

# Continuous-fibre reinforced thermoplastic tailored blanks

Fiberforge's continuous-fibre reinforced thermoplastic (CFRTP) tailored blanks improve cost-effectiveness of high-performance advanced composites. Rapid, automated laminate tailoring improves material efficiency and minimizes scrap and weight, leading to cost-efficient production.



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Fiberforge has developed a novel automated process for fabricating thermoplastic composite parts. This process, illustrated in Figure 1, begins with the creation of “tailored blanks”, which are flat, net-shape preforms comprising layers of continuous-fibre reinforced thermoplastics (CFRTP). Tailored blanks can vary in thickness, fibre orientation, composition and shape based on the needs of the part. These blanks are fabricated using automated machinery designed for high throughput while maintaining precise fibre alignment. Once created, tailored blanks are consolidated and thermoformed into their final shapes. Thermoforming CFRTP provides a means for reducing cycle time to one minute or less while maintaining high mechanical performance.

The primary benefits of fabricating parts with tailored blanks are rapid processing, high material efficiency, low scrap and excellent mechanical properties. The company has made tailored blanks using a range of materials ranging from glass fibre and polypropylene to carbon fibre and PEEK. Starting materials are either dry fibre and resin or pre-impregnated tape. Figure 1 illustrates an automotive seating application of tailored blanks that used carbon fibre and polyamide 6 (PA6).

## Focus...

Fiberforge® is a startup-stage engineering firm developing and commercializing a breakthrough manufacturing process for the production of low-cost advanced composite structures.

Fiberforge's focus is on reducing scrap and optimizing material use while maintaining performance and volume scalability.

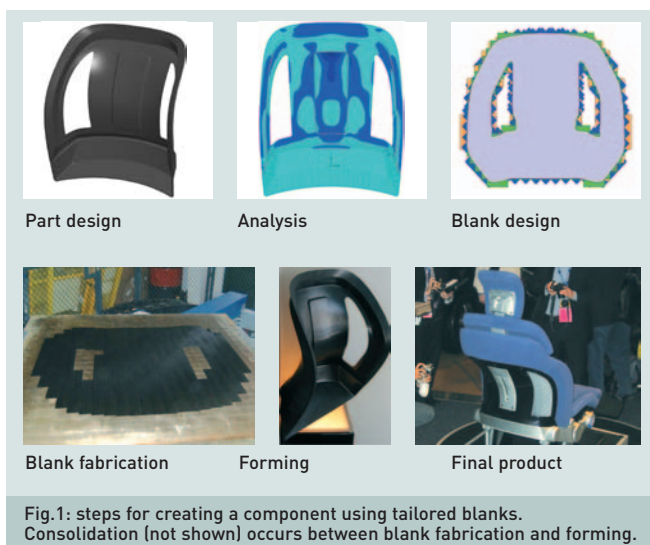


Fig.1: steps for creating a component using tailored blanks. Consolidation (not shown) occurs between blank fabrication and forming.

Several features of the tailored blank process contribute to overall cost-effectiveness. Fiberforge and École Polytechnique Fédérale de Lausanne collaborated on a study to investigate the comparative cost of manufacturing a spare wheel well using tailored blanks and other commercially available thermoplastic sheet materials. The study concluded that for high-volume applications, carbon/ PA and carbon/glass/PA hybrid tailored blanks significantly improve cost-effectiveness compared with existing composite sheet materials while still achieving 50% weight savings. In this study, manufacturing the spare wheel well with carbon/PA tailored blanks would save 50–75% of the scrap compared with existing composite sheet goods while reducing the overall part cost by 30%. Glass/PA tailored blanks were shown to be 20% less costly to produce, and carbon/glass

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# FEATURE "AUTOMOTIVE"

## →···/···Continuous-fibre reinforced thermoplastic tailored blanks

hybrid blanks were shown to be 29% less costly than hybrid sheet goods.

### Forming study

To investigate material properties of stamp-formed tailored blanks, Fiberforge formed several 200-mm diameter hemispheres and measured mechanical performance of the formed parts compared with un-formed flat-blank specimens. Additionally, tailored blanks with resin-rich surfaces were fabricated to improve surface finish.

