Claus Langer

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Form follows function: 3D printing starts in your head

Designers need to rethink their approach to unlock the huge opportunities offered by this relatively new manufacturing technology. The experts in coolant systems at Grindaix and Bionic Production did exactly that.

The biggest challenge of internal diameter (ID) cylindrical grinding is the limited space between the part and the tool. It's not easy to accommodate a conventionally produced coolant nozzle that meets all the requirements — and in the case of very small holes it's often impossible. That's why, in practice, manufacturers tend to carefully inject the lubricoolant required for grinding from the outside. That makes the ID cylindrical grinding process very slow, and it poses a risk that not enough lubricoolant will reach the machining site. This results in higher cycle times and correspondingly reduced productivity as well as high scrap rates due to parts suffering thermal damage. Dirk Friedrich, owner and CEO of the company Grindaix, was far from satisfied with this solution.

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Dirk Friedrich, Owner and CEO, Grindaix

Headquartered in Kerpen, Germany, Grindaix GmbH specializes in optimizing and remodeling coolant supply systems for machine tools and develops optimum solutions for minimizing grinding burn and coolant wastage. The experts at Grindaix are always open to new manufacturing technologies that might help them achieve these goals. "We've been focusing on 3D printing for a long time. When we took a look at the market, we saw very few tailor-made, highly efficient, customized nozzles for specific applications in ID cylindrical grinding. So we reckoned that this new manufacturing technology would be a good choice for making those kinds of nozzles," says Friedrich.

Impossible is nothing

Anything is possible in the world of 3D printing. In theory that's true - but before a part can be made, extensive engineering expertise is required to ensure that what the 3D printer builds up layer by layer will actually fulfill its purpose. Injecting this kind of specialist knowledge to create a 3D printing-compatible design is far from easy, as the Grindaix engineers discovered. "We're used to designing things in the traditional way, in other words with a constant focus on the manufacturing process. I'm not saying 3D design is alchemy, but it does require a shift in thinking," Friedrich emphasizes.

So Grindaix decided to enlist the help of the Hamburg-based company Bionic Production GmbH. Founded by former employees of the Laser Zentrum Nord, Bionic Production aims to ramp up 3D printing processes to an industrial scale. As well as manufacturing parts, Bionic Production also offers services including consulting, training, component optimization, and process and material development.

"The team of experts at Bionic Production revised and optimized our initial design to make it suitable for 3D printing. They showed us what we needed to focus on. We learned so much from them that we're now able to design 3D parts on our own," Friedrich explains. Matthias Schmidt-Lehr, head of sales at Bionic Production, knows all the ins and outs of 3D printing. "Designers need to start by forgetting everything they've learned before and opening their minds to this new technology. Only in exceptional cases do you need straight lines and rectangular structures. 3D printing gives you the opportunity to create free-form surfaces, many of which would be difficult or impossible to produce using conventional CAD tools."

Matthias Schmidt-Lehr, head of sales at Bionic Production, (right) and his colleague Eric Wycisk know all the ins and outs of 3D printing: designers need to start by forgetting everything they've learned before and opening their minds to the new technology. Picture: Erik Krüger

Equally important is the ability to recognize the limitations of the 3D printing process and sidestep them where possible. "In 3D printing we hold the part in position on the 3D printer platform using supports, which have to be removed once the process is finished. But in many cases you can avoid using supports completely by designing the part in a certain way," says Schmidt-Lehr.

To design a part for 3D printing, the first step is to model all the essential aspects, in this case the defined lubricoolant entry and exit points and the space required to avoid collisions with moving machine parts. The designer then adds only as much material as is absolutely necessary for the part to fulfill its purpose. "Machine cost per hour is still a key cost driver in 3D printing. The smaller a part's volume, the shorter the process time required to construct it. By leaving out any material that is unnecessary we make the part lighter, and that's often a major advantage in its own right. But even if it doesn't matter how heavy the part is, reducing the volume still makes it cheaper to produce," says Schmidt-Lehr.

Unlike conventional methods, the designer can focus purely on optimizing how the part works. In the case of Grindaix coolant nozzles, curved channels lead to a lower drop in pressure thanks to reduced flow losses. That reduces the amount of pumping power required, so the end customer benefits either from the ability to use a smaller pump or from a higher coolant exit velocity.

