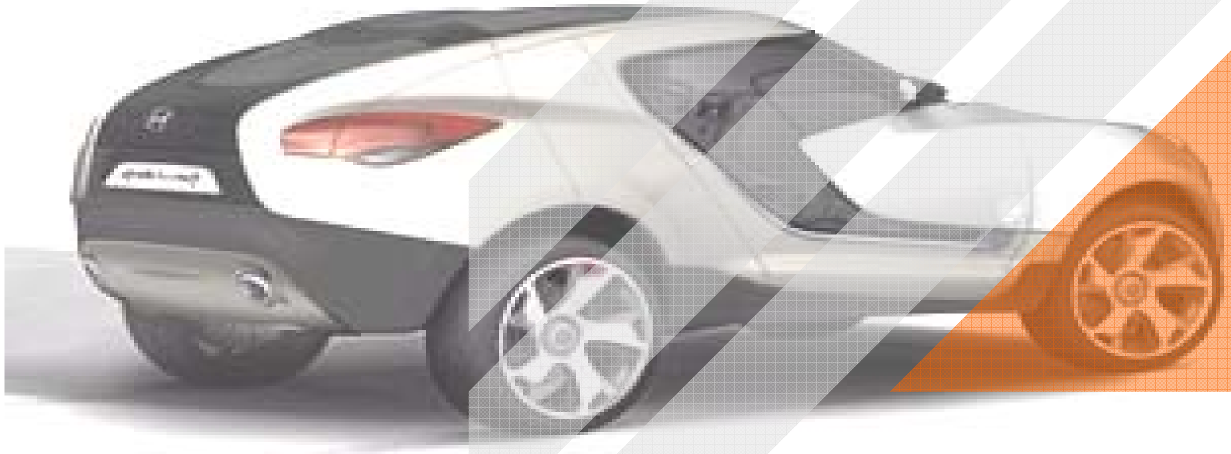
Automotive
Composites
Conference
& Exhibition 2008

IXIS ®

Hybrid ThermoPlastic Composite (HTPC) for Horizontal Automotive Panels



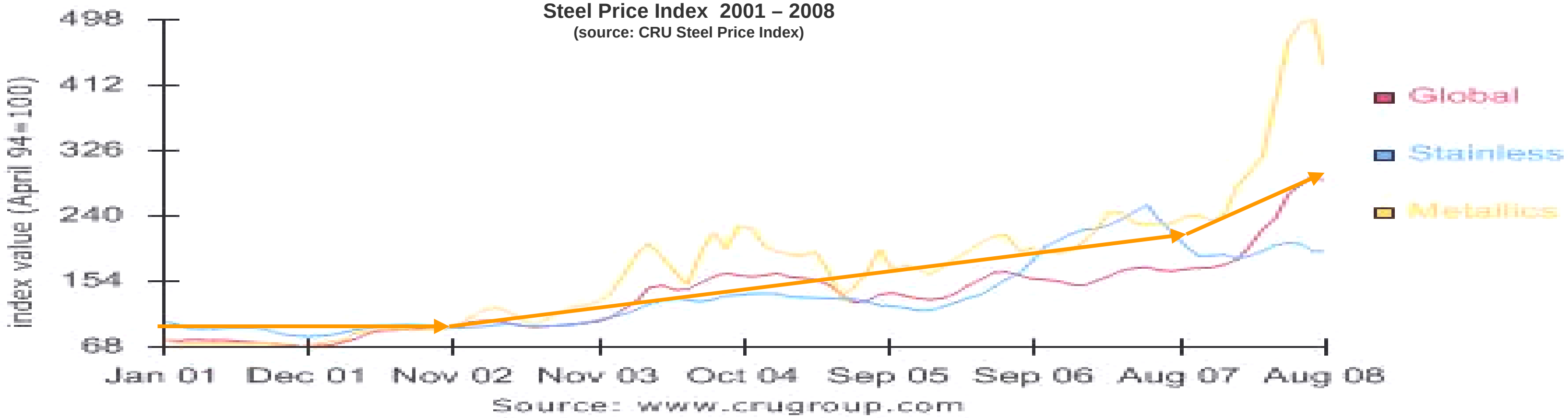
Presentation by

Mike Birrell - Director - Exterior Composites - Azdel Inc.

Why consider composites?
Steel cost trend – 2001 to present

- Global steel prices have been rising at 14.4% year on year 2001-2007 **(source: CRU Steel Price Index)**
- The largest market for steel is in construction
- The second largest market (18%) is automotive
- Energy to produce: 20 Giga joules (10^9J) / tonne

Steel Price Index 2001 – 2008
(source: CRU Steel Price Index)



What does the market require?
Automotive

- Light weight ‘body in white’ solutions are needed to match energy efficient power trains
  - Hybrids can achieve 100mpg without loss of performance
  - Steel is heavy and expensive to tool
- Energy efficient material production and conversion
  - Steel production is energy intensive
- New materials must add safety and be easy to recycle
  - Thermoset composites are not economically recyclable
- OEMs also require:
  - Damage tolerance
  - Low NVH
  - Low cost and investment
  - Design flexibility
  - Signal transparency

Learning from Aerospace Technology
A Thermoplastic Solution

In aerospace applications, continuous unidirectional fibres give the required dimensional stability and surface finish.

Engineering composites, using the same technology, have been developed to meet Automotive Industry requirements.

High temperature resins are replaced by engineering plastic polymers that can be fast cycled.

Carbon fibre is replaced by glass fibre, but can be offered as a premium product where the additional 20% weight saving will withstand the added cost

Commercial airliners >50% composite structures
Military aircraft up to 100% composite structures

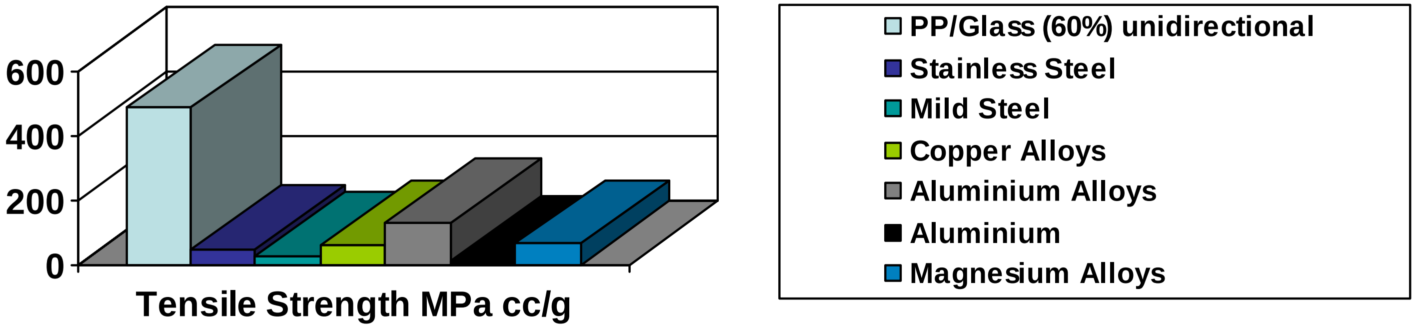
Aerospace composites – predominantly thermoset

Automotive ≈ 20% composites

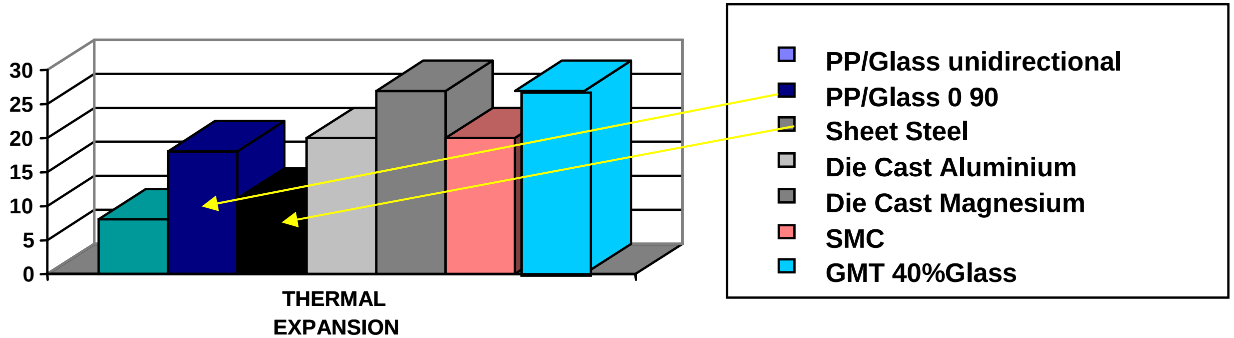
Continuous Unidirectional Glass Fibre Reinforced Polypropylene Composite

Continuous unidirectional glass fibre reinforced (60% by weight 35% by volume) Polypropylene composite (melt impregnated)

Specific Tensile Strength



Linear Coefficient of Thermal Expansion

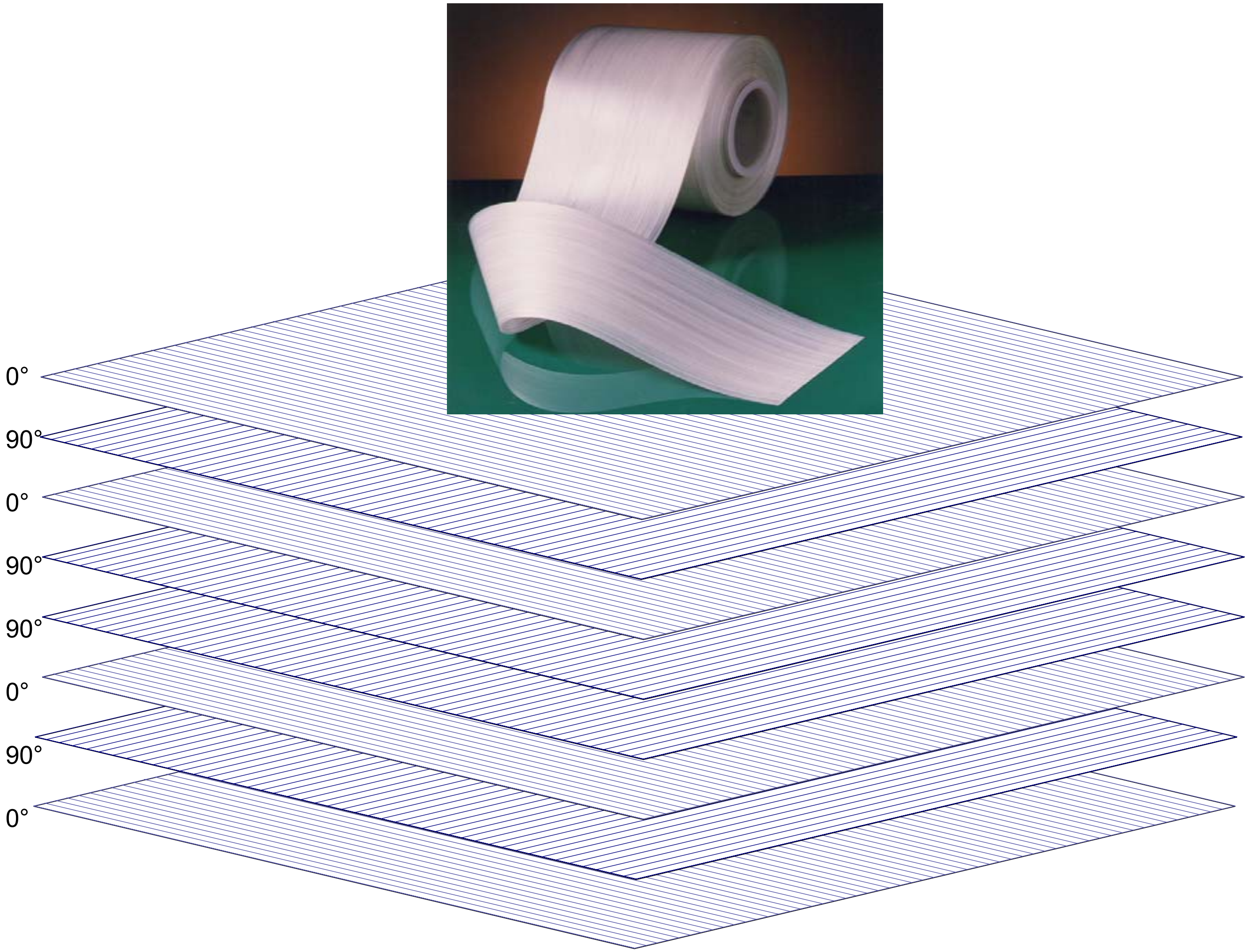


Composite pre-preg lay-ups

Conventional composite prepregs are laid up as quasi-isotropic or 0º 90º balanced structures.

