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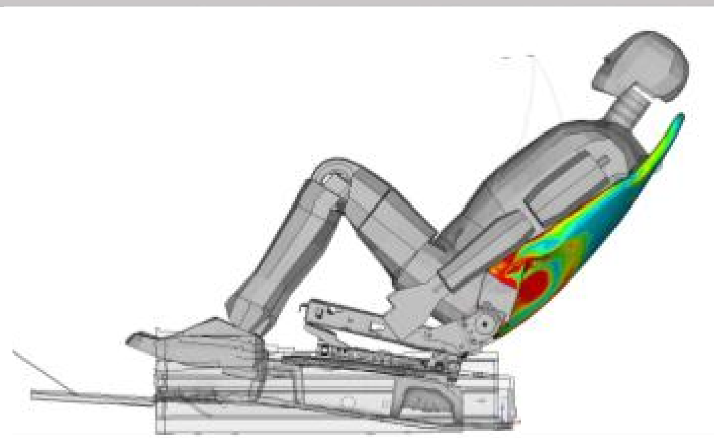

3-D Seamless Knitted Preforms for Automotive Seating Applications

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Futuris in Australia - programs

seating
door trims
headliners
floor carpets
nvh products
spoilers
aftermarket

VE SWB

WM LWB

HSV sports

Utility

Wagon

seating
steering
pedals
window regs
headliners
floor carpets
nvh products
aftermarket

SWB sedan

FPV sports

Utility

Wagon

Territory SUV

headliners
nvh products
spoilers
aftermarket

Camry & Aurion

aftermarket & vehicle personalisatio n products

vehicle electronics
vehicle security
driver aids
vehicle safety aids
rear-seat entertainment
packaging
carpet floor mats

Futuris in China – seating programs

CHERY

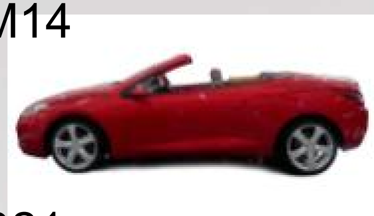
A21

S21

M12

M11

M14



A01

B21

plus other confidential

JAC AUTOMOBILES

A108

B926

HSV

Elfin (Aust export)

Comparison of various textile preforms

In order of best to worst for each parameter

Strength & Modulus	***Cost***	***Damage Tolerance***	***Formability***	***Waste***
UD Tape	Non woven	Knitted	Knitted	Knitted
NCF	Knitted	Nonwoven	Nonwoven	Nonwoven
Braid	Woven	Braid	UD Tape	Braid
Woven	UD Tape	UD Tape	Woven	UD Tape
Knitted	NCF	Woven	NCF	Woven
Non woven	Braid	NCF	Braid	NCF

Knitted preforms – Effects of yarn orientation

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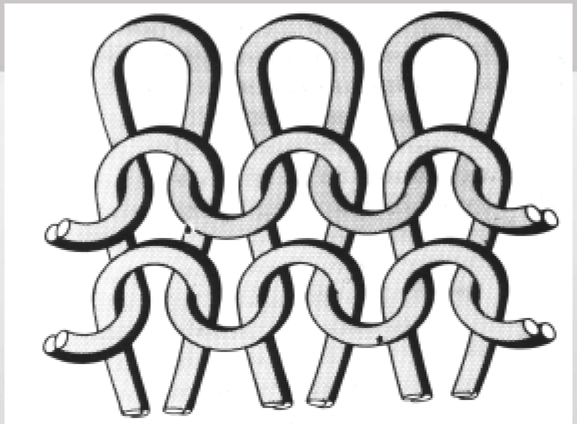
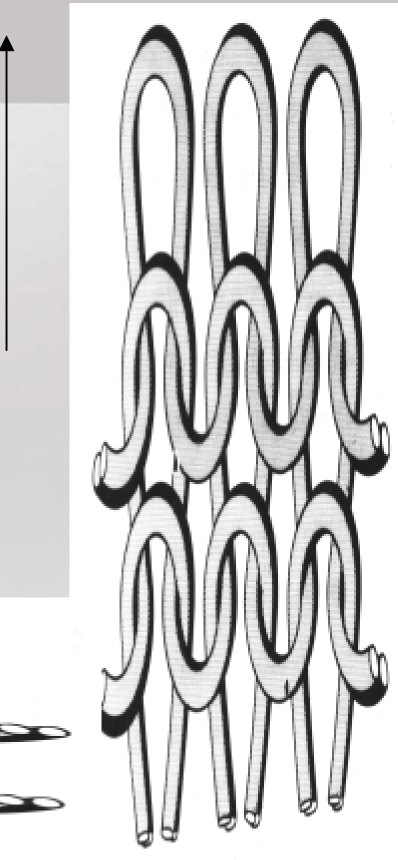
(a)



