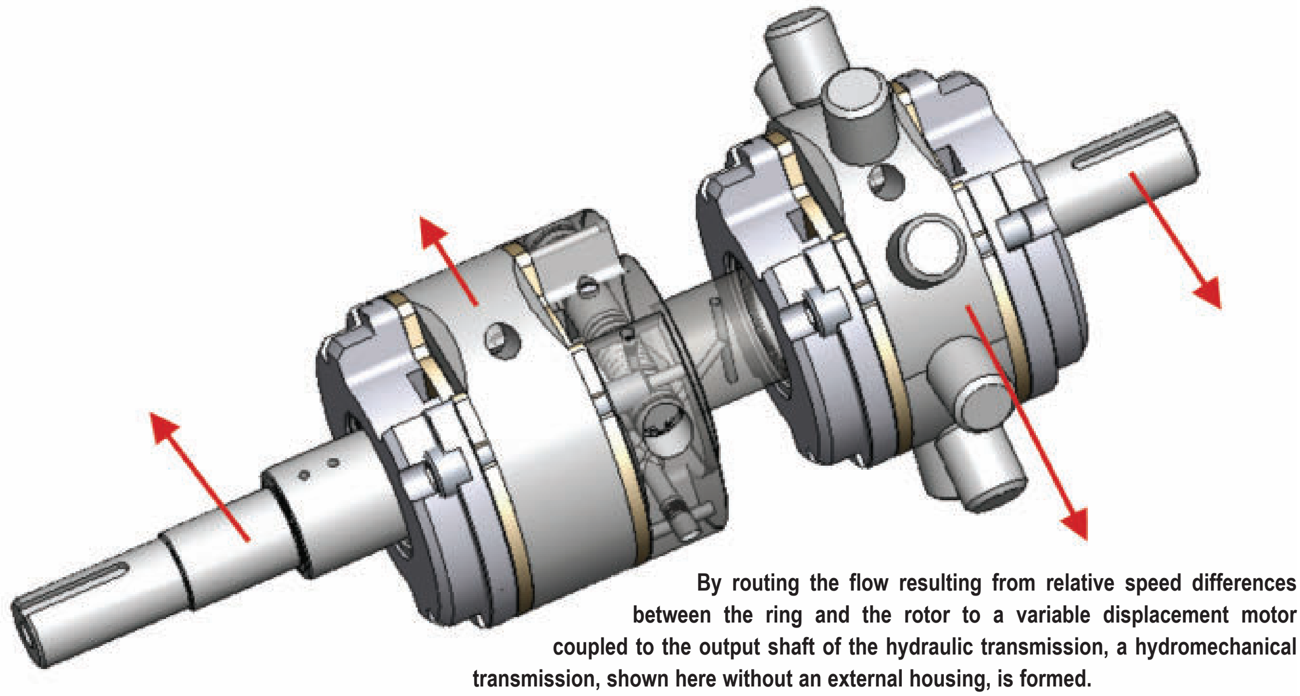

By routing the flow resulting from relative speed differences between the ring and the rotor to a variable displacement motor coupled to the output shaft of the hydraulic transmission, a hydromechanical transmission, shown here without an external housing, is formed.

STRIKING THE RIGHT BALANCE

Balanced, double-acting vane pump key to hydromechanical transmission prototype focus of CCEFP research

BY JACK BURKE

Michael Gust spent more than 20 years working in the hydraulics industry in various engineering roles. Over that time he saw several innovative products developed that were never brought to market. Simply put, just because something can be built that's technically better or more efficient than existing solutions doesn't mean the market will be willing to pay for it, said Gust, who now serves as the industrial liaison officer for the Center for Compact and Efficient Fluid Power (CCEFP) at the University of Minnesota.

"I've had more good ideas not make it out of the lab because of cost than for any other factor," Gust said. "Cost is a real barrier to commercialization."

Gust said one example of that truism is the hydromechanical transmission (HMT).

"Hydromechanical transmissions have been around a long time — they're in production on high-end vehicles typically — and they work," he said. "They've been proven in the field, they're durable. But to me, one of their biggest obstacles is that they're expensive."

A hybrid combination of both a hydrostatic transmission (HST) and a mechanical gearbox, the HMT is designed to provide the continuously variable transmission of power that a hydrostatic transmission provides, but in a more efficient manner. It combines the variable ratio of a hydrostatic transmission and high efficiency of a gearbox in one unit. A typical HMT usually employs a planetary gear set as the power split device. Although it is more efficient than an HST, the HMT is usually more bulky, more complex, has more components and thus, is more costly.

Next month, the CCEFP will be launching its next set of two-year research projects and one will be researching a novel, compact and efficient, pressure-controlled HMT suitable not only for on- and off-road vehicles, but scalable also to mid-size and perhaps even larger wind turbines. The new transmission is expected to be as efficient as conventional HMTs with planetary gears, but much more compact and cost-effective, Gust said.

A prototype will be built with support from Mathers Hydraulics, an Australian company that has developed some base technologies that the new HMT will build upon. One example is a vane pump with retractable vanes — a key to providing a wide neutral for this new HMT design, Gust said. The core of this new HMT is a rotating group similar to a conventional vane pump except that it has a rotating ring. By coupling the rotating ring and accompanying faceplates to an output shaft, a mechanical path for transmitting power is provided.

