Using 100% Recycled ABS (rABS) in Plastic Products (Phase 2, Prototype Development and Testing)

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Outputs Contents

Materials Strategy for BT plc

Materials Comparison Testing

Contents

1. Background

The De Montfort University Design Unit has recently completed a risk assessment relating to the use of %100 recycled plastic in their products, typically DECT phones

This has been part of BT's Better Future initiative to help deliver on BT's strategic aim to be a responsible and sustainable business leader.

The assessment will contribute to BT's 'North Star Goals' to be part of the wider, Better Future programme structure, achievable within 5 to 15 years. One of these North Star Goals is 'Net Good' where BT's products will achieve three times the carbon saving for their customers than they emit over their lifetime. An enabler of Net Good is implementation of the Circular Economy (CE) principles.

BT's goal is to make good quality, inclusively-designed products that exceed BT customers' expectations, while minimising the environmental impacts inherent in their manufacture and use. This is going far beyond 'compliance'.

2. Evaluation of ABS, rABS and Recycled Polycarbonate/ABS Mix

A number of test methods were used to compare identical injection moulded samples of Acrylonitrile Butadiene Styrene (ABS), 100% post-consumer recycled Acrylonitrile Butadiene Styrene (rABS) and 100% post-consumer recycled Polycarbonate/ABS mix (PC/ABS) against each other to evaluate their suitability for use in consumer products (fig 1).

Fig.1 (left to right) rABS, rPC/ABS and ABS mouldings from the Materials Prototype tooling of a DECT handset.

2.1 Screw Torque Tests

A calibrated ‘dial indicating screwdriver’ (Gedore TT500 FH, fig.2) was used to tighten a M3 thread forming screw in a moulded boss (fig. 3). The screw was then over-torqued until the plastic boss had stripped; meaning the screw no longer gripped the plastic material. The force at which the boss stripped was recorded for samples of ABS, rABS and PC/ABS (see figures 4 to 7).

Fig.2 Gedore TT500 FH dial indicating screwdriver

Fig.3 Dial indicating screwdriver and material sample

100% rABS (CNm)	Virgin ABS (CNm)	Recycled ABS PC (CNm)	100% rABS with modified screw boss (CNm)
78	**120**	**40**	100
40	85	70	110
25	80	50	**80**
52	**70**	40	**110**
80	80	60	100
50	100	**75**	100

Fig.4 Results of screw torque tests

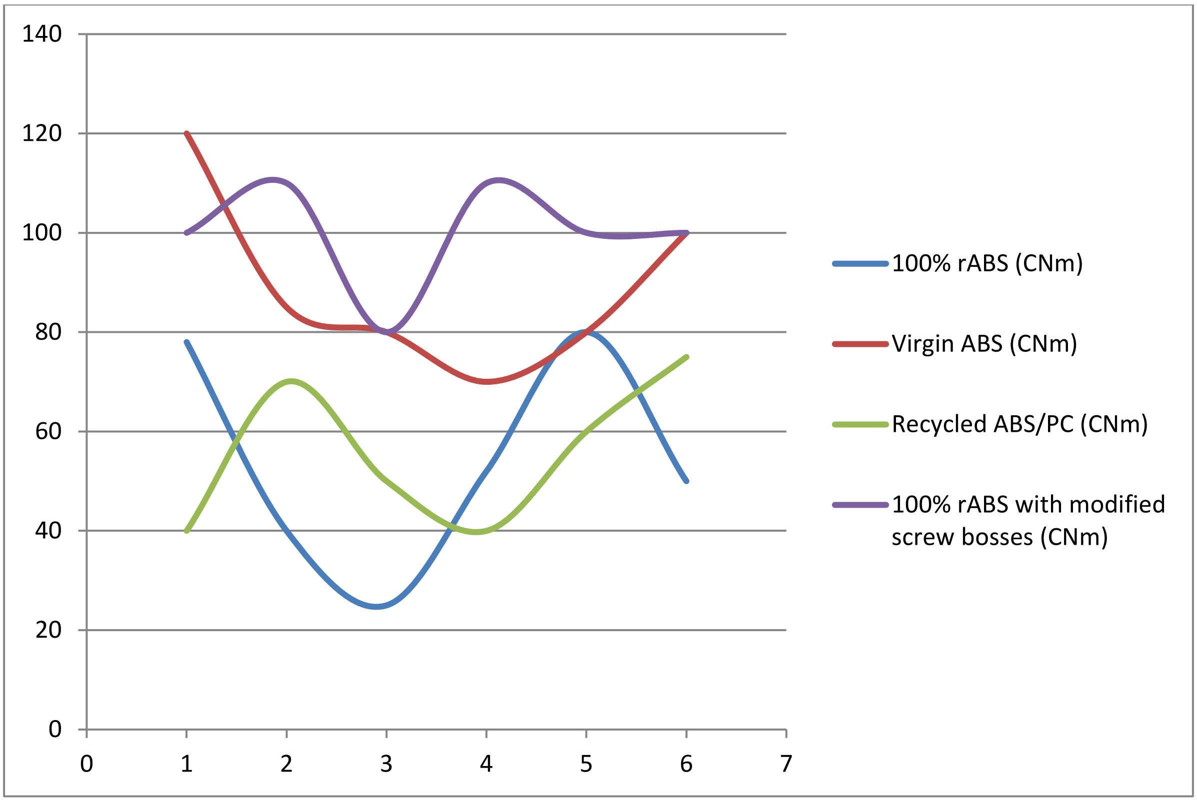


Fig.5 Results of screw torque tests

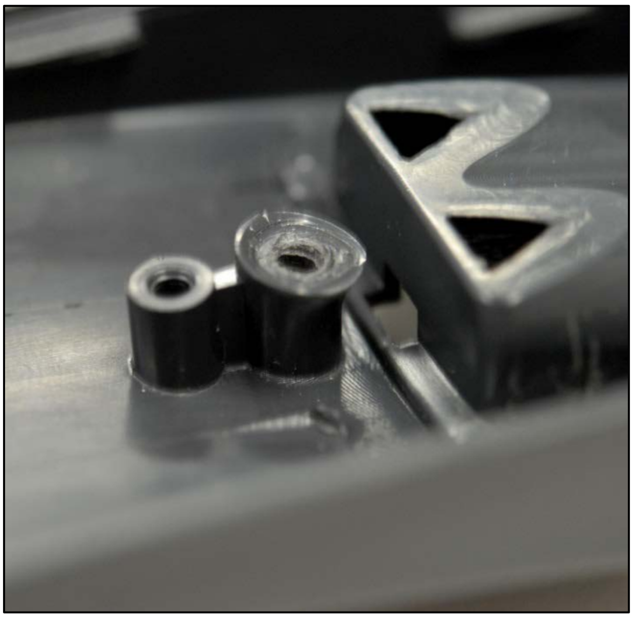


Fig.6 Moulded screw bosses post test

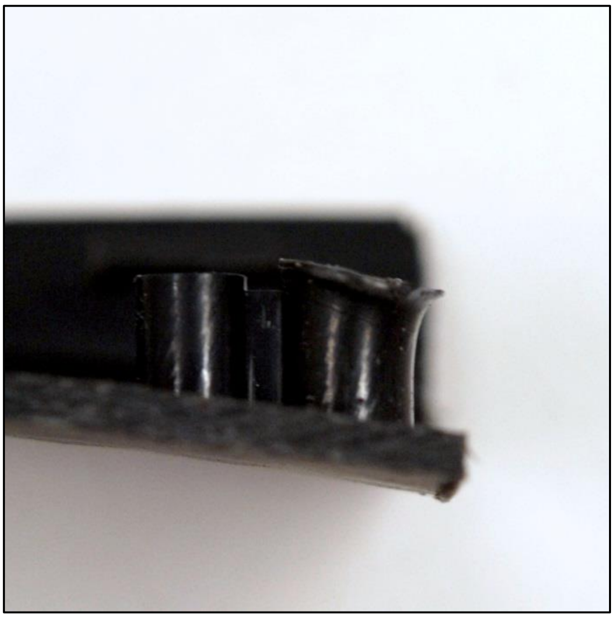


Fig.7 Moulded screw bosses post test

2.2 Heat Tests

Testing was conducted on the handset mouldings to examine the effect of heat on the different polymers, simulating an overheated/faulty battery (for example). The testing was carried out using a 200Watt “AAA battery-sized” cartridge heater (figure 8). The heater was placed inside an assembled set of DECT handset mouldings in place of a triple-A battery. A sintered Nylon component was produced and used in place of the handset’s front lens and a Nylon handset holder was produced to ensure all the samples were positioned in the same way throughout the tests. The cartridge heater was connected to a power supply unit to heat up for one hour.

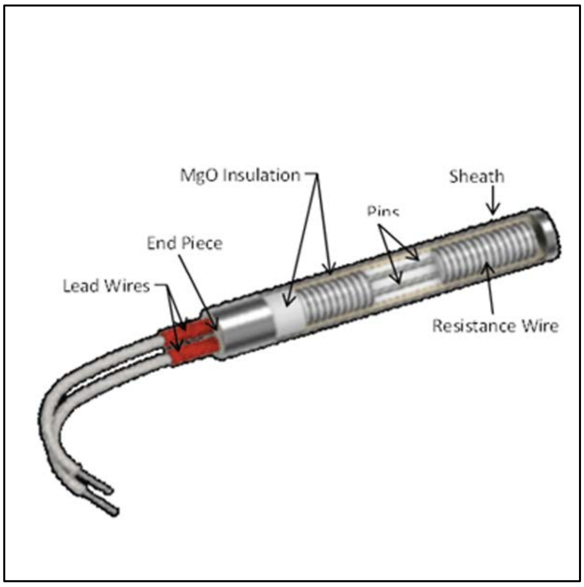


Fig.8 Cartridge heater

Fig.9 Heat testing

The external temperature of the assembly was monitored periodically throughout the tests using an infrared thermometer (see figure 9) and examined for signs of cosmetic and structural damage (see figures 10 to 13).

