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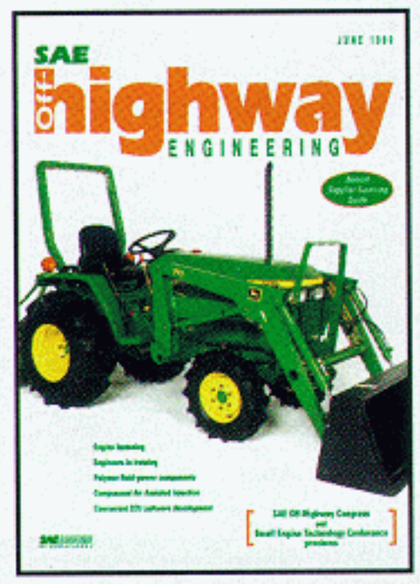
Cover: *John Deere's new 790 Compact Utility Tractor is used for mowing, working with a loader and backhoe, digging post holes, and clearing snow (see page 34).*

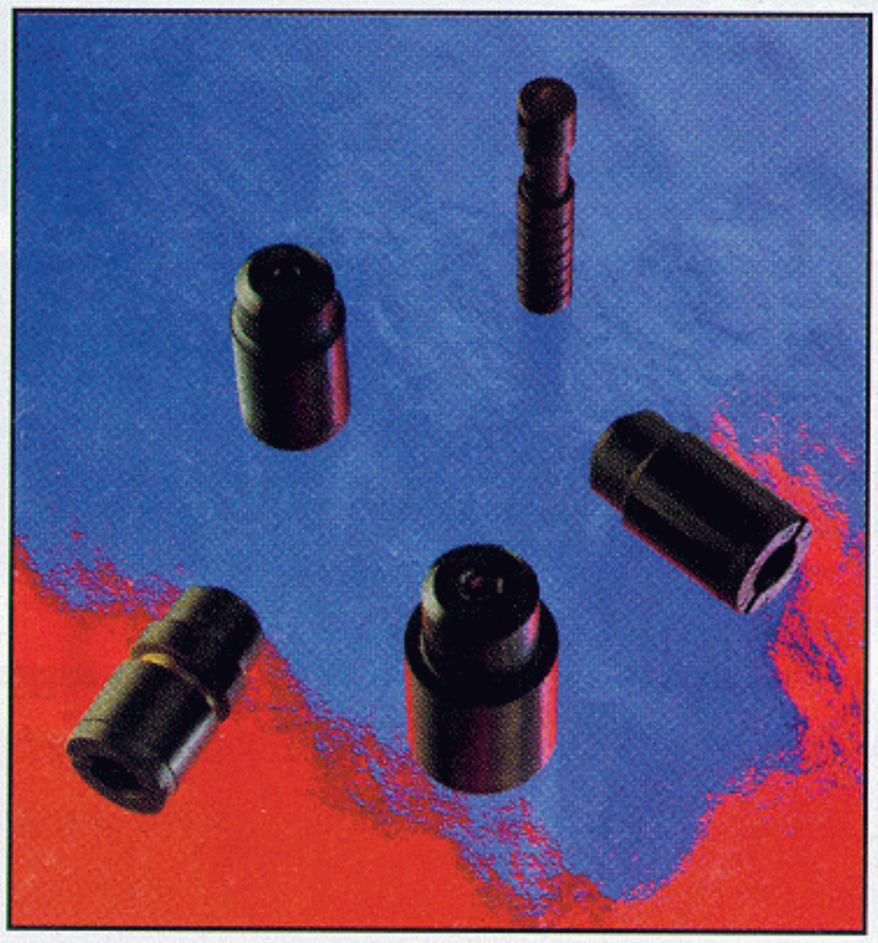


Polymer components for fluid power systems

Aztec Plastic has been combating leakage problems in poppets and spools by using TORLON polyamideimide from Amoco Polymers, with its customers seeing dramatic results.

As hydraulic power systems undergo design changes to handle heavier loads and provide longer service life, internal components are changing. Where steel poppets and spools were once sufficient for most fluid power applications, new parts made of an advanced engineering polymer are delivering superior performance and service.

