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THERMOPLASTIC SANDWICH STRUCTURES WITH BEAD FOAM CORE – NOVEL PROCESSING APPROACHES

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1. INTRODUCTION

Lightweight construction makes an important contribution to resource efficiency and furthermore allows improvement of functionality and reduction of costs regarding energy consumption as a result of reduced weight. The use of lightweight structures in aerospace sector is well known. The relevance of lightweight construction in further application fields like energy technology, construction and especially transportation has strongly increased in recent years. The light weight construction market in the transportation sector (in particular automobiles) will grow in the coming years to 2020 according to market forecasts at 140 billion euros [1]. Thermoplastic composite sandwich structures offer a great potential to meet the demands of lightweight structures as they provide low weight and high stiffness at the same time [2]. Using a thermoplastic foam core, particularly a bead foam core, offers further advantages like additional thermal insulation, elevated energy adsorption and thus improved crash behavior and enhanced recycling compatibility. Therefore, this approach will gain more significance in e-mobility [3]. Furthermore, the use of thermoplastic materials allows shorter cycle times in production compared to thermoset based systems as no curing step is needed. Another advantage is the integration of functional elements such as ribs or connecting elements by injection molding.

Nevertheless, there is a lack of established processes allowing the economic manufacturing of thermoplastic sandwich structures in high-volume production as necessary for automotive industry. Thus, this work deals with efficient and highly integrated processing solutions to meet the mentioned demands.

2. STATE OF THE ART

The sandwich concept can be expressed as increasing the bending stiffness of a panel without adding significant weight. By separating two stiff face sheets, the bending stiffness increases with rising distance between the sheets as a result of the increased moment of inertia about the beam centroid. To keep the face sheets separated usually core materials like honeycombs, polymer foams or balsa wood are used [4].

Polymer bead foams are lightweight materials consisting of fused microcellular beads. Their multiscale structure makes bead foams unique in terms of a free choice of shape combined with extreme low density down to 15 kg/m³. Further benefits of bead foams are good energy absorption properties, excellent impact resistance and their low thermal conductivity having values in the order of 0.03 W/m K. The processing of bead foam components is usually done by means of steam which enables the welding of the single beads. The best-known representatives are expandable polystyrene (EPS) and expanded polypropylene (EPP). Typical applications are insulation of buildings, packaging, load carriers and technical parts in automotive interior [5].

3. AIM OF STUDY

The main goal of the present study is the identification and establishing of economic processing technologies for large-scale production of thermoplastic sandwich structures with bead foam core.

4. PROCESSING APPROACHES

The manufacturing of thermoplastic sandwich structures with bead foam core can be realized by different processing routes. The conventional technique is compression molding of two thermoplastic face sheets (e.g. organo sheets, UD-tapes) and a thermoplastic foam core (e.g. semi-finished products). The joining by welding of the single components is initiated by preheating of the face sheets and if necessary of the core material too. By using compatible polymers there are no additional adhesive films necessary because a substance-to-substance bond with rather high strength can be achieved. In order to achieve a three-dimensional sandwich structure built up of two different face sheet geometries by the use of this technology, there are at least three different molds required (shown in Fig. 1). Furthermore, advanced handling and heating in both molds is necessary. Another disadvantage is given by the inhomogeneous compression of the foam core by different and complex shapes of the face sheets and resultant inhomogeneous properties.

