World of Components

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LIEBHERR

Components

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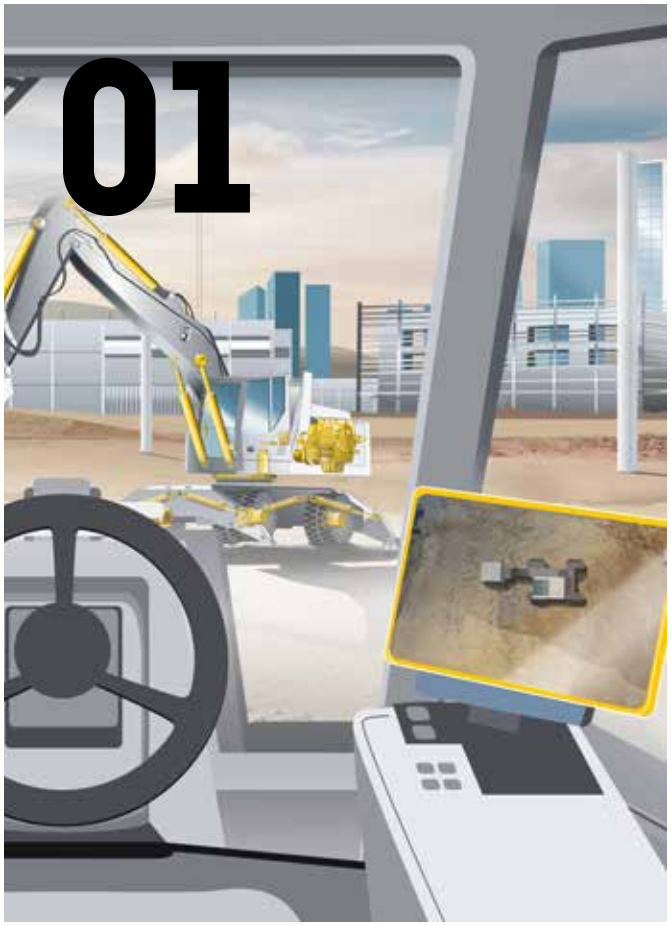

Introduction

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More than meets the eye

For several decades already, components by Liebherr have been used to build the machines that help shape the world we live in, construction site by construction site. Since the patenting of the first Liebherr crane in post-war Germany in 1949, the Liebherr Group has been developing innovative products that have stood the test of time, withstanding the harsh environments in which they are used. Components have also been part of Liebherr's product portfolio since the late 1950s: The production of gear wheels shortly after the company's foundation marked the starting point for the development of innovative components that are now an indispensable part of modern mechanical engineering. Today, Liebherr's portfolio includes high-quality components from the areas of mechanical, hydraulic and electric drive technology, as well as control technology. These include combustion engines, injection systems, axial piston pumps and motors, hydraulic cylinders, slewing bearings, gearboxes and winches, switchgear, electronic and power electronic components and software.

Although they might not be visible at first glance, components by Liebherr have been achieving great things: on construction sites, in the generation of wind power, as control systems in aviation or as components for innovative sailing systems in shipping. Take a closer look and dive into the wide world of components by Liebherr.

Pushing forward with purpose
The high-quality components are used in cranes and earthmoving machinery, in the mining industry, in maritime applications, in wind turbines, in vehicle technology or in aerospace and transport systems. Covering a wide variety of applications, the product segment exploits synergy effects from the Group's other product areas to drive forward technological development. In doing so, Liebherr pursues one key objective: to offer state-of-the-art components for various applications from a single source. In the spirit of cooperative collaboration, the company acts as a reliable partner to develop innovative solutions that meet customers' requirements and needs. As complex as the challenges may be, the components product segment produces many of the most remarkable innovations. We will present some of these in more detail on the pages that follow.

With a high level of vertical integration, as well as modern and adaptable production facilities, Liebherr pursues a customer-oriented and technology-open approach. As a result, the company offers tailor-made solutions to all customers and partners.

Focusing on customers
The driving force behind the successes of the components product segment is the motivation to support customers with innovative solutions and to contribute to their technological progress. Liebherr has always attached great importance to close cooperation and a trusting partnership with its customers and business partners. This is why customer satisfaction is always the focus. As a technology leader, Liebherr masters the key technologies necessary to offer its customers a suitable solution for even the most demanding tasks. At Liebherr, however, the customer focus does not end with the product. The Group's many services keep customer requirements in mind at all times and, therefore, make a real difference.

Our history

1949

Foundation of the first Liebherr company
Together with design engineers and craftsmen, Hans Liebherr develops the first mobile tower crane in 1949. It is also the first product coming out of the machines factory founded in Kirchdorf (Germany) in 1949.

1952–1954

The first components
At the beginning of the 1950s, gears for the production of gearboxes are in short supply. In order to be able to produce cranes, Hans Liebherr begins to manufacture gear hobbing machines, along with the first winches and slewing gears for tower cranes.

1955–1956

Electric drive systems and slewing bearings
In the years 1955–1956, the first slewing bearings, electric motors and control cabinets are manufactured in Biberach an der Riss (Germany).

2000

Foundation of Liebherr-Electronics GmbH
In 2000, eight new plants are established worldwide, including Liebherr-Elektronik GmbH in Lindau (Germany). It serves as a dedicated plant for the development and production of electronic hardware components.

2002

First frequency converters
The first frequency converters were produced in Biberach an der Riss in 2002 for use in the mining sector. The drive systems (converters, motors and gearboxes) were developed and optimised at Liebherr right from the start, with the aim of achieving maximum efficiency for the specific application.

2007

Foundation of Liebherr-Component Technologies AG
For the first time, Liebherr is consolidating the development, design, manufacture and reconditioning of its high-performance components in a single product segment.

1956

Electrical control technology
In 1956 in Biberach, the development and manufacture of products in the fields of control technology and electronics begins.

1958

Production of hydraulic cylinders
As early as 1958, the first hydraulic cylinders were produced under the roof of the Liebherr-Hydraulikbagger GmbH in Kirchdorf an der Iller.

1980

Opening of Liebherr Machines Bulle SA (Switzerland)
Here, Liebherr kicks off the development of the first axial piston pumps and motors.

1984

Production start of the first combustion engines
In 1984, series production of diesel engines begins in Bulle. At this time, Liebherr recognises the optimisation potential of construction machinery and designs its own engines that work reliably even under the most difficult conditions.

2008

Injection system development
In 2008, Liebherr Machines Bulle SA started the development of injection systems, consisting of injector, high-pressure pump, rail and engine control. Within just four years, a market-ready product is created.

2015

Foundation of Liebherr-Components Deggendorf GmbH
Two years after the successful start of production of Liebherr injection systems, in 2014 Liebherr decided to bundle the development, production and assembly of injectors and micro-precision parts in a new plant at the Deggendorf site in Germany.

2018

New plant for hydraulic cylinders in Oberopfingen (Germany)
Liebherr-Components Kirchdorf GmbH opens a dedicated production plant for the assembly of hydraulic cylinders. With a new building, Liebherr doubles the production area for hydraulic cylinders, dampers and system solutions.

The management board of Liebherr-Component Technologies AG
From left to right: Pietro Iemmi, Gebhard Schwarz and Maximilian Schaut

Executive trio with a vision

“We have to make sure that everything we develop fits perfectly into the technical strategy of our customers.”

Pietro Iemmi
Liebherr-Component Technologies AG

In an interview with the editorial team, the three managing directors of Liebherr-Component Technologies AG, Gebhard Schwarz (Development and Production), Pietro Iemmi (Sales and Customer Service) and Maximilian Schaut (Finance and Administration) explain, where the components product segment is heading to, what goals and visions are being pursued and where the fascination for these products lies.

Mr. Schwarz, your professional career has led you back to Liebherr time and again: In total, you have dedicated almost 40 years of your life to the company, the last 15 of them to the components product segment – that is very impressive. Why have you devoted yourself particularly to this product segment and what exactly draws you to it?
I joined Liebherr directly after concluding my mechanical engineering studies, during which I even completed all my internships at Liebherr. I finally got my first job in Biberach an der Riss (Germany) in the field of drive technology. This was in 1981.

Two years later, the company’s founder Hans Liebherr decided to relocate a wide variety of drive technology product lines to the newly established site in Bulle (Switzerland). At the age of 24, it was the opportunity for me to take over as head of the design department for the gearbox series, and thus my first management responsibility.

Despite five interesting years in the field of development, I was always keen to study business administration, so that I could then continue my career in technical sales. The use of high-quality technology in an international market environment was what fascinated me.

Completely unplanned and yet full of confidence, my path led me back to Liebherr and sales of construction machinery. After working in the sales regions of Germany and the USA, I took on the responsibility as a managing director for dozers, loaders and teleloaders. It was then that I realised how important it is to use technically flawless components in working machines, while I was responsible for a company in this industry.

During this time, however, I also wanted to gain management experience outside of the Liebherr Group and so I pursued a different avenue over the next four years. As fate would have it, however, I then met Dr. Willi Liebherr, who offered me the prospect of founding the components product segment. So I accepted a new position at Liebherr for the third time. Dr. Liebherr gave me the inspiration for components: He saw it as an opportunity to supply not only our own companies with components, but also the free market.

This vision electrified me as I started my professional career with components and never lost the joy for technology. The multitude of product lines that the Liebherr Group has built up over the past decades is unique. Pure technology from combustion engines to hydraulics, electrics and electronics to a wide variety of mechanical components, everything that drives any working machine. All these are part of the Liebherr components product segment.

When we take a look at the components today, we immediately notice what we have built up over the decades. We can look back on an enormous potential for growth and development that can only be dreamed of. In this development, I see the opportunity to generate growth in the future as

well, so that not only each individual product line becomes successful in its own right, but that we can establish ourselves as a system provider and thereby achieve a unique position. I see this as a supreme discipline. And that's exactly what fascinates me about components. Of course, we are up against some very big competitors. But we have all the prerequisites, including the full support of the ownership, to achieve precisely these goals.

Mr. Iemmi, you too are now a "Liebherr veteran" with a 25-year career in the Group. You have been involved in the components product segment as a member of the management board for ten years now. Your application experience, which you have gained in the earthmoving product segment plays a very important role, as does your understanding of customer requirements for components.

We would like to hear more about what goals and visions you are pursuing as Managing Director for Sales and Customer Service?
When it comes to the visions and goals of this product segment, it is essential to know the history of the components. It was always the wish of the founder Hans Liebherr to develop high-quality components for his own equipment, and thus to be independent on the market as a construction equipment manufacturer. The two areas – construction machinery and components – were never considered separately. The aim has always been to design our construction machines in the best possible way for our customers. An important prerequisite here is to understand the applications correctly and to create the necessary core competencies in-house.

This understanding, which has been deeply anchored in the genes of our company over the decades, is what we use today to offer our customers the best possible solution. And this applies to the entire portfolio – from mechanical to hydraulic and electronic components. And for each and every one of them, we strive to position ourselves in the market with corresponding unique selling points.

We are part of the group of companies that still attaches great importance to designing machines in such a way that

customers benefit from them and are satisfied. But we can only achieve this, if our innovative components and solutions are in harmony with the technologies of our original equipment manufacturers (OEMs). We must, therefore, ensure that everything we develop fits ideally into the technical strategy of our customers. By offering innovative suggestions for improvement, we support them. In Liebherr's almost 70-year history, we have built up an incredibly extensive expertise, which we wish our customers to share.

For 25 years and in whatever position, I have done nothing other than to understand customers, translate their needs into technical requirements and pass them on to our development departments. At the same time, I have communicated, what design we consider to be the most suitable solution to the customer.

