Tailored blanks based on foamable aluminium sandwich material

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Abstract

Lightweight composites offer high potential application for future car body concepts. Due to the structural and metallurgical light weight constructions, sandwich materials with a core of foamable aluminium are very important for the design of modern, fuel saving vehicles.

Tailored blanks with foamable aluminium sandwich material offer the possibility of near net shape design using aluminium foam sandwich only in the areas, in which a increased stiffness or the increased energy absorption ability are required. Costs and weight are saved by the optimised application of material in large surface workpieces. Complex joining elements for the connection of sandwich materials are completely omitted by the binding over the sheet metal. This will lead to a clear decrease of the process steps, which would be needed with conventional cutting and joining processes for the production of wide integral components with lightweight composite materials.

Within this paper fundamentals of the process sequence laser beam cutting and welding for the fabrication of tailored blanks with foamable aluminium sandwich material are described. First results of laser beam cutting and the quality of the cutting edge are presented. The processing results and properties of laser welded aluminium sandwich materials are described by metallurgical examinations as well as foaming properties of the weld seam are presented.

1 Introduction

In the future the development of "intelligent mixed construction" will continue to gain significance in the field of lightweight construction. Thereby the best characteristics of different material systems are brought together [1]. Since a short period of time an innovative, fully reusable material system, foamable aluminium sandwich material which possesses outstanding characteristics concerning weight and stiffness is available. Tailored blanks with foamable aluminium sandwich material offer the possibility of near net shape design using alu-

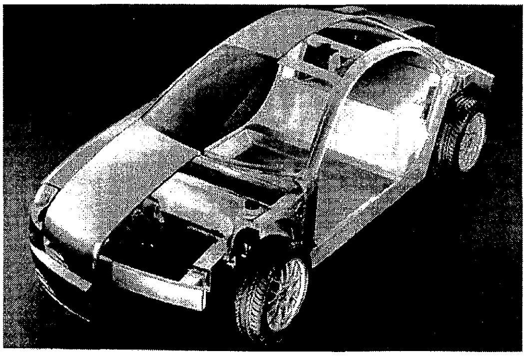

Fig. 1: Modern car body concept (AFB, Karmann)

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minium foam sandwich only in the areas, in which an increased stiffness or the increased energy absorption ability is required. Costs and weight are saved by the optimised application of material in large surface work pieces. Complex joining elements for the connection of sandwich materials are omitted by binding over the sheet metal. This will lead to a clear decrease of the number of process steps, needed within the conventional cutting and joining processes for the production of wide integral components with lightweight composite materials.

2 Foamable aluminium Sandwich material

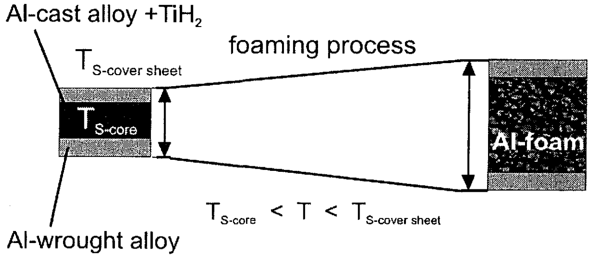


Fig. 2: Foamable aluminium sandwich material

As test materials roll-plated semifinished material with a core from a close-eutectic aluminium alloy will be used. A propellant (e.g. TiH_2) is added to this core. The surface layers consist of a higher-melting aluminium alloy. Before foaming it is possible, to transform the sandwich pre-material by bending, deep drawing or profiling to get 3-dimensional structural sheet elements. In the case of heating up the core material to liquidus temperature a foaming process is taking place, with which the final thickness of the 3d-structured sandwich material is achieved (fig. 2) [2].

3 Process sequence for tailored blanking of foamable aluminium sandwich material

Fig. 3 shows the process sequence for the production of tailored blanks of foamable aluminium sandwich material. Laser cutting serves both, the adaption of the sheet metal and the joint preparation (see 4.2) for the following laser beam welding process.