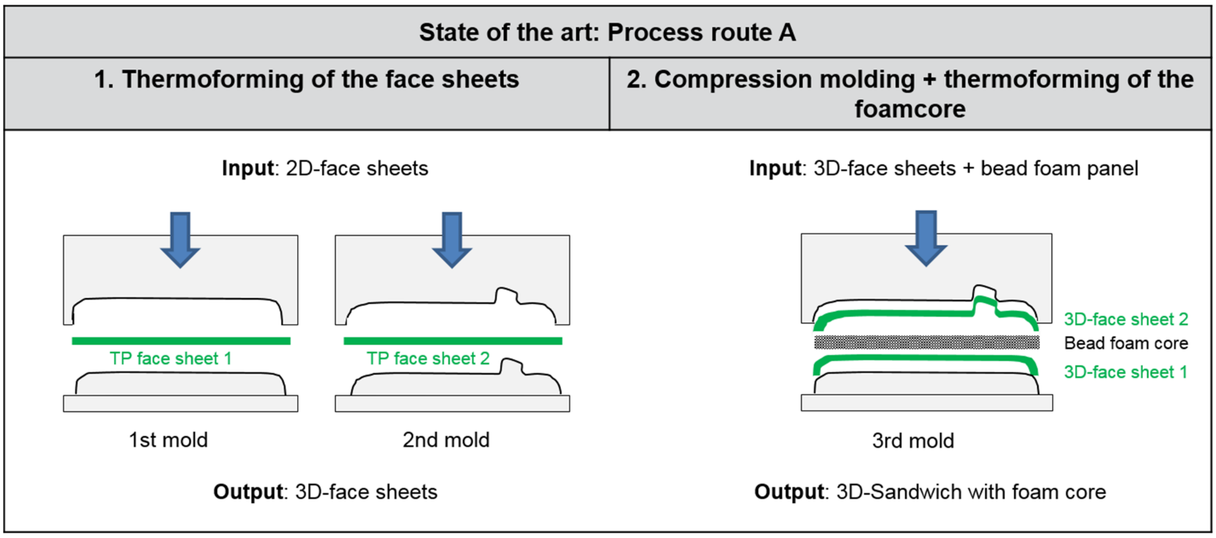

Fig. 1: Schematic sketch of conventional technology for manufacturing 3D-sandwich structures.

A second processing route for fabricating three-dimensional sandwich structures is given by using in-situ techniques which are more suitable for complex structures. For this purpose, 3D-face sheets are inserted and fixed in the mold and the foam core is fused directly by welding of foamed beads in-between the face sheets. By the use of bead foams like EPP, core densities between 20 kg/m³ and approx. 300 kg/m³ can be achieved. Bead foams allow for shaping very complex geometries and enable varying core thickness between 5 mm and several centimetres. Furthermore, theses closed-cell foams offer superior thermal insulation properties [3]. Besides the mentioned advantages of the in-situ bead foaming technology there are the same economical limits (primary the long cycle time) for high-volume production. Again, three different molds are necessary. The processing sequence is shown in Fig. 2.

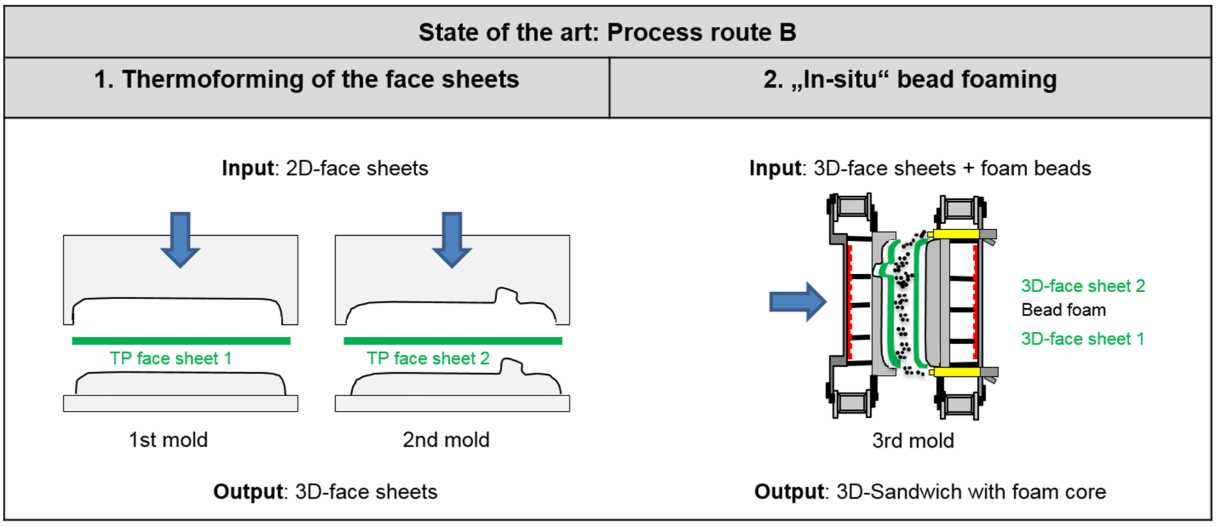

Fig. 2: Schematic sketch of in-situ bead foaming technology for manufacturing 3D-sandwich structures.

