PROCESS DEVELOPMENT FOR GENERATIVE MANUFACTURING OF FIBER THERMOPLASTIC COMPOSITES STRUCTURES – THERMOPLASTIC PATCH PLACEMENT (TPP)

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Abstract

A novel process for the generative manufacturing curved composite shell structures is developed. This Thermoplastic Patch Placement (TPP) process utilizes pre-consilidated thermoplastic sheets for generative manufacturing of load adaped composite structures.

1. Research objective

In the context of the LuFo V joint research project Sylvia, a novel process for the generative manufacturing of load-adapted curved composite shell structures is developed at the Institute for Lightweight Engineering and Polymer Technology of the Technische Universität Dresden. The Thermoplastic Patch Placement (TPP) process utilizes pre-consolidated thermoplastic sheets (patches) for generative manufacturing of fiber reinforced structures [1].

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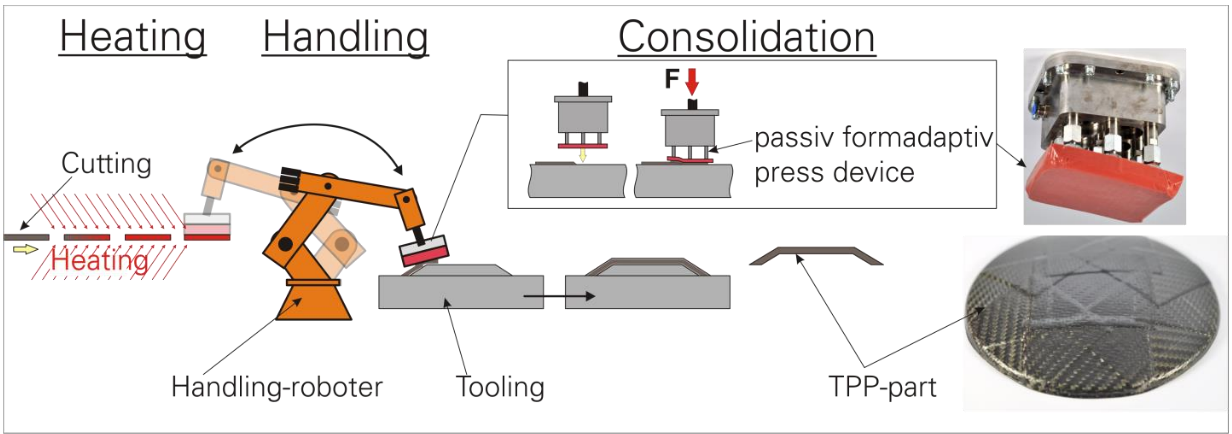

Figure 1. TPP process

The process offers the possibility to adapt the local mechanical properties of structures according to the present stress state by varying the orientation of the patches. Advantages of this technology are a significant reduction of manufacturing complexity and tool costs compared to e.g. the press molding process along with a greater flexibility in terms of local fiber orientation, part geometry and local thickness variation. In addition, the TPP-process cannot only be used for the production of components, but also for repairs or local reinforcement of existing structures.
The conceptual design of the individual process steps “heating”, “handling” and “consolidation” (figure 1), as well as the resulting mechanical properties of composite specimens manufactured in the TPP-process are ín the focus of the resaerch at ILK. Furthermore, methodes for the FE-simulation to optimize the stacking sequence and a derived design guideline are developed.

2. Prototypic automated quick stroke press

For the demonstration of reproducibility, for investigation and optimization of the single process steps and for the manufacturing of demonstrator structures, a semi-automated pneumatic quick stroke press was set up, for further investigations regarding the integration of the handling and heating system into the elastic press device and its optimization. Three different types of press devices were set up and tested in relation to the resulting pressure distribution on the patch (figure 2).

