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Direct bolting of railway aluminium vehicle components with flow drill screwing (FDS)

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Abstract

The aim of the research study is to investigate the increase of the load-bearing capacity by utilising a shear-/bearing loaded joint for both, the static and the fatigue strength verification of flow drill screwed aluminium components. The focus is set on load-bearing capacity investigations for bolted joints in aluminium profiles with sheet thicknesses from 3 mm to 7 mm, as they are commonly used in extruded aluminium profiles for supporting structures in rail vehicles. A decisive obstacle for the utilisation of the economic potential of directly bolted connections is the lack of design rules and load capacity verifications. As research objectives, the existing deficit of an analytically unified design and the lacking determination of the load-bearing capacity of directly bolted aluminium components must be eliminated. Considering the process chains of railway vehicle manufacturing, this is an economical advantage for the many supplier companies in the business.

Keywords: Flow Drill Screwing FDS, bolted joints, aluminium alloys, railway vehicles

1 Introduction

The submitted study deals with bolted joints for railway vehicles, especially for wagon bodies made of extruded aluminium profiles. Bolted joints become necessary due to maintenance and for improved accessibility for a variety of attachments and equipment parts. Applying bolted joints in extruded profiles often becomes a constructive challenge. A blind bolting into the profile requires blind rivet nut, for which a strength verification is usually difficult to apply. Otherwise, special c-rails or consoles become necessary, which already must be considered in the extrusion tooling. This results in with a major impact on the tooling costs, while at the same time reducing the flexibility of positioning the assemblies. Anyway, the interfaces of bolted joints must be free of thick coatings to prevent losses of preload and normally must be executed with slotted holes, which allow the compensation of tolerances and positions of the assemblies. Together with the necessary tightening for preloading, to match the requirement of slip resistance, all mentioned efforts as mentioned lead to rising manufacturing times and costs.

A technically smarter and highly economical solution is direct bolting by flow drill screwing (FDS). Figure 1 shows the FDS procedure according to [1].

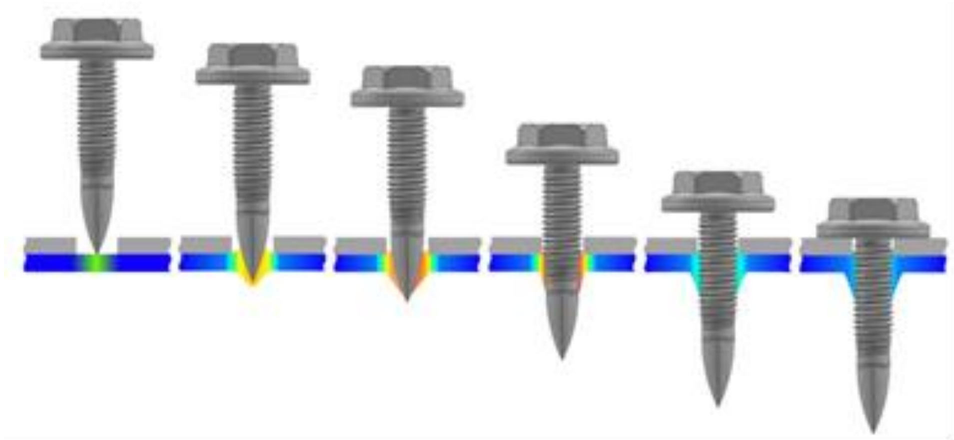

Figure 1: Procedure of flow drill screwing (FDS) acc. to [1]

The FDS technology is well known in automotive industry, prioritizing joining of extruded aluminium profiles and higher strength steels [2, 3, 4]. In respect to the sheet metal thicknesses und strengths, FDS is also applicable with the aluminium alloys in railway wagon bodies. FDS goes hand in hand with many advantages and benefits. Pre-holes in the support structure or the final coated interfaces of the assemblies are no longer needed. In addition, there is no preload necessary as it would be to execute a slip resistant joint. The mechanism to transfer vertical loads should be caused by shear-/bearing load capacity, which allows significantly smaller bolt diameters. Therefore, it is possible to downsize from a metric bolt M10 to a diameter M5 by maintaining the static resistance.

