Pneumatics Provide the Backbone to Spinal Testing System

Andrew McCarty

The Project: Design a spinal implant testing device that can both withstand the rigors of prolonged testing timeframes and also offer extremely precise accuracy

The Solution: Use a pneumatic solution that takes advantage of air valve and cylinder technology in place of more traditional servomotors.

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Spinal Joint Testing Machine—An undulating drive and rotate system generates wave motion at 0.5 Hz (30 rpm) and 3.0 Hz (180 rpm) and sets the operating angle of the tank that holds the test specimens.

Spinal cord injury (SCI) has potentially devastating consequences for not only the individual involved, but in a larger context, on the national economy as well. As of June 2006, there were over 253,000 people in the U.S. with an SCI-related pathology. According to the most recent statistics, SCI costs the nation over $9.73 billion per year.

Evaluation of spinal implant devices requires testing systems that can replicate the complex, physiological motions and loads human joints commonly undergo. Continually improving equipment capable of performing meaningful tests of strength, range-of-motion and endurance contributes to breakthroughs in the treatment of SCI patients.

Datum Industrial Design Inc. recently designed and built a new spinal joint endurance testing machine to evaluate how spinal joints will function in human bodies. The versatile machine has the ability to test a variety of spinal joints in a range of scenarios and is already being used in the field.

The Datum spinal joint testing machine can be programmed for specific operating parameters. One of the keys to the machine's success is its ability to quickly and easily set-up or change parameters for different tests. The use of air cylinders and valves, rather than servomotors simplifies this process.

Datum's Design Breakdown

Among the numerous benefits of the Datum joint endurance testing machine are small footprint in a lightweight package, ease of maintenance, quick set-up, and smooth operation. Its ability to change testing parameters in seconds with cylinder-supplied air pressure as opposed to time-consuming, complicated, and expensive servomotors, makes the system extremely cost-competitive.

The machine's modular design consists of:

•**Frame**—Constructed with aluminum, titanium, and stainless steel. Solid and maintains rigidity while holding all operating mechanisms securely in place with no deflection during test cycles. The unit weighs about 400 pounds, with two side-by-side machines in the same frame. Pneumatic components and air gauge panel are on top of the unit for ease of access.
•**Touch Screen and Controls**—All electrical subsystems and the touch screen for operational parameters are located on the front panel of the machine frame. The touch screen is used to set-up operating parameters of the selected test. The parameters are total count, cycle count, total downward pressure, undulating speed, and rotation speed.
•**Undulating Drive and Rotate System**—Controlled by a variable DC drive motor to create wave motion at 0.5 HZ (30 RPM) and 3.0 HZ (180 RPM). The rotate system is operated with a similar controller.
•**Undulating Platform**—This is the disc which sets the operating angle of the tank that holds the test specimens. The platform is controlled with a small electric drive that allows angle adjustments up to six degrees.
•**Articulating Arm**—A triple-sectioned, double-hinged arm mounted on the frame's upper section and extends outward above the platform's centerline to syncopate upper/lower tank specimens as they undulate, rotate, and ripple.
•**Push Rod/Control Package**—Electronically controlled DC air valves supply the proper pressure to the air cylinder above the articulating arm that moves the push rod up and down for testing joint specimens according to selected parameters.
•**Test Tank**—Filled with liquid, a six-inch diameter test tank, mounted on a titanium base with a roller finger extending from the base plate, controls tank rotation motion during test cycles.

Each component is networked to a computer for data acquisition, analysis, and evaluation. The main electrical box contains input relay, transformer (120 VAC to 24 VDC), PLC, motor controller, and appropriate connections. This modular assembly completes the analytical instrument package.

Keyed on a Pneumatic Solution

When this opportunity to build a special piece of medical equipment came to Datum Industrial Design, company president William Salvesen recognized that pneumatics and the unique use of an air valve would provide the needed solution to meet demanding parameters.