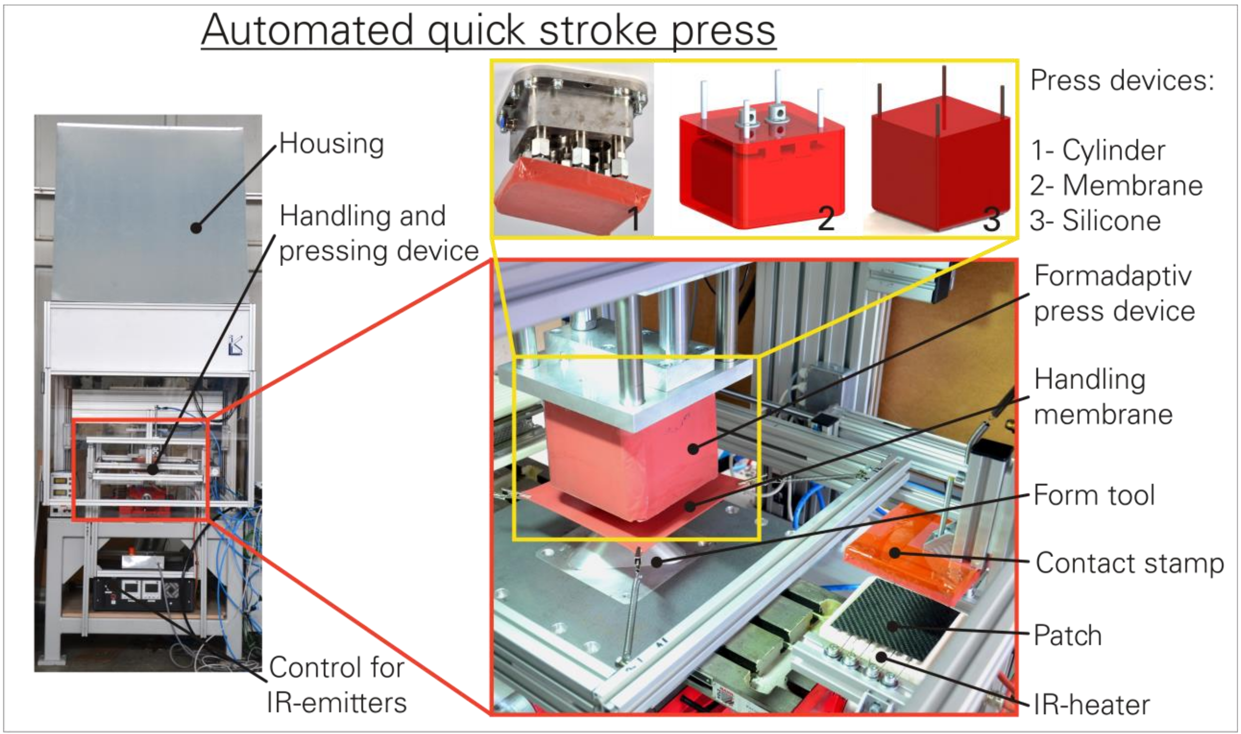

Figure 2. Automated quick stroke press

3. Parameterization of the process

Aside the influences of a variation of consolidation parameters on mechanical properties, different patch layouts for the structure as well as varying geometric parameters were investigated, using CF-patches with a PA6 matrix. Especialy, the influence of the overlap of the patches was evaluated, regarding the mechanical behavior of the structure.

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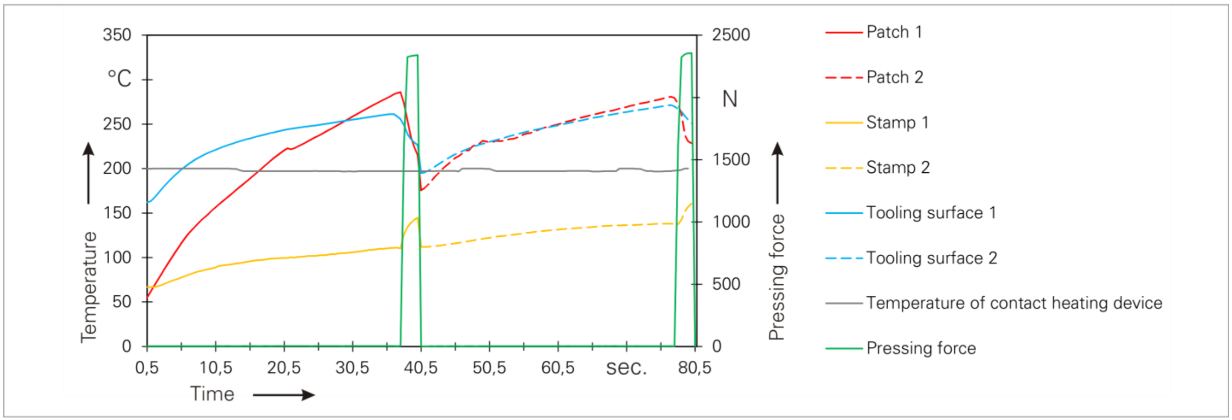

Figure 3. Parametrisation of press process

Further parameters that were investigated are the process pressure and temperature (figure 3). It was found that the heat storing capacity of the patches is the main restricting factor, since the high cooling rate encloses a processtime of about 3 sec. By using preheated patches, very short cycletimes are possible.

4. Mechanical characterization

The results of the conducted mechanical tests show that a very high material utilization can be achieved in a composite structure manufactured in the TPP-process. Here, up to 96% of the strength of continuously reinforced, pristine material was reached (figure 4). Since the fiber orientation has a significant influence on the mechanical behavior of composite structures, slight losses of mechanical properties due to fiber shortening can be compensated by a locally load path adapted fiber orientation. A similar process for thermoset parts was investigated by Meyer [2] in 2008. The main advantage of thermoplastic over thermoset matices is the avoidance of a consolidation process, after the lay downof the patches.