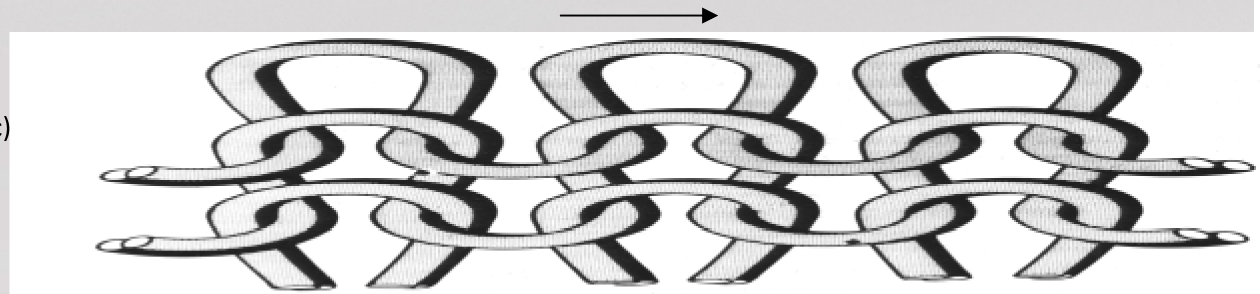
Single jersey un-stretched

(b)



Single jersey wale-stretched

(c)



Single jersey course-stretched

Strength and stiffness increases in the direction of stretch at the expense of the orthogonal direction

CSIRO FUTURIS AutoCRC Smarter Safer Cleaner DEAKIN UNIVERSITY

Effects of Fibre Orientation - Nonwoven

(a) No Stretch

(b) 75% MD Stretch

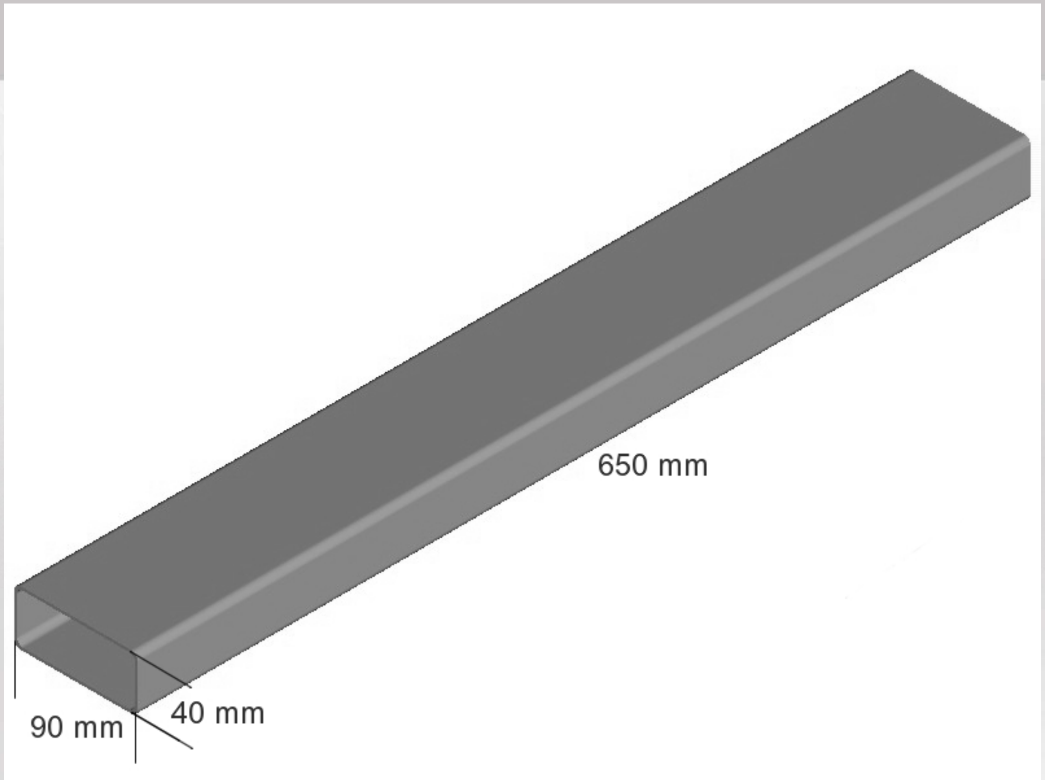
(c) 100% MD Stretch

Nonwoven Twaron fabric has ~ 4:1 MD:CD orientation and fibres are highly crimped. Stretching in the MD gives straighter fibres and aligns them in the machine direction to give higher strength and stiffness