Mr. Schaut, you have been part of Liebherr since 2011. Primarily, thanks to your work in both the operational and strategic areas of the components product segment, you bring valuable experience to your new role as the Commercial Director of Liebherr-Component Technologies AG. How do you see the further development of the product segment? What are your personal wishes for the future of components?
At the moment, I see the further development of the product segment being shaped in particular by the major transformations in drive technology and digitisation. For example, electric drive systems are already being used in a large number of applications. But combustion engines with alternative fuels are also becoming increasingly important alongside conventional diesel engine technology. We are looking for the right solution for each application, with an open approach to technology. For us as a component manufacturer covering the entire powertrain, these technological changes are having a massive impact – not only on our product portfolio, but also on our organisation and the skills we need for the future. A key to success is, therefore, the continuous development of our employees, attractive working conditions and a flexible and agile organisation that works closely together. In this way, we strive to seize the opportunities to continue our growth with these new technologies, to create added value for our customers and to continue to develop constantly.

For the future, I therefore hope that we will be able to successfully master these changes and make the right decisions at the right time together with our motivated employees and partners.

Mr. Schwarz, everyone is talking about alternative drive systems. But they also create a kind of internal competition, namely among the companies involved in the development of traditional technologies, such as internal combustion engines. As Managing Director for development and production, how do you think we will deal with this duality?
That is indeed the case. Nevertheless, we have to look at this issue as a whole. On the one hand, we have a broad product portfolio within the Group that has included electrically driven machines from the very beginning, but also machines that can be converted to alternative drives relatively quickly. On the other hand, there are very different operating conditions and areas, where it is still very challenging to replace combustion engines at the moment. The world is big and the regions diverse, but not nearly as diverse as the operating conditions. We will have to work with fossil fuels for many years to come.

And it is precisely for this reason that we aim to develop these drives even further in a significantly more ecological way. Because the requirements for the reduction of exhaust gases or emissions are what we work on every day. Emissions regulations will continue to tighten in the future, posing a significant challenge to traditional technology. That's why we are being called upon to develop in two directions: firstly, this concerns drives that are completely CO_2-free; and secondly, conventional drives that are significantly more efficient and environmentally friendly. We see ourselves in a position to drive these two developments forward in parallel.

Mr. Iemmi, in addition to alternative drives, people often talk about the megatrend of "digitisation". Do you think we will continue to develop these topics on an equal footing or will alternative drives be more our focus topic?
The areas of digitisation and alternative drives affect some, if not all, component manufacturers. And I believe that not a single company in our industry can afford not to address these issues.

Although the two topics are completely different in some aspects, they have many touch points in some respects. One important aspect, for example, is that our customers are also in a phase of discovery in these areas. So we have to work with them to find possible ways forward, learn from their experience and find suitable solutions. In doing so, however, we must ensure that the additional functions for our components are not developed without aim, but rather precisely according to customer needs – and in such a way that they can be incorporated into the overall architecture of the equipment and machines and thus simplify the work of our customers.

Gebhard Schwarz (adds): The future in the area of digitisation will be characterised by Big Data and knowledge management. This is precisely why digitisation is of great importance. We already know quite a bit about our customer's applications and components today, but by no means everything there is to know. And this is where digitisation provides a solution. We are on a very good path with our developments. We have already prepared the basics for data transmission, storage and, of course, data acquisition. The big challenge, however, is data evaluation, which allows us to develop components that are even more application-specific. This is particularly true of applications and countries, in which our components are used, as well as to additional services, with which we can offer our customers added value. For us, this is a unique opportunity.

Pietro Iemmi (adds): As far as new drive systems are concerned, we have also been building up new competencies in this area for several years. These include combustion and hydrogen engines, electric drive technology, alternative injection and drive concepts, as well as research regarding the use of alternative fuels, such as methanol or ammonia. These are all topics that also affect our OEMs. The environmental aspect plays a key role here. We, therefore, see it as our responsibility to develop the relevant technical expertise to support our customers in the optimal design of their machines.

Unfortunately, today, it is difficult to predict, which future technologies will be needed for the machines of tomorrow. Although there are certain indicators, we still don't know exactly, what the world will look like in ten to twenty years' time in terms of technological achievements. For us, as for many other companies, this means understanding the new developments and driving them forward in different directions.

Mr. Schaut, how do you define the global success of components? What does the success of the product segment look like to you personally?
Success means first of all that we are in demand as a supplier on the market, and that our customers are satisfied with our products. We can also gauge success by the added value that our technologies generate for the Liebherr companies and OEMs.

In addition to these basic prerequisites, a clearly structured product portfolio, lean processes and a global setup of our production and procurement network create the basis for profitable growth.

And last but not least, Mr. Schwarz – you have dedicated your life to components and have done so successfully, loyally and for a very long time. What would you have done, if you were not at Liebherr? What alternatives would you have considered?
It was always my goal to combine technology and business administration in a management position. I am extremely satisfied and happy with my career path. I have a high regard for the Liebherr Group and its family shareholders, who, with their incredible personal commitment, offer the company every opportunity to continue growing. To be able to work in such an environment is a great blessing for me personally. I have also been able to gain some years of experience in companies outside our Group. Today, I am extremely happy and proud that Liebherr has been my home for all these years.

Thank you very much, Mr. Schwarz, Mr. Iemmi and Mr. Schaut for these personal words and the extremely exciting insights into your world of components.

Chapter 1

Innovative product technologies

Hydraulic cylinders at a click of a button

Online shopping has become an indispensable part of everyday life in modern societies. There is hardly anyone on the planet, who does not regularly shop online. Granted, some of us still enjoy a tangible experience, when it comes to buying goods or fashion. But overall, shopping online has offered more than enough advantages to become the most popular way of purchasing the things that we desire. What online shoppers appreciate the most is the fact that shopping can occur anytime, anywhere, regardless of shop opening hours. This does, in fact, sound like a good deal, no pun intended.

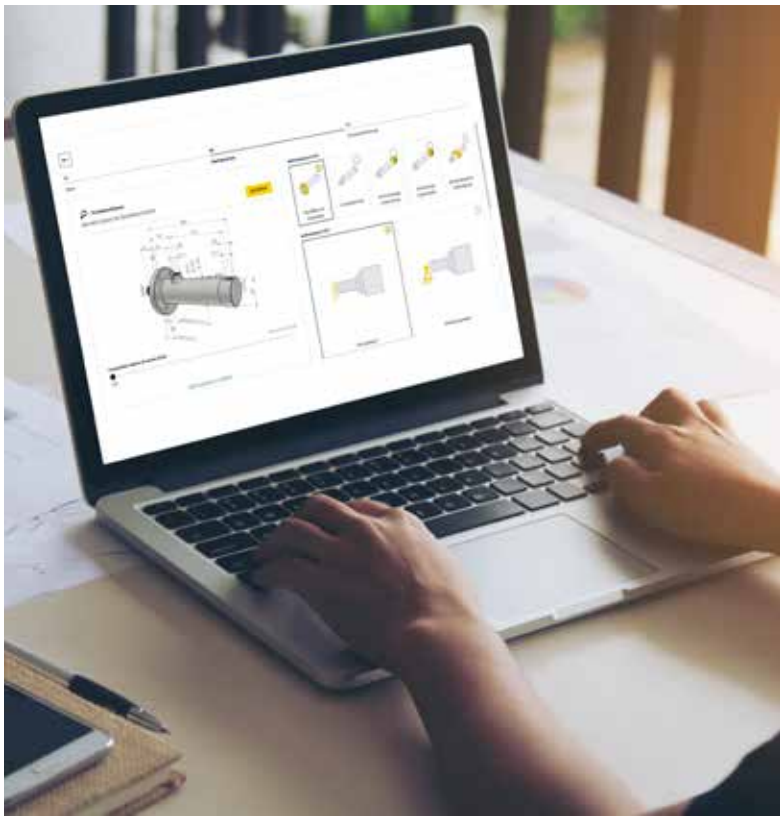
But what, if you could apply that same principle to your demand for hydraulic cylinders of the standard product line? For the first time ever, Liebherr has made it possible to individually and easily customise all hydraulic cylinder series via an online-based configurator on the company's website. Depending on the application and requirements, the configurator offers all kinds of variations: from the 380 bar series for mobile applications or the ISO 6022 series for industrial use all the way to the 260 bar series, as a link between mobile and stationary applications.

The team at Liebherr-Components in Kirchdorf an der Iller (Germany) has been tirelessly working on the development and construction of a standardised series for quite some time. The goal has been to offer customers a versatile selection of easily combinable and modular solutions for a wide range of applications. Now, with the development of an online configurator for options and features, a new milestone in digitalisation has been reached.

Smart solutions to help you pick the right product
Liebherr-Components Kirchdorf GmbH has been pursuing a potential solution to offer support technicians, buyers and product managers, with or without an expertise, a quick and easy way to get their desired product. A corresponding 3D simulation provides users with an actual visual representation of the design. Should needed requirements lie beyond the range of the construction series, corresponding inquiry options are stored, in order to be able to make a special inquiry.
Configuring a design is a completely anonymous process. By means of a self-generating product key, each variation receives its individual "code", which can simply be copied and used for recall. In addition to a clear data sheet, 3D models of the configured cylinder can be downloaded immediately, so that the hydraulic cylinder can be installed directly in the user's application.

Available at any time and any place
The configurator is currently available in two languages, German and English, and can be accessed anywhere in the world at any time via the Liebherr website. In the future, Liebherr intends to add further languages, as well. In addition to hydraulic cylinders, Liebherr has recently started offering piston accumulators as a standardised series, thereby creating the ideal conditions for the integration into the configurator. Moreover, Liebherr has already ventured into the future by offering products of the 380 bar series in the form of a hybrid cylinder as a separate option – i.e. the classic cylinder in combination with carbon fibre-reinforced plastic.

Configurator for hydraulic cylinders



How standardisation creates opportunities

Series production in the hydraulics sector

The term "standardisation" has become an integral part of modern business. No wonder, because the advantages are obvious. Standardisation unifies processes, which directly leads to a higher quality of the designed products. The focus is no longer on a multitude of variants, but rather on the optimisation of the existing parameters, which can also offer customers added value in the long run. In the following interview, Jessica Schwarz and Jan Winter, product managers at Liebherr-Components Kirchdorf GmbH, explain why they are increasingly focusing on standardisation and what advantages customers can benefit from.

Ms. Schwarz, in your opinion, why is standardisation in product management so important?
Standardisation has had a significant impact on our product portfolio. We are continuously working to reduce variance and complexity of different product groups. At the same time, it is key to further optimise the products, in order to meet individual customer requirements at the lowest possible cost and with highest delivery performance.

In doing so, a holistic implementation within the organisation must be taken into account. Our focus is on the optimisation of all internal processes, from order placement all the way to shipping.

The focus is always on the individual customer requirements, which are constantly changing, just like the state of technology. Further requirements arise in terms of digitalisation. The most challenging aspect hereby is to meet constantly shifting customer needs.

You have just mentioned challenges. Are there also challenges in the standardisation process itself? How do you counter these?
Due to constantly changing framework conditions, it is essential to react to the changes with a certain dynamic, and commence development at an early stage. In doing so, we strive not only to take into account latest technological developments, but also to better understand our customers' challenges and to incorporate them into our technical solution. To achieve this, we make use of the synergies within the Liebherr Group, among other things. Our company has always been a pioneer, when it comes to innovation, and that is exactly what we would like to maintain and how we're positioning ourselves for the future.

Jessica Schwarz (Liebherr-Components Kirchdorf GmbH)

How do you think this is beneficial to the customer?
The advantages are, of course, short delivery times, attractive prices, as well as outstanding and consistent quality. In order to guarantee this to a full extent, standardisation acts as the foundation.

Each product in our existing hydraulic cylinder series can nonetheless be individually configured. Here, we already offer a broad portfolio of standardised solutions. A flexible selection is possible at any time, thanks to numerous customisation options.

Mr. Winter, please tell us which series Liebherr-Components Kirchdorf GmbH already offers today?
A total of three product series are available, which are all designed to meet different customer and application requirements.

