HYBRID, NEAR-NET-SHAPE AND NET-SHAPE MANUFACTURING OF COMPOSITE PARTS USING TOWPREG

Dr.-Ing. Jan Hodde[1], Dr.-Ing. Matthias Meyer[2] and Dipl.-Ing. Stefan Geh [3]

[1]BMW Group, Landshut, Germany
Email: jan.hodde@bmw.de
[2]Broetje Automation GmbH, Grenzach-Wyhlen, Swiss
Email: matthias.meyer@broetje-automation.de
[3]SGL Carbon GmbH, Meitingen, Germany
Email: stefan.geh@sglgroup.com

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Abstract
Due to high costs in particular for Carbon Reinforced Composites (CRFP) the major factors to be considered in large series manufacturing of automotive parts are low waste and low production costs. The main steps for the production of CFRP are layup, nesting, cutting, preforming and moulding. Especially parts with adverse shapes lead to scrap caused by nesting. Scrap can be reduced by using a material that can be fitted in near-net-shape. For example ribbon materials like the pre-impregnated TowPreg can be used for near-net-shape blank production. Automated machines with laying heads are used for the placement of the TowPreg and production of 2D blanks. These blanks can be processed by hybrid (CFRP + metal) and Wet Compression Moulding (WCM). Cost and process analysis proved that by the use of TowPreg costs can be reduced by 50 % for a hybrid and up to 20 % for WCM parts. To demonstrate this competitive advantage achievable TowPreg costs had to be determined. Ongoing analyses demonstrate the high potential of TowPreg for the utilization in future automobiles especially for parts with local reinforcements.

1. Introducction

The main costs in large series manufacturing of automotive parts come from carbon fibre (CF) material. Especially scrap produced by nesting and process faces leads to high costs. For example, state of the art (Fig. 1) process facings for the clamping during the preforming in the RTM process chain or the sealing of the cavity during the wet compression moulding are mandatory.

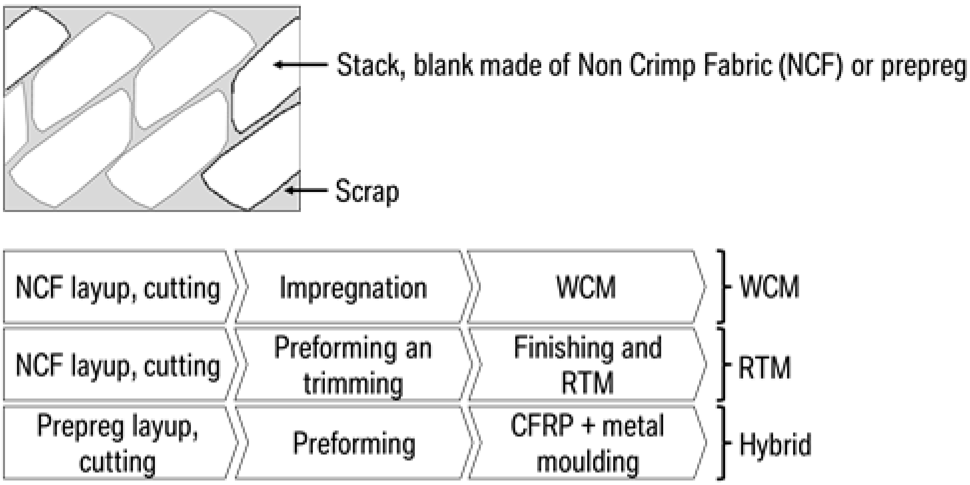

Figure 1. Initial situation.

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An important index for the efficiency of the material utilization is the Material Exploitation Quote (MEQ). The definition of the MEQ is shown in the following equation 1.

$$\text{Material Exploitation Quote (MEQ)} = \text{Material in the final part} / \text{Material input} \quad (1)$$

A reduction of the MEQ can be achieved by avoiding the nesting process. This can be done by using ribbon materials that can be placed close to its near-net-shape. Especially impregnated fibre ribbons so called TowPregs promise high efficiency. These TowPregs offer the opportunity to produce near-net-shaped or even net-shaped, load and conversion optimized blanks that can be processed by hybrid or Wet Compression Moulding (WCM). The aims for this new technology are the reduction of costs by -50 % for hybrid and -20 % against WCM parts.

