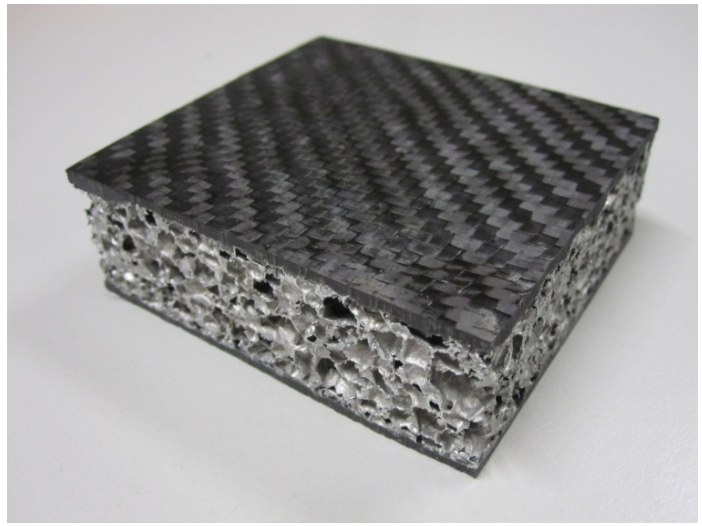
AutoCRC
Smarter Safer Cleaner

SWINBURNE UNIVERSITY OF TECHNOLOGY

C2-C23
Lightweight Modular Vehicle Platform (LMVP)

Composite Sandwich Panels – Deformation and Energy Absorption



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Chris Berndt

- Energy Absorption
  - Materials
  - Systems
- Overview of Composite Sandwich Structures
  - Brief History
  - Face and Core materials
  - Deformation Modes
- Research Outline
  - Aluminium Foams
  - Research Components
  - Outcomes
  - Applications

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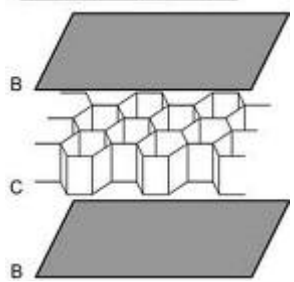

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$$\boldsymbol{P} = \begin{bmatrix} 2(\alpha_4+\alpha_6) & -2\alpha_4 & -2\alpha_6 & 0 & 0 & 0 \\ -2\alpha_4 & 2(\alpha_4+\alpha_5) & -2\alpha_5 & 0 & 0 & 0 \\ -2\alpha_6 & -2\alpha_5 & 2(\alpha_6+\alpha_5) & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha_7 & 0 & 0 \\ 0 & 0 & 0 & 0 & \alpha_8 & 0 \\ 0 & 0 & 0 & 0 & 0 & \alpha_9 \end{bmatrix}$$

[1] www.wn.com
[2] www2.tbo.com

[1]

Table 1. Changes in ranking for most important causes of death from 1990 to 2020 in baseline scenario

Disorder	Ranking		Change in ranking
	1990	2020 (baseline model)	
Within top 15			
Ischaemic heart disease	1	1	0
Cerebrovascular disease	2	2	0
Lower respiratory infections	3	4	↓1
Diarrhoeal diseases	4	11	↓7
Perinatal disorders	5	16	↓11
Chronic obstructive pulmonary disease	6	3	↑3
Tuberculosis	7	7	0
Measles	8	27	↓19
Road-traffic accidents	9	6	↑3
Trachea, bronchus, and lung cancers	10	5	↓5
Malaria	11	29	↓18
Self-inflicted injuries	12	10	↑2
Cirrhosis of the liver	13	12	↑1
Stomach cancer	14	8	↑6
Diabetes mellitus	15	19	↓4
Outside top 15			
Violence	16	14	↓2
War injuries	20	15	↑5
Liver cancer	21	13	↑8
HIV	30	9	↑21

[2]

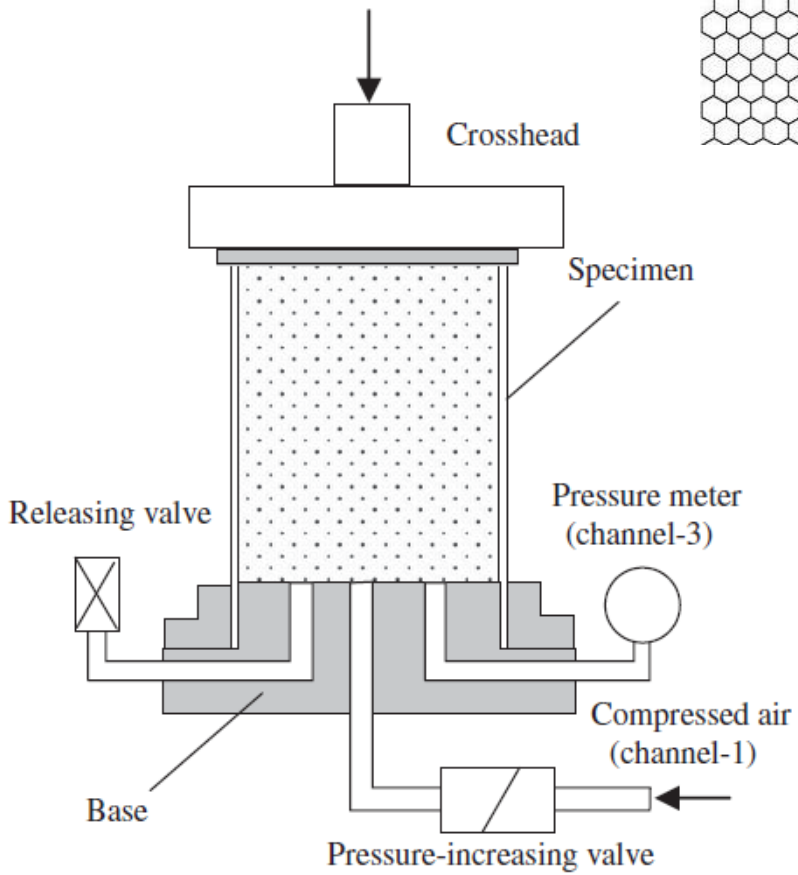
[3]