The hydraulic cylinder series according to ISO 6022 is ideally suited to the needs of customers in the industrial sector, as it is based on the corresponding standard specifications. The 260 bar hydraulic cylinder range is the right choice for applications without extensive additional conditions in mobile and stationary areas. The hydraulic cylinder series 380 bar was designed for use in highly dynamic applications in the mobile sector, such as in construction machinery. All series can be flexibly expanded with numerous options.
Our product ranges are a step in the right direction, which is why we wish to push standardisation for new products, as well. This is why we have expanded our hydraulic cylinder se-

Jan Winter (Liebherr-Components Kirchdorf GmbH)

ries with piston accumulators. The piston accumulator series is available in the pressure ranges of 250 and 350 bar. It can be used flexibly in mobile and stationary applications. In addition, we are also working on various lightweight construction concepts, such as the CRP version of our 380 bar series, as well as other exciting projects.

Ms. Schwarz, what new avenues do you think this opens up in the hydraulics sector?
Despite standardisation, our existing product ranges are characterised by a high degree of flexibility, as numerous options can be individually selected. New paths can be identified, among other things, by our digital product configurator. Even today, you can assemble a hydraulic cylinder within the scope of the three series ranges according to your requirements. Many additional functions, such as a configuration assistant or the creation of a 3D model, round off the features. Furthermore, we guarantee our customers a quote within 24 hours – the service can, of course, also be used via mobile devices.

All future product improvements and new product developments will take into account continuously increasing customer requirements. We have already integrated a lightweight version of a hybrid cylinder. In the near future, the piston accumulator series will also be available in the configurator.

“The focus is always on individual customer requirements, which, like technology, are constantly changing.”

Jessica Schwarz
Product manager at Liebherr-Components Kirchdorf GmbH

“Steeling” the show – hybrids are in fashion

Lightweight construction is considered one of the most important trends in construction machinery and all the way to stationary applications. By reducing weight, a significant amount of added value can be generated in the daily use of any equipment and its application. Contributing to this trend, Liebherr offers its established hydraulic cylinders made of steel and wrapped with CRP. Liebherr will present its hybrid cylinder at Bauma 2022 and offer further insights into future competencies, as well as development opportunities in the fibre composite sector.

For the first time, Liebherr-Components introduced its work in the field of fibre composites at Bauma 2019. In the meantime, the Components site in Kirchdorf an der Iller has not only gathered further expertise and production capabilities, but also worked on transferring this technology into its established hydraulics portfolio product range in the fibre composite area. Even today, following preliminary development and targeted design, all classic hydraulic cylinders can be wrapped with CRP.

Why hybrid cylinders?
Reducing weight is not only increasing efficiency. The advantages of using a lightweight component, such as a hybrid cylinder, varies from application to application. Weight saving can increase operating speeds and payloads, as well as enlarge attachments and booms. In addition, emissions are lowered and fuel consumption is reduced. The basis for overall product improvement, however, is and always will be a close cooperation with customers. By maintaining a close relationship, Liebherr can offer solution-oriented products out of one hand. This is crucial with fibre composites, because the structure and individual DNA of the product are what counts in achieving the desired results.

From hybrid towards full-fledged CRP
Recent research and development efforts were directed towards one common goal: the creation of a full-fledged CRP cylinder. Although there are still a number of steps that have to be taken to achieve said goal, Liebherr is already digging into a variety of merging concepts between steel and fibre composite parts, undertaking tests along the way. The implementation of CRP conversions in conjunction with steel components can also be transferred to other products in the portfolio. In the future, for instance, piston accumulators can also be wound from CRP.

Hydraulic cylinder with CRP wrap

Lightweight construction through hybrid cylinders

How fibre composite helps increase the efficiency of the application

Carbon reinforced plastic (CRP) is a composite material that has increasingly been used in a variety of engineering fields. Although it is known for its use in aerospace application, CRP has been enjoying a growing popularity due to its light-weight and sturdy characteristics. Dominic Gottwald, team leader of the CRP department at Liebherr-Components Kirchdorf GmbH, provides us a unique look behind the scenes of the company's research in CRP, including some exciting technological leaps towards the future of hydraulic cylinders.

Mr Gottwald, what does lightweight construction mean to you and what does it mean from the customer's point of view?
Lightweight construction means more than simply replacing a high density material with one of a lower density. Often, weight can also be saved through clever geometry or design adaptations. Also, lightweight construction isn't necessarily associated with higher costs. The use of materials can be compared to the use of energy: The best material or best energy is the one I don't need or don't have to use in the first place. With metal constructions, one is usually limited to available semi-finished products, or has to design a weight-optimised geometry from a solid material by machining, if forming processes are not possible. This means that components may well be oversized and heavy. With fibre composites (FRC), the actual material is only formed into the component during production, offering many more degrees of geometric freedom, which sometimes make it possible to save entire parts or integrate functions. In addition, there are material-specific advantages, such as higher strength with lowest density. As a matter of fact, these are ideal levers to save weight to the maximum.

There are still many areas, in which lightweight construction is not really considered in the design phase. For customers, lightweight construction is usually a "bonus", if there is no real need for action. In such cases, lightweight construction is often neglected, although, as I have already mentioned, it is not always associated with additional costs.

What challenges do users face today with regard to the possibility of saving weight through clever, intelligent design and material selection?
One challenge is, in fact, the immense choice of materials, be it metals or composites. And for every application and component there is a best suitable material. In order to be able to identify these materials, the corresponding component must be closely examined and its environment must also be taken into consideration.

Each material has its strengths and weaknesses – these need to be understood. With steel and the available high-strength material types, we can design lightweight constructions very well today. Metal simply has the advantage of having been established for a long time. The processing is known and can be applied to new materials with what feels like few adjustments. This is not the case with composites. Although materials, such as glass-fibre reinforced (GRP) or carbon-fibre reinforced (CFRP) plastics are certainly no longer a novelty, there is still room for improvement in respect to what we know of the specifics of handling and processing these materials on a large scale.

What does "away from pure steel, towards fibre composite cylinders" mean to you?
With the vision of building extremely lightweight cylinders, we are taking quite a risk. The hydraulic cylinder itself has not changed significantly for over 115 years (oil hydraulics in 1905). The component still consists of a cylindrical tube and a piston rod. This is highly unlikely to change in the future (laughs). What may change, however, are the materials used. In fact, the design and manufacture of these components with or from fibre composites is something completely different. The entire process is being fully rewritten.

On the way towards a fibre composite cylinder, we go through various development stages, in order to have a grasp on all the adjusting screws in production, as well as the properties in operation. Users also have to be gradually "adjusted" to any special features in operation, service, etc. and develop an understanding for the material.

Why do you think the hybrid cylinder offers a potential solution for this?
As the term hybrid implies, these cylinders consist of different materials, for example, a steel cylinder tube with a reinforcing CRP wrap. With such a construction, the lightweight properties of fibre composites can already be used (to some extent) and weight can be saved without having to deal without the tribological properties of a metallic functional surface. We, thus, have a lightweight cylinder that makes the substitution of a classic steel cylinder relatively easy and usually at marginally higher costs. For me, the hybrid cylinder is not just an intermediate stage towards the full fibre composite cylinder, but rather a good compromise between weight and cost savings, as well as simple implementation.

What benefits can your customers expect from your solutions?
The advantages are always closely tied to the customer application. One of the main advantages will always be weight saving. However, this in turn can lead to a variety of different advantages.

In a dynamic application with a high number of cycles during a working day, for example, this means less weight and mass have to be moved. If I have less mass, I can execute faster movements, require less energy and therefore less fuel. In addition, I may be able to reduce the drive power and use smaller units. But I also have less wear on the moving parts and thus lower service costs.

In addition to the advantages resulting from lightweight construction, a hybrid cylinder can be designed to have certain mechanical properties, like lower elongation. Thus, a cylinder would expand less in operation under internal pressure and have less tendency to require flushing of the piston in the event of overload or overpressure.

Where do you see the opportunity to become more efficient through the use of lightweight construction?
Let's take dynamic applications as an example one more time and look at a material handler. Its task is to move material from A to B all day long. By saving mass, it may be possible for the material handler to perform more handlings in the same amount of time and, thus, have increased efficiency. But even if less energy is needed for the identical quantity to be handled, we're looking at an increase in efficiency.

Would you please tell us what you are currently working on?
As a cylinder manufacturer, logically our focus is on products, such as cylinders and pressure accumulators. Hybrid cylinders are currently designed to absorb tangential stresses only. In the future, however, axial stresses will also be increasingly absorbed by the fibre composite material, so that the proportion of steel can be further reduced. The production of fibre-reinforced piston accumulators will also be a relevant avenue. In addition to all the products from the hydraulics sector, we are also able to manufacture other components with our technology. For example, we already

Dominic Gottwald (Liebherr-Components Kirchdorf GmbH)

“We always strive to offer our customers the best possible solution – fiber composites are another option, especially in terms of weight savings.”

Dominic Gottwald
Head of fiber composites at Liebherr-Components Kirchdorf GmbH

supply torsion shafts, magnetic rotor bandages, as well as profiles and tubes for various purposes in mechanical engineering.

How can users benefit from your hybrid solution?
In order to react to customer needs as specifically as possible, in recent years we have gathered the entire process chain in-house. This means that the products are not only manufactured by us, but also designed and calculated according to the current technologies. This enables us to manufacture cylinders from a few kilos up to two tonnes.

What do you think the application of tomorrow will look like?
One of our current objectives is to act in an energy-saving, resource-conserving and sustainable manner. Lightweight construction is an important pillar in achieving this. Meaning that, if we save weight in our equipment, we also reduce CO_2 emissions. This is where fibre composite cylinders can make a significant contribution.

In the very beginning you mentioned that the use of lightweight construction is not necessarily related to high costs. Could you please elaborate on this in more detail?
The purchase price for a fibre composite cylinder will always be higher than that of a conventional steel cylinder. For a hybrid cylinder, we deal with costs that are 1.2–1.5 times higher. Nevertheless, the cost advantage is only generated in the application. How quickly a payback is achieved depends on the cylinder type and the application. We always strive to offer our customers the best possible solution – fibre composite is another option, especially with regard to weight savings.

Would you say that a pure CRP solution is imaginable in the future?
I don’t think that a full-fledged CRP solution will be feasible. There is an optimal material for every component, meaning that the use of several materials in a hydraulic cylinder is the correct way. Nevertheless, I still see potential for achieving a higher proportion of CRP in our solutions, for example in the design of the piston rod or the cylinder tube.

Pump up the jam with the new LH30VO100

The product line of the new LH30VO medium-pressure series with the well-known nominal sizes of 28, 45 and 85 cm³ has a new member to it – the nominal size of 100 cm³. Upon its development, Liebherr has once again placed major emphasis on scaling the already established and proven technology, as well as the concept of the pump family. The extraordinary design has once again been applied to the new pump: It also makes use of the familiar modular construction kit and embodies the flexibility of the concept.

It consists of eight basic controllers, that can be adapted to any application via numerous combination options. This consistently built modular system includes standard hydraulic-mechanical controllers, such as load sensing with pressure cut-off or power controllers. The Components team has also equipped it with electrically actuated controllers, such as an electric pressure controller or electrically proportional volume flow controllers. A cable break detection is available, if required, making it perfectly suited for a wide range of present and future user requirements.

The variable through drive concept allows the attachment of additional pumps in a tandem. Even when installed, the available through-drive can be used and an additional unit put into operation by attaching another pump. Thereby, breakthrough torques of up to 130 percent are possible. In this way, it optimises logistical processes, reduces inventories and increases product availability.

Furthermore, the modular options open up potential for the use of this product family in numerous applications and markets. Within a very short time, Liebherr has succeeded in developing, testing and industrialising its new nominal size of 100 cm³. In addition, Liebherr has been able to tap into new areas of application with customers in agriculture and forestry, mechanical and plant engineering, special vehicle construction, mining and maritime applications.

The pump's compact design makes the smaller units suitable also for tiny installation spaces, such as power take-offs on diesel engines – tiny causes, major implications.

The new LH30VO100

Our new product development DPVO 550i

A customer‘s perspective

Guillaume Bonnetot is head of the “systems” department at Liebherr-Mining Equipment Colmar SAS (France) and has been with the company since 2002. In the following interview, he provides a behind-the-scenes look at the joint development work of the Components product segment and Liebherr-Mining, which is based in Colmar (France). The two business units jointly designed the new DPVO and DPVO 550i axial piston pumps.