Fluid power systems for earthmoving and agricultural equipment are changing. For years, the industry standard for pressure within fluid power systems has been 21 MPa (3000 psi). However, new technologies are allowing engineers to design systems that run up to 34 MPa (5000 psi), which is a significant advance. Operating at higher pressure gives a fluid power system the capacity to do much more work. Another advantage is that a much smaller system can do the same work that once required a larger system.



Traditional steel poppets and spools have served as a barrier to higher, more efficient operating pressures. Designers accept the fact that steel parts will leak to some degree during normal operation, and that the leakage will increase with the number of operating cycles. Systems that use steel poppets and spools generally require frequent rebuilds.

Poppets are used in check valves to prevent the flow of hydraulic fluid in one or more directions. When pressure inside a hydraulic cylinder reaches a specified upper limit, the poppet moves, allowing fluid to flow out of the pressurized cylinder and into an overflow tank. A high efficiency poppet does not leak fluid until it reaches release pressure.

Spools are components in restrictive flow regulators, which work like an automatically variable orifice to control flow by throttling or restricting, allowing smooth operation of the fluid power system. Compensator spool movement blocks fluid flow through the valve. Flow passing through the metering orifice is accompanied by a pressure drop that is applied to each end of a balanced spool. The resulting force imbalance moves the spool against the control spring. Spool movement progressively blocks off flow area, restricting or throttling flow through the valve. Like poppets, spools should ideally work without leaking, but steel spools tend to leak increasing amounts of fluid as they wear in normal service.

Aztec Plastic Company is doing something about the leakage problem in poppets and spools, and its customers are seeing some dramatic results. The Chicago-based custom injection molding company specializes in metal replacement, using structural composites and engineering resins in place of conventional materials. Aztec has a wide array of molding equipment, ranging from 70- to 230-t (75- to 250-ton) capacity. The company also performs many secondary manufacturing operations for its customers, including machining tasks such as drilling, tapping, stamping, centerless grinding, and ultrasonic welding. Aztec's customers include many widely known manufacturers of farm equipment, earthmoving equipment, forklift trucks, and other industrial machines that use fluid power systems. By using a high-performance engineering polymer as raw material, Aztec is making poppets and spools that give hydraulic systems higher performance and much longer life.

"About nine years ago, we started experimenting with an engineering polymer called TORLON polyamideimide (PAI), which is made by Amoco Polymers, Inc.," recalls Martin Wielgus, Aztec's president. "TORLON PAI lets us make poppets and spools that improve the operation of fluid power systems. Components made from TORLON are lighter than steel, so they have a quicker response. Also, because TORLON PAI has the ability to hold sharp contours, the system's performance increases."

TORLON polyamideimide provides good strength at high temperatures, and has high resistance to creep and wear. Low friction-wear characteristics have made the resin a better-performing replacement in many applications that traditionally used metals. For example, it has been used to replace seals in some large cracked-gas process compressors. In one particular compressor, the aluminum seals previously used required replacement at six-month intervals. Seals made from TORLON have been in operation in this system for five years, with no failure and no replacement. The resin has also been used with excellent success in automotive transmission thrust washers, check balls, and seal rings. Wielgus says Aztec has had equally impressive results using the PAI for fluid power system components.

"Our customers' engineers are telling us that hydraulic

poppets and spools made from TORLON are remaining leakless after more than one million cycles — that's unheard of," Wielgus says. "One customer has just finished a comprehensive test. Hydraulics of the future are going to be running at 5000 psi (34 MPa) of pressure, so that's their test criteria. They've tested our poppets at 5000 psi (34 MPa), and after 1.5 million cycles, they're still leakless. Our customer is very enthused about these results." Aztec has over one million (21-MPa) 3000-psi poppets in service, and over 90,000 of a new (34-MPa) 5000-psi poppet in service. Aztec reports that both designs are leakless, and spools have been tested, with the same results as the poppets.

