Current information from the Welding and Joining Institute of the RWTH Aachen University

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Material combination of continuous fibre-reinforced plastics and metal with integrated sensor monitoring

Jens Lotte

Abstract: For the production of light weight structures, an increasing number of industrial branches (automotive engineering, aircraft and aerospace industry and plant engineering) use hybrid structures consisting of continuous fibre-reinforced plastics and metals. The joining point, consisting of FRP and metal is often the limiting variable for the application. For this research project, a joining technology that is appropriate for the fibre and allows for the application of a failure monitoring system was developed.

Joining technique for FRP/metal composites: Currently, the controlled joining of metals with plastics is possible only by mechanical joining methods and adhesives (adhesive). Mechanical joining methods are carried out via clinching of an auxiliary joining part (for example, a screw). Due to the process design, fibre damage in the FRP occurs which has a strong negative influence on the directionality of the material properties. Moreover, a gap remains between the joining members which facilitates due to capillary forces the penetration of corrosive media. Structural adhesive bonds, however, are mainly subjected to brittle failing without the possibility to recognize optically imminent failure in good time. The joining members are only superficially joined by the adhesive and this is why the application of force into subjacent fibre layers via the matrix is carried out insufficiently. For reproducible strength values of bonded joints, complex surface pre-treatment of the joining members is, moreover, required.

Small-scale positive fit elements: A new approach is the intrinsic joining of FRP and metals using small-scale positive fit elements. These are produced by application of filler material or directly from the base material, Figure 1, for example, CMT and additive manufacturing processes, or Surfli-Sculpt- and GripMetal structures.

Intrinsic Joining: These are methods where at least one material develops only during the joining process. Here, pin structures which are applied via CMT pin welding are investigated. The fibre material is, in the dry state, guided around these pins where after the infusion of the matrix resin and its hardening an additional adhesive bond is developing. The pin structures allow to induce attacking forces into subjacent fibre layers which causes the reinforcement fibres to absorb the loads more uniformly and thus the optimal exploitation of the bond material. By the additional positive fit, the joining point fails, other than in purely structural adhesive bonds, not abruptly but shows a ductile post-fracture behaviour.

Structural Health Monitoring: The resulting multistep failure characteristic allows for the simple monitoring of the joining point. It is, therefore, possible to take safety measures before the connection parts are failing. The inbuilt sensor system is based on a continuous electric connection in the part which is, in the case of damage, separated, Fig. 2.

Fig. 2: Hybrid joining point consisting of carbon fibre reinforced plastics and steel with integrated sensor monitoring

Other than in an adhesively bonded joint without pin, after the first decline of the absorbed forces another rise of force until final fracture force is observed. The integrated sensor reacts in the case of adhesive failure and thus before the joining partners are completely separated.

Acknowledgements: The IGF-project 17971 N/2 of the Forschungsvereinigung Forschungskuratorium Textil e.V. and the Forschungsvereinigung Stahlanwendung e.V. is funded via the AIF within the framework of the program for the support of the industrial cooperative research and development (IGF) by the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie) on the basis of a resolution passed by the Deutscher Bundestag. We would like to thank for the support.
Investigation of the load-carrying behaviour of filigree pin structures for steel-concrete composite construction

Johannes Schäfer

**Abstract:** Within the framework of the research project, a bond is tested which forms a form-fitting connection between steel and concrete up to a height of 5 mm by means of filigree pin structures. The particular in this age of resources saving, weight-reducing material combinations in the construction sector are in the focus of current research work. For this reason, a consortium consisting of the Institut für Massivbau (IMB), the Institut für Stahlbau (STB) and the Institut für Schweißtechnik und Fügetechnik (ISF) of the RWTH Aachen University are working on the investigation of a filigree positive fit for weight-reduced steel-concrete bonds. The “streamlining” is, at that, obtained by the application of high-strength (HSC) and ultra high-strength concrete (UHPC) which develop a favourable ratio of strength to own (dead) weight. This way, in composite construction, composite designs between steel and concrete with a part thickness which is reduced to a few centimetres are obtained and which allow thus for smaller cross-sections. A problem, however, is the joining of the two materials. With materials as thick as those on hand, the known positive fit elements such as shear studs or composite plug grounds for transferring the shear forces are no longer appropriate or they are, in their smallest form, already oversized. A suitable solution under these circumstances is the use of small-scale pin structures which can be generated by Fronius International with the aid of CMT pin processes. By the exertion of influence on the forming processes, different pin formations (e.g. Figure 1) can be generated from welding wire diameters of between 0.8 and 1.2 mm (base material ASTM A633 and AISI 304).

The achievable height development ranges, at that, in an interval of between 2.5 and 5 mm which may vary, depending on the specification, in the formation of the pin base, the shaft and the head. By testing the pin formations via tensile and shear tests, failure within the shaft above the pin base was determined. The successful use for composite construction was carried out via tests where pin formation with high-strength and ultra high-strength concrete (largest grain diameter max. 0.6 mm) were cast-in and subjected to tests about pull-off, torsion and shear in small-part specimens. While the failure types in destructive testing by pull-off- and torsion tests were mainly caused by concrete failure with the formation of failure cones around the pins, a different behaviour is observed in the shear tests. Here, the shear-off of steel is observed, particularly when ultra high-strength concrete is used which results in the complete shear-off of the pin base or, alternatively, in punching of the concrete when high-strength concrete is used (Figure 2). From the bond tests and additional FE studies about the development of the load-bearing model, for the successful application of a steel-pin-concrete bond, a required undercut of the concrete to the pin head with the diameter pin-head / diameter pin ≥ 1.4 and a pin-pin minimum distance with a pin height of ≥ 2.3 x was calculated.

