NUMERICAL SIMULATION OF WELDABLE METALLIC FORCE TRANSMISSION POINTS IN FIBRE REINFORCED THERMOPLASTICS (FRTP)

A. Kunze[1], F. Jansen[2] and A. von Hehl[3]

[1]IWT Stiftung Institut für Werkstofftechnik, Bremen, Germany
Email: akunze@iwt-bremen.de, Web Page: www.iwt-bremen.de
[2]Faserinstitut Bremen e.V., Bremen, Germany
Email: jansen@faserinstitut.de, Web Page: www.faserinstitut.de
[3]IWT Stiftung Institut für Werkstofftechnik, Bremen, Germany
Email: vonhehl@iwt-bremen.de, Web Page: www.iwt-bremen.de

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Abstract

Joining technologies are major challenges for multi material design (MMD) body works. Many technologies such as riveting, bonding etc. require preventable investments in the excisting production lines. This paper describes the mechanical design and numerical simulation of spot weldable organic sheets – components equipped with so called welding patches – on coupon level. In a first step, different geometrics are developed, compared to each other and evaluated. For the interface modelling selected surface treatments are considered. With special regard to the interfaces between the welding patch and FRP/metallic car body, representative load cases are simulated. To estimate the failure behaviour, material related failure criterions are taken into account. The results of the simulation are validated on the basis of experimental data generated by simultaneous testing of specimens on coupon level and show that the patches fulfil the mechanical demands.

1. Introduction

Structural components made of fibre reinforced plastics (FRP) exhibit a high lightweight potential due to the high strength and low density. For serial applications like in the automotive sector, thermoplastic matrices are highly demanded, because already existing forming technologies enable economical processing and short clock cycles. Many concept cars of OEMs show the strategy to substitute single metallic components or subassemblies by FRPs in areas with the highest lightweight- and cost potential [1], [2]. The advantage of this multi material design (MMD) is to use the locally optimized materials with the required properties and low costs.
A vital challenge of the MMD is the requirement of suitable technologies for joining different types of materials like metal and FRP with regard to the performance and large-scale production. Conventional joining techniques like rivets, FDS-screws, adhesives or ultrasonic joining may harm the FRP component or require a high manufacturing effort and quality assurance [3]. Furthermore, modifications of the installed state of the art spot welding production lines are necessary.
The aim of the project is to avoid such investments in new production lines by using spot welding as joining technology between FRP and metals. Therefore, the FRP need to be enabled for spot welding by application of so called welding patches. These welding patches consist of a metal component and a FRP component, which are combined and consolidated during the thermoforming process.

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2. Production Process

The force transmission point consists of four components (Fig.1):

- Metallic body work
- Base sheet made of glass-fiber reinforced thermoplastic (GF-TP)
- GF-TP patch
- Metallic insert

The aim of the patch is to fix the metallic insert to the GF-TP base sheet. The insert and the patch together are forming a *welding patch*, which enables the force transmission between GF-TP base sheet and metallic body work. Both the GF-TP base sheet and the metallic body work are structural parts of the body work which can be joined via spot welding.

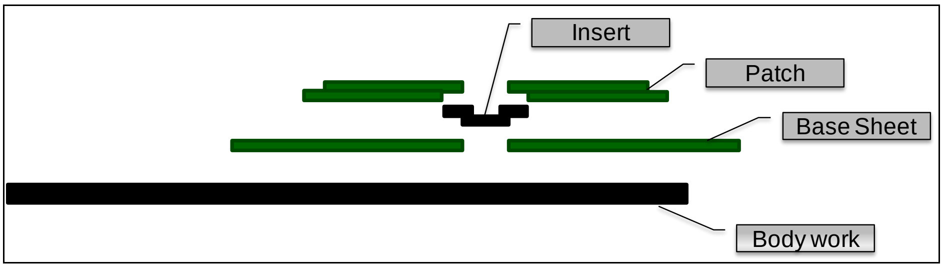

Figure 1. Components of force transmission point. Green: GF-TP, black: metal.