To establish FDS several requirements need to be fulfilled. One of them is the activation of the bearing capacity by elimination of any hole clearances. This in particular requests a sufficiently well calibrated positioning and tightening procedure. Additional requirements are construction dimensions like edge distances and pre-hole clearances.

2 Methods

The experimental studies separated into two investigation complexes. In both complexes, the aluminium alloys EN AW 5083 H111 and EN AW 6082 T6 are subject of investigations. The first complex includes the application of FDS (Figure 2, left) in several sheet metal thickness and pre-hole diameter combinations. Therefore, two aluminium plates are positioned according to the dimensions as shown in Figure 2, right. The illustrated pre-holes are only part of upper sheet metal called clamped part. There are no pre-holes needed in the bottom plate, which is the part to be threaded in.

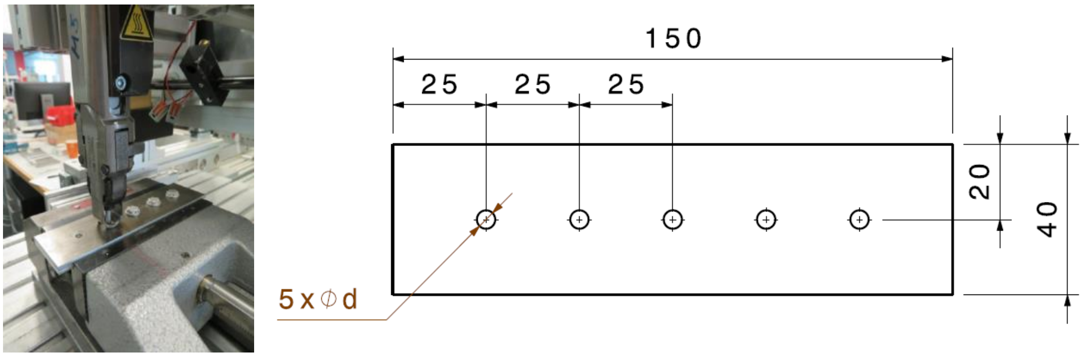

Figure 2: Application of FDS (left) and specimen for tightening procedure investigations (right)

The subject of the first investigation complex is to specify machine parameters for the joining process and the tightening procedure. There is an enormous set of parameters for the several stages of flow drill screwing, which in the end influences the result of the joint. The axial forces, the rotation speeds as well as the different torques to be monitored are the key parameters for the FDS process. Also the blank holder force and process time have a major impact on establishing robust and reproducible procedures. Flow drilling screws of diameter M5 from two different suppliers were investigated to handle the count of experiments.

In the second complex, the load bearing behaviour is determined for selected combinations of procedure parameters, sheet thicknesses and pre-hole diameters by tension testing. Figure 3 (left) displays the test arrangement with the test machine Zwick Z50. The specimen for the tension testing is shown on the right hand of Figure 3. To allocate the inclination to the load behaviour, the bolt angle was measured by videotaping with a circular disc and was then related to the machine load as well as the displacement.

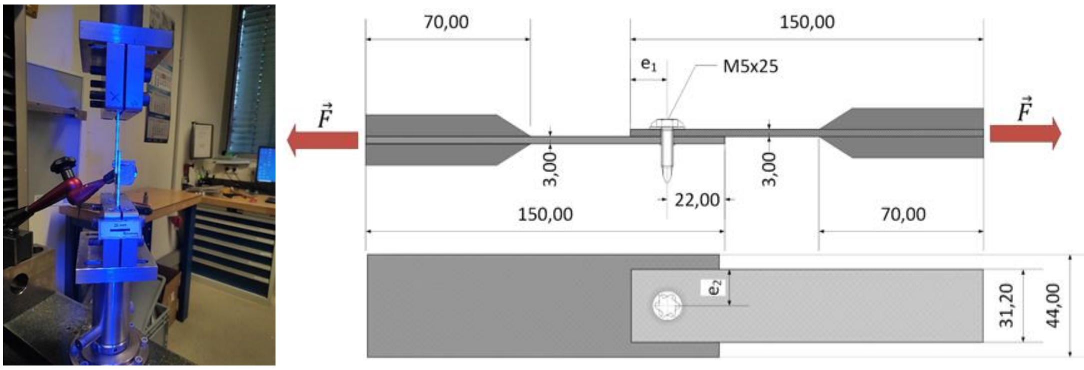

Figure 3: Test arrangement (left) and specimen (right) for tension testing

To determine the construction dimensions, the edge distance e_1 in load direction was varied in relation to the bolt diameter. As second construction parameter, the edge distance e_2 was modified transverse to the load direction. Both construction dimensions were investigated with the specimen illustrated in Figure 3 (right).

