HIGH STRENGTH JOINING OF SHORT FIBRE REINFORCED POLYMERS AND METALS WITHOUT THE USE OF ADHESIVES IN COMPLEX JUNCTIONS

K. Kose[1], F. Eggers[2], B. Faisst[3] and L. Hoffmann[4]

[1]inpro Innovationsgesellschaft für fortgeschrittene Produktionssysteme in der Fahrzeugindustrie mbH, Berlin, Germany
Email: kim.kose@inpro.de, Web Page: http://www.inpro.de
[2]Mercedes Benz Werk Hamburg, Germany
Email: fred.eggers@daimler.com, Web Page: http://www.daimler.com
[3] TRUMPF Laser- und Systemtechnik GmbH, Ditzingen, Germany
Email: birgit.faisst@de.trumpf.com, Web Page: http://www.trumpf-laser.com
[4]Neue Materialien Fürth GmbH, Fürth, Germany
Email: leo.hoffmann@nmfgmbh.de, Web Page: http://www.nmfgmbh.de

Keywords: short fibre thermoplastics, joining, hybrid materials

Abstract

The joining of polymers to metal without the use of adhesives is of interest because this will make the use of chemical agents redundant at least in this manufacturing step. In the automotive industry polymer-metal-hybrid parts are of high interest because they combine a high functional integration with a low weight, which is needed to achieve future low $C0_2$ standards. The results gained for a joining technique based on a finely-structured metal surface and thermoplastics using only one-sided contact and no overmolding are very promising and in the range of conventionally joined polymer-metal hybrids. The original load bearing capacity is good and stays also nearly unchanged even after severe prior loadings like cyclical thermal and corrosive tests.

1. Introduction

Combinations of metals and short fibre reinforced polymers often give a good weight/performance ratio while retaining low cost. In the automotive industry polymer-metal-hybrid parts are of high interest because it is possible to combine a high functional integration with a low weight. However the joining of dissimilar materials with different characteristics (stiffness, strength, thermal expansion) poses a considerable problem. Here we present a joining method of metals to polymers without the use of adhesives of any kind as well as making the use of additional chemical agents for joining redundant, also overmolding with the need of two-sided contact of polymer to metal is not necessary. The joining is achieved due to a finely structured surface of the metal parts, which in turn are used as inserts in the injection molding process. Having shown the basic principles of this method as well as results for strength and stiffness using this method in preceding conferences using small coupon tests, see [1], [2], we present results for parts called “Berlin Torsion Beam”, see Fig. 1, using this technology on a much bigger size and under complex loadings. Materials used are aluminum and different thermoplastics (PP-LGF30, PA66-LGF50) with a fibre length of 12 mm in the granulate. The thermoplastic materials are from SABIC with the trade names STAMAX™ 30YM240 resin and VERTON™ RV00AESP compound.

Excerpt from ISBN 978-3-00-053387-7

The results presented here are an outcome of a research project executed together by the companies Albis, Allod, Audi, BASF, Daimler, inpro, Neue Materialien Fürth, SABIC, thyssenkrupp, Trumpf Lasertechnik, Volkswagen as well as the Technical University Berlin.

.

2. Tests

2.1. Test specimen “Berlin Torsion Beam”

In order to show the characteristics and capabilities of this new joining method a new test specimen called “Berlin Torsion Beam” was devised. It consists of a core made out of thermoplastic and two sidewalls made out of metal, see Fig. 1. Its production is as follows: first the side walls made out of 1 mm thick aluminum are structured finely using a short pulsed laser resulting in a depth of approx. 0.2 mm into the base metal and a scanning spacing of approx. 0.7 mm. These sidewalls are then used as inserts during the injection molding process. The flow of the polymer into the small pits can be alleviated using an inductive heating which is included in the mold tool. There is only one-sided contact to the metal during molding and the joining is based purely on the micro interlocking made possible by the structure. Visible in the middle of the beam is a flow channel. This is used to make different injection molding scenarios possible. Before Testing cuts were made into the flow channel, see Fig. 2, thus eliminating stiffening of the channel.