Fig.10 Sample with signs of heat damage

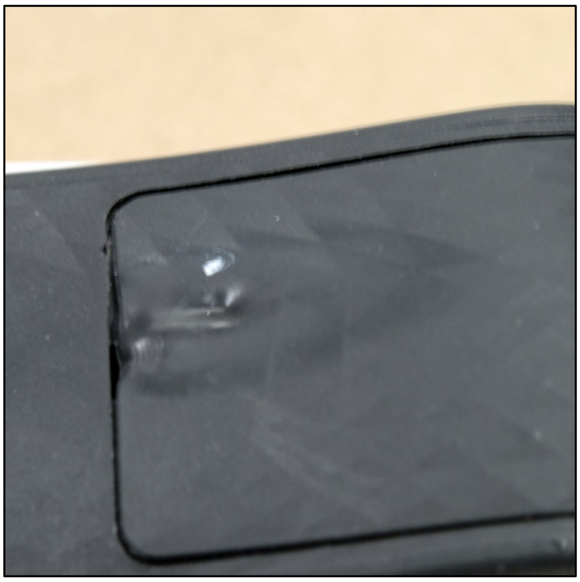


Fig.11 Sample after one hour

Temperature at which the moulding shows signs of heat damage externally (100% rABS) (degrees centigrade)	Temperature at which the moulding shows signs of heat damage externally (Virgin ABS) (degrees centigrade)	Temperature at which the moulding shows signs of heat damage externally (recycled ABS PC) (degrees centigrade)
80	80	99
88	85	105
82	88	100
84	86	105
82	82	98

Fig.12 Results of heat test

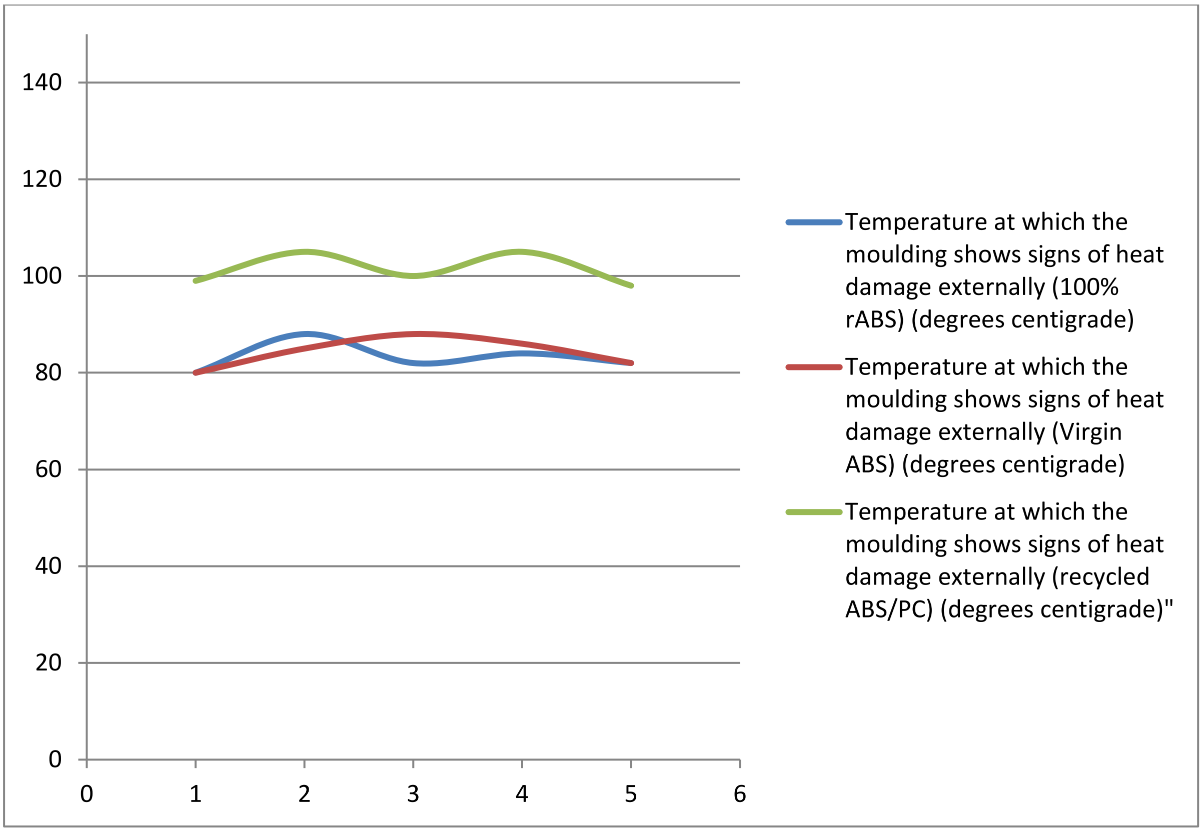


Fig.13 Results of heat test

Temperature after 1hr (100% rABS) (degrees centigrade)	Temperature after 1hr (Virgin ABS) (degrees centigrade)	Temperature after 1hr (recycled ABS PC) (degrees centigrade)
116	107	108
105	114	135
125	101	115
127	104	135
128	102	120

Fig.14 Results of heat test

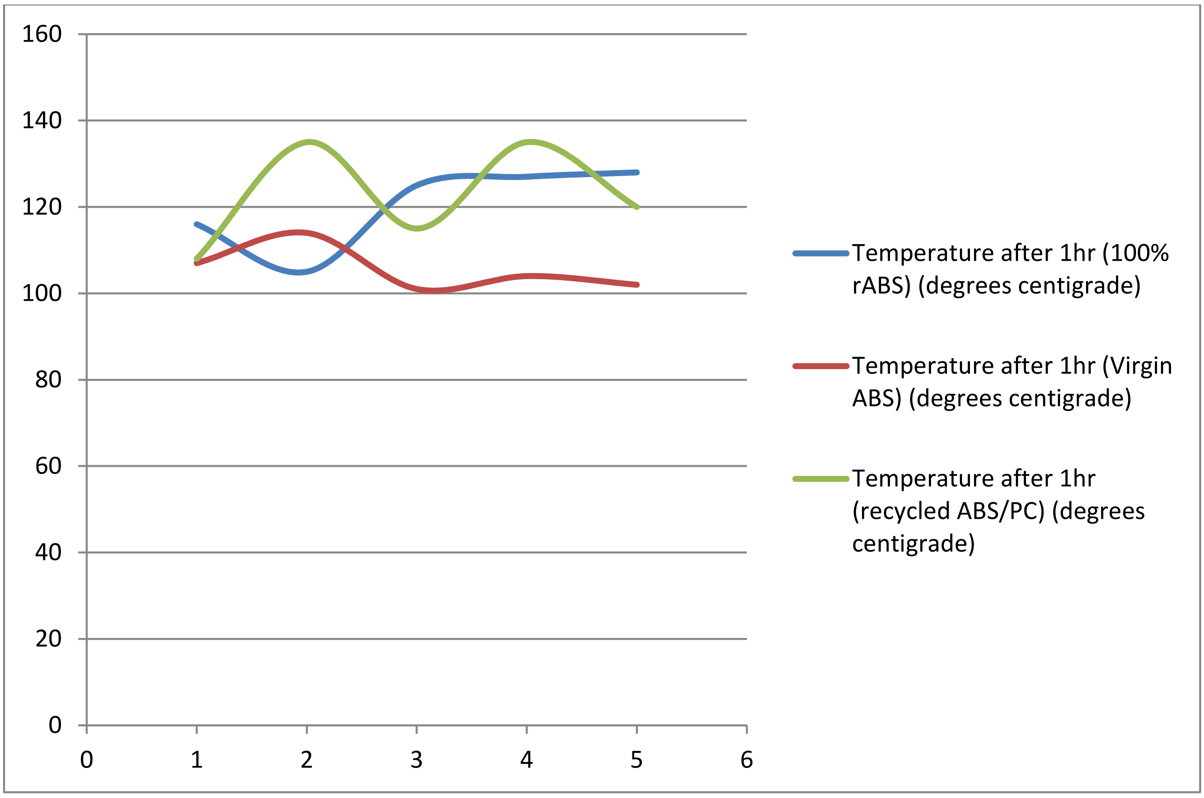


Fig.15 Results of heat test

Fig.16 Material samples showing cosmetic damage after heat testing

2.3 Screw Pull-out Tests

Screw pull-out tests were conducted on the moulded screw bosses using an Instron 3367 Dual Column Testing System to pull an M3 thread forming screw from the mouldings. Custom sample holders were produced in sintered Nylon (figures 17 and 18) allowing a screw to be pulled from mouldings which were trimmed down to the area surrounding the bosses. The results are documented in figures 21 – 24.