2.1 Pre-consolidation

In a first step, the insert and the patch are fixed together by heating up and cooling down both components under pressure (Fig.2). This process can be realized in a subassembly production line by a subcontractor isolated from the production of the base sheet.

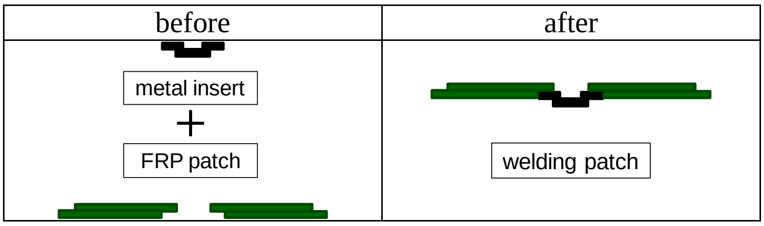

Figure 2. Metal insert and GF-TP patch before and after pre-consolidation to *welding patch*.

2.2 Thermoforming

In a second step, the planar semi-finished GF-TP base sheet together with the welding patch are formed to the final GF-TP part (Fig.3). The GF-TP is heaten up above melting tempature e.g. in an infra-red spotlight. Then the GF-TP is moved between the dies of the thermoforming press and formed to the threedimensional final part. After cooling the GF-TP below glass transition temperature the dies can be opened to remove the final part (Fig.4). With regard to industrial demands such as short cycle times, cost and energy efficieny, it is favourable to use an isothermal process. This means a constant temperature of the dies below glass transition temperature of the thermoplastic instead of heating up and cooling down the dies.

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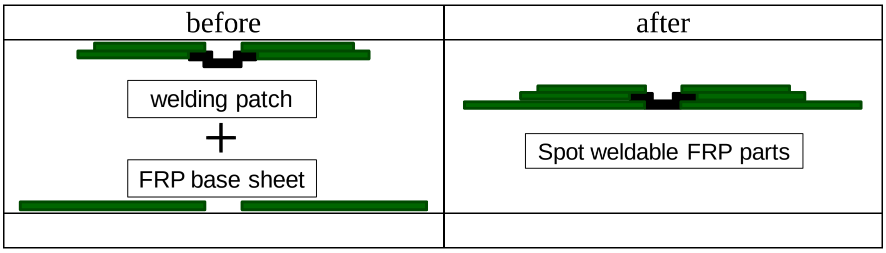

Figure 3. Welding patch and base sheet before and after thermoforming to spot weldable FRP parts.

Two variants are possible to match the welding patches to the base sheet: fixing the welding patches to the planar base sheet and heating up both simultaneously or equipping the die with welding patches and heating the welding patches and the planar base sheet separately.

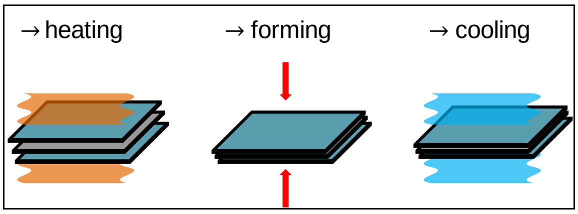

Figure 4. Thermoforming process.

2.3 Spot welding

The final step is to assemble the spot weldable GF-TP part in a conventional spot welding assembly line. As mentioned before, there is no need of extra investment in alternative joining infrastructure. Regarding the tendency to assemble different types or variants of cars at the same assembly line, hybrid and metallic car bodies can be assembled parallel at the same line.

