**Direct fastening into plastic for 3D printed components**
*Screw connections in highly resistant LUVOCOM® 3F materials with the EJOT EVO PT® screw.*

Alongside clip joints, welding and cementing, the incorporation of technical screw connections into the component assembly is one of the most important jointing methods for a wide range of industrial sectors. Whether the printed plastics parts are intended for small series production or for prototypes in assembly trials and validation, the aim is in any case to guarantee a reliable screw connection in 3D printed parts, comparable to those in injection-moulded goods.

The aim of the investigation presented here was to demonstrate the high quality standard of available printing materials, the reproducibility in the printing process and the basic attributes of screw connections in printed parts.

The compound producer Lehmann&Voss&Co. assumes that all jointing methods used with injection moulding materials can also be applied to its 3D printing materials for fused filament fabrication (FFF). These materials with the trade name LUVOCOM® 3F are especially optimized for FFF technology. They enable components to be produced via 3D printing that are certainly on a comparable level with the mechanical properties of components produced in classical techniques.

In order to test the suitability of these materials for screw connections, jointing trials were conducted in cooperation with EJOT GmbH & Co. KG of Bad Berleburg on 3D-printed screw bosses.

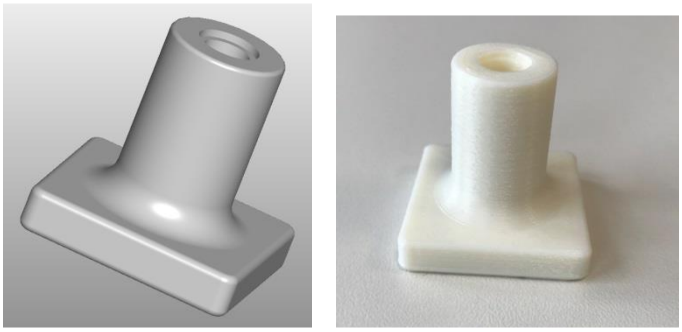


Fig. 1: Boss as print template: left: CAD 3D rendering, right: printed boss

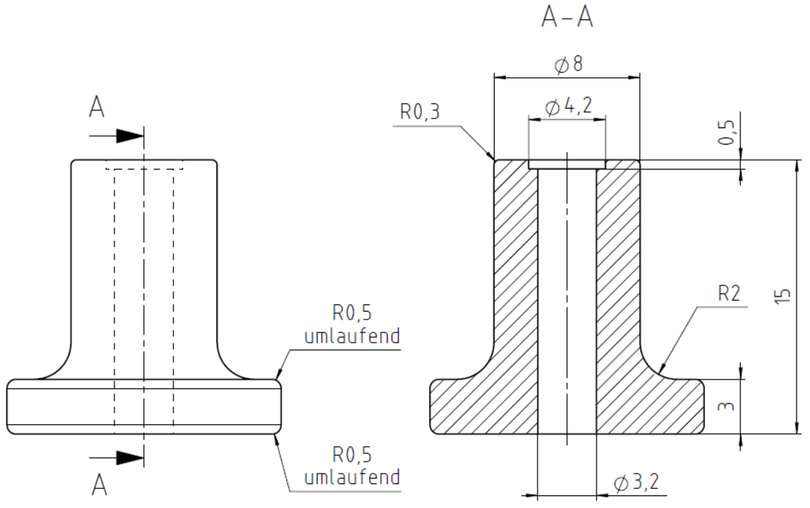



Fig. 2: Drawing of screw boss (umlaufend = around full perimeter)

The EJOT EVO PT® screw, which has recently launched onto the market, was used for the jointing experiments. Apart from the optimized positioning characteristics in this type of screw, the installation torque is almost independent of the insertion depth.

Fig. 3: EJOT EVO PT® screw

To enable a comparative investigation of screw fastening, standard bushes were injection moulded in the existing EJOT screw boss tool using the materials to be compared. Analogous LUVOCOM® 3F materials were printed in the 3D printing laboratory at Lehmann&Voss&Co.

Fig. 4: left: injection-moulded screw boss; right: printed screw boss


Fig. 5: Pilot plant for 3D printing (FFF division), Lehmann&Voss&Co.

