FAREWELL TO THE METERING EDGE

Summary

Out at sea, hydraulics often power motion compensation systems onboard ships. By using a new generation of Electrohydrostatic Actuators, such systems can be significantly optimized. In this particular gangway application the following improvements were achieved:

- Higher energy efficiency enabled a 90 % reduction in input power
- The amount of hydraulic fluid was reduced by 80 %
- The total system footprint was cut by 30 %

Background

In many applications hydraulic cylinders remain irreplaceable as no other actuator can produce linear movements, while subjected to such large forces, so easily and cost effectively. The cylinder's motion is usually controlled using valves, which regulate the flow of oil to and from the cylinder by opening and closing specially designed metering edges. Such valve-controlled cylinder solutions enable precise and dynamic actuation but suffer from one major problem, poor energy efficiency. To ensure a sustainable future for fluid power it is necessary to design systems that exploit the distinct advantages of hydraulic cylinders while delivering improved efficiency. This was exactly the challenge facing the Dutch company Ampelmann three years ago.

As a leading supplier of Motion Compensated Gangways, the Rotterdam based company has come to appreciate the performance of valve-controlled circuits during the past ten years. On the other hand, they always regretted that a system that in principle only lifts and lowers a mass and on average practically performs no work, still consumes so much energy. Together with Moog, they decided to develop a new architecture based on an Electrohydrostatic Actuation System (EAS). The new solution is significantly lighter and more compact, requires less than a fifth of the amount of hydraulic fluid previously needed, lowers energy consumption and reduces the gangway's input power demand by 90 %.

The Technical Challenge

In sea states with significant wave heights of up to three meters, the Ampelmann A-Type Gangway allows 20 people to be transported from a vessel to a fixed or floating object in less than five minutes. The heart of the system is a valve-controlled hydraulic hexapod that counteracts the ship's wave motion and provides full motion compensation. A traditional centralized hydraulic power unit supplies the valves with pressure and flow. This design offers two major advantages. First, all six actuators can be supplied with power from one common motor-pump unit,

Fig. 1: New Ampelmann A-Type Gangway with EAS

and second, this unit only has to cover the average flow rate demand, since hydraulic accumulators, used to cover peaks in flow demand, can be integrated with relative ease in the supply line. In the event of a power failure, these same accumulators perform the function of an emergency pressure supply and ensure that passengers can be safely brought back on board even if electric power from the ship's generator is lost.

Unfortunately, from an energy point of view, this setup is not optimal. To allow flow to pass through the inlet metering edges the supply pressure must always be greater than the highest load pressure in the system. This mismatch between the supply and load pressure levels leads to unnecessarily high pressure drops across the valves. A loss-free transformation of the supply pressure down to the currently prevailing load pressure in each cylinder, similar to a buck converter used in power electronics, is not possible using valves. A variable supply pressure can reduce these losses, but as mentioned previously in these types of applications hydraulic accumulators are needed. Consequently, the supply pressure level is fixed and cannot be adjusted. These pressure losses, also called throttling losses, occur not only across the inlet edges, but also across the outlet edges, since oil flowing back from the cylinder always ends up in the pressure-less tank. This means that any power returning from the actuator is throttled across the outlet edge and turned into heat, i.e. no mechanical energy can be recovered from the process.

In the case of a Motion Compensated Gangway, conditions are particularly unfavorable as the hexapod is continuously delivering and absorbing energy as it lifts and lowers the gangway. Ideally, the actuators would store energy from the waves during each retraction motion and reuse it during extension, meaning that the average power consumption would be close to zero. During the retraction motion in a valve-controlled system, not only is the energy absorbed from the waves lost across the outlet metering edge, the cylinder's inlet side is simultaneously being supplied with oil from the accumulators. Consequently, the actuators consume power during both extension as well as retraction. Since the system's average mechanical output power is close to zero, this means that all the hydraulic energy supplied from the accumulators is ultimately lost across the metering edges. To make things worse, an additional cooling circuit must be installed to extract the heat from the system and prevent the oil from overheating.

The large hydraulic power unit together with the accumulators results in a total system weight of 40 tons and requires 300 kW of input power. This meant that such gangways could only be installed on larger vessels. To enable operation on smaller ships, the weight and above all the required input power had to be significantly reduced.

An Electrohydrostatic Solution

It quickly became clear, that the only feasible approach to reach these goals would be to remove the control valves and use an Electrohydrostatic Actuation System, in which every cylinder receives its own dedicated motor-pump-unit. This completely eliminates throttling losses as each cylinder now has its own independent source of flow, delivering hydraulic power at exactly the required load pressure level. Cylinder movement is no longer controlled by opening and closing metering edges inside a valve, but by changing the speed of the pump. For energy recovery, a closed loop hydrostatic circuit powered by a hydraulic unit capable of operating as a pump and motor in both rotation direction, i.e. four quadrant operation, must be used. Moog's Electrohydrostatic Pump Unit (EPU), shown in Fig. 2, fulfills these requirements and is the heart of the new system.

The actuator, displayed in Fig. 3, was developed in collaboration with the company Vydraulics, headquartered in Belgium. Due to safety reasons a redundant setup consisting of two smaller EPUs mounted directly onto an aluminum manifold was used. Twelve drives, connected to a common DC bus, control the motors and allow power to be exchanged between the actuators. An additional bank of supercapacitors takes on the same role as the hydraulic accumulators in the previous system and additionally allows energy recovered from the waves to be stored.

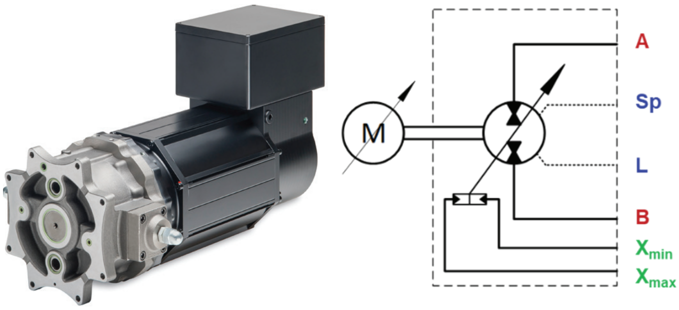

Fig. 2: Moog Electrohydrostatic Pump Unit (EPU)

Fig. 3: Moog / VAPO Electrohydrostatic Actuation System (EAS)

Savings in Multiple Areas

Whereas the valve-controlled system required an input power of 300 kW, the EAS solution requires just 10 % of this, i.e. only 30 kW. Only the efficiency losses of the drive components (cylinders, pumps, motors and drives) must be fed in. Thanks to the closed loop hydrostatic circuit, the amount of hydraulic fluid required was reduced from 1,700 liters to 300 liters, which is quite significant for marine applications, as no external oil leaks are tolerated. The new system is also more compact, allowing a 30 % reduction in footprint and a cut in total weight amounting to 35 % (from 40 to 26 tons).

Ampelmann's new gangway clearly highlights that Moog's hybrid actuation technology is also very well suited to marine applications. The robustness of a hydraulic cylinder combined with all the advantages associated with electric drives and motors is convincing in terms of energy efficiency, input power, oil quantities, weight and noise emissions.

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