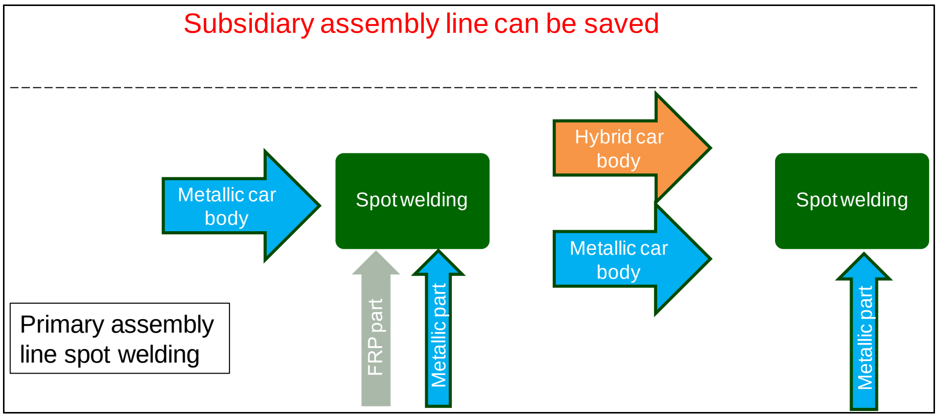

Figure 5. Assembly of hybrid and metallic car bodies at the same spot welding assembly line without the necessity of extra investments in alternative joining technologies.

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Critical parameters of the process are the position tolerance of the welding spot, the pressure and the temperature profile, which effects the adhesion forces between metal and thermoplastic and the distortion of the whole part. These parameters have to be investigated in the ongoing studies.

One approach to improve the handling properties of the welding patch is to combine several welding patches (Fig. 6). Such a multiple welding patch containing several welding spots, has a lot of geometrical degrees of freedoms and can be realized linear or angular. A promising case of application is one welding patch matching the surrounding edge of the GF-TP part.

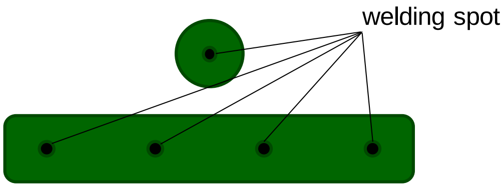


Figure 6. Single (above) und multiple (below) welding patch.

3. Design of Welding Patch

The structural design of the welding patch has to fulfill several requirements. On the one hand there are mechanical and thermal properties such as density, strength, stiffness, thermal resistance etc.

Pullout	Shear
3 kN	5 kN

Figure 7. Required loads of spot weld [4].

On the other hand there are automation and economic aspects as mentioned before. Several geometrics were investigated in a structural analysis. Although a deep-drawing insert might not be the best structural optimized part for the insert, it has a lot of economical advantages and is favourable for cheap mass production.

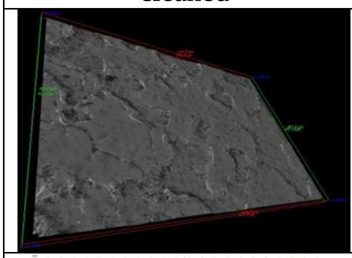
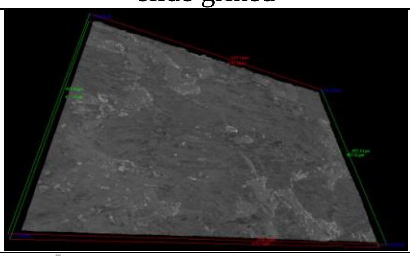
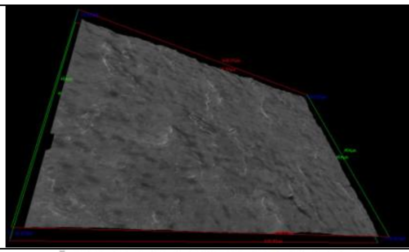
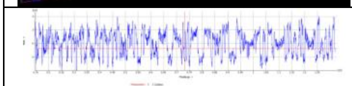
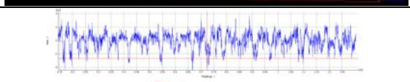
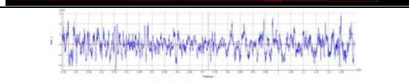
cleaned	slide grined	corroded
		
		
Ra = 1.4µm	Ra = 0.9µm	Ra = 1.2µm
Rz = 7.2µm	Rz = 6.8µm	Rz = 8.9µm

Figure 8. Roughness of surface treated metal insert measured with REM.

