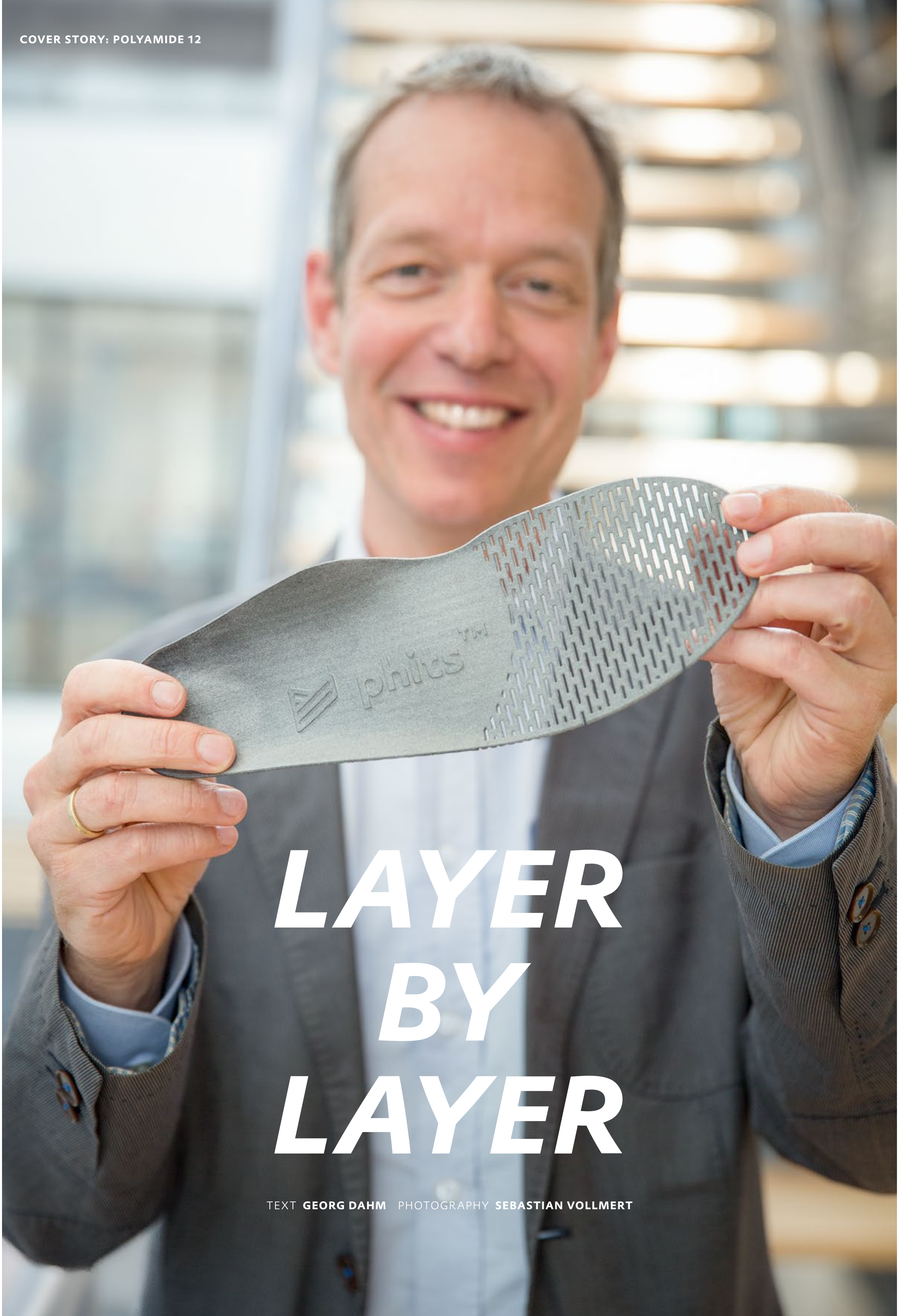


LAYER BY LAYER

TEXT **GEORG DAHM** PHOTOGRAPHY **SEBASTIAN VOLLMERT**

The Belgian company Materialise has more experience with 3D printing than almost any other European company. It produces innovative products made of polyamide 12. A visit to the pioneers in the university city of Leuven in Belgium