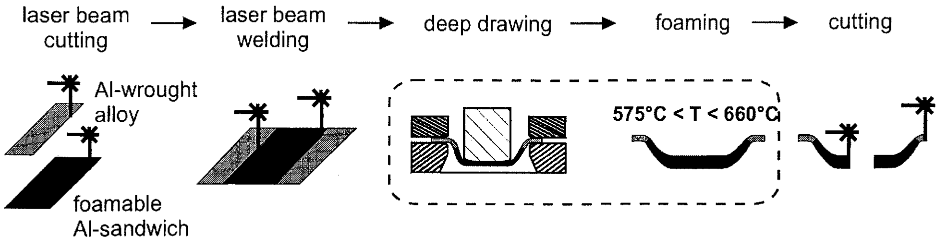


Fig. 3: Process sequence

Due to the process sequence laser beam cutting and welding in one clamping device further handling operations are omitted. A robust process results from the integration of the joint preparation and the joining process into one setting attachment, whereby positioning inaccuracies and processing errors are eliminated or compensated. Tailored blanks can be manufactured near net shape because of the transforming step leading the foaming process (see 2). The final component thickness is achieved after the foaming process. A further shortening of the process sequence can be reached via integration of the two process steps, transforming and foaming, into one heated tool. A laser beam cutting process can follow the other processes.

4 First experimental results

4.1 Experimental set-up

For the laser material processing, sandwich materials with a typical sheet metal thickness of 3.0 mm in the pre-material status and 10 mm in the foamed status are used.

A CO_2-laser of high beam quality (K=0,47, TEM_{01^*}), with 5.1 kW output power combined with a 5-axis gantry was used for the cutting and welding experiments.

4.2 Laser beam cutting

Laser beam cutting of pre-material represents a substantial step in the process sequence for the production of tailored blanks of foamable aluminium sandwich material. In comparison to conventional aluminium alloys, during high pressure laser beam cutting of the roll-plated pre-material difficulties occur because of the two different alloys and the propellant. The different liquidus temperatures and viscosity of the melt lead to melt ejection problems, this becomes clearly recognisable in fig. 4 right. Cutting with high Laser Power (P_L = 2600W, focus position z_f = -3mm) leads to a high dross length (up to 0.7 mm) within a wide area of the cutting speed.

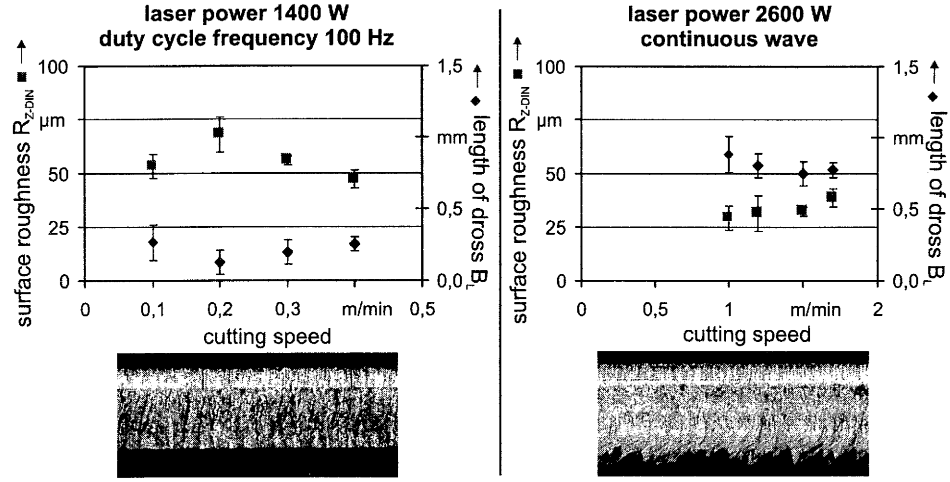


Fig. 4: Laser beam cutting of foamable aluminium sandwich material

Pulsed lasers beam cutting with feed rate leads to a better cutting edge quality. The area melted during one laser pulse is completely removed by the inert gas from the kerf. The dross length reduces to approx. 0.1 mm. The low duty cycle frequency leads however to an increase of the surface roughness (fig.4 left).

Fig. 5 shows a scanning electron microscope image of the upper area of the cutting edge. One clearly detects the orientation of the drag lines. In an area underneath the upper surface layer of the roll-plated pre-material clear melt ejection's are recognisable. It is obvious that already during the laser beam cutting process a decomposition of the TiH_2-propellant takes place, although the decomposition process is described in literature as strongly tempo-

