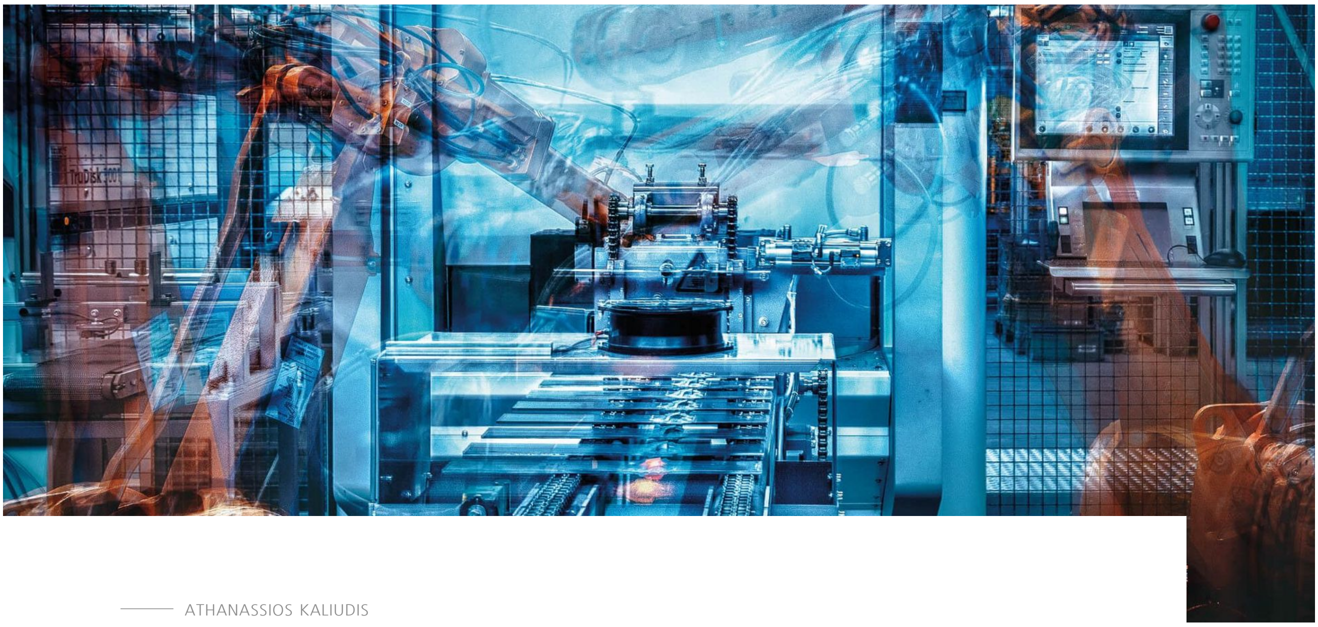


ATHANASSIOS KALIUDIS

Why the laser is fundamental for Industry 4.0

Data, light & the factory of the future: Digitalized manufacturing in terms of Industry 4.0 promises speed, directness and flexibility – so it needs a tool to match. Fortunately, the right tool has been ready for action for quite some time: laser light.

Ask people where the future of manufacturing lies and talk will quickly turn to concepts such as data analysis, programmed algorithms, smart ultra-flexible part flow, and connected machines. “One question is often left unanswered, however: what tools will we be using to actually machine the workpiece in all these highly connected, flexible operations?” says Andreas Gebhardt, Professor at the Aachen University of Applied Sciences and a pioneer in additive manufacturing and Industry 4.0. The problem is that data is intangible, yet at some point it has to be turned into products we can touch.

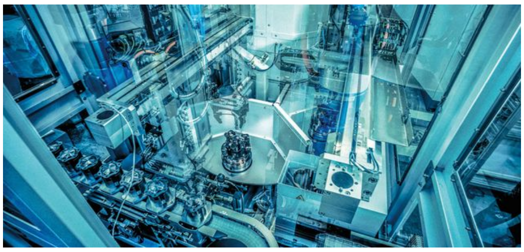
“Digitalization is crying out for a tool that offers the same fast, flexible and physically unconstrained benefits that it does. And that’s a pretty good description of a laser.” After all, when it comes to laser machining, the only thing standing between data and form is a focused beam of light. Yet that light can do so much, from ablation and material deposition to drilling, cutting, joining, producing metallurgical changes and inducing intrinsic tension in glass, as well as roughening, smoothing and cleaning surfaces. Lasers are on for just about anything. “And the benefits don’t stop there,” says Gebhardt. “One of the biggest advantages of lasers is that they can process whatever material you like, from metals and glass to plastics and even skin. They give you complete freedom.”

