The Multilayer EPS Foam Configuration for Amphibian Aircraft Passive Absorber

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ABSTRACT: This study explored the impact performance of expanded polystyrene (EPS) foam in improving aircraft impact energy absorber. For examining the EPS foam characteristics, three layers of EPS foams with varying densities were tested at 2 m/s, 3 m/s and 4 m/s. This study found that the best material configuration for landing performance reduced the acceleration (g) impact towards the structure for 3 m/s and 4 m/s impact velocity. Since displacement fluctuates, it indicates that displacement is a critical component in impact energy absorption.

Keywords: *EPS Foam; Energy Absorber; Dynamic Impact*

1. INTRODUCTION

In sports and military equipment, polymeric foams are commonly used for energy absorption [1]. Many studies focused on preventing impact energy from reaching the occupant [2]. The use of foam behind a rigid surface in bumpers and doors may help protect passengers from accidents.

Many studies have used foam to absorb impact energy in various applications [3][4][5][6]: cycling helmets with foam liners, absorbing pads to reduce occupant injuries in vehicle side impacts, polymeric foam composite for vehicle arresting system, military helmets and roof padding to protect from vertical impacts. EPS foam is proven to effectively absorb impact energy. Public research on EPS foam for aircraft applications is limited, especially for impact energy absorbers in amphibian aircraft. This study will fill a gap in utilizing the full potential of EPS foam for amphibian aircraft landing performance.

2. METHODOLOGY

The sandwich structure's skin was made of carbon fiber reinforced plastic, foam for the core of the sandwich and seating cushion, and the water acting as the impact base. The impact velocity applied in this study was 2 m/s, 3 m/s, and 4 m/s, and flat layer design uses single, multiple, and combination of EPS foams. (Figure 1).

Composition	Velocity (m/s)	Layer Design
A	2	Flat / No-Space
B	3	Flat / No-Space
C	4	Flat / No-Space
Multiply		Flat / No-Space
Hybrid		Flat / No-Space

Density, Volume and Mass Values for Commercial Grades of IMPAXX

IMPAXX Grades	Density (kg/m^3)	Volume (cm^3)	Mass (kg)	Layer Name
300	35	6.063×10^{-3}	0.0212	A
500	43	6.063×10^{-3}	0.0260	B
700	45	6.063×10^{-3}	0.0273	C

Sequence	Code	IMPAXX Type/ Grade	Composition
1	A	300	Single Layer
2	B	500	
3	C	700	
4	AAA	300, 300, 300	Multiple Layer
5	BBB	500, 500, 500	
6	CCC	700, 700, 700	
7	ABC	300, 500, 700	Combination Layer or Hybrid
8	CAB	700, 300, 500	
9	BCA	500, 700, 300	
10	CBA	700, 500, 300	
11	BAC	500, 300, 700	
12	ACB	300, 700, 500	

IMPAXX Foam Types

Figure 1 Parameter and IMPAXX type for the Study

It is necessary to evaluate the impact velocity on acceleration and displacement, as well as the dynamic characteristics of each material. Different IMPAXX foam materials were evaluated using acceleration and displacement. The IMATEK IM10R-15 Drop Weight Impact Tester was used to collect data through dynamic compression test. The collected data were statistically analysed for average value and time (t). This material will be tested at 2, 3, and 4 m/s. Equation 1 was used to calculate average acceleration and displacement.

$$\text{Average} = \bar{A} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

where i = n = 1, 2, 3, ….n.

3. RESULTS AND DISCUSSIONS

Table 1 shows the simulation results for impact velocity towards single, multiple, and combination layers (hybrid). The highest simulation acceleration was plotted in blue, while displacement was plotted in pink.

Table 1 Experiment Results of Acceleration and Displacement (Maximum Values)

MATERIAL DESIGN (MAX VALUE)		SINGLE LAYER			MULTIPLE LAYER			COMBINATION LAYER						MAX
		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	
2 m/s	ACCELERATION	34.92	60.59	**81.28**	32.97	64.37	75.30	34.41	35.50	34.50	34.09	35.94	36.35	81.28
	DISPLACEMENT	9.80	8.13	7.57	**11.68**	10.27	8.37	12.31	11.37	11.31	9.64	10.33	1092	11.68
3 m/s	ACCELERATION	34.69	67.31	**84.94**	34.56	65.03	82.12	34.61	35.68	36.22	36.47	36.71	35.47	84.94
	DISPLACEMENT	16.00	13.63	7.56	**18.73**	15.81	14.66	15.78	18.37	15.78	9.79	17.54	18.36	18.73
4 m/s	ACCELERATION	35.41	68.65	85.40	34.83	67.31	**86.06**	36.13	35.64	36.49	37.51	37.60	35.92	85.06
	DISPLACEMENT	25.92	20.31	16.99	**28.46**	21.31	18.99	25.45	25.43	26.96	27.94	26.74	28.88	28.46

According to the study results, acceleration and displacement are diametrically opposed. Considering

According to the study results, acceleration and displacement are diametrically opposed. Considering that both results were contradictory (Figure 2), the study would compare single and multiple layer designs. In this study, D1, D2, D3 represented D4, D5, D6. Material C should represent the highest acceleration, while material A represents the highest displacement. Choosing the best material for both acceleration and displacement was difficult in this study because they were contradictory.