If you were to put a blindfold on Bart Van der Schueren and lead him through his company's widely branching halls full of 3D printers, he would know which area he was in by the smell alone. That way he'd know which of the many printing techniques was being used there to create airplane parts, medical implants, shoe insoles, eyeglasses, lamps or prototypes—layer by layer, out of nothing.

For example, there's the slightly pungent smell of the big stereolithography printers, which look like gigantic terrariums with flickering blue lights. And there are the warm plastic fumes of the fused deposition modeling printers and the selective laser sintering printers, which are lined up in rows like incubators. Further along are the hospital-disinfectant vapors of the Multi Jet Fusion devices, which look like oversized laser printers. Every morning the technicians take the rollboxes, inside which objects have grown overnight in successive layers of powder, out of the printers.

We were unable to find out what a metal printer smells like, because in Leuven metal 3D printing is used only for the medical sector, and that area is closed to visitors. But Van der Schueren mainly wants to direct our attention to the plastics. And we do see plastic everywhere, from the exhibits in the lobby to the building's many delicate ceiling lamps, whose seemingly organic structures are based on mathematical formulas. "Many of our visitors are fascinated by the fact that we can print metals such as aluminum, titanium, and steel," says Bart Van der Schueren, the Chief Technology Officer (CTO) of the Materialise company. "But our workhorse is plastic. We produce about one million items annually, and 800,000 of them are made of PA 12."

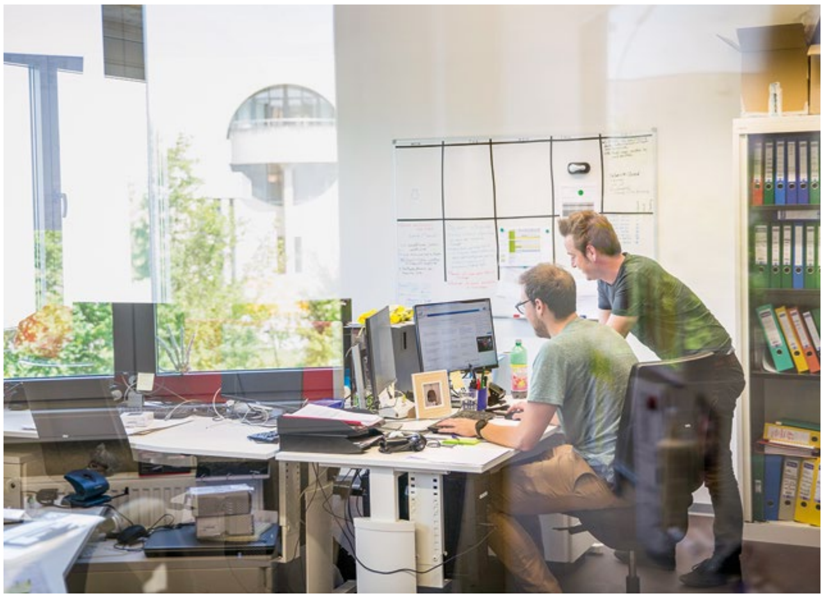
3D printing has to create added value, says Bart Van der Schueren (left photo). The selective laser sintering printers stand in long rows (bottom)

A NEW APPROACH FOR INDUSTRY

The CTO is still bemused by the fact that the company produces so many different things from polyamide 12—prototypes as well as finished products for end consumers, medicine, and automobile and airplane construction. "Actually, this material is overqualified for many applications," he says. "It's a bit too robust, too stiff, too temperature-resistant. For many applications you'd be better off using polypropylene, which is cheaper. But we've discovered time and again that PA 12 is more practical to use for additive manufacturing because it can do so many things."