[3]

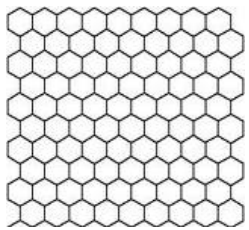
[1] Allan D. Lopez, World Health Organisation/World Bank, "The Global Burden of Disease", Geneva, 2002
[2] HeraldSun.com.au
[3] www2.tbo.com

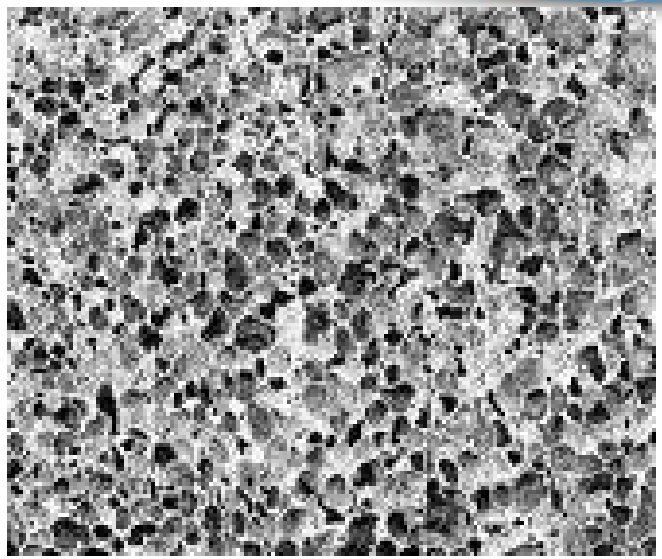
Energy Absorbing Systems and Materials

[1]



Pressurised thin wall tubes

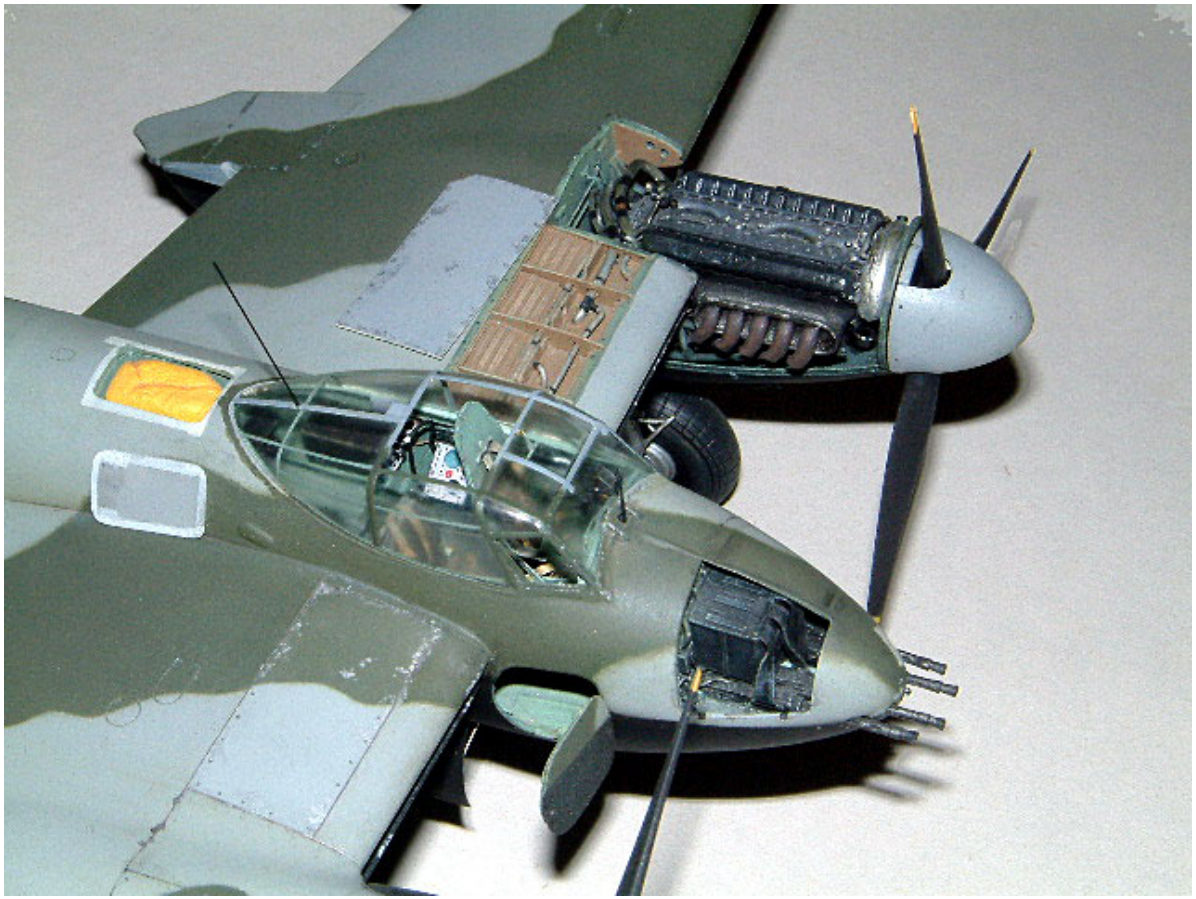




[2]

