

Industrial machinery and heavy equipment

## Liebherr Group

Simcenter Amesim enables off-highway equipment manufacturer to streamline hydraulic component development

### Product

Simcenter

### Business challenges

Optimize axial piston unit design

Increase off-highway vehicle performance

Improve design process efficiency

### Keys to success

Gain better understanding of physical behavior

Optimize swash plate dynamic behavior

Reduce noise emissions

### Results

Significantly reduced number of prototypes

Enhanced collaboration among company sites

Strengthened internal expertise from component design to system integration

### Liebherr Group uses Siemens PLM Software solution to enhance collaboration among its company sites

#### Increasing efficiency

Just like car makers, off-highway equipment manufacturers must fulfill ever-escalating market requirements for high performance, robustness and driver comfort. Moreover, to meet the latest revisions of emission regulations, they must also offer cleaner and more energy-efficient solutions. The Tier 4 Final and Stage IV emission standards for off-highway vehi-

cles will take effect in 2014, and will be the regulatory standard for the American and European markets.

The Liebherr Group (Liebherr) is one of the world's leading manufacturers of construction machinery and mining equipment. Liebherr's main competitive edge is its expertise across many domains – from component design to system integration – which is extremely rare in the large off-road equipment market.

To address the environmental challenge, Liebherr focuses on developing innovative hydraulic products, which can considerably



*R 9XX concept, a Liebherr electro-hydraulic hybrid crawler excavator, demonstrates the energy recuperation technology. It has a fully integrated mechatronics system, including hydraulic, electric and energy management components.*

The company uses Simcenter Amesim for hydraulic and mechanical subsystem modeling, system integration and design optimization. Simcenter Amesim supports the entire development process at Liebherr Machines Bulle and allows engineers to tackle technical challenges, which would be difficult to do with a traditional engineering approach.

increase overall machine efficiency. Compared to previous product generations, today's solutions are more difficult to design because they include a greater number of mechatronic components and require a higher degree of component interaction.

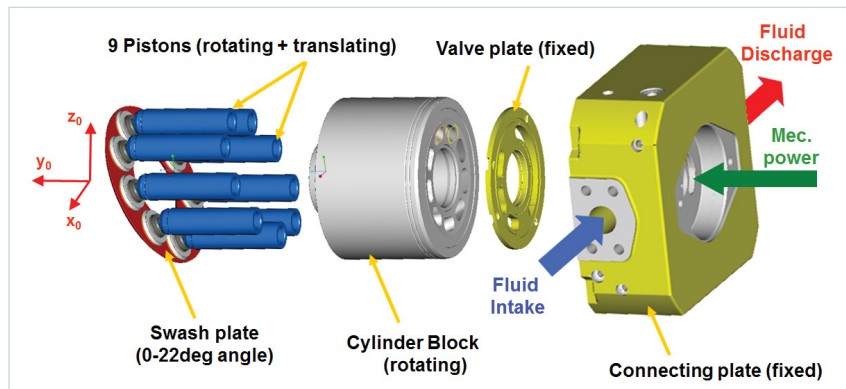
### Facilitating collaboration

One of the examples of the design paradigm shift is the R 9XX, a Liebherr hybrid excavator displayed at the Bauma 2013 International Trade Fair for Construction Machinery. This cutting-edge machine combines a standard diesel engine with hydraulic and electrical energy storage devices, such as a hydraulic pressure accumulator and supercaps. The energy generated and stored in the hydraulic accumulator while lowering the boom of the excavator is then used to feed the hydraulic cylinders and lift the boom in the next digging cycle.

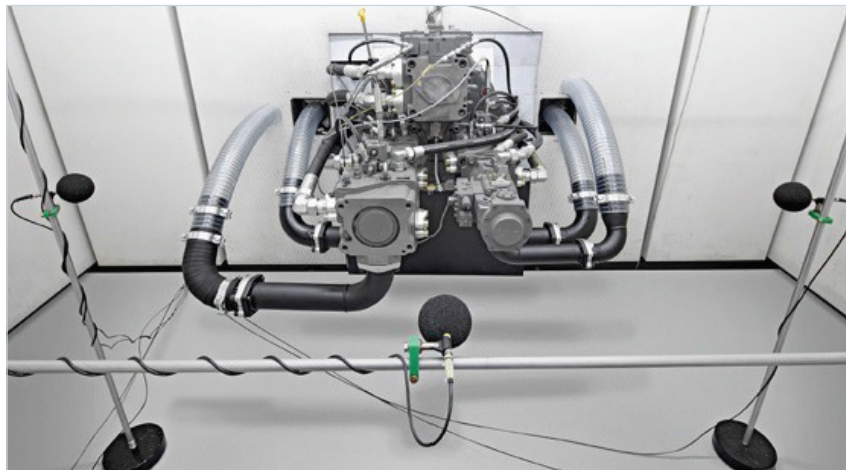
Due to increased system complexity and component interdependence, this development project required close collaboration between several facilities within the Liebherr Group. In particular, Liebherr-France SAS (Colmar, France) was in charge of the system integration and the design of the whole machine. Liebherr Machines Bulle SA (Switzerland) supplied the hydraulic components.

