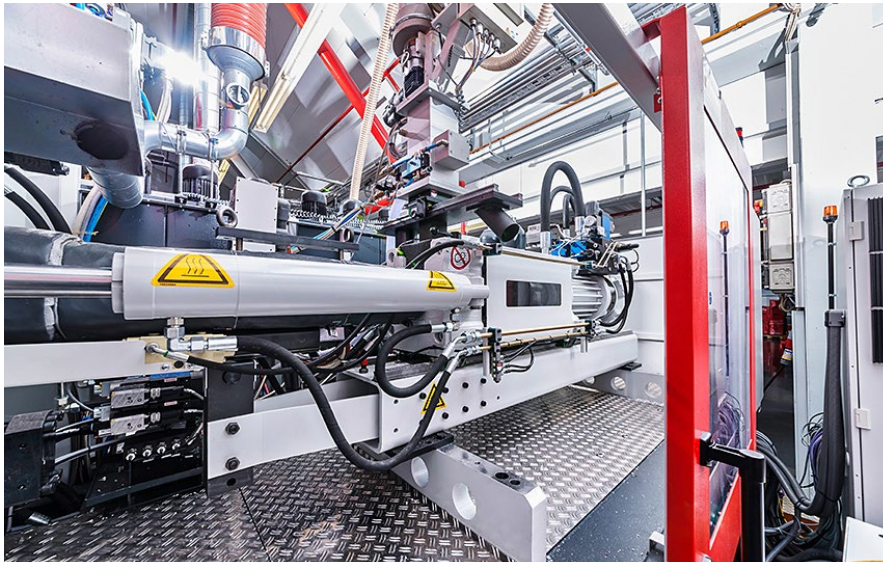


Drive & Control profile

Technical Article

Electric drive technology options for plastics machines



The newest generation of plastics processing machines are increasingly incorporating a range of all-electric drive systems into their designs, such as variable frequency drives and servo drives, to support improved energy efficiency and operational flexibility.

In modern plastic machines, the motive force powering the machine can take several forms and technologies. Traditionally most machines were hydraulically driven, using a hydraulic pump driven by a fixed (constant speed) electric motor. This technology typically powered most of the machines' processes.

Over time, incremental improvements in efficiency, accuracy and operating speeds were introduced. In the 1990s, a new technology became available

for injection molding machines: the all-electric machine, which utilizes electric servo motors powering gears, racks and ball screws to drive most of the machine functions.

The all-electric machines feature low noise, high-speed operation and the freedom from certain issues associated with hydraulics, related to fluid handling and leaks within processing equipment. For all of the advantages of the all-electric machine, there are limitations—such as those

Key Considerations

- A range of technologies is now available to drive hydraulic systems on plastic production machines, offering higher speeds, greatly improved energy efficiencies and higher reliability
- Variable frequency drives (VFDs) vary the frequency of the drive output to vary the motor RPM; they are relatively low-cost but only provide speed accuracies of around ten percent
- Vector drives use microcontrollers to precisely manipulate drive output to control torque of a standard AC induction motor
- Servo drives offer a high speed range, maximum torque available at zero RPM, and very high dynamics
- Servo drives are more costly and require more complex drive electronics; they offer the ability to precisely control speed, torque and position of the servo motor.
- In certain molding machines, servo drives used with variable displacement pumps dynamically control pump speed to match the varying flow and pressure requirements through the course of a machine's duty cycle, reducing energy consumption and operating more efficiently

associated with the machine's capacity (tonnage) as well as increased maintenance requirements for physical components, due to wear on ball screws, belts and gears.

Newer drive technologies

Today, new technologies are available to drive large-tonnage injection machines, technologies that offer higher speeds, greatly improved energy efficiencies and higher reliability. These new technologies build on existing motor drive systems present in all machines and fit into three basic drive types:

- Variable Frequency Drives (VFD) utilizing V/f technology
- VFD Drives using Vector Drive Technology
- Electric Servo Drives



New hybrid drive concepts for plastics machines, such as Rexroth's Sytronix variable speed pump drive system, integrate intelligent control electronics and variable electric drives with powerful, energy efficient hydraulic pumps.