[1] X.W. Zhang and T.X. Yu,"Energy absorption of pressurized thin walled circular tubes under axial crushing"' IJMS 51 (2009), 335-349
[2] Z. Y. Gao:,T. X. Yu; and H. Zhao, "Mechanical Behavior of Metallic Hollow Sphere Materials:Experimental Study", ASCE , 2008

Early implementation of sandwich panels



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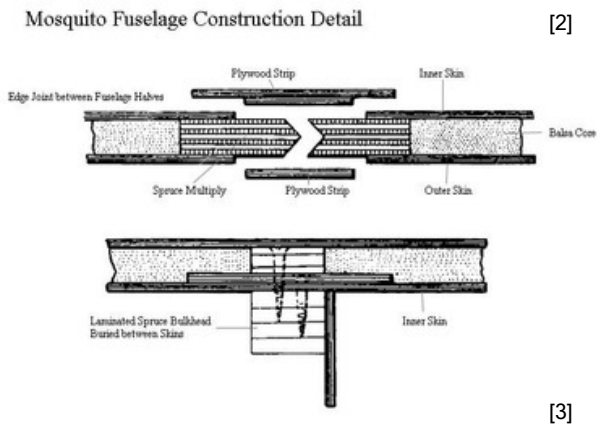


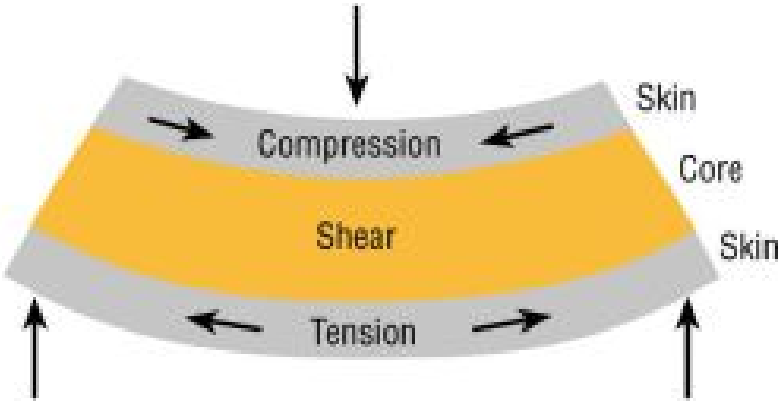
[2]

[3]

de Havilland Mosquito – Veneer face sheets and balsa core used for fuselage parts

[1] www.hsgalleries.com
[2} www.cr4.globalspec.com
[3] www.sequair.com

Deformation of sandwich panels



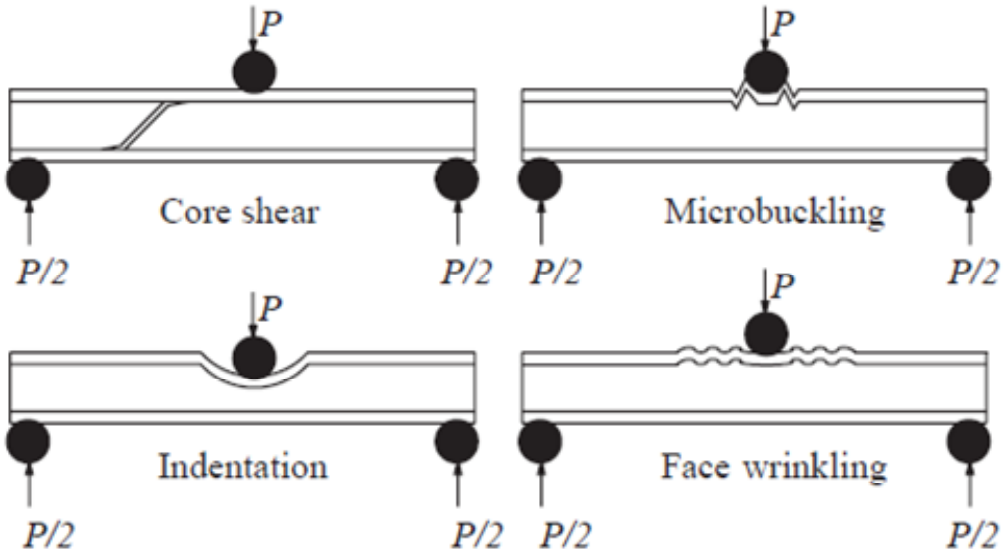
$$\delta = \frac{PL^3}{48(EI)_{eq}} + \frac{PL}{4(AG)_{eq}}, \quad [1]$$

where $(EI)_{eq}$ is the equivalent flexural rigidity

$$(EI)_{eq} = \frac{E_f b t_f d^2}{2} + \frac{E_f b t_f^3}{6} + \frac{E_c b c^3}{12} \approx \frac{E_f b t_f d^2}{2}$$

and $(AG)_{eq}$ is the equivalent shear rigidity

$$(AG)_{eq} = \frac{bd^2 G_c}{c} \approx bdG_c,$$



[2]

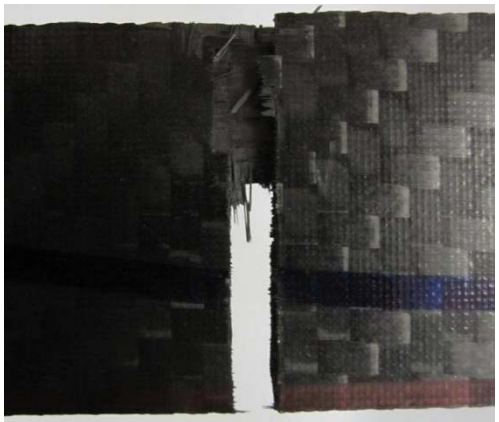
C. A. Steeves and N. A. Fleck, "Material selection in sandwich beam construction," *Scripta Materialia,* vol. 50, pp. 1335-1339, 2004.