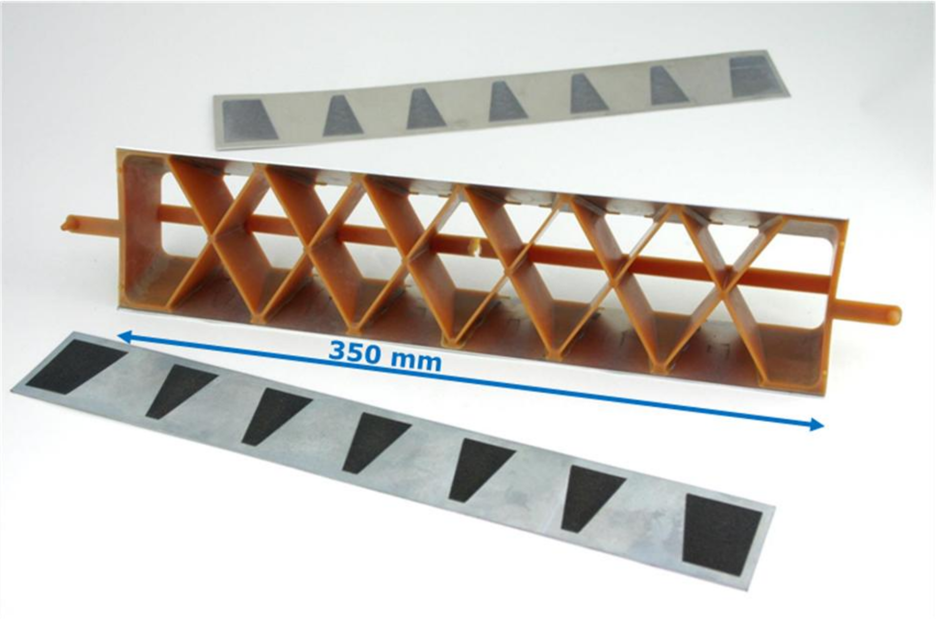

Figure 1. Berlin Torsion Beam with sidewalls

2.2. Test setup

Having tested this joining method with small coupons [1], [2] we here use bending and torsion tests to introduce a complex load onto the part and its joints. For this purpose a torsion test and a bending test are used. With the torsion test it is also possible to determine the stiffness of all parts of the beam separately while the bending test results directly in loads on the joining area.

In Fig. 2 the test set-up for torsion is shown. Both ends are clamped completely to introduce loads primarily on the metal sidewalls. During a test, the core will be loaded too. First cracks in the interlocking zone of polymer and metal are nearly simultaneously with first cracks in the polymer core.

Excerpt from ISBN 978-3-00-053387-7

Figure 2. Berlin Torsion Beam in torsional test

In Fig. 3 the different contributions to the total torsional strength of the beam are shown. It demonstrates that the contribution of the sidewalls is small. The contribution of the polymer core is roughly double that but shows first failure at about 12° degrees torsion. The combination of sidewalls and core results in a roughly added strength of the parts but with later cracks in the polymer. The joining of walls and core causes the big jump in the torsional strength and stiffness. This shows not only that the joining is crucial for the performance even in totally clamped situations but also that the joining carries significant loads.

