DIALOG 55

DIGITAL PROCESS TWIN –
Boosting efficiency in manufacturing

ROI
MANAGEMENT CONSULTANTS

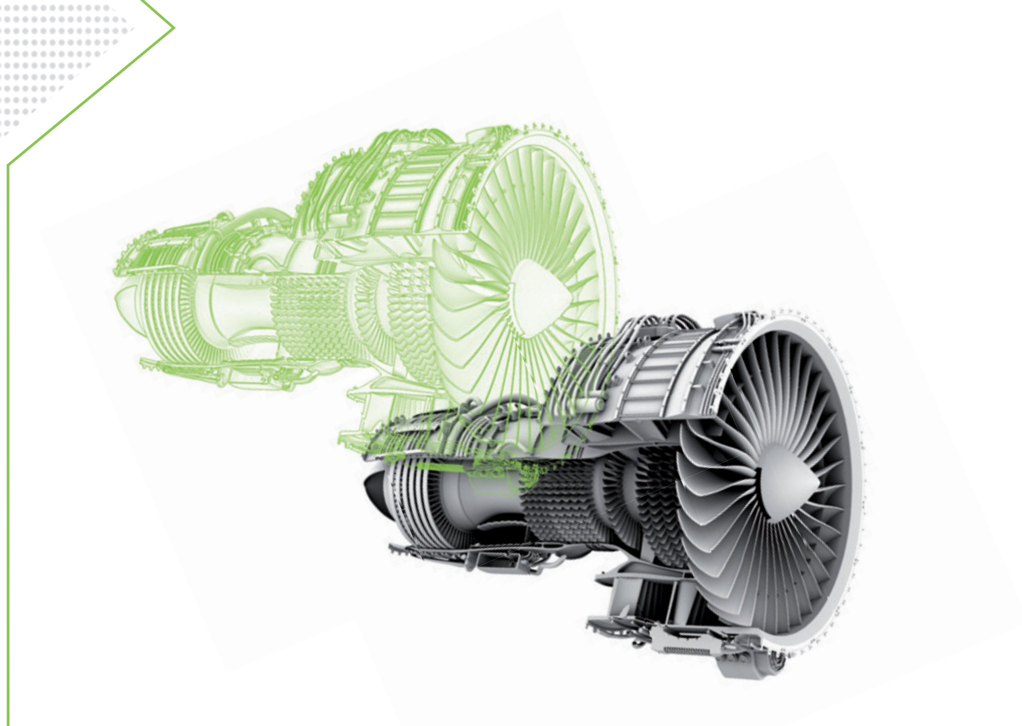
STEP BY STEP

TO A VIRTUAL PROCESS TWIN

1 **Areas of application for digital twins**

2 **Set up a digital twin for a process: that's how it's done**

3 **New options for evaluating, controlling and qualifying suppliers**



NEW OPPORTUNITIES FOR A MORE PRECISE ANALYSIS AND DESIGN OF VALUE NETWORKS

By Hans-Georg Scheibe,
Member of the Management Board,
ROI Management Consulting AG

Digital twins, i.e. virtual models that mirror their physical counterparts extremely closely and in real time, are among the particularly impressive examples of Industry 4.0 and the Internet of Things. The transformative role of this approach will most certainly take on even greater significance in the next few years as it gains universal acceptance. Until then, there is still a long way to go. If we take a look at where digital twins – at least those that actually deserve the name – are deployed, we will see that they are used in particular in the field of highly complex capital goods: **wind generators and turbines, power station components, and special machinery.** It is here that the effort associated with developing a digital twin is worthwhile, and it is here that it is possible to collect sufficient operating and status data in order to design a valid mirror image. And it is here that a digital twin offers real added value.

For example, if you can develop a digital twin for an aircraft turbine – something which is very expensive, critical and durable – you can, ideally, very accurately predict when material fatigue or operational deterioration will occur, when the turbine needs preventive maintenance, and what environmental factors are particularly critical. This **naturally saves a great deal of money,** as nothing costs more than an aircraft in a hangar. And furthermore, you can also generally learn where the weak points in the design are and draw important conclusions from this for future production.

So far, so good – exciting and very promising. And yet this interpretation of a digital twin still falls short of the mark because, while the approach described above definitely supplies valuable lessons regarding the optimization of a product and its maintenance, **you only gain real optimization leverage when not just the product but also the entire process – or even the entire value network – is improved.** It is only when digital twins are established for processes and not just for products that the full potential of digitalization and interlinking can be leveraged.

