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

Far-field measurements on a polymer optical fiber during a shear test in relation to crosshead travel.

Topics:

- Evaluation of high-performance welding processes under the conditions of new wind turbine production
- Non-destructive condition monitoring of bonded joints by integration of a polymer optical fiber
- News

German version is available at: https://www.isf.rwth-aachen.de
High-performance welding processes such as the laser submerged-arc hybrid welding (LUPuS Hybrid) developed at ISF are currently not used in wind turbine construction due to component tolerances that are too large for the joining processes.

In the field of renewable energies, wind power plays an important role in achieving the climate targets, not least because of the “Wind-an-Land-Gesetz” (Wind on Land Act), which came into force on February 1, 2023. According to this law, 2% of the land area is to be designated for the expansion of wind energy by 2032.

Up to now, conventional arc processes such as MSG or submerged arc multi-wire processes have been used exclusively for the joining of large-diameter pipes. These processes are characterized by the fact that virtually the entire plate thickness has to be filled with filler material in many welding layers due to the large-volume seam preparation, which entails significant costs (filler material, production time, energy requirement). In order to meet the wind energy expansion targets, joining technologies are needed that enable higher productivity (e.g. through lower seam volumes and number of weld layers) and are at the same time just as robust as the conventionally used welding processes with regard to component tolerances occurring in everyday industrial use.

Laser submerged-arc hybrid welding (LUPuS Hybrid) combines the two individual processes mentioned above in a single process zone and thus makes it possible to exploit the synergy effects resulting from the two individual processes (e.g. good gap bridging capability with the submerged-arc process; high welding depth with the laser-beam process). LUPuS hybrid welding has already been tested in various research projects at ISF. Here, mainly in the technical zero gap, plate thicknesses of up to 50 mm could be reproducibly joined in position/counterposition with a high weld seam quality.

In order to meet the requirements for component tolerances (joint gaps, offsets), the LUPuS single-wire process was further developed into an LUPuS tandem process, Fig. 1.

The conventional LUPuS single-wire process was further developed into an LUPuS tandem process in order to cope with the component tolerances (joint gaps, offsets) that occur in everyday industrial practice.

The LUPuS tandem process consists of two submerged-arc torches and the laser beam optics. A separator plate is used to shield the welding flux from the effective range of the laser beam. Compared to the LUPuS single-wire process, the weld seams produced with the LUPuS tandem process are characterized by an optimized weld seam width-to-depth ratio. This favors the robustness of the process in relation to components with joining gaps, Fig. 2.

In order to avoid root-side fall-through of molten material, a counter-pass was first performed with the submerged-arc process. The basic welding parameters of the subsequent hybrid weld Laser power (PL = 16 kW) and welding speed (VS = 0.6 m/min) were kept constant for both welding tests shown in Fig. 2. Due to the current selection of the two submerged-arc torches in the LUPuS tandem process (1st torch DC+, 2nd torch AC), a geometrically uniform weld seam was produced with a constant joint gap of 1.5 mm compared to the LUPuS single-wire process (DC+). Furthermore, a homogeneous transition from the upper, submerged-arc-dominated to the lower, laser-dominated weld seam area is generated with the LUPuS tandem process in this joining task. In the further course of the research project, the newly developed LUPuS tandem process was also tested for joining different offset widths and for combined component tolerances (joint gap and offset).

The IGF project no. 21.304 B of the research association “Schweßen und verwandte Verfahren des DVS e.V.” (Welding and Allied Processes of DVS) was funded by the German Federal Ministry of Economics and Climate Protection via the German Federation of Industrial Research Associations (AiF) within the framework of the program for the promotion of industrial community research (IGF) on the basis of a resolution of the German Bundestag.
Non-destructive condition monitoring of bonded joints by integration of a polymer optical fiber

Josef Weiland

In cooperation with the Polymer Optical Fiber Application Center (POF-AC) of the Nürnberg University of Applied Sciences Georg Simon Ohm, ISF is researching a method for monitoring the condition of bonded joints during the integration of polymer optical fibers (POF). For this purpose, basic adhesive and mechanical bond investigations as well as the investigation of optical effects in POF are necessary. Subsequently, the optical effects will be interpreted for monitoring the adhesion state. The results show a direct correlation between the applied force and the transmission of the POF for semi structural adhesives.

Bonding is a so-called special process that requires separate standardization, according to DIN EN ISO 9001. One of the reasons for this classification is the fact that it is not possible to test bonded joints completely non-destructively. This gives rise to the motivation to continuously monitor bonded joints in order to record their structural condition and - associated with this - to ensure reliable force transmission.

The sensor concept investigated in this research project is based on the integration of a polymer optical fiber (POF for short) into the bond. Using the example of a pipe-sleeve bond with a two-component polyurethane adhesive, the principle is outlined in Figure 1. Due to the similar mechanical properties of POF and adhesive (both plastics), stresses are transferred from the adhesive to the POF. These lead to geometric changes, strains and stresses in the photoconductive material and in the core-cladding interface. The effects are investigated in terms of transmitted and reflected light power and their distribution in the near and far field and interpreted for condition monitoring. The aim is to develop a simple and cost-effective method based on the integration of a POF into the bond and the measurement of the integral light output.