### Tailored blank fabrication

Tailored blanks were fabricated using the company's automated lay-up system (ALS). This system includes a three-axis motion table and a lay-up head that feeds, heats and places strips of material on the motion table to create a ply. The ALS forms a laminate by placing successive plies on top of each other. Any two-dimensional pattern that fits within the geometric constraints of the system can be created including those with holes, variable thickness, and any laminate orientation.

In this study, square cross-ply tailored blanks were used so that test specimens could be cut from the corners following consolidation. The starting material for the tailored blanks was pre-impregnated AS4/PA6 tape. Following lay-up, tailored blanks were consolidated using heated flat platens in a 408-metric-ton press. Pressures suitable for consolidation range from 3 MPa to 10 MPa, and common consolidation temperatures of carbon/PA6 tailored blanks range from 220°C to 260°C.

### Forming

Rapid forming is an important benefit of CFRTP, and may be performed using a variety of techniques, including diaphragm forming, hydroforming, matched-die forming, and rubber-die moulding (2). In this study, tailored blanks were formed into hemispheres with a matched-die mould illustrated in figure 3. For this study, the flat blanks were attached to a shuttle system using eight mechanical clamps fastened to springs connected under tension to a metal frame. After being attached to the fixture in the loading station, blanks were shuttled into an infrared (IR) oven. Blank sag was used to trigger transfer into the press, where the blanks were non-isothermally formed. Mould temperatures between 160°C and 180°C were used with 60–90 second dwell times. Forming pressure was significantly higher than

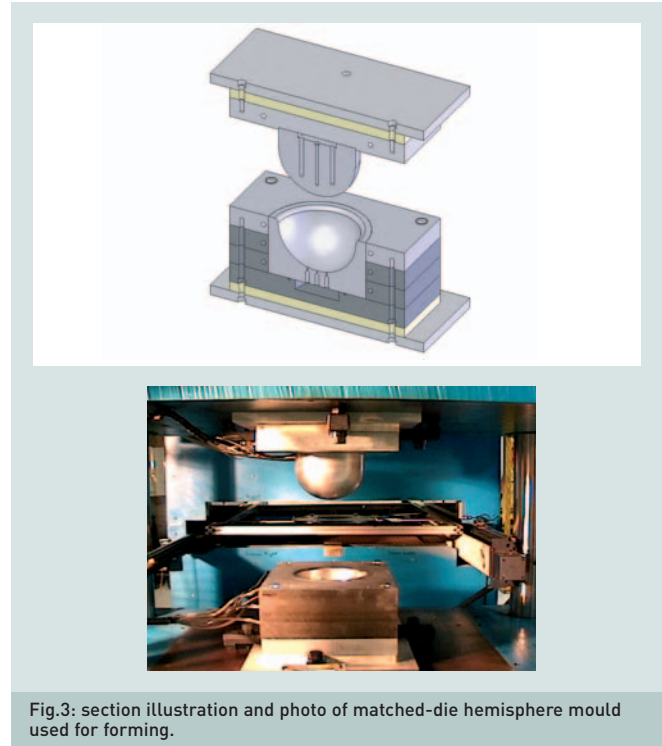


Fig.3: section illustration and photo of matched-die hemisphere mould used for forming.

consolidation pressure, but well within the limits of the press and tooling.

### Testing

Short beam shear testing is commonly used for reasons of speed, cost and small specimen size. Short beam shear test specimens were cut from both consolidated blanks and formed hemispheres in both 0° and 90° principal material directions. ASTM D 2344-84 (apparent interlaminar shear strength) was referenced for testing, although deviation from the method was necessary due to specimen geometry. The test standard allows curved (ring) specimens to be tested, but does not include specimens with compound curvature (hemisphere specimens). Also, the span-to-thickness aspect ratios in this study ranged from 7 to 9, which exceeded the ratio specified in the standard. An examination of tested samples revealed multiple failure modes, indicating the presence of a combined stress state with significant shear and bending stress components.

Table 1: comparison of apparent interlaminar shear strength between consolidated blanks and formed hemispheres for 0° and 90° orientations.