> The starting point for this is the definition of process parameters that might possibly influence the performance of the production line

WHAT DOES THE DEVELOPMENT OF A DIGITAL TWIN FOR A PROCESS INVOLVE?

Let's take the example of a production line for dashboards in the automotive industry that processes – i.e. molds and hardens – polyurethane foam. It frequently suffers from a relatively low level of efficiency and high reject rate, especially in the light of very high standards in the industry. **The problem here is not located at the product level, but at the process level.** A digital twin will now be developed to improve this process.

The starting point for this is the definition of process parameters that might possibly influence the performance of the production line. These values are derived from experience and might initially comprise far in excess of one hundred different parameters, which may increase or decrease during further analysis.

The second step involves ensuring that existing process data are correctly aggregated and configured, that data which can be captured but have so far not been registered are collected, or that data which have not yet been captured but are required in the light of the defined parameters are then measured using additional sensors. The data pool that is generated in this way is then merged and analyzed in a cloud application. This gives rise to a model that maps the process being optimized as accurately as possible: the relevant parameters, their interdependencies, and critical values. **One particularly interesting aspect here is that this model can reach out far beyond the company in question – like the process itself.** In this example, it may also extend to the logistics service provider that transports the foam, or even to manufacturer of the foam itself, because the causes of the problem, such as dangerous temperature fluctuations in the highly reactive polyurethane, can arise at any point in the value chain. The result is a digital copy of the process that can monitor the entire physical process in real time, allowing for early intervention based on critical process parameters – a "digital process twin".

INCREASED EFFICIENCY AND QUALITY

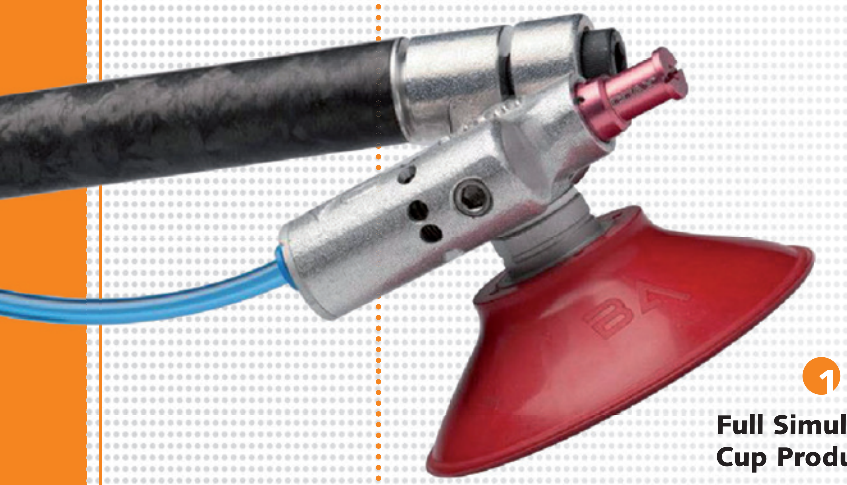
are the obvious benefits that can be achieved with the "digital process twin" – but not the only ones by a long shot. The approach thus opens up new possibilities for evaluating, managing and qualifying suppliers, since using virtual process models makes it possible to analyze the actual structures and processes in the value chain much more accurately and thoroughly than with the checklists and lean manuals that are customary today. First, this provides a very good lever for qualifying suppliers. Second, it allows new partners to be integrated far more rapidly and easily, reducing dependencies and facilitating the establishment of new, local production facilities. This also makes virtual process twins a major strategic factor in developing smart supply chain management.

» INCREASED EFFICIENCY AND QUALITY ARE THE OBVIOUS BENEFITS THAT CAN BE ACHIEVED WITH THE "DIGITAL PROCESS TWIN" – BUT NOT THE ONLY ONES BY A LONG SHOT «