Effects of Orientation

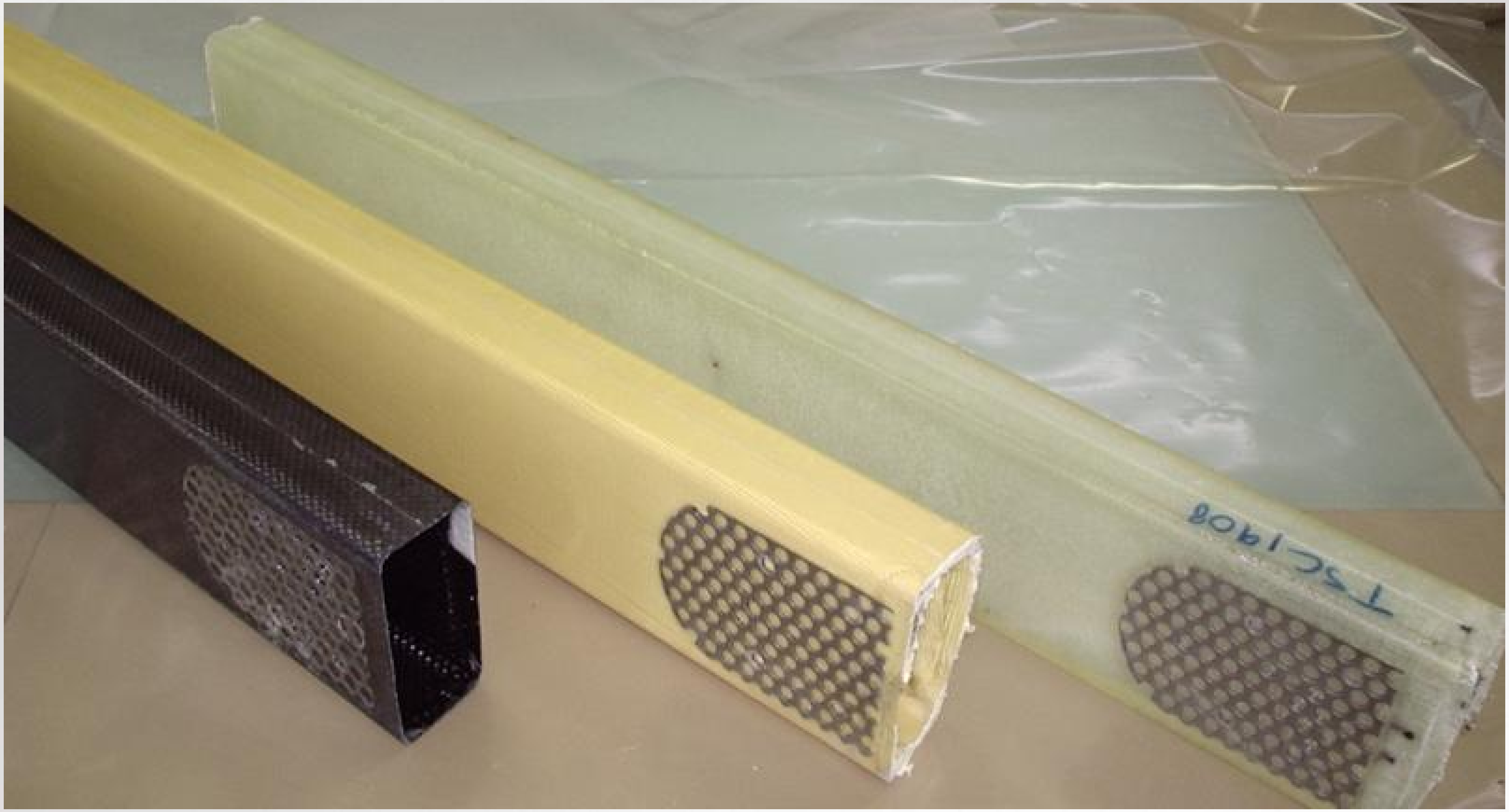
Fabric Type & Conditions	Test direction	Ultimate Tensile strength (MPa)	Axial strain (%)	E Modulus (GPa)
Non-Wovens				
Epoxy – Twaron (cured 80C/12min)	MD	51	1.8%	3.00
Twaron stretched along MD	MD	122	2.1%	6.00
Twaron stretched along MD	CD	93	2.1%	5.50
Knitted				
Epoxy Twaron-No stretch	Whale	137	11.0%	7.67
Twaron 75% stretch along courses	Whale	157	6.9%	7.67
Twaron 100% stretch along courses	Whale	196	8.5%	9.00
R246 (cold cure) Twaron Knit Stretch-MD 1	MD	201	2.7%	9.89
	CD	45	3.7%	3.55
Twaron-R246 Knit Stretch-MD 2	MD	182	6%	15.1
	CD	38	4%	4.5
Twaron-R246 Knit Stretch-CD	MD	55	2.6%	5.1
	CD	75	5%	6.6