Blank ID	Apparent interlaminar shear strength [MPa]					
	0°			90°		
	Consolidated blank	Hemisphere	% Change	Consolidated blank	Hemisphere	% Change
J	50.4	56.7	12.33	33.2	39.0	17.56
L	45.9	44.0	-4.30	37.7	41.4	9.88
M	49.7	44.9	-9.70	46.1	47.4	2.90
O	51.1	52.0	1.77	37.8	38.9	2.71
Average	49.3	49.4	0.02	38.7	41.7	8.26

Table 2: comparison of tensile strength between consolidated blanks and formed hemispheres for 0° and 90° orientations.

Blank ID	Tensile strength [MPa] 0°			90°		
	Consolidated blank	Hemisphere	% Change	Consolidated blank	Hemisphere	% Change
J	890.8	965.4	8.38	574.5	678.9	18.18
L	778.9	732.8	-5.91	628.3	688.2	9.54
M	820.8	743.9	-9.37	774.2	768.6	-0.72
O	828.3	772.1	-6.78	582.8	604.2	3.67
Average	830	804	-3.42	640	685	7.66

Tables 1 and 2 compare strengths of specimens cut from hemispheres and from flat consolidated blanks. Calculated apparent interlaminar shear strength is shown in Table 1 and calculated tensile strength is shown in table 2. Hemisphere specimens had higher strengths in all cases except for tensile stress in the 0° direction. Differences in strengths may be due to geometric differences between flat consolidated blank specimens and compound curvature hemisphere specimens. Higher hemisphere strengths may be due to reduced void content in the formed parts compared with the flat-blank parts. The lower hemisphere tensile strength in the 0° direction may be a result of de-consolidation during forming.

### Surface finish

Many applications require structural parts made from tailored blanks to have aesthetic appeal. Two techniques for improving the aesthetic surface of thermoformed tailored blanks were investigated: fabricating blanks with a resin-rich surface and applying a surface veil to mask underlying fibre orientation.

veil did not completely mask the oriented fibres in the blank, but a heavier veil or multiple plies of the same veil would produce an aesthetic composite.

### Conclusion

Tailored blanks can be used to produce structural CFRTP components in a cost-efficient manner. Material efficiency of these thermoplastic composites allows a very stiff, strong, and lightweight component to be fabricated into a complex shape with minimal associated scrap. Surface finish improvements using a resin-rich surface layer with or without a veil show promise in producing structural composites with excellent appearance. Work is ongoing using a variety of materials for applications in many market segments. ■

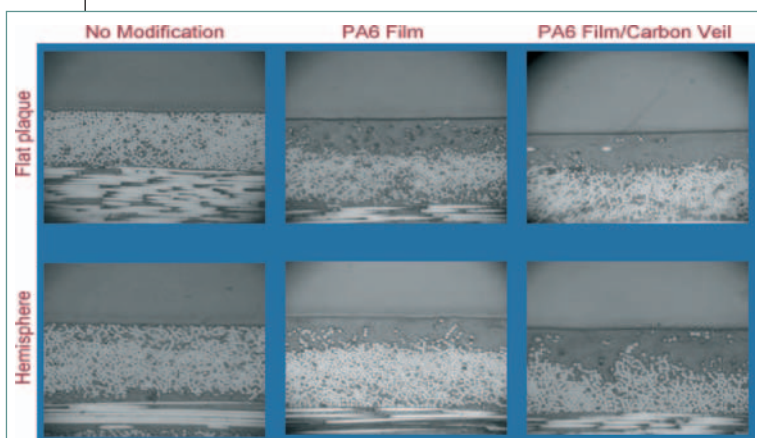


Fig.4: cross section micrographs of three consolidated blank specimens and three hemisphere specimens: unmodified surface (left), PA6 film added to the surface (centre), and PA6 film and veil added to the surface (right).

To investigate these techniques, blanks were given a surface treatment of either 0.075-mm PA6 film or a combination of 6.8-g/m<sup>2</sup> carbon veil with 0.075-mm PA6 film. The blanks were then consolidated and formed. Figure 4 illustrates the resin-rich surface following consolidation and following forming. The additional resin in both cases produced a more lustrous finish. The surface



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