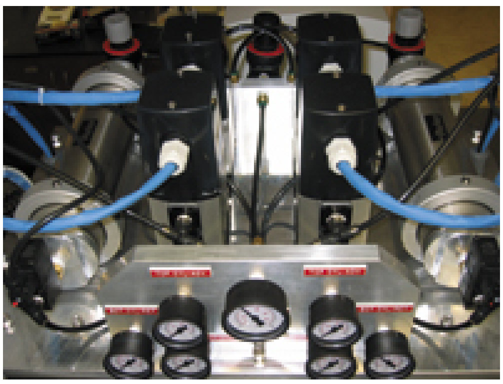
Servomotor technology—typically used for such functions—would have presented too many difficulties in this particular application to overcome in the time frame Datum had to design and manufacture the machine. Salvesen contacted Progressive Hydraulics Inc. (PHI), a Parker Hannifin distributor that Datum has been working with for more than 20 years.

"I contacted Chris Shatteman, an engineer at Progressive Hydraulics, and he recommended a variable-pressure output valve to be controlled with an input voltage," Salvesen explained. According to Salvesen, "it was never a question of ‘could it be done with air' but what were the best pneumatic choices to make the project cost effective and practical."

The main requirement of the system was to vary the air pressure of the cylinder to control pressure placed on the spinal implant joints during testing. Control had to be easy to establish and maintain without a large degree of fluctuation. PHI met with Datum to review available pneumatic choices available for the machine as specified.

Quite a few Parker components were recommended for the testing machine, including 05E piggyback filter regulators, P3P-R Input to Pressure (I/P) series regulators, P1L series air cylinders, and an array of gauges and fittings.

Pneumatic Dynamo for Testing Device



Electronic Control—According to selected parameters, DC air valves provide the proper pressure to the air cylinder for up and down movement during specimen testing.

The push rod/control assembly system serves as the dynamo of the testing machine by delivering sufficient, controllable punch and power to simulate actual conditions under which a spinal joint is expected to function.

"The centerpiece of the system is the Parker P3P-R series regulator," explained Shatteman. "Though it's a standard electropneumatic product, we used it in a unique and interesting way in this application."

Parker 050 inlet regulators control maximum input air pressure to the testing machine at 100 PSI. Electropneumatic regulators or I/P (input-to-pressure) valves use variable-voltage input signals, ranging from 0 to 10 VDC, to set pressure. In this application, the P3P-R regulators control the air cylinder pressure from a low of 7 PSI to a maximum of 100 PSI.

As stated, the inlet supply in this application is set at 100 PSI. Sending a 5 VDC signal from the P3P-R, for example, results in 50 PSI at the valve's outlet.

The PSI is translated into downward force generated by the machine. In this case, 500 pounds maximum and 25 pounds minimum. An internal pressure transducer, mounted on the upper end of the push rod, controls the downward pressure created and transferred to the cylinders by generating a signal that combines with the input voltage signal to produce an appropriate drive voltage signal to achieve required pressure levels.

"This closes the loop by producing excellent tolerance on valve outlet pressure," Shatteman continued.

The machine's specs called for controls to be easy to initiate and maintain without a high degree of fluctuation. By means of an integrated electronic control system and pulse width modulated solenoid valves, the Parker P3P-R regulators control output pressure proportionately to an analog electrical signal.

Datum's Salvesen noted that the Parker air valve was easily controllable via the main PLC across the entire range—from the low of 7 PSI to the maximum 100 PSI. "The actual downward force on the spinal joint test specimen," he said, "was ±4.0 lbs. on a controlled force of 270 pounds. You can't do much better than that."

Fine-Tuning the Refinements

Swinging Arm—A triple-sectioned, double-hinged arm syncopates upper and lower tank specimens as they undulate, rotate, and ripple.

Datum engineers further refined the spinal testing apparatus by deploying a load cell on the work piece itself to achieve even tighter control over the process. According to Schatteman, "by utilizing the internal pressure transducer, you're achieving accurate pressure control at the valve outlet, but that doesn't account for frictional forces which can skew work piece accuracy."