Many aspects of additive manufacturing—the term this expert uses instead of "3D printing"—contradict conventional experience and expectations. "Normally, a company would keep pestering its materials suppliers with all kinds of wishes for better material properties," he says. But at Materialise, almost every time the technicians calculate how much it would cost to manufacture a certain design, they find out that PA 12 will produce exactly what they need—everything from lacy lampshades to metallic-looking precision parts for automobile construction, for which the PA 12 powder is mixed with aluminum particles.

"In additive manufacturing, we don't alter the properties of the material," says Van der Schueren. "We give items the desired properties by creating the structure we've developed for them at the computer. For industry, this is a whole new approach." →



Many customers (of Materialise) are looking for detailed advice about 3D printing

APPLICATION: MEDICAL TECHNOLOGY

This new approach has caused a minor revolution in the field of orthopedics, for example. People who wear orthopedic insoles in their shoes know that these are expensive customized items consisting of a combination of cork and leather or various plastics, depending on the stresses they will bear. Alternatively, they are inexpensive models made from a single piece of plastic on the basis of the user's footprint.

Materialise prints orthopedic insoles made of PA 12 that are based on 3D impressions of the user's gait. "We analyze the user's movements and calculate how much support he or she needs at which part of the foot," says Van der Schueren. "Our software then designs a structure that has the right properties at every point—firmer in some places, more elastic in others. Then we print it in one piece, using one single material." Does such an insole wear well? "Let me put it this way: We made a fairly big mistake with our business model. Our customers need to reorder their insoles much less often than we expected."

He says that many companies still need to have someone explain to them how 3D printing can contribute to value creation. "Many companies come to us saying they want to do 'something with 3D printing', but they don't know exactly what. They often have completely unrealistic expectations." The most frequent misconception is that 3D printing can replace the traditional injection molding process in mass production. The technology will someday be advanced enough to do that, but today the additive manufacturing of many series-produced items is still more expensive than many people realize.

NEW BUSINESS MODELS

Value creation by means of 3D printing is different, and that's why Materialise cooperates with each one of its customers to look for its practical applications. For instance, additive manufacturing is ideal for batch sizes that are so small that it's not worthwhile to make injection molds and other processes such as milling would not provide the desired properties.

One example of that is flying drones, in which a fiberglass support frame provides stability. Materialise prints plastic guides in which tiny channels precisely align each of the razor-thin fibers in the right order, so that they can be glued. "Considering the batch sizes in which these drones are sold, no other process would be economically feasible," says Van der Schueren.

3D printing also creates added value in segments where it enables the mass production of unique items. Examples of that include orthopedic insoles and eyeglass frames: "Here you can see the added value more clearly than in series-produced eyeglasses. We can calculate exactly where the lenses should be in front of your eyes and where the frame should sit on your nose so that the glasses will precisely match your skull. And we can produce the glasses in any design and color you want."

LIGHTWEIGHT CAR SEATS

Another example of potential value creation can be seen in the lobby: an experimental car seat for Toyota that weighs only seven kilograms—a normal seat weighs 30 kilograms—and is made entirely of PA 12. Only when you look at it up close can you see that it's made in one piece but combines a variety of structures. A weblike body gives the seat rigidity, and small feathery structures on the surface provide flexibility.

The seat is only a prototype that shows how much weight could already be saved today in automobile construction. But before it can be series-produced a great deal of technology will have to be developed. At the moment, the technology for large components is still too expensive—and here the manufacturers and engineers have to do some rethinking.

"With injection molding, you simply multiply the cost of the material by the density by the quantity and you've got your costs," says Van der Schueren. In additive manufacturing, the structures are produced in a powder bath, and there are no fixed formulas for calculating how much raw material is ultimately discarded as scrap. In addition, the energy costs increase exponentially. "Normally, if you double the size you also double the costs, but in 3D printing, doubling the size means multiplying the costs by eight," he explains.