DIGITAL TWIN

CUSTOMERS BENEFIT FROM QUALITY ACROSS ALL PROCESSES

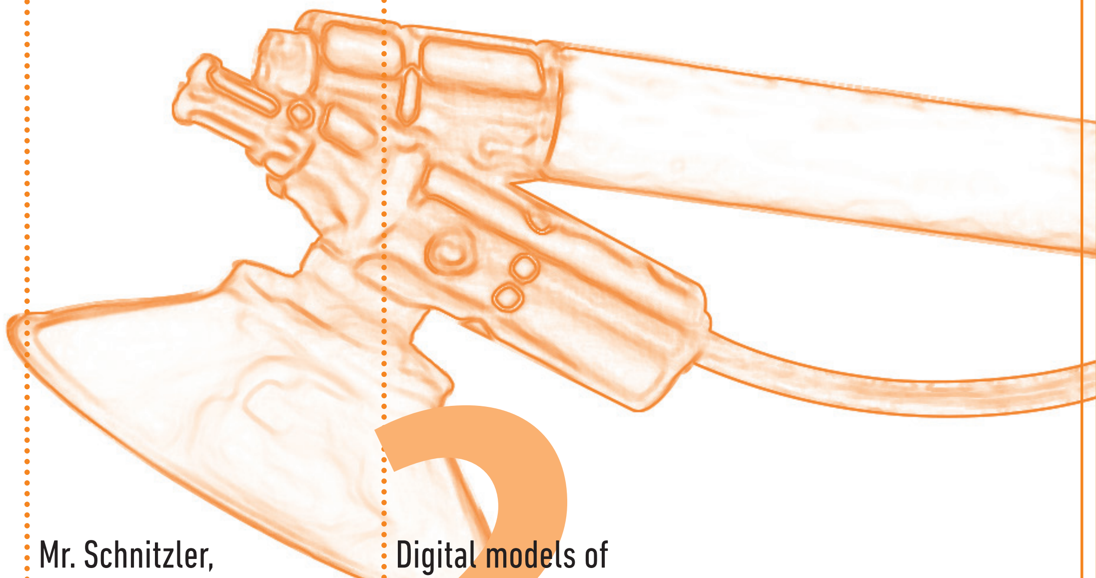
Interview with Daniel Schnitzler, Head of Supply Chain Management, Bilsing Automation GmbH



1 **Full Simulation of Vacuum Cup Production**

2 **Advantages in the assembly line**

3 **Standard software is not enough**



1 Mr. Schnitzler, your company has created a virtual copy of the vulcanization process for vacuum cup production – what exactly is that?

We produce vacuum cups, in particular for body shop and press room automation. One problem with vulcanization is that you don't notice defects in the process immediately. These faults later become noticeable to customers, for example through increased wear on the vacuum cup. **Subsequent replacement costs many times what it does if the fault is rectified in the production process.** In this instance, the digital twin not only models vulcanization but also the upstream and downstream steps. This gives us a full simulation of our vacuum cup production.

2 Digital models of the production line allow you to run through different virtual production scenarios. How does this benefit your customers?

The digital twin enables us, for example, to analyze quality-related aspects. In particular, we take a look at the influence of upstream and downstream steps of vulcanization. The storage of the vacuum cups and of the raw material, for example, has a considerable influence on the durability of the products, as incorrect storage can result in them becoming hard and brittle. The twin has resulted in a significant improvement in storage processes for work in progress, allowing us to improve the durability of the vacuum cups. **We are thus able to ensure quality across all processes** – this ultimately benefits our customers, as they receive products with a longer service life than comparable products from our competitors.

What special challenges are there for press and robot movements in the automotive industry, and how does your twin help overcome them?

The twin helps us to give **a holistic view of the overall process.** With other models, the focus on the core process is often too acute, resulting in important aspects not being modeled. An example of this is the often universal simulation found in common software systems. I am sure that they can be used to easily identify which transitions of the individual process steps did not occur optimally, resulting in idle times – for example, a queue upstream from the tool store causing unscheduled holdups. The effect of an incorrect temperature in the hardening oven due to incorrect papers cannot be simulated by standard software.

How will you continue to develop your digital twin in future?

We are currently introducing digital twins to the area of CNC production. The reason behind this is that we have begun to preproduce some of the parts for Bilsing tool production in the Czech Republic, which specializes in the manufacture of heat protection plates. The processes for milling a tool are, however, different for parts required in automation (tolerances, etc.). The aim is to streamline upstream and downstream steps in order to increase productivity of bottleneck machines.

DIGITAL PROCESS TWINS IN MANUFACTURING

DIGITAL PROCESS TWINS ENABLE HOLISTIC PRODUCTION MANAGEMENT

1. **Initial point: a complete mapping of the value stream as Digital Twin**
2. **How to build a Digital Process Twin**
3. **Basic rules for the further development of the twin**

By Robert Benacka,
Member of the Management Board,
ROI Management Consulting a.s.