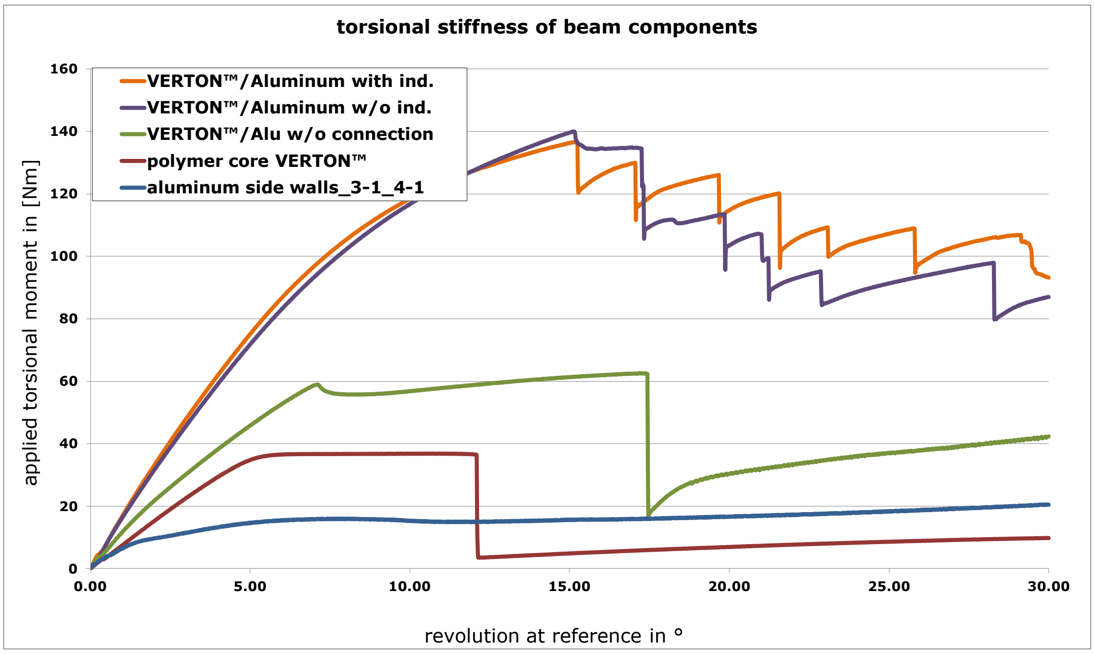

Figure 3. contribution to torsional stiffness of different parts of torsion beam

In the bending tests all loads on the beam are introduced via the polymer core, thus a local bending of the sidewalls is prevented, see Fig. 4. The position of the stamp is located in the middle which leads to

Excerpt from ISBN 978-3-00-053387-7

a four-point bending in the test because once the beam has a little curvature further loads on it will be introduced only at the edges of the stamp.

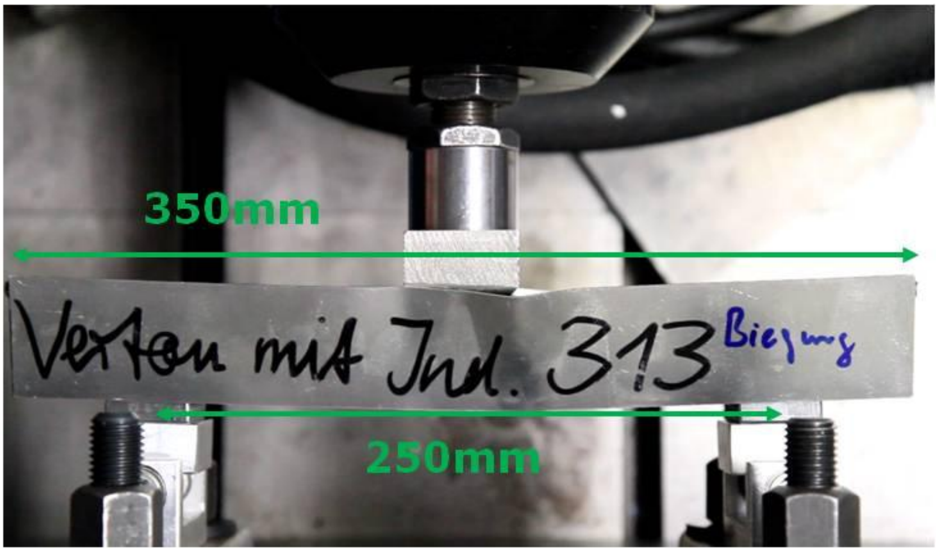

Figure 4. Berlin Torsion Beam under bending load

A beam after bending is shown in Fig. 5. Although it is heavily damaged the interlocking zone is mostly intact thus forcing the polymer to follow the deformed metal.