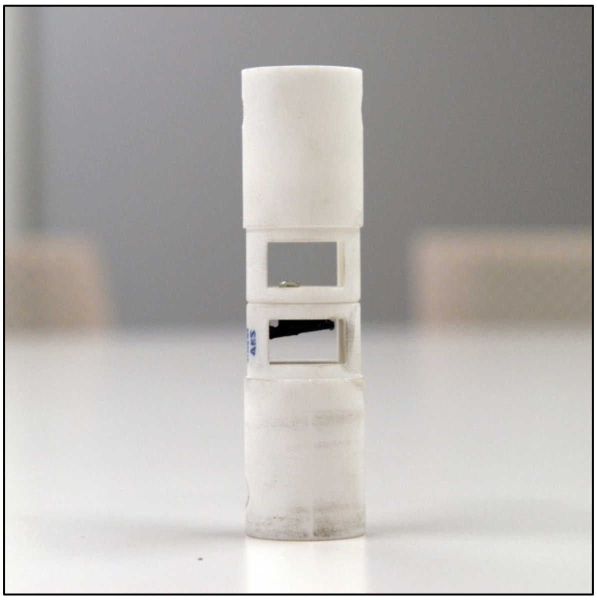


Fig.17 Sample holders

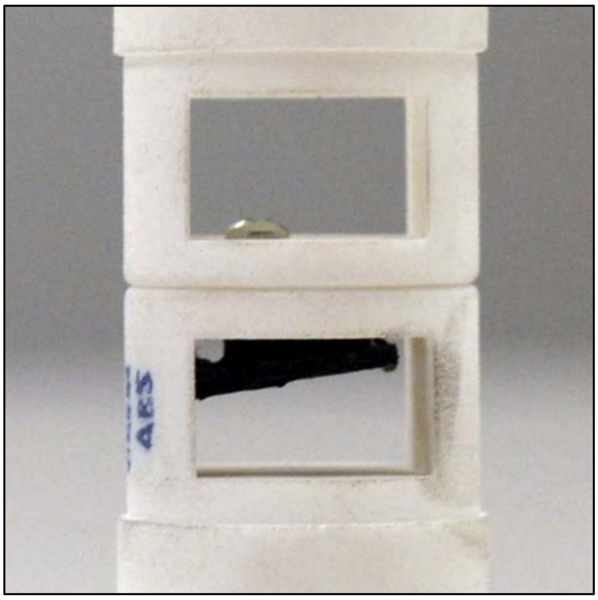


Fig.18 Sample holders

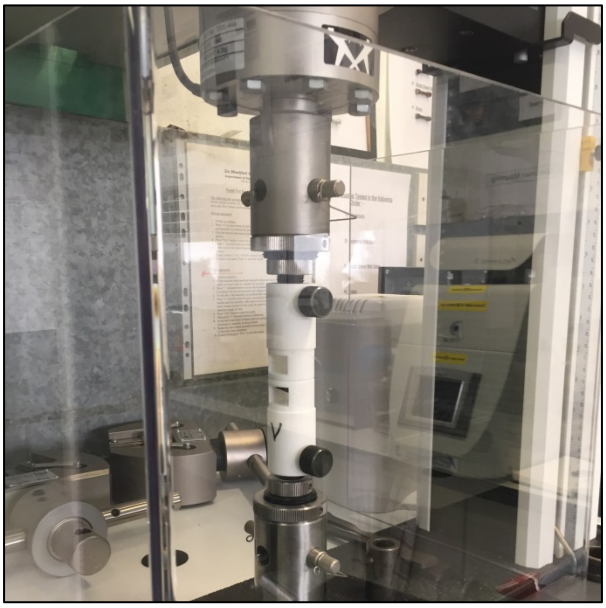


Fig.19 Instron 3367 Testing System

Fig.20 Instron 3367 Testing System

	Material	Maximum Load (N)	Break (Load 0 N)	Extension at Break (Load 0 N) mm
1	ABS	989	853	7.361
2	Recycled ABS	970	963	5.43
3	ABS	628	628	2.532
4	Recycled ABS	1039	1034	5.697
5	ABS	752	752	3.313
6	Recycled PC/ABS	1040	1001	5.377
7	Recycled PC/ABS	588	583	4.043
8	Recycled PC/ABS	799	799	3.756

Fig.21 Screw pull-out test results

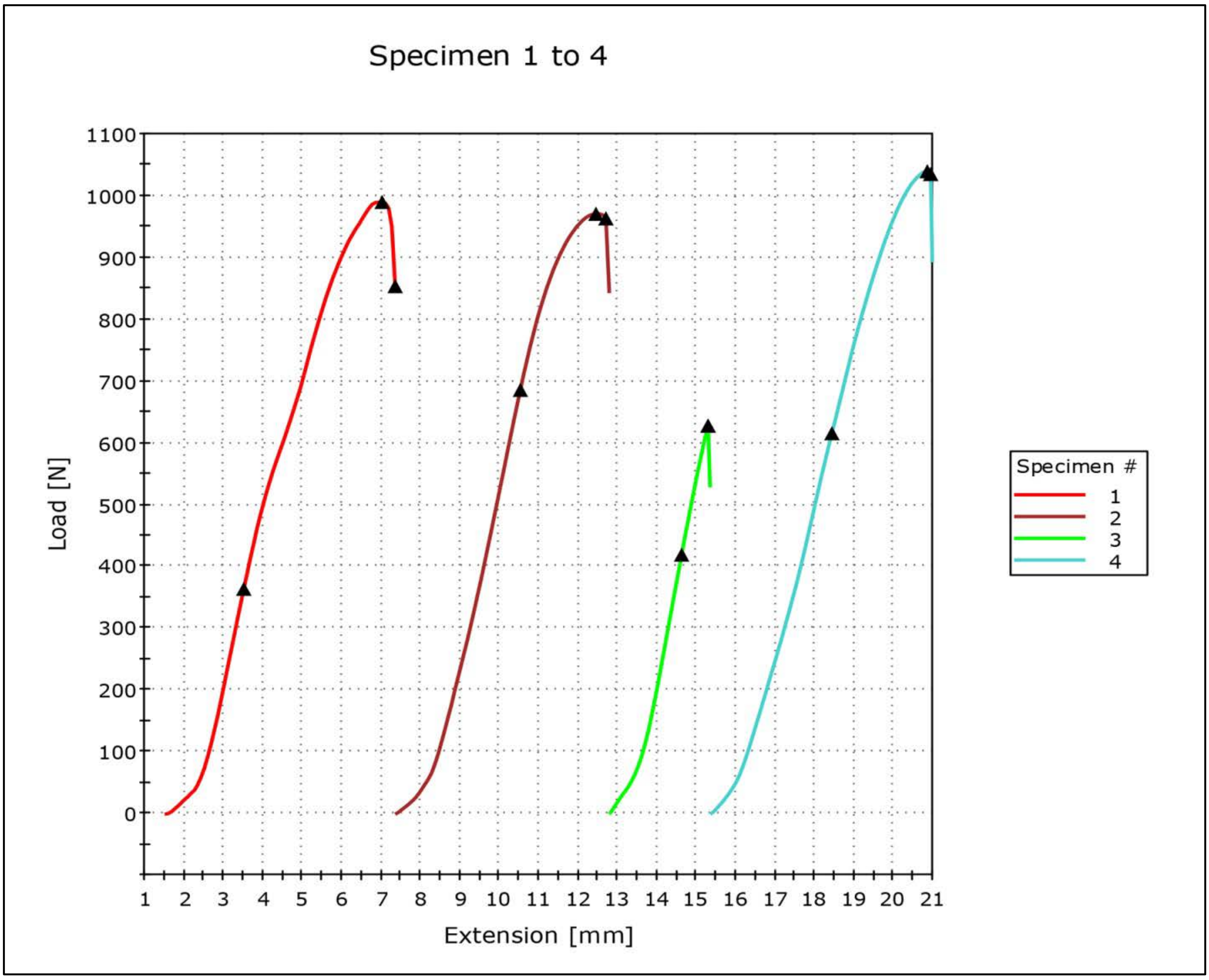


Fig.22 Screw pull-out test results – (left to right) ABS, rABS, ABS, rABS

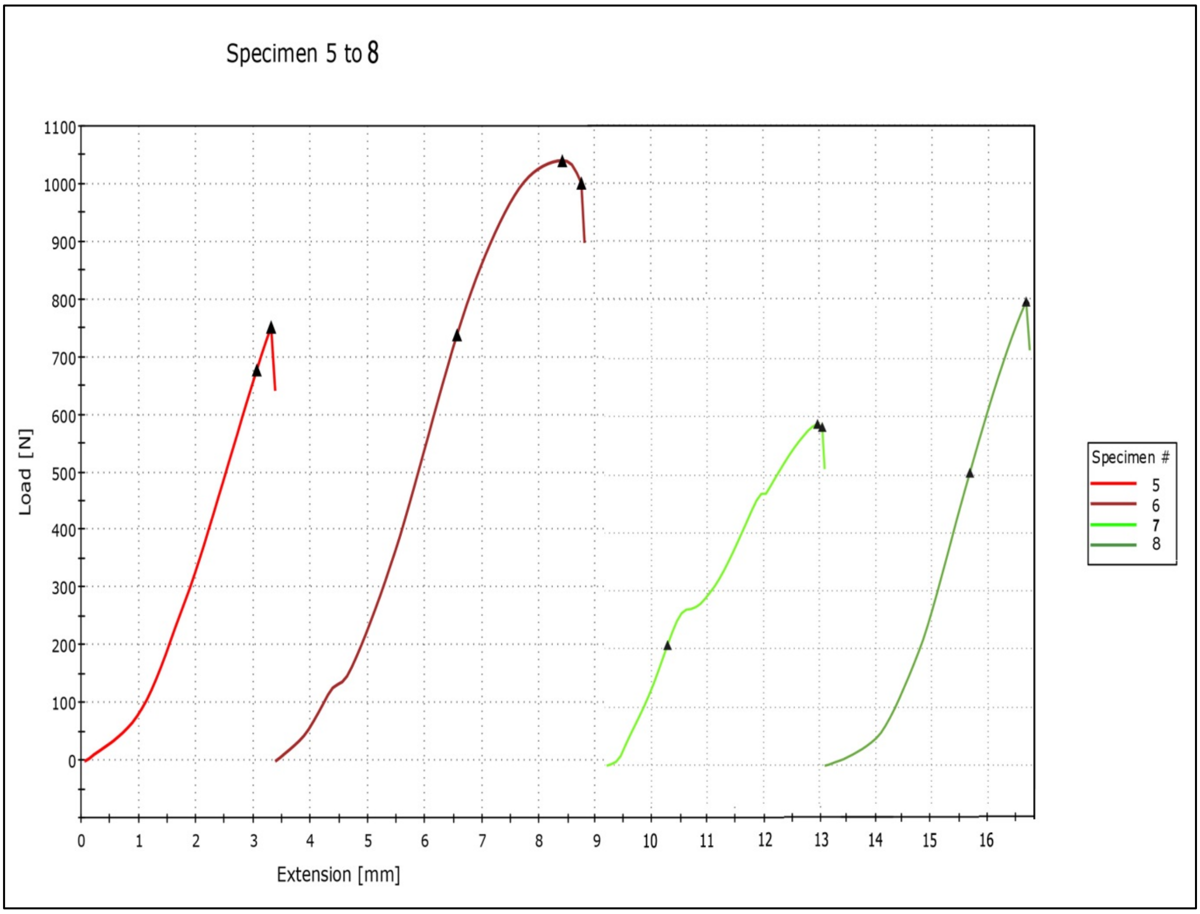


Fig.23 Screw pull-out test results – (left to right) ABS, rPC/ABS, rPC/ABS, rPC/ABS

Fig.24 Screw pull-out test results ABS (left) rABS (right)

2.4 Drop Tests

Drop tests were carried out on the samples in accordance to S4002 v14 *"Dynamic, Environmental & Ageing Test Requirements for Consumer Devices"*, test method 'IEC 60068-2-31'; with the handset being dropped from a rig onto its upper and lower faces from a height of 1.5 metres onto a concrete surface. The tests were video recorded (figure 26) and the test samples were examined for cosmetic and structural damage.