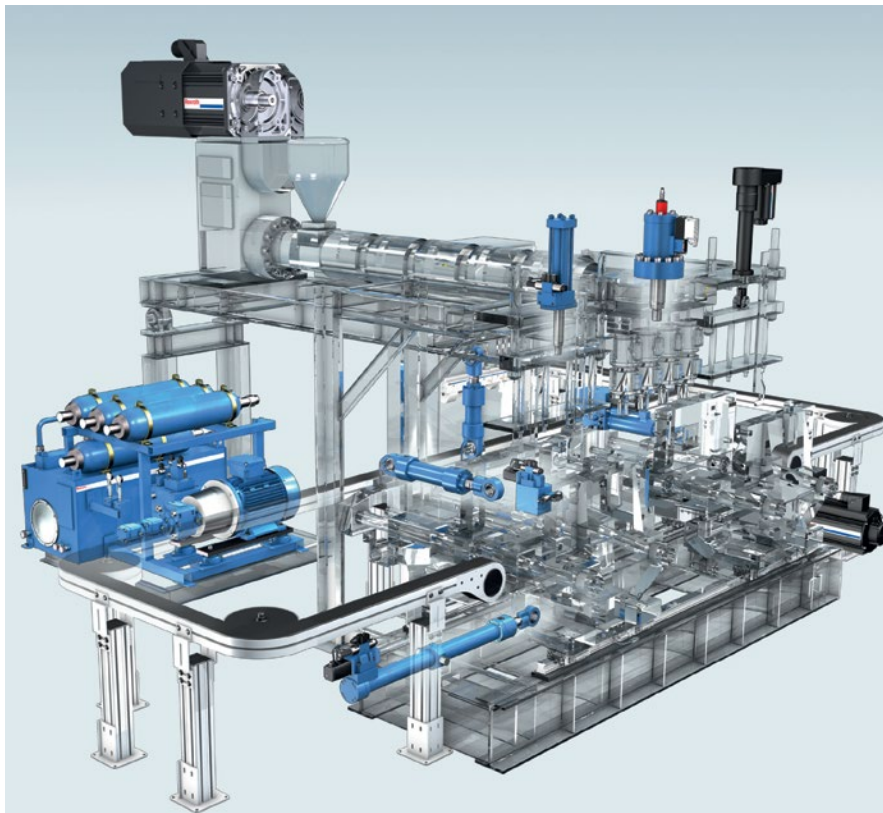
It is true that these more advanced drive technologies (such as servo drives) incorporate a variety of electronic control components and have a higher installed cost than a simple fixed speed electric motor

driving a hydraulic pump. It is useful to consider the advantages—related to energy efficiency, operational flexibility and overall system control and effectiveness—that machine designers and plastics manufacturing end-users can achieve from through use of these technologies.

Variable Frequency Drives: Variable frequency drives generate an output to drive a conventional AC induction motor. With V/f technology, the output can be varied in its frequency, which correspondingly varies the RPM of the motor. Due to the electrical characteristics of the motor, the output voltage is also varied in proportion to the frequency, thus the V/f designation. This relationship helps maintain the motor's torque over its usable operating range.

These drives feature low relative cost but only provide motor speed accuracies of around ten percent with varying loads. They have been used for many years to power plastic extrusion drives. Speed accuracy is more consistent with a steady load and can be improved over varying loads with the addition of a speed measuring tachometer. However, dynamic performance (ability to respond and control pressure and velocity changes) is low and mainly suited to slowly changing processes. VFD drives using V/f technology have low speed limitations and are only usable to about 400-500 RPM.

Vector Drive Technology: In the 1980s a new technology for VFDs emerged called Vector Drive technology. Utilizing microcontrollers, drive output could be manipulated to precisely control torque of a standard AC induction motor—even to zero RPM, when the motor is at standstill. This



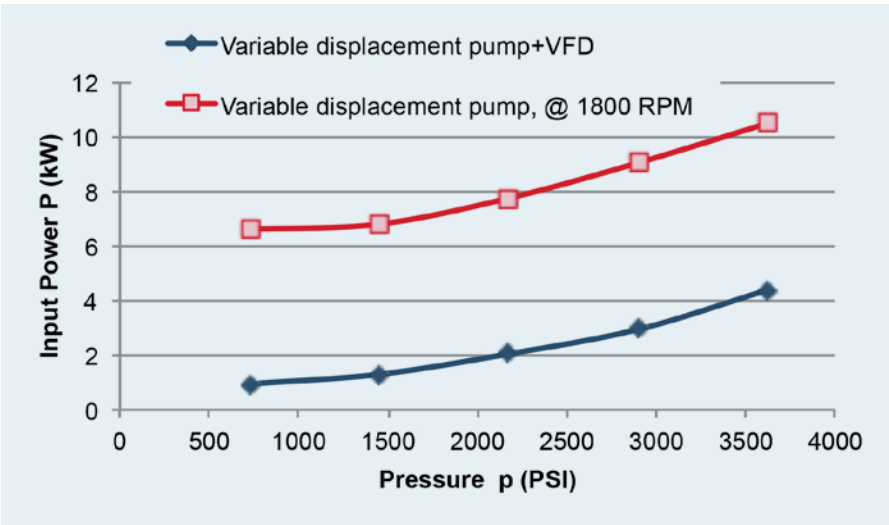
In certain molding machine applications, electric servo drives are used with variable displacement pumps to accurately and dynamically control pump speed, which can match the performance of all but the top tier of servo valve control technology.

technology allowed servo-like control of the motor for a small additional cost.