3 Results

The first challenge was to qualify the reproducible manufacturing of shear-/bearing loaded joints by FDS within the first complex of investigation. Therefore, every single sampled combination of pre-hole diameter and sheet thickness was investigated by a macro cross section, as shown in Figure 4. The pictures of the cross sections delivered characteristic values of the occurring gaps and allowed an evaluation of the filling levels by the displaced material.

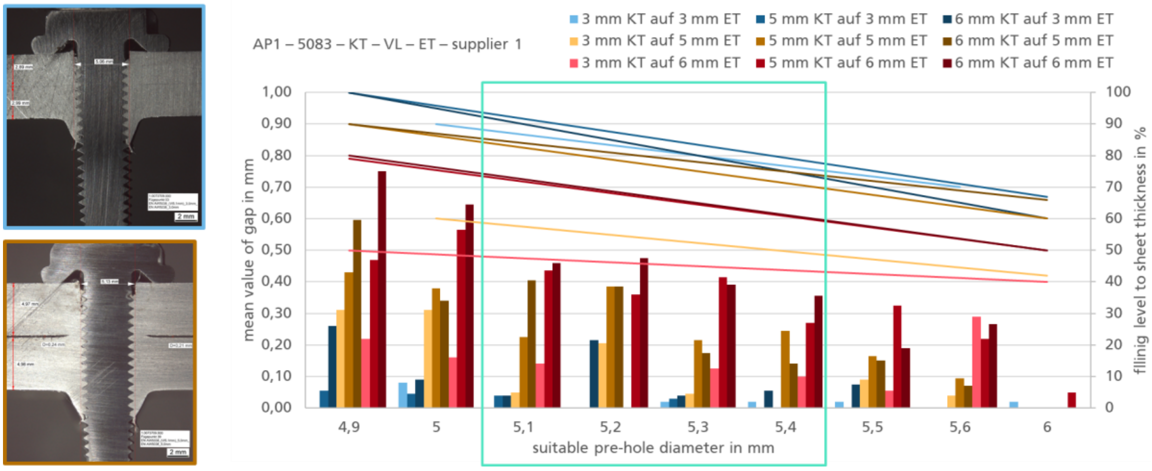

Figure 4: Evaluation of the samples by cross section and results regarding suitable pre-hole diameters

With these results and the assessment, the optimum pre-hole diameter could be determined for each tested thickness combination, which is the basis for the following load bearing behaviour tests. The machine load-displacement-relations, in form of graphs as shown in Figure 5, could be derived from the shear tension tests of the second investigation complex. Additionally, characteristic fracture modes were observed during tensile tests, according to Figure 5 (left).

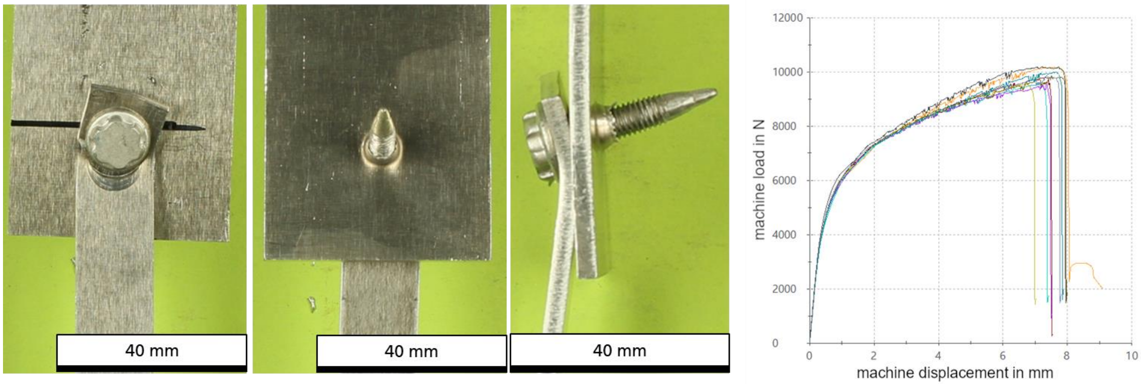

Figure 5: Fracture mode (left) and corresponding machine load-displacement-graph (right)