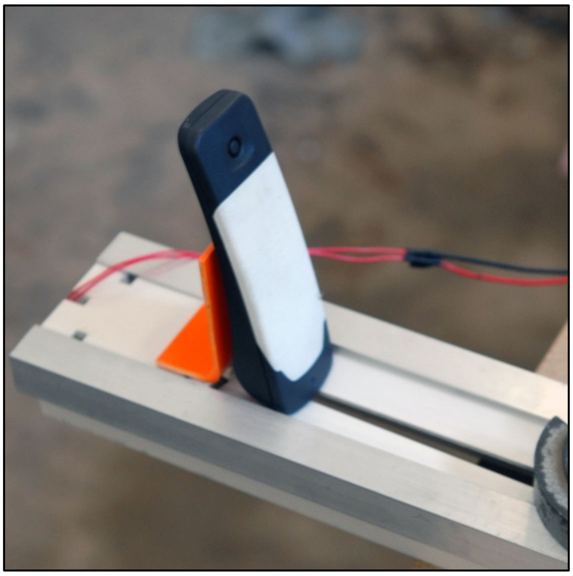


Fig.25 Drop test rig

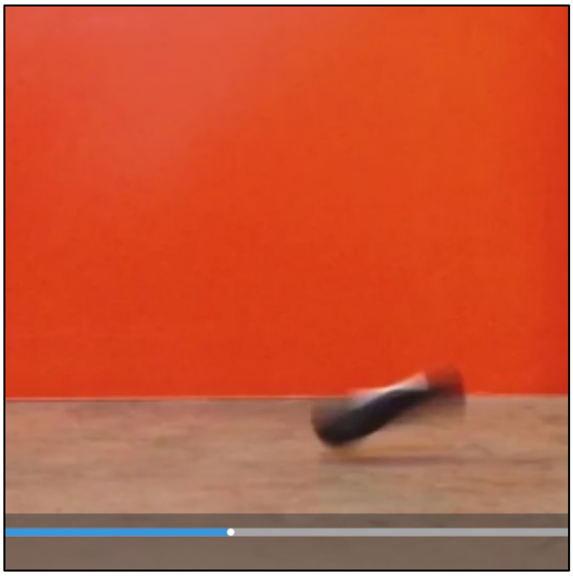


Fig.26 Still from a drop test video recording

Fig.27 Drop test sample examination (left to right) ABS, rPC/ABS

2.5 Tensile Tests

Tensile tests were conducted on moulded material sample plaques using an Instron 3367 Dual Column Testing System (see figure 30).

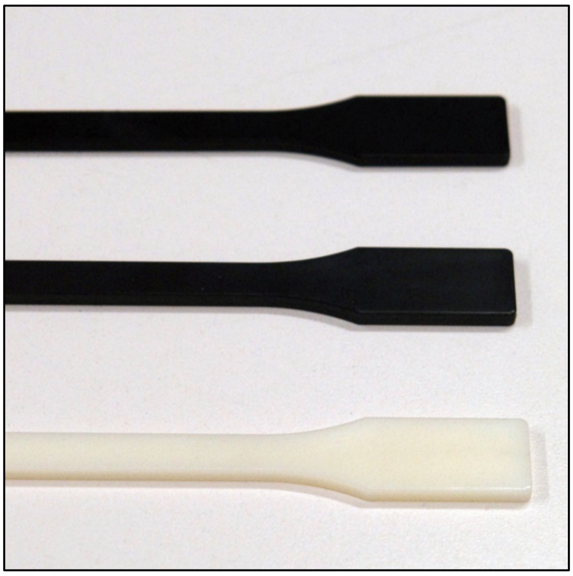


Fig.29 Material sample plaques

(top to bottom) rABS/PC, rABS, ABS

Fig.30 Instron 3367 Tensile Testing System

Fig.31 Material sample plaques post-test

(left to right) rABS/PC, rABS, ABS

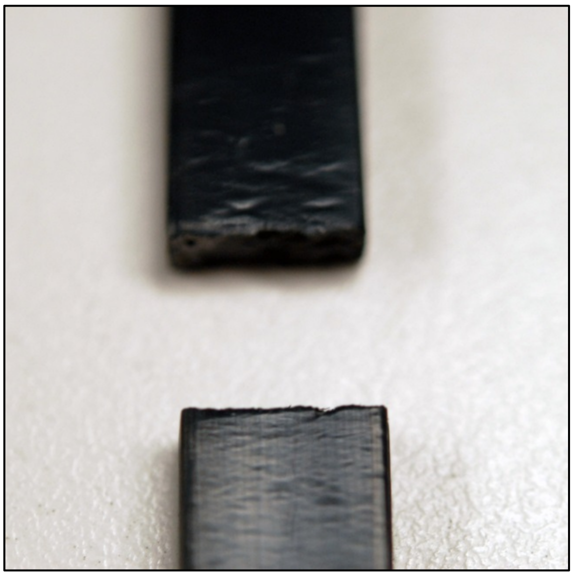


Fig.32 rABS material sample plaque post-test

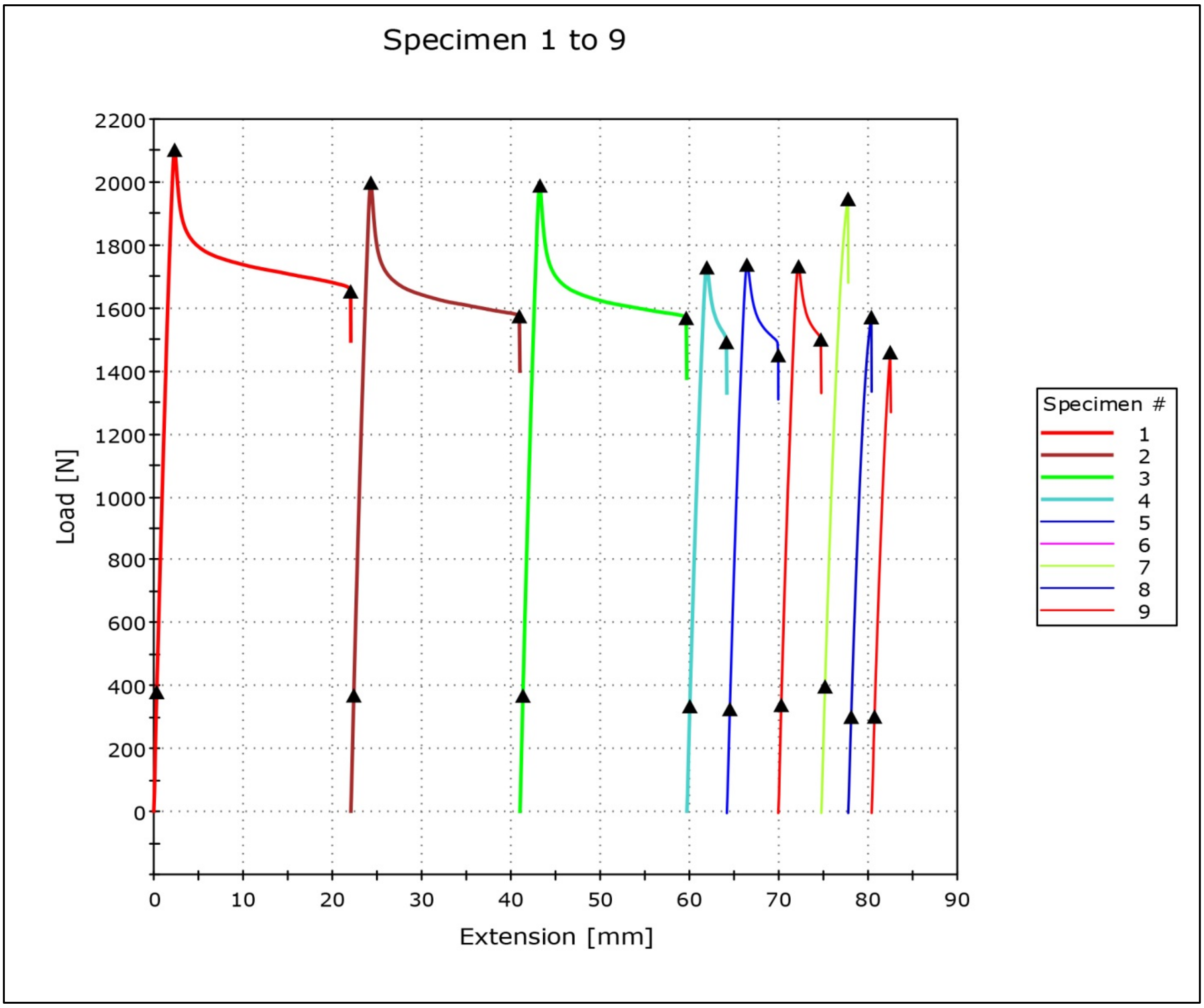


Fig.33 Tensile test results – ABS (specimens 1-3), rABS (specimens 4-6) & PC/ABS (specimens 7-9)

	Material	Maximum Load (N)	Break (Load 0 N)	Extension at Break (Load 0 N) mm
1	ABS	2103	1654	22.007
2	ABS	1999	1575	18.841
3	ABS	1989	1570	18.591
4	Recycled ABS	1730	1493	4.424
5	Recycled ABS	1739	1452	5.758
6	Recycled ABS	1733	1501	4.758
7	Recycled PC/ABS	1947	1947	3.008
8	Recycled PC/ABS	1572	1572	2.591
9	Recycled PC/ABS	1461	1461	2.092

Fig.34 Tensile test results

3.0 Conclusions

Overall, these tests indicate that there is very little mechanical difference between moulded virgin ABS polymer and moulded 100% post- consumer recycled ABS polymer. The main differences seem to be cosmetic. 100% recycled ABS lost mechanical properties when coloured master-batch was added during moulding; the absence of master-batch colouring leaves the parts with a charcoal grey colour rather than a more desirable black colour. In comparison, the post-consumer recycled Polycarbonate/ABS mix mouldings were closer to the black colour of the virgin ABS mouldings.