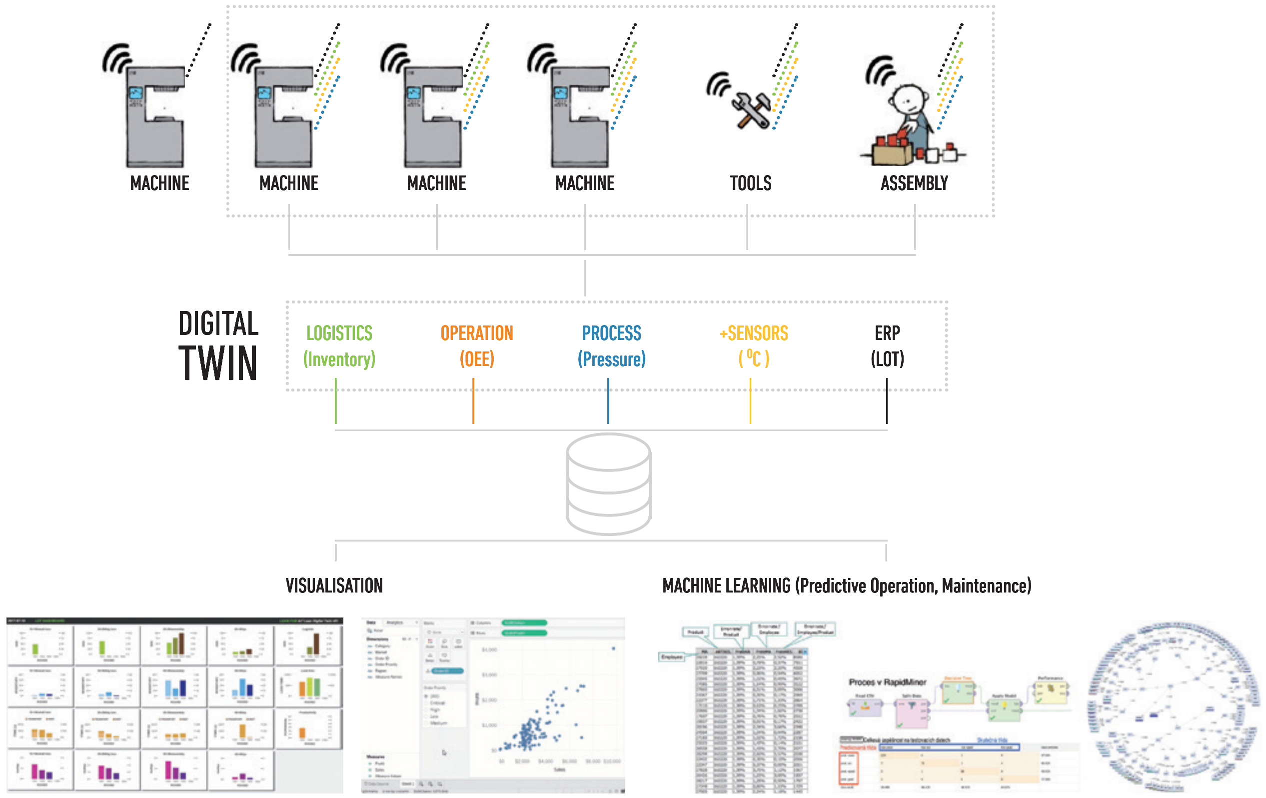
A good 150 years ago, an interesting custom took root among the Yoruba people of West Africa: While the Yoruba had regarded twins as evil for centuries, their superstition now suddenly shifted and saw them in a positive light – a cult of twins emerged. This adoration found a special expression in the production of Ibeji, figures of twins carved in wood that serve as containers for the soul of deceased twins, because the Yoruba believe that the souls of twins remain connected beyond death. If one twin dies, it must be fed, bathed and talked to like a living family member in order to ensure the survival of the other twin. In a certain way, this idea of interdependence between the real and symbolic worlds also influences the way we regard "digital twins" today. Of course, a digital twin in our factories no longer involves superstition. Instead, it is a digital copy of a concrete, physical object or product – for example a turbine, whose operational parameters are measured and represented virtually in order to allow predictions to be made concerning possible changes in performance or material characteristics. This may open up very exciting perspectives for the further development of products in terms of cyber-physical networking in Industry 4.0, but, as with the Ibeji of the Yoruba, it ge-

nerally only focuses on the interaction of one pair of twins.
However, the digital twin approach offers significantly greater potential. What can be achieved when the entire value stream with all its processes is represented by a digital twin, i.e. a "digital process twin"? It would, for example, prevent quality problems in the manufacturing process before they arise, avoid downtimes, and predictively simulate new customer requirements.

