While the basic design of iron and coke blast furnaces is centuries old, today’s steel makers are looking for innovative ways to produce molten iron with increased production and efficiency. That’s why one of the world’s largest steel producers in China turned to Woodings Industrial Corporation of Mars, PA (www.woodingsindustrial.com) to improve a key blast furnace component with a solution using Bosch Rexroth industrial hydraulics.

“The way iron pellets and coke are charged in layers inside a blast furnace really affects the melting process,” says Al Colucci, Woodings Industrial, vice president, engineering. “The layers are created by a system called a hydraulic distributor, using a chute located in the throat of the blast furnace, to deposit raw materials in precise locations.”

“Woodings’ challenge was to develop accurate control of the hydraulic distributor for a blast furnace, achieving a level of control previously unheard of in our industry.”

Handling the burden of the industry’s tightest tolerances
A hydraulic distributor has two functions: rotating and tilting the chute. The more accurately the chute can be controlled, the more precise the layers and the more efficient the blast furnace becomes.

Woodings Industrial Corporation, founded in 1883, is a manufacturer of metals industry equipment such as tap hole drills, mud guns, blast furnace top hydraulic charging units, blast furnace valves and engineered specialty products.

One of its key customers, a major Chinese iron and steel producer, asked the team at Woodings to design and build hydraulically-controlled distributors for two new, 4,150 cubic meter blast furnaces that will produce up to 16 million metric tons of iron per year.

The majority of burden distributors use electromechanical gearing systems to drive the up-down movement of the distributor chutes. These systems do not provide the level of precision or control the Chinese steel manufacturer sought; in addition, they are difficult to repair and maintain in the high-temperature environments atop the blast furnace.

According to Woodings, the Chinese steel manufacturer had been using a hydraulic distributor of their own design on six blast furnaces. However, these systems used a traditional hydraulic circuit with open loop control. The end-user called on Woodings to help increase accuracy and performance.

The level of precision and control the company wanted was unprecedented for this type of system, according to Colucci. They wanted chute movement at the endpoint limited to no more than 0.01 of an inch (0.25 mm). That’s one-tenth of one degree.

Typically, burden distributor chute endpoint control is lower accuracy — within inches. However, Woodings’ customer set this accuracy goal because they are convinced that the more precisely they can control the material distribution into the blast furnace, the more efficient and productive the blast furnace will be.

That degree of chute control is difficult to achieve, because as tons of iron ore pellets and coke tumble down the chute, the load and the angle of the chute change. The chute tends to extend when loaded, and when the load is released, it retracts.

Plus, all this is happening on the move. The chute rotates at 8 rpm, completing a cycle every 7.5 seconds. The rotation changes the loading on each of four hydraulic cylinders. The load on the first cylinder passes to the second cylinder, then to the third and fourth, then back to the first.

Adding to the challenge is the extremely demanding environment atop the blast furnace: with heat from the furnace, along with high levels of debris and soot associated with iron manufacturing. Given these conditions, it was necessary to position the hydraulic control valves for the circuit in an enclosure away from the cylinders, resulting in long hydraulic lines.
This distributed design has advantages: the hydraulic valves and controlling electronics last longer and are easier to maintain away from the harsh furnace top environment, and the hydraulic distributor uses far fewer rotating components, so that the control components last much longer.

However, the design presents a controls challenge: fluid in long hydraulic lines acts like a spring – expanding and contracting--making accurate motion control even more difficult.

**Advanced simulation of dynamic loads**

Woodings has had a working relationship with Bosch Rexroth since the 1990’s. This application, however, was one of the most daunting drive and control challenges Woodings had ever presented.

“What made this project unique was the stringent specification on accuracy for an application with huge dynamic load changes,” says Charles Erdo, Bosch Rexroth, industrial machinery engineer based in Bethlehem, PA. “The control system has to react fast enough to maintain a very tight cylinder stroke tolerance between four differential hydraulic cylinders.”

The Woodings hydraulic distributor employs hydraulic cylinders with a controlled 4WRPEH, directly operated high-response proportional directional valves, with electrical position feedback. The closed-loop cylinder-position control system utilizes load pressure feedback provided by HEDE 10 electronic pressure transducers.

To verify that the targeted accuracy and repeatability of the Rexroth hydraulics system would be achieved, Erdo involved Bosch Rexroth simulation groups in the U.S. and its headquarters in Lohr am Main, Germany.

“The short nine-month time window ruled out building a physical prototype to prove it to Woodings,” Erdo said. “So we used several simulation tools to model the system.”

Bosch Rexroth has been a leader in designing and utilizing advanced software tools to simulate the performance and effectiveness of hydraulic systems and controls. Simulation can save both time and development costs, while providing more accurate answers about how a complex array of hydraulic components will perform, without going through the cost and effort of assembling and testing a physical prototype.