This has design limitations for high volume production.

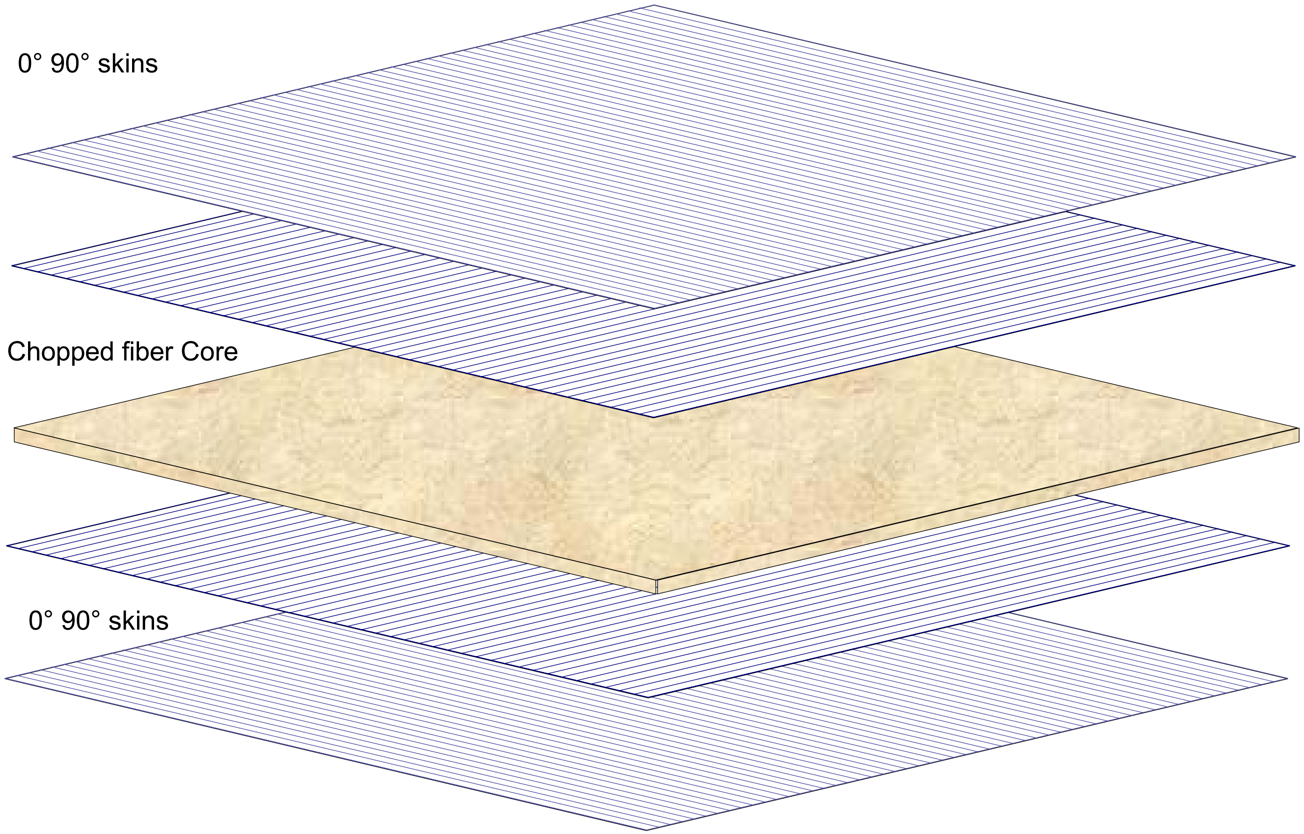
It can also be expensive.



Hybrid Thermoplastic Composite (HTPC) Developed for volume Automotive Production

The core structure of HTPC has a random glass reinforced structure.

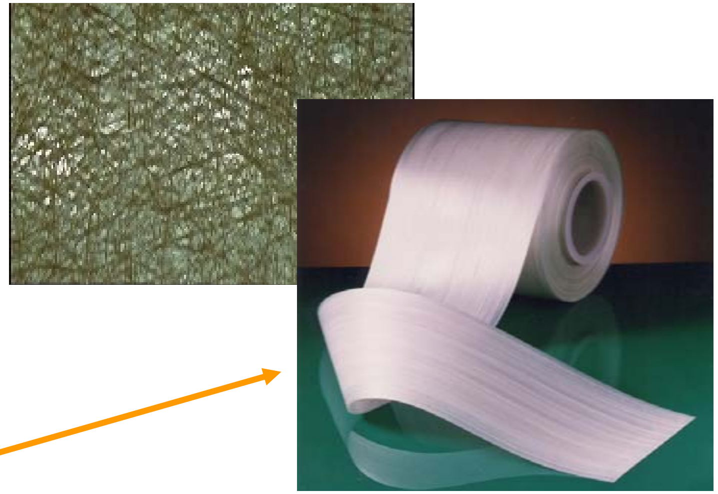
This improves processability allowing greater design flexibility and faster component production



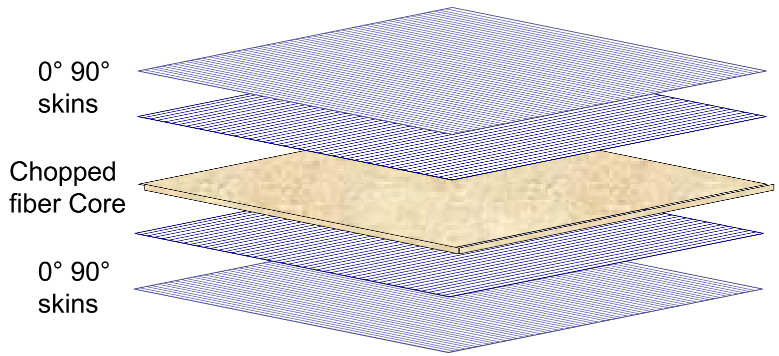
Hybrid Thermoplastic Composite (HTPC) Product Form

HTPC is a hybrid composite, combining the versatility of random fibre reinforcement with the thermal stability, strength and paintability of continuous unidirectional fibre reinforced thermoplastic

- Continuous random glass fibre reinforced thermoplastic
- Continuous unidirectional glass fibre reinforced thermoplastic (melt impregnated)



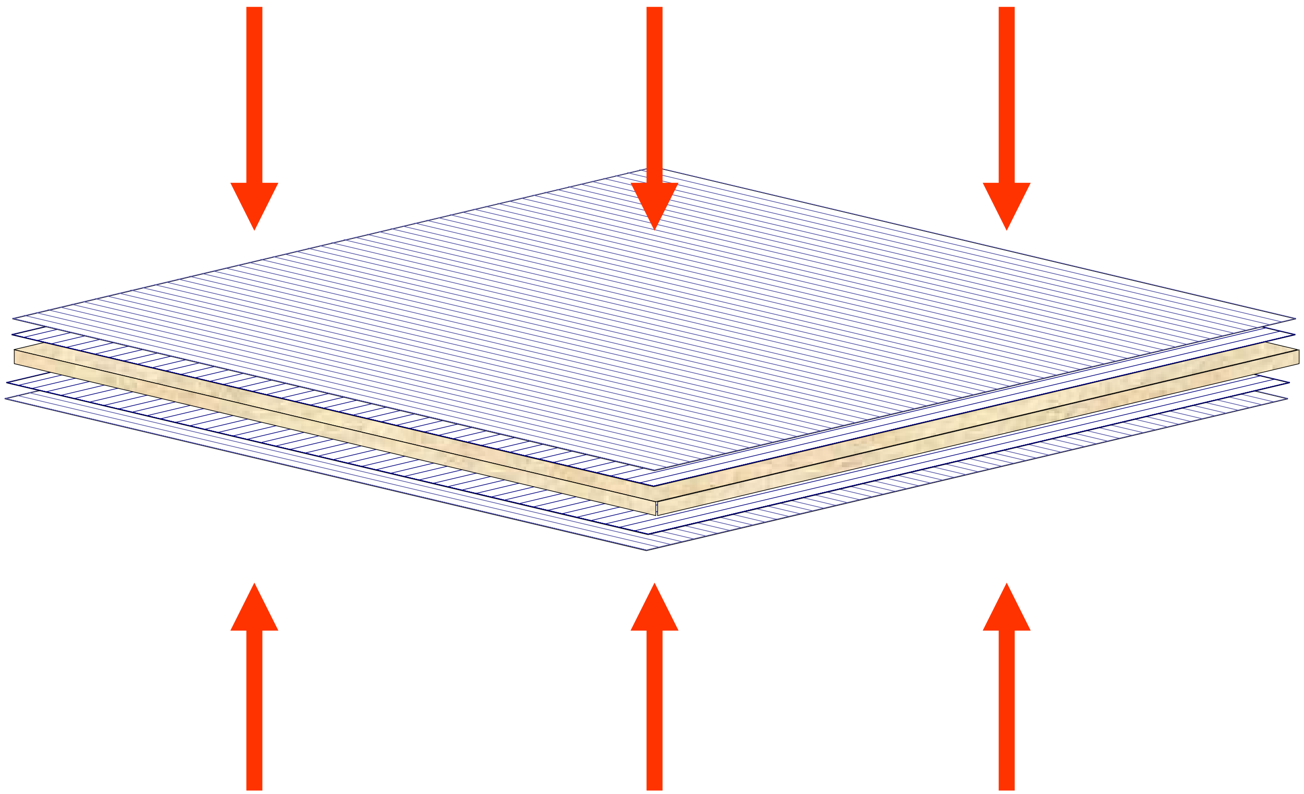
HTPC competes with steel on cost, but offers the weight of aluminium, together with the damage tolerance and sound deadening of thermoplastic materials.