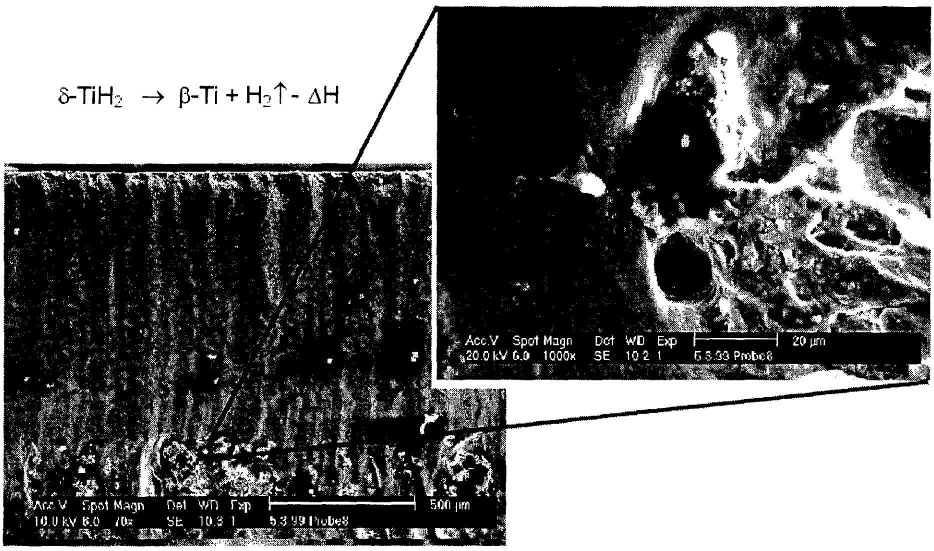
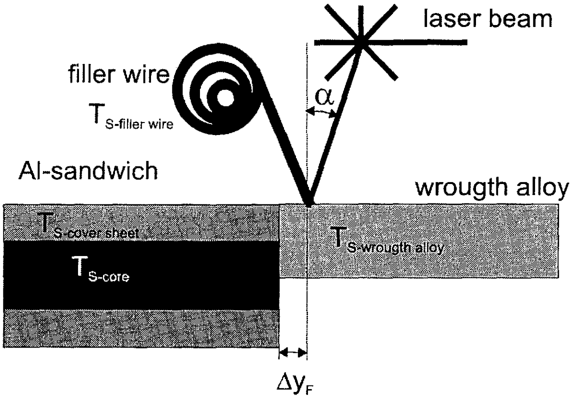


Fig. 5: Melt ejection on the cutting edge

rally dependent [4]. A topic of further examinations must be the question, how this described process affects the following welding process.

4.3 Laser beam welding

Four different aluminium alloys with different solidus temperatures (T_S) define a complex material system (see fig.6). During the laser beam welding process alloying elements evaporate and a mixing of the alloys takes place inside the melted zone. Furthermore a decomposition of the propellant within the weld seam can already take place, this would cause pores.



Regarding the following foaming process, special attention must be paid to the alloy composition within the weld seam (see 4.4). The weld seam will be arranged optimal, by a suitable selection of the joining partners and the selection of the process parameters (lateral beam position, focus position, angle of incidence...).

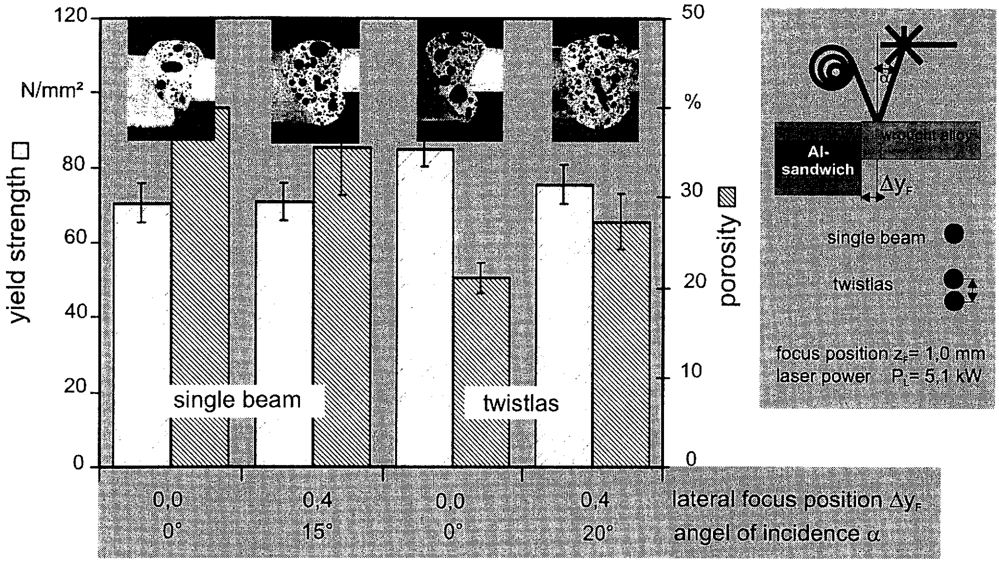


Fig. 7: Laser beam welding of foamable pre-material with different process parameters

