Advanced Core Materials for Sandwich Structures used in the Aerospace Industry: Past, Present and Future

SAMPE Brazil Conference 2015
22nd October - Sao José dos Campos

Fabio Tufano
Technical Sales & New Business Development South America
Evonik Degussa Brasil Ltda.

M. Alexander Roth, Dr.-Ing.
Director ROHACELL® Americas & Vice President
Evonik Foams Inc.
1. Overview
2. Sandwich Structures in the Aviation Industry
3. Core Materials
4. Composites Evolution in Aircraft Applications
5. Success Case: NLGD Airbus
Common principle found in nature and older than mankind itself!
Common principle found in nature and older than mankind itself!

- Bigger cells in the center
- Close to a monolithic structure in the outside

Source of image: http://www.thebonsaicast.com, 10/13/2015
Overview

Common principle found in nature and older than mankind itself!

Agave

- Foamy material in the center
- Close to a monolithic structure in the outside

Stipe

- Foamy material in the center
- Close to a monolithic structure in the inner/outer skin

Natural sandwich structures are subjected to complex load cases!

- Repetitive Moves
- Super positioned bending and compression loads

Moreover nature imposes a strict demand for lightweight primary structures!

Principle of structural optimization: minimum use of material for maximum performance!
What are sandwich structures?

A structural SANDWICH is a special form of a composite that combines at least two different materials by bonding them to each other so as to utilize the properties of each separate component to the structural advantage of the entire assembly.
A structural **SANDWICH** is a special form of a composite that combines at least two different materials by bonding them to each other so as to utilize the properties of each separate component to the structural advantage of the entire assembly.
Why sandwich constructions?

- bending stiffness
- bending strength
- weight

Why sandwich constructions?

- bending stiffness
- bending strength
- weight

Sandwich Structures are especially suitable for bending and axial compressive loaded parts to increase:

- Bending stiffness and strength
- Buckling and crash performance
- Lightest solution!

In a nutshell, core materials serve to...

Mainly:
- Keeping Distance between Layers
- Stabilization of Cover Layers
- Transferring Shear Forces from Layer to Layer

But also:
- Absorption of Impact Loads
- Thermal Insulation
- Acoustic Insulation
- Vibration Dampening
- ...

(Evonic Industries logo)
1. Overview
2. Sandwich Structures in the Aviation Industry
3. Core Materials
4. Composites Evolution in Aircraft Applications
5. Success Case: NLGD Airbus
A long time ago...

1924: Von Karman and Stock patented a glider plane applying sandwich constructions for fuselage structures

A long time ago...

1924: Von Karman and Stock patented a glider plane applying sandwich constructions for fuselage structures.

1938: S.E Mautner presented in Paris, at the Salon d’Aeronautique, first complete research about the use of sandwich structures in aircrafts. The result was a monoplane fully equipped with core materials in its wings.

25th of November, 1940: First flight from **DeHavilland DH.98 Mosquito**.
- Manufactured by DeHavilland, a british company, the plane was nicknamed as “The Wooden Wonder”, because it was almost entirely made of balsa-wood core with plywood skins.
- Was largely used by the British army during World War II as a fast bomber.
And the first aircraft produced in series

**DH.98 Mosquito** was a breakthrough in the history of composite applications in the aircraft industry.
“The Mosquito was an unusual machine, reflecting unconventional thinking in both operational concept and manufacture. It had to overcome stiff official resistance before it was finally accepted for service. Once it was, it was built in the thousands, with dozens of marks”.

Air marshall Sir Wilfrid Freeman
1915: H. Junkers patents the first honeycomb cores for aircraft applications.

1946: R. Steele and R. Hughess, two young World War II veterans found Hexcel, the world largest composites company.

1969: First well known application for Honeycombs with Boeing 747 (fuselage cylindrical shell and interior applications) and with Apollo 11 Project (shock attenuation along the command landing module).

1915: Chemistry of Methacrylic acid starts to be developed by Evonik, under the former company Röhm & Haas GmbH. (Acrylic Sheets with the trade name Plexiglas)

1965  First laboratory Sample
1967  Presentation at the Plastics Exhibition K 67 in Düsseldorf
1969  Laboratory Production
1915: Chemistry of Methacrylic acid starts to be developed by Evonik, under the former company Röhm & Haas GmbH. (Acrylic Sheets with the trade name Plexiglas)

- 1965  First laboratory Sample
- 1967  Presentation at the Plastics Exhibition K 67 in Düsseldorf
- 1969  Laboratory Production
- 1972  Production Line of ROHACELL® 31 IG, 51 IG, 71 IG, 110 IG
- 1981  Production Line of ROHACELL® 51 WF, 71 WF, 110 WF, 200 WF, 300 WF
- 1989  Production Line of ROHACELL® HF
- 1990  ROHACELL WF was used in McDonnell Douglas MD11
1915: Chemistry of Methacrylic acid starts to be developed by Evonik, under the former company Röhm & Haas GmbH. (Acrylic Sheets with the trade name Plexiglas)
1965 First laboratory Sample
1967 Presentation at the Plastics Exhibition K 67 in Düsseldorf
1969 Laboratory Production
1972 Production Line of ROHACELL® 31, 51, 71, 110 IG
1981 Production Line of ROHACELL® 51, 71, 110, 200, 300 WF
1989 Production Line of ROHACELL® HF
1990 ROHACELL WF was used in MD11
1993 Production Line of ROHACELL® S
1997 Production Line of ROHACELL® XT
2002 Production Line of ROHACELL® RIST and RIMA
2003 Production Line of ROHACELL® EC
2010 Production Line of ROHACELL® HP, WIND-F
2014 Production Line of ROHACELL® HERO and SL (ductile)
2015 Production Line of ROHACELL® TripleF (in-mold-foaming)
Nowadays ROHACELL is used in numerous Aerospace applications:
1. Sandwich Structures
2. History of Sandwich Structures in the Aviation Industry
3. Core Materials
4. Composites Evolution in Aircraft Applications
5. Success Case: NLGD Airbus
Honeycombs

