SIEMENS
Ingenuity for life

Automotive and transportation

BorgWarner

Leading all-wheel drive system manufacturer reduces testing efforts, costs and time with Simcenter Amesim

Product

Simcenter

Business challenges

Increase vehicle stability and handling under any driving conditions

Reduce torque losses and fuel consumption

Shorten coupling response time

Reduce coupling volume, weight and manufacturing cost

Keys to success

Use predefined and validated Simcenter Amesim components

Model oil properties depending on the temperature

Study coupling response time at different temperatures

Analyze pressure fluctuations and pulsations in the axial piston pump

Results

Optimized component size

Maximized performance of the pump and, consequently, the coupling

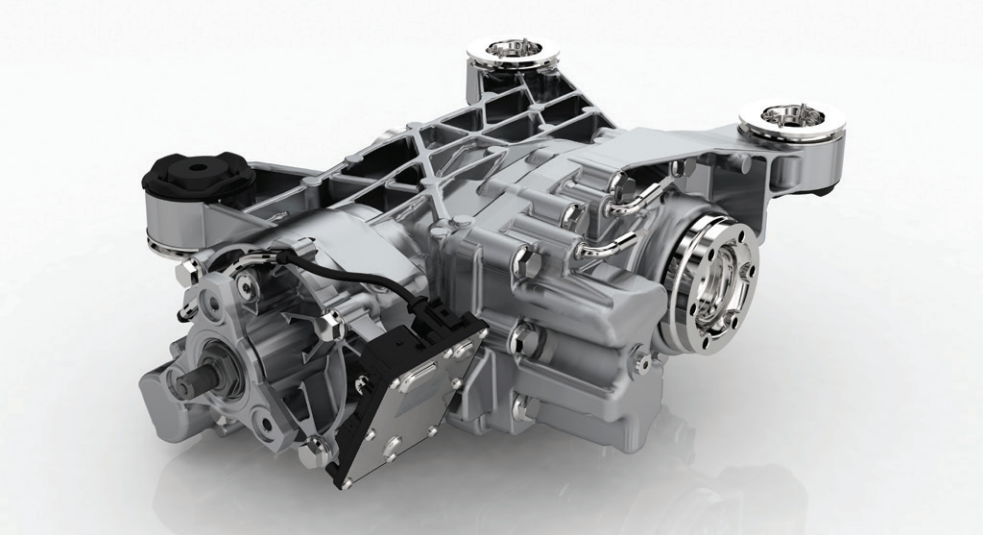
Decreased modeling time
Reduced number of prototypes, testing costs, time and effort

Siemens Digital Industries Software solution helps BorgWarner TorqTransfer Systems design high-performance all-wheel drive systems.

"The only suitable software"

Although drivers do not wish to compromise on vehicle stability and, therefore, safety, they are becoming harder to please when it comes to vehicle handling, regardless of driving conditions. To win them over, carmakers must figure out the best way to meet customer preferences for driving characteristics. To enhance vehicle performance and safety, original equipment manufacturers (OEMs) offer full-time all-wheel drive (AWD) cars with four wheels receiving torque continuously, and part-time AWD vehicles with front- or back-wheel drive under normal driving conditions.

One of the solutions is the fifth-generation (GenV) AWD coupling offered by BorgWarner, a leading auto supplier that specializes in the development of key engine, transmission and driveline technologies that reduce fuel consumption and emissions and enhance vehicle performance. Introduced to the market in 2012, the electrohydraulic actuated GenV coupling is used by best-in-class automakers such as Volvo, Volkswagen, Audi, Porsche, Land Rover and Lamborghini.



BorgWarner's GenV AWD coupling with a differential unit.

"We believe that Simcenter Amesim was the only suitable software for this application on the market. By using a simulation model built with Simcenter Amesim, we can easily analyze the efficiency of the pump, calculate losses and manufacturing tolerance, and, therefore, boost the efficiency of our couplings."