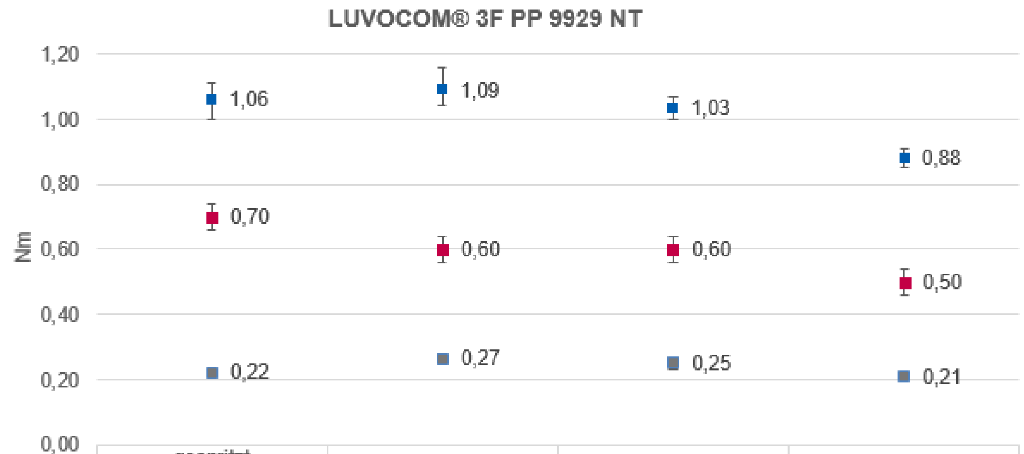
As a certain level of dimensional inaccuracy always occurs in the printing of drill holes due to the procedure used, the hole for the screw (guide hole) was recalibrated in each case in order to observe a reliable experimental standard. All the bosses for testing were produced using the FFF technique.

| Material | Lehmann&Voss&Co. Material designation | Description of material, possible processing method |
|---|---|---|
| PP | LUVOCOM® 3F PP 9929 NT | PP unreinforced<br>injection moulding, direct and filament printing |
| PP | LUVOCOM® 3F PP CF 9928 BK | PP-CF<br>direct and filament printing |
| PA66 | LUVOCOM® 1/CF/15/HS | PA66-CF15<br>injection moulding |
| PA-HT | LUVOCOM 3F PAHT® CF 9742 BK | Analogous to PA66-CF15<br>direct and filament printing |

Table 1: Materials used in the series of experiments

**Polypropylene (PP) unreinforced**

Unreinforced PP is not an easy material to print. In some cases, the material can also prove to be challenging in injection moulding, particularly for thick-walled screw bosses. Occasionally slow crystallization occurs with pronounced cavitation. This was not observed for LUVOCOM® 3F PP 9929 NT, which was also injection moulded in these trials. As a result, it was possible to create screw connections with very good, reproducible parameters for all injection moulded bosses. Calibration of the screw hole on the printed boss showed that if a technically practical geometry is selected for the guide hole, screw fastening values can be achieved that are almost at the same levels as those of the injection moulded boss. This affected all characteristic parameters, such as installation torque (Me), tightening torque (Ma) and stripping torque (Mü). The range of fluctuation for all three values was within the usual technical orders of magnitude.




| | gespritzt injection molded | FFF, DIA=3,2 mm | FFF, DIA=3,3 mm | FFF, DIA=3,4 mm |
|---|---|---|---|---|
| Mü (Nm) | 1,06 | 1,09 | 1,03 | 0,88 |
| Ma (Nm) | 0,70 | 0,60 | 0,60 | 0,50 |
| Me (Nm) | 0,22 | 0,27 | 0,25 | 0,21 |

Fig. 6: Screw parameters for PP

**Polypropylene with carbon fibre reinforcement (PP/CF)**

In these experiments, it was observed that screw-fastening values were achieved for a PP/CF (LUVOCOM® 3F PP CF 9928 BK) that were approximately 60% above those of an unreinforced PP. No significant differences can be detected in terms of the torque measurements if the pre-hole diameter is varied from 3.2 mm to 3.4 mm. On the contrary, the measured values remain at almost the same level. There is clearly delineated optimum for the stripping torque (low dispersion of measured values) at a pre-hole diameter of 3.3 mm. The comparably low elasticity of the material has a distinctly positive effect in this case.