CUSTOMIZED SKI BOOTS

In additive manufacturing, products are created grid point by grid point. The raw material is heated, melted, and cooled, and then it takes shape. In processes such as selective laser sintering and Multi Jet printing, the →

COMPLEX STRUCTURES THAT WOULD OTHER-WISE REQUIRE EXPENSIVE HANDCRAFTING

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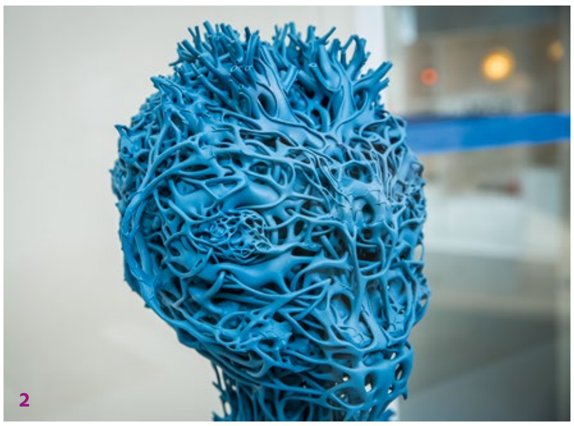
1 Materialise printed this replica of a robot for a trade fair **2** 3D printing also inspires artists: Nick Ervinck's sculpture AGRIEBORZ is based on tomographic images of blood vessels **3** Customized orthopedic insoles **4** The 3D-printed lining of ski boots precisely fits the wearer's legs **5** For the medical sector, Materialise produces implants, surgical tools, and replicas of organs that surgeons use to plan and practice operations **6** A non-proprietary prototype with a delicate structure **7** Eyeglass frames are produced to match the wearer's head measurements **8** Workpieces are made light, yet stable, through their interior structures—like those of human bones



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A PRINTED CAR SEAT IS ONE FOURTH AS HEAVY AS A CONVENTIONAL ONE. AN ADVANTAGE FOR RECYCLING: NO COMPOSITE MATERIALS

raw material is a powder that is laid on layer by layer and heated at the specific points that are to remain.
By contrast, the 3D printers you can buy in an electrical supplies store work with a strand of plastic that is unrolled from a spool, heated, and laid on through a nozzle that resembles a hot glue gun. This process, which is called fused deposition modeling (FDM), is used by professionals, even though it is slower and less efficient. However, it can be used to make closed structures that are hollow inside. For example, Materialise uses FDM machines to produce the lining of ski boots on the basis of 3D scans of the wearer's feet.

Besides, more different kinds of plastic can be processed by FDM printers. That's a crucial advantage in industries where every raw material, or every production process, must be individually approved. For example, in a closed-off area FDM machines are printing components for the Airbus A350, because this process has been certified for the manufacture of airplane parts. "A couple of hundred components from Materialise are installed in every airplane," says Van der Schueren. "The batch sizes per component are so small that injection molding isn't worthwhile here, and other production processes would be too expensive."

This car seat, which is on show at Materialise headquarters, was printed in one piece from PA 12 and weighs only seven kilograms

A REPLICA OF THE ÖTZI MUMMY

Most of the 3D printers that Materialise works with at its production facilities all over the world come from manufacturers such as HP. If no printers for specific applications are currently available on the market, the company develops such devices on its own. One example of that is printers for very large components. In this area, Materialise has built printers that created a replica of the "glacier mummy" Ötzi, copies of Greek statues, and more mundane items such as complete instrument panels. "In the course of developing these printers we learned a lot about what works and what doesn't," Van der Schueren says.