Fully recyclable into engineering applications

HTPC - Product Form

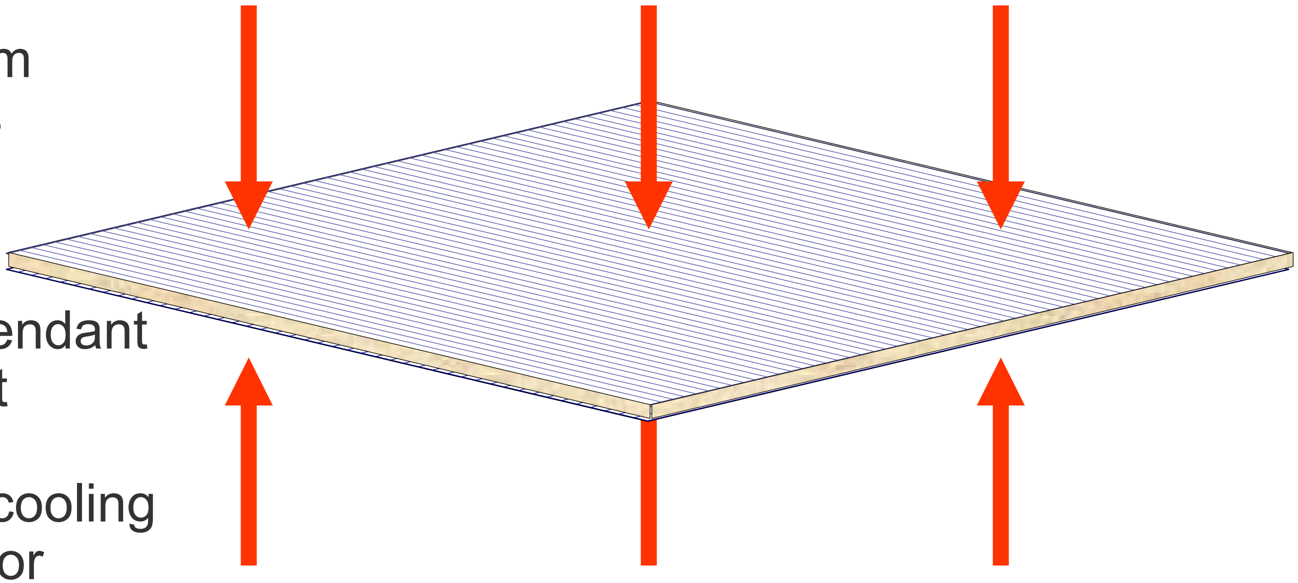
The HTPC product is supplied in a semi consolidated state for ease of processing and full consolidation



HTPC - Component Consolidation

The sheet is heated to melt temperature and fully consolidated into the required panel.

This can be by vacuum consolidation or press consolidation in a matched tool.



The cycle time is dependant on fast heating to melt temperature, to fully consolidate, and fast cooling (typically 20 minutes for vacuum consolidation; 2-3 minutes for compression moulding).

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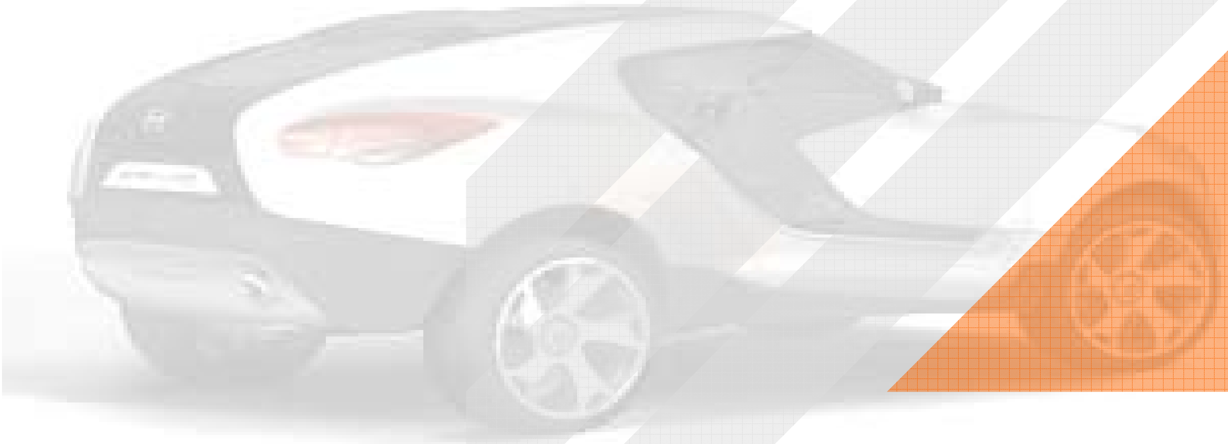
HTPC

Automotive Applications

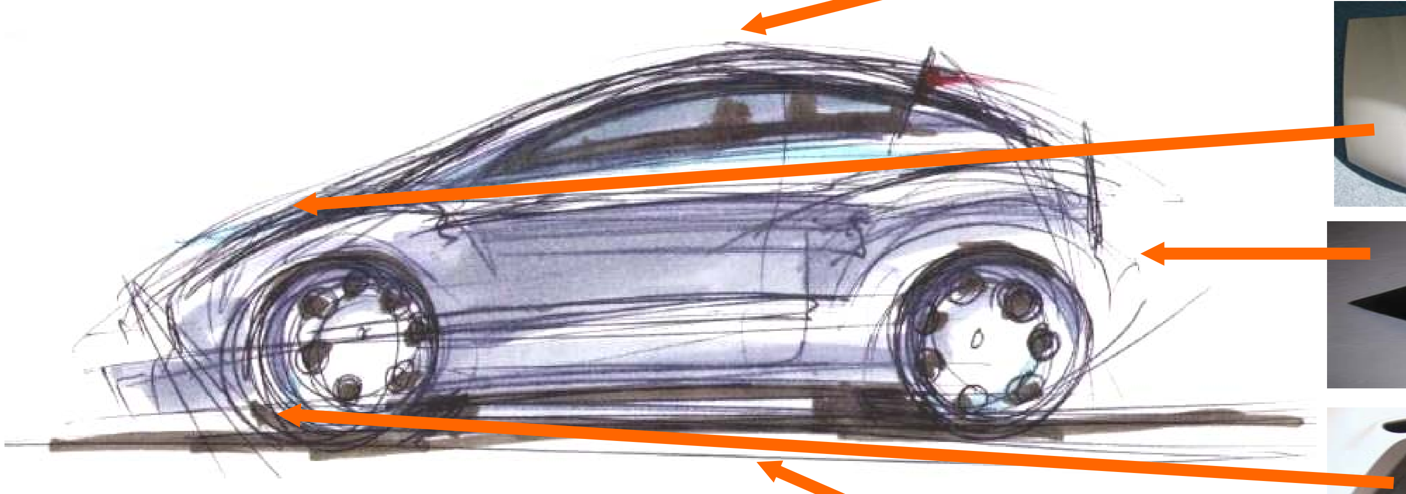


Automotive Applications

Large area horizontal panels with limited form

Low cost tooling

Low energy processing

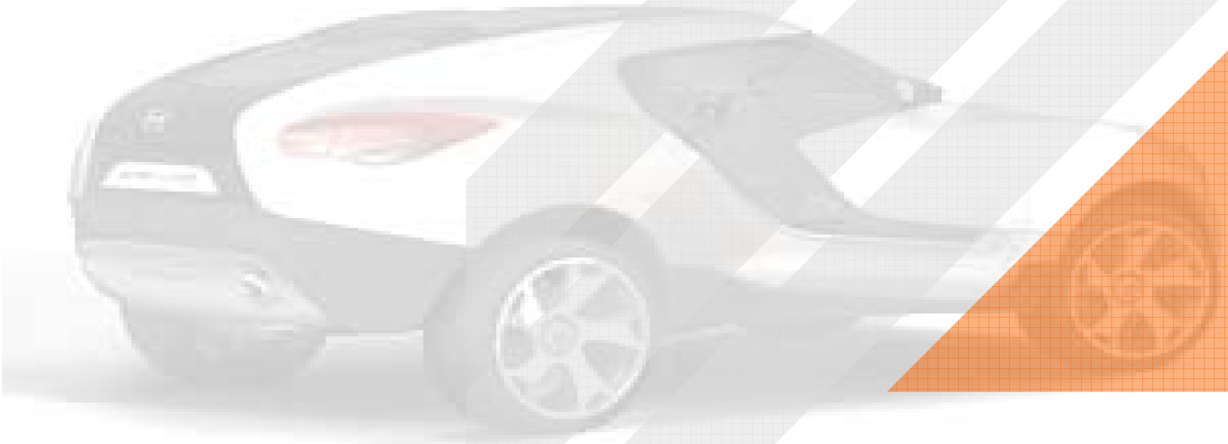


Potential 18 Kg / car (Hood & roof alone)

weight saving over steel

HTPC

The Benefits



HTPC Weight Saving

2mm HTPC composite

50% weight saving over steel.

50% weight saving over SMC

Possible weight saving over carbon fibre/epoxy composite, which has a heavier polymer matrix.

Development bonnet skin panel (Full Size Car):-

Steel (standard skin)	9.29 Kg
Aluminium	4.50 Kg
SMC	9.40 Kg †
HTPC PP/glass	4.50 Kg
HTPC Xenoy/glass	4.50 Kg
HTPC PP/carbon fibre	3.77 Kg

† Figure calculated from panel development shown

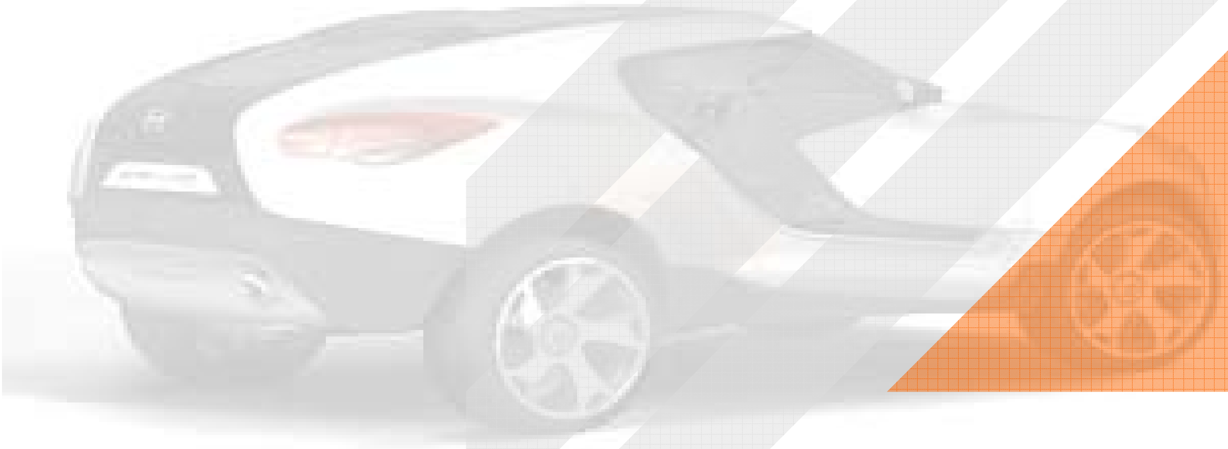
HTPC Recycle

HTPC Polypropylene / glass composites have a good polymer / fibre bond and can be granulated and re-moulded into engineering applications.