Beam and Coupon Testing



Test beam dimensions.
The wall thickness varied but was usually approximately 2 mm.

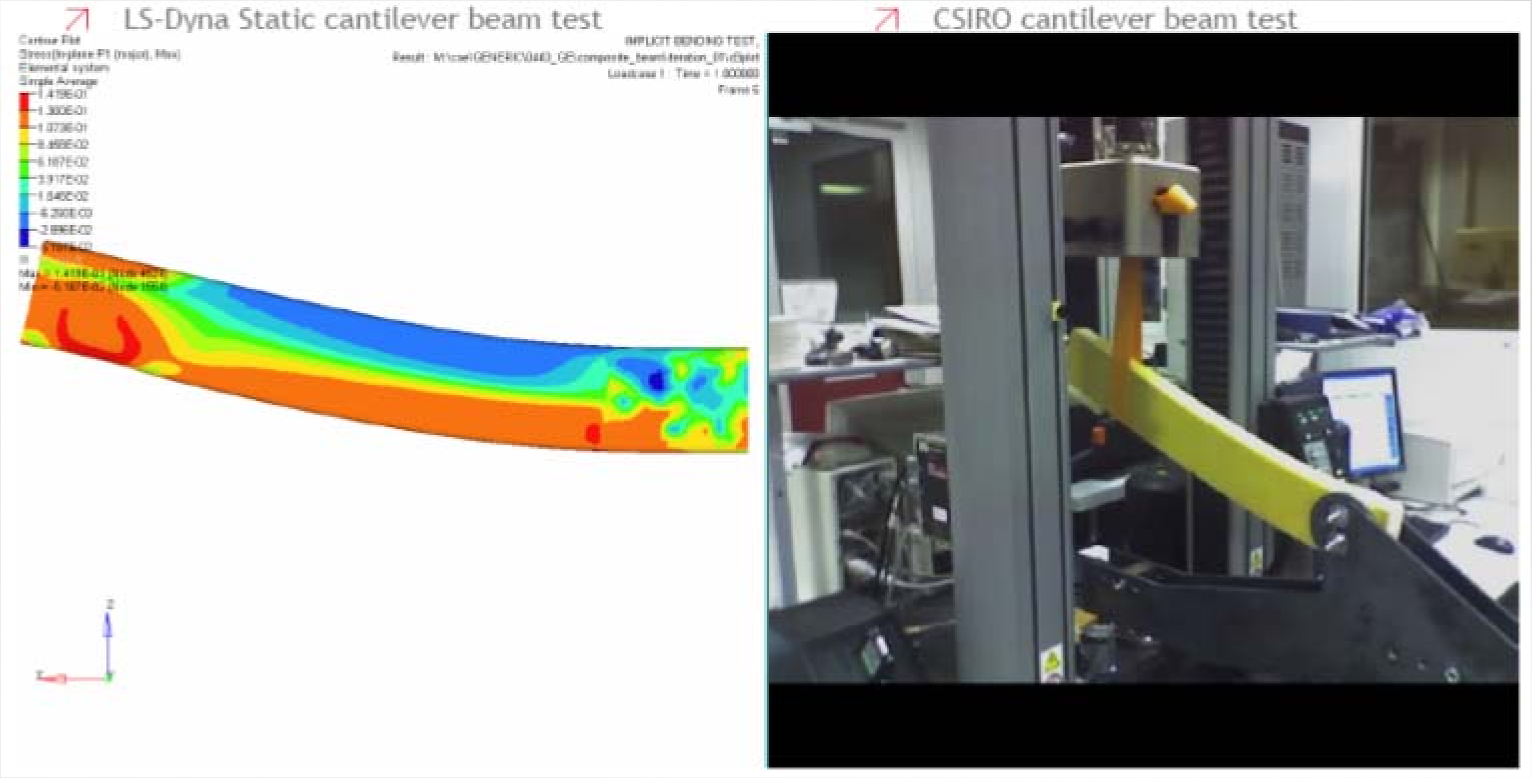
Carbon, Aramid, and glass fibre beams



Hot press and beam mould

Shima Seiki 3D Whole-Garment knitting machine, 14G

CAE Model validation



Beam Testing Results

	Transition Values - maximum elastic limit of material			Ultimate values - for max stress/strain[1]		
	Value	Unit	Stdev	Value	Unit	Stdev
In-Plane Tensile Test						
E11 Modulus longitudinal	8.48	GPa	0.72	8.48	GPa	0.72
E22 Modulus transverse	4.83	GPa	0.73	4.83	GPa	0.73
Poisson's Ratio12 - Poisson ratio in the 1-2 direction	0.55		0.088	0.55		0.088
σ11 UTS longitudinal	75.1	MPa	4.9	99.7	MPa	8.1
σ12 UTS transverse	30	MPa	1.3	35.7	MPa	1.1
ε11 TFS longitudinal	0.0135		8E-04	0.05		0.018
ε12 TFS transverse	0.0082		5E-04	0.02		0.002