Bosch Rexroth’s proprietary simulation tool called MOSIHS (Modular Simulation of Hydraulic System), allows the user to model and simulate overall hydraulic system. With a library of standard hydraulic components and Bosch Rexroth valves, the engineer can design a system of any size and complexity and determine how it will behave. Each component can be parameterized to match the design requirements. An extensive array of electronic control and mechanical components is available in MOSIHS to replicate real world applications.

As in the real world, mechanical structures -- in this case, the distributor equipment -- interact with the hydraulic drive. Sub-models of the hydraulic system, mechanical systems and controls can be coupled with each other and simulated together. This allows the designer to investigate dynamic behavior of the overall system, including resonance modes of hydraulic and mechanical systems and the interaction of the controller, actuators and mechanical structure.

The hydraulic circuit and controls for the distributor, designed by Rexroth, comprised input data for the MOSIHS simulation program. CAD drawings of the distributor assembly, including 3-D models of Woodings-sourced components such as the chute and the rotating distributor head, were imported into a commercially available Multi-Body Simulation Program coupled with MOSIHS.

“It’s unique for a drive and control company to have a dedicated simulation group developing software and libraries of model components, both hydraulic and electro-mechanical,” Erdo said. “It gave us a real advantage in this application.”

As the chute rotates through 360°, the chute is lifted and lowered by the Rexroth hydraulics to precise endpoints, as tons of iron ore and coke pellets pour down the chute into the molten iron in the furnace.
The simulations verified the hydraulic circuit design and the selected Rexroth components were suitable to meet flow, pressure and other specifications, and demonstrated the required static, dynamic and response time behavior to reliably deliver the hydraulic distributor endpoint accuracy.

In addition, the MOSIHS simulation showed that using a specialized spool flow characteristic control valve would increase control performance. According to Erdo, this was a valuable improvement to the Rexroth hydraulic design, and one that would have been more difficult and time-consuming to discover using a physical prototype.

Virtual commissioning and 3-D animation help to convince customers

One of the most significant issues studied using the simulation was evaluating the hydraulic circuit’s motion control scheme. Simulation demonstrated that a large moved mass and long hydraulic lines result in relatively low natural frequency of the hydraulic distributor system. Specialized control algorithms, using dynamic pressure feedback, actively damp system oscillations and provide optimal performance.

In the course of evaluating the closed-loop control and fine-tuning the system feedbacks, the Rexroth engineers developed a better understanding of how the forces moving through the chute can affect accuracy as the distributor rotated.

“As it turns out, the cylinder load changes with the chute angle” Erdo notes. “The drive and controls have to quickly react to load variations as the chute working point changes, as well as centrifugal forces and dynamic loads. The simulation verified our closed loop control strategy and demonstrated that all four cylinders remained synchronized as required.”

The simulation also provided Woodings with an additional valuable tool: An animation which was used to prove to the Chinese steel manufacturer that the hydraulics solution Woodings proposed delivered their targeted endpoint accuracy. “That’s good from the marketing perspective,” says Erdo. “From an engineering point of view, it was reassuring to see all the components performed as specified.”

Controls enable pinpoint accuracy

The hydraulic distributor control system utilizes advanced digital controls technology. A programmable logic controller (PLC) at the top level manages the closed loop control of the chute hydraulics and supervisory tasks; a variable frequency drive (VFD) handles the chute rotation; and a human machine interface (HMI) takes care of the front end for operator control and supervision.

The closed loop control of the chute angle is accomplished using position feedbacks located inside each of the hydraulic cylinders. The chute angle command comes from the blast furnace’s upper level control system; this command is then converted to a cylinder position which is maintained by the controls. The PLC also controls...
ancillary functions such as burden distributor cooling, generating system alarms to be displayed on the HMI, and communicating with the steel mill’s upper level control system.

**Advanced components and engineering deliver accuracy**

Along with performance challenges, Bosch Rexroth had a short delivery window for all of the components. Valves were obtained through Bosch Rexroth’s GoTo focused delivery program for hydraulics, another service that gave Woodings a high degree of comfort with the Rexroth process.

Three final versions of the Woodings hydraulic distributor were assembled and tested at the company’s facility in Youngstown, OH, to confirm proper function, after which they were then disassembled and shipped to China for installation. In addition, Woodings believes there is significant opportunity to introduce this hydraulic distributor technology to blast furnace operators worldwide, providing them with a system that offers dramatic improvements in distributor accuracy and repeatability.

"Bosch Rexroth made the deliveries they promised," Colucci says. "When we had inevitable situations where things didn’t work exactly as expected, they stuck with me through the whole thing and came up with solutions. That’s where this simulation was valuable. When we put the system on the test stand, it performed exactly the way we wanted it to go."

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