	2006	2015
Re-Use & Recycling of Materials	> 80%	> 85%
Energy Recovery	< 5%	< 10%
Recovery	> 85%	> 95%
Landfill	< 15%	< 5%

HTPC

Painting



Painting – HTPC PP/Glass Composites

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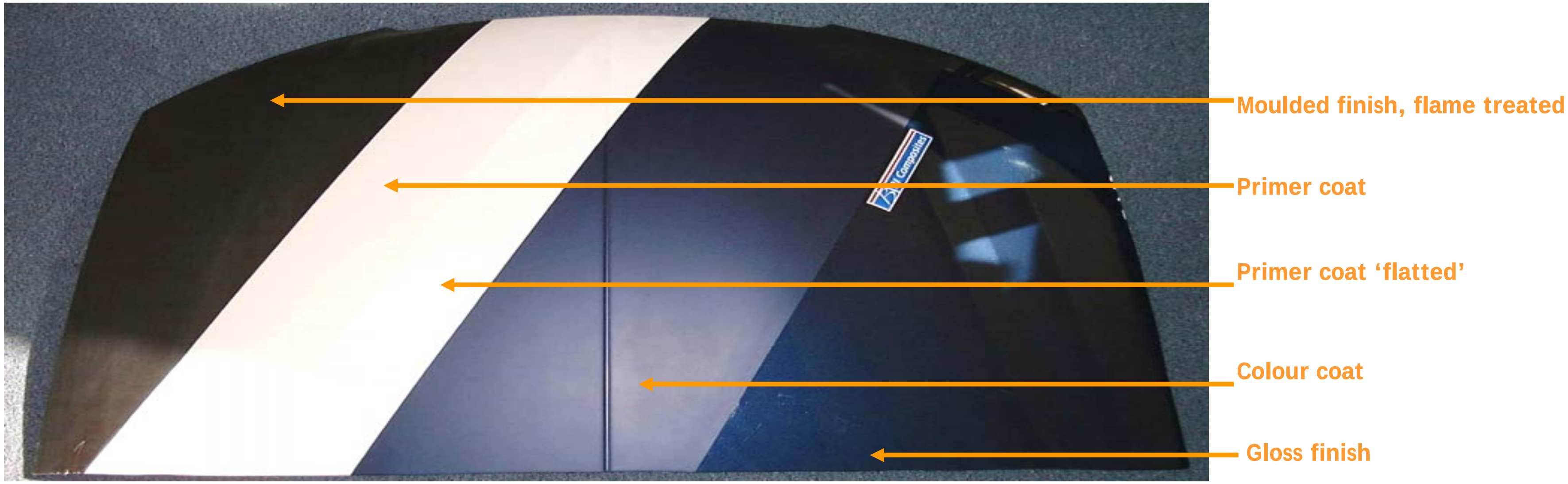
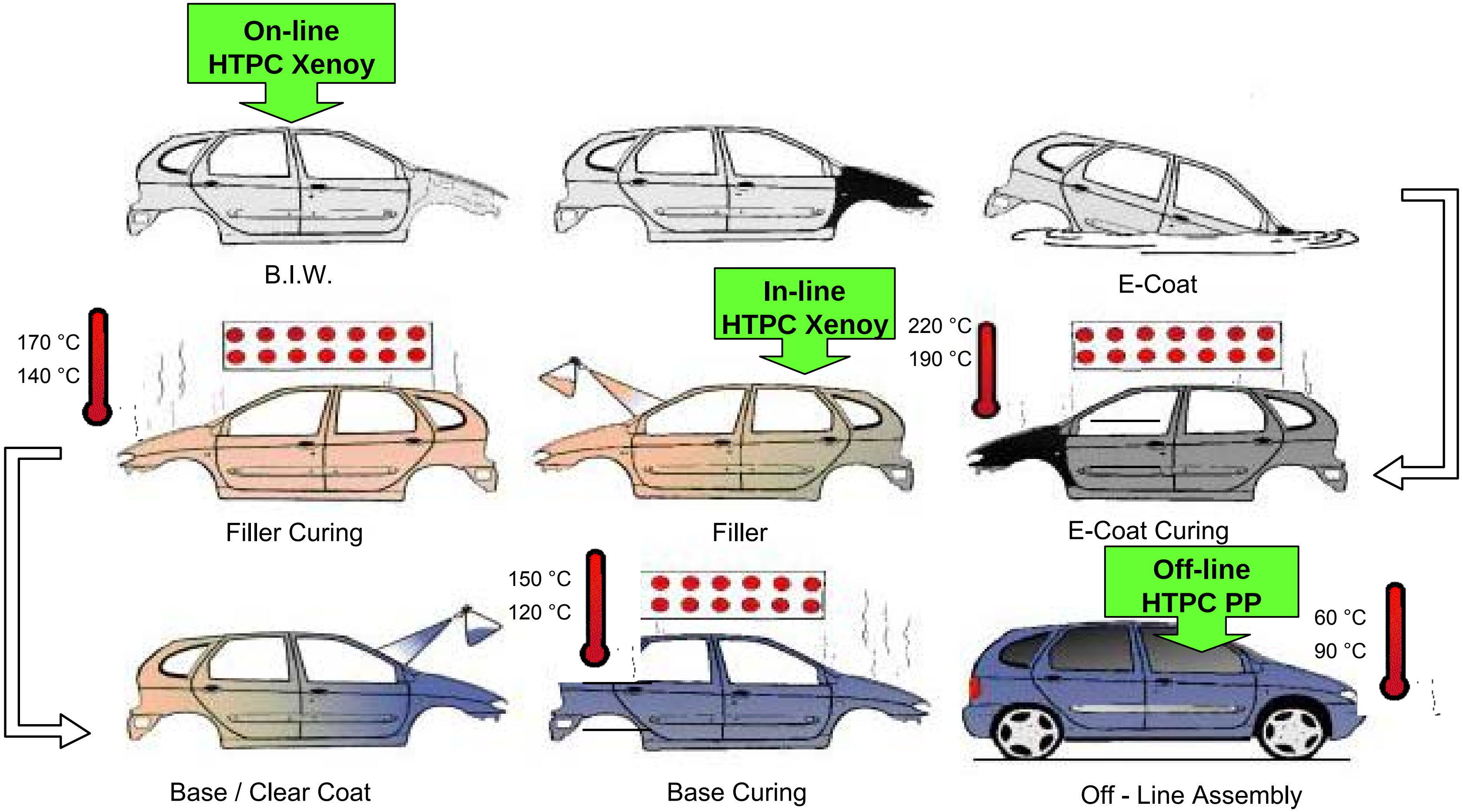
'A' class paint finish, using standard polypropylene primers on flame or plasma treated surface



OEM Paint Options - HTPC Options

HTPC Polypropylene based for cost and 'off line' painting
HTPC Xenoy based for 'on line' e-coat painting



HTPC

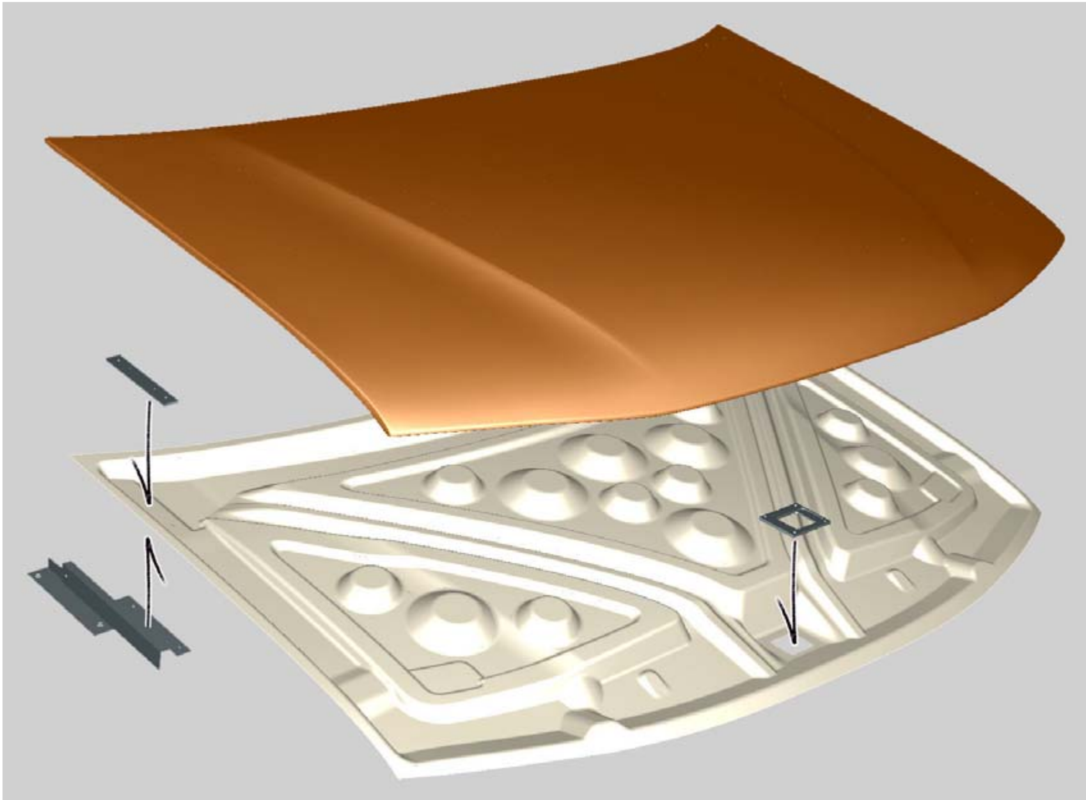
Automotive Applications

Hoods

Hood Construction

The inner hood moulding can be designed to integrate sound deadening and improved energy absorption.

Hinge and lock mechanisms can be assembled to the inner and encapsulated when the two parts are bonded together.



Crash Testing

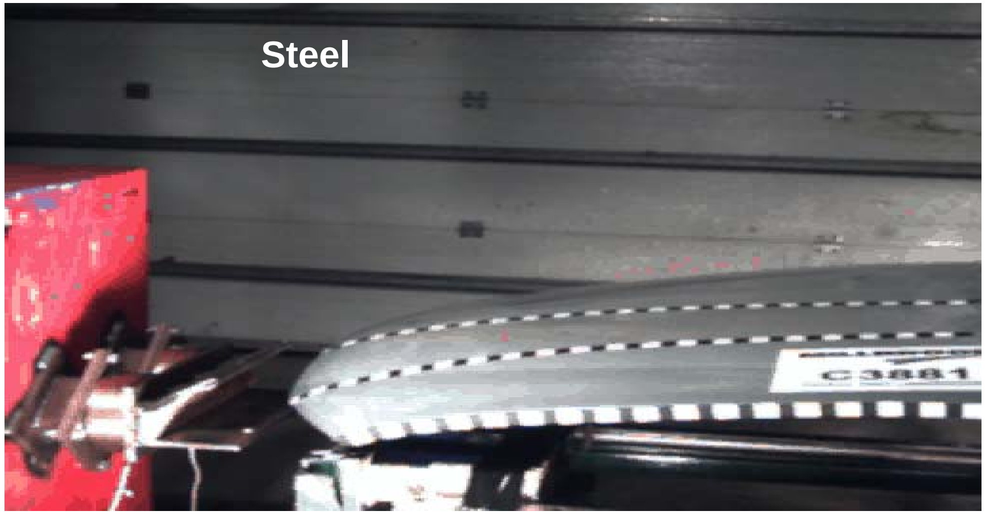
Offset front impact test at 56kph (35 mph)

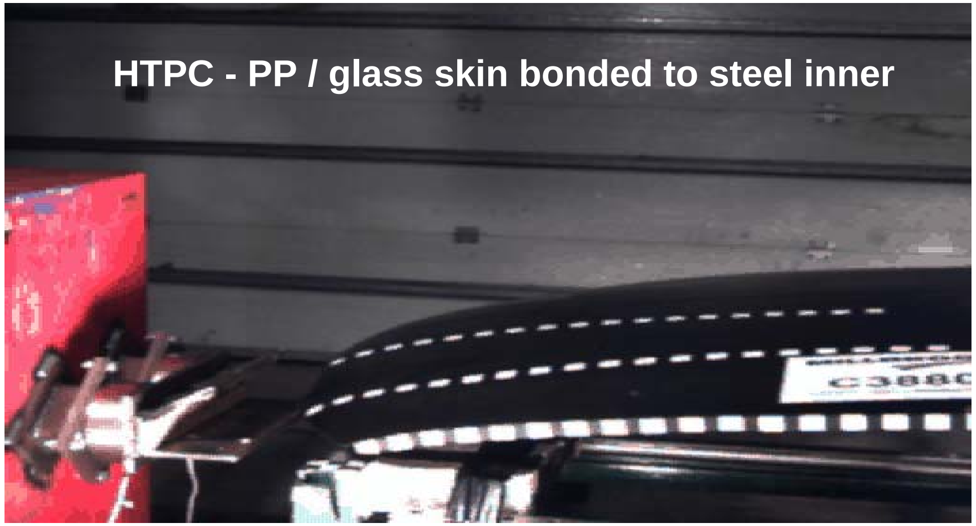
Prime advantages of HTPC PP/Glass

- Improved damage resistance
- 5kg weight saving on bonnet skin alone
- Improved energy absorption
- No catastrophic failure within the composite or adhesive

Top right:
All steel bonnet in silver
Welded steel inner and outer.

