Abstract

Continuous fibre reinforced thermoplastics are a high competitive material class for diversified applications because of their inherent properties like light-weight construction potential, integral design, corrosion resistance and high energy absorption level. Using these materials, one approach towards a large volume scaled part production rate is covered by an automated process line, consisting of a pressing process for semi-finised sheet material production, a thermoforming step and some additional joining technologies. To allow short cycle times in the thermoforming step, the utilised semi-finished sheet materials, which are often referred to as “organic sheets”, have to be fully impregnated and consolidated.

Nowadays even this combination of outstanding physical and chemical material properties combined with the economic processing technology are no guarantee for the break-through of continuous fibre reinforced thermoplastics, mainly because of the high material costs for the semi-finished sheet materials. These costs can be attributed to a non adapted material selection or choice of process parameters, as well as by unfavourable pressing process type itself.

Therefore the aim of the present investigations was to generate some alternatives regarding the choice of raw materials, the set-up or the selection of the pressing process line and to provide some theoretical tools for the determination of process parameters and dimensions.

Concerning raw material aspects, the use of the blending technology is one promising approach towards cost reduction for the matrix component. Novel characteristics related to the fibre structure are CF-yarns with high filament numbers (e.g. 6K or 12K instead of 3K) or multiaxial fibre orientations. These two approaches were both conducted for sheet materials with carbon fibre reinforcement and high temperature thermoplastics.

Two new developed ternary blend matrices consisting of PEEK and PEI as the main ingredients were tested in comparison with neat PEEK. PES and PSU were used as the third blend component, which provides a cost reduction potential of approximately 30 % compared to the basis PEEK polymer. The results of the static pressing experiments pointed out that the processing behaviour of the new blends is similar to the neat PEEK matrix. A maximum process temperature of 410 °C should not be surpassed, otherwise thermal degradation will occur and will have a negative influence on mechanical laminat properties. To accelerate the impregnation progress a process pressure of 25 bar in combination with a sidewise opened tooling concept is helpful. No differences were identified if film-stacking technique was substituted by powder-prepreg-technology or vice versa. By increasing the yarn filament number from 3K over 6K to 12K, which is equal to an increase in bundle diameter and therefore transverse flow distance, the impregnation time has to be extended. If unspread yarns are used, the risk of void entrapment rises tremendously, especially with 12K and UD-structures. To reach full impregnation with a woven 6K-fabric, an increase of process time of 20 to 30 % compared to a 3K textile structure is required. Furthermore, it was shown that if only transverse flow is used for the impregnation of a UD-structure, a maximum area weight of 300-400 g/m² should not be exceeded. Additionally, the transport of air is strictly affected by the fibre orientation, because the main amount of displaced air runs in longitudinal fibre direction. These facts play an important role in the design of a multaxial laminat or an impregnation process for such a structure and have to be taken into account.

Apart from these static pressing experiments the semi-continuous (stepwise compression moulding) and continuous (double belt press processing) processing technology were investigated and compared to each other. The first basic processing trails on the stepwise compression moulding equipment were carried out with the material system GF/PA66. Whereas the processing behaviour of this material combination in a double belt press is known quite well, there is only little information about semi-continuous processing. The performed trials pointed out that the resulting laminate quality for both technologies only differs in the achievable local surface quality. Mechanical laminate properties like three point bending stiffness and strength are directly comparable. Due to the fact that there is only small experience with the stepwise compression moulding process, potential improvements regarding surface quality are feasible by adapting the step procedure and the temperature distribution within the tooling concept. If laminates, produced by semi-continuous processing, are deployed in a thermoforming process or in a non visible structural application, the surface appearance only plays an inferior role.

The present results with high temperature thermoplastic matrices and CF do confirm the positive assessment for the stepwise compression moulding technology, even though the mechanical laminate values have only reached 90 % of the data received by static press processing. In comparison to the data from literature, 90 % is already a high mechanical performance level. The results are quite promising for the use of the semi-continuous technology, despite the process set-up and processing parameters not being optimised. Furthermore there are tremendous advantages in processing equipment costs.

Finally a process model was developed based on the experimental data pool. This model can be characterised as a tool, which provides useful boundary conditions and dimension values for the selection of a certain pressing process depending on the desired material combination, laminate thickness and production output. The applicability and accuracy of the model was proofed by a direct comparison between experimental and calculated data.

First of all the temperature profile of the pressing process was generalised by a very common structure. This profile reflects the main characteristics for the processing of a thermoplastic composite material. Depending on the material combination, the laminate thickness and the occurring heat transfers, several process- and processing-portfolios were calculated. For a defined combination of the aforementioned parameters, these portfolios directly provide the periods of time for heating and cooling of the laminate structure. The last step is to convert these information into an equipment dimension and to decide which machinery configuration fulfils these requirements.