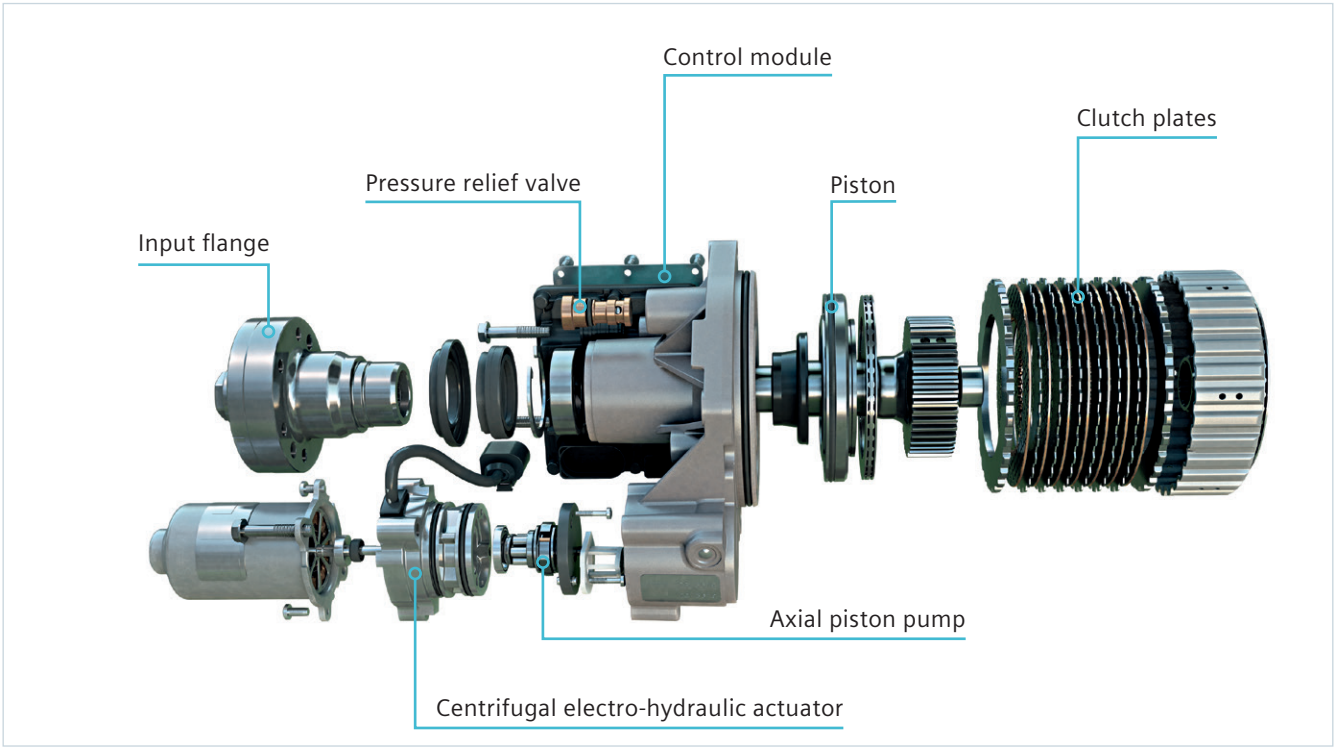
Kathiravan Ramanujam
Simulation Engineer
Mechanical Design Department
European Tech Center
BorgWarner TorqTransfer Systems

Product lifecycle management (PLM) specialist Siemens Digital Industries Software helped BorgWarner maximize the performance of the pump, which is at the heart of the GenV AWD technology. The implementation of Simcenter Amesim™ software enabled design engineers to predict the efficiency and analyze manufacturing tolerance for the pump in the early design stages.

"Unlike a traditional gear pump, for which it is usually quite easy to measure the input, output and losses, our pump has a quite complicated design and it's very difficult to obtain its efficiency through measurements," says Kathiravan Ramanujam, a simulation engineer in the Mechanical Design Department at the European Tech Center (ETC), BorgWarner. "We believe that Simcenter Amesim was the only suitable software for this application on the market. By using a simulation model built with Simcenter Amesim, we can easily analyze the efficiency of the pump, calculate losses and manufacturing tolerance, and, therefore, boost the efficiency of our couplings."

