
CASE STUDY

# Additive manufacturing of complicated sand cores for hydraulic rotary transmissions

The ExOne S-Max® 3D-printer enables GF Casting Solutions Leipzig GmbH to consolidate 12 shot cores into one printed core. In addition to improving the core quality, time-intensive and laborious core assembling and fettling steps are eliminated

ExOne™

Founded in 1887 as a Meier & Weichelt company, Georg Fischer in Leipzig, Germany, has been running a foundry that is home to **Europe's largest molding box for machine-molded iron castings** since 1995. With around 280 employees, **the iron foundry produces large and heavy casting components weighing up to 1.2 tons for commercial vehicles and the off-highway segment** including construction equipment, agricultural and forestry machinery, regenerative energy, engine technology and general engineering. Up to 60.000 tons of iron castings are produced annually and the demand is continuing to grow.

**CUSTOMER**
GF Casting Solutions Leipzig GmbH

**LOCATION**
Leipzig

**INDUSTRY**
Iron-Foundry

**APPLICATIONS**
Agricultural and forestry machinery, construction equipment, commercial vehicles

**3D PRINTER**
S-Max®, S-Max® Pro

**MATERIALS PRINTED**
Sand: Silica sand & thermally-stable special sand
Binder: CHP

**WEBSITE**
www.gfcs.com/en/about/locations/leipzig.html

## Challenge

In the production process, the foundry creates green sand molds fully automatically with the aid of pattern plates, which serve as negatives for the subsequent casting contour. Cores, shot in the cold box process, form the inner cavities of castings. Due to the high initial expenditures such as models and core boxes as well as reactions to design uncertainties for the production of prototypes, the production process involved a lot of costs and time.

Usually, it can take months for foundries to produce a single prototype for presentation to the customer. It often causes significant delays until the final market launch. As times changed, the requirements for early delivery and complexity of such prototypes became more and more demanding, which could hardly be realized by conventional means. Therefore, GF Casting Solutions Leipzig GmbH decided in 2017 to invest in a 3D sand printer from ExOne, the S-Max® to produce **rapid prototypes as well as complicated cores for series production**. With the help of the 3D printer, the foundry could fabricate complicated component geometries within a very short time without having to produce models and to avoid time-consuming assembly steps of complicated core structures.

The company chose ExOne's 3D printing technology because it offered the best concept of mechanical engineering, binder and technology.


**Figure 1**
GF Casting Solutions Leipzig GmbH's employees operating ExOne S-Max®

*"At GF Casting Solutions in Leipzig,* ***we are constantly on the lookout for new applications for 3D sand printing in series production*** *in order to optimize it and achieve the best possible casting results."*

Eric Nierenberg, Technologist of GF Casting Solutions Leipzig GmbH

## From Rapid Prototyping to Series Production

Realizing further benefits of 3D sand printing with the S-Max, the foundry decided to explore new applications with 3D printing beyond rapid prototyping.

In this context, the foundry's additive manufacturing process has to compete with the cold box process established in the company, which in very many cases is the cheaper option. However, the foundry faced major challenges with the cold box process particularly when it produced complicated core structures due to undercuts, thin channels, and laborious core assembly. This has brought its 3D printing solution to the forefront.

Moreover, the foundry shared that regulatory requirements in Germany are increasingly restricting the use of older technologies or processes, such as the Hot-box process, which the company had used for many years to produce its thermally highly stressed cores. Due to this requirement, the company was in need to find an alternative technological solution for the production of thermally highly stressed cores. The CHP process by ExOne brought the solution for the challenge.

**Figure 2 (left)**
Machine cleaning

**Figure 3 (middle)**
Core finishing

**Figure 4 (right)**
Process observation

## Complicated Core Consolidation due to 3D Printing

Before the introduction of 3D printing technology, the foundry had to produce 12 sub-cores in the conventional core shooting process and later assemble and glue them together. For such complicated cores, the traditional production process requires a lot of time, skilled labor, and effort.

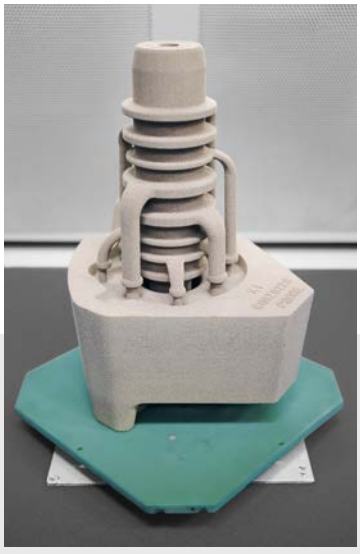
With the aid of a S-Max® 3D printer, the foundry prints, among other things, described cores with dimensions of 350 × 400 × 550 mm (L × W × H) in one piece. After the printing process, the cores only require a thermal post-treatment to achieve the required final strength.

