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Add functionality to hydrostatic drives

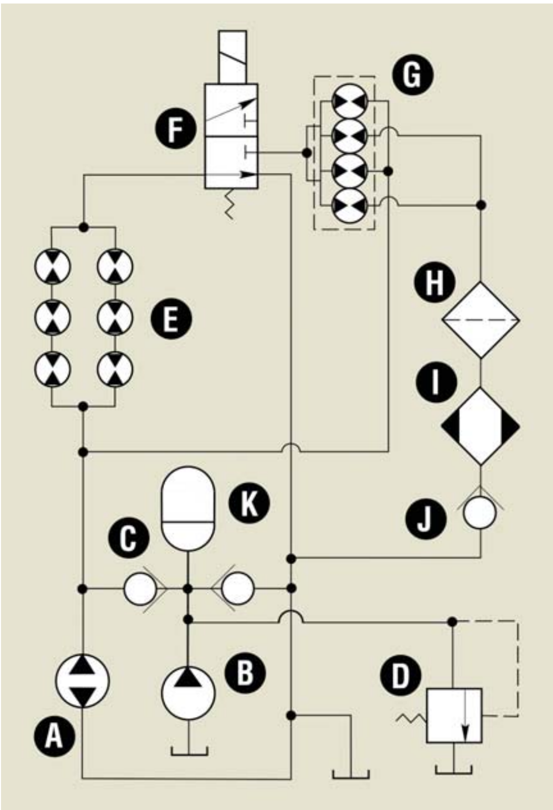
Innovative use of common components can add functionality and boost performance of your designs.

Hydraulic system designers are continually looking for ways to obtain broader ranges of speed and torque from a hydrostatic drive with a given pump, motors, and prime mover. The existing successful schemes can be summarized as:

- using a mechanical transmission with a variety of gearing arrangements in conjunction with one or more hydraulic motors, and
- incorporating valves to switch the hydraulic motors from a parallel circuit to a series circuit and back again, as required.

The patented hydrostatic drive system with regeneration circuit described here was developed to expand the speed range of vehicles. The system incorporates a gerotor-type flow divider in a branch circuit supplied by exhaust flow from the hydraulic motor or motors. Currently, flow dividers appear in regeneration circuits for open-loop, fixed-displacement circuits. But neither regeneration circuits, nor regeneration circuits with rotary flow dividers (particularly gerotor-type rotary flow dividers), have ever been used before with closed-loop hydrostatic drives — and certainly not in hydrostatic drives for mobile equipment.

ABCs of regeneration



Schematic circuit diagram of closed-loop hydrostatic drive with regeneration circuit (shown in its non-regeneration mode). Case drain lines are omitted to simplify the drawing, and although HSTs typically use a single reservoir, multiple reservoirs are drawn for the same reason.

Exploring the circuit

The basic circuit in the diagram at right consists of hydrostatic pump A, supplied by charge pump B, with check valves C and relief valve D. It also contains one or more hydraulic motors E in a conventional closed-loop configuration. Valve F, rotary flow divider G, filter H, oil cooler I, and reverse-flow check valve J round out the system. (The diagram also shows optional accumulator K in the charge-pump circuit.)

Solenoid-actuated, 2-position, 3-way valve F normally isolates the flow divider from the hydrostatic loop. (Pneumatic, hydraulic, or manual actuation would serve the same purpose.) When valve F is energized, exhaust flow from the motors is routed through the flow divider.

Flow from half of the sections of the rotary flow dividers is routed to a tee connection upstream from the motors in the high-pressure side of the hydrostatic loop. Thus, the branch circuit provides regenerative flow into the hydrostatic motors — for increased speed. Flow from the balance of the sections of the rotary flow divider passes through the filter, cooler, and check valve J to a tee connection on the low-pressure side of main pump A.

The role of flow dividers

Rotary flow dividers exhibit an intensification characteristic. If resistance to flow out of one section of a rotary flow divider exists, outlet pressure from that section can be intensified to a level higher than the supply pressure. The intensification force is applied by the other sections of the flow divider — if flow from those other sections is encountering a much lower resistance.

Such is the case with this circuit. Pressure builds up on the outlet side of the flow divider until it becomes high enough to join in with main pump flow going into the hydraulic motors. The circuit stabilizes when approximately half of the pressure generated by pump A drops across at least one hydraulic motor, while the other half of the generated pressure drops across the sections of the flow divider. The end result is that if pump A is putting out 20 gpm, after valve F is shifted, 40 gpm will go into at least one motor. And if the pressure drop across at least one hydraulic motor is 2000 psi, the resistance to flow at pump A is approximately 4000 psi.

These numbers are theoretical. In practice, and in accordance with the Second Law of Thermodynamics, the house takes its cut. Losses are due to internal leakage and pressure drops through various elements of any hydrostatic drive, with or without re-

Intensification circuit uses rotary flow divider

A gerotor-type flow divider provides simple, controllable intensification in the hydraulic circuit patented by patent agent George Morgan, P.E., Evansville, Ind. For example: if hydraulic motor A is the actuator (right), 3-position valve B selects the motor's direction of rotation. As pictured, flow passes through valve B and bypass valve C to drive the motor at the circuit's lowest pressure. Flow divider D is idle.