Mr. Bonnetot, what is your specific business area and what is your role in it?
Our customer sector is the mining industry, for which Liebherr-Mining supplies mobile machinery, such as hydraulic excavators, dump trucks and bulldozers, including all related services. As a department head in the systems division, which is tied to the engineering department in Colmar, I am responsible for the entire hydraulic installations, testing and preliminary development. I also manage the hydraulics competence centre for Liebherr-Mining.

What was the reason for you to choose Liebherr’s own hydraulic solutions?
Our machines are always operating under the most extreme working conditions. These include high loads, intense heat, dust, vibration, acceleration, humidity, as well as Arctic conditions. Therefore, our customers have very high expectations in terms of reliability of our machines. This is why it is not possible to find standard components for key parts of the drive system. It is, therefore, essential to develop specific solutions within Liebherr, that meet the high expectations of our application and ensure the operation of our components in the long run.

In which applications do the DPVD 550 and DPVO 550i find their use?
The DPVD550 and DPVO 550i pumps are installed in hydraulic mining excavators with an operating weight of 350 t to 800 t. There, they are used as working pumps in open circuits and provide for movement and power transmission. On our largest machine, for example, a total amount of ten DPVO 550i are responsible for the power transmission of the 3,000 kW, which are supplied by the diesel or electric motors.

Guillaume Bonnetot (Liebherr-Mining Equipment Colmar SAS)

In your opinion, what are the necessary key features of a product, such as the DPVO 550i?
The two main requirements for a hydraulic component in our machines are safety and reliability. The robustness of a component is crucial to largely extend its service life in the application, thus limiting the downtime of our production machines. Due to its design and make, a product, such as the DPVO 550i, must reduce the operating costs of the overall machine to a minimum, while ensuring extremely high availability.

The safety aspect also plays an important role. This includes, for example, simple pump settings, live monitoring of the component condition or, if possible, the avoidance of hydraulic leaks, which could have dramatic consequences.

The ability to refurbish a component is also important in our business. The remanufacturing of components allows to reduce operating costs. Moreover, reusing parts helps to protect the environment. This is why we’re strongly promoting component remanufacturing.

Would you tell us more about how you’ve experienced the joint collaboration with Liebherr Machines Bulle SA and some of the challenges you faced?
Aside from the many technical aspects we faced upon the development of a completely new pump with a flow rate of over 800 l/min, high performance and reliability, the biggest challenge was to ensure that this pump was “designed” in

accordance with the prevalent requirements from the very beginning. In addition, we had to make sure that an actual need of this product would be there before starting with series production. To this end, we conducted a large number of field tests in our machines before going ”live”. For this specific component, our goal was to achieve the highest possible satisfaction rate with our customers.
As far as the cooperation with Liebherr Machines Bulle is concerned, it has exceeded all expectations on our end. And even-though it was a challenging process, the end result really speaks for itself. Due to the initially set common goal, we were able to create and deliver a well-engineered product.

Is there anything you would wish to improve going forward?
The long-term efforts that both of our companies brought to the table eventually paid off, although we all would have wished to go through the validation phase faster. Nevertheless, no bench test can replace actual trials in the field. Therefore, they are a necessary step to gain factual experience during real operation under the harshest conditions.

Are there essential product features that you’re currently missing in today’s marketplace? And do you see them fulfilled with your product?
Absolutely! Designing products that are second to none in terms of robustness has always been one of our most dominant aims in all our endeavours. Being able to provide durable products in all aspects of operation has always come first. With our newest pumps we do, in fact, believe that we have been able to set new standards with regard to robustness and tightness of the pumps.

What specific product features, do you think, will play an increasingly important role in the future?
An essential factor in mining applications is to increase the uptime of a machine. Therefore, by reducing maintenance intervals, up-time can be increased. Our pumps have been designed in such a way that they allow the implementation of condition monitoring. By applying such digital tools, only the necessary maintenance work is carried out. Also, issue detection times during operation will be reduced.

What was your personal highlight in the project? Is there a particularly exciting, curious or funny occurrence that has stayed in your memory?
There were indeed many highlights during this exciting development period. Two of them, which speak for the excellent cooperation between our teams in France and Switzerland, are particularly memorable to me:

As the first pump was commissioned in a coal mine during a field test in Indonesia, the installation went smoothly, until they tried to start the diesel engine. The customer had given us a few hours to complete the installation and get the machine moving again. However, it took us a lot longer to figure out, why the engine wasn’t starting than installing the actual pump. As you can imagine, we were all relieved once we were able to hand over the functioning machine to the customer late at night. Months of preparation could have been rendered worthless, all due to a 10-dollar sensor. For the Liebherr team from Bulle, this was the first time that they had ever been in a mine. And you can be sure that this experience will never be forgotten.

Another highlight was the fact that we were able to achieve the set number of operating hours in the mining excavator. Although it was “only” the first pump to successfully complete such a test, the result was a welcome reward for the years of development work. It was indeed an important milestone for all colleagues involved in the development process.

How do you see the future cooperation with Liebherr Machines Bulle SA?
Liebherr Machines Bulle SA is and will remain our most important partner for hydraulic products. There is still a lot of potential in hydraulics to further increase performance and reliability. Having gathered a variety of invaluable data, we are still in the process of learning from our components in order to reduce energy consumption further. A tight knit cooperation between OEMs and component or system manufacturers is essential for the improvement of all our products. Our joint project is a testament to that. This is why we look forward to realising a whole slew of promising projects together with Liebherr Machines Bulle SA, ideally with regard to the successors of the DPVD550 and DPVO550i pumps.

Chapter 2

Alternative drive concepts

Hydrogen – the future of combustion engines

In the future, combustion engines will no longer be powered solely by fossil diesel. To enable climate neutrality, energy carriers from renewable energies or sustainable energy sources will have to be used, for example, e-fuels or green hydrogen. The possibility of burning hydrogen directly in the engine is one of the fastest ways to power mobile off-highway vehicles in a wide range of applications in a CO_2-neutral way.

In an interview, the management of the two Liebherr-Components sites involved into the development of CO_2 neutral solutions offer insights into their vision of the topic under discussion.

Ulrich Weiss is Managing Technical Director at Liebherr Machines Bulle SA (Switzerland), where hydraulic components, splitter boxes and combustion engines are developed and produced. These components and systems have proven their worth successfully both in Liebherr equipment and that of OEMs. Richard Pirkl is Managing Director for Technology and Development at Liebherr-Components Deggendorf GmbH (Germany), where approximately 500 employees develop and produce single components and system solutions for fuel injection equipment.

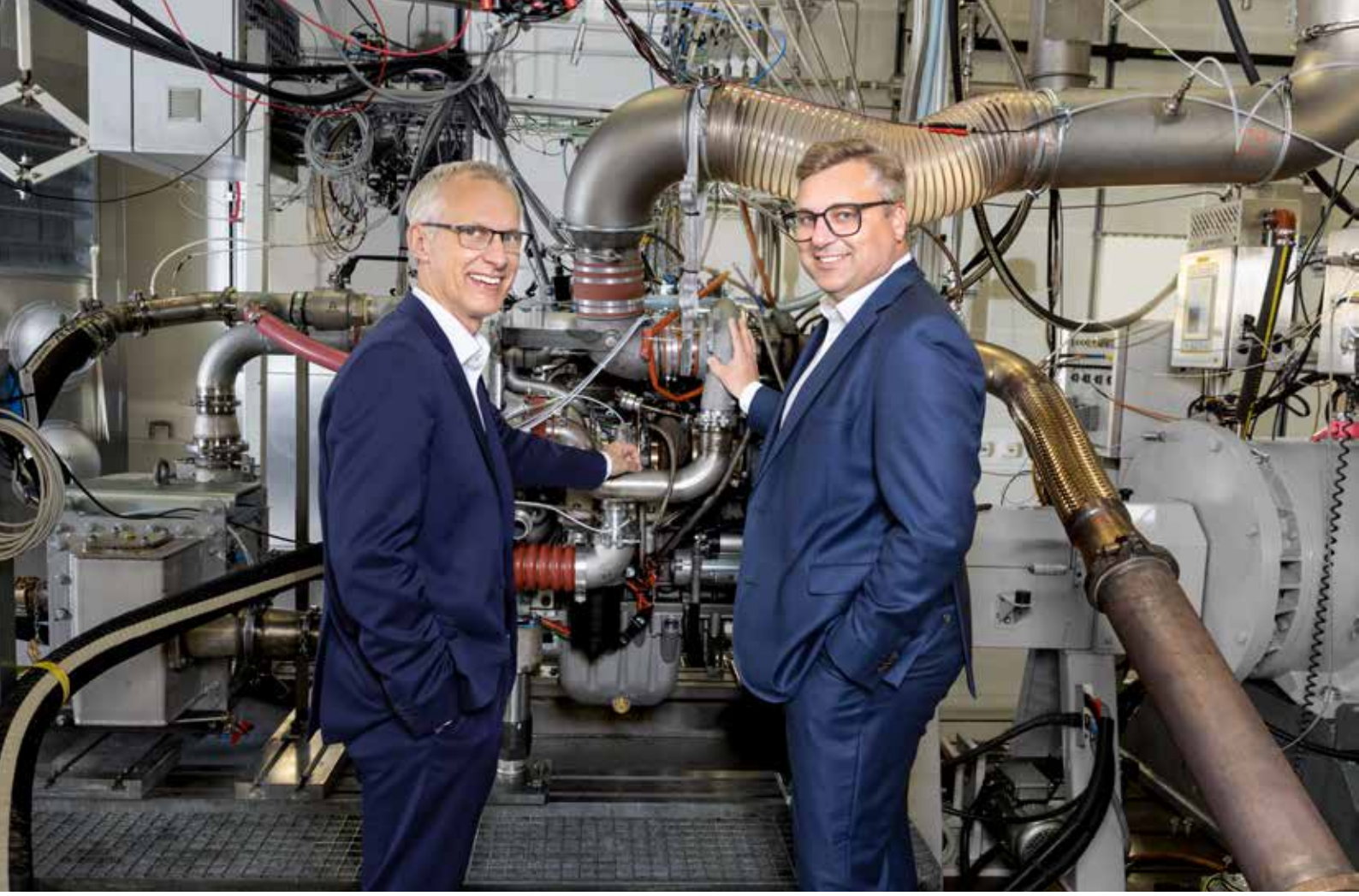
Liebherr Machines Bulle SA and Liebherr-Components Deggendorf GmbH work together to develop and produce high-quality internal combustion engines equipped with Liebherr injection systems. In the frame of this collaboration, the companies tackle the CO_2 neutrality challenge the world is currently facing. Hydrogen internal combustion engines (ICEs) are among the solutions to cope with it.

Mr. Weiss, to begin with, could you please explain why you believe that ICE will remain a solution for heavy mobile off-highway vehicles?
From our engine manufacturer point of view, the internal combustion engine is the only possible way for the generation of high mechanical power under extreme operating conditions in the off-highway industry today. These are, for example, high and low humidity, high altitude, dusty air, high shocks and vibration levels. From today's perspective, other powertrain solutions, such as fuel cells or electric batteries are not able to operate efficiently and reliably under these typical off-road working conditions.

Thus, we are convinced that the internal combustion engine will remain the drive solution here. In terms of pollution, the internal combustion engine as such is not the challenge – the fuel and the emissions it causes upon combustion are. The challenge then is to find the right fuel and to adapt the engine in a way that the fuel can be burned free of emissions.

Which fuel would you then see as CO_2 neutral and why?
We do not exclusively focus our research and development activities on one single fuel solution, as we believe that multiple solutions will work in the future, depending on factors that differ from one industry and application to another. Hy

From left to right: Richard Pirkl and Ulrich Weiss



drogen is one of the options, since it is a promising carbon-free fuel. It can burn inside the internal combustion engine without causing CO_2 emissions. Therefore, our expertise in the ICE development and industrialisation will allow us to introduce hydrogen technologies quickly to the market without excessive risks.

