Technical Topic

Hydraulic Efficiency

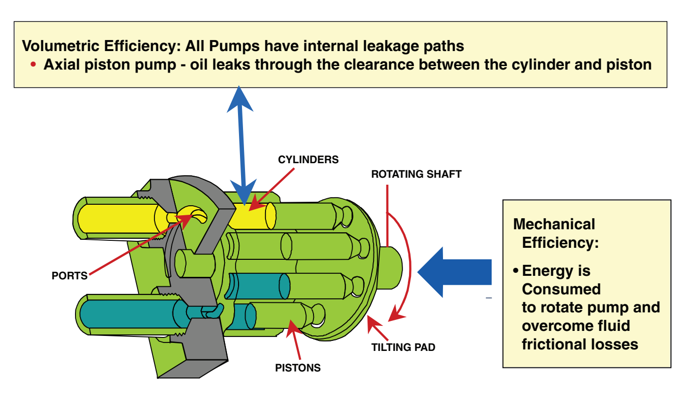
Today's globally competitive business world drives manufacturers to get the most out of their equipment. Even small increases in machine productivity can mean the difference between profit and loss. Additionally, environmental concerns demand focus on sustainable business practices and energy efficient systems. In response, industrial and mobile equipment hydraulic systems have become smaller and lighter, and utilize higher pressures to achieve maximum system efficiency. Now, advanced hydraulic fluids are available to meet the demands of these systems, as well as to contribute to overall hydraulic system and energy efficiency.

Hydraulic Efficiency: Theory

Hydraulic systems convert mechanical energy input from an electric motor or internal combustion engine into fluid flow and pressure that can accomplish a specified amount of work.

Hydraulic pumps convert the mechanical energy of the prime mover into fluid flow. Pressure is generated by the restriction of this flow in the system. Unfortunately, the hydraulic pump cannot be 100% efficient in this energy conversion. A typical hydraulic pump is only 80-90% efficient in this process. The energy is lost in two main forms.

- Mechanical losses – energy lost to fluid friction
- Volumetric losses – energy lost as the result of internal fluid leakage (slippage) within the pump.

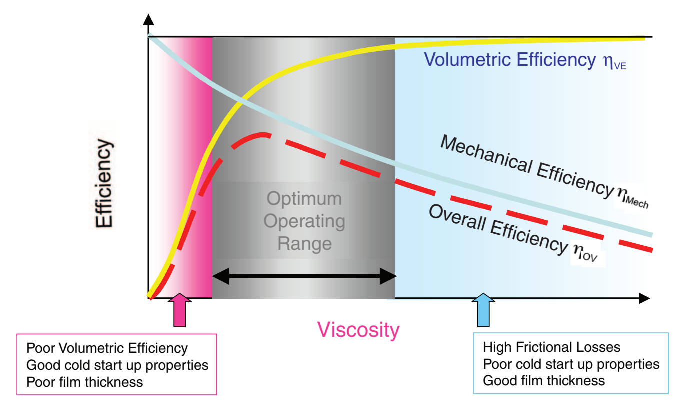


Volumetric Efficiency: All Pumps have internal leakage paths
- **Axial piston pump - oil leaks through the clearance between the cylinder and piston**

Mechanical Efficiency:
- **Energy is Consumed to rotate pump and overcome fluid frictional losses**

Hydraulic Pump

The amount of mechanical and volumetric loss in a pump is primarily a function of the fluid's viscosity and lubricity properties. This can be shown on the graph (top right).