The standard tightening torque for M3 screw thread is 1.1 Nm. The screw torque tests undertaken show a maximum stripping force of 120 CNm (1.2 Nm) for virgin material and 110 CNm (1.1 Nm) for recycled material with modified screw bosses; with a range of 40 CNm (0.4 Nm) between the two. This is a relatively small difference. The PC/ABS samples stripped at a slightly lower force, with a minimum stripping force of 40 CNm (0.4 Nm) and a maximum of 75 CNm (0.7 Nm), a range of 35 CNm (0.35 Nm). This suggests that PC/ABS mix is slightly more brittle than the other material samples.

The tensile tests show that all three materials have a similar break load. However, the recycled materials are less flexible with a considerably shorter extension at break than the virgin material, with the PC/ABS mix being more brittle than the rABS.

All three materials fared well in the drop tests, with no internal clip geometry cracking or breaking……

Presented at Better Future Supplier Forum at BT on 2nd July 2015

Present:

- British Telecom (host)
- Vtec
- Sagemcom
- Arcadyan
- Humax
- SGW Global
- De Montfort University

A recap on phase 1

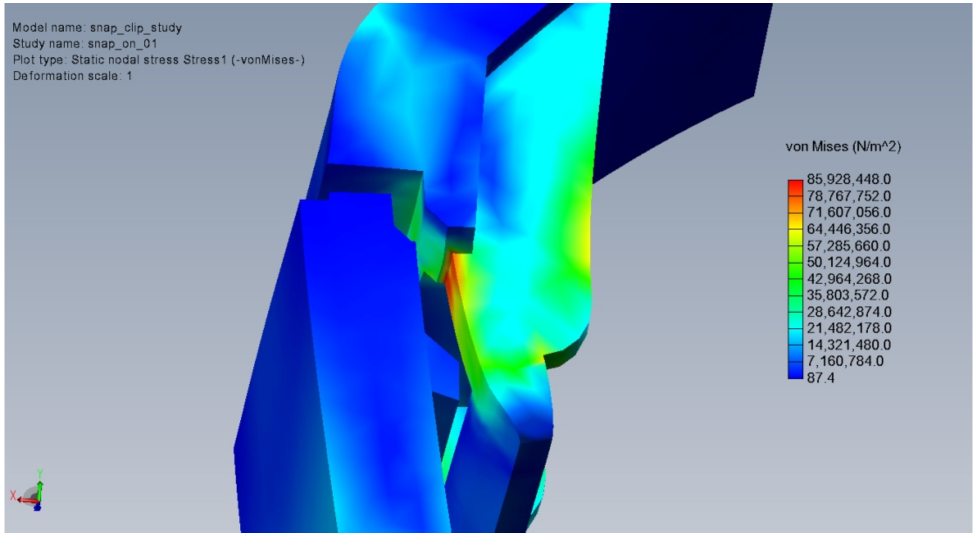
An ***adapted 6500*** with a protective shrink film to provide strength, colour and graphics

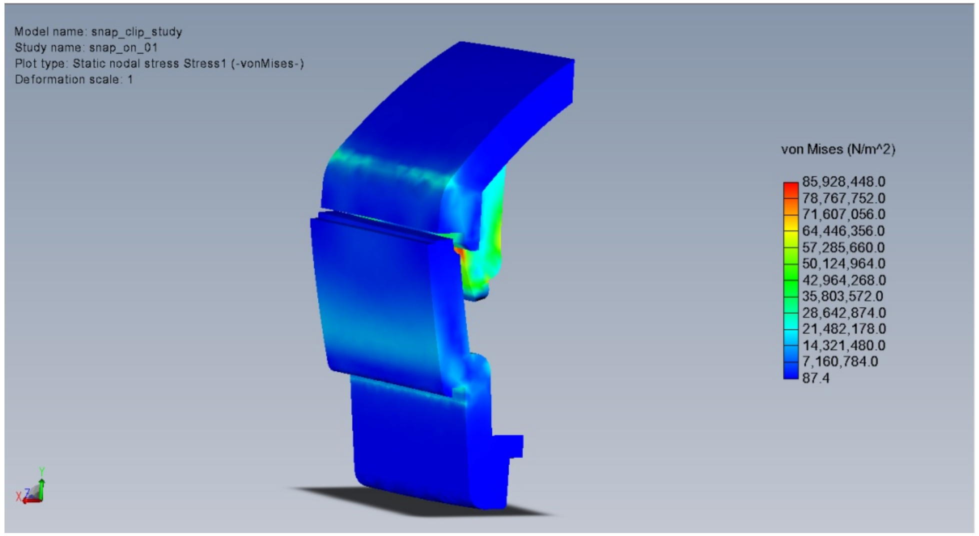
Strength (Typically Around Clips)

Yield Point on
Typical Clip

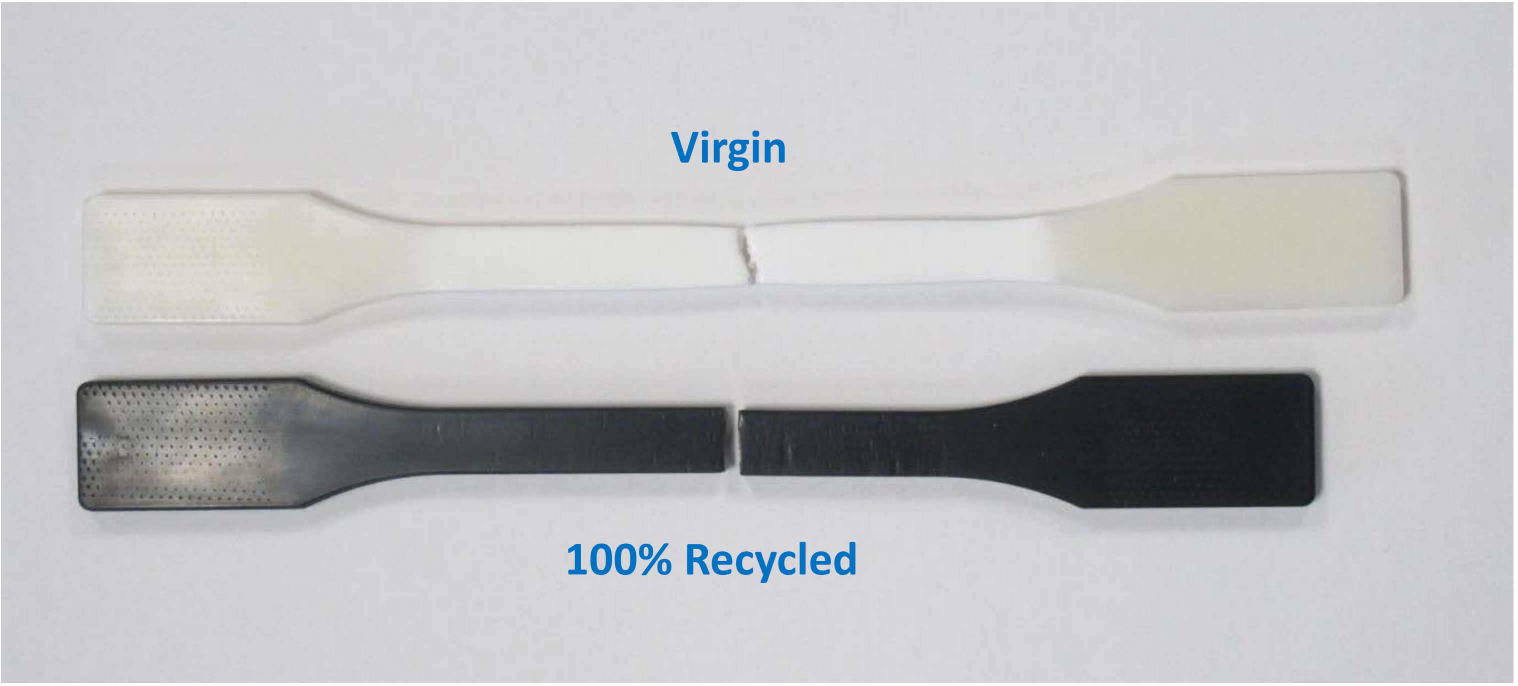
Strength (Theoretical)

100% Recycled Versus Virgin Material:



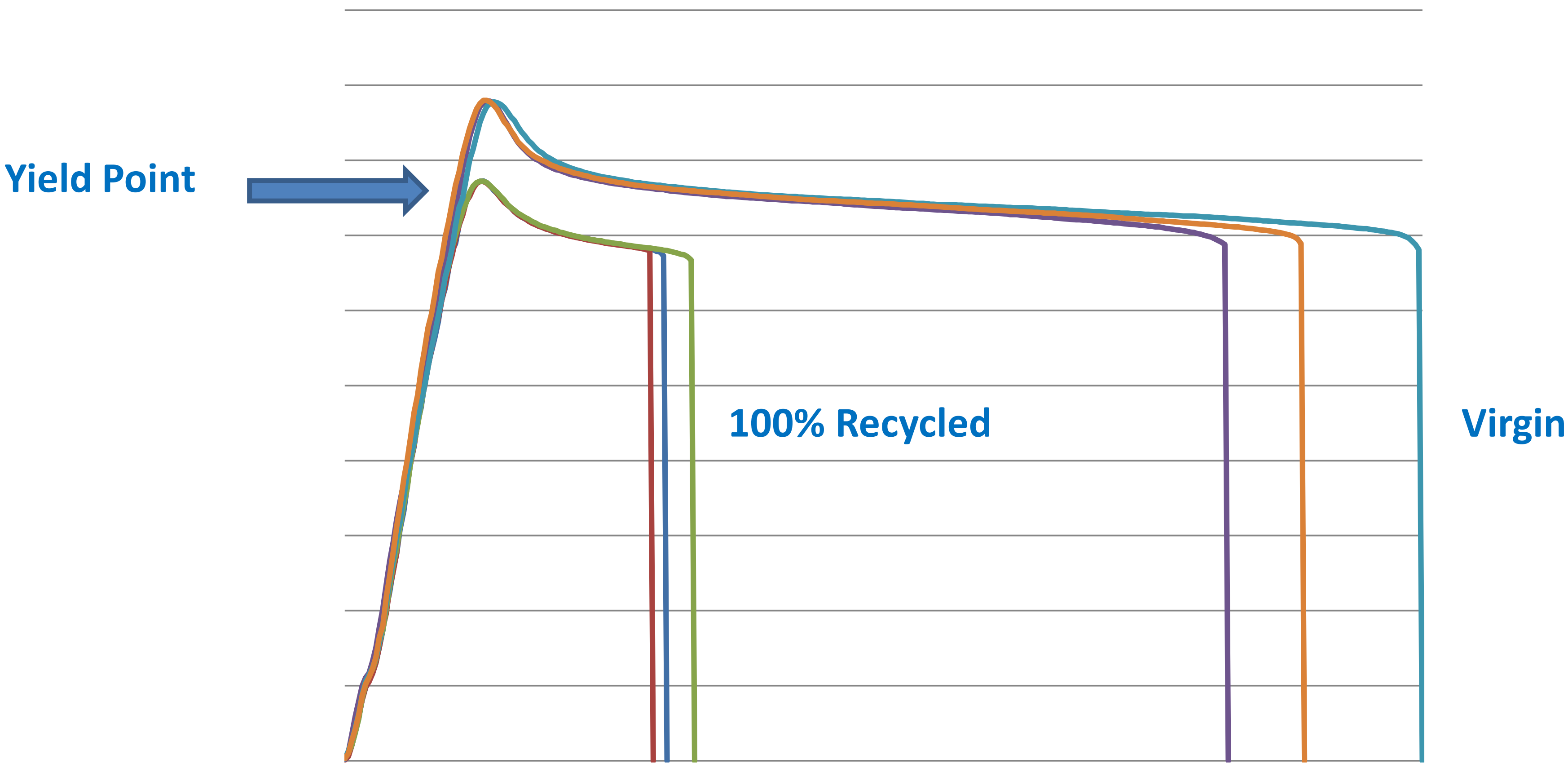


Strength (Practical)