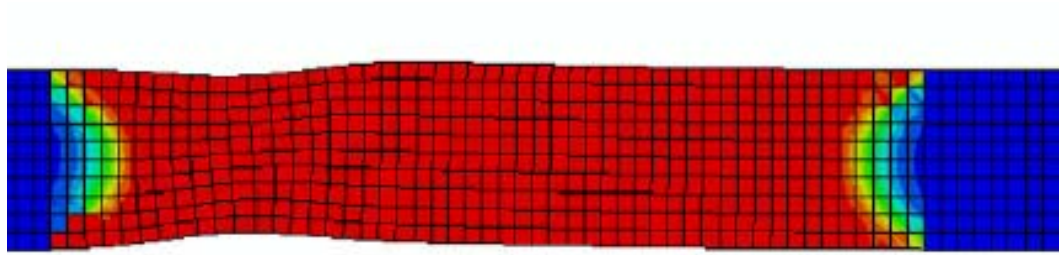
Carbon Fibre Composites

[1]

Hierarchy of structure and models of a textile composite

Structure	Elements	Models
Yarn (tow)	Fibres	Fibre distribution in the yarn and its change under load/strain Mechanical properties of the yarn
Fabric (woven, knitted…)	Yarns	Geometry of yarns in the fabric and its change under load/strain Mechanical behaviour of the fabric repeat under complex loading
Composite unit cell	Fabric Matrix	Mechanical properties (stiffness matrix/non-linear; strength) Permeability tensor
Composite part	(Deformed) unit cells	Behaviour under loading Flow of the resin Behaviour in the forming process

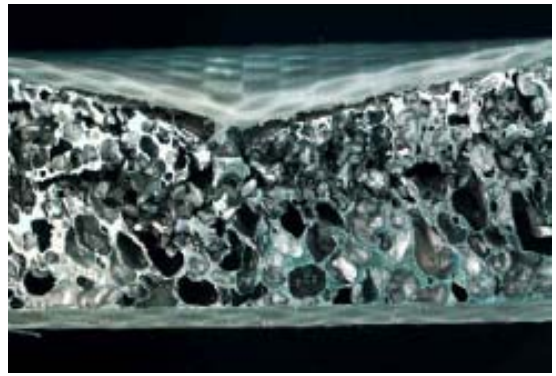


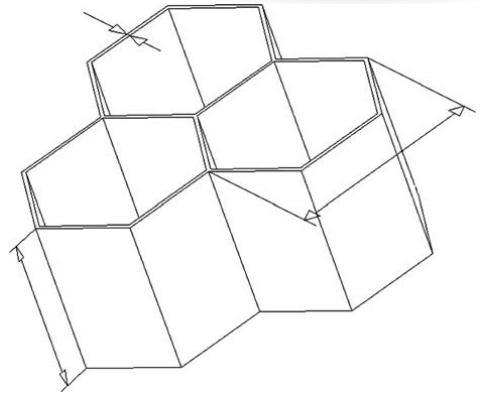


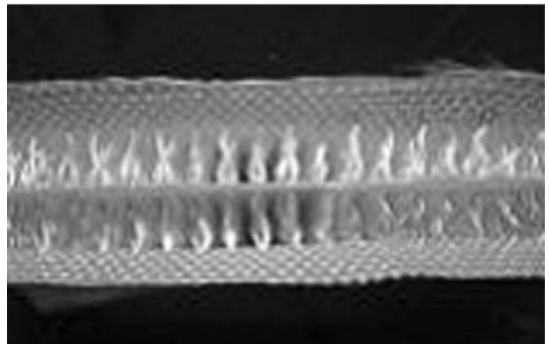
[1} Christos C. Chamis, “Polymer Composite Mechanics Review 1965 to 2006”, *Journal of Reinforced Plastics and Composites 2007; 26; 987*

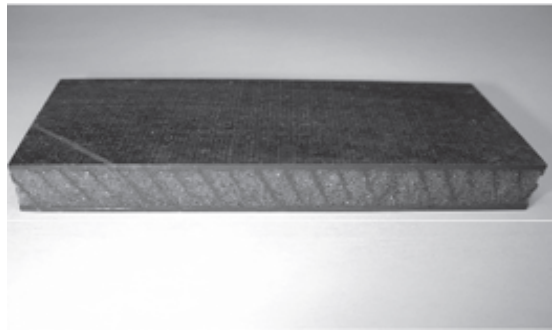
Core Types

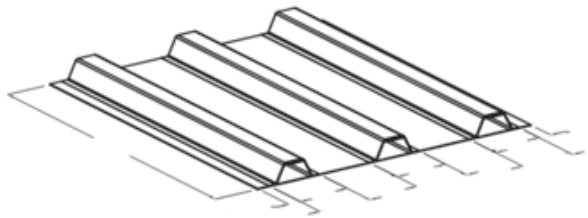
- Foams
  - Syntatic
  - Metallic
  - Polymeric
  - Ceramic
- Honeycombs
  - Polymeric
  - Metallic,
- 3D integrated
- Corrugated
- Truss
- Z-pinned