In-Plane Compression Test						
E11 Modulus longitudinal	1.67	GPa	0.44	1.67	GPa	0.44
E22 Modulus transverse	1.82	GPa	0.45	1.82	GPa	0.45
σ11 UCS longitudinal	51.9	MPa	2.8	64.9	MPa	2.8
σ12 UCS transverse	55.8	MPa	2	69.8	MPa	2
ε11 CFS longitudinal	0.0458		0.01	0.08		0.013
ε12 CFS transverse	0.0418		0.008	0.08		0.021
In-Plane Shear Tests						
G12 shear modulus in the 1-2 direction	2.18	GPa	0.04	2.18	GPa	0.04
G23 shear modulus in the 2-3 direction	1.4	GPa	0.01	1.4	GPa	0.01
G31 shear modulus in the 3-1 direction	1.31	GPa	0.01	1.31	GPa	0.01
τ ultimate shear strength in the 1-2 plane	38.5	MPa	2.13	42.8	MPa	2.13
Y shear failure strain	0.0206		0.002	0.03		0.002
Through Thickness Compression Test						
E33 through thickness modulus	1.79	GPa	0.33	1.79	GPa	0.33

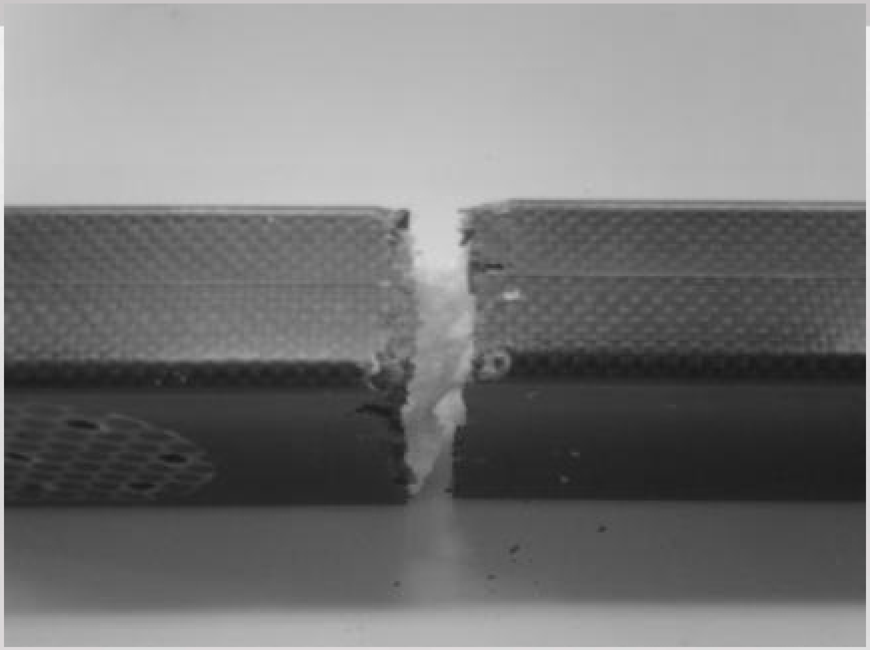
[1]Strain at maximum stress rather than ultimate failure is given.