Following the specific requirements of high-volume production for automotive industry a more efficient process technology has been established that allows the production of 3D-sandwich components with additional functional integration realized by injection molding. At first the thermoplastic face sheets based on PP or PA6 are pre-heated by applying infrared radiation. By means of a suitable core dummy (made of steel) the two face sheets are thermoformed within one multi-stage mold and functional elements are attached via injection molding at the same time. Within few seconds the dummy is removed and the foam core (e.g. bead foam cores) is placed by a handling system between the functionalized face sheets. By closing the mold again the thermoforming of the core as well as the welding process of the face sheets and the core take place. If needed edge closures can be formend by subsequent injection molding within the same mold. The schematic sketch of this technique is shown in Fig. 3. With this innovative multi-stage process only one mold and one machine is necessary, and it is possible to produce components without any post-processing. The new intelligent process and tool design allows a high level of functional integration as well as short cycle times which leads to a suitable and economical process for large series production.

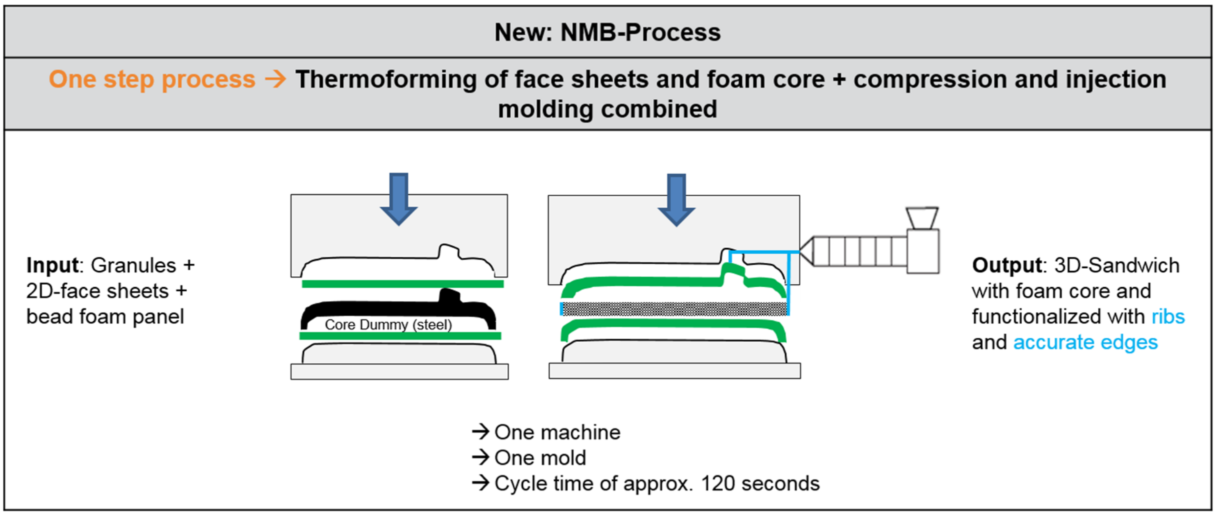

Fig. 3: Schematic sketch of the new NMB-processing technology for manufacturing functionalized 3D-sandwich structures within one mold.

In order to investigate the process capability of the new processing technology a demonstration part based on polypropylene with the dimension of approx. 350 x 450 mm was engineered and produced (Fig. 4).

Fig. 4: Demonstration part "Functionalized 3D-Sandwich with bead foam core" (CAD-view on the left and realized component on the right).

5. CONCLUSION AND OUTLOOK

The economic use of full thermoplastic sandwich structures in large-scale production like in automotive industry is only expedient if a high degree of functional integration and a short cycle times below 120 seconds can be realized. By means of the introduced NMB-processing technique a highly promising solution statement for an efficient manufacturing process for full thermoplastic sandwich structures is outlined. This innovative approach, especially with the use of bead foams as core material offers a great potential to meet the demands of prospective sustainable lightweight developments for the use in electromobility.

In order to reach an even higher degree of functional integration the combination of the shown process with the technique of additive manufacturing will be taken in account and investigated. The use of 3D printing processes enables the individualization of special functional variants (Fig. 4, right side - yellow screw boss) as well as design variants.

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