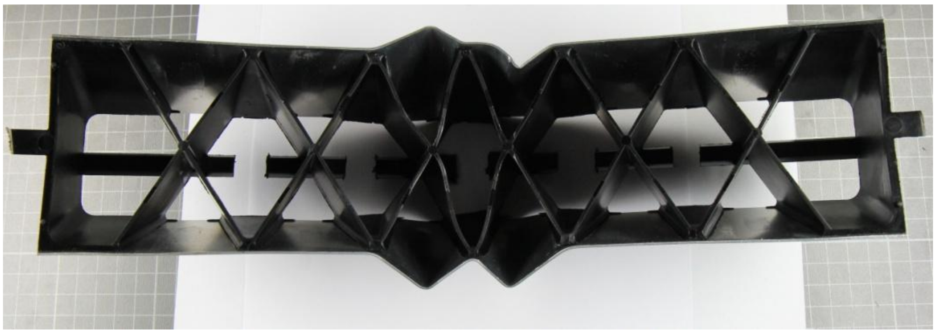

Figure 5. deformed beam after bending

2.3 Test results

In the following some results are given for torsion and bending of the beams. Fig. 6 shows results of torsion tests for beams made out of VERTON™ compound and aluminum (with and without inductive heating) as well as beams made out of STAMAX™ resin and aluminum (also with resp. without the use of inductive heating in the mold during molding). For the case of VERTON compound and aluminum there is obviously no significant difference of behaviour between beams made using inductive heating or not. This is different to the beams made of STAMAX resin and aluminum. Here the inductive heating has a clear positive effect.

Remarkable in the results for the combination VERTON compound / aluminum is the difference to results gained with test coupons. The coupons showed a significantly inferior load bearing capacity when made without the help of inductive heating. Due to inner stresses in the beam after manufacturing caused by different thermal expansion an early failure could have been expected. That this is not the case points towards a positive effect of the inner stresses helping the interlocking between polymer and metal.

Excerpt from ISBN 978-3-00-053387-7

Fig. 7 shows results of bending tests for beams made out of STAMAX resin and aluminum, without the use of inductive heating. One group was tested after manufacturing, the other after exposing them to 50 cycles of alternating temperature. The temperature cycles run between -40°C, RT and 80°C with a rate of change of 1°C/min and holding the temperature for 2 hrs. at the specified temperatures.

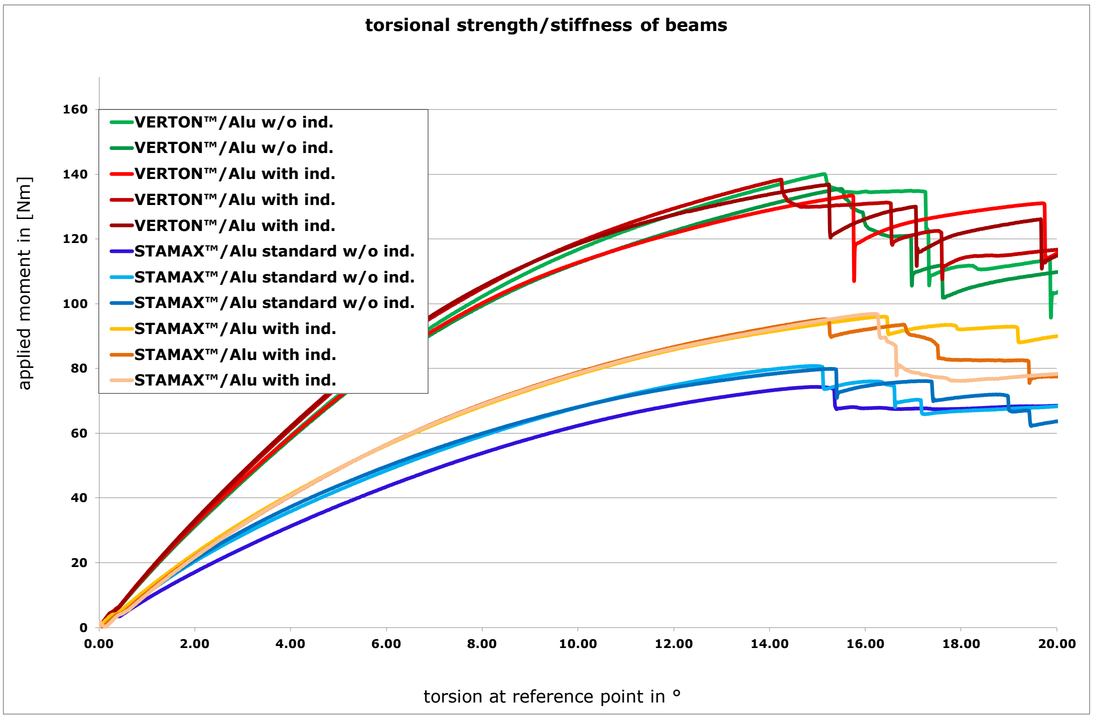

Figure 6. torsional stiffness of different beams made with or without using additional inductive heating