Honeycombs (AF-Fiber, Aluminum, Nomex)

- Hexcel
- Euro-Composites
- The Gill Corporation

Pros

- Best specific mechanical values
- Nomex best FST behavior

Cons

- Debonding issues due to water ingression
- Anisotropic behavior
- Complex geometries are very difficult to handle
- Potting leads to weight gain and lots of work
- 2 shoot curing leads to high production costs
Rigid Foams for Aircraft Applications

- PMI – EVONIK
- PVC – DIAB/Gurit
- PEI – AIREX / SABIC
- PPSU – SOLVAY
- PES – DIAB

**PROS**
- Closed or partly closed cell - less resin absorption
- Easy handling also at complex geometry
- Isotropic behavior

**CONS**
- Havier than honeycomb in non-complex structures
- More expensive
Rigid Foams for Aircraft Applications

- PMI – EVONIK
- PVC – DIAB/Gurit
- PEI – AIREX / SABIC
- PPSU – SOLVAY
- PES – DIAB

**PROS**

- Closed or partly closed cell - less resin absorption
- Easy handling also at complex geometry
- Isotropic behavior

**CONS**

- Havier than honeycomb in non-complex structures
- More expensive
1. Sandwich Structures
2. History of Sandwich Structures in the Aviation Industry
3. Core Materials
4. Composites Evolution in Aircraft Applications
5. Success Case: NLGD Airbus
Composites Evolution

45 Years of Composites Evolution (Commercial Transports)

BUT WHY?

Main reason: why so much composites?
Main reason: why so much composites?

Resource efficiency!
- Structural optimization
- Aerodynamics improvements
- Falling production costs
- Increase of knowledge

1. Sandwich Structures
2. History of Sandwich Structures in the Aviation Industry
3. Core Materials
4. Composites Evolution in Aircraft Applications
5. Success Case: NLGD Airbus
Foam / Infusion
This foam sandwich part was originally constructed as a 71/200 WF core in infusion technique for Do728. All qualification steps were made. Now, it was optimized for 71 HERO with dry fabrics to stay in infusion manufacturing technique.
Foam / Infusion
This foam sandwich part was originally constructed as a 71/200 WF core in infusion technique for Do728. All qualification steps were made. Now, it was optimized for 71 HERO with dry fabrics to stay in infusion manufacturing technique.

Honeycomb / Prepreg
Baseline for the comparison is an NLG door similar to the A320 design and a process using Nomex honeycomb (64 kg/m³ - 4,8 mm) and prepreg (Fibredux 913C-926-40%).
Demonstrator and evaluation part:
Nose Landing Gear Door (NLGD)

Foam / Infusion
This foam sandwich part was originally constructed as a 71/200 WF core in infusion technique for Do728. All qualification steps were made. Now, it was optimized for 71 HERO with dry fabrics to stay in infusion manufacturing technique.

Honeycomb / Prepreg
Baseline for the comparison is an NLG door similar to the A320 design and a process using Nomex honeycomb (64 kg/m³ - 4,8 mm) and prepreg (Fibredux 913C-926-40%).

Foam / Prepreg
Additionally, we compare the foam with an Autoclave (Prepreg) process in a situation where honeycomb is replaced by foam, but the process stays the same (180°C / 50psi).
The time advantage: Where are the main differences?

Comparison of time by process step

- Honeycomb/Prepreg
- Foam/Prepreg
- Foam/Infusion
The time advantage: Where are the main differences?

Comparison of time by process step

Honeycomb/Prepreg
Foam/Prepreg
Foam/Infusion
2 shot curing
Core handling

Prepreg instead of infusion

Time for each step [h]
Cost advantage results: Save 21 – 25 % using foam!

Cost comparison NLG door

Labor: 55€/h
Machine and Labor: 85€/h

- Honeycomb/Prepreg
- Foam/Infusion
- Foam/Prepreg
Weight advantage results: Save 19% using foam!

Weight comparison NLG door

- Honeycomb/Prepreg: 100%
- Foam/Prepreg: 81%
- Foam/Infusion: 81%

- No need for potting
- No adhesive film
The main structural load case for an NLG door is the bird strike test. To prove the weight and cost optimization, the part must pass a typical bird strike test (1.8kg bird strike / speed of 540 km/h).

A bird strike is most critical when the NLGD is closed during the landing approach!
Main load case: Bird Strike test results

Condition of the part after bird strike testing

Test parameters:
1.9 kg gel bird / speed: 515 km/h

Evaluation:
Local delamination, but the part is still working and can withstand all required aerodynamic loads. Even without any rivets on the structure!

The NLGD passes the test!
HERO outperforms honeycomb

4 - Superior
3 - Excellent
2 - Very good
1 - Good
0 - Unacceptable
Making the WORLD lighter!

ROHACELL®
The Core of Sandwich Solutions