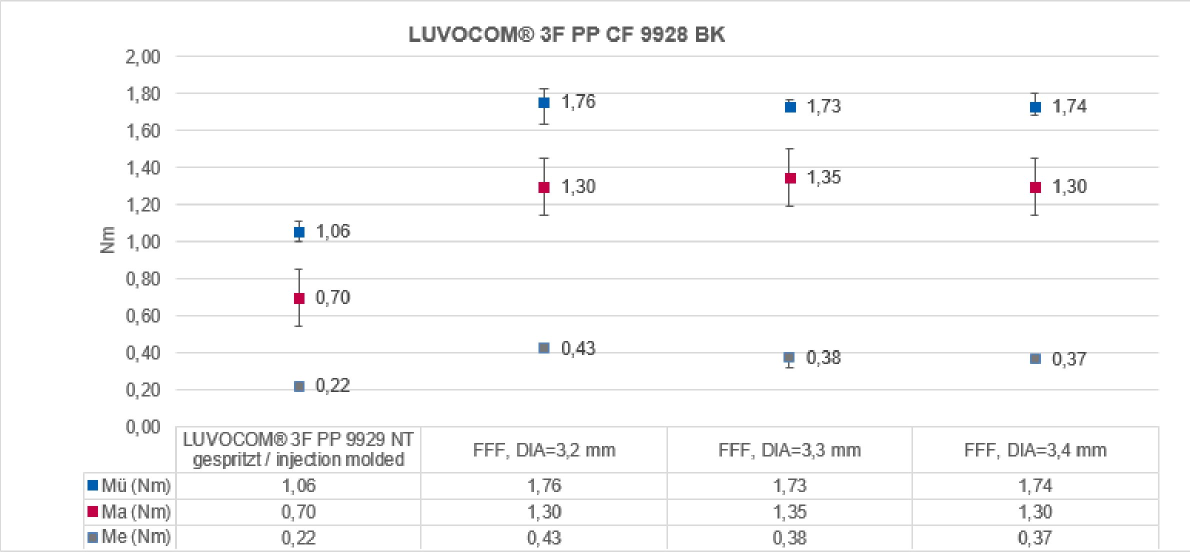


Fig. 7: Screw parameters for PP/CF

**Polyamide with carbon fibre reinforcement (PA/CF)**

LUVOCOM® 1/CF15/HS (PA66 CF/15) is a very high-performance product for injection moulding. High tightening torques are possible for the screw bosses produced from this material by injection moulding. Both the installation torque (0.6 Nm) and the stripping torque (3.8 Nm) are stable with a large safety margin to the tightening torque. Moreover, the installation torque and stripping torque are very clearly defined with a narrow range of values and a small standard deviation. The large gap between the stripping torque and the tightening torque, in particular, indicates that the fastening operation is governed by a reliable process that can be mastered in all situations.

LUVOCOM 3F PA$^{HT®}$ CF 9742 BK was processed for purposes of comparison. This is a highly developed material for FFF. The formulation differs from that of the injection-moulding material tested but does also contain 15% CF. The mechanical parameters, such as tensile strength at break and elongation at break, are at a higher level in the injection moulding material. In the printed boss, this can be seen in the somewhat lower screw fastening values. Nevertheless, reproducibly good torque values were achieved (Me=0.55 Nm; Ma=1.6 Nm; Mü=2.8 Nm). Here too, there is a sufficiently large safety margin between each of the torque values. The material LUVOCOM 3F PA$^{HT®}$ CF 9742 BK enables a direct connection to be achieved with the EJOT EVO PT® in a reliable process.

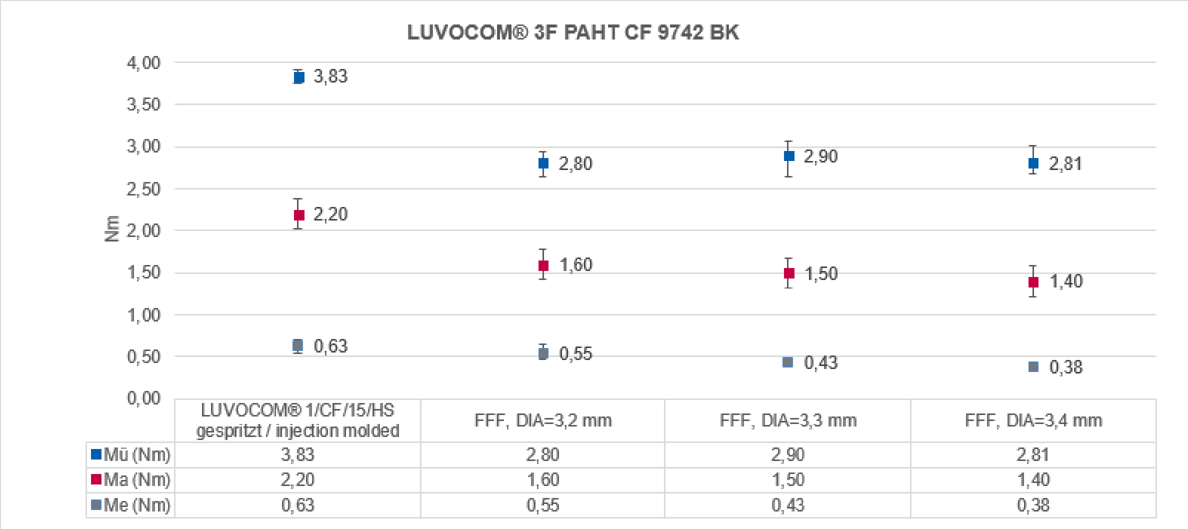



Fig. 8: Screw parameters for PA/CF

**Conclusion and outlook:**
The continuous series of experiments described here has been able to demonstrate that a reliable process can be achieved for the direct fastening in printed parts with the EJOT EVO PT® self-tapping screw. Components produced by 3D printing achieved strengths that are comparable with their injection-moulded counterparts. This makes applications possible in series production.