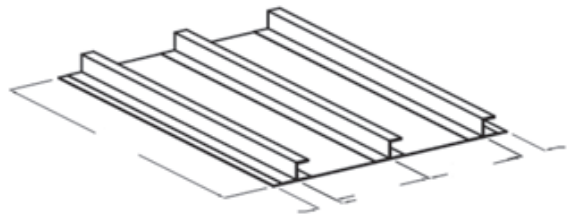






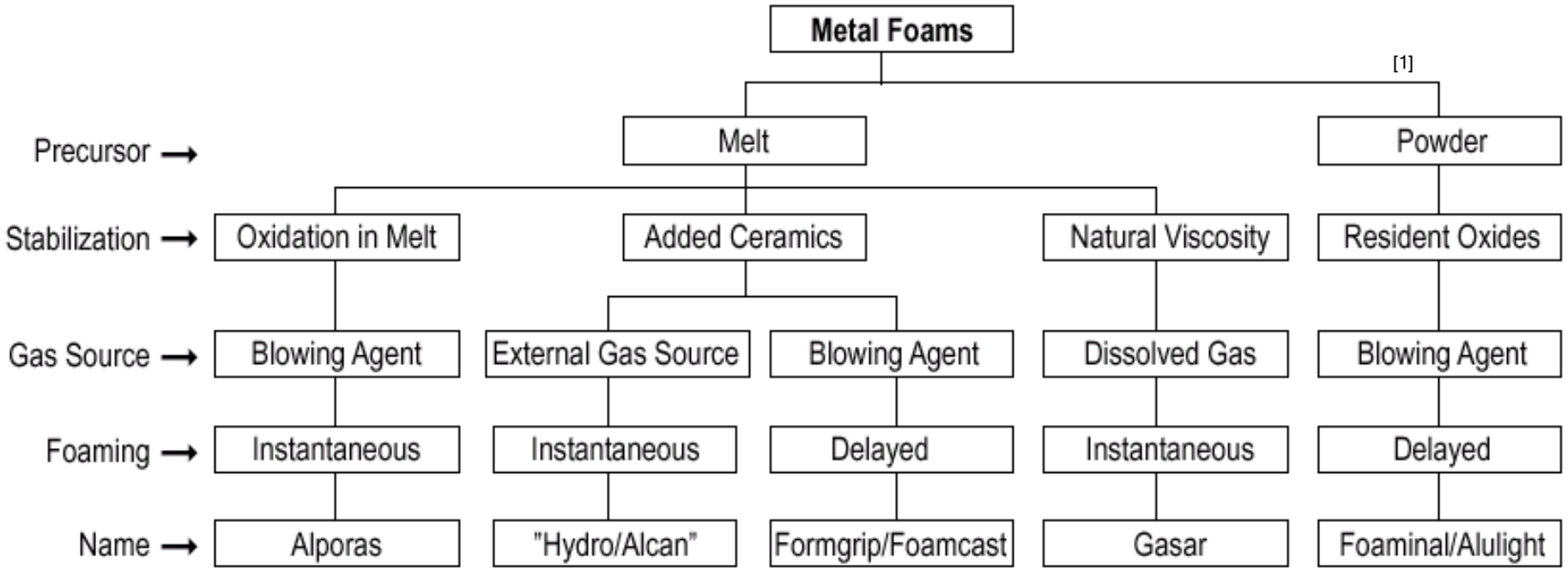




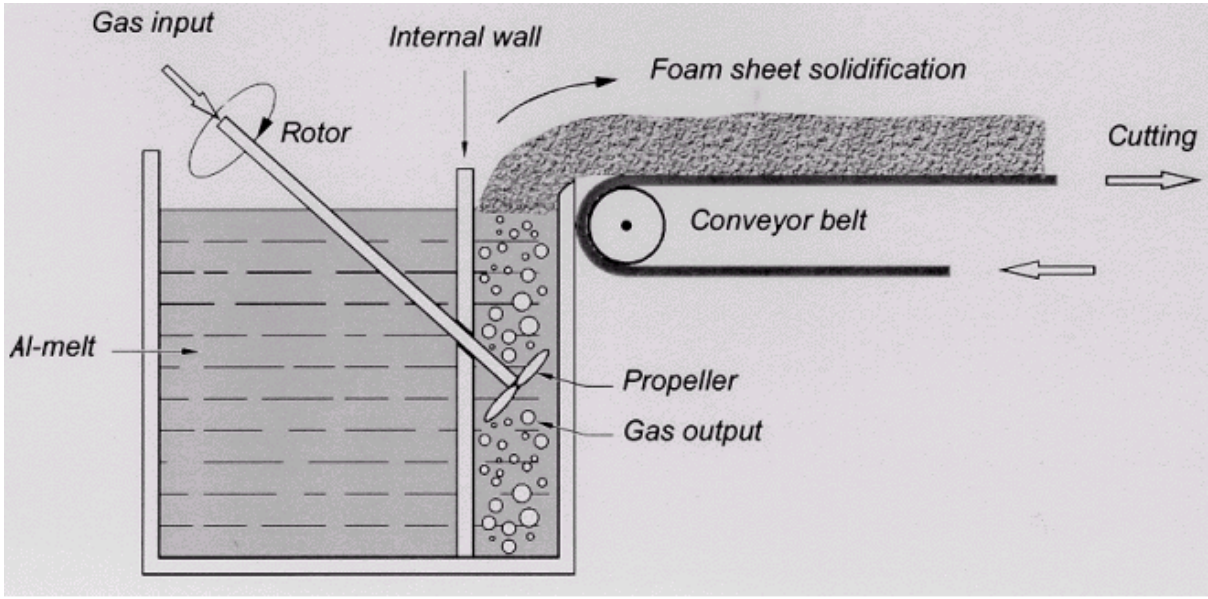


Shaokai Wang, Min Li, Zuoguang Zhang and Boming Wu, „Properties of Facesheet-reinforced 3-D Spacer Fabric Composites and the Integral Multi facesheet structures", JRPC 29, 2009
F. Eladi, "Structural Efficiency and Post-buckling Strength of J- and Hat-stiffened Composite Panels", JRPC 29, 2009
D. Long, J. Guiqiong and H. Tao, "Investigation of the Effect of Z-Pin Reinforcement on the Collapse of Foam-Cored Sandwich Structures:, JRPC 27, 2008
Uday K. Vaidya , *Selvum Pillay , Shane Bartus , Chad A. Ulven* Dana, T. Growc, Biju Mathewc, "Impact and post-impact vibration response of protective metal foam composite sandwich plates", Materials Science and Engineering A 428 (2006) 59-66