Plastics such as PA 12 sometimes reach their limits in the area of medicine. For example, permanent implants are still made of titanium. "PA 12 is biocompatible," says Van der Schueren, "but there are still no long-term studies that prove this material can safely remain in the human body permanently." In the area of metal printing there are other disadvantages, such as the good thermal conductivity, which the engineers have to compensate for. According to Van der Schueren, "If you close up a hole in a patient's skull with a titanium plate, the patient can no longer hold his head in the sun, because the plate will get too hot. And he can't go swimming, because that would cool off his brain too much." Materialise therefore prints metal implants that have a fine mesh structure, which acts as a temperature buffer.

DRILLING AND SAWING TEMPLATES

Compared with these delicate workpieces, some of the most important medical applications of PA 12 look completely unremarkable: individually produced drilling and sawing templates that are used by surgeons doing complicated bone operations. The templates help them to place their cuts and screws in such a way that the newly aligned bones grow together in exactly the way the surgeons have previously calculated at the computer. This process enables several thousand patients per month to avoid a trial and error process on the operating table.

Medical technology is one of the three specialist areas of Materialise. The two other areas are the industrial contract manufacture of prototypes and end products and the development of software for 3D printing. The latter area represents the roots of this company, which was founded in the 1990s in the university city of Leuven.

"Back then we quickly realized that 3D printing is actually quite easy in itself," says Van der Schueren. "The only problem was that we had to figure out how to prepare a design we could print in 3D." In view of today's boom

One of the company's specialist areas is the development of software for 3D printing

in virtual reality applications, it's strange to remember that back in the 1990s industry was a two-dimensional world. "There wasn't a single company in Belgium that could create a design in 3D," Van der Schueren recalls.

Materialise decided early on that it would not keep its inventions to itself. Thanks to this policy of openness, the company is now one of the market leaders. "Our software is the backbone of a large segment of industry," he adds.

Glossary

Additive manufacturing
This technical term expresses how this production process differs from processes such as injection molding: It does not involve material being poured into a mold or a workpiece being carved out of a block of material. Instead, the component is calculated on a computer and the 3D model is built up layer by layer—in a process of addition, so to speak.

Selective laser sintering
In this 3D printing process, the product is created when a plastic or metal powder is laid on in layers and melted at the key spots with a laser. The finished product finally lies in a bath of powder that has not yet been melted and is then separated from it.

Stereolithography printer
Here too, a laser creates the component. However, instead of a powder, a plastic solution is laid down and then hardened by means of UV light.

Multi Jet Fusion This is a further development of the selective laser sintering process. The difference is that the shape that is to be printed is sketched out in black paint, and then the entire powder layer is exposed to a heat source. The dark areas heat up quickly and melt.

Fused deposition modeling (FDM) This printer works in the same way a baker uses an icing bag: A strand of plastic is rolled off the spool, heated, and applied with a nozzle, layer by layer.

A GIANT PLASTIC JELLYFISH

One of the big development-related themes in the field of 3D printing is the recycling rate. 3D printing has a huge advantage when it comes to recycling finished products after they can no longer be used. PA 12 is so versatile that it can be used on its own for manufacturing even complex products. As a result, no composite materials have to be separated during recycling.

What the field of 3D printing needs today is technical innovation and, even more importantly, innovative designs. "Most designers in product development still think in terms of blocks from which they can carve out individual components and then assemble them. We are teaching them a new approach," Van der Schueren tells us. It's also possible to design components that have many more functions than conventionally produced parts. He illustrates this by picking up an object that looks like a plastic replica of a giant jellyfish. In fact, it's a folding stool consisting of many hinged components that a flick of the wrist can transform into an elegant chair. "It slides right out of the powder bath this way. All you have to do is to brush it off and fold it out."

Through its search for new employees, Materialise has also become aware of the appeal of tangible products and the fascination of 3D printing. "At our location in Bremen we initially did only software development, and it was very hard to attract new employees, even though we were located directly next to the campus. That's the kind of positioning we like to have at all of our locations." Today, Bremen is also a production location—and suddenly it has become much easier to find new programmers. "That's because now they can not only tell people that they've programmed something, but also pick something up and say, 'I've programmed something, and that's why this cool thing exists today.'"