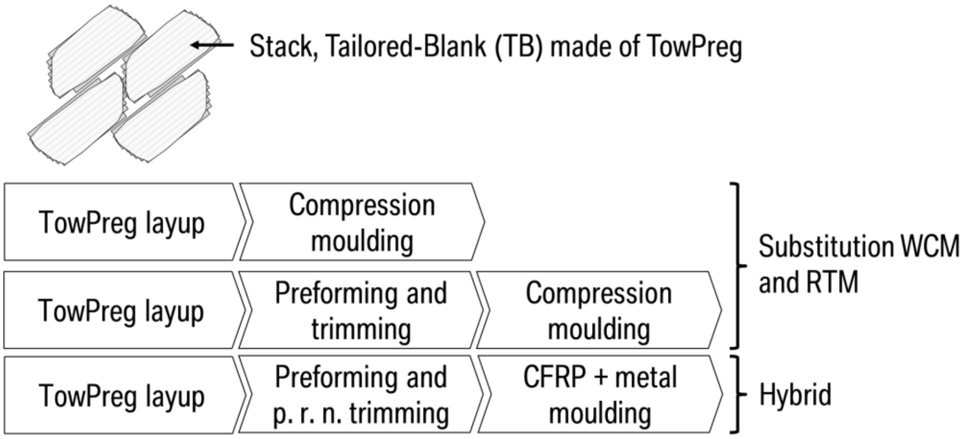

Figure 2. Target

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2. Solution process

To determine the optimum processing a practical and virtual process chain from roving to final part was set-up in the project MAI Recar (03/2015-05/2017) which is funded by the German Bundesministerium für Bildung und Forschung within the Spitzenclusterinitiative MAI Carbon. The work is supported by an internal BMW project. The partners in the project MAI Recar are SGL Carbon GmbH, SWMS Systemtechnik Ingenieurgesellschaft mbH, Broetje-Automation GmbH und Fraunhofer ICT Branch Functional Lightweight Design.

The process chain consists of the following steps:

- TowPreg manufacturing.
- Layup of 2D blanks.
- Preforming.
- Hybrid moulding or compression moulding (substitution WCM or RTM).

The goals are:

- Provision of an automated placement machine with production rates higher 5 kg/min.
- Reduction of scrap by -80 %.
- Reduction of processing costs by -90 %.
- Cycle time 1 minute.
- Provision of software for the dimensioning of parts and simulation of conversion for the preforming.

A 360° analysis for process, material, dimensioning, costs and product is carried out for generic parts (Fig. 3)

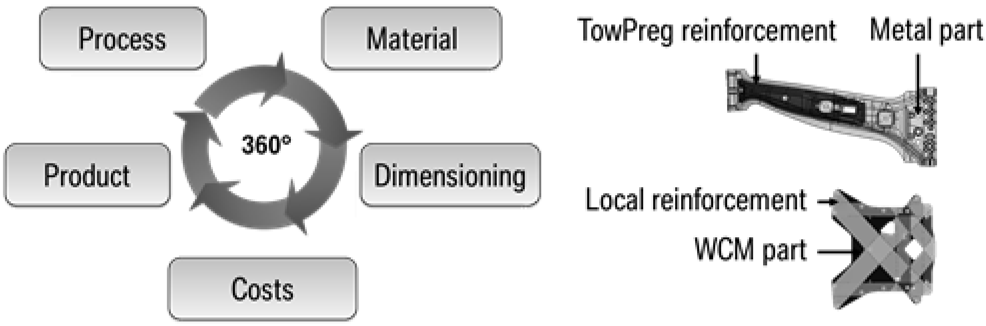

Figure 3. Solution process and generic parts

3. Results

Together with the project partners a process chain from roving to final part was established. A suitable TowPreg was developed by SGL Carbon GmbH (Fig. 4).

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Advantages

- Ease of processing (low tack)
- Fast curing cycles
- Health and safety
- Excellent mechanical performance

Typical property	Unit	C T24-5.0/270-E911/30%
Roving weight	g / 1000 m	1600
TowPreg weight	g / 1000 m	2280
Width	mm	5
Resin content	m %	30
Youngs modulus 0° *	Gpa	170
Tensile strength 0° *	MPa	2570

Typical applications

- Pressurized containers
- Marine masts & riggings
- Leaf springs
- Sports articles

*Experimental values based on filament wound plates

Figure 4. TowPreg SIGRAPREG® by SGL Carbon GmbH.