For higher pressure, valve C shifts to direct flow to the flow divider (far right). Output flow from the left-hand section of the divider is dumped to tank. Because the two flow divider sections are mechanically connected, the pressure drop across the left-hand section converts the right-hand section to a pump. Flow to the motor from the right-hand section is pressure intensified.

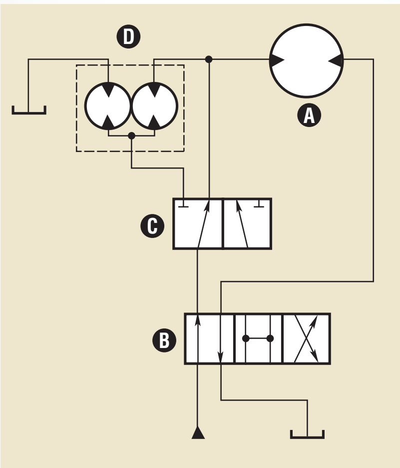
In this simple example, if the two sections of the flow divider have the same displacements (for equal flow), the new flow rate to the motor will be one half of the original — at double the pressure.

Gerotor flow dividers — such as Roller Stator flow dividers from White Drive Products, Hopkinsville, Ky. — are used for this circuit because they have a relatively flat efficiency curve across a wide range of flow volumes. (Gear-type flow dividers, on the other hand, must be designed for a specific flow range because their efficiencies are so dependent on an optimum speed.)

Furthermore, the White Drive flow dividers are structurally tougher than typical gear-type flow dividers and can be ordered with an integral relief valve. Finally, these rotary flow dividers are available with sections that have different displacement ratios, allowing designers to select a variety of flow and pressure combinations to match an application.

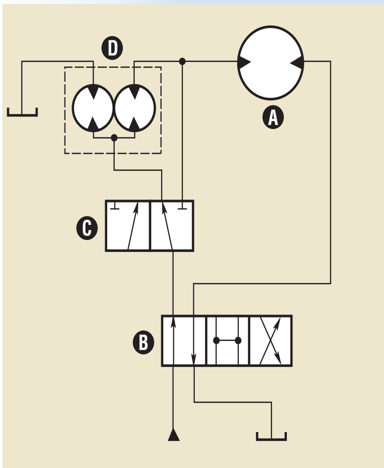
As to other components in the circuit, the center position of valve B can be whatever configuration the designer feels is appropriate, or even eliminated. Likewise, valve C could have three positions, if necessary, for some circuit function. The type of valve actuator is inconsequential to circuit performance. And, of course, the type of hydraulic fluid also does not affect the effectiveness of the circuit.

Situation normal



In normal operation, the circuit routes hydraulic fluid at system pressure to motor A through valve C.

The pressure is on



In high-pressure mode, valve C routes fluid through flow divider D, which intensifies pressure to motor A.

generation. Energy is not created or destroyed by the flow dividers, merely changed in form.

Rotary flow divider G in the schematic diagram is a 4-section unit, such as the Model FD 18181818 Roller Stator gerotor type from White Drive Products, Hopkinsville, Ky. This component was selected because of its modest internal leakage and relatively low pressure drop — typically 140 psi at 40 gpm fluid flow. Pressure drop steals horsepower and adds heat. For vehicle drives, both the extra horsepower requirement and the need to dispose of extra heat are undesirable. (Although high-capacity, gear-type rotary flow dividers with low pressure drop exist, they tend to be more expensive and less efficient across the lower speed ranges than gerotor flow dividers.)

Additional functionality

Variations in the amount of regenerated flow can be achievable by varying the ratios of sections of the rotary flow dividers. Smaller gerotor sections in the regeneration line would make more pressure drop available for work across at least one hydraulic motor. Conversely, larger gerotor sections result in less pressure drop being available, but more flow.

When pump A is reversed, what was the low-pressure side of the closed loop becomes the high-pressure side. In this mode, de-energized valve F and check valve J protect the cooler, the filter, and the flow divider from reverse fluid flow at high pressure.

In vehicle drive systems, the hydrostatic pump would typically be a bidirectional, variable-displacement, axial-piston model. In industrial drive systems, the pump is not necessarily an axial-piston type, nor does it have to be bidirectional; it could have fixed displacement. (If the pump is not bidirectional, check valve J is not required.)

There is another benefit to the circuit that does not involve regeneration. For conventional hydrostatic drives with bidirectional pumps, the approaches to proper filtration and cooling are limited. High-pressure filtration arrangements are expensive, so typically they are not used on mobile equipment. Similarly, coolers that can withstand the high pressures of the hydrostatic loop also would be heavy as well as expensive. Consequently, most filtration and cooling designs are limited to case-drain or charge-pump flow, or hot-oil shuttle arrangements where only a small percentage of flow is cooled and filtered at a time. The bulk of the flow often is not properly filtered or cooled, opening the door to accelerated component wear.

The filter and oil cooler in the regeneration circuit only have to deal with relatively low-pressure flow. Whenever valve F is energized, half of the flow in the circuit goes through the filter and cooler at low pressure.

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