[2]Not the strongest material produced but one used for model verification.

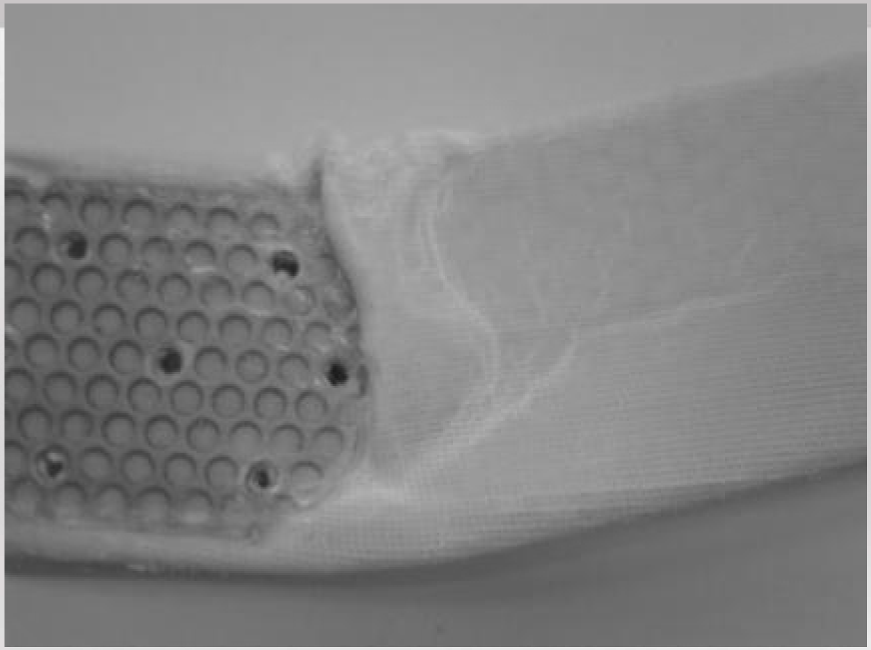
Summary of Beam Tests

Beam Type	Beam Mass (g)	Mass per Lineal Metre (kg/m)	Failure Torque (Nm)	Specific strength (Nm^2/kg)
Steel (0.9mm wall)	1200	2.00	1668	910
Aramid Rib + local woven aramid	617	0.82	1295	1582
Woven Glass (5 layers)	514	0.66	980	1497
Woven Carbon (5 layers)	509	0.70	2326	3318
Woven Aramid (2 layers)	365	0.48	564	1166
Aramid Jersey Knit	481	0.68	973	1437
Aramid Jersey Knit + spacer (small size)	492	0.75	1225	1654
2 Layer Aramid Rib	749	1.21	1936	1624
2 Layer Aramid Rib + local reinforcement	573	0.83	1588	1927
Single Layer Aramid Rib	489	0.72	613	849
Longitudinal courses Knit	508	0.76	1247	1646
Warp insertion weft knit (0/90 combined)	506	0.76	1301	1706
Hybrid Nylon / woven carbon beam	560	0.84	1323	1566
4 layer Twaron (2x folded 510 circumference)	510	0.76	931	1227
Hybrid with straight yarns	533	0.88	1567	1764

Beam test results



Woven carbon Beam



Knitted Twaron Beam

Woven Carbon fibre produced the stiffest, strongest beams but wovens cannot be easily formed into 3d shapes. Carbon also cannot be easily knitted and its failure mode is to fracture leaving sharp edges. Hybrids show promise but add complexity to manufacturing. Knitted preforms fail in a more benign manner that increases occupant safety in an accident.