Aluminium Foam Manufacturing



[1] www.tms.org



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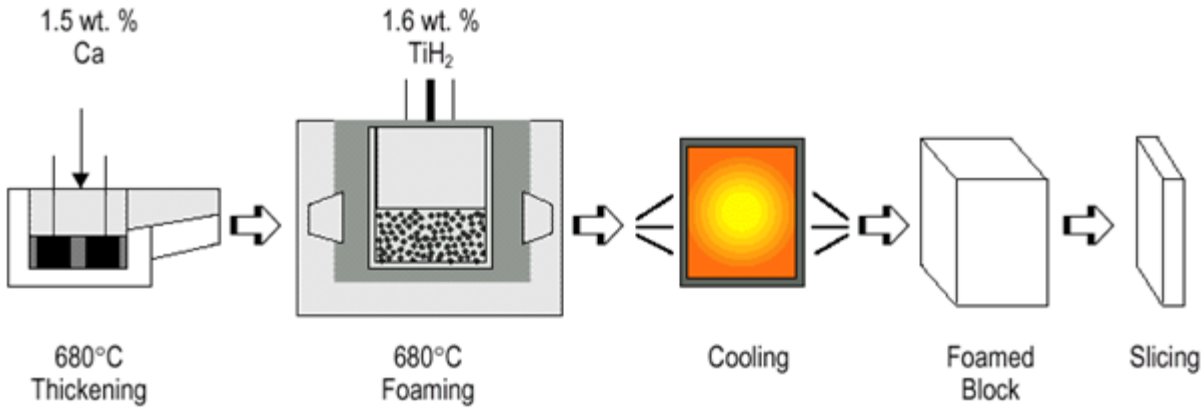
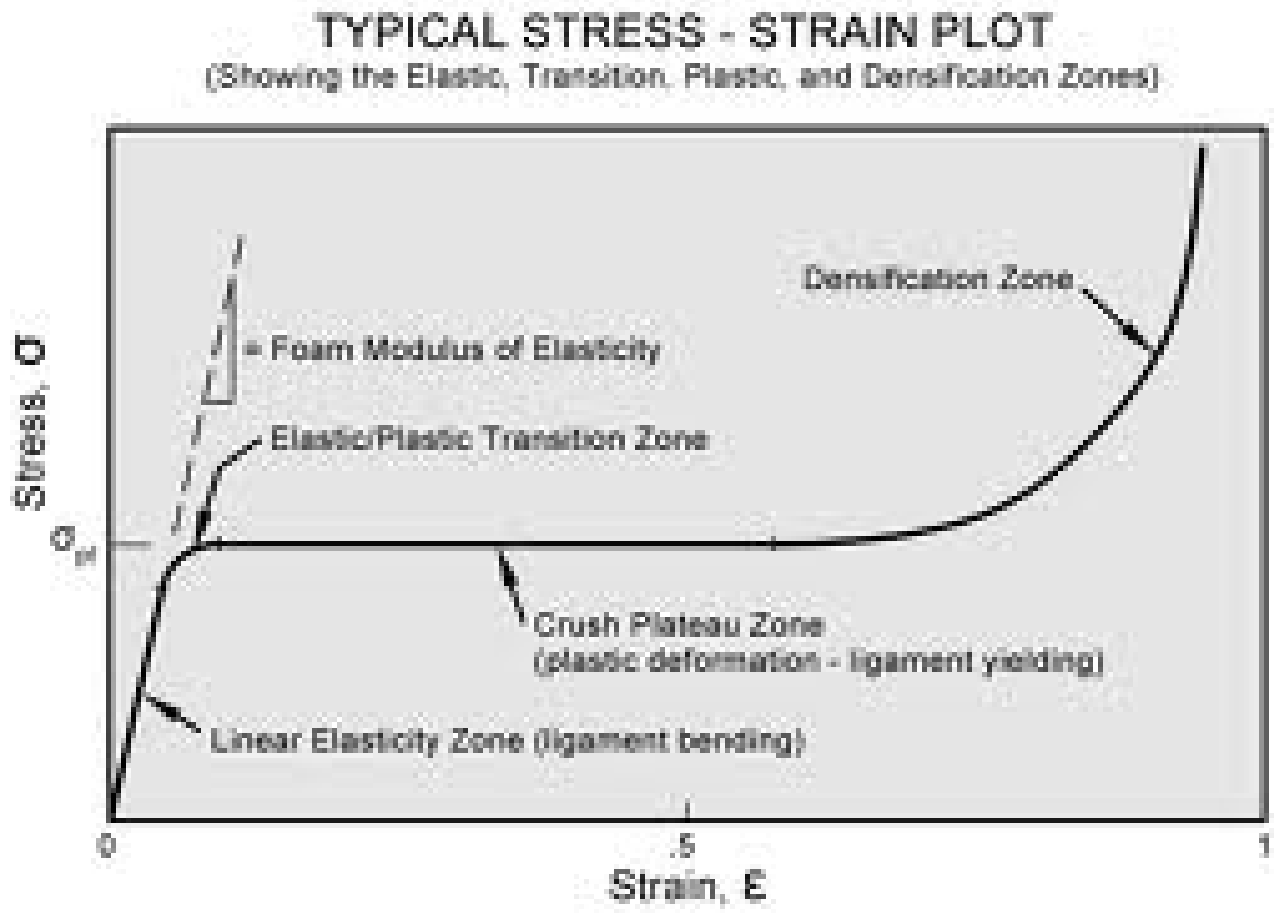


[2]