The determined shear resistances in tensile tests are, against the expectations, sufficiently high in relation to the strength of the aluminium. Over this, the load bearing resistances and the fracture modes depend on the edge distance e_1. Evaluating these results leads to a minimum edge distance for construction and to a maximum of bearing capacity.

4 Conclusions and Contributions

With the present studies the tightening procedure is investigated, which allows the utilization of the load-bearing behaviour for FDS bolted joints. In a second step experimental investigations were performed to determine characteristic loads of resistance and edge distances. The results of the study introduce the possibility to implement a shear-/bearing loaded joint for flow drill screwing the first time. Although many experimental and numerical studies [5…10] figured out, it has never been intended to further investigate the load bearing behaviour or to utilize FDS performing as shear-/bearing loaded joints. The obtained results with the macrographic cross sections display how flow drill screwing can be applicated sufficiently in aluminium wagon bodies. Bolting by flow drill screwing can be performed blindly into a profile without requiring pre-holes in the support structure.

With the additional tensile tests and the determined load displacement behaviours it is possible to derive characteristic values of the load bearing capacities. These characteristic capacities of the static load-displacement behaviour also offer the opportunity to apply FDS instead of preloaded slip resistant bolted joints. In combination with the observed fracture modes it is possible to carry out the required dimensioning and to set up static strength approvals for railway vehicles. Afterwards the oscillation tests will be performed to determine a detail category for fatigue strength verification.

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References

[1] J.-K. Sønstabø, D. Morin and M. Langseth: „Testing and modelling of flow-drill screw connections under quasi-static“ In: Journal of Materials Processing Tech. 225, pp. 724-738, 2018

[2] O. Hahn and C. Burs: Qualifizierung der Direktverschraubung in Fließlochdurchzüge für Aluminiumleichtbaustrukturen des Automobilbaus, Shaker Verlag, 2014

[3] Abschlussbericht Nr. P657: „Eignung von lochformenden und/oder gewindefurchenden Dünnblechschrauben zum Verbinden von hochfesten Stahlwerkstoffen,“ Forschungsvereinigung Stahlanwendung e. V., Düsseldorf, 2006

[4] Arbeitskreis "Fügen": „Entwicklung und Qualifizierung des Fließformschraubens zum Fügen höchstfester Stahlbleche und -profile, 2. Zwischenbericht,“ 2018

[5] S. Dehghan, M. I. S. Ismail, M. K. A. Ariffin, B. T. H. T. Baharudin und S. Sulaiman: „Numerical Simulation on friction drilling of aluminium alloy“ In: Materialwissenschaft und Werkstofftechnik, pp. 214-248, 2017

[6] M. Grujicic, J. Snipes und S. Ramaswami: „Process and product-performance modeling for mechanical fastening by flow drilling screws“ In: International Journal of Structural Integrity, pp. 370-396, 2016

[7] A. Neag, F. Aslan, P. Mangin, L. Langlois und T. Balan: „Modelling of Flow Drill Screw Process“ IRT M2P, Metz, Frankreich, 2018

[8] F. Aslan, T. Balan und P. Mangin: „Identification of Drilling Parameters during the Flow Drill Screw Driving Process“ Key Engineering Materials Vol. 767, 465-471, 2018

[9] J. K. Sønstabø, P. H. Holmstrøm, D. Marin und M. Langseth: „Macroscopic strength and Failure properties of Flow-Drill Screw Connections“.

[10] J. K. Sønstabø, D. Morin und M. Langseth: „Static and dynamic testing and modelling of aluminium joints with flow-drill screw connections“. International Journal of Impact Engineering 115, pp. 58-75, 2018