Infusion Studies, effect of pressure difference

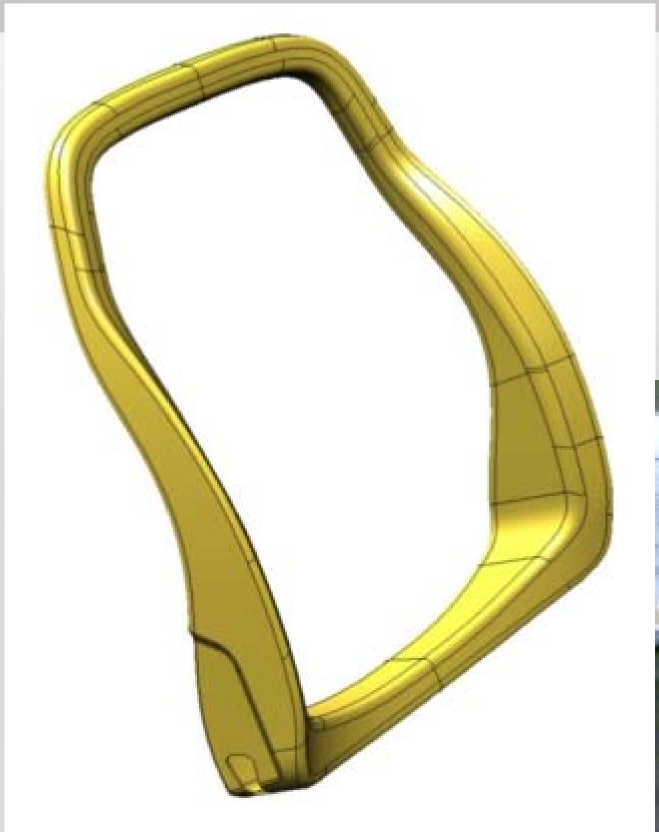
Nylon17 (above) full vacuum – 103KPa

Nylon18 (above) half vacuum – 50KPa

Nylon19 (above) quarter vacuum – 25KPa

Knits can provide excellent infusion rates, yarns and knit structures affect rates

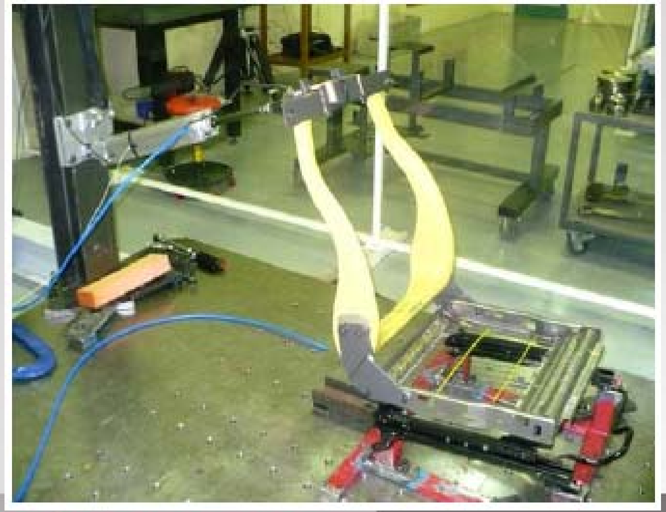
First Prototype aramid composite seat frame



Quasi-static Testing

Rearward static load

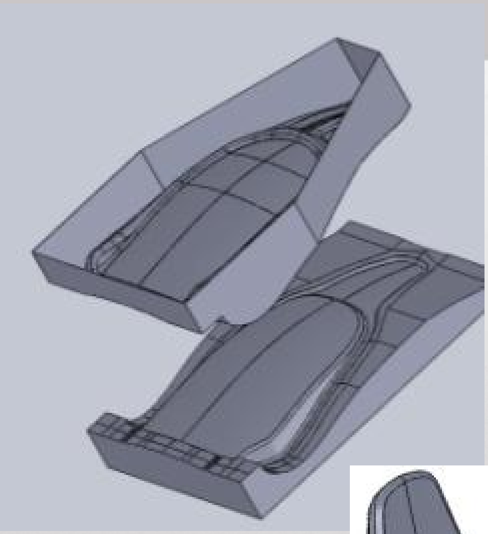
Average Load	Load (kN)	Torque (Nm)
Composite	3.47	2061
Steel	3.31	1806