For the processing of the TowPreg a software (CAESA® Composites | TapeStation) for part and machine programming environment tailored to the respective AFP process and the equipment was developed by SWMS Systemtechnik Ingenieurgesellschaft mbH (Fig. 5). This software divides product definition in two steps. First step consists of the product adaption in order to fulfil machine and process specific requirements, such as the minimum tow length. The second step is the evaluation of the product regarding required material, MEQ and the estimation of material costs. The process establishes methods to analyse the layup, possible collisions, reachability, the required layup time and generates, after validation of layup, the machine program.

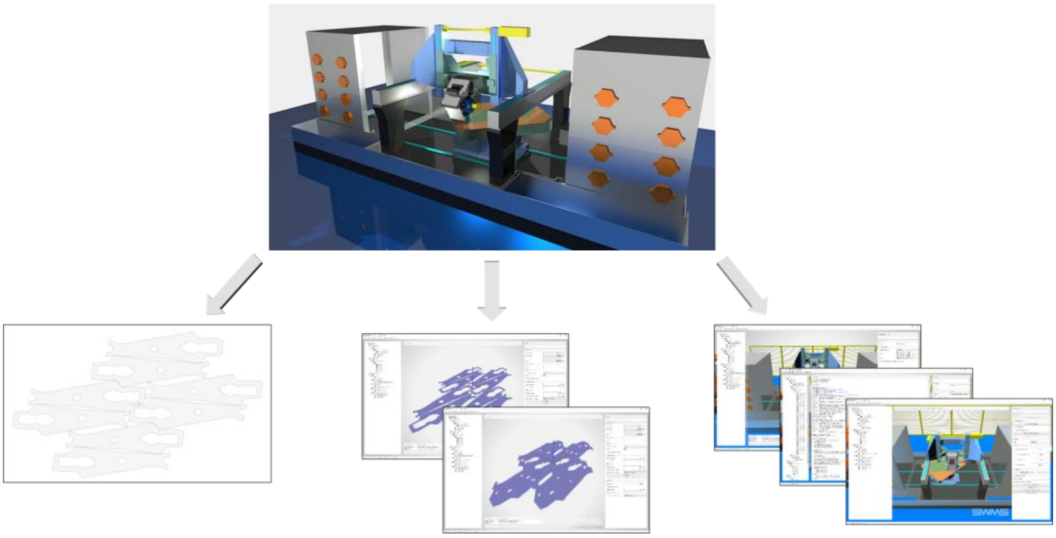

Figure 5. AFP programming software.

For the production of the TowPreg blanks a placement technology suitable for large series manufacturing was developed and evaluated by Broetje-Automation GmbH (Fig. 6 + 7).

Figure 6. TowPreg placement machine.

Figure 7. Production scenario.

By practical analyses it was determined that TowPreg with 50k fibre can be processed. Process ability was proven for a hybrid part. Analysis showed that the quality of the TowPreg is comparable to prepreg material. Preliminary trials showed that net-shape manufacturing is possible. Process and cost analyses proved the advantage of TowPreg for a generic WCM part. Required and achieveable TowPreg specific costs were determined (Fig. 8). Achieveability of the aimed costs (-50 % for hybrid and -20 % against WCM parts) was proved by process and cost analysis.

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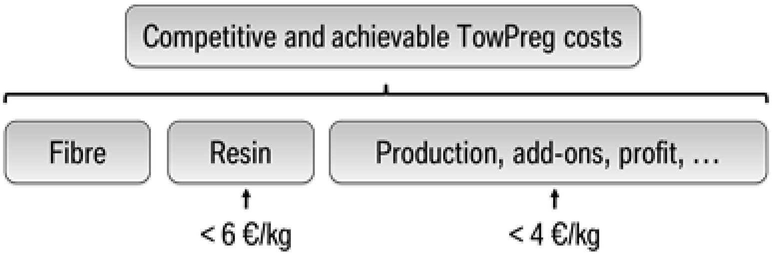

Figure 8. Achievable and reachable TowPreg costs determined by process and cost analysis.

4. Conclusion

The analyses showed that substitution of prepreg by TowPreg for hybrid parts is expedient. Important potential fields where TowPreg can be exploited are load conform and near-net-shape or net-shape manufacturing. It became clear that TowPreg can be a competitive alternative for WCM and RTM parts. A high potential of TowPreg for the utilization for future automobiles could be demonstrated.

The next steps are the analysis of the preforming, the manufacturing of near-net-shape and net-shape parts and the determination of costs of potential target parts.

Acknowledgements

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