Aztec's adoption of the Amoco resin came about gradually. "We first started making parts from TORLON PAI for the military," Wielgus remembers. "Military projects always get us into using materials that are ten years ahead of their time. Alliances with contractors such as Northrop Grumman helped develop our use of TORLON PAI." Wielgus adds that the traditional method of making parts from the resin was to machine the parts from solid rods.

"One of the engineers we were working with said he had heard you could mold TORLON resin, and he was interested in the possibility of our doing it because we were doing molding on other projects for his company," says Wielgus. "We looked into it. One thing about Aztec: don't tell us something can't be done, because it pushes us harder to accomplish the task and make it a reality."

"Through our research and development and with modifications to one of our molding machines," Wielgus continues, "we were able to accomplish the molding of TORLON screws." We found that a savings of 30-50% could be achieved with production of 150 pieces or more. The conventional machining technique couldn't compete any more."

"Based on our success there, we started telling our other customers about the material. It's a slow process, because many engineers don't really believe that engineering plastics can perform better then metals." In one instance, a now-satisfied customer required two years of what Wielgus calls "hand-holding" before they would use parts made from TORLON, because the engineers were concerned about using plastic.

"They didn't think the parts would work," says Wielgus. "They had very strict criteria that we needed to meet. The turning point occurred when the customer completed a 300,000-cycle test. When they unscrewed the threaded plug in the back of the valve, an engineer looked into the valve and said 'Oh my God!'. I became concerned, because I thought the part had failed. As it turned out, the poppet had hobbed itself into the steel plug without breaking the TORLON poppet. You could almost see a cartoon light bulb come on over everyone's head. And that was it. They thought it was fantastic, and business has been ever upward since then. We've been molding for hydraulic applications since 1989."

Poppets and spools made from the resin still require some machining after molding because of the close tolerances involved. "For precision poppets, we hold plus or minus about nine-millionths roundness," Wielgus explains. "That means you have to do centerless grinding for angles and other operations of that nature. You can't mold any material to those kinds of tolerances. Even with steel, the material has to go into secondary machining, precision grinding, etc. The good news is that we do all of the work in-house, which enables Aztec to keep the costs down. Parts are ready for installation when they leave Aztec. Between the price/performance advantages of the material and the savings of molding versus machining, parts made from TORLON are still highly competitive. When you factor in the dramatically improved service life and the fact that the parts are leakless, nobody can really afford not to use TORLON PAI."

Using the PAI resin requires support from the manufacturer. Wielgus is pleased with his relationship with Amoco Polymers. "Our satisfaction with Amoco is very high," he says. "The people who originally taught us about TORLON resin processing were very knowledgeable. Back when we first started using the material, people from Amoco Polymers would come to our plant and provide advice to help us design the parts. Nowadays, we typically ask the people at Amoco for their input when someone comes to us with a new application idea, and they've been quite helpful. If we have a part fail for some reason, I can send it to Amoco Polymers, and they'll be able to tell me if they think the problem was with the material, the processing, or the part design. Aztec has experienced very few problems with TORLON PAI, due to our extensive experience with the material and Amoco's technical support."

TORLON 5030 Resin Mechanical Properties

Tensile strength	250 MPa	(32.1 ksi)
Tensile elongation	2.3%	
Flexural strength	338 MPa	(48.3 ksi)
Flexural modulus	11.7 GPa	(1700 ksi)
Compressive strength	260 MPa	(38.3 ksi)
Shear strength	140 MPa	(20.1 ksi)
Impact strength, Notched Izod	79 J/m	(1.5 ft•lb/in)
Heat deflection temperature @ 1.82 MPa (264 psi)	282˚C	(539˚F)

Despite all the potential advantages of switching to parts made from the resin, Wielgus finds old prejudices die hard. "The biggest challenge we face in metal replacement," he observes, "is the engineers who have what we call a 'metal mentality,' meaning they simply don't understand that plastics can have performance characteristics that can be superior to metals in certain applications. Once they're convinced, though, they never go back."

This article was submitted to *SAE Off-Highway Engineering* by **Patrick Clemensen** of BP Amoco.

For more information about Aztec Plastic Company, circle 1
For more information about TORLON resin, circle 2

Interesting? Circle 3
Not interesting? Circle 4