One positive observation in the trials was that no screw bosses suffered radial tension failures (splitting). Neither did any peeling of layers occur in the z plane. In 3D printing this is the build axis, which coincides with the screw connection axis. It is of particular importance because in 3D printing the z plane is comparable with the joint line in injection moulding. In printed parts, this is generally a zone of weakness. It demonstrates once again that LUVOCOM® 3F materials can be regarded as high-strength materials across all axes of strain. It is therefore also possible to achieve strength values in 3D printing that are directly comparable with those of injection-moulded parts. The measured values determined for printed parts in this preliminary investigation were without reservation in the same orders of magnitude as are customary for injection-moulded parts. In each case, they are accompanied by low standard deviations for the measured fastening parameters. Further trials are planned for LUVOCOM® 3F materials based on PA$^{HT}$ CF, PPS, PEEK and PEI.

**Overall it may be stated that reproducible and validatable screw connections can be reliably implemented with the EJOT EVO PT® in 3D printed parts.**

As is the case with all direct screw connections into plastic, optimum dimensioning of the screw boss and particularly the diameter of the pre-hole are critical. Additional parameters such as the screw surface or the speed of the screwdriver have an effect on the overall result, but were not varied in this case in order to keep the scope of testing within reasonable limits. In any case, close cooperation between the plastics producer and screw manufacturer is recommended if optimum results are to be achieved.

An approach in which the forecasting program EJOT EVO CALC® is to be used to allow the dimensioning of screw connections in printed parts to be calculated in advance is under discussion and being planned for the future.

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Following many years in component and assembly development, applications development in the plastics industry and setting up a new product line for a plastic raw materials producer with global operations, he is now in the Business Development Division as a Market Development Manager at Lehman&Voss&Co. in Hamburg, Germany, where he is responsible for the development of new markets and applications.

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Initially in the applications technology laboratory of the company EJOT Verbindungstechnik, he was responsible for the development of test facilities and trials with customer components and basic investigations for various raw materials producers. The development of screws for thermoplastics and thermosets became his area of activity, which then led to his assuming global responsibility for product management of direct screw fastening into plastic.

*Company profiles:*

*The LEHVOSS Group under the management of Lehmann&Voss&Co. is a group of companies in the chemicals sector that develops, produces and markets chemical and mineral specialities for various industrial clients. Lehmann&Voss&Co., Hamburg, was founded in 1894 as a trading company. In its success story dating back some 125 years, the owner-run company has developed into a powerful global organization – with long-standing connections to prominent suppliers and with its own production sites in Europe, the USA and Asia. For more information, please visit [www.lehvoss.de [lehvoss.de]](www.lehvoss.de)*

*With its product lines LUVOSINT® and LUVOCOM® 3F, the LEHVOSS Group is offering innovative and tailor-made plastics for 3D printing. These products have been adapted to the most common production processes, such as powder bed fusion, fused filament fabrication (FFF) and fused granulate fabrication (FGF) processes. The materials are distinguished by their good processing characteristics and excellent material properties. [https://www.luvocom.de/de/produkte/3d-druck-materialien/ [luvocom.de]](https://www.luvocom.de/de/produkte/3d-druck-materialien/)*

*EJOT is a medium-sized group of companies specializing in fastening and forming technology. The customers come primarily from the automotive and supplier industries as well as telecommunications, consumer electronics and the construction sector.*

*In its Industrial Division, EJOT offers a broad range of innovative fastening elements, in particular self-tapping screws for metals and plastics, multifunctional cold-form parts, individual metal-plastic assemblies, technical plastic parts and complete fastening solutions. In close cooperation with its customers, EJOT develops individual solutions to solve their technical joining challenges. The aim here is to secure an outstanding joint quality through the use of "intelligent" products.*

*EJOT has a company history dating back more than 90 years and employs a workforce of more than 3,500 people in 31 subsidiaries to ensure rapid availability of its products and personal contact to the customers.*

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