It would have been very difficult to carry out such an important project successfully without a model-based system engineering approach, which was supported by the use of Simcenter Amesim™ software, the mechatronic system simulation platform from Siemens PLM Software. The use of Simcenter Amesim allowed Liebherr to adapt to the hybrid product development process, which required strengthened collaboration to integrate each component

Typical axial piston pump components.



The acoustics test of the Liebherr axial piston unit according to the DIN 45635-26 standard.



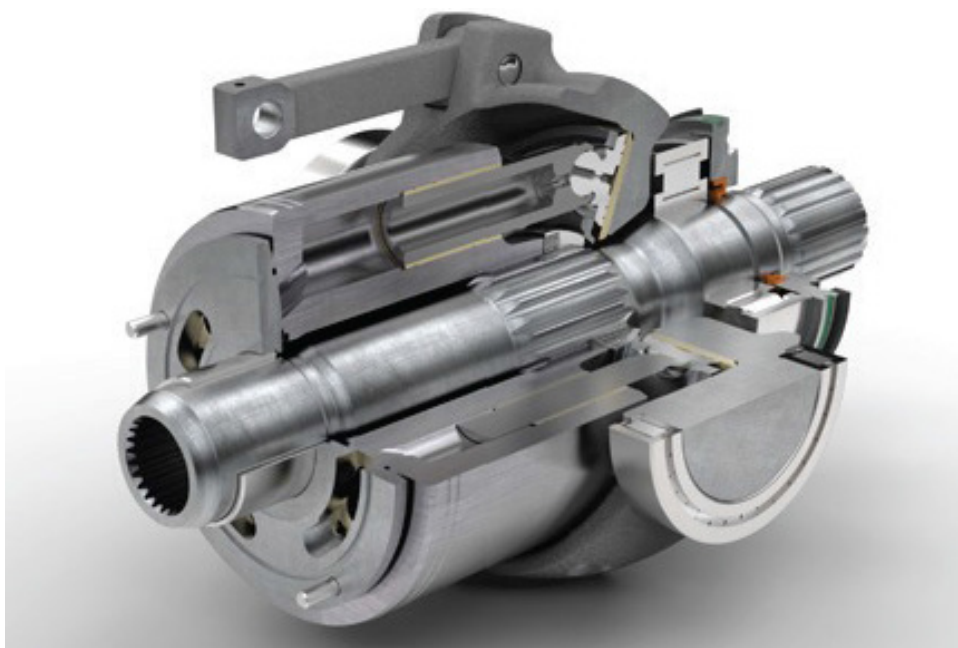
# *The multi-domain system simulation approach supported by Simcenter Amesim helps Liebherr Machines Bulle SA and Liebherr-France significantly enhance design process efficiency.*

into a system environment. Using Simcenter Amesim facilitated simulation model and parameter exchange among the Liebherr plants involved in the project.

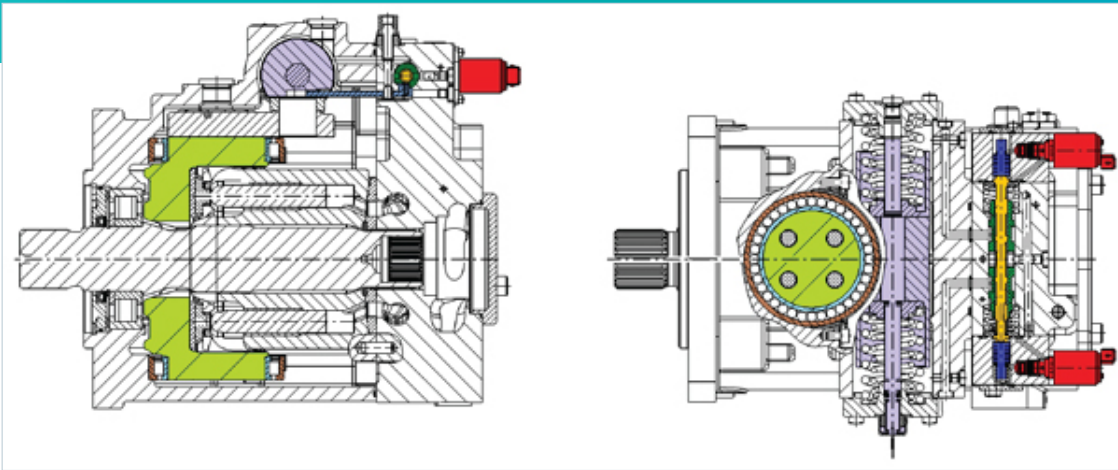
## **Supporting the development process**