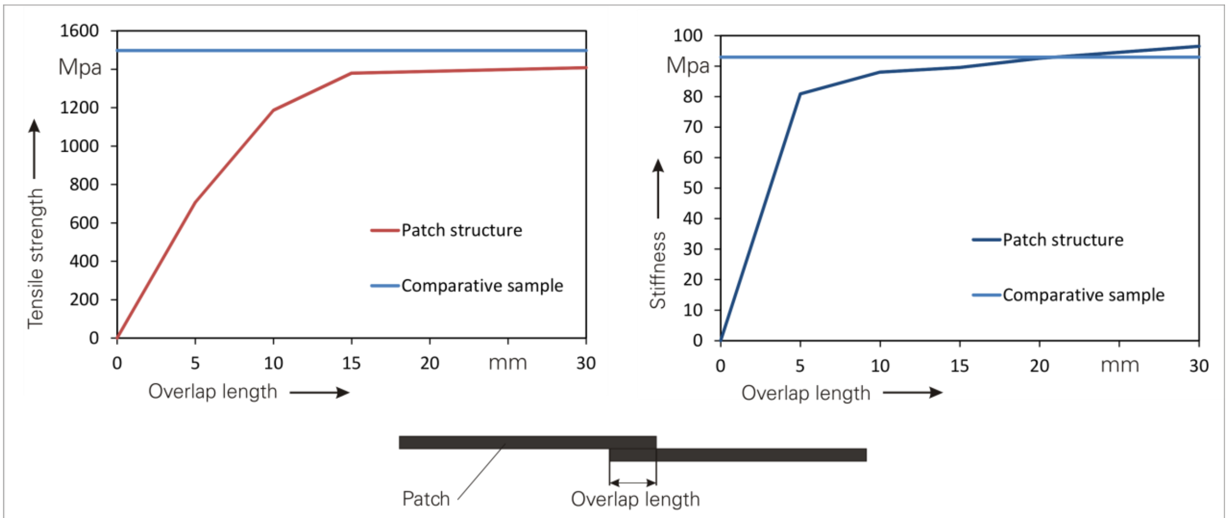

Figure 4. Mechanical characterisation of patch structure

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For complex shaped parts the first results show a very high potential to compete with current state-of the art manufacturing processes while offering a higher degree of automation and flexibility of fiber orientation and so a higher potential of further mass reduction.

5. FEM analysis

To predetermine the deformation and the failure behavior, a finite-element-model taking into account the results of the mechanical characterization was set up. The optimization of the patch-layup is performed considering the single patches, parameters due to the patch-structure – as for example the overlapping length – and the geometric parameters of the part.

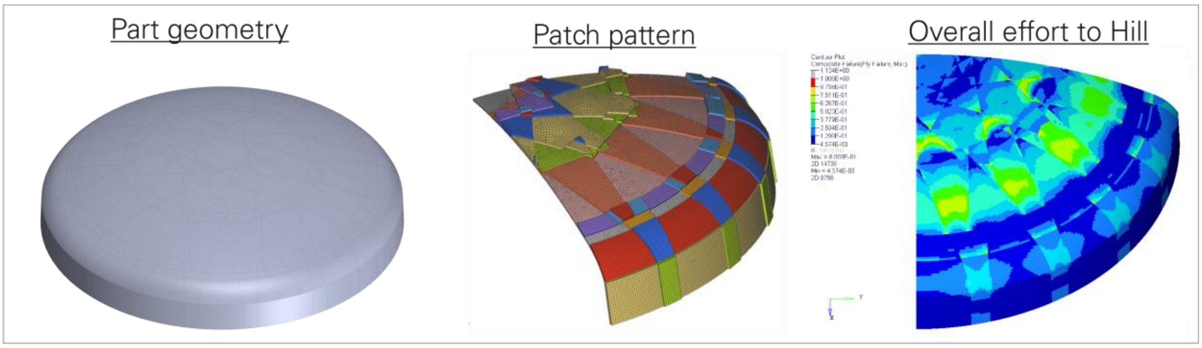

Figure 5. FEM analysis of sample part for pressure on the inside of the part

6. Conclusions

The TPP-process shows very high potential for manufacturing or repairing CFRP structures with local changes in thickness and/or varying fiberorientations. A noval consolidation head and according handling technology has bee developed and implemented in an automated quick stroke press. The manufacturing concept was validated with the conducted manufacturing trials and high laminat qualities could be manufactured. The gained experiences will be used to setup a mobile pressing unit and merge into guidelines for the TPP-process.

7. Acknowledgement

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8. Literature

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