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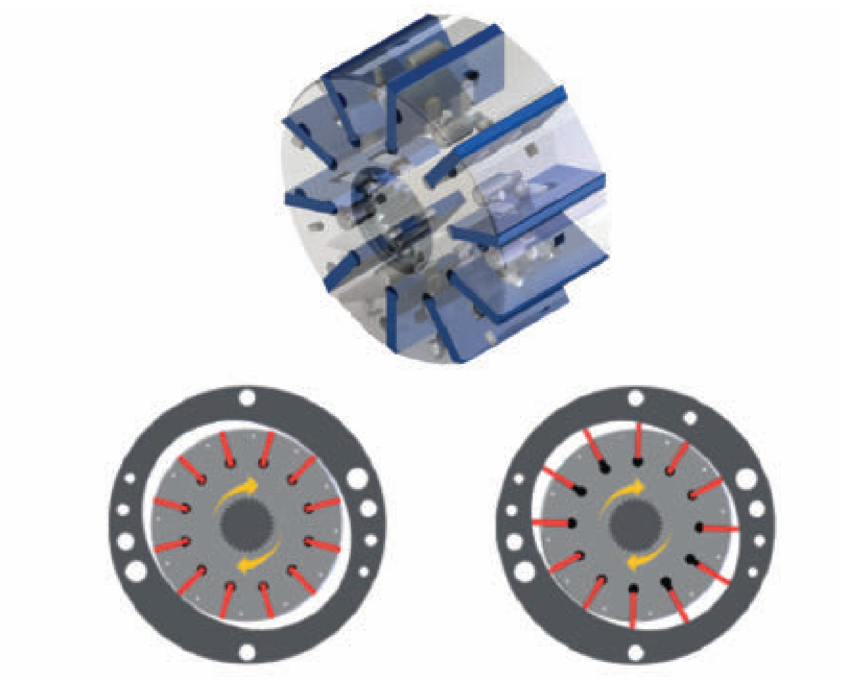

The pressure-controlled hydraulic transmission has a clutch feature. For each vane, there is a pin driving a ball. By providing pilot pressures to these pins, the vane can be fully retracted, decoupling the output shaft from the input shaft and making the transmission function as a clutch. The figure at top shows the vane structure and the bottom figures (left to right) illustrate the idle and transmission mode.

The hydrostatic power path is provided via the flow created by the relative speed difference between the ring assembly and the input shaft and rotor. If this flow is routed internally to a variable displacement hydraulic motor coupled to the ring's output shaft, it turns the overall assembly into a hydromechanical transmission. The net result is a transmission system that is very compact, Gust said.

"And size and weight equals cost," he said. "When you have a stand-alone pump, a stand-alone motor, normal gearbox, a couple of input or output couplings, it's complicated — lots of parts, lots of weight.

"What excites me about this technology is that it has the potential to meet the cost point of competing transmissions while providing the features of a hydromechanical transmission."

Since the core technology originates from a balanced, double-acting vane pump, through which the rotating group takes in and discharges oil twice per shaft revolution, the positive attributes of vane pumps — quiet operation and durability — are also inherent in this design. Because the two inlet chambers and two outlet chambers are symmetrically distributed between the rotor and the ring assembly, the rotor shaft does not endure unbalanced pressure forces, resulting in low bearing loads that translate into long life.

Similarly the continuous rise and fall contour of the inner ring profile results in a gentle flow profile, which makes the whole unit quieter, Gust said. Another positive feature of vane pumps, he added, is that they have inherent high displacement density, which equals power density.

"You can transmit hydraulic power through flow or pressure," Gust said. "With a vane pump, it's best to take advantage of the flow density and cap the maximum pressure at 3500 or 4000 psi. I fully recognize that this is lower pressure than what piston pumps can handle, but that might be an advantage in some ways.

"When you start going to really high pressures, there's a lot of things that can go wrong. So if you want durability and life, I think there's nothing wrong with a 3500 psi system. It's still possible to package over 100 hp in a 6 in. diameter."

In theory and principal, the maximum power should be scalable into the megawatt range, Gust said. The only speed limitation is the speed differential between ring and rotor so as long as the maximum differential speed is not exceeded the entire coupling can spin at virtually any speed.

Another potential positive is the possibility of incorporating a lockup function that would make the whole transmission work as a direct shaft drive when necessary. The on/off clutch functionality of the retractable vanes is also beneficial, especially for hybrid vehicle applications Gust added, since no additional clutch is needed to disengage the engine to enable shutoff or idle. All these characteristics have made this pressure controlled HMT very promising for hydraulic hybrid vehicles, Gust said.

"It gives a host of control options to a systems engineer not the least of course is the ability to optimize the engine operation," he said.

The system will enable the engine speed to remain relatively constant, which allows the engine management system the best chance of offering fuel efficiency, he said.

"The other thing that excites me is, OK, why not put an accumulator in here and make it a hybrid?" he said. "There are a lot of things we have to study, but my gut feeling is telling me that this will enable a smaller sized hybrid vehicle which will be cheaper than other concepts."

CCEFP research project goals include incorporating the HMT into a Ford F-150 truck, but "the sky's the limit" for what the transmission could be used in. "The potential of this technology truly excites me," Gust said. "And I can't wait to get started." dp

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