Bottom right:
HTRC Polypropylene/glass composite skin (black as moulded)
bonded to steel under frame





HTPC Hood Assembly - Bonded skin to inner

HTPC PP outer skins may be bonded to steel/aluminium/SMC or HTPC sub structure.

Development with adhesive manufacturers established an adhesive for a bonnet skin that remained intact through 56 kph (35 mph) offset front impact testing.

HTPC PP parts are flame or plasma treated and prior to bonding.

In 56 kph impact testing there is no ‘catastrophic’ failure of the composite and little delamination or loose fibres.

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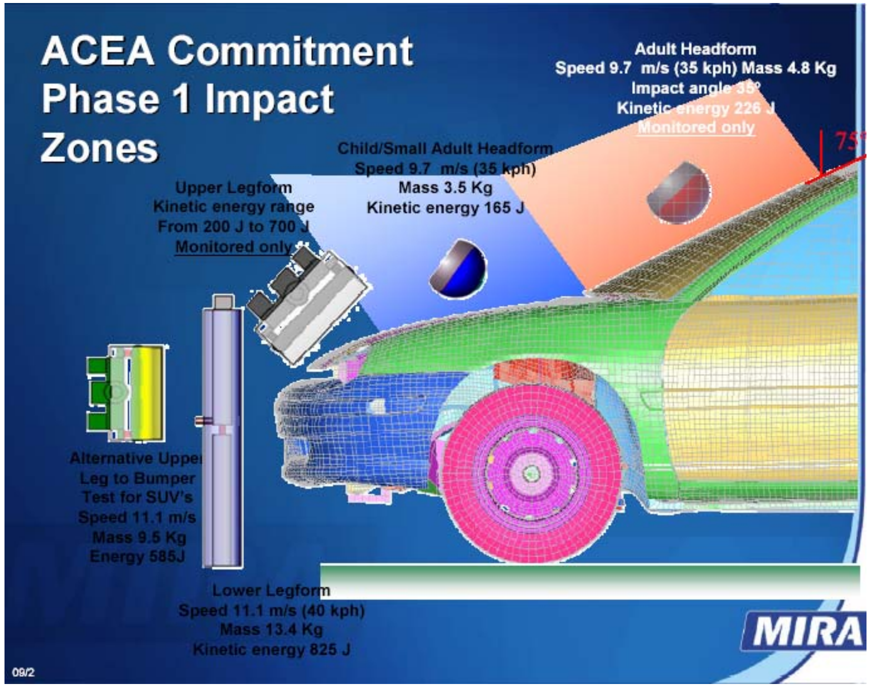
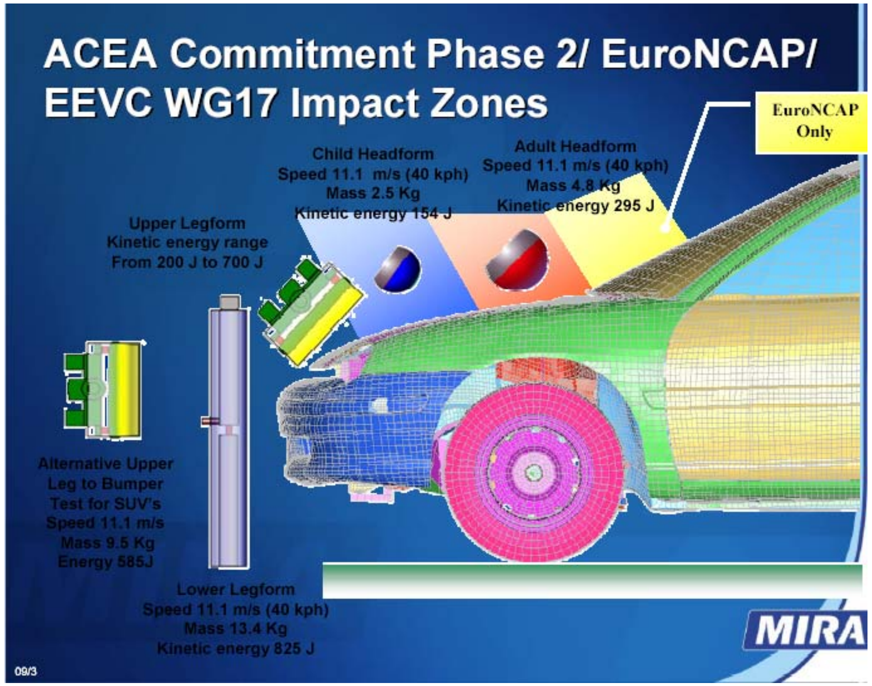
Pedestrian Safety

Head Injury Criterion Value requirements are expected to become more severe (Head energy to increase from 165 to 295J). This requires an increasing gap between bonnet skin and engine block, or other means of absorbing energy .

Current Pedestrian Crash Testing



Future Direction for Pedestrian Crash Testing



Pedestrian Head Impact

Thermoplastic composites can absorb head impact.

Inner construction may also be 'lofted' for energy absorption.

- Example shown:- Hyundai 'QarmaQ' Concept Vehicle with HTPC 'Xenoy' hood.

HTPC

Automotive Applications

Roofs

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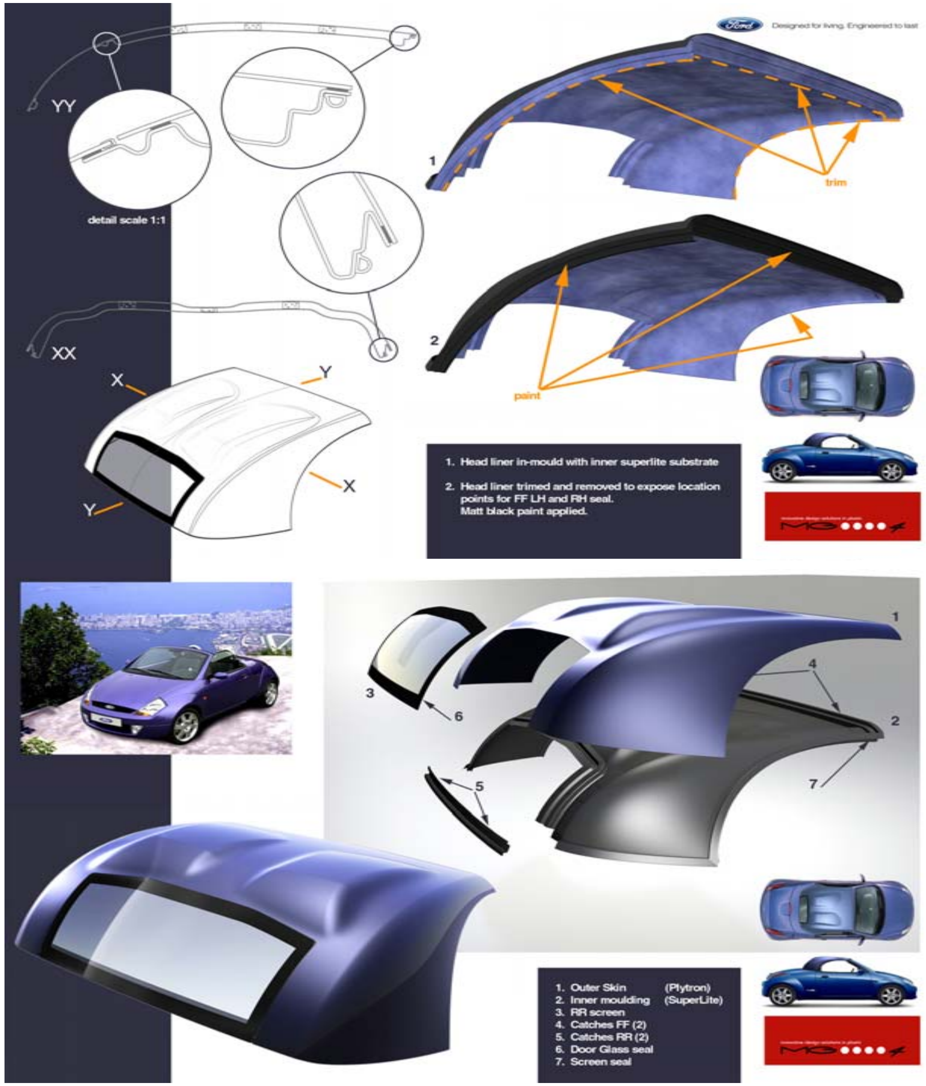
HTPC for Vehicle Roofs

Replacing steel or GRP/RTM …

- Reduced weight
  - Engine efficiency / emissions
  - Lower centre of gravity
- High impact performance.
  - Damage resistance / safety
- Sound Deadening.
  - Improved Noise Vibration & Hardness
- Recyclability (v thermoset composites)
  - Environmental legislation
- Cost saving
- Low energy processing
- Low cost tooling
  - Carbon Fibre reinforced option from same tool for higher performance vehicles.



Composite roof modules

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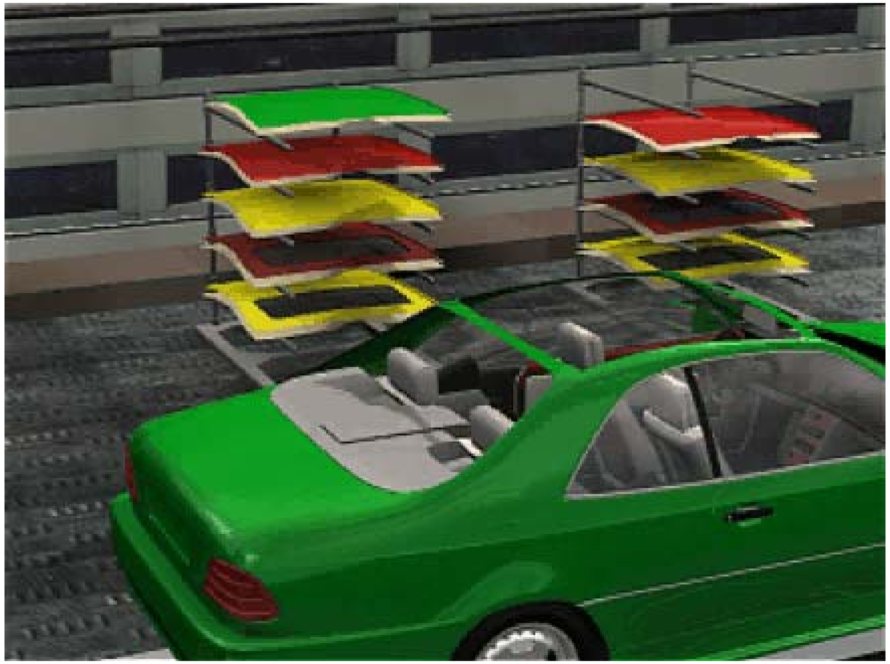
Roof modules allow an integrated solution in production.

Tier Ones can supply complete roof modules, allowing vehicle interior assembly through the roof aperture on track.