Poor Volumetric Efficiency
Good cold start up properties
Poor film thickness

High Frictional Losses
Poor cold start up properties
Good film thickness

Volumetric Loss

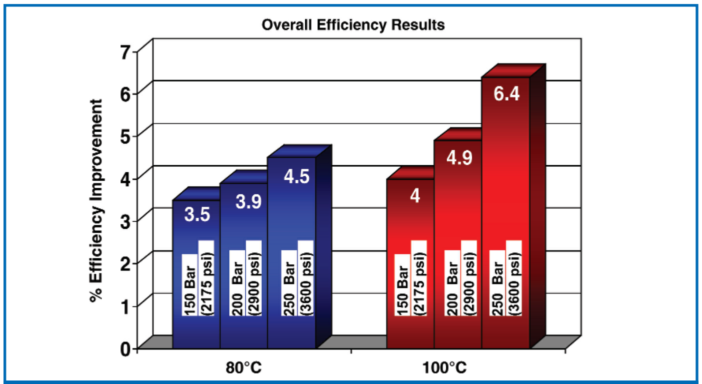
Mechanical losses are highest when fluid viscosity is high and volumetric losses are highest when fluid viscosity is low. Viewing these two curves on the graph illustrates a viscosity range for optimal efficiency. Because hydraulic fluid viscosity is high at low temperatures and decreases as the fluid temperature rises, staying within this optimal operating range is not simple. Specially formulated hydraulic fluids can reduce the magnitude of these losses by utilizing a high viscosity index to maintain fluid viscosity in the optimum range across a wide operating temperature range. Increasing system pressure also reduces hydraulic pump efficiency. Higher pressures generally lead to both increased mechanical losses (there are higher loads on the pump) and increased volumetric losses (higher pressures increase the amount of internal leakage).

In addition to the hydraulic efficiency benefits from maintaining hydraulic fluid viscosity in the optimum range, additional efficiency gains can be achieved through selection of optimal base fluids and additive technology to reduce traction – the inherent resistance of the fluid to shear under Elasto Hydrodynamic Lubrication (EHL) conditions.

Theory into Practice:

Differences in hydraulic efficiency can be quantified by comparing two fluids in a simple hydraulic circuit. The circuit contains a hydraulic pump and the system pressure is controlled over a specified range. The mechanical energy input to the system and the flow rate from the pump can then be measured and used to calculate the mechanical and volumetric efficiency of two different fluids.

The following graph shows this comparative data between a typical ISO VG 46 anti-wear hydraulic fluid and specially formulated high VI test fluid. The test fluid demonstrates a hydraulic efficiency increase between 3% and 6% in this bench test. Note that as temperature and pressure increase, the efficiency benefit of the test fluid increases.



Efficiency – Mobil DTE 10 Excel

This demonstration shows the impact that fluid formulation and physical characteristics can have on overall hydraulic efficiency. But hydraulic efficiency is not an end goal in and of itself. This additional pumping efficiency can translate into energy savings, as measured by fuel or electricity consumption, or into decreases in time to complete a work cycle in hydraulically powered equipment.

Hydraulic Efficiency = Productivity Improvements

A prime candidate for demonstrating the impact of hydraulic efficiency on energy consumption and cycle time is an excavator. An excavator employs high pressure hydraulics, driven by a diesel engine, to operate the boom as well as to turn the machine and drive the tracks. Hydraulic system pressures can reach 4,000 psig (275 bar) and temperatures often approach 100°C.

A demonstration was arranged with a medium sized excavator to compare a typical SAE 10W fluid, commonly used in mobile equipment applications, with a hydraulic fluid specifically designed to optimize hydraulic efficiency. For the purpose of this demonstration, a single operator and batch of fuel was used to operate the excavator through a prescribed set of motions. In this demonstration, application of efficient hydraulic fluid resulted in up to 6% reduction in fuel per cycle and a decrease of up to 5% in time to complete each work cycle. The machine operator also noted that the responsiveness of the system improved immediately upon addition of the test fluid.

The results of this demonstration clearly show the impact of increasing hydraulic efficiency: reduced fuel consumption or increased productivity! Use of this specifically designed hydraulic fluid for a full year in a medium sized excavator would reduce fuel usage by as much as 900 gallons and reduce CO_2 emissions by as much as 9 metric tons.

Similar energy savings opportunities exist in industrial hydraulic applications. A prime example is plastic injection molding, which is characterized by relatively high temperatures and pressures, large power consumption, repeated cycles, etc. Use of efficient hydraulic fluids in plastic injection molding has shown energy savings up to 10% versus a typical hydraulic fluid in controlled testing.

Conclusion: Applying knowledge of how hydraulic efficiency can be improved through proper hydraulic fluid selection can increase the bottom line. Utilizing a well-formulated hydraulic fluid can reduce efficiency losses in hydraulic systems, leading to energy savings and increased productivity.

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