Four actions in a revolution

Laser systems were up and running in factories long before anyone was talking about connected manufacturing or Industry 4.0. “Laser technology was digital right from the word go because it can only be controlled numerically you could almost say that data-based manufacturing is in its DNA,” says Gebhardt. Many of today’s production planners are discovering that they already have experience with one highly mature industrial tool that is the perfect choice to meet the new requirements they are facing. “When laser experts hear about Industry 4.0, they simply take it in their stride.” For everyone else, it feels like a revolution. And there are four key actions to this revolution that are playing out simultaneously:

1. Manufacturing chains with lasers are on their way in, manufacturing chains with mechanical tools are on their way out.
2. The workpieces themselves are turning into data carriers with the power to communicate.
3. Parts can change shape with each different set of data.
4. Parts are being made completely from data sets.

For this to work, the production needs highly flexible, easily controllable tools. (Picture: Jens Oswald / Gernot Walter)

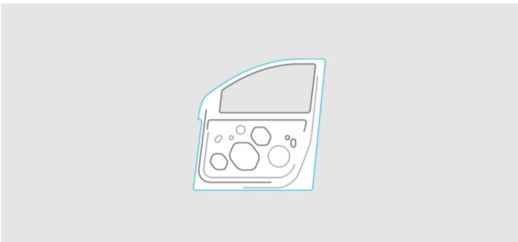


Intelligent production means: the machine finds out for itself what to do. (Picture: Detlef Göckeritz / Gernot Walter)

Action 1: Fighting for greater variety

Marketing departments always want to offer potential customers products that match their needs and surprise them with special editions. Meanwhile you can almost hear the production planners grinding their teeth as they field one request after another for new varieties and small batch sizes. And that’s especially true in factories that still depend heavily on mechanical processes such as milling, punching, sawing and drilling. The costs of toolmaking go through the roof□□□and tool set-up times stretch out to absurd lengths. Increasingly, set-up actually takes longer than the production process itself.

This was exactly the situation faced by Zwilling, a German knife manufacturer based in Solingen. After the drop forging process, the company would use a punching machine to remove the final blade geometry from the blank. But Zwilling doesn’t just have three or four blade geometries in its portfolio□□ it has hundreds. And the numbers just keep going up, including a highly exclusive special series chef’s knife made from steel taken from Germany’s highest railway bridge to celebrate the company’s 285□th anniversary. Ulrich Nieweg, who heads up Zwilling’s prefabrication department, recalls how tough things were getting: “We were building a new punching tool every time we had a new product or a change in geometry. It was tremendously costly and time-consuming, and so was the constant tool repositioning.”



Manufacturing chains are gradually bidding farewell to mechanical tools. Laser light offers a faster, simpler and more flexible way to produce things on demand. (Illustration: Gernot Walter)

More freedom through laser light

To tackle this problem, they opted for a laser cell that is loaded and unloaded by two robots□□□a flexible and programmable solution. Worries about toolmaking and set-up times are now a thing of the past: “Nowadays we simply send across a new data set and that’s that.” So is the laser cheaper than the punching machine? That question misses the point entirely. Companies like Zwilling that choose to rethink their production processes and manufacturing chain understand that laser light offers a level of freedom that mechanical processes simply can’t match. That’s because, by definition, their mechanical nature means they need something exerting an influence on something else.

This shift in thinking is now taking hold in all sorts of places. The Swiss mechanical engineering company THE Machines uses one and the same set of laser optics and one and the same beam source to process coils of different sizes made from different materials, first making a precise cut and then welding them together. The automatic switch from "cutting" to "joining" happens in the blink of an eye. Meanwhile the shears and TIG welders have quietly disappeared — and nobody wants them back.

Laser optics instead of mechanical production

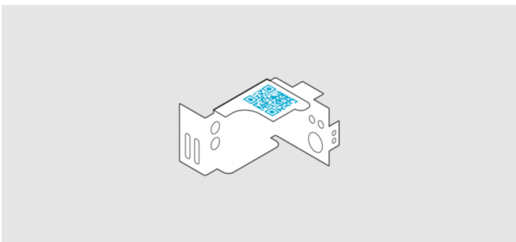
The big automakers have spent decades eliminating one mechanical production step after another downstream from the forming press and replacing them with laser stations. One example is car doors: the designs currently used by automakers allow them to cut the highest possible number of different models from the pressed metal panels. After all, it makes no difference to a downstream laser whether an angle in car door A needs to be flatter or whether the diameter of a hole in car door B is larger. The laser simply receives its instructions in the form of data packets and immediately puts them into practice.