Thinking is a key

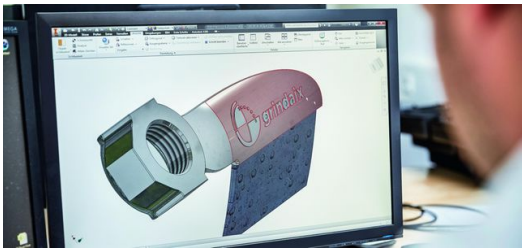
Using the specifications provided by Grindaix and a TRUMPF TruPrint 1000, Bionic Production created the perfect model of the new nozzle in a step-by-step process. "Software allows you to perfectly simulate many aspects of the design, such as the direction of the coolant jet. But the benefit of 3D printing is that it makes it so much easier to create prototypes, try them out, and then modify them as necessary," says Schmidt-Lehr. That enabled the team to implement every possible

optimization within a reasonable timeframe and budget. The improvements are clear: as well as fitting in the smallest of spaces, the new nozzle can also be individually tailored to each customer application. Dirk Friedrich is delighted: "We make a huge number of different product variants. The 3D manufacturing technique enables us to supply the perfect nozzle to virtually every single one of our customers."

The new nozzle is efficient in many different respects. The flow of coolant has been optimized, reducing pressure losses by up to 20 percent. That means you need a lower pressure - and less energy - to achieve the specified coolant exit velocity. The curved channels and optimized jet trajectory take the lubricoolant to the precise place it is needed, delivering no more and no less than is required to carry out the process in an optimum manner without causing thermal damage to the part. This reliable and automated solution for delivering lubricoolant eliminates factors that may have previously caused hold-ups in the manufacturing process.

All one piece: Redesigned by Bionic Production, this nozzle offers gentle curves straight from the 3D printer. Picture: Claus Langer

Dirk Friedrich: "The new nozzle features an optimized coolant flow that reduces pressure losses by up to 20 percent. The curved channels and optimized jet trajectory take the lubricoolant to the precise place it is needed." Picture: Claus Langer



3D printing gives you the opportunity to create free-form surfaces, many of which would be difficult or impossible to produce using conventional CAD tools. Only in exceptional cases do you need straight lines and rectangular structures. Picture: Erik Krüger

Benefits outweight downsides

Despite his enthusiasm for 3D printing, Friedrich essentially sees this particular manufacturing method as just the icing on the cake. What really gives the nozzle its unique selling point is the clean engineering process that guarantees an accurate geometric design.

"There's a correlation between the pressure of the lubricoolant in the coolant line upstream from the Grindaix nozzle and the velocity with which it exits the nozzle. We calculate the exact figures for each custom-made nozzle shape. And there's also a correlation between the velocity at which the water or oil exits the nozzle and the grinding speed," says Friedrich. "If you know the grinding speed, then you can achieve adaptive control of the pressure with the aid of the Grindaix nozzle flow rate diagram. That means we can tell our customers exactly what pressure they should use upstream from the nozzle to achieve a specific coolant exit velocity in the grinding process. We never used to be able to achieve such tremendous precision in nozzle applications for ID cylindrical grinding."

But no matter how pleased Friedrich is with the new nozzle, he never tries to conceal the process drawbacks from his customers. "Sintered parts have a rougher surface than those made from conventional metals. On the outside, at least in our case, this is an issue in how the part looks, and we can correct it through polishing. And to eliminate the roughness on the inside surfaces, which would once again lead to flow losses, we pump an abrasive fluid through the coolant nozzle at high pressure."

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Matthias Schmidt-Lehr, Head of sales, Bionic Production

The roughness of the connecting thread also has to be corrected in a separate process to achieve a tight seal. On the plus side, the original nozzle was produced in a total of four production steps, while the new one only requires two steps, so that cancels out these apparent drawbacks. All in all, Friedrich argues that the high flexibility of the process significantly outweighs the disadvantages. "This nozzle would be impossible to produce without 3D printing. If you're aware of the limitations, then you can compensate for them." Matthias Schmidt-Lehr from Bionic Production agrees: "In many cases you don't actually need smooth surfaces, they are just a side effect of the drilling or milling process. But in cases where smooth surfaces are vital to how a component functions, then you inevitably need to do some reworking if you take the 3D printing route."
He finishes off by clearing up another myth: "Many companies seem to think that you can make any component using 3D printing and that it will end up cheaper. But in fact this method is really only suitable for a small number of parts. When you do get the right match, however, the benefits can be huge."

50 nozzles at once

The new Grindaix nozzle is still a development project at the moment, though some customers are already using the nozzles and Friedrich is optimistic about their future sales potential. "We've already progressed well beyond the prototype stage. Together with TRUMPF and Bionic Production, we've been developing concepts that will allow us to print 50 different nozzles at once in the future using a printing process on large-scale printers. That will obviously have a positive impact on manufacturing costs." He is clearly impressed by the flexibility offered by 3D printing. "With all the know-how we've accumulated in this joint project, we would certainly consider producing 3D printed parts ourselves in the future."

Only suitable for prototypes? Absolutely not! Grindaix, Bionic Production and TRUMPF have been working on a joint project to develop concepts that make it possible to print multiple different nozzles in a single operation on large-scale printers.

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