The complete roof module can then be fitted at the end of the track as with panoramic roofs



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Testing HTPC PP/Glass Roofs

- NVH
  - Improved NVH levels compared with steel
  - Reduced sound deadening / headliner requirement
- Centre of gravity
  - 50% weight saving over steel (≈10 Kg)
  - Increased Payload
- Signal transparency
  - Component integration possible
    - Aerials for radio/Sat.Nav./Telephone
    - Speaker system integrated into the roof panel (QinetiQ process)

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Vehicle Stiffness

Modulus of 35% v/v glass/PP laminates

Lay-up	Measured Modulus (GPa)
Steel (Density 8gm/cm^3)	200.0▫
PP/glass $(0^\circ/90^\circ)_{2s}$ (Density 1.45gm/cm^3)	15.8*
PP/glass $(+45^\circ/0^\circ/-45^\circ/90^\circ)_{2s}$	11.2*
Polycarbonate (as used in new vehicle roof structures)	2.3[GE]

* Test results from Wilton Research Centre

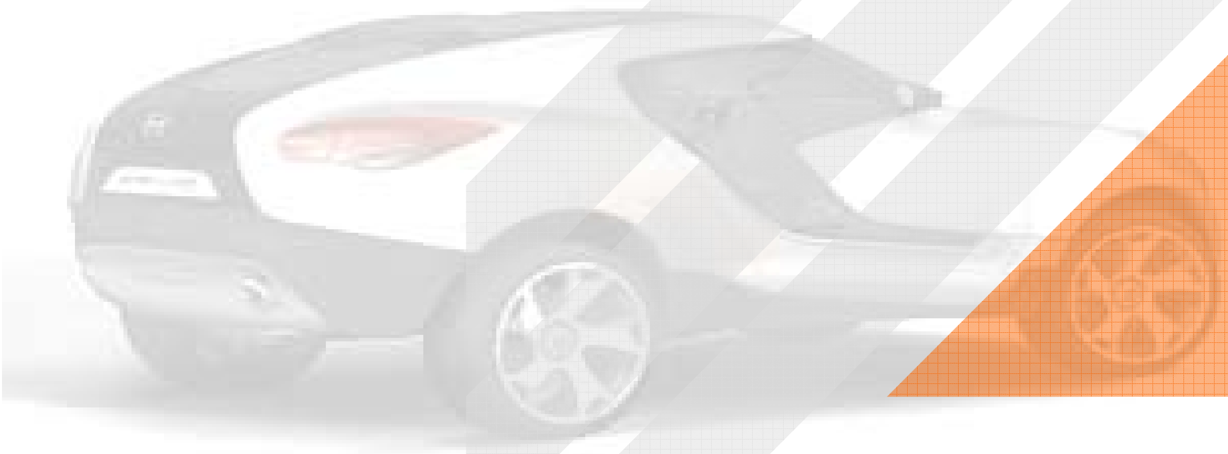
▫ Test results from Oxford Brookes University

[GE] Test results from Sabic Innovative Plastics

Vehicle stiffness is no longer so dependant on the roof panel as stiffness has been increased below waist level to improve dynamics

HTPC

Tooling



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Tooling for Low Volumes & Prototypes

Shell tools need to withstand thermoplastic melt temperatures for component consolidation.

Tools may be produced in higher temperature composites or cut from aluminium billet using CAD.

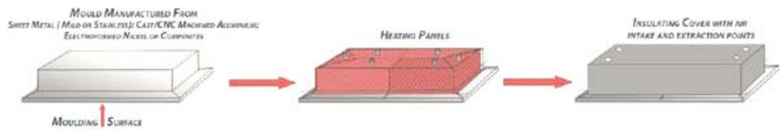
The composite is then laid in the tool.

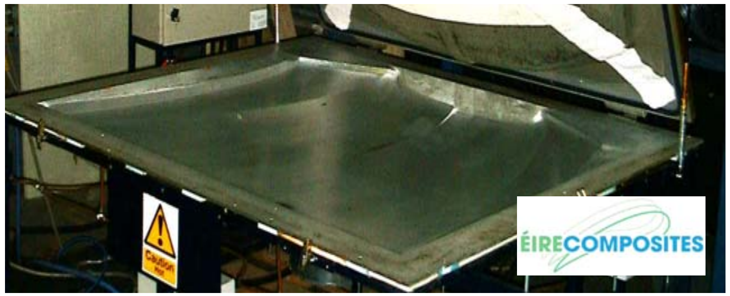
Depending on depth of draw, the composite may need to be pre-heated and formed into the rough shape of the tool.

Vacuum is then applied and the tool cycled to melt temperature.

Once parts have been validated, heating and cooling can be applied directly to the tool surface (aluminium shells) and a re-useable vacuum bag applied to allow stand alone units without the need for an oven.

Cycle times can be brought down to 20 minutes for HTPC Polypropylene/glass.



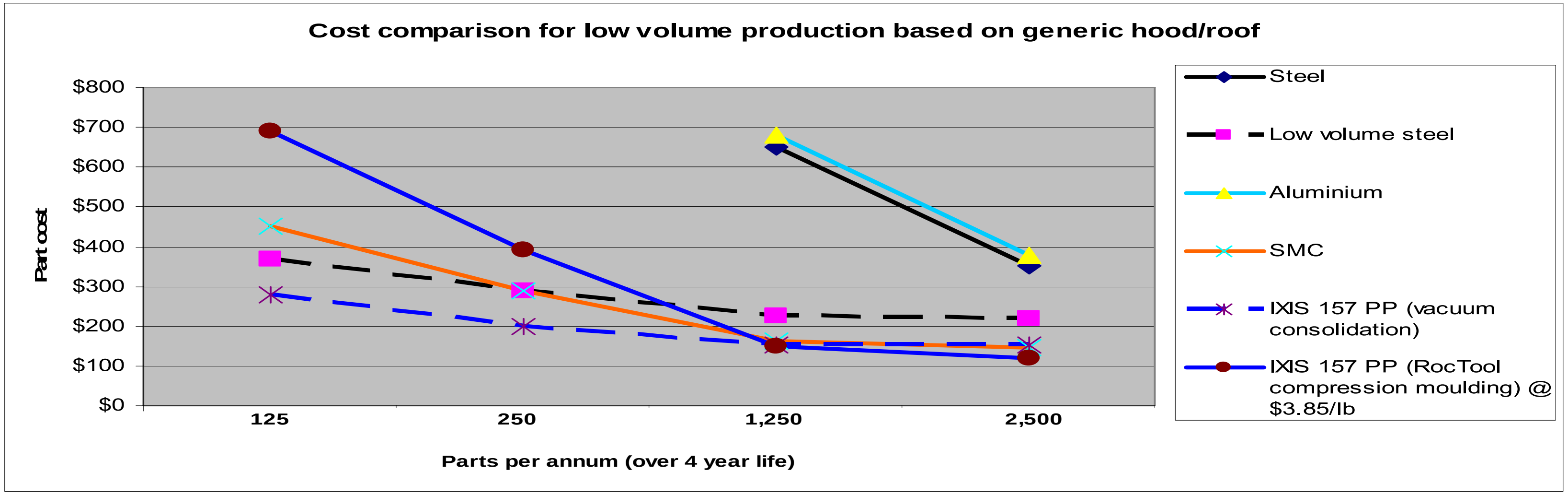


Low volume cost comparison

Thermoplastic composites are very competitive for low volume, niche vehicle production, where low tooling investment and short cycle times benefit over metals and thermoset composites.

Vacuum consolidation cost competitive for 500-4,000 units.

Cost comparisons for typical bonnet skin – 1.5m x 1.5m contoured panel.



Tooling for high volumes

Induction tool surface heating can produce a large panel in a 2 minute cycle time allowing 150,000 parts pa from a single tool.

The process gives a surface on HTPC composites suitable for ‘A’ Class paint finish.

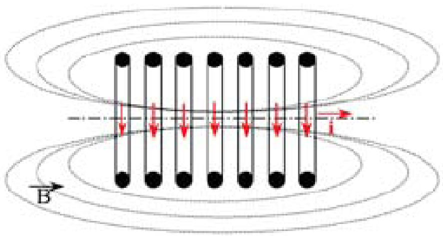


Fig.1: inductor and magnetic field.

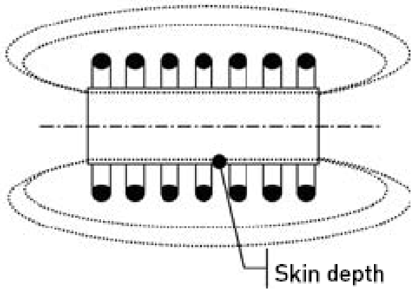
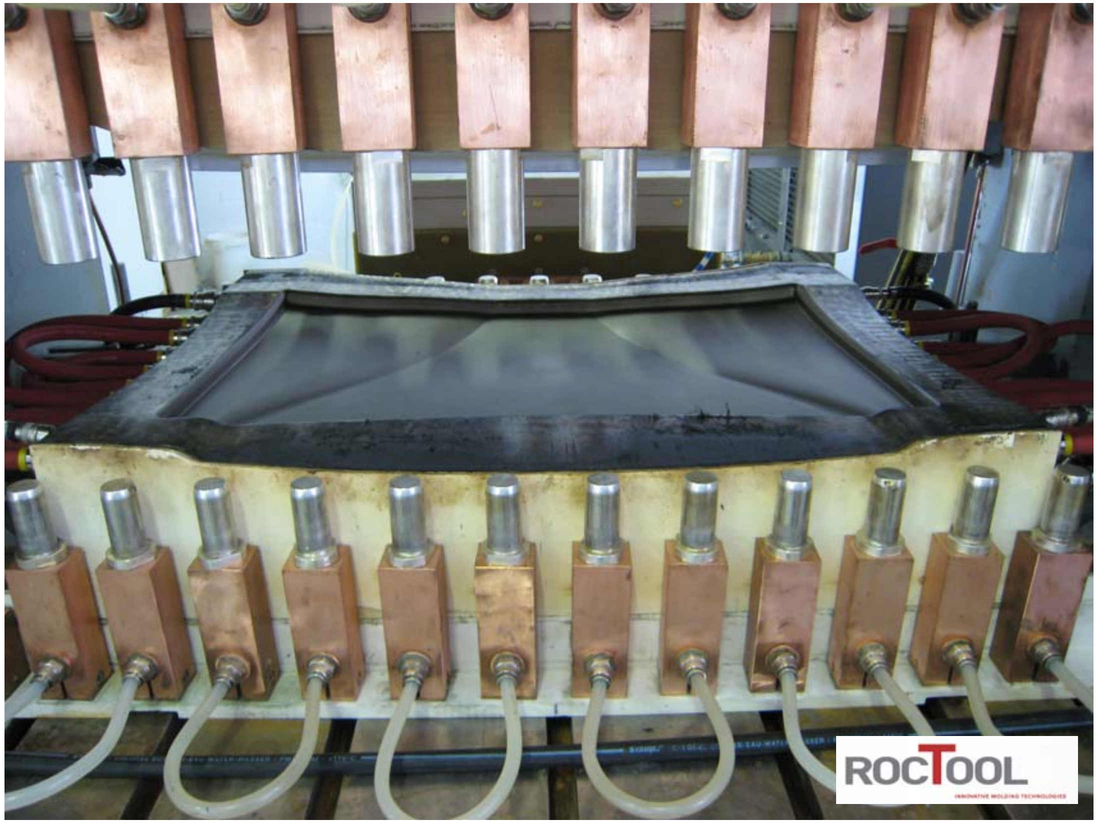


Fig.2: electromagnetic skin depth.