Strength (More Dramatic Failure at Yield Pint With rABS)

100% Recycled Versus Virgin Material:

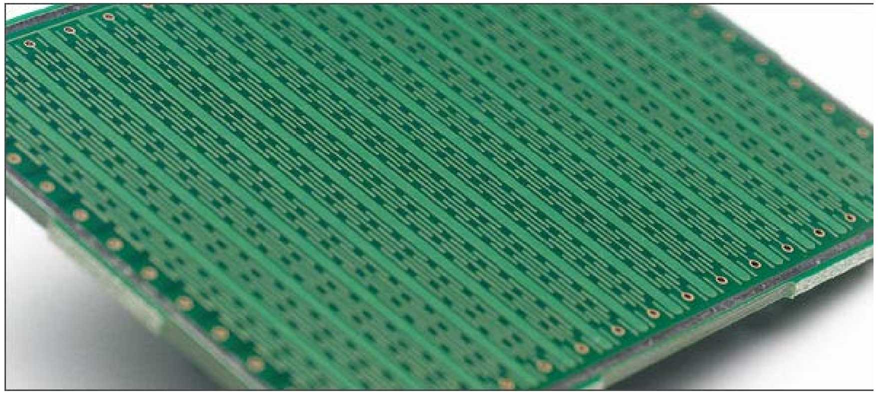


Colour and Texture

100% Recycled

Virgin

Rationalisation of Components (Typically Keyboard)



‘E-Ink’ Display

Using Heat Shrink Material for Colour, Graphics and Product Assembly

Heat shrink for assembly, colouring and the ability to customise/personalise

A Revised 6500 Using rABS, ‘E-Ink’ Display, Capacitive Touch Keyboard and Heat Shrink Material for Graphics and colour

Phase 2 – Initial Prototype Based on the Phase 1 Recommendations

Using Heat Shrink Foils

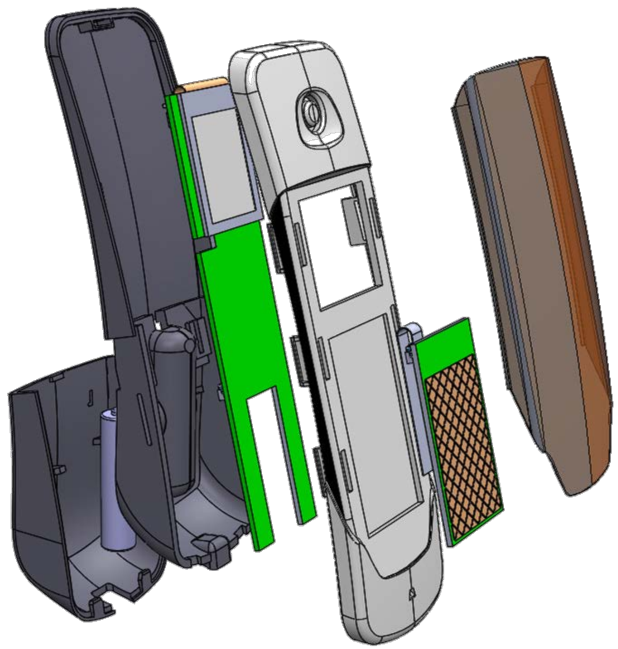
First Prototype Based on, 'E-Ink' Display, Capacitive Touch Keyboard and Heat Shrink Material for Graphics and colour

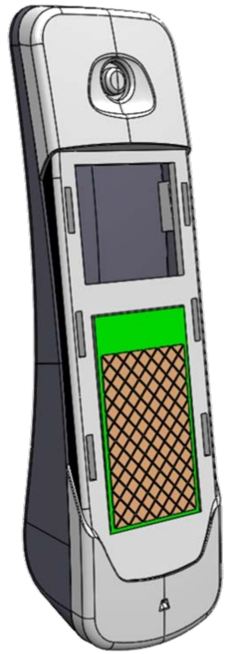
- **‘E-Ink worked**
- **Capacitive touch keypad worked**
- **The heat shrink foil worked mechanically but was rejected due to the quality of feel when in use**

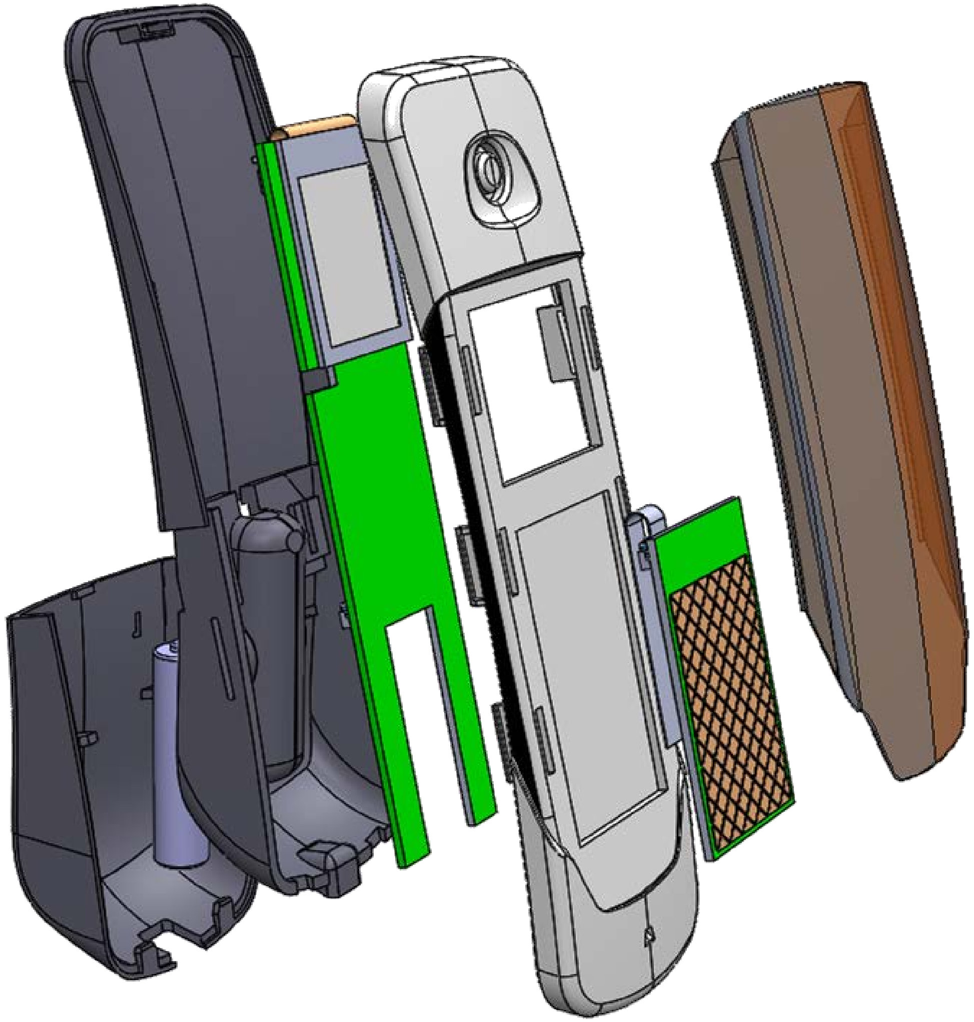
Phase 2 – Second Round Prototype Based on Surfcace Texturing and Mechanical Design Features to Replace the Option of Using Heat Shrink Foils (Due to Feel and Touch)