The influence of the lateral beam position Δy_F to the formation and the porosity of the weld seam were examined. One can recognise the positive effect of the lateral beam offset clearly on the weld seam characteristics. With an offset of $\Delta y_F = 0$ mm a high foaming process occurs within the weld seam. With increasing beam offset the porosity decreases, whereby however with a $\Delta y_F = 0.8$ mm no complete binding of both surface layers of the foamable pre-material, which is necessary for a good static and dynamic mechanical strength properties, is achieved.

Fig. 7 shows first results of the influence for different process parameters on the porosity an yield strength of the weld seam. It is obviously the welding with twistlas (the laser beam is divided by a roof mirror into two beams) is advantageous for the porosity and the static tensile strength. The combination of lateral beam offset and angel of incidence is also a probable way to optimise the weld seam quality, but already the optimum is not found.

4.4 Foaming properties of the tailored blank nearby the weld seam

As already mentioned in the preceding, the alloy composition within the weld seam determines the foaming behaviour of the tailored blank in the weld seam boundary region. If by mixture processes the solidus temperature of the fusion zone drops so far that it is exceeded during the foaming process, a breaking of the weld seam takes place Fig. 8 shows a broken weld seam, which leads to a non-optimum distribution of forces.

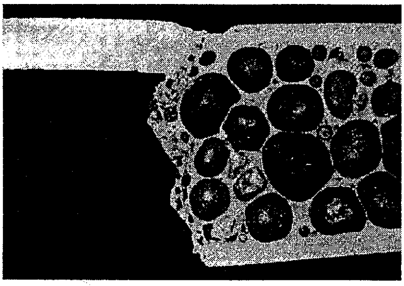


Fig. 8: Breaking of a weld seam during the foaming process

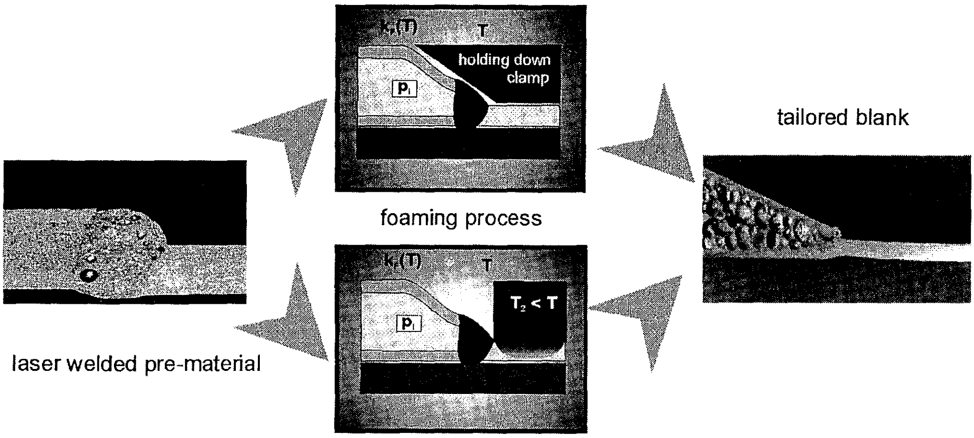


Fig. 9: Foaming process with thermal or mechanical blocking

To prevent the weld seam from breaking, alloying or process-technical measures can be used (see 4.3). Another possibility is to prevent the breaking thermally or mechanically (Fig. 9). Thermal blocking means, that cooling prevents the solidus temperature from exceeding. The mechanical blocking is shown in the top of figure 9. A holding down clamp squeezes the weld seam area during the foaming process and leads to a much better distribution of forces in the weld seam.

5 Conclusion and outlook

Tailored blanks with foamable aluminium sandwich material offer fundamental advantages for the application in modern car body concepts. By the represented processes "tailored sandwiches" can be manufactured in a robust, shortened process sequence.

The problems in addition to the fundamental advantages for the application of the laser technology during processing of this innovative lightweight construction materials were pointed out. First experimental results point out the possibilities of the technology and shows that still another large research requirement exists.

6 Acknowledgement

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