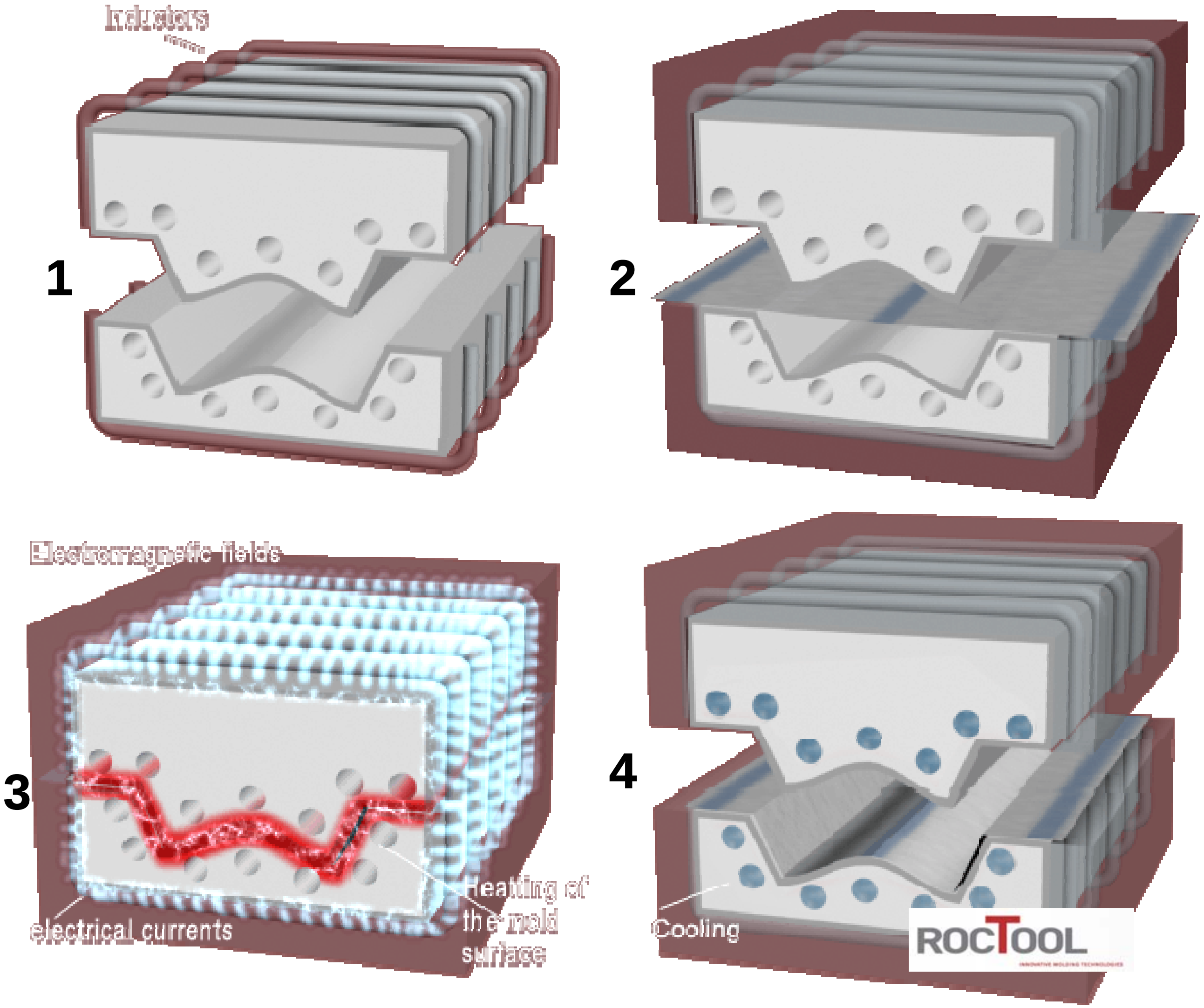


Induction Heating on Tool for high volumes

RocTool Cage System®
uses an inductive heating process heating the alloy tooling surface instantaneously.

An electromagnetic field is created and electrical currents circulate around the cage without heating the volume of the mould.

The surface is then rapidly water cooled.

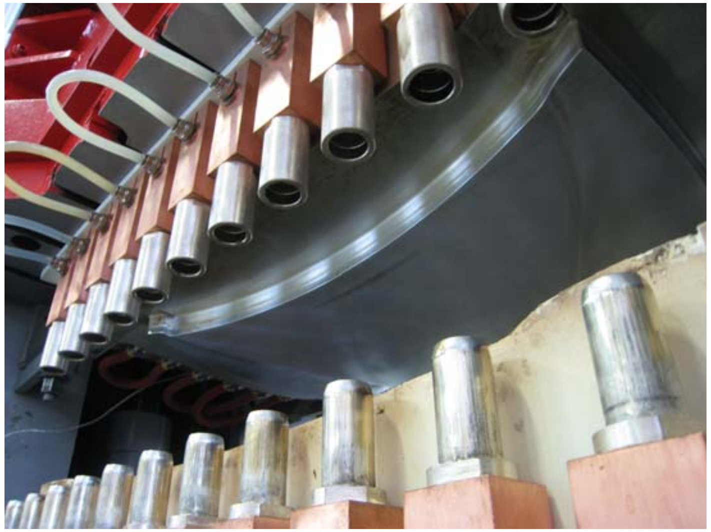


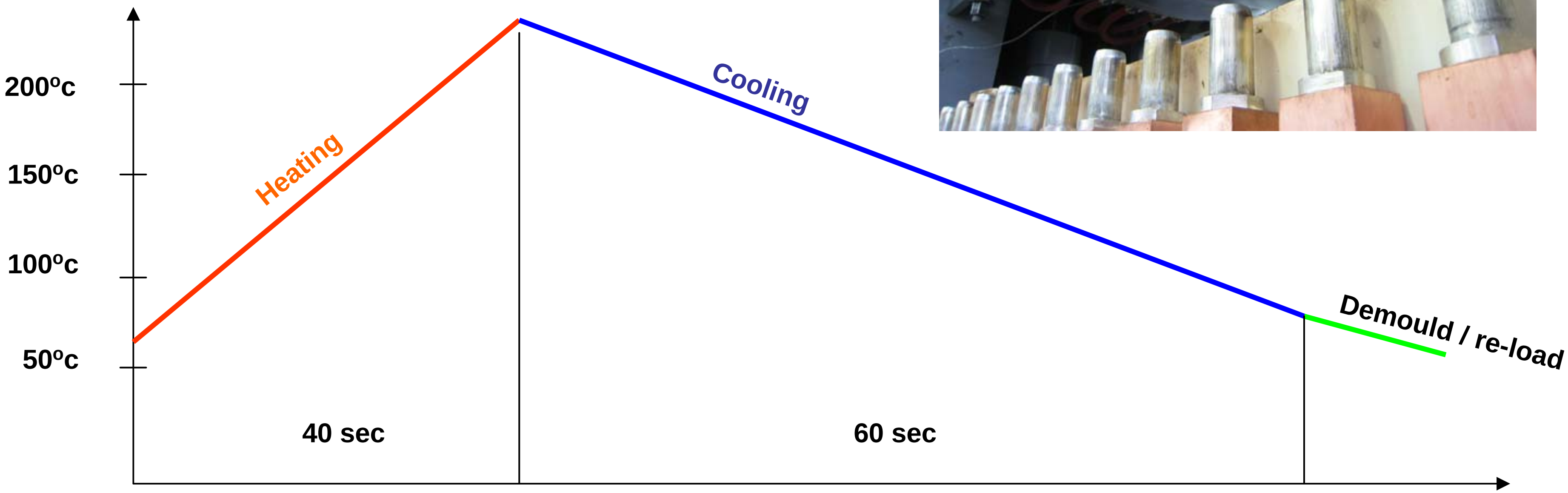
HPPC Inductive Moulding Cycle

HTPC PP component cycle

HTPC Xenoy takes approximately another 60 seconds
(peaking at higher melt temperature)

Induction contacts need re-silvering after 100,000 parts
- Contacts would be carried as spares





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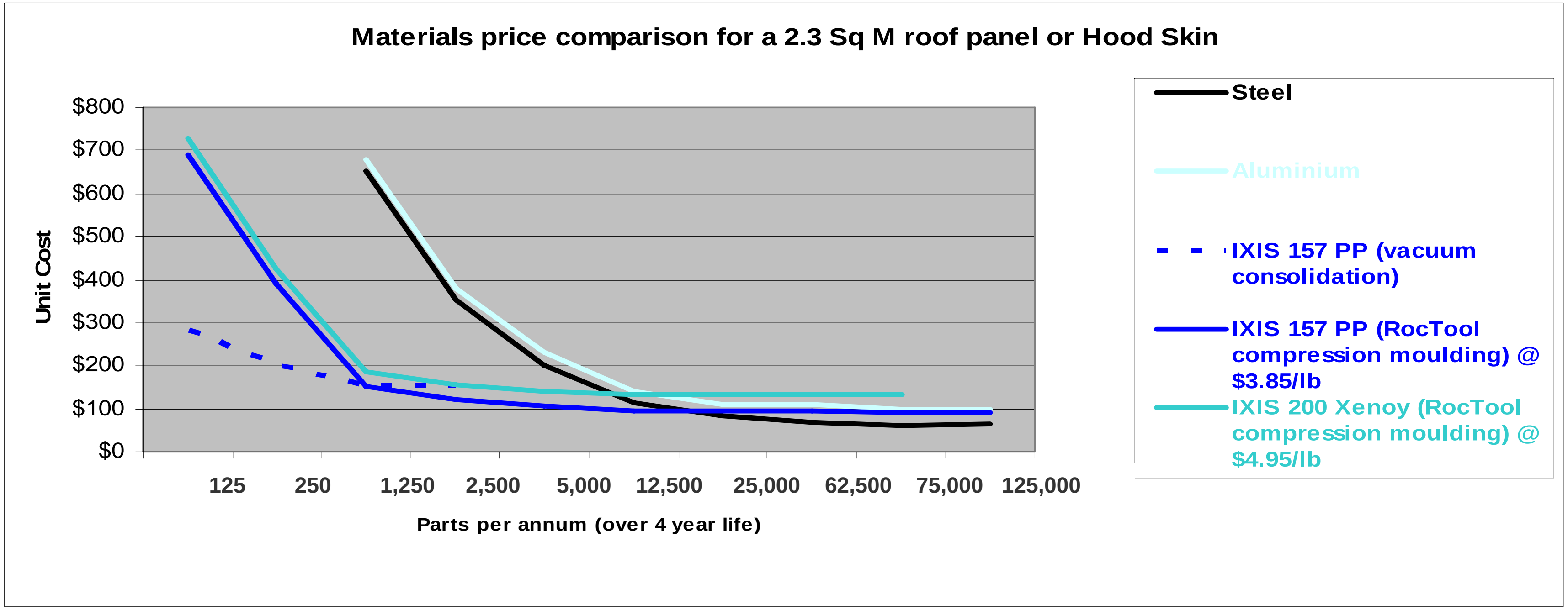
High volume cost comparison

Cost comparisons for typical bonnet skin - 1.5m x 1.5m contoured panel.

Cost saving against steel to 100,000 vehicles (25,000 vehicles pa over 4 year life).

- **85% tooling cost saving**
- **50% weight saving over steel (7Kg)**
- **Improved sound deadening**
- **High impact performance**
- **Possible aerial integration**
- **Above 100,000 units, $2-$4/kilo cost of weight saving compared with steel**

Lower weight reduction option than aluminium



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Faraday Advance Partnership Project

Design & Fabrication of

Low NVH Multi-Material Automotive Vehicle Structures

Faraday Advance Partnership Project
Low NVH Multi-Material Automotive Vehicle Structures

A Project Team from Industry and Academia aimed at assessing alternatives to steel in automotive structures to improve NVH and save weight.

The Team also measured the effects on vehicle stiffness and hybrid joining techniques.