GREEN = OK to YELLOW = sticking can be observed. In the same way, the change to the red area = not OK. In RED, the bond must be checked, or the force applied must be reduced. In the simplest case, the transmission limits are based on empirical values. These are determined in advance by tests. The SHM traffic light is a simple method for monitoring the condition of bonding on the basis of transmission limit values. In addition, a method based on the change in transmittance over time is also possible. The project also showed that the sensor signal can be made even more sensitive by using somewhat more complex optical components, such as a laser and a camera.

The results of the research project show that it is possible to monitor the condition of bonded joints and thus also to detect failures at an early stage. This opens up new fields of application for SMEs across all sectors, for example in the construction, wind turbine, aerospace and rail vehicle industries, as well as in conventional mechanical and plant engineering. Further joint research activities are planned in cooperation with POF-AC.

The IGF project "KlebPOF" No.: 21.314 N of the research association "Schweißen und verwandte Verfahren des DVS e.V." (Welding and allied processes of DVS e.V.) was funded by the Federal Ministry of Economics and Climate Protection via the AiF within the framework of the program for the promotion of joint industrial research (IGF) on the basis of a resolution of the German Federal Parliament. In addition, the authors would like to thank all project partners involved.

Figure 1: POF-integrated pipe-socket bonding and sensor concept

To investigate the load-specific phenomena for the change of the optical properties of the POF and to use them for condition monitoring is an essential task of the investigations. Figure 2 shows a time-force and time-transmission curve of a bond. The signal course could be recorded with simple optoelectronic devices, where the coupling was done via an LED and a photodiode recorded the total light power. An almost linear correlation can be seen between the curves. On the basis of a transmission threshold value, the SHM traffic light changes its state from
**News**

**ISF Internal**

Since December 2022, Mr. Kellerwessel supports the arc welding department.

We warmly congratulate Dinah and Jens Lotte on the birth of their daughter Anna. In addition, we congratulate Miriam and Florian Müller on their wedding.

We congratulate Ms. Jessica Kommer and Ms. Julia Hesse on the successful completion of their training as industrial mechanics. Due to her excellent qualification acquired at ISF, Ms. Kommer was offered a position as a trainer at the RWTH Vocational Training Center, which she took up on January 1, 2023. Ms. Julia Hesse has been working as an employee for the mechanical workshop since January 2023.

Mr. Steffen Treinen has left the institute to take up a new position in industry. Mr. Pascal Österreich started his new employment at FEF-Forschungs- und Entwicklungsgesellschaft Fügetechnik GmbH at the beginning of the new year.

**Promotions**

The ISF congratulates the golden doctoral graduates who successfully completed their doctorate at the ISF in 1973 with the oral examination: Dr.-Ing. Sigurd Rasche, Dr.-Ing. Rainer Boldt, Dr.-Ing. Kurt Niederhoff.

We congratulate Dr.-Ing. Bernd Baumann and Dr.-Ing. Jörg T. Dickersbach on the silver anniversary of their doctorate with examination in 1998.

**Completed research projects**

Novel welding system technology for simple and reliable contacting of high-frequency strands in electrical engineering (HF-Connect) (EF-RE-0400365)

Laser assisted double wire buildup welding (LDNA) (DFG-No.: RE 2755/62-1)

Non-destructive condition monitoring of elastic and structural bondings under tensile and shear stress by integration of an optical polymer fiber (KlebPOF) (IGF-No.: 21314 N)

Welding process-dependent control of the extraction power when using extraction torches for MSG welding (IGF-No.: 20.977 N / DVS-No. Q6.3175)

Methods for the design and simulation of me-tall-glass bonds in the construction industry with regard to failure prediction (IGF-No.: 21348N)

**New research projects**

Integration of fiber-optic textiles in bonded joints for photoinitiated curing of adhesives on radiation-transparent joining partners (IGF-No.: 22727 N)

Resistance spot welding of die-cast aluminum alloys and wrought aluminum alloys (IGF-No.: 22700 N)

Multi-Axis Multi Material Wire Arc Additive Manufacturing (BMBF)

Self-consistent model of laser-assisted TIG welding of aluminum or copper (LA-TIG) (DFG-No.: 503656242)

Optimization of the power density distribution to influence the temperature gradient during beam welding of thin sheet metal with a special focus on the resulting residual stresses and distortion (IGF-No.: 22.828 N)

Recently, the FEF GmbH, which is close to the institute, also likes to participate in research consortia as an industrial partner. At this point, the BMBF project "Investigation of MSG welding technology for the generative production of macroscopic structural bodies from stainless steels using WAAM" funding code "13XP5188D" should be mentioned. The partners in the project are Oscar PLT GmbH, IconPro GmbH, Access e.V., Fraunhofer Institute for Laser Technology (ILT), German Aerospace Center (DLR) and Siemens AG. Further information on FEF research projects can be found here: https://www.fef-aachen.de/de/aktuelles

**Advance notices**

The SFB 1120 (Precision from Melt) in collaboration with the SFB 814 (Additive Manufacturing, Erlangen) and the CCE (Centre Computational Engineering, Darmstadt) invites you to the 2nd International Joint Conference EMPOrIA from May 16-17, 2023.

More information and topics are available on the website: https://www.emporia2023.de

The Faculdade de Engenharia da Universidade do Porto (FEUP) and the Wissenschaftliche Gesellschaft Fügetechnik e.V. (WGF) invite you to the third “International Conference on Advanced Joining Processes” from October 19 to 20, 2023.

More information and topics are available on the website: https://web.fe.up.pt/~ajp2023/