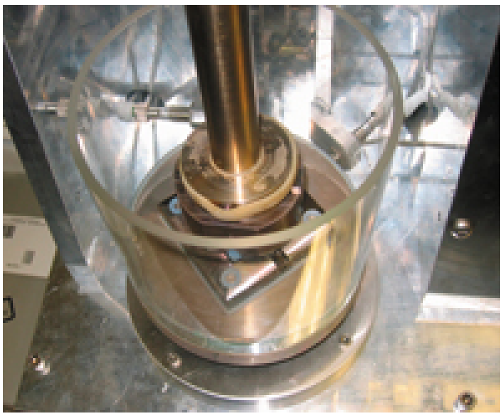
Thus, between the work piece and cylinder rod end, Datum technicians installed a load cell with a range of 0 to 10 VDC depending on load cell compression. The Parker P3P-R has an optional input sensor that accepts a signal from the load cell without solely relying on the pressure transducer on the internal I/P interface. This results in extremely tight pressure tolerances on work piece load forces because there's nothing in between to generate additional error.

"With a downward-pushing cylinder being the only moving part," Salvesen noted, "maintenance is reduced to practically ‘nil' while invariable air pressure results for the specimen in the testing cycle."

Pressure to Zero-Point Precision

A pneumatic solution proved to be the ideal approach to meeting specifications for the endurance testing apparatus. The pneumatic design makes it easier to control desired pressures than with servomotors and controllers. With a servomotor, even slight movement can cause the system to continually self-correct and trigger ball screw/motor wear, as well as impair system functionality and operating life.

Installing Parker P1L air cylinders was quick and easy. The pressure transducer is mounted on the upper end of the cylinder's push rod while a block on the end of cylinder rod contains a locked-position center pin leaving a small gap between the transducer and the block assembly on the cylinder rod. The signal from the transducer controls pressure parameters while final downward pressure is controlled by two Parker variable-voltage input DC air valves that supply the proper preset test pressure levels to the air cylinder on the articulating arm that performs the undulating motion on the spinal joint specimen being tested.



Test Tank—A six-inch diameter tank controls rotation motion during test cycles and is networked to a computer for data acquisition and analysis.

For higher testing pressures, a back-to-back cylinder configuration is used. When the bottom air cylinder reaches the preset pressure (e.g., 200 pounds), the pressure is held at this level and the top air cylinder is activated to supply additional pressure until it reaches its preset level. The air cylinder pushing down is the only moving part in the process, which significantly simplifies maintenance issues.

Parker's air cylinders are low friction, delivering long life. The long life of the air cylinder is critical because the spinal joint being tested has to move through 10 million cycles under the specific force being used.

"Usually, when you're looking for tight force or position control and the application's loads simply don't justify hydraulics, the obvious alternative is an electromechanical solution, said Schatteman. "Because," he continued, "with pneumatics, employing air—which by nature is spongy—attaining precision is sometimes difficult. This, however, is one of those rare applications in which pneumatics actually increases force control," he said.

Spinal joint testing causes slight "upward and downward" motion on the air cylinder rod. The spongy consistency of air compensates for a servomotor system that would react to that slight movement by continually trying to correct itself, which would be bad for the life of the motor, as well as the ball screw. The mechanical parts would be in constant motion and eventually fail.

The result of this air-balancing act is tight force tolerance on the test specimen while the pneumatic system is in a state of near-constant equilibrium. This allows sensors gather information on test specimen potential endurance and performance parameters.

The pneumatic design used with the joint endurance testing machine also eliminated the hassle of maintaining ball-screw assemblies, while air valves with electrical input for pressure control proved user-friendly and easy to program.

Datum Industrial Design reports that the pneumatic products can be adjusted or changed quickly, with minimal problems, eliminating downtime.

"This cannot be said for a servo system," Salvesen commented. "Servomotors are great and I use them all the time," he continued. "But not for this system. Parker pneumatic products are the only way to go."

Online

For additional information on the technologies and products discussed in this article, see *MDT* online at www.mdtmag.com [2] and the following websites:

•www.parker.com [3]
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