Would you please tell us more about the current development status of your hydrogen engines?
Liebherr has made a significant investment into the development of its hydrogen engine and test facilities recently. We have been putting our prototype engines to the test since 2020. They provide promising results in terms of performance and emissions. Different injection and combustion technologies, such as port fuel injection (PFI) and direct injection (DI), have been examined thereby. First prototype machines equipped with these solutions have been running since 2021. In the coming three years, we plan to further develop and validate the adaptations necessary for the engine to run efficiently on hydrogen, like a new turbocharger, an ignition system or an exhaust gas recirculation system, for example. We expect to start with the series production of hydrogen engines by 2025.

Mr. Pirkl, you are the expert in fuel injection. What are the differences between the afore mentioned combustion concepts?
In case of PFI, hydrogen is injected directly into the intake system, which is designed for injection pressures lower than 20 bar. The injector used for this kind of injection is exposed to a simpler and less aggressive environment outside the combustion chamber. This means that it has to withstand lower temperatures and pressures, which makes it easier to design. In addition, the mixing process in the intake manifold is significantly more uniform, which results in lower nitrogen oxide emissions. One argument against intake manifold injection, however, is lower power output and slower engine transient response as compared to diesel and hydrogen direct injection.

Hydrogen low-pressure direct injection (LPDI) takes place at pressures below 60 bar directly in the cylinder, that is, inside the combustion chamber. This results in a power density similar to that of the diesel engine. When installed in the combustion chamber, the injector is naturally exposed to higher temperatures and pressures, which makes the component highly complex in its design and requirements. As compared to PFI, uniform mixture formation in the cylinder is more complex than the injection in case of intake manifold. In our view, the LPDI process is ideal for dynamic applications that require high engine power density and have a limited engine installation space. Mobile construction machinery is one good example of this.

What are, in your opinion, the biggest challenges of hydrogen injection?
The biggest challenges in the development of a hydrogen injection system for internal combustion engines are different combustion processes and hydrogen behaviour. While diesel is injected into the engine in liquid form and acts as a lubricant for the moving control components in the injector as well, gaseous hydrogen, with no lubricating properties, is

blown into the combustion chamber by a special valve. Therefore, a hydrogen injector needs to be designed in a way to ensure gas-tight injection. Keeping abrasion among the control components to a minimum is in this case the most critical factor. However, our hydrogen components run without additional lubricants thanks to their special design. The hydrogen injector also needs to be particularly gas-tight, since leakage may occur. This is the challenge, when working with hydrogen, since it is the element with the smallest atomic mass. Therefore, it is able to escape even through the tiniest gaps. To prevent this from happening, we use special state-of-the-art materials and material combinations that guarantee maximum hydrogen tightness.

What is then unique about Liebherr's solution?
To begin with, components by Liebherr have a long history, having proven themselves already in Liebherr machines and applications. This is also true of our hydrogen engine and the injection system. So, our high quality and innovation spirit lie at the core.

From the very start, our components for the hydrogen injection system have been developed exclusively for this type of fuel. This means that no lubricating oil is required for the smooth operation of our H2 injectors, which is not the case for diesel injectors. This allows us to avoid undesired contamination of the hydrogen in the injector and to ensure a clean combustion.

Although most customers require pressures of 15 to 30 bar in the LPDI process, we have decided to design the LPDI injector in a way that it can be reliably operated at pressures of up to 60 bar. In doing so, the injector offers a high degree of flexibility in terms of application.

Mr. Pirkl and Mr. Weiss, where do Liebherr-Components see the application for H2 combustion engines?
It is everywhere, where batteries or fuel cells reach their limits. These are the applications, in which the engine is exposed to strong vibrations or a lot of dust and dirt that could contaminate the hydrogen or the air. From our point of view, these are mainly mobile construction machines, like a wheel loader, or heavy-duty commercial vehicles, such as special municipal refuse collection vehicles. In our opinion, it also makes sense to use it in rail traffic or smaller maritime applications, as harbour tugs. In these areas, logistics and operating range are particularly easy to calculate. With rail, for example, the infrastructure is simple. You always know where a train is going to and how long a journey will take. This makes the use and consumption of hydrogen very easy to plan. The infrastructure is also an argument for coastal marine applications, assuming that hydrogen will be delivered through ports in the future.

Ulrich Weiss (adds): Indeed, the supply of hydrogen is important to be mentioned. The energy has to reach the machine and not the other way around. In future, we will also need solutions for workplaces without infrastructure. If I may add to Mr. Pirkl's answer, another application I could think about here would be power generation for data centres, for instance. Hydrogen production units could be installed very close to the engines. In doing so, potential leaks could be minimised, and huge energy consumption required for the delivery of hydrogen from the production unit to the point, where it will burn, avoided.

"We do not focus our research and development activities exclusively on a single fuel solution, as we believe that there will be several solutions in the future."

Ulrich Weiss
Director Liebherr Machines Bulle SA

H2 direct injection for a cleaner tomorrow

Since the industrial revolution, which introduced a widespread change in manufacturing processes across the world, mankind has been relying on fossil fuels for many aspects of everyday life. Over the span of more than a century, fossil fuels have been used to fuel vehicles, provide heating for homes and help fulfil all our culinary needs.

However, our dependence on oil, coal and natural gas has also become an imminent threat to the global ecosystem and human health. This is why, despite of the domination of fossil fuels, a variety of legislative strategies have been implemented worldwide to facilitate the deployment of alternative energy sources.

For many years, hydrogen has been considered to be a promising alternative to fossil fuels, as it is able to eliminate carbon-based emissions, whilst achieving high energy efficiency. In addition, hydrogen can be produced from renewable energy sources.

H2 direct injection: challenges and solutions

Wanting to contribute to a much safer environment in line with current energy trends, Liebherr has been focusing on the development of a wide range of technologies to accommodate hydrogen as a fuel of the future. One of said technologies is now being researched at the Liebherr-Components Deggendorf GmbH (Germany), home of the fuel injection systems. Currently in sample stage, Liebherr is undertaking tests of H2 fuel injectors and complete injection systems for their ability to operate safely and accurately in direct injection (DI) applications. The higher injection pressure and the exposure to combustion pressures and temperatures lead to greater requirements on the injector tightness and durability. So far, Liebherr has been able to display very promising results of their current injector concept and is, therefore, planning to further pursue its concept.

The asymmetrical geometry of the diffuser caps allows a wide variety of injection angles.

Injection system with pressure control

Using a system-oriented approach to hydrogen injection, the aim is to match the performance of an H2 DI engine to that of a diesel engine. This requires any system to be capable of ensuring high flow rates. Due to the low density of hydrogen gas, an injector needs large valve cross-sections. To enable a precise control of even the smallest quantities, the system pressure must be regulated with pinpoint accuracy. In Liebherr's hydrogen injection system, this is achieved by means of a gas volume control valve. In conjunction with other pressure- and flow-regulating components, the result is a system-oriented approach to hydrogen injection. In addition to its direct injection activities, Liebherr is working in parallel on intake manifold injection components to meet different engine requirements.

H2 injector with axial or radial inlets

Construction site of the future

The Liduro Power Port – mobile energy storage system for local emission-free supply of construction sites

It is yet still unclear, whether and when the construction sites of the future will be operated with autonomously moving machines and robots. However, one thing is for certain: Electrification and digitalisation are both advancing at a great pace, driven by efficiency-enhancing technologies and global developments in climate, politics and safety. So let's take a look at how Liebherr approaches these developments and drives said technologies forward.

Reduction of emissions
In order to meet local, national and global climate goals by reducing emissions, construction sites will most likely see an increasing need for further electrification in the coming years. Currently, a significant portion of total emissions in cities, such as engine noise, particulate matter, CO_2 and others (NOx, SOx) are still primarily caused not only by mobile machinery, but also by diesel generators. To achieve a reduction of emissions, Liebherr engineers are developing the most efficient solutions for hybrid and fully electric drives and energy storage systems. Power electronics, motors and gear units are designed to achieve maximum performance in the smallest possible installation space.

Mobile energy storage systems
In the future, hybrid or fully electric construction machinery and vehicle fleets will cause a significantly higher demand for electrical energy on inner-city and peripherally located construction sites. In order to meet this ever-growing energy demand with higher efficiency – especially on construction sites with limited or no power supply – Liebherr is developing mobile energy storage systems. Electrified machines, such as cranes, excavators and wheel loaders can be operated or charged locally without causing emissions via the battery-based energy storage units.
The most challenging aspect on fully electrified or hybrid-powered construction sites is the operation of machines at maximum power, charging of all machines during break periods or smoothing out power peaks on sites with limited grid supply. Liebherr is devoted to meet these challenges by developing energy storage systems with the highest power density, efficiency and quality.

Energy source requirements
Among the many challenges construction sites or fleet operators will face in the coming years will be the allocation of expected energy requirements of their vehicles, as well as setting up the electrical energy supply for different types of construction sites and infrastructures.

As a manufacturer of construction machinery, Liebherr is ready to offer its customers professional support in planning a framework for the energy supply. Using its internal expertise in the electrification of construction machinery, Liebherr has developed tools to calculate exact energy requirements of customer-specific machine fleets.

Peak shaving
Many construction sites have limited and sometimes no access to power grids. In order to absorb the power peaks of the machines, energy storage systems can be used to match the power profiles of the machines or a specific construction site. An energy storage system can supplement an insufficient grid connection or be used as an "island grid", that is when no grid connection is available.

Energy efficiency
High load peaks and longer periods of very low power demand, for example, when operating computers or small machines, are typical for construction sites. A mobile (electrical) energy storage system provides power without surplus and waste. Unlike diesel generators, which produce power at a given level regardless of the actual power demand per second, an energy storage system can be operated at maximum efficiency.

Cleaner, quieter, safer – electric!

The benefits of electric construction machinery are not limited to decreasing harmful climate gases. Fatigue-free work, savings in fuel costs and advantages in contracting increase the interest of users. A rethinking is also underway in the construction industry. However, the basic prerequisite is that the performance of electric machines is comparable to that of well-established combustion engines. Is that possible? And if so, how? Potential choices include electro-hydraulic and all-electric concepts, holding different advantages. Liebherr-Components supports both with suitable travel drive components.

The goal is clear: The EU aims towards becoming climate neutral by 2050. To achieve this, it will reduce its net CO_2 emissions by 100 percent. Most countries in Asia and America are also pursuing similar strategies. In the Paris Agreement on climate protection, 195 countries have set themselves the goal of drastically reducing greenhouse gas emissions by 2050. The mobility sector is playing a pioneering role in this. In the automotive industry, the shift from fossil fuels to electric drive concepts has long been underway. Now other sectors and applications are coming into focus. The construction industry is a major factor here: According to estimates, it is responsible for around 35 percent of global energy consumption and for more than half of the emissions of climate-damaging gases. Savings in the production of building materials, but also in the use of machinery in civil engineering, loading and transport can make a significant contribution to achieving climate targets. But can something, which succeeds in a small e-car, also be transferred to heavy construction machinery and off-highway applications? “Yes, it can – and we’re already doing it,” explains Falk Nübel, Project Manager for Crawler Crane Development at Liebherr in Nenzing (Austria). Recently, the Drive Technology business unit at Liebherr-Components in Biberach (Germany) and the ´ product development department in Nenzing have successfully electrified machines for heavy-duty applications, such as drilling rigs and crawler cranes. “We are no longer talking about a distant future here. Our machines are already standing out on numerous construction sites and in different countries in daily use by our customers.” It is apparent that the changeover brings several advantages at once: “One important side effect is the considerable reduction of noise on the construction sites. The machine operators perceive this as a real gain and an additional safety factor,” Nübel sets forth.