For more than 30 years, Liebherr Machines Bulle SA has been specializing in the production of axial piston units, such as pumps and motors with swash plate design, and control-system components for construction machinery, mining equipment and aerospace applications. Following the emergence of new hybrid off-highway solutions, the role of

displacement controlled pumps has recently expanded. System simulation is one of the major factors enabling Liebherr Machines Bulle SA to develop new axial piston units and improve existing units. Conducting simulations allows the company to analyze behavior and performance prior to any testing of newly designed products. To optimize performance of existing products, once axial piston unit models are built and validated through measurements, Liebherr Machines Bulle SA runs offline simulations.



*The rotating group of the Liebherr axial piston pump.*



The servomechanism of the displacement-controlled axial piston pump and its model, built in Simcenter Amesim.

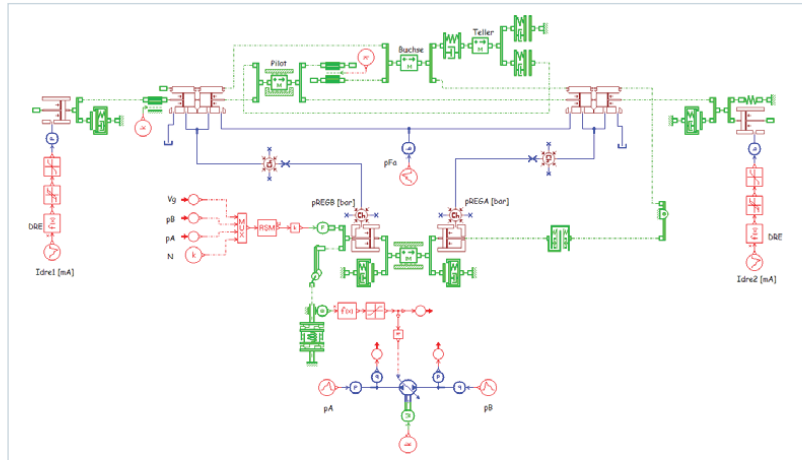
Today, the company uses Simcenter Amesim for hydraulic and mechanical sub-system modeling, system integration and design optimization. Simcenter Amesim supports the entire development process at Liebherr Machines Bulle and allows engineers to tackle technical challenges, which would be difficult to do with a traditional engineering approach.

### Two challenges, one solution

Simcenter Amesim is well integrated in the development process at Liebherr and is actively employed to address two critical issues when designing axial piston pumps: optimization of the swash plate dynamic behavior and noise reduction.

One of Liebherr Machines Bulle SA's major design challenges is to develop axial piston units with better dynamic behavior to meet the requirements of modern high-speed applications. By using Simcenter Amesim, the company has decreased response time and increased bandwidth frequency of the pump's displacement servomechanism.

Since Liebherr-France SAS devotes particular attention not only to component performance and reliability, but also to



maximizing driver comfort, Liebherr Machines Bulle SA is continuously working on reducing both fluid- and structure-borne noise. The fluid-borne noise is caused by pressure ripples transmitted to the hydraulic system while the fluctuating mechanical loads are responsible for structure-borne noise. The design of the valve plate, which separates the inlet and outlet ports, is critical for reducing both the flow ripples and force pulsations in axial piston units.

When minimizing noise emissions, one of the challenges is the variety of working conditions affecting pump performance, such as the pump speed, differential pressure, adjusted displacement volume and oil viscosity. The simulation is the only effective way to investigate different design options.

Using Simcenter Amesim, design engineers at Liebherr Machines Bulle SA build and validate a model of the axial piston pumps. This model is used to analyze the detailed geometry of the valve plate, hydraulic dynamics in the pistons and at the outlet of the pump, as well as mechanical dynamics of the pistons and swash plate. Afterwards, simulation results are validated through measurements of the piston's internal pressure, pressure ripple at the outlet and torque on the swash plate. Therefore, Simcenter Amesim allows Liebherr Machines Bulle SA to predict efficiency, swash torque and vibration depending on the valve plate geometry.