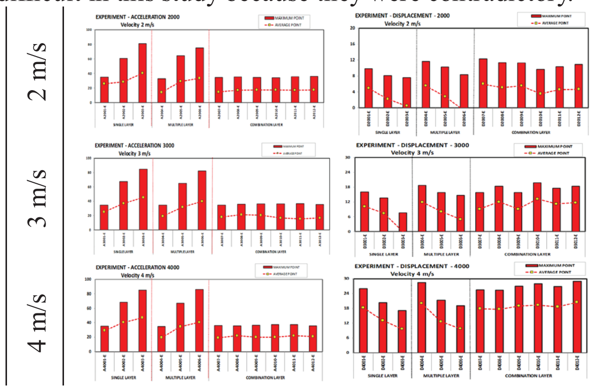

Figure 2 The Results of Acceleration and Displacement

This experiment resulted in average acceleration and displacement of 44.60g and 9.60mm (Table 2). All values were averaged. The best material design configurations were D1 and D10. While the experiment of acceleration and displacement at 3 m/s has average values of 46.49 g and 15.13 mm, the best material design configurations are D1, D7, and D9. The experiment of acceleration and displacement with 4 m/s, chosen as the best material design configuration, shows no values below average. D1, D7, D9, and D10 have the best material selection. However, since this study only focuses on combination layers, further research should focus on designs D7, D9, and D10 (see Figure 1).

Table 2 Experiment Results of Acceleration and Displacement (Average Values)

MATERIAL DESIGN (AVERAGE VALUE)		SINGLE LAYER			MULTIPLE LAYER			COMBINATIOn LAYER						AVE
		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	
2 m/s	ACCELERATION	**33.37**	58.03	77.49	31.49	61.81	71.81	32.96	33.29	33.06	**32.53**	34.52	34.87	44.60
	DISPLACEMENT	**9.27**	7.69	7.16	11.07	9.73	7.94	11.66	10.78	10.71	**9.13**	9.79	10.35	9.60
3 m/s	ACCELERATION	**32.59**	64.53	80.79	32.52	61.85	79.74	**33.18**	34.12	**34.36**	35.42	34.80	34.02	46.49
	DISPLACEMENT	**15.12**	12.87	7.15	17.73	14.97	13.88	**14.93**	17.36	**14.93**	18.69	16.58	17.36	15.13
4 m/s	ACCELERATION	33.02	64.41	80.27	32.52	64.28	82.50	34.21	34.27	34.83	34.12	35.76	33.79	47.00
	DISPLACEMENT	24.46	19.18	16.02	26.90	20.16	17.96	24.03	24.02	25.46	26.40	25.26	27.25	23.09

The displacement was also different for each impact velocity based on the hybrid layer's characteristic. The 2 m/s graph is slightly aligned and downward, while the 3 m/s graph is fluctuating. The graph shows an incremental trend for 4 m/s (Figure 2). Based on the experiment, impact velocity affects displacement more than acceleration for hybrid layer. Figure 3 shows a huge impact on material combination is shown for 2 m/s. It should be placed below B and C for maximum efficiency. Material B has a huge impact at 3 m/s. Material B should be positioned between A and C in terms of acceleration and displacement. Material C has a huge impact at 4 m/s. Material C should be placed in the middle or top of the design configuration for best results.

	D7	D8	D9	D10	D11	D12
2 m/s	**A**	C	B	C	B	**A**
	B	**A**	C	B	**A**	C
	C	B	**A**	**A**	C	B
	D7	D8	D9	D10	D11	D12
3 m/s	A	C	**B**	C	**B**	A
	B	A	C	**B**	A	C
	C	**B**	A	A	C	**B**
	D7	D8	D9	D10	D11	D12
4 m/s	**A**	C	**B**	C	**B**	**A**
	B	**A**	C	**B**	**A**	C
	C	**B**	**A**	**A**	C	**B**

Figure 3 The Combination/Hybrid Layer Result

4. CONCLUSION

Choosing the best materials based on acceleration and displacement is difficult. With a combination layer, however, both requirements can be met. This study found the best material using average values. To achieve 2 m/s and 3 m/s impact velocity, the best configuration is XXA (BCA, CBA). At 4 m/s, the foam tends to lose its acceleration and displacement functions. The combination layer sequence also affects acceleration and displacement. The best material is defined by its layers (i.e., density and mass). Using low density material at the bottom and high density material at the top is the best design. Also, for 3 and 4 m/s impact velocity combination layers, acceleration is flat while displacement fluctuates. Thus, when optimizing impact energy absorption, displacement is critical.

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