Crawler cranes and drilling rigs “unplugged”

The team at Liebherr in Nenzing started its development efforts towards electrification quite early on and presented the first battery-powered rotary drilling rig at Bauma 2019. That same year, Oslo became the environmental capital of Europe and accelerated the trend even further with the requirements resulting out of it. At that time, the first customers from the north approached Liebherr and expressed their interest in electrically driven, heavy construction machinery. After all, the Norwegian capital strives to become fossil-free by 2050 – cutting its emissions from fossil fuels by half by 2030. Since then, the motto has been ‘local zero emission’, and the requirements for emission protection on construction sites are already correspondingly high. Other cities, such as London, Lucerne and Hong Kong, as well as countries like Sweden or Finland wish to follow suite. In Norway, the first battery-electric Liebherr crawler crane was then used by Kynningsrud Nordic Crane AS in November 2020. And many more followed. Liebherr now offers the LB 16 unplugged electrified drill rig, as well as four crawler cranes: starting with the 130t LR 1130.1 unplugged crane, through the LR 1160.1 unplugged and LR 1200.1 unplugged to the 250t LR 1250.1 unplugged. The LB 25 and LB 30 drilling rigs and the LRH 100 pile-driving rig in the unplugged version represent a continuous expansion of the unplugged models.

HDD drilling rig (horizontal directional drilling)

Liebherr runs electro-hydraulic

In its current machines, Liebherr relies on a battery-electric drive system with a hydraulic power distribution into the "turn, travel and lift" functions. This means that a battery-powered electric motor supplies the necessary power, which is converted hydraulically – as is the case with conventional variants with combustion engines. Falk Nübel explains the advantages: "The electro-hydraulic drive is compatible with the existing equipment, so that all functionalities can be further used. In addition, the machines exhibit a familiar travel and control behaviour. Operation is, therefore, the same as before, which simplifies the changeover. From our point of view, however, the most important thing is that with the electro-hydraulic drive we achieve the common high reliability and performance without any loss of performance, while at the same time reaching the desired goal of "zero emissions" and a significant reduction in noise. Our customers even report that the control and positioning accuracy of the crawler cranes is much more sensitive." And there are other pluses for crane operators: "Crawler cranes often have to wait in idle mode during the day, sometimes up to 60 to 70 percent of their operating time. With a diesel drive, the engine is usually running constantly during this time, but not with an electric drive. For the driver, this is an added benefit: On the one hand, the machine is quieter and also less tiring due to the lower vibrations, and on the other hand, energy consumption is significantly reduced."

STREICHER is betting on all-electric

Noise reduction of electric machines is also an important aspect for Boris Böhm, responsible for Business Development & Equipment at MAX STREICHER, which should not be underestimated: "Our drillers say that they are much less tired after a working day with our new all-electric HDD (horizontal directional drilling) rig than before. Noise means stress and the lower noise level in the construction site environment is perceived as an important contribution to occupational safety by

Boris Böhm (MAX STREICHER)

our employees." Among other things, the STREICHER Group is active in pipeline construction and, at the same time, offers the necessary technology needed as a machine manufacturer. The new HDD drilling rig by STREICHER relies on a fully electric drive without hydraulics. "Since we were able to tackle a new design from the ground up, we decided right away to consciously go for an all-electric solution," explains Boris Böhm. Liebherr has been viewed as a competent system supplier. "We need a partner who is open to new developments. And we did not want to use a special design, but rather apply standard components. This is important for subsequent support, spare parts logistics and cost-effectiveness. Liebherr already had all the solutions and components we needed. In the long run, Liebherr's international support will also help us use our machines worldwide." With the new HDD unit, STREICHER is taking full advantage of the possibilities offered by the all-electric drive. For example, according to Anja Leitsch, responsible for product management, reaction times are shorter than those of diesel-hydraulics: "The power is applied directly at the front, and we are much faster, when drilling. This results in a new, different drilling experience. Those who are open to it, will be able to feel the charm." For the STREICHER Group, therefore, the future is definitely electric. In the meantime, STREICHER has even introduced its own "ecotec" label for its machines. Under ecotec, only sustainable and future-oriented applications are built in the Equipment Technology division at STREICHER. "We see more and more tenders that reward sustainability aspects and where, for example, the use of electric machines is preferable. Construction companies that adapt have clear advantages, when it comes to being awarded contracts."

Installation space, speed and torque transmission – gearbox development is in full swing

The transmission specialists of the Liebherr team in Biberach also see no restrictions in the use of an electric drive in said cases. The experts supply the components that are installed in the crawler cranes at Liebherr in Nenzing or in the drilling rigs at STREICHER. Their task is to implement the required performance with travel drives. Matthias Kiebler, Predevelopment and Innovation Manager, sees different paths to the same goal: "Electrification is progressing rapidly, and will be pushed even further with the bottlenecks and rising costs of fossil fuels. We will certainly see many different types of drive systems in the coming years – electro-hydraulic, all-electric and hybrid solutions with diesel or hydrogen engines. The challenge for machine manufacturers is to decide, whether to adapt existing models to new drive concepts or to completely redesign them. Since a new design requires time and experience, the adaptations will predominate in the short and medium term. For us as a component manufacturer, this means that we have to meet new requirements with the same installation space." In this context, Liebherr drive technology must be able to offer suitable gearbox solutions for a wide variety of applications and also constantly meet new challenges of tight installation space, high speed, high torque density, best efficiency. For Falk Nübel at Liebherr in Nenzing, the main requirements for the travel drives were also compact and lightweight. "It is important that the components can be easily integrated into the machine, while staying within the permissible transport weight range – and of course maintain their reliability." Norbert Hausladen, lead engineer at Liebherr in Biberach, believes it is important to always keep the application in mind: "After all, we are not involved in racing, where a machine is immediately serviced again after a two-hour operation. Our travel drives have to reliably operate in harsh environments and under all conceivable climatic conditions worldwide and permanently – from -50°C to blistering heat, in rain, snow and ice – which is why we must not design them to be too complex and delicate."

But the drive technology team in Biberach expects further requests from customers in the future. Thorsten Pohl, Sales Manager at Liebherr Drive Technology, says: "A major cost advantage of electric drives is their low maintenance requirements. Here, expectations of gearboxes will also grow accordingly in the future." An important argument also shared by Maximilian Apfelbeck, Head of Electrical Engineering at STREICHER: "Low maintenance effort is also a decisive criterion for us, as our machines are used a lot in terrain that is difficult to access." And noise development will certainly become more of an issue in the future. After all, once the engine noise is gone, you can hear the transmission. "Basically, all the issues are already on the table – we just can't tell yet, which one will come up next," says Frowin Wack, Head of Drive Technology Development at Liebherr in Biberach. "What is certain, however, is that there will be more approaches to solutions in the coming years." That is why product development in Biberach looks at a wide variety of drive scenarios, in order to be prepared for future requirements.

Falk Nübel (Liebherr-Werk Nenzing GmbH)

Electrified crawler crane

Wind-assisted propulsion

Harnessing the power of the wind

Trade arteries of the world
According to the International Maritime Organisation (IMO), around 90% of all global trade today is handled via commercial shipping. And the demand for global freight is constantly on the rise, leading to more opportunities for business but an increase in challenges, when it comes to the environment.[1] Ocean shipping makes out 3% of total greenhouse emissions, but according to the IMO, this number could triple by 2050.[2] Most mega-ships still rely on heavy oil as fuel. Burning it not only produces carbon dioxide, but also emits sulphur dioxide, which is harmful to the environment. To reduce the impact on ecosystems worldwide, ships in certain regions are required to use fuel with a 0.1% sulphur content limit or apply gas-cleaning systems (gas scrubbers) to minimise sulphur dioxide emissions.[3] Retrofitting ships or using alternative fuels, however, impose steep economic challenges on shipping companies. One possible solution would be to harness the power of the wind.

Unlimited power
One thing that the oceans provide in unlimited amounts is wind. It is freely accessible and above all, it is environmentally friendly. Engineers at Liebherr have been working on a solution to harness the power of the wind for clean energy shipping, which includes two essential components: a slewing bearing and a gearbox. The overall design of wind-assisted propulsion consists of high, futuristic-looking sails that turn towards the wind, adding more push to conventional ship propulsion provided by diesel engines. The technology directly converts wind into power to propel a wide variety of vessels, such as bulk carriers, and thus ensures the reduction of fuel costs by up to 30% without losing speed.

Applying maritime expertise
In the development of components, Liebherr taps into decades of experience in the production of offshore cranes and wind turbines, or more precisely blade bearings. In order to better understand the forces on high seas and implement said learnings into the production of components, Liebherr has created its own dedicated tool. The slewing bearings and gearboxes, which are responsible for the turning of the sails in the wind, can thus be optimally designed. To prevent salt water from penetrating the bearing and grease from leaking out, Liebherr has developed special sealing systems in the slewing bearings for offshore applications, which ensure safety during seawater operation. The double sealing system consists of two sealing lips: While the first protects against coarse dirt, the second prevents the intrusion of contaminants. Thus, the double seal hinders seawater from entering the raceway system and avoids major damage to the slewing

Wind-assisted propulsion: the perfect interplay of Liebherr components ensures optimum use of wind as a resource.

bearing. In addition, the maritime CX coating according to DIN EN ISO 12944 ensures that the surface of the slewing bearing remains resistant to seawater.

The gearboxes with lubrication pinion comes with an optional tooth safety geometry. This inhibits the gear from jamming, and thus protects the entire system – the slewing bearing and the gearbox – from major damage.

Going where the wind blows

To collect the wind and its power in full, the sails must be able to turn in the right direction. This is where the electric adjustment system by Liebherr comes into play. As a pre-assembled module, the components underneath the sail work together in aligning the sails. In the process, a higher-level control system submits a specific value for rotation to the sails. The Liebherr electric adjustment system then implements this rotation along with a target/ actual value comparison.

An integrated position detection and monitoring system handles the constant target/ actual comparison of the rotation. In addition, a lubrication system is built into the module. Regulated via the control cabinet, the system triggers appropriate lubrication intervals for the bearing raceway, the gearing and the pinions. The module is offered as a plug-and-play solution. As it is completely pre-assembled, it can be deployed extremely quickly, rendering the assembly of the gearbox or the adjustment of the tooth-flank backlash, for example, obsolete.

[1] Source: https://www.imo.org/en/OurWork/Environment/Pages/Default.aspx 20.06.2022

[2] Source: https://www.theoceanbird.com/the-oceanbird-concept/ 20.06.2022

[3] Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx 20.06.2022

All-in-one: The electric adjustment system consists of slewing bearings, gears, electric motors, control and power electronics, lubrication system and position sensing.

Chapter 3

Digitali-sation

Reading the pulse of components

Digital clearance monitoring for slewing bearings

Digitalisation is considered to be one of the most promising megatrends of our time. No wonder that throughout so many sectors worldwide, it has become a buzzword, which simply can't be ignored. In recent years, umpteen companies have introduced noteworthy innovations in the field of digitalisation. Although it is not a brand new term by any means, the amount of explorable opportunities, that digitalisation holds, are nearly endless. Through new information technologies and digital data, new solutions and business models have been developed to face the challenges users worldwide see themselves confronted with.

And Liebherr has been working tirelessly to stay one step ahead in the digital transformation of existing technologies to make them fulfil an increasingly demanding marketplace. In the research process, one key aspect has always taken centre stage: the ability to understand and read components during their life cycle. This, in turn, allows further design improvements for future applications of components and ensures the supply of state-of-the-art products.

Reading the pulse of slewing bearings
The bearing clearance monitoring (BCM) by Liebherr is a digital condition monitoring for slewing bearings, which is ideal for use in various applications, from mining and material handling up to maritime equipment. The BCM can be used to measure bearing wear in axial and radial directions, as well as tilting clearance. Such a digital system does not only ensure flexibility in measurement, but also reduced downtime, lower costs in maintenance and, above all, increased protection of personnel.

The focus of digital clearance maintenance lies on personnel safety. Since the measuring devices are already permanently installed on the bearing, service technicians will not have to mount dial gauges or other measuring devices directly onto the slewing bearing in dangerous areas under the excavator or other machines. An additional advantage is the fact that measurements can be carried out at any time autonomously, without the help of external service providers.