![Fig. 1: High-speed recording pin forming (top), different pin formations by electric variation (bottom)](image1)

![Fig. 2: Shear failure types shear-off of steel (left) and punching of the concrete (right)](image2)

**Acknowledgements:** The authors gratefully acknowledge the funding of the project “Untersuchung der Tragmechanismen neuartiger, kleinskaliger PinVerbundmittel zwischen Stahl und Beton” (Investigations about the load-bearing mechanisms of novel small-scale pin composites between steel and concrete), funding number: RE 2755/32-1/FE 459/5-1/HE 2637/20-1 by the Deutschen Forschungsgemeinschaft (DFG) (German Research Foundation).
On May 20, 2015, after 15 years of highly committed work, Dr. Elmar Stracke handed over the presidency of the Freundeskreis to Dr.-Ing. Johannes Weiser. We would like to express our sincere thanks to Dr. Stracke.

New Staff

In August 2016, Mr. Christian Schmitz started his vocational training for industrial mechanics in the ISF mechanical workshop. Mr. Janis Künzer successfully completed his vocational training for industrial mechanics and has, since January 2016, been working successfully as skilled worker in the ISF mechanical workshop. Mr. Lukas Oster started his work as new scientific researcher in May 2015 in the arc welding department. Mrs. Sharareh Mortazavi worked from May till September in the electron beam department as research assistant. Robin Schwenke has successfully passed the IHK (Chamber of Industry and Commerce) exam for mathematical-technical software developer in August 2016. Mrs. Jennifer Pobehaj, who after her vocational training for office communication manager worked in the ISF for approximately 1.5 years has taken on a new task in the Institut für theoretische Elektrotechnik at the RWTH Aachen University.

Doctoral Jubilees

The ISF congratulates the “golden” doctoral jubilarians who, in 1966, concluded their dissertation with the final oral examination: Mr. Dr.-Ing Jürgen Fortmann, Mr. Dr.-Ing. Peter Buschhoff

Completed Research Projects

Untersuchung der Tragmechanismen neuerartiger, kleinskaliger Pin-Verbundmittel zwischen Stahl und Beton* (Investigations about the load-bearing mechanisms of novel small-scale pin composites between steel and concrete) DFG (RE 2755/32-1/FE 459/5-1/HF 2637/20-1)

Untersuchung des Einflusses der materialabhängigen Eigenschaften von Aluminiumdrahtelektroden auf die Stabilität und das Schweizergebnis bei Schutzgasschweißprozessen. (Investigations about the influence of the material-dependent properties of aluminium wire electrodes on the stability and the welding result in gas shielded welding processes) (AIF 17.524 N / DVS 01.084)

Entwicklung und Qualifizierung einer modifizierten äquivalenten Wärmemequelle für die Simulation der Wärmeeinbringung beim Lichtbogenschweißen (Development and qualification of a modified equivalent heat source for the simulation of the heat input in arc welding) (IGF-Nr. 17.942 N)

New research projects

Schichtsystem für Strömungsbauten aus Gusseisen unter Degradation durch Verschleiß, Kavitation und Korrosion. (Layer system for flowing components made of cast iron under degradation by wear, cavitation and corrosion) (DFG RE 2755/41-1)

EquineHoofRepair – Entwicklung eines Klebstoff-systems sowie eines Hufhornsplattpflasters zur Behandlung von Hornspaltfehlern bei Pferden; Erarbeitung eines Anforderungsprofils für EquineHoofRepair sowie die Qualifizierung eines geeigneten Hufhornsplattpflasters (Development of an adhesive system and of a hoof crack patch for the treatment of hoof crack effects of horses; Development of a requirement profile for EquineHoofRepair and qualification of a suitable hoof crack patch) (ZIM ZF4134804AJ6)

AlCu-Buckelschweißen - Untersuchungen zum Widerstands- schweißen zur Erzeugung elektrischer Al-Cu-Kontaktierungen. (AlCu projection welding – Investigations about resistance projection welding for the production of electric Al-Cu contacts) (IGF -Nr. 18581 N / 1)

Serielles Plasma-MSG-Hybridschweißen bei Verwendung angepasster Prozessvarianten zum wirtschaftlichen Fügen von Aluminium. (Serial plasma GMA hybrid welding using adapted process variations for the economic joining of aluminium). (IGF-Nr. 19.203 N)

New Measurement Techniques

NOH-Analysator Bruker Galileo G8 – Determination of N, O and H via carrier gas hot extraction

Material specimens are molten in a graphite crucible at high temperature in the inert gas flow and the released gas is analysed. An external infrared furnace allows, moreover, for the measurement of the diffusible hydrogen content, e.g. in welded seams according to ISO 3690 and AWS A4.3, Fig. 1.

Fig. 1: NOH-Analysator

Miscellaneous

ISF-Weldmeister – The Final “Zerspaner Cup”

After having got fifth place last year, the ISF-Weldmeister were defeated in the final of the “Zerspaner Cup” and left the football pitch as second best team from among 18 Aachen company teams.

“FAMOS für FAMILIE“ 2016

For the past nine years, the family service of the RWTH Aachen University has been granting the award “Famos für Familie” where executives are awarded for their particularly family friendly personnel management. This year, Professor Reisgen is also among the laureates upon proposal of the institute staff.

Fig. 2: Award “Famos für Familie” for Prof. Reisgen

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