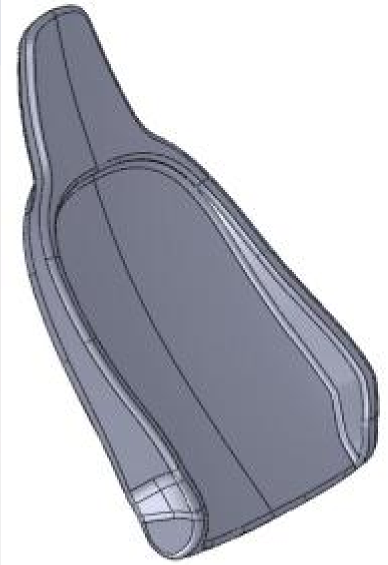


Durability test

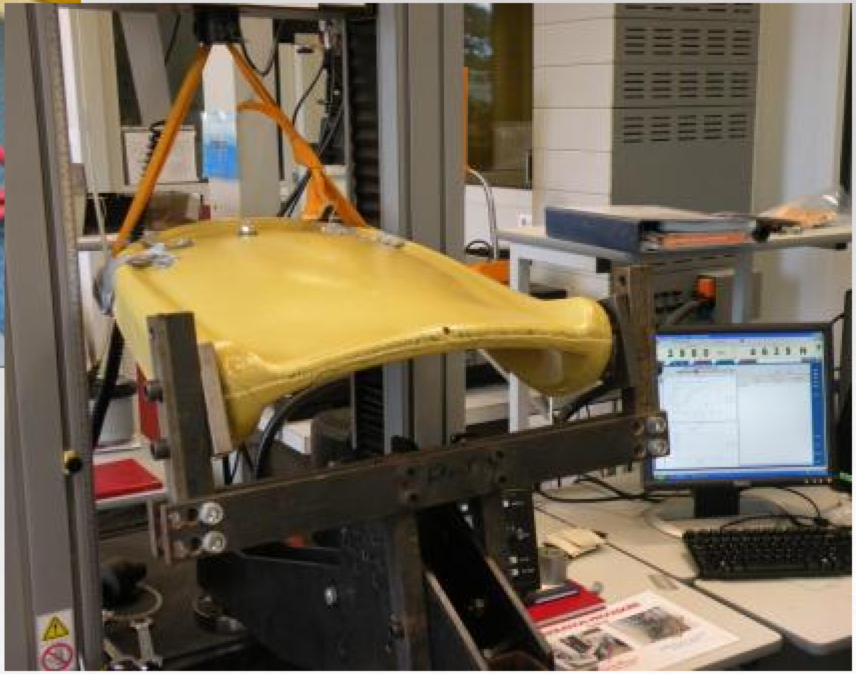
50,000 fatigue cycles - passed

Second Prototype Design: Monocoque Seat mould

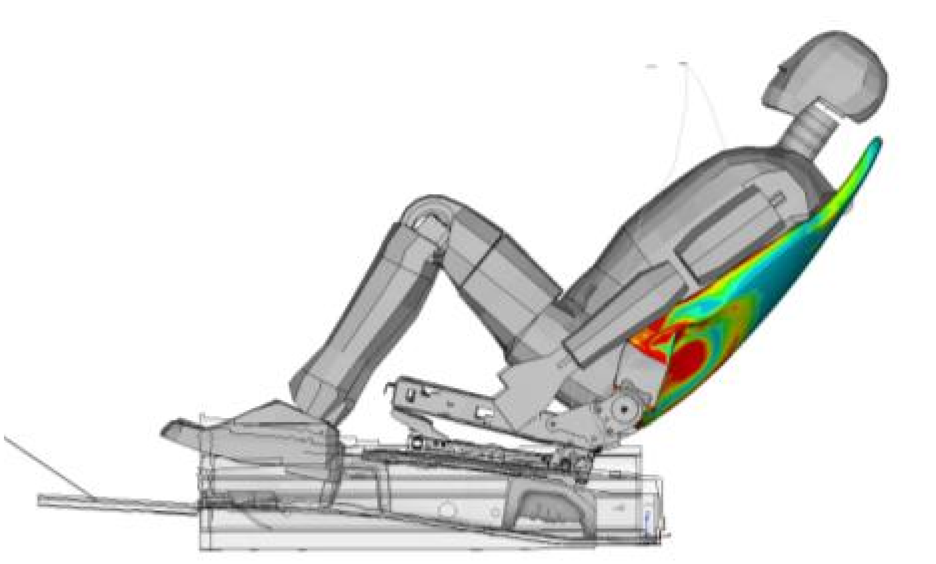




Clam-shell mould and destructive testing



CAE modelling of seat performance



The final design was shown to pass most of the industry requirements and was lighter than existing seats while being price competitive

3D knitted structure – benefits over existing steel frame

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Reduce weight, time to market, and cost

- Utilise CAE technology – design optimisation & validation
- Eliminate labour intensive lay-up processes
- Eliminate tooling, heavy presses, welding
- Integrate features, form and function
- Manufacture close to the end user
- Minimise waste

3D knitted structure – benefits over existing steel frame

Design flexibility with customisation potential

- Quick design changes possible
- CAD to preform in short time
- Low cost tooling
- Rapid manufacturing methods
- Prototype to production with more confidence

for more info please contact:

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