3 ASPECTS ARE PARTICULARLY IMPORTANT FOR THIS FURTHER DEVELOPMENT OF THE DIGITAL TWIN APPROACH:

- **a holistic understanding of the value stream and processes**
- **a more effective deployment of existing technological infrastructures**
- **data-based forecasting of events in the value stream and processes**

EXAMPLE OF A DIGITAL PROCESS TWIN FOR CONSOLIDATING AND VISUALIZING VALUE STREAM DATA



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A CHANGED VIEW OF THE VALUE STREAM

New technologies on their own do not make a digital process twin. The way the value stream and value stream management are understood must change as well. In the past, production managers have concentrated on one question in this respect: How do I configure the value stream to make it more effective? The question is correct, but it only provided limited influence on the quality and OEE (overall equipment effectiveness) of the process. In order to improve these as well, quality and OEE results should be aligned with other information from production IT systems and thus be viewed holistically. This, however, is exactly what is not done in most production systems. On the contrary. A production planning and control (PPC) system has its "own view" of the manufacturing process, along with the machinery control units, the workstation operators, etc. Furthermore, many production lines are complex systems, especially in the automotive supply industry: The production process is subject to dynamic change over time, machines are not configured optimally, and fluctuation and differing levels of qualification among the production team are not uncommon. **All this places a strain on production, and at the same time, there are generally no personnel capacities available to solve problems systematically.** Quality assurance falls short in this instance, as it identifies and removes the symptoms of process errors but not the causes.

A digital process twin aims to resolve these problems: It collects and visualizes information that is relevant prior to, during and between the manufacturing steps (see diagram). This is valuable in two ways. Once a twin has been successfully developed, it can be adapted to other manufacturing systems. In addition, it reveals all the relevant correlations and thus makes the process more manageable. **Two kinds of information output are important here.** First, directly visible values such as lead time, and second, the history of machinery and process data that, thanks to digitalization, can be represented and analyzed.

Directly visible values to be identified should include, for example, a wide range of KPIs concerning effectiveness, productivity, OEE, etc. However, a comprehensive evaluation of manufacturing processes needs to take into account that different value streams, e.g. for injection molding or die casting, also have different requirements and need different templates. For example, the temperature of the drier or tool for the production process may be relevant for injection molding, since a slight variation in the temperature or drying time can affect the quality. In contrast, other factors can be important in die casting or stamping.

TECHNOLOGIES AND PROCESSES IN HARMONY

The PPC or enterprise resource planning (ERP) systems supply essential information for a digital process twin, e.g. order numbers, production times, material consumption, and the assignment of staff to machines. How much material is used when and by which machine does not by any means adequately reveal sources of error or process obstacles. In addition, the (often manual) interim work steps often lead to waste and interruptions – this can very quickly cause losses running into thousands each day.

> A larger number of relevant values will result in more correlations and hence greater insights

THE FOLLOWING POINTS SHOULD BE TAKEN INTO ACCOUNT WHEN IMPLEMENTING A DIGITAL PROCESS TWIN, IN ORDER TO REDUCE THESE COSTS:

1. Existing PPC systems generally fail to adequately represent the manufacturing process. The following questions are helpful when developing a digital twin of the value stream: **How were the implementation data qualified?** What important information is still not yet captured? Do the models that have been set up match actual production?

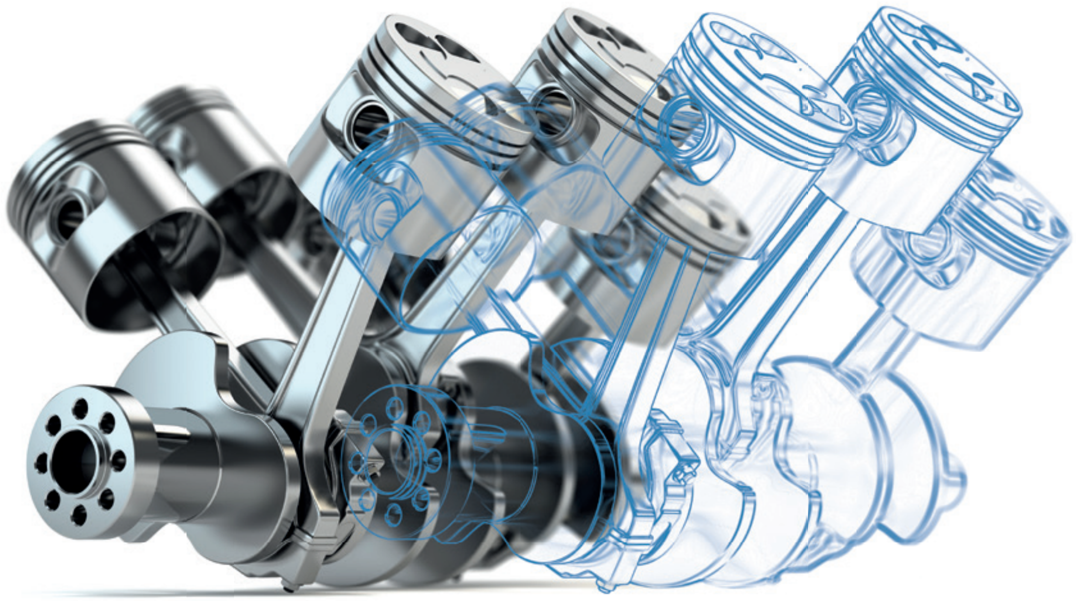
2. Once implemented, many teams think that the PPC system automatically standardizes workflows. Here, it is **important to examine whether the standards still meet current requirements for batches, cycle times and material usage.** A twin should, for example, make any classical "black box" area transparent, e.g. details about workshop processing or reworking work items, or about what material was used on which machine. What programs were used to control it? Which employees are especially well suited for which tasks?