Sanctioned to Completely Re Design the DECT Phone

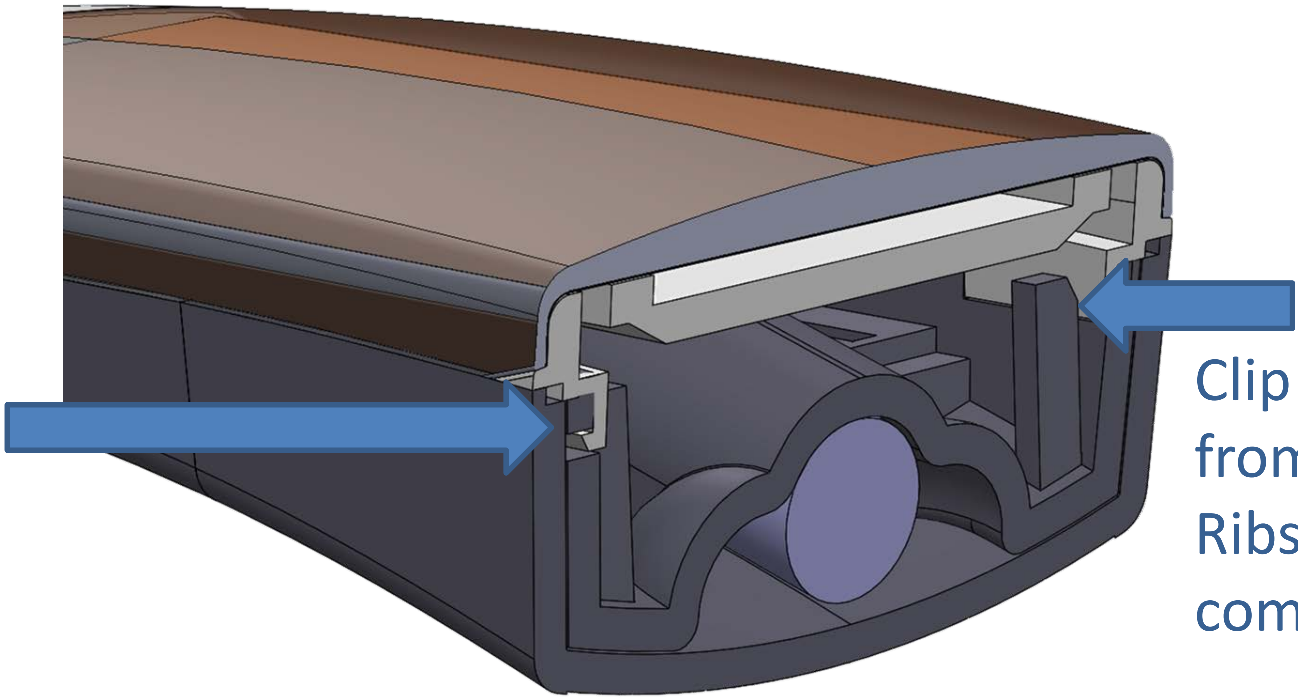
Capacitive Touch Keypad and 'E-Ink' Display Retained



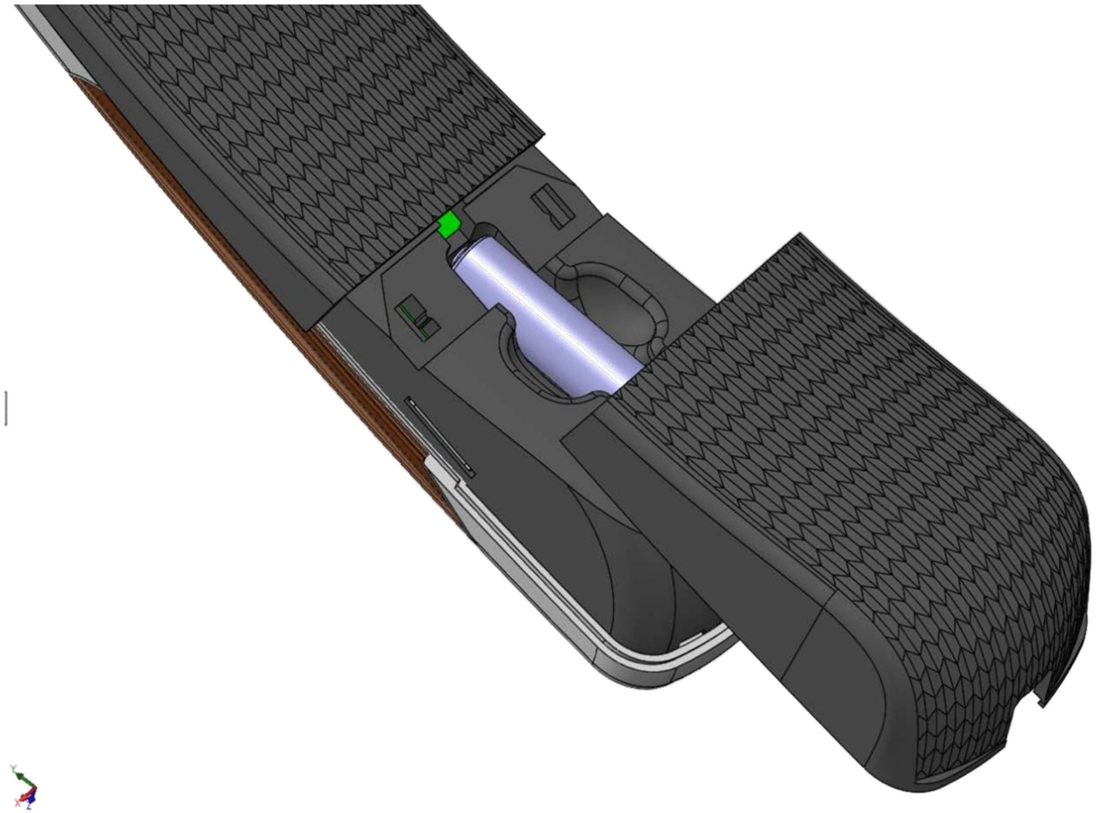




Innovative Approach to Lengthening Clips and Buttressing these off the Battery Compartment

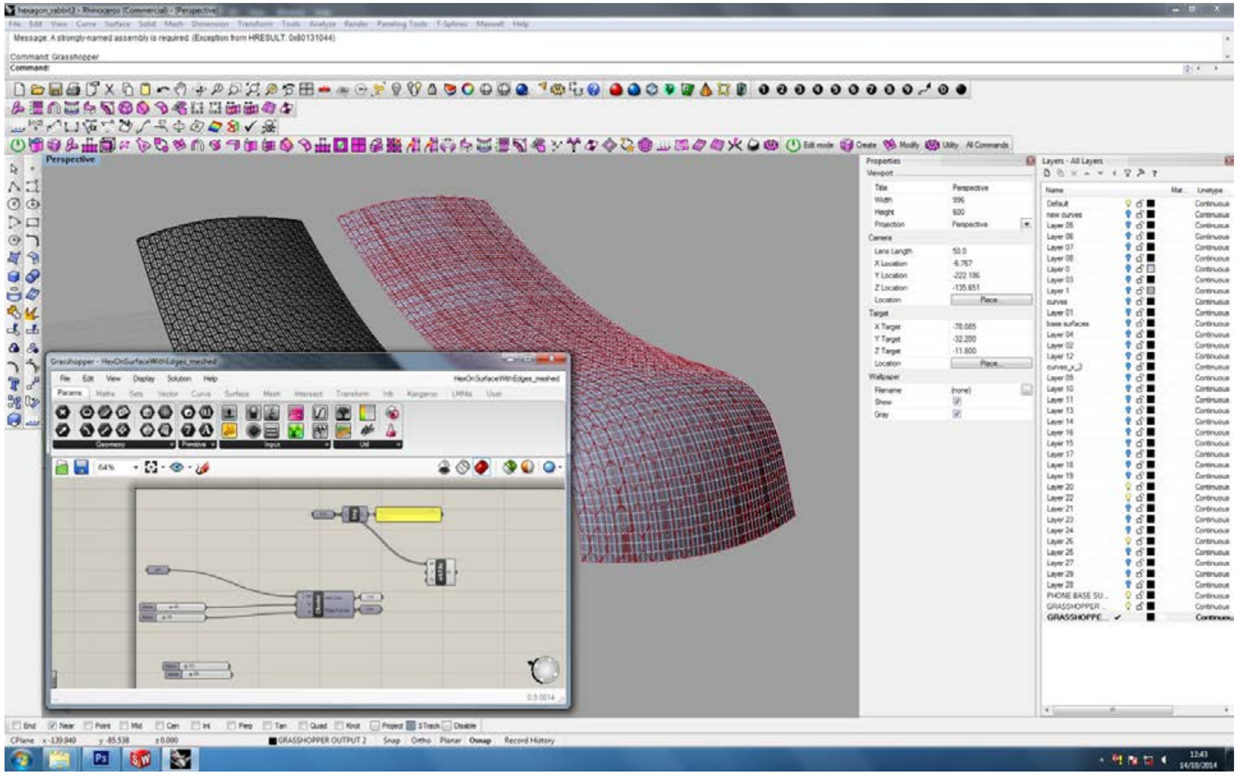


Battery Compartment Buttresses Clips and Serves to Lock the Body Halves Together

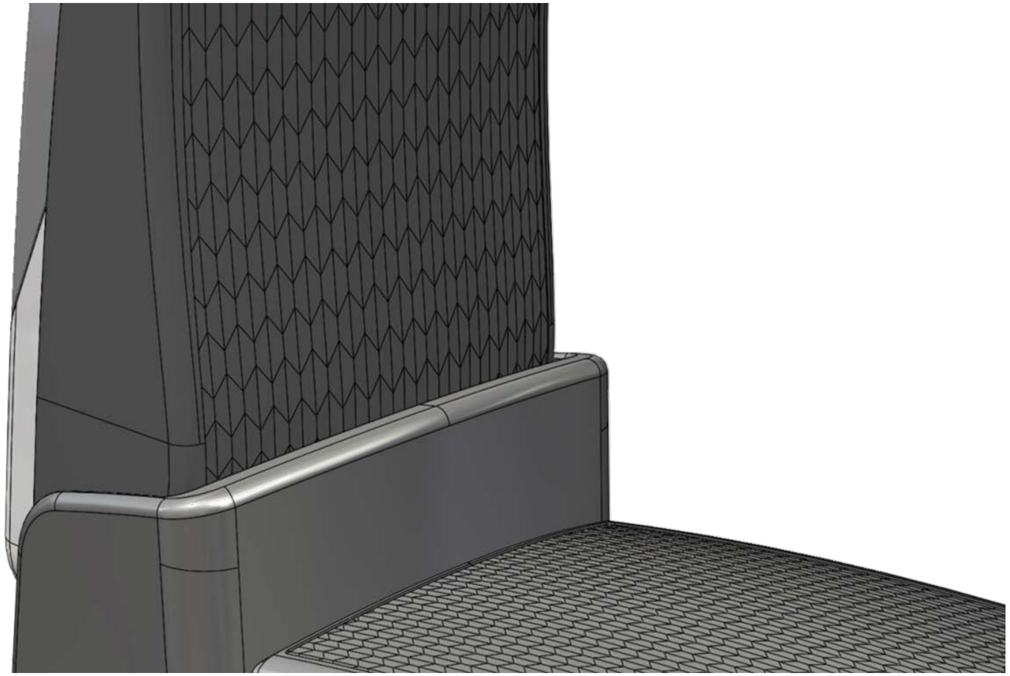


Product Visualisation

Innovative Use of Low Cost CAD Techniques for Texturing Components to Scatter Light and Hide Imperfections (Inclusions) in the rABS