*"The core for the rotary transmission is an example of a very complicated core in our foundry.* ***Conventionally produced, twelve partial cores were needed*** *to form the undercuts and thin channels. The assembly is time-consuming and error-prone.* ***The 3D printer enables us to produce the cores in one piece only.****"*

Eric Nierenberg, Technologist of GF Casting Solutions Leipzig GmbH

## Improved Core Quality

GF Casting Solutions Leipzig GmbH prints the cores for the hydraulic rotary transmission with a ceramic sand and a cold-hardening phenol (CHP) binder. The foundry exploits the good properties of the 3D printer's single-component binder system, such as high temperature resistance, good disintegration properties and low core cleaning effort. Due to the long resistance at high temperatures compared to conventional cold box binders, high dimensional accuracy and clean interiors can be ensured for very thin channels. Although this results in higher costs and production times per core (compared to the conventional processes), **the quality of the cores for the hydraulic transmission has improved significantly and the laborious manual assembly and subsequent fettling work is reduced.**



## 3D Printing Process

The ExOne printer type S-Max® consists of a job box, an open-top rectangular container with a height-adjustable base plate, the so-called build platform. Form printing takes place in the job box: At the beginning of the printing process, it automatically moves into the printer. The printer's recoater initially applies several layers of sand evenly onto the build platform, which at this point is adjacent to the upper edge of the job box.

The print head now distributes the liquid CHP binder on the sand layer, but only on the areas that are to bond to the rotor core. In the process, the binder precisely encloses each individual grain of sand. The build platform then lowers minimally so that the recoater can apply a new layer of sand. On top of each new layer of sand, the print head again applies the binder to the appropriate areas before the base plate lowers again. This process, applying sand, applying binder, lowering the building platform, is repeated until sufficient layers of sand have been bonded. In this way, the desired part – the rotary core – is created layer by layer.

**Figure 5 (above)**
Assembled core

**Figure 6 (below)**
3D printed core in one piece

The 3D printer requires 30 seconds per sand layer. If the job box is optimally filled, it has a maximum build volume of 1,260 liters and up to 15 such cores can be printed at the same time within 23 hours. However, the foundry decides not to use the entire build height. In this case, the entire printing process takes **18 hours**.

After printing, the job box automatically moves out of the printer. The excess, non-bonded sand is removed with the aid of a vacuum suction cup. Following the cores are removed from the job box, cured in a thermal oven at around 160 degrees and then cleaned from adhering sand residues. The cores are now ready for casting. A coating is not necessary.

**Figure 7 (above)**
Infrared heating

**Figure 8 (below)**
Layer on building platform

**Figure 9**
Post-printing: Vacuuming non-bonded sand

## Expansion of the manufacturing capabilities

The 3D sand printing technology has developed and spread significantly in recent years, leading to wider acceptance and thereby increased demands by foundries. GF Casting Solutions Leipzig GmbH has been following this development closely, especially in the field of 3D printing with CHP binder. The company has also driven a cooperation with ExOne in order to be fit for the future. For this reason, the company has taken the step of adding a second ExOne printer to its production in June 2023.

**"With a 3D printer, we can merge 12 cores into one printed rotary core only. Assembling and gluing of cores is no longer needed.** *After the printing process is done, the core can be taken out easily from the job box and only requires a thermal post-treatment to achieve the required strength."*

Eric Nierenberg, Technologist of GF Casting Solutions Leipzig GmbH

*"Customers understand that **it is possible now to produce highly complicated parts with a 3D printing technology.** The demands from our customers to produce complicated parts are increasing too. **We could hardly realize it by conventional means.**"*

Eric Nierenberg, Technologist of GF Casting Solutions Leipzig GmbH

When the first printer was installed in 2017, a new hall was also built off-site the foundry, with space for a second printer as well as a showroom for its additive manufacturing technology. This means that customers, guests and clients can view this technology on site and understand the company's additive manufacturing process.

With the widespread use of the 3D printing technology, GF Casting Solutions Leipzig GmbH can now produce parts from 5 kg to 1,100 kg starting at one piece. With the CHP sand printing process suitable for steel and aluminum castings as well, partnerships were established to offer those materials to their customers, too.

The commissioning of the internal mechanical processing at the end of 2022 completed the expansion of the manufacturing capabilities. This means that GF Casting Solutions Leipzig GmbH is now able to produce a machined prototype based on a data set in a very short time, make it available to the customers, implement adjustments, and finally switch to series production. On this path, the foundry is getting better every day.

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