Efficient and safe maintenance: digital wear measurement for slewing bearings

BCM in action

The sensor connection box receives data from the sensors attached to the slewing bearing and supplies the entire BCM system with power. The gateway stores all sensor data and updates them for the BCM. This allows for an autonomous usage of the system, even in regions without data connection. This might be the case in mines, for example, as these often lack the necessary mobile coverage to establish a proper connection. Via Bluetooth the measurement process is possible from a safe distance and without any additional network.

Slewing bearing with a sensor

Liebherr bearing clearance monitoring system

Safety through digitalisation

How bearing clearance monitoring provides more safety and reduces costs at the same time

With the help of intelligent components equipped with sensors, applications can be maintained with maximum efficiency. In addition to solutions for measuring the operating temperature and water content in various devices, bearing clearance monitoring (BCM) is among the latest innovations in Liebherr's Components product segment. In an insightful interview, Wolfram Halder, product manager for slewing bearings, explains why Liebherr's new BCM solution increases safety around applications, for example on construction sites, whilst at the same time boosting efficiency.

Mr. Halder, what is bearing clearance monitoring and where does it come in handy?
Bearing clearance monitoring stands for a digital wear measurement technology for slewing bearings. We have developed it mainly for mining, material handling and maritime applications. Our system accurately and reliably measures the wear of slewing bearings by means of permanently integrated sensors. It is possible to control all measurements via a mobile terminal or a BUS interface, for example in an excavator, and have them displayed on a monitor.

The installed sensors transfer measured values to the sensor connection box, which is mounted in a protected place on the device. The measured values are then sent to the gateway, from where they can further be viewed, processed and analysed. This is all done by our specially developed app.

Our bearing clearance monitoring does not only facilitate the measurement of wear, it also increases the measurement speed at the same time. Digital measurement only takes 15 to 30 minutes as compared to analogue measurements, which take up to three hours, as the dial gauge has to be installed manually. In addition, thanks to our newly developed system, personnel are no longer required to enter the danger zone of the machine.

Furthermore, it is easy to transfer updates upon bearing clearance monitoring. The firmware of the gateway can be updated conveniently via a mobile device. A dedicated message on the app informs users that updates are available. These can then be loaded onto the gateway during the next measurement.

Would you please tell us how the idea for the product came about?
We know that our customers have high costs and require a great deal of time to measure the wear of slewing bearings. This is why we have developed the BCM system, as it has been our aim to increase the benefit for our customers and help them achieve a maximum yield with their equipment. With the help of our BCM, maintenance and replacement of slewing bearings can be predicted, which, in turn, increases the service life of the equipment.

And what does your business unit expect to gain from this?
With the new system, we include intelligent components into our slewing bearings portfolio, and thus take an important step towards digitalisation. On the one hand, we expect an even closer cooperation with our existing customers. On the other hand, we also wish to win over new customers, who recognise and appreciate the benefits of our bearing clearance monitoring system.

How long did it take to develop the BCM?
We have invested a total of two years in product development.

In your opinion, what makes the BCM so safe?
As mentioned before, the integrated sensors allow wear measurement from outside the machine's danger zone, all from within our app. In addition, there is no need to involve external measurement service providers.

Our system also supports in maintenance planning and proactively safeguards against failures. Machine maintenance schedules always require measurements to be taken at regular intervals. These measurements help to identify, what the condition of a bearing is, whether it needs to be replaced or whether further measures are necessary to maintain the bearing. One of these measures would be, for example, to lubricate the bearing. If it does indeed need to be replaced, actions can be initiated at an early stage. If a bearing is used over the clearance limit, the adjacent construction of the unit can also suffer. If a new bearing is then installed, it can be affected by the adjacent construction, which minimises the service life of the new bearing.

The danger zone is located directly where the service personnel attach the measuring device during manual measurement.

In addition to maintenance planning, data security was also an important concern for us during development. The connection between the mobile device and the gateway takes place via Bluetooth. For this reason, no cloud connection is necessary, which means that all measurement data remains on the device. Furthermore, there is no interface between the gateway and the internet.

What does BCM represent to you personally and where do you think further developments will be headed towards?
With the development of the BCM system, we have laid the groundwork for the digitalisation of our slewing bearings. On top of that, we are constantly on the lookout for innovative, digital extensions for our bearing, which can offer the necessary benefit for our customers and interested parties. Bearing clearance monitoring represents the first major step into a promising future full of digital solutions, that will give our components even more momentum.

Wolfram Halder (Liebherr-Components Biberach GmbH)

360° of more efficiency

All-round vision for mobile machines

In our private lives, we are all increasingly becoming amateur photographers – not least through social media. When it comes to choosing the right camera, you are spoilt for choice. It has to be high-resolution, of course, as compact as possible and robust to capture even the most demanding mountain bike tour in pictures. Now take these requirements times 100 – and we are already in the milieu of mobile working machines. Digital images acquire a completely different meaning here.

Meet LiXplore®, a newly developed camera system that is able to display multiple views on one single monitor, for example the rear and boom of a harvesting machine. The advantage of digital camera technology over analogue is image quality and sharpness. High-resolution cameras by Liebherr provide detailed images and result in more efficiency and comfort for the operator. Drawing from over ten years of experience in the development of ethernet cameras and displays, the LiXplore® product line offers a high degree of flexibility. From the number of digital cameras, the field of view angles to the size of the display – users can assemble a customised system, depending on their individual requirements.

360° variant as an intelligent assistance system
The 360° LiXplore® Bird's Eye variant offers operators a surround view of their machine's working environment. The system seamlessly merges the images from four mounted cameras into one single frame. Known as "stitching", this feature is mapped directly by an intelligent algorithm behind the display controller. Unlike conventional, mostly analogue, surround view solutions that require an additional electronic control unit (ECU), the system is thus simple in design and economically wired.

In addition to a 360° top view, the Bird's Eye allows users to define detailed views and customisable overlays according to their requirements and to assign the corresponding function keys to the display. Drivers can switch between views quickly and intuitively at the touch of a button.

Calibration in seconds
Prior to operation, every surround view system has to be adjusted or calibrated. This can result in a time-consuming task, especially with a large fleet of machines. When developing Bird's Eye, Liebherr-Components was adamant to developing a simple system that can be calibrated within a few minutes. The calibration mats do not have to be precisely placed, nor do the distances to other objects have to be measured. Bird's Eye is thus ideal for anyone, who wishes to save time and money with a streamlined commissioning process.

MDC3 digital smart camera: the heart of the system
For the LiXplore® product line, Liebherr relies on its high-performance MDC3 camera. The HDR functionality continuously ensures high-contrast images without overexposure or underexposure, even in very dark or volatile light conditions. The highly robust cameras are based on years of experience from operation in challenging industries, such as construction or agricultural machinery. This makes them ideal for demanding operating conditions, for example, vibration, humidity and temperature fluctuations.

A 360° vision for our customers

Automation, artificial intelligence and autonomisation: The digital construction site of tomorrow has many facets and does not leave even the smallest components of mobile machines – the electronics – unscathed. Alexander Bertsch tells us how assistance systems and digital 360° surround view systems ensure more efficiency and comfort on the construction site, and what all of this has to do with ethics. He is responsible for sensor technology at Liebherr-Elektronik GmbH in Lindau (Germany).

Mr. Bertsch, for how many years has Liebherr-Components been involved with digital camera technology? How has this knowledge impacted the development of your LiXplore® Bird's Eye 360° surround view system?
We have been producing digital ethernet cameras for mobile machines for more than ten years, today in the third generation. Our in-depth expertise in this field is no coincidence. It is based on the long-standing partnership with our customers and the insights we have been able to gain as a result.

Alexander Bertsch (Liebherr-Elektronik GmbH)

A major plus for our customers is certainly that we know the demanding conditions, under which their mobile machines are used – strong temperature differences, vibrations, changing light conditions, etc., very well. We use this knowledge to develop our products according to the requirements put on them in terms of robustness. Accordingly, the experience we have gained over the last few years has helped us a great deal in the development of the Bird's Eye 360° surround view system. Basically, it is a digital camera-monitor system, that provides operators with a reliable all-round view of the working environment of their machines. The intelligent algorithm behind the display controller creates the 360° view by combining the individual images from four digital cameras into a complete picture.

What are the benefits of such a 360° all-round vision system?
Difficult operating conditions in the field, such as dust, moisture or vibration, as well as a partially restricted field of vision, do not exactly make it easy for the driver. This starts with classic construction machines, such as wheel loaders, and stretches up to agricultural machines, e.g. during harvesting. Municipal and special vehicles, such as waste disposal vehicles also face this problem.

In order to be able to depict blind spots and to avoid personal injury and damage to property, perfect visibility is indispensable. The sharper the image, the better, because work becomes easier and more pleasant for the drivers. In concrete terms, drivers, who spend eight hours a day in their cabs have a limited attention span – just like the rest of us. On top of that, they have to deal with the complex machine operation. It is obvious to use a system that makes work easier for humans: a win-win situation for everyone involved, the operators and the machine manufacturers.

Many machine manufacturers have been using cameras to monitor processes and increase efficiency for some time. What is the benefit of digital systems compared to analogous ones? Couldn't multiple mirrors be used instead?
The answer is yes. It's possible, but it's no fun (laughs). You can think of it like a tube TV compared to a full HD LED TV with a 40 inch diagonal. A digital camera has more power, a sharper image, richer contrasts and less distortion. In other words, it is an assistance system that actually makes drivers more comfortable. And not only that: If you think about the future in terms of automation, connectivity and the autonomisation of machines, digital cameras do not only open up completely different functionalities, but also function as a

“My personal learnings from years of product development? Even if something doesn‘t run optimally, there‘s always a lesson to be learned.”

Alexander Bertsch
Product line sensors at Liebherr-Elektronik GmbH

prerequisite for them. So it makes perfect sense to invest in the field with foresight. We would like to turn the “someday” into a “now”, in order to remain competitive as a machine manufacturing company.

However, investing in a digital surround view system is not entirely cost-effective. Wouldn’t it suffice to use a conventional surveillance camera and adapt it to the respective application?
Over the last few years, we have observed the following: Our customers know the challenging conditions, in which their machines are used, and thus also the expectations put on the assistance systems. These include demanding environmental conditions in the field, as well as changing light conditions, for example when working underground. However, all these conditions must be taken into account, when choosing a suitable visual aid. Our experience shows that customers often underestimate these requirements or, for cost reasons, use cameras that are unsuitable for the extreme conditions mentioned.

Another problem is that customers often do not consider the overall process behind the use of an assistance system. Before commissioning, such systems must first be calibrated, which is often time-consuming and cost-intensive due to the complex geometry of mobile machines. Unfortunately, this subsequent adjustment is often forgotten, but it causes non-negligible additional costs.

If a machine manufacturer equips five of his machines with a surround view system, the calibration effort is still limited. However, if we are talking about several hundred machines, things look very different.

Therefore, it was our concern to develop a time-saving system, that can be calibrated within a few minutes. More specifically, this means that neither the calibration mats have to be placed exactly, nor the distances to other objects have to be measured.

What is your conclusion on the assistance systems?
Basically, they are the result of the extensive experience we have gained over the years with mobile machines in a wide range of industries. Due to our constant proximity to customers, we know the demanding environmental conditions and the correspondingly high requirements for the components very well. We use this expertise to further develop our products and continue offering the greatest possible benefits.

What does the future hold for camera monitor systems and surround view solutions?
As in most other areas of life, we are moving towards a completely digital future. Digital image processing will soon find its way into even simple camera-monitor systems.

In the course of developing Bird’s Eye, we kept asking ourselves the following questions: How can we achieve the greatest possible benefit for our customers and at the same time differentiate ourselves from other providers? Which technologies, that have proven successful in other industries, have enough potential to be adapted to the requirements of mobile machines? One example is collision warning, which is already being used in the automotive industry. Soon it will also find its way into the area of mobile machinery.

Today’s systems still have to cover these extended assistance functions via additional sensors. With digital technology, intelligent algorithms take over this task. It is a leaner system overall that reduces possible sources of error and takes comprehensive account of processes on the construction site. Moreover, there is the additional comfort for the drivers. An interface, that displays all essential functions in one, is far easier and more intuitive to operate.