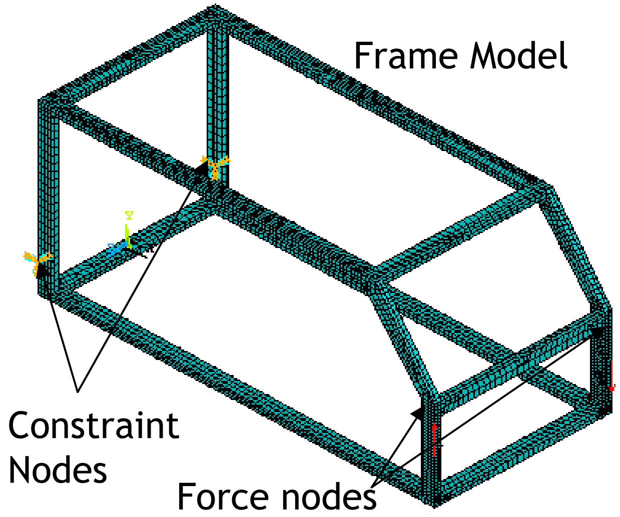
Project Partners:

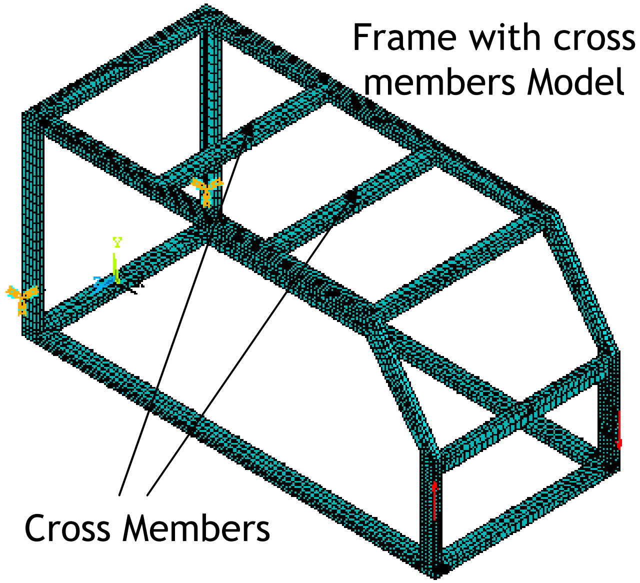
- BI Plastics Division
- Crompton Technology Group
- Ford Motor Company
- MIRA (Motor Industry Research Association)
- Oxford Brookes University
- Siemens Magnet Technology
- Hodgson & Hodgson

Faraday Advance Partnership Project
Low NVH Multi-Material Automotive Vehicle Structures

Oxford Brookes - Base FE Models

The Ford Transit Connect light delivery vehicle was chosen for the project.

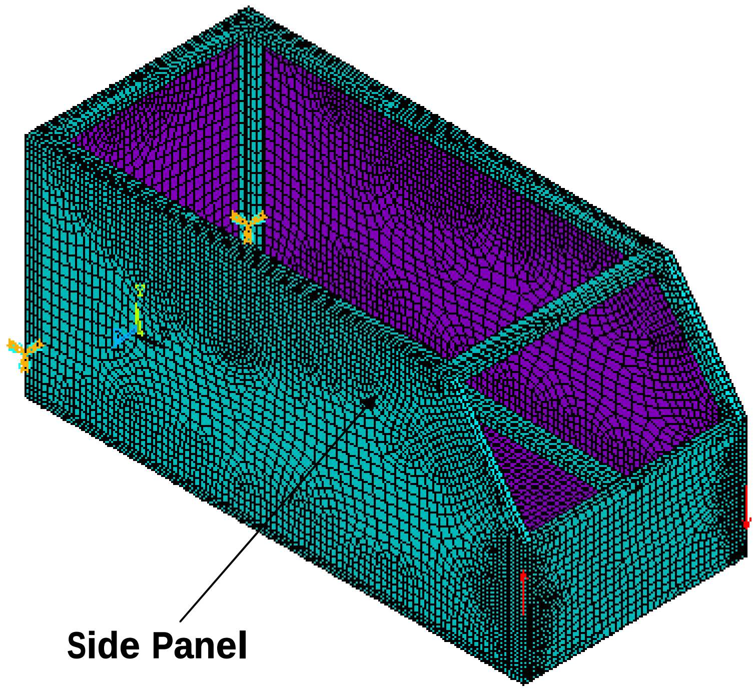




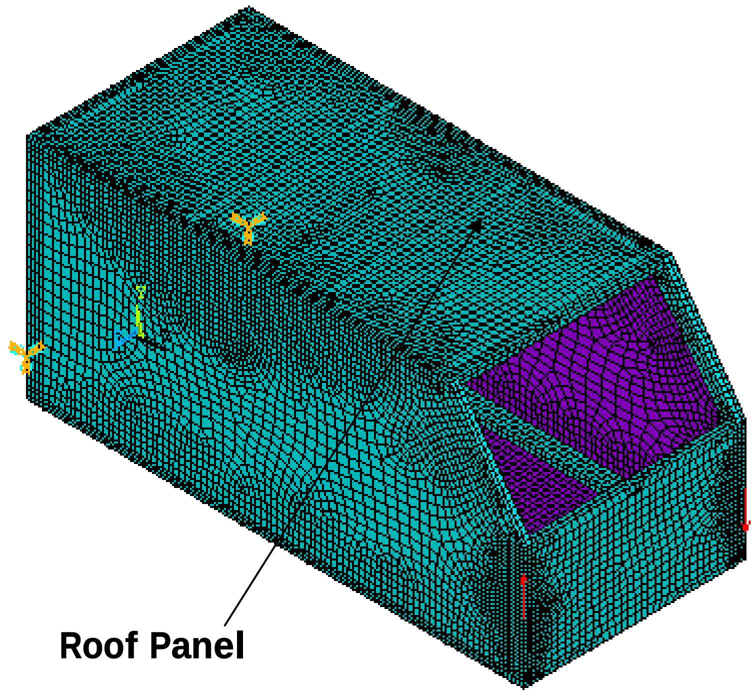
Faraday Advance Partnership Project
Low NVH Multi-Material Automotive Vehicle Structures

Oxford Brookes - Base FE Models
Panels from a variety of materials were assessed by comparison to steel in the model.
The polypropylene/glass hybrid composite was chosen for full scale assessment.

Frame with all panels except roof



Frame with cross members and Roof Model



MIRA - Testing HTPC PP/Glass Roofs

Tests carried out on
'Body in White'

- BIW Static Stiffness
  - (Bending and Torsion)
- BIW Modal Test
- Roof Mobility Test

Three Conditions

- Baseline – Standard Welded Steel Roof

The roof was then cut off and replaced by:

- Bonded Steel Roof
- Bonded HTPC Polypropylene/Glass Roof

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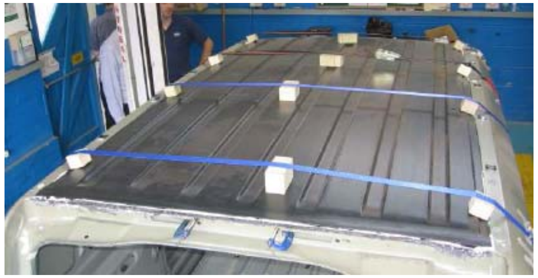
Low Cost Prototyping of PP/Glass Roof Panel

Prototype HTPC PP/Glass Composite Panels:

- Sheet steel panels supplied by Ford
- Ribs removed (welds drilled out and sealed)
- Composite laid on inner surface and vacuum bagged
- Vacuum consolidated at BI Composites
- Part trimmed and perimeter plasma treated for bonding
- Adhesive applied with 2mm bond line
- Roof assembled to vehicle for BIW Modal Test



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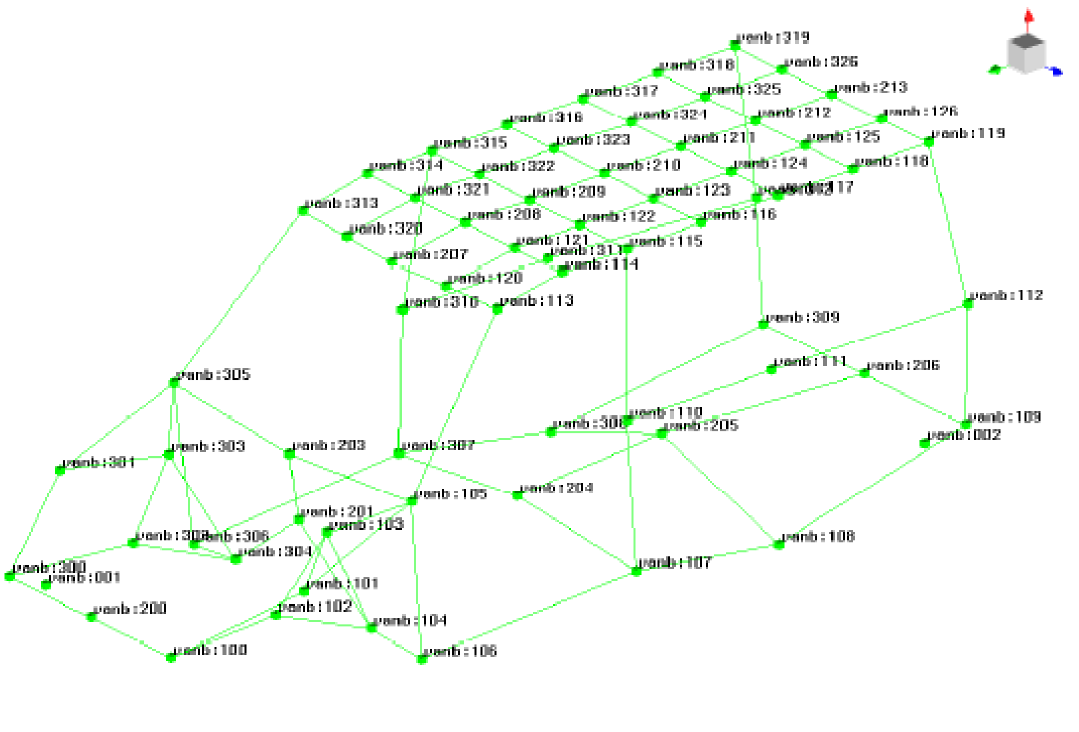
MIRA - Testing PP/Glass Roofs

Body in White – Modal Test

- 67 tri-axial measurements
  - 35 measurements on roof
- Two shakers
- 256 Hz bandwidth
  - 0.25 Hz resolution
- BIW mounted on airbags



MIRA Test Summary

Removing the welds and bonding the steel roof

- Reduced acoustic radiation
- Reduced static stiffness
- Reduced frequency of BIW 1st torsion & roof 1st bending modes

Replacing the bonded steel roof with Polypropylene / Glass Hybrid Composite roof

- Increased frequency roof 1st bending mode
- Negligibly difference in BIW torsion
- Recovered some torsional stiffness

	Modal Frequency (Hz)		Static Stiffness		RSS Mobility (ms^{-1}/N)		
	BIW Torsion	Roof (1,1) Bending	BIW Torsion (kNm/deg)	BIW Bending (kN/mm)	Point	Transfer	A-weighted Transfer
Welded Steel	30.1	34.4	14.55	13.90	0.441	0.0366	0.0036
Bonded Steel	29.4	33.4	12.81	13.80	0.440	0.0321	0.0036
Bonded PPG	29.4	34.9 ✓	13.80 ✓	13.76	0.825	0.0417	0.0032

Summary

The Polypropylene/Glass Hybrid Composite Roof performed well in the application:

- 50% weight of steel
  - Lower centre of gravity
  - Improved payload
- Improved NVH
  - Reduced requirement for additional sound deadening
- Signal transparency
  - Allowing integration of antennae

Project extension

The PP/Glass Hybrid Composite Roof may be combined with electrics and head-liner to achieve a roof module



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Azdel's Trade Name for HTPC

Hybrid ThermoPlastic Composite is

IXIS®

Azdel - Working in Partnerships, developing better solutions

Presentation by Mike Birrell Azdel Inc.