3. Deconstructing production lines into many segments makes it more difficult to maintain an overview of the whole process. Although all the people involved are sometimes familiar with the problems that exist and the available solutions, change initiatives fail at departmental or business unit boundaries. Questions need to be asked in this case about **where breaks in competence occur** and how they can be overcome with the help of a digital process twin.

RECEPTIVENESS FOR NEW INSIGHTS

However, the digital process twin of a value stream does not concentrate solely on representing correlations between machines or on human-machine interaction. It also considers tools and workplace equipment in order to detect additional potential sources of error. At the same time, it compares past and current information from the entire value chain. An important point here is that a larger number of relevant values will result in more correlations and hence greater insights. **This creates the information basis for the "preventive" mode of the twin,** i.e. predictive planning that, for example, assigns the right tool to employees, or which could use future shift or vacation schedules to show which employees with which qualification need to be available for new customer orders, and possibly need to be trained accordingly in time – „could" because the PPC systems in current production lines generally create work orders anonymously.

And yet even without this information, a digital process twin will allow a comprehensive picture of the production process beyond the existing production system relatively quickly. It is worthwhile being open for spontaneous ideas, new developments and extraordinary outcomes. Incidentally, there is also a special twist in the case of the Ibeji mentioned at the beginning of the article: The cult of the wooden figures may have contributed to the fact that, on average, every sixth birth among the Yoruba sees a delivery of twins – a peak value worldwide, as only one in 40 newborn children around the world is a twin. This is certainly not what the first Ibeji artists planned.



WE SOLVE PROBLEMS DIRECTLY WHERE THEY ARISE

HOW A DIGITAL COPY OF A GEARWHEEL EMERGES FROM ITS "COMPONENT DNA"

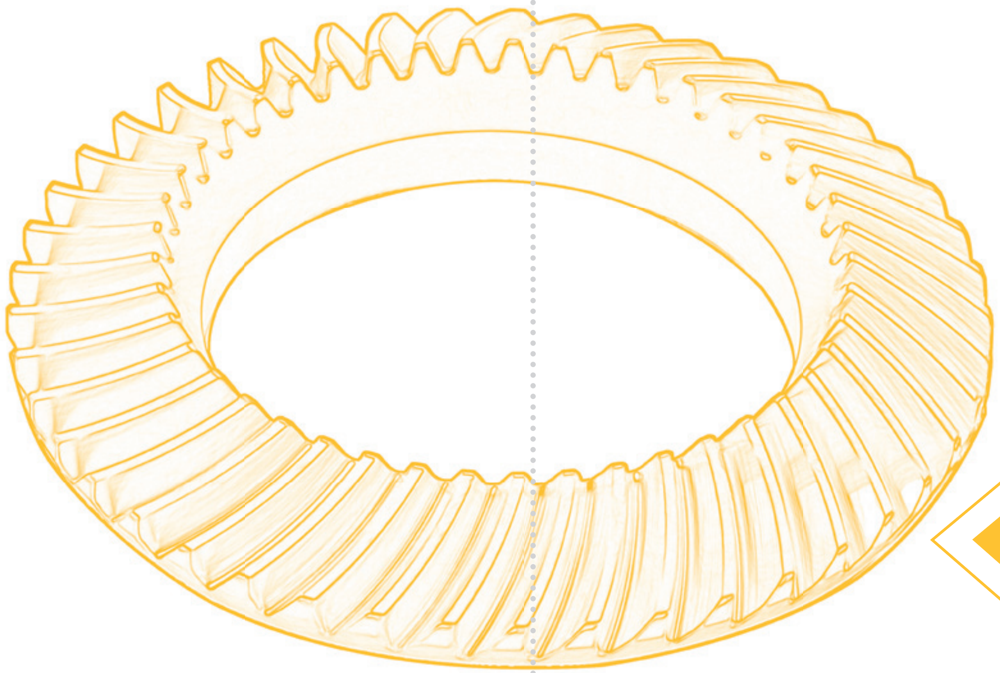
1. **Winner placement at the „Industry 4.0 Award"**
2. **Reduce complexity with big data**
3. **Incorporate and motivate employees**