[1],[2] www.tms.org

Stress-Strain curve for Aluminium Foams

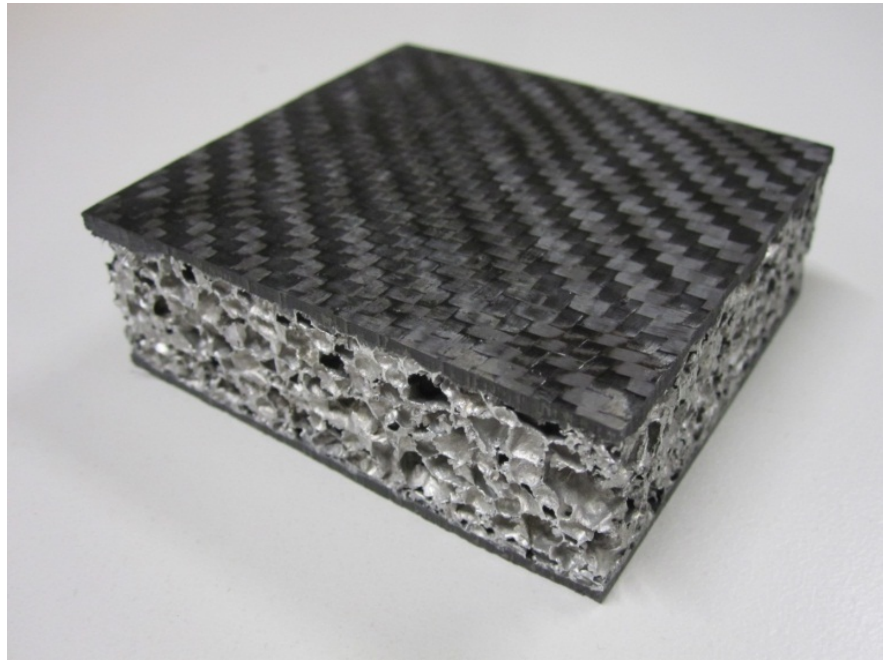


[1]

[1] www.ergaerospace.com

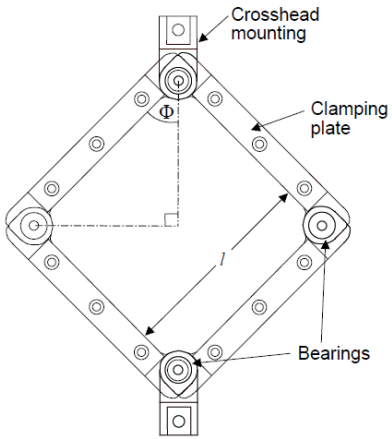
Research

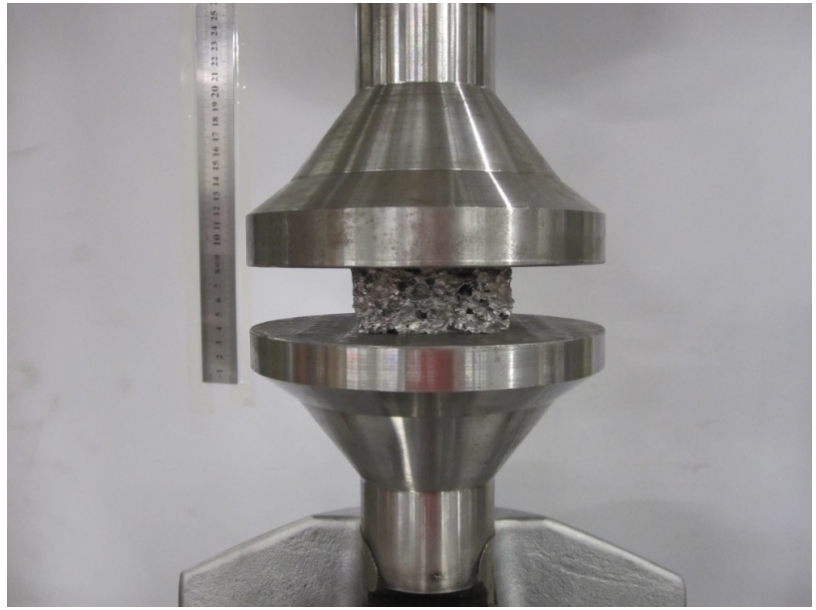
- Experiments
- FEA
- Analytical model



Experiments

- Quasi-static material testing of face sheet and core materials
  - Compression
  - Tension
  - Four-point bending
  - Picture frame testing

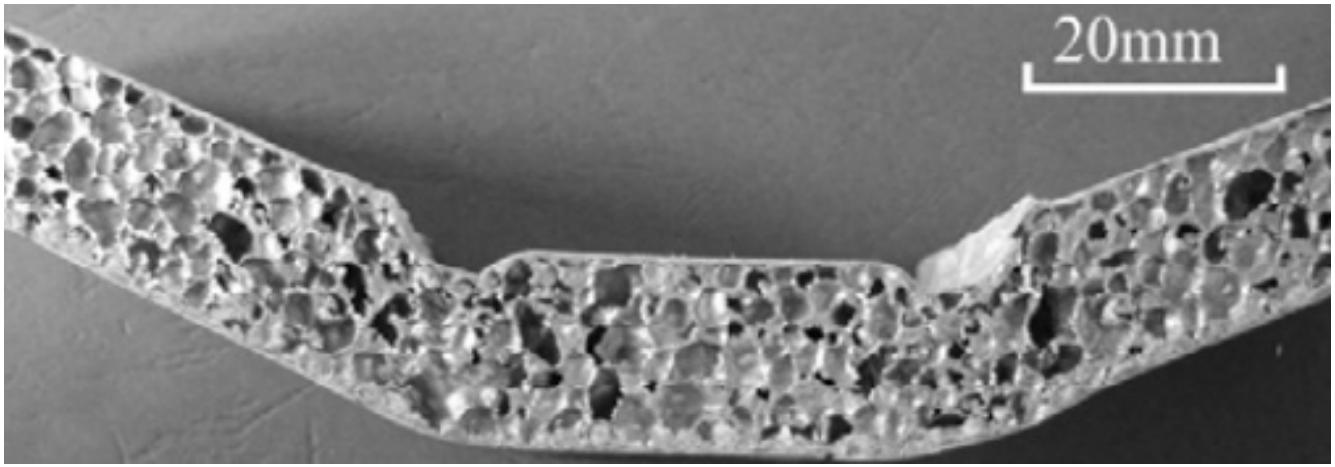




- Quasi-static mechanical testing of composite sandwich structure
  - Compression
  - Four-point bend testing