Facilitating efficiency

The GenV AWD coupling consists of a hydraulic power system (including an axial piston pump and a centrifugal regulator), a wet multi-plate clutch and an electronic control unit (ECU) that can be adapted to brand attributes of an OEM. The electronically controlled multi-plate clutch automatically distributes power between the front and the rear axles. Full locking torque can be achieved whenever necessary. At the same time, when cruising, only a very limited amount of torque is transferred to the rear axle. Therefore, while optimizing vehicle traction on all terrains, the GenV AWD coupling also helps improve fuel economy by distributing only the needed amount of torque depending on driving conditions. The



Exploded view of a GenV coupling.

"We can find out the frequency and, in case of noise, optimize the design using Simcenter Amesim rather than trying it out on a prototype, which would require much more time and effort."

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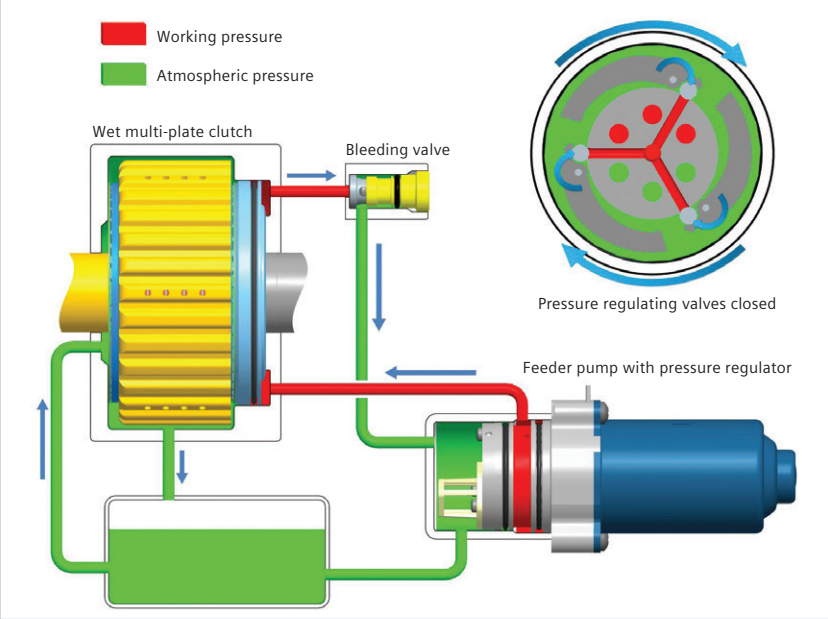
coupling takes into account information provided by the traction control and anti-lock brake systems, such as wheel speed, steering wheel angle, yaw rate and the torque supplied by the engine, and the position of the acceleration pedal.

The multi-plate clutch transfers torque between the drive shaft and the rear drive unit (RDU) pinion, and the percentage of transferred torque depends on the axial force acting on the lamella package. This in turn depends on the pressure generated from the pump flow.

The axial piston pump is powered by an electric motor and consists of a barrel with pistons, a pump lid with suction and discharge ports, a swash plate and pressure regulating valves. Rotary motion is converted to linear motion by the angular swash plate. As the barrel rotates, the pistons start to reciprocate inside the barrel. Hence the oil from the suction port is delivered to the discharge port, creating a flow. As the flow to the coupling piston increases, the pressure on this working side increases as well.

The pressure, in turn, is controlled by the pressure-regulating valves. The valves are located on the circumference of the barrel. Pressure is regulated because of the force balance between the centrifugal force from the arms and the oil pressure acting on the ball. When the required pressure needs to be built up, the centrifugal force will be greater than the hydraulic force and the valves will remain closed and vice-versa. With this design, the accumulator from the earlier generation is removed without compromising the response time.



The operation of the hydraulic circuit in the GenV coupling.

"Our further ambition is to perform co-simulation by coupling our Simcenter Amesim model with a controls model built with Simulink, so that the Simcenter Amesim model can be used by different departments at BorgWarner."