Interview with
Dr. Hartmuth Müller,
Head of Technology
and Innovation at
Klingelnberg GmbH

Dr. Müller, your company won the "Industry 4.0 Award" with a digital twin implementation in gearwheel production. What's so special about your solution?

1

The simple underlying idea. We wanted to create a complete, digital copy of the actual physical manufacturing world – in this case, gearwheel production. When you imagine a gearwheel, you think of a certain number of teeth and flank shapes – and it ought to be completely sufficient to describe the geometry in order to create a "copy". This, however, is not the case, as **a gearwheel has "inner values"** that depend on the material, such as compressive residual stresses or hardness profiles. We used all this information – the "DNA" of the component so to speak – to create a digital replica that can be accessed at the press of a button anywhere along the production process chain.



What advantages did you hope to gain from this and how has your production process changed?

A major advantage emerged, for example, in the area of quality control. Prior to digitization, this process step was also carried out by us following a simple model at the end of gearwheel production. If the gearwheel worked, you were happy; if the state of the contacts was poor, you weren't happy, and you had to "repair" the wheel set. The fact that our gearwheel twin has been implemented from end to end means that we have defined a specific, individual geometry for every process step. We therefore learn immediately when something goes wrong with that process step and are able to intervene to correct the problem straightaway.

The same applies when setting up the gear-cutting tools. Since the geometry of a bar blade cutter head is available in digital form, a comparison with the actual tool geometry and a superordinate closed-loop enables a high-precision gear-cutting tool to be set up for machining. **The efficiency gain can be found in the high first-pass yield,** in other words, the extremely small number of defective components and in reliable set-up and machining processes. This automatic "closed-loop assistance system" has given us a production process that runs very smoothly without interruption. We therefore no longer repair after the fact; instead, we solve problems directly where they arise.

It nevertheless sounds like a huge amount of data to handle – how do you ensure that the "digital twin" doesn't end up pushing complexity?

With our big data approach: We only collect data that help us better understand the process. Hardening gearwheels always leads to distortions. Using analytical methods, we tried to create a causal chain in order to calculate the hardening distortions. However, this couldn't be done, and so we decided instead to use correlation as an approach to solving the problem. We collect geometric variations that arise in hardening processes and use them to create a knowledge base. This allows us to predict with relative certainty how a particular component with a certain geometry will behave in the hardening process. This, in turn, permits us to calculate a minimum but safe machining allowance. This is how we create the optimum conditions for subsequent process steps during hard-fine machining.

What tasks does the GearEngine IT platform perform in yourclosed-loop production system?

This is where several services converge: GearEngine manages the gearwheel data and all production resource data, and **ensures traceability over the manufacturing process for every single gearwheel** – provided they can be identified using a DMC code or RFID chip. As soon as a gearwheel is identified in the process chain for the first time, GearEngine creates a digital component file for it. Each machine involved in the process reports the previously defined parameters for the gearwheel currently being processed back to the platform. This is how the actual component and the digital file evolve over the value chain. Networking the processing machines and the gearwheel calculation software with the GearEngine platform permits the data to be made available directly to each machine involved at all times. The IT platform also monitors the current state of wear of all production resources.

What challeng should production companies always keep an eye on when developing and introducing a digital twin?

The biggest challenge is getting employees properly involved in the project at the very beginning: if the team doesn't fully back the project, it well never succeed. For example, when we were developing the support system that I just mentioned, a number of employees were concerned that their expertise would be incorporated into the software and thus make their job superfluous – this was definitely not the case. In this instance, you have to put a lot of effort into convincing employees that the software can't do a thing without their knowledge, and that it will remain this way in future. We succeeded in doing this. The digital twin not only enjoys a high level of acceptance among employees, but we have also been able to leverage the aforementioned benefits from the word go.