Experiments

- Low Velocity impact testing of face sheets and mechanical testing of the composite sandwich structure
  - Instron High Velocity Testing Machine
  - Drop Tower
  - Four point bending



M. Styles , P. Compston, S. Kalyanasundaram, “The effect of core thickness on the flexural behaviour of aluminium foam sandwich structures”, Composite Structures 80 (2007) 532-538

FEA and Analytical Model

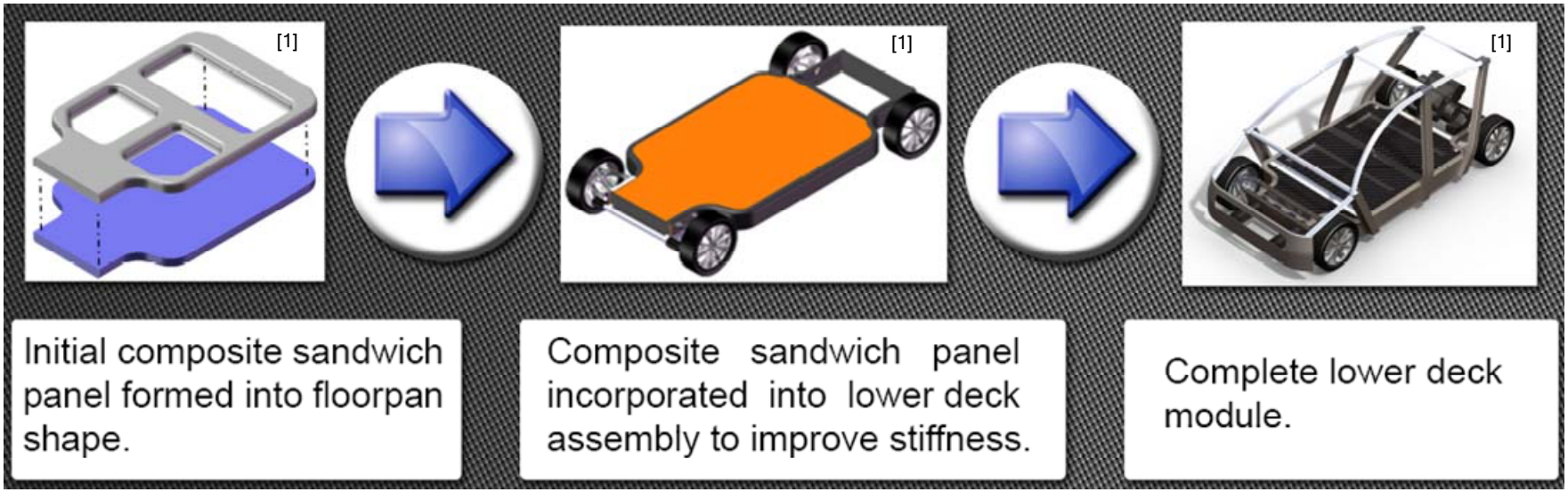
- FEA models will be created to mimic testing load applications and validated with experimental data.
- Parametric studies will be conducted to study effects of
  - Core thickness
  - Face sheet thickness
  - Bonding layer thickness

On the structure to observe the flexural behaviour and energy absorption.

M. Styles , P. Compston, S. Kalyanasundaram, “The effect of core thickness on the flexural behaviour of aluminium foam sandwich structures”, Composite Structures 80 (2007) 532-538

Outcomes

- Accurate analytical model to describe loading cases required for virtual prototyping
- Experimental data
- Robust FEA models



[1] Timothy de Souza, “100706_concept_design_TD”, AutoCRC Portal, 2010

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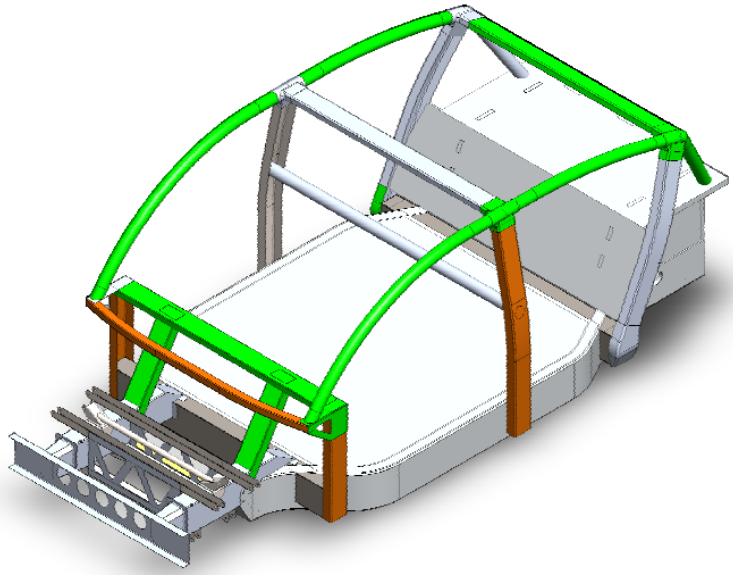

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