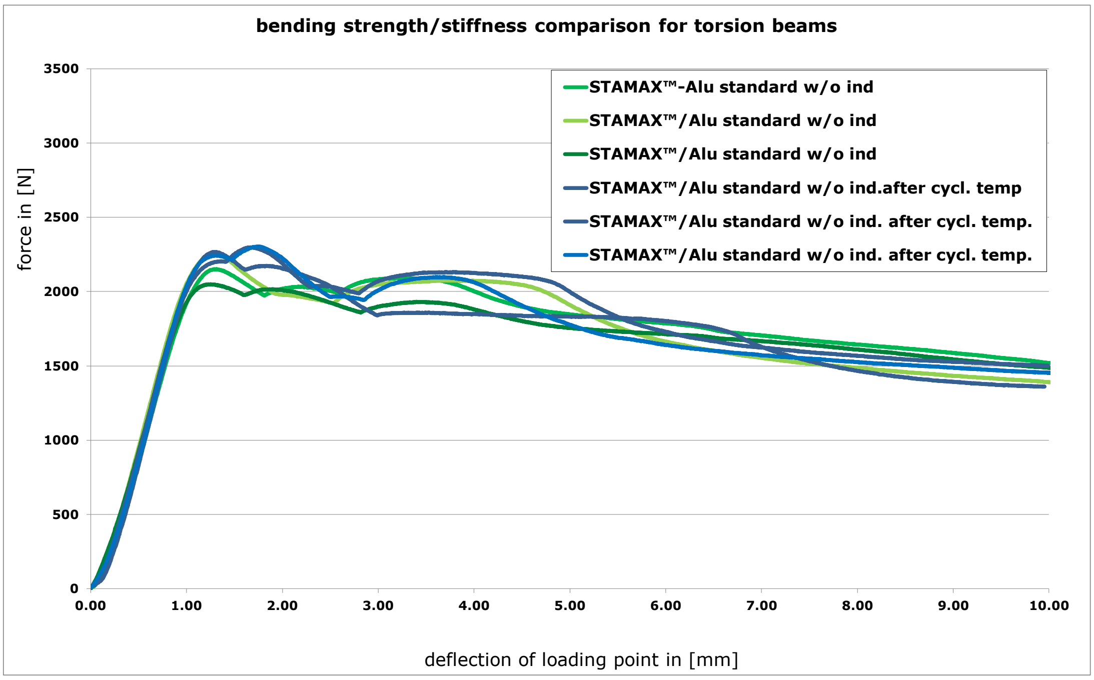

Figure 7. beams of aluminium / STAMAX™ resin under bending load. Tests performed before and after cyclic temperature loadings (-40°C, RT, 80°C)

Excerpt from ISBN 978-3-00-053387-7

3. Conclusions

The results presented in this paper show not only that the technique to join metal and polymer purely by finely structuring the metal prior to molding is feasible for large parts but also that inductive heating is no requirement for a high load bearing capacity. All results have been gained using long glass fibre reinforced materials by SABIC thus showing that the good joining properties provided by the interlocking of short fibre reinforced polymer including the fibres with the metal [1] persist also when the glass fibres are much longer, here 12 mm.

Acknowledgments

The research of the project presented in this paper is funded in part by the German Bundesministerium für Bildung und Forschung (BMBF) in the WING-program with the title “ExtraLight – Extremer Leichtbau mit Kunststoff-Metall-Hybriden” with the grant codes 03X3037A, 03X3037H, 03X3037C, 03X3037E.

References

[1] K. Kose, I. Clausner, F. Eggers and B. Faisst. Research into the direct adhesion of pa66 to steel using structured metal surface. *Proceedings of the 16th European Conference on Composite Materials ECCM16 , Seville, Spain,* June 22-26 2014.

[2] K. Kose, I. Clausner, F. Eggers and B. Faisst. Method for enabling highly loadable material Combinations of pp and aluminum without the use of Adhesives. *Proceedings of the 20th International Conference on Composite Materials ICCM-20, Copenhagen, Denmark,* July 19-24 2015.

STAMAX and VERTON are trademarks of SABIC or its subsidiaries or affiliates.

Excerpt from ISBN 978-3-00-053387-7