### Carrying out tradeoff analysis

Swash plate dynamic behavior and noise emissions cannot be studied separately. Modifying valve plate parameters, which is intended to reduce noise emission, directly affects the dynamic behavior of the pump.

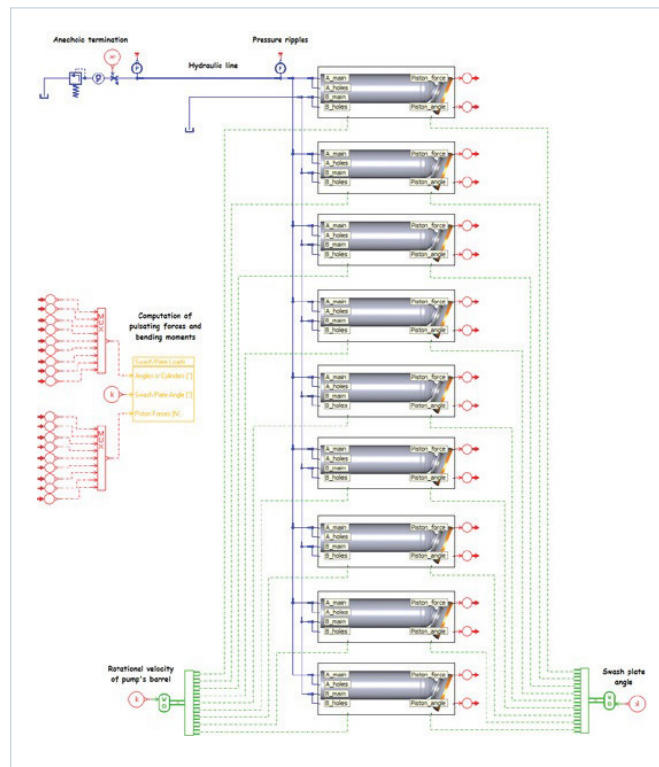
For example, changing the geometry of the ports affects the opening time, which helps to decrease the magnitude of the forces generated by switching from low to high pressure. At the same time, it also results in a different distribution of the

forces on the swash plate. As a result, the force available to pilot the swash plate is modified. To address swash plate dynamics and noise emissions issues together, system simulation is the only effective solution allowing for efficient tradeoff analysis.

### Toward efficient design of innovative off-highway vehicles

The new simulation approach has enabled Liebherr Machines Bulle SA to gain a better understanding of the physical behavior of axial piston pumps. Simulation results are taken into account in the early stages of the development process, which increases the chances of designing a solution right the first time.

The use of Simcenter Amesim allowed Liebherr to adapt to the hybrid product development process, which required strengthened collaboration to integrate each component into a system environment. Using Simcenter Amesim facilitated simulation model and parameter exchange among the Liebherr plants involved in the project.



Simulation of pressure transients for valve plate design and optimization.

## Solutions/Services

Simcenter Amesim  
[www.siemens.com/plm/simcenter-amesim](http://www.siemens.com/plm/simcenter-amesim)

## Customer's primary business

The Liebherr Group is one of the world's leading manufacturers of construction machinery, cranes, mining equipment, aircraft systems, domestic appliances and components. In 2012, the company had sales of 9 billion euros and employed 38,000 people in more than 130 companies worldwide.  
[www.liebherr.com](http://www.liebherr.com)

## Customer location

Bulle  
Switzerland

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Simcenter Amesim also helped Liebherr to obtain some parameters that would have been very difficult or even impossible, to obtain through tests. For instance, with a traditional engineering approach, it is extremely difficult to gain insight into what is happening inside the pump because of its rotation. The simulation of instantaneous pressure in the piston chambers enables Liebherr to avoid the classic trial-and-error approach.

Using the new simulation methods has completely changed the development process for hydraulic products at Liebherr Machines Bulle SA as the engineers don't have to rely exclusively on measurements any more. This significantly decreases the number of prototypes, especially for the valve plate design.

Simcenter Amesim features a robust solver and a broad set of industry-oriented component libraries for hydraulic applications that enables Liebherr to build ever more detailed and accurate models. Simcenter Amesim models and simulation results are easy to share among the Liebherr facilities that use the simulation platform.

Hydraulic drives have great potential for increasing the overall performance of off-highway vehicles. However, this potential will only be realized if complex development issues involving numerous multi-domain systems are handled efficiently. The multi-domain system simulation approach supported by Simcenter Amesim helps Liebherr Machines Bulle SA and Liebherr-France SAS to address this new challenge and significantly enhance design process efficiency.

## Siemens PLM Software

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