNECTED EVTOL WING UNDER BIRD-STRIKE

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# Motivation



Comparison of damage results at the parts of the rivet-connected and the adhesively bonded configurations of a composite eVTOL wing leading edge.

Investigation of the best absorbent core material to be implemented to develop the lightest composite eVTOL leading edge which can stand against bird impact.



## **Introduction and Motivation**



**QUEEN'S** 

**BELFAST** 

VFRSITY

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# Introduction and Motivation



[2] M. Guida, F. Marulo, F. Z. Belkhelfa, and P. Russo, A review of the bird impact process and validation of the SPH impact model for aircraft structures, Progress in Aerospace Sciences, 129, 2022.

#### Numerical Models & Cases Adhesively Bonded and Rivet-connected eVTOL Wing Under Bird-Strike





Figure – 5 Skin, honeycomb and auxiliary spar attachment configurations at the leading edge of the wing, The rivet-connected configuration



Figure – 6 Skin, honeycomb and auxiliary spar attachment configurations at the leading edge of the wing, The bonded configuration



ADVANCED COMPOSI

# Material Properties & Test Campaign (UD Skin & Aramid Core)

• ASTM C365 - Applied Force vs Displacement

0.5 min/mm 6.35 x 50 x 50 mm



 UD; Stacking: [0/90/-45/45]3s UD M91/IM7 Each ply: 0.184mm (24 plies Facing & 24 plies Backing) <image><image><image><image>





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#### www.qub.ac.uk/sites/acrg Material Properties & Test Campaign (UD Skin & Aramid Core)



• ASTM C364 5 min/mm 6.35 x 50 x 50 mm



Figure – 11 ASTM C364 (Test System)

Figure – 12 ASTM C364 (Compacted Specimen)

\* Experiment-3 is failed because of stability problems. Therefore, Experiment-4 supersedes, Experiment-3.
\*\* Experiment-5 is failed because of stability problems. Therefore, Experiment-6 supersedes, Experiment-5.

ADVANCED COMPOSITES

#### Loading Condition – Normal Impact

• The Impact Condition vs Time





#### FEA Results 1st Principal Stress Distribution, Lower Attachment





#### **UFFN'S** FEA Results - 1st Principal Stress BELFAST 120 120 110 110 100 100 1st Principal Stress [MPa] 1st Principal Stress [MPa] 90 90 80 80 70 70 Upper Upper Attach Connection 60 60 Lower 50 50 Lower Attach Connection 40 40 30 Spar 30 20 20 10 10 0 9 10 0 10 0 9 Time [ms] Time [ms] Figure – 16 1st Principal Stress Distribution at The Attachment Parts and Figure – 15 1st Principal Stress Distribution at The Attachment Parts Spar of The Adhesively Bonded Case and Spar of The Rivet Connected Case $\left(\frac{1}{X_t} - \frac{1}{X_c}\right)\sigma_1 + \left(\frac{1}{Y_t} - \frac{1}{Y_c}\right)\sigma_2 + \frac{\sigma_1^2}{X_t X_c} + \frac{\sigma_2^2}{Y_t Y_c} + \frac{\tau_{12}^2}{S^2} + 2F_{12}\sigma_1\sigma_2 = (\text{Failure Index}) \quad \dots (1)$ Tsai-Wu Failure Theory $\sigma_1, \sigma_2, S \text{ and } \tau_{12}$ $F_{12}$ $X_t, X_c, Y_t$ and $Y_c$ **FEA results** Material properties Numeric parameter $\left[\frac{\sigma_1^2}{X_t X_c} + \frac{\sigma_2^2}{Y_t Y_c} + 2F_{12}\sigma_1\sigma_2 + \frac{\tau_{12}^2}{S^2}\right]SR^2 + \sigma_1\left[\frac{1}{X_t} - \frac{1}{X_c}\right] + \sigma_2\left[\frac{1}{Y_t} - \frac{1}{Y_c}\right]SR = 1$

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### Shear Stress & Safety Reserve Results



Table – 1 Shear Stress Resultsat The Attachment Parts and Spar of The Adhesively Bonded Case											
Time	Rivet-	Adhesively	Rivet-	Adhesively	Rivet-	Adhesively					
	connected	Bonded	connected	Bonded	connected	Bonded					
[ms]											
	Upper Attachment	Upper Connection	Lower Attachment	Lower Connection	Spar	Spar					
2.5	52.9	29.3	51.3	37.0	36.2	9.4					

	at T							
Time	Rivet-	Adhesively	Rivet-	Adhesively	Rivet-	Adhesively		<b>A</b>
	connected	Bonded	connected	Bonded	connected	Bonded		>1 Safe
[ms]							Safety Reserve	
	Upper	Upper	Lower	Lower	Spar	Spar		≤1 Not safe
	Attachment	Connection	Attachment	Connection				+
2.5	9.56e-3	5.3e-3	9.27e-3	6.69e-3	6.54e-3	1.7e-3	[Unitless]	

ADVANCED COMPOSITES

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# **Concluding Remarks & Future Work**



- Lower principal stress and shear stress results are evaluated for the adhesively bonded case. Moreover, the safety reserve results are lower than the rivet-connected case. However, both cases are beyond safe region. Therefore, the following tasks will be performed as a future work to compare these cases and make a reliable comment;
- Results under various stacking configurations
- Investigation of connector fails (i.e Pull-through mode)





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# Thank you!

### **Questions & Answers**