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To improve the adhesion forces, the surface of the hot-dip galvanized cold rolled deep-drawing steel was treated in three different ways: just cleaned, slide grined or corroded. The roughness was measured with REM (Fig.8). The measured adhesion forces as well as values from the literature were implemented in the numerical simulation.

In the numerical simulation of the welding patch the failure behavior of tensile loads was investigated using non-linear anisotropic solid model with an adhesive zone representing the interface between metal and GF-TP. The required loads of one welding spot were satisfied without failure in the metal insert or GF-TP and with tolerable deformation. When increasing the loads until failure, the adhesive zone degraded step by step (Fig.9). Depending on implemented adhesion forces the failure occurred at one side of the insert and proceeded at the other side or at both sides simultaneously.

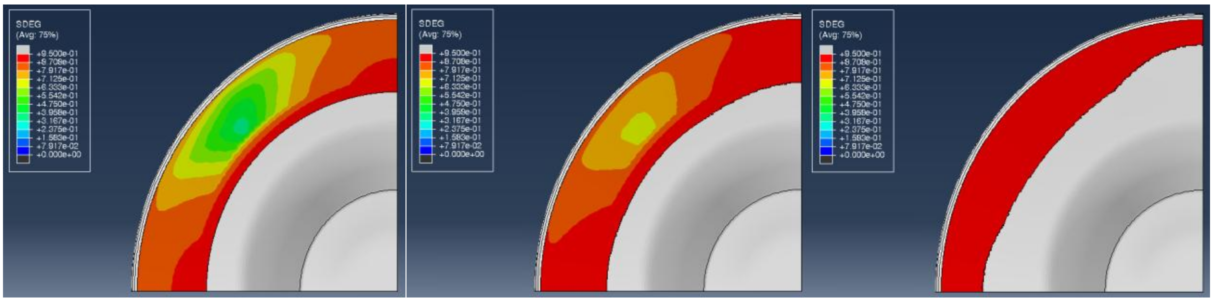


Figure 9. Degradation of adhesive zone between metal insert and GF-TP.

The design of experiments includes variables such as cooling rate, pressure and surface treatment (Fig.10). The produced planar coupons show good correlation between the numerical investigations.

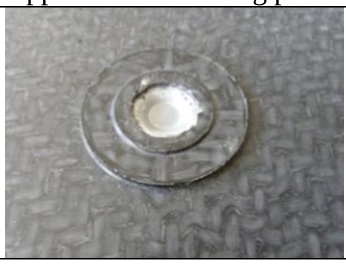
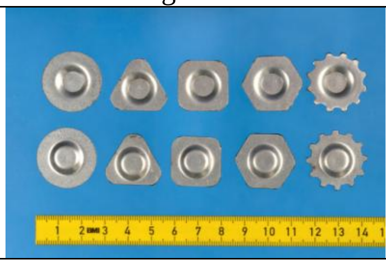
bottom side of welding patch	upper side of welding patch	investigated inserts
		

Figure 10. Investigated welding patches and insert geometrics.

4. Conclusions

Several insert and patch geometrics were investigated for different load cases in a numerical simulation. Deep-drawed inserts with a thickness of 0.7mm and patches with a thickness of 2mm are fulfilling the mechanical demands. The interface between metal and GF-TP was modeled with an adhesive zone. The material parameters for the adhesive zone were determined in prelimary experimental studies under consideration of the surface treatment of the metal.
Ongoing studies treat further load cases such as shear or fatigue stresses on both planar or three-dimensional coupons and economic aspects such as handling and time cycles.

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- Faserinstitut Bremen e.V.
- IWT Stiftung Institut für Werkstofftechnik

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