All that smart scanner optics need is the data from a 3D simulation software program and they are ready to apply the welds to the workpiece — no teaching required. Even the word "set-up" no longer applies, because it's the machine itself that makes the necessary adjustments for each part.

Action 2: It can talk!

Things get even more connected when the parts themselves can communicate with the tool to say how they should be handled. Argo-Hytos, a German manufacturer of hydraulic and filter systems, is one place where the laser head asks each part "What can I do for you today?" Joachim Fischer, who heads up manufacturing process technology at the company, explains how this works: "We produce lots of short-run batches based on a strategy of zero set-up time."

One example is the laser transmission welding of plastic filters and tanks. The scanner optics in the laser cell are mounted on a robot head and fed by a diode laser. The optics move freely around the workpiece, forming the welds in the correct places. Every part that enters the laser cell has a bar code. The code tells the machine what to do, so it can fetch the relevant parameters from the database and get to work. Argo-Hytos works with many different kinds of plastic. "In many cases even the supplier of the semi-finished product doesn't have accurate information on its laser transparency." That's where the pyrometer integrated in the optics comes in handy, monitoring the temperature in the melt and providing data to the laser robot in real time. The robot and beam source adjust the power output as they work, producing optimum welding results. "It boosts the efficiency of our manufacturing process and produces even the smallest batches at a level of quality you would normally associate with large-scale production," says Fischer.



Marking lasers write data onto parts. Laser machines read the data on each part to find out how to process it and execute the instructions immediately. (Illustration: Gernot Walter)

Laser systems teach workpieces to communicate

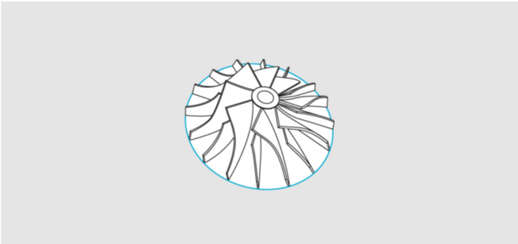
As well as being the perfect recipients of the messages transmitted by parts, laser systems can also teach workpieces to communicate in the first place. The machine tool manufacturer Chiron, based in southern Germany, has incorporated a marking laser in its laser cells that provides each finished part with a data matrix code. "Normally the production data includes information such as the time the part was manufactured, the processing station, the supplier number and the order number. But obviously you can also add additional codes to the marking," explains Thomas Marquardt, head of automation at Chiron.

For example, these codes could tell a transport system where the part needs to go, and explain to a control system at the next processing station what program it needs to load. This transforms the workpiece into a carrier of its own blueprint□□□and it marks the beginnings of a genuine smart factory.

Action 3: Data is changing parts

Modern data-driven production, which offers a way to construct geometries, is entering the next phase. "Additive manufacturing is turning the process for manufacturing many components on its head," says Andreas Gebhardt from the Aachen University of Applied Sciences. That's exactly what Elfim, a high-tech contract manufacturer in southern Italy, is doing□□□starting with an unspectacular milled base, they use laser metal deposition to construct complex blades for various impellers. "We used to start with a metal block and then mill away more than 70 percent of the material to end up with the right impeller geometry. Completely crazy, really," says Michele D'Alonso, the company's co-founder. "Now we just add the necessary material instead of cutting away the unnecessary." Although Elfim is manufacturing its impeller blades using different methods, the blades essentially look the same as before.

Not only is this process faster and more resource friendly, but the final impellers are also better. "With laser material deposition, we can construct other, more exact blade geometries. As a result, one of our gas impellers has 50 percent more capacity!"



Laser metal deposition systems construct complex geometries on base parts. Additive manufacturing turns the production process on its head. (Illustration: Gernot Walter)

Lighter through laser metal deposition

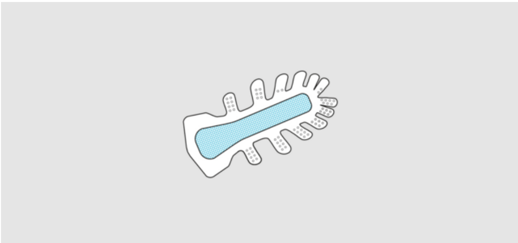
"Yet designers all over the world are discovering that additive manufacturing offers the ability to completely rethink parts," Gebhardt argues. Automakers are currently working hard to modify the design of many components and reduce vehicle weight. Currently, each individual manufacturer uses the same economical, mass-produced cast parts for all its vehicle models, including chassis and body parts, engine components, and brake discs. That means the load-bearing capacity of the parts is dictated by the heaviest model. In other words, little city runabouts typically contain parts that are heavier and more stable than they need to be. Experts are hoping to turn that around in the future by designing parts based on the lightest load they will have to withstand. That makes them lighter and cheaper. For heavier models, these parts are then partially reinforced with weld beads, creating a fusion of customization and lightweight design.