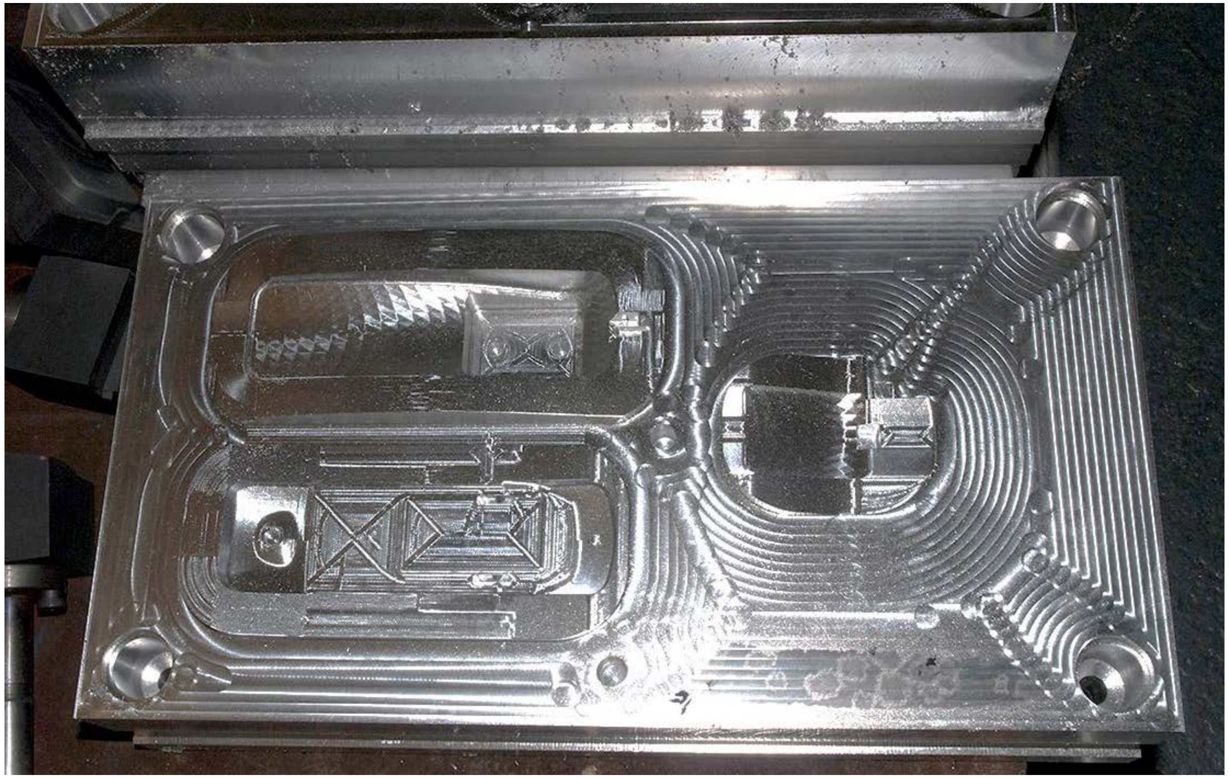


Strength (Theoretical)



Direct Machining of Texture Effects Into Tool Steel

Fully Tooled and Injection Moulded Prototype Parts

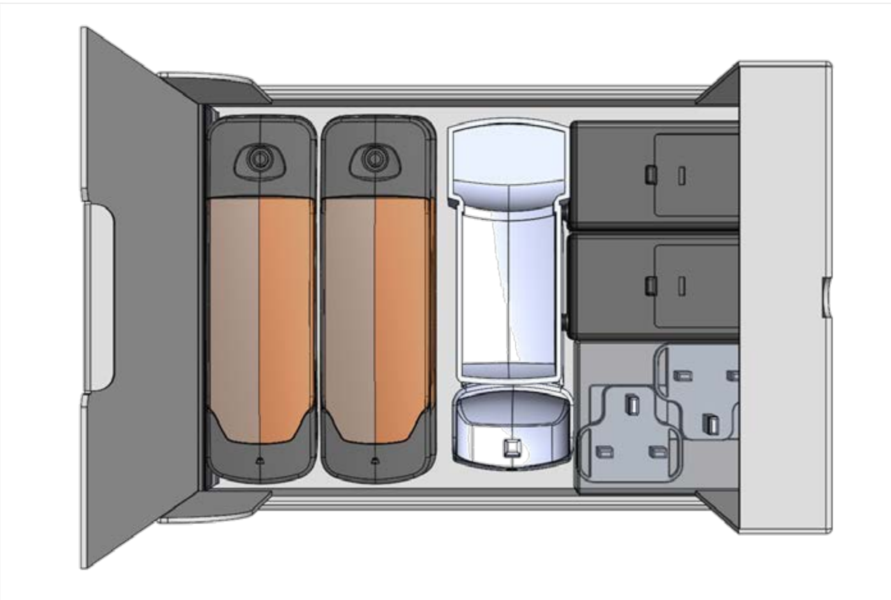


Fully Tooled and Injection Moulded Prototype Parts

A Complete Working Second Prototype Was Produced

(needs better photos)

Packaging Designed to Fit Through Standard EU Letterbox



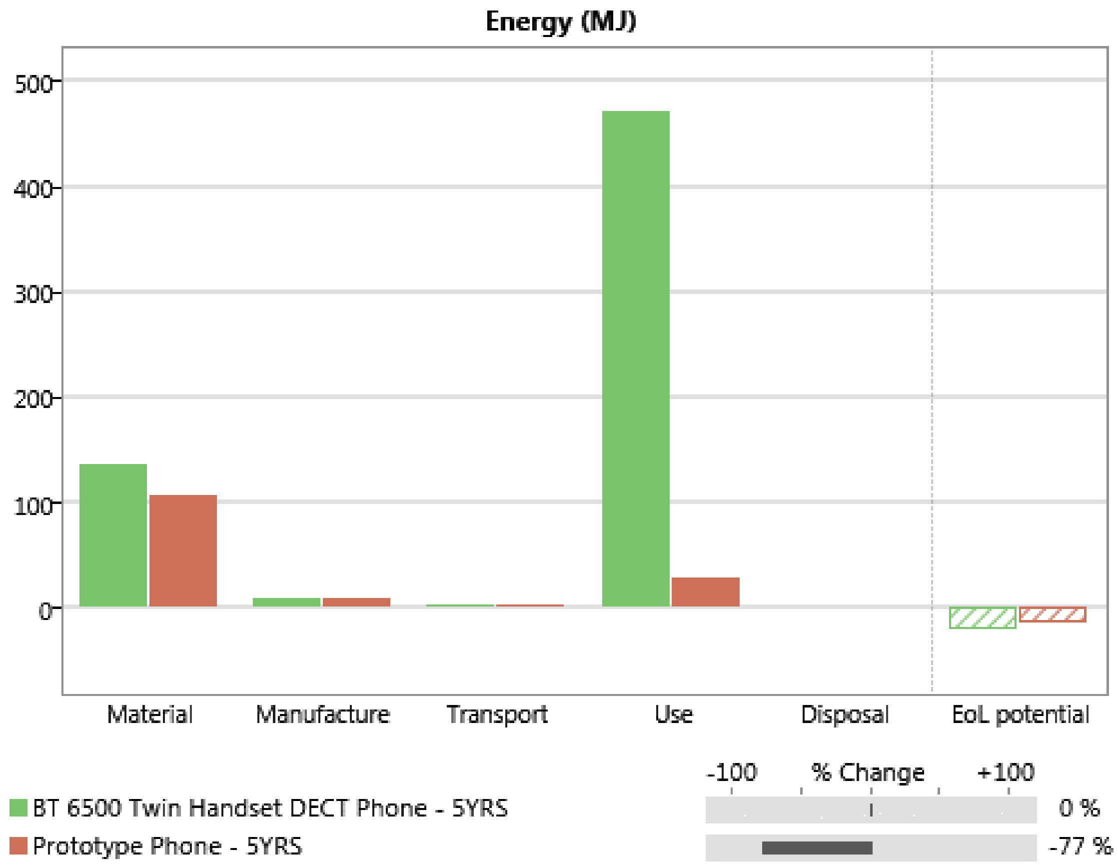
Prototype Packaging *(needs better photos)*

Results – Component and Weight Evaluation

Component	6500 (material volume)	Weight	Materials Prototype V1 (material volume)	Weight	Materials Prototype V2 (material volume)	Weight
Lens	Polycarbonate - 3404.23 cubic millimetres	4.08	DR Acrylic - 14909.98 cubic millimeters	17.74	DR Acrylic - 3404.23 cubic millimeters	4.05
Front Moulding	ABS - 15182.78 cubic millimeters	15.79	rABS - 20449.35 cubic millimetres	21,27	rABS - 20449.35 cubic millimeters	21.27
Rear Moulding	ABS - 20800.96 cubic millimeters	21.63	rABS - 25240.73 cubic millimetres	26.25	rABS - 25240.73 cubic millimeters	26.25
Battery Door	ABS - 8796.98 cubic millimeters	9.15	rABS - 4145.35 cubic millimetres	4.31	rABS - 4145.35 cubic millimeters	4.31
Display Assembly	Conventional	15.8	eInk	3.50	eInk	
Capacitive Keypad PCB	n/a		Integrated into main PCB*		Integrated into main PCB*	
Keypad Assembly - Plastic Keys	ABS - 4450.52 cubic millimeters	4.63	n/a		n/a	
Keypad Assembly - Rubber Keys	Rubber - 6588.85 cubic millimeters	7.71	n/a		n/a	
Keypad Assembly - Steel BKT	Stainless Steel - 347.89 cubic millimeters	2.74	n/a		n/a	
Keypad Assembly - Metal Dome Sheet	Polyester - 502.73 cubic millimeters	0.64	n/a		n/a	
Electronics	Poplulated Single PCB	17.4	Populated Single PCB*	17.40	Populated Single PCB*	17.40
TOTALS		99.57		90.47		73.28

A 10 to 25 g Weight Reduction

Results – LCA Evaluation



Significant Reduction in Energy Consumption

Results – Cost Evaluation

A Significant Component Reduction and Using rABS Leading to a £1-00 Per Handset Cost Reduction (BT Produce Several Million DECT Phones a Year)