Analogue cameras will continue to exist, but I see them more in simpler applications, such as material handling. For more complex requirements and larger machines, like harvesters, digital solutions will be essential.

If we think about artificial intelligence and a networked, autonomously working construction site that has to process large amounts of data, digital cameras are a mandatory prerequisite.

However, there are still a few hurdles on the road ahead of us, until we get there. Who is responsible, if an autonomously driving machine causes personal injury or damage to property? In my opinion, this nearly ethical issue is still an open book and a work in progress from a political standpoint. Assistance systems must, therefore, be developed in the future in such a way, that they are able to compensate for malfunctions in automation and minimise risks in business operations. Striking a balance in this area of tension between artificial intelligence and functional safety will, in my view, still be a giant task.

LiXplore® Bird's Eye 360° surround view system

The force within

Force measurement for hydraulic cylinders

Continuing down the path of developing intelligent components, Liebherr has been increasingly focusing on sensor technology and its valuable use in hydraulic cylinders. One key aspect, that most recent research efforts have been focusing on, is the ability to measure force within cylinders. One potential application would be the monitoring of loads in excavators and cranes. In doing so, dangerous situations during crane operation can be avoided, whilst improving the efficiency of machines. The prevailing force in cylinders is conventionally determined indirectly via oil pressure. However, these measured values are prone to error due to, for example, internal friction. This is why Liebherr relies on direct force measurement via strain with a force measurement sensor.

The internal measuring points keep track of both tensile and compressive forces regardless of lateral forces and torques. This helps us to ensure significantly more precise and dynamic measurement results. Having an exact data output establishes the conditions for higher productivity and safety in daily use in a wide range of applications.

Intelligence meets versatility
Liebherr force measurement on hydraulic cylinders is currently still a functioning sensor prototype. One of its many advantages is the fact that the sensor holds a vast variety in application. During the design phase, Liebherr's development team has been taking into account individual adaptations with regard to operators' wishes and needs. As a result, an extensive range of customised solutions with many advantages arose. These include, for example, an increased performance of assistance systems through optimised sensitivity. Thanks to a highly dynamic and precise measurement, higher service life prediction is also possible in the future, which will play a decisive role in the area of condition monitoring and downsizing.

A focus on customers: exactly our cup of tea

Lindau at Lake Constance (Germany). The sun is shining, not a cloud dims the bright blue sky – a glorious day. Martin Lorenzen, Head of the IoT gateways product line at Liebherr-Elektronik GmbH in Lindau, also sees bright prospects for the future. He himself is focused on the construction site of tomorrow, which will be more connected than ever as part of the Internet of things (IoT). We accompany him on a short walk into the future.

Mr. Lorenzen, to what extent are IoT gateways an answer to the megatrends of digitalisation, connectivity and automation?
The past two years in particular have shown how important it is to have relevant machine data, like position data and wear information, available regardless of location. For example, due to international travel restrictions, maintenance work on a machine could only take place directly on site under difficult conditions, until recently.

Artificial intelligence behind the technology of our IoT gateways opens up a whole new range of functions. Not only do they allow customers to access their equipment conveniently from anywhere in the world, but also to monitor its status 24/7. And the more we move into the future towards autonomous construction sites, the more relevant it will be to carry out functions, such as maintenance work, condition monitoring and software updates, remotely. Automation based on artificial intelligence creates the prerequisite for an increase in productivity and efficiency, as well as cost reduction.

What advice can you give customers for the implementation of their IoT solution? What conclusions have you been able to draw from the last few years of product development?
From my point of view, it is incredibly important not to underestimate the high complexity of this technology. The topic is extremely challenging, therefore, requiring thorough planning. Only the hardware, the gateways, is not enough here, because many issues are linked to it. These include, for example, the specification of the software, mobile technology coverage, approvals in different countries and so on. Technology is constantly evolving at a dizzying pace, which, of course, does not make things any easier. Long-term and reliable partnerships are crucial.

What conclusions have you been able to draw from the last few years of product development?
This major challenge can only be mastered as part of a team. Since 2020, we have had a strategic partnership with Reycom, a Swiss manufacturer of software and hardware solutions. Our competences complement each other ideally here. It's the best of both worlds, so to speak. We, Liebherr-Components, can contribute over 40 years of experience in the manufacturing of durable and robust electronic hardware. Reycom AG complements our knowledge with more than 20 years of experience in end-to-end solutions in the areas of TV, Smart Home and IoT – cross-industry expertise that contributes directly to high availability in the field. Our common goal is to make it as easy as possible for our customers and to support them optimally in the implementation of their IoT solution. This means, that we wish to offer a product that is ready for use immediately and remains so throughout the entire product life cycle.

"My lessons learned from the past? Proximity to customers and reliable partnerships are the be-all and end-all."

Martin Lorenzen
Director IoT gateways at Liebherr-Elektronik GmbH

“We have the big picture in mind, which means we think in terms of platforms instead of individual products. With our strategy of backwards compatibility, we are already producing for a new tomorrow.”

Martin Lorenzen
Director IoT gateways at Liebherr-Elektronik GmbH

In your experience, what do machine manufacturers need to pay particular attention to before implementing their IoT solution? What challenges have you encountered?
The main challenge is that technologies, such as mobile communication, develop much faster than machines. In order to be able to detect and close potentially dangerous security gaps at an early stage, regular updates are imperative. The necessary preconditions for this are the right tools and mechanisms. This means the possibility to “roll out” over-the-air updates (OTA). In order to create a secure IoT solution from start to finish – from the gateway to the mobile phone contract and the cloud solution to the user interface/back end – the entire process must be considered over the entire product life cycle.

This concept, which has been thought through to the end, is also referred to as end-to-end asset or device management. It defines what a secure IoT solution must look like, and what adjustments are necessary to ensure that it remains secure in the future – despite constant changes in technology. Everyone who deals with IoT solutions has to deal with security matters to a similar extent. We know the challenges so well, that we offer our customers consulting services to accompany them as best as possible on the way to a secure overall solution. In addition, when developing the gateways, it was a particular concern of ours to ensure that data security and flexibility in use do not get in each other’s way.

What does that mean exactly?
With the appropriate interfaces, our flexible Linux environment creates the prerequisite for the greatest freedom in the choice of application. At the same time, the open environment is always state-of-the-art.

Constantly adapting your devices to the latest technologies, e.g. mobile radio standards and interfaces, is certainly costly. What solution or what advantages do the gateways by Liebherr-Components offer in concrete terms?
With our gateway solutions, we pursue a strategy of backward compatibility. This means that the devices we manufacture today are state-of-the-art. In addition, they are already developed with such foresight, that they can also be used in the future without any problems. If components, such as radio standards, computing and memory performance or security requirements change, this only affects the “inner

Martin Lorenzen (Liebherr-Elektronik GmbH)

workings" of the gateways. Connectors, installation space, software and hardware interfaces, etc. remain virtually unchanged. This is the basic idea behind form-fit-function.

For our customers, this so-called form-fit-function strategy means a future-proof investment that is worth its weight in gold. There is no need for costly redesigns. This has another positive side effect. This so-called retrofitting is a way to bridge the gap between fast-moving technology and sustainability. By making old machines fit for the new technology and not having to replace them we can also contribute to the responsible use of finite resources. Therefore, I not only see a great potential for growth here, but also a meaningful field of activity for Liebherr-Components.

However, this requires forward-looking planning. We already think about what 6G might look like and what hardware and software we might need for it.

What future will await us in this area, apart from 6G?
As I mentioned before, I think that the need for digital solutions will increase enormously in the future, in every aspect of life. Our current working environment will also change drastically, in my opinion. Physically demanding jobs are increasingly being eliminated, making room for more creative jobs. But that is a different matter.

Gateways by Liebherr as IoT-enablers: from smart farming to smart cities

The pumps of tomorrow

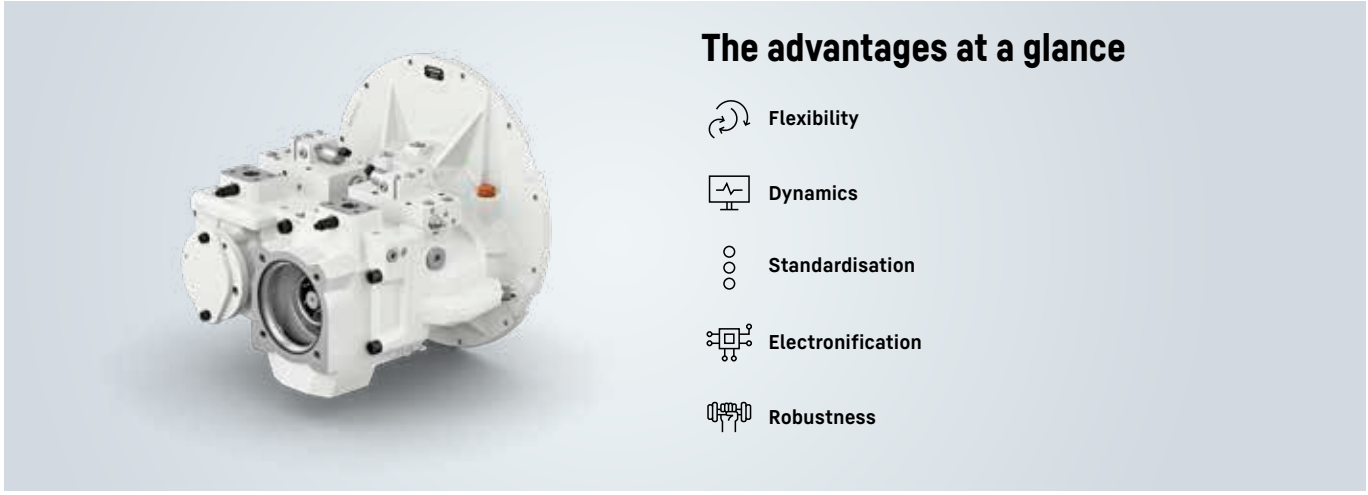
Concept parallel pump with EHC
In a current concept study, Liebherr-Components focuses on an improved open-circuit parallel pump driven by the changing requirements of different applications. Upon development, Liebherr has also taken such aspects as electrification, digitalisation, energy efficiency, system design and installation conditions into consideration.

Throughout the research phase, one simple but yet powerful principle has been at the forefront of all endeavours: understanding customer requirements and their applications, as well as a well-planned application in Liebherr own solutions. When designing a product or a product line, the aim is not only to focus on a consistent modular structure with flexible solution approaches, but also on the digitalisation of the equipment combined with the electrification of controllers.

The Liebherr-Components team in Bulle (Switzerland) has always been striving to link different types of controls, which was not possible hydro-mechanically by means of conventional controllers. Using software to link different kinds of controls, however, allowed achieving the desired benefits for the operator and the respective application. Regulating the controllers in this way allows to flexibly meet the demand for volume flow, pressure or torque control. Hard and soft control, with and without positional feedback, are also possible. As a result, there is no further need for a modular controller system – there is one controller for everything.

The software-based monitoring of the controllers ensures a flexible operation of various applications and functions, which was not possible before by means of conventional controllers. Moreover, the dynamics is now improved and the functions of the pump are expanded. The electro-hydraulic control (EHC) can now be fully integrated by implementing the software into the machine controller. This enables equipment manufacturers to design their systems in an efficient and flexible way. Downspeeding and downsizing are the key criteria here, which allow to reduce fuel consumption and noise emissions, making the pump operate with the best possible efficiency in the optimum operating mode.

The advancing digitalisation of the units with the integrated EHC offers further advantage like data collection and application for the optimisation of maintenance and servicing, which is an important first step towards condition monitoring. In the area of conventional components, such as transmissions and power units, the focus lies on the broadest possible speed spectrum. This allows to address a wide range of drive concepts beyond internal combustion engines and electric drives in the future. Respectively, the modular system offers the possibility of variation in the transmission ratio and high-speed stability of the engines due to the use of an impeller. This also supports the compact design by integrating smaller engines.



The advantages at a glance

- **Flexibility**
- **Dynamics**
- **Standardisation**
- **Electronification**
- **Robustness**

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