In the future, auto designers are also hoping to use this method to improve crash-relevant parts made from high-strength steels: clever application of weld beads can allow them to absorb so much force in the event of an accident that the actual base part can be made thinner and lighter. Car body panels essentially have predetermined points beyond which a panel should not travel in a crash. Combined with the predetermined bending points incorporated using laser annealing, the engineers can determine precisely how the parts should crumple in the event of a crash. Targeted reinforcement of parts using laser metal deposition is on the verge of moving into full-scale production.

Action 4: Idea - Light - Object

Additive manufacturing using powder bed fusion takes this process to its logical extreme. Loaded with metal powder, the machine simply waits for instructions and then produces whatever is required. The designers' ideas are immediately brought to life. “3D printing is the pure embodiment of data-based manufacturing,” says Gebhardt. With such tremendous freedom to choose geometries, designers can create new and improved parts. That’s exactly what happened at Grindaix, a German manufacturer of coolant supply systems that was determined to improve its coolant nozzles using 3D printing. These nozzles are used to distribute lubricoolant on the part during ID cylindrical grinding. Now they are designed on the basis of bionic principles — and the benefits of this new approach are remarkable.

“We can create nozzles with curved channels designed for optimum flow,” says Dirk Friedrich, owner and CEO of Grindaix. “They deliver the right doses of coolant to exactly the right place on the part with lower pressure losses. Our customers benefit because they can run their grinding process faster and even achieve higher quality.” “We’re currently seeing a transition from the mass production of mass-produced parts to the mass production of individualized parts,” emphasizes Gebhardt.



Powder bed fusion turns an idea straight into an object like this bionic spine implant. Offering new levels of design freedom, it is the pure embodiment of data-based manufacturing. (Illustration: Gernot Walter)

This change has not gone unnoticed by contract manufacturers, and some of them are seizing the opportunities it offers. The company C.F.K. Kriftel GmbH, based near Frankfurt, has been using 3D printing since 2004. It all started with rapid prototyping, but it has progressed in leaps and bounds. “We get lots of jobs that involve printing finished parts in our laser metal fusion machine,” says managing director Christoph Over. C.F.K. Kriftel’s products include spinal implants with a fine lattice structure that promotes tissue growth. “We can produce between 120 and 180 implants simultaneously in 20 variants with just one load of metal powder. That’s certainly one step closer to mass production.”

Produce components as one piece

Other customers contact Over because they want to finally produce components as one piece. “We often see specialist nozzles and connection plates for industrial automation consisting of multiple individual component parts that all have to be manufactured in different ways and then joined together. We can simply print the complete part as a single piece. And in many cases we can even make it better or more compact.” Customers are increasingly discovering the design freedom 3D printing offers, and contract manufacturers with the right machinery are springing up on every corner. At the same time, more and more engineers have the expertise required to design parts specifically for 3D printing.

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>
> Andreas Gebhardt, Professor at the Aachen University of Applied Sciences

The Laser Zentrum Hannover, for example, began offering courses to 3D printing professionals this year. “Design know-how will be the key to 3D printing — and we’re only at the beginning of that road,” says Over. He also cites two other key tasks for the future: “We need to conduct more research into the core process and understand how lasers and metal powders actually interact. And it will be even more important to automate machines and integrate them into the manufacturing chain.”

The tool of the data society

Gebhardt has a strong hunch as to which tools will be needed in these manufacturing chains: “Nobody knows exactly what additional requirements will emerge in the field of connected manufacturing, but my personal feeling is that laser systems are a great way to prepare for whatever lies ahead. There are simply so many cases where if anything can do it, it’s a laser!”

When the laser first saw the light of day in the 1960s, some people said it was a tool looking for an application. Now it appears it may have finally found its purpose as the tool of the data society.

ATHANASSIOS KALIUDIS
SPOKESPERSON TRUMPF LASER TECHNOLOGY

TRUMPF MEDIA RELATIONS, CORPORATE COMMUNICATIONS