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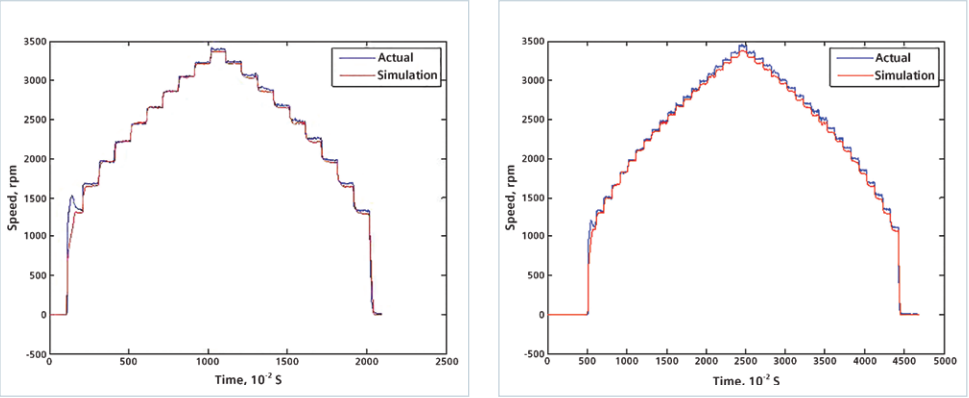
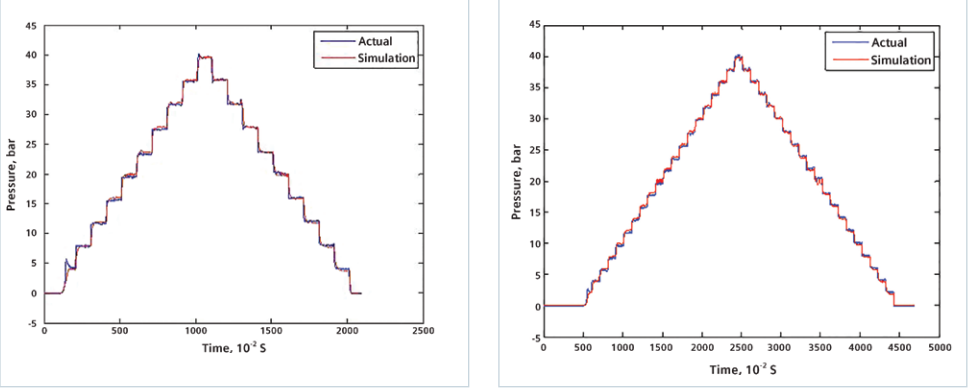


Result plot comparing the simulated and measured speed of the electric motor powering the pump (drive cycles 1 and 2.)



Comparison of results for the oil pressure in the coupling piston obtained through simulation and tests (drive cycles 1 and 2.)

The level of pressure conveyed by the pump depends on the required torque. For instance, high pressure is delivered under traction or high-slip conditions, while much lower pressure is provided when making tight curves to park a car or when driving at high speed.

Optimizing coupling parameters

BorgWarner's couplings need to achieve the necessary torque within a few milliseconds, so the reaction time is very important. Even in Europe, the temperature in couplings varies from -40 degrees Celsius (°C) when starting the vehicle in winter to approximately 100°C under extreme driving conditions like hill climbing with a heavily loaded vehicle and a trailer. Thus, the coupling's response time must be studied at different temperatures. "It would be extremely costly and time-consuming to obtain the response time without simulation," says Ramanujam. "Just imagine what would be required for a test-based approach, whereas with Simcenter Amesim it is so easy to accurately model oil properties depending on the temperature.

"Moreover, Simcenter Amesim helps us perform noise, vibration, and harshness (NVH) analysis of the hydraulic system by studying pressure fluctuations and pulsations in the piston pump. We can find out the frequency and, in case of noise, optimize the design using Simcenter Amesim rather than trying it out on a prototype, which would require much more time and effort.

Solutions/Services

Simcenter Amesim
siemens.com/simcenter-amesim

Customer's primary business

BorgWarner develops leading powertrain technologies that improve fuel economy, emissions and performance. The company employs 19,700 people in 60 locations across 19 countries. BorgWarner TorqTransfer Systems AB, formerly Haldex Traction Systems, which was acquired in 2011, produces electronically controlled allwheel drive systems for cars.
www.borgwarner.com

Customer location

Landskrona
Sweden

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