We only collect data that help us better understand the process

The mechanical engineering company Klingelnberg GmbH is the global market and technology leader in the development and manufacture of machines for the production of gearwheels, precision measuring centers for axially symmetrical objects of all types, and of high-precision gear components made to customers' orders.

With around 1,300 employees – of whom 220 are R&D engineers – around the globe and more than 100 patents, the company consistently demonstrates its capacity for innovation. Today, Klingelnberg operates engineering and manufacturing facilities in Zurich, Switzerland, Hückeswagen and Ettlingen, Germany, and Györ, Hungary. The company maintains a global presence with sales and service offices for customers and partners from a range of industries including the automotive, commercial vehicle and aircraft industries, shipbuilding, the wind-power industry, and general gear manufacturing.

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THAT'S STRATEGIC INTELLIGENCE

TOOL SHED MANUFACTURER BIOHORT IS WORKING WITH A DIGITAL TWIN TO BRING ABOUT THE FUTURE

1. **Garden tool sheds 4.0**
2. **Real-life modulation of the production**
3. **Limits for digital twins**

Interview with Martin Höller, MSc, Technical Manager at Biohort GmbH

Mr. Höller, Biohort is Europe's leading producer of garden tool sheds – a very sound line of business. Why do you need to engage with Industry 4.0?

Nowadays, every manufacturing company needs to get involved in Industry 4.0, or more generally speaking, digitalization. We are currently building a new factory covering 4 hectares in Herzogsdorf in Upper Austria. While it's only 15 kilometers from our old location in Neufelden, it represents a whole new world. Of course, we also need the factory after enjoying years of steady growth and now having to ensure that we have sufficient capacity for the long term. It's a logical development. But we wish to – or rather, we need to – tread new paths with this new factory. We need to structure our production in such a way that we can meet complex market conditions – and it is very easy to underestimate the dynamics of our market. The new factory is also intended to enable our business to face the challenges of the future, and not just to scale up capacities.

What are the specific challenges and corresponding solutions?

First, the large fluctuations in sales. Sales can vary by a factor of five between weak and strong months. The fact that the new plant will be able to keep pace with these fluctuations is a huge benefit and, at least for us, a blueprint of how we need to think about production in future. And it's of course only possible with a digital approach. To begin with, we need data, which, incidentally, we've been collecting for years anyway. We also need software capable of analyzing the complex relationships and interdependencies between the data. We've had this for about a year and a half. What we're doing here, ultimately, is setting up a digital twin: a real-life modulation of our production and the relevant framework conditions. This allows us to implement a completely new quality of management and planning compared with traditional approaches.

How complex does data management need to be in order to enable a digital twin?

Essentially, a cyber-physical production system (CPPS) lives from and through data – and in a dimension that is really huge. We therefore realized right from the start that setting up the processing of existing and constantly newly generated data was crucial. Our simulation software now has access to historic and current data from our ERP, CAD and MES systems, and integrates them into analytical models, enabling various scenarios to be simulated. On this basis, the digital twin **can validate decisions for initial investments or even propose them.**

> You will always need human experience and intuition as a corrective

When will the digital twin be so far advanced that it no longer needs human input?

I don't think that's a realistic scenario. At the end of the day, software that operates in a purely rational manner doesn't have enough intuition for the living system that production is. You will always need human experience and intuition as a corrective. Digital twins help us to prevent disruptions in production and massively boost our analytical capacities. This represents huge progress. Instead of speculating about when systems are likely to act independently, we prefer to tackle the question of how we can ensure that employees can grow with technological progress, as otherwise you won't achieve sustainability of change.

Biohort is the market leader in Europe for storage solutions made from metal for garden and leisure. With 250 employees and sales of EUR 47.5 million (2016), the company, which is located in Neufelden, Austria, produces garden sheds, boxes and equipment lockers.

www.biohort.com

A longer version of the interview can be found at www.roi-international.com

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ROI helps industrial companies worldwide to optimize their products, technologies and global production networks, and also to exploit the potential of the Internet of Things (IoT) for the benefit of business model and process innovation. As initiator and co-organizer of the "Industry 4.0 Awards", which were first presented in 2013, ROI actively promotes the development of technological innovation in Germany.

ROI has won numerous major awards for its highly implementation-oriented projects. The company employs over 100 experts at its Munich, Stuttgart, Beijing, Prague, Vienna and Zurich sites, and is also represented by partner offices in Italy, France, the United Kingdom, Thailand and the USA.

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