The high inertia of an induction motor is the limiting factor of dynamic performance of the drive. Sensorless Vector VFDs offer tight speed accuracy, with lower limits at 200-300 RPM. Adding an encoder sensor to the electric motor allows the vector drive to operate as low as zero RPM and has the capability to electronically position the motor's shaft to a high degree of accuracy.

While both types of VFDs are capable of a wide range of operation, there are certain technical design considerations. The driven induction motor must be rated for "inverter duty," which provides internal shaft grounding. This prevents damage to the motor's bearings from electrical currents induced in the shaft and frame of the motor by the high frequency currents in the VFD.

In addition, operation at low speeds and high torque can result in destructive heating of the motor



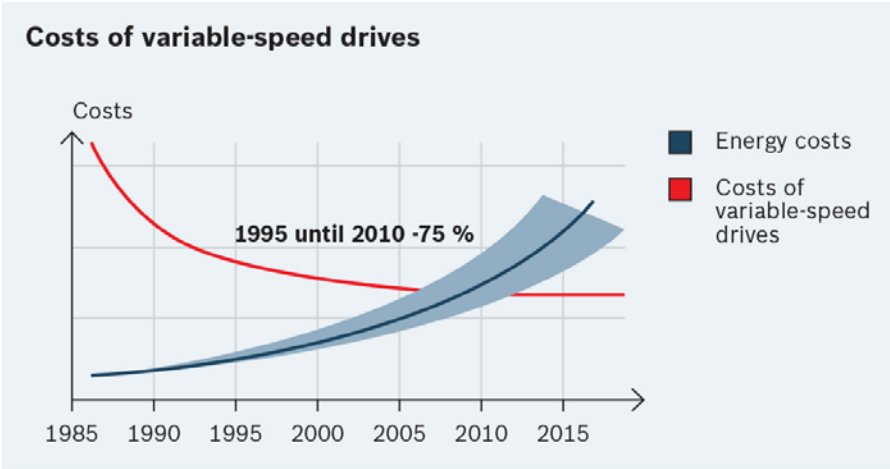
The increased component cost associated with using a VFD can be recovered via reduced energy costs: When comparing power consumption for a 125 cc axial piston pump driven by a 100HP premium efficiency constant-speed motor, the energy used is considerably lower when using a VFD.

unless auxiliary air or water cooling of the motor is present. Limitations of high speeds also exist, generally limiting the maximum speed to two and a half to three times the motor's rated RPM.

Servo Drive Technology: Electric servo motors are permanent magnet AC motors that are designed for a

minimal inertia and have peak torque that is two to three times higher than steady state torque, so highly dynamic speed changes are possible. A high-speed range, maximum torque available at zero RPM, and very high dynamics are the hallmark of servo motors.

This technology does require more complex drive electronics; however, this is offset by the ability to precisely control speed, torque and position of the servo motor. Like VFD driven motors, low or zero speed operation combined with high torque may require additional air or water cooling. Servo motors are limited in horsepower compared to AC induction motors, so the application of multiple servo motors may be needed for higher power requirements.



In recent years, the cost of using variable-speed drive technology has become more economical, making it effective to combine variable-speed electric drives with hydraulics to provide an energy saving, high-performance alternative for use in many applications.

Drive selection for different applications

Both simple VFDs and Vector VFDs are well established in extrusion



Servo motor + pump



VFD driven pump



Intelligent pump

machines. Servo motors are also the standard in all-electric molding machines. Hydraulic machines, comprising the vast majority of plastic molding machines, are increasingly adopting these drive technologies to power their hydraulic systems.

Injection machines using fixed speed electric motors progressed from simple hydraulic drives, using a fixed displacement pump, to the more modern and efficient variable displacement pump. Variable displacement pumps can be more energy-efficient; however, it is possible that when servo and proportional valves are used to provide a high degree of precision pressure and flow control, energy losses can still be significant.

An emerging and more efficient approach is to utilize variable speed motors and drives to accurately and dynamically control pump speed. By modulating pump RPM, precise control of pressure and flow can be attained.

Servo motor driven pumps can match the performance of all but the top tier of servo valve controlled machines. Pressure and flow control response in the range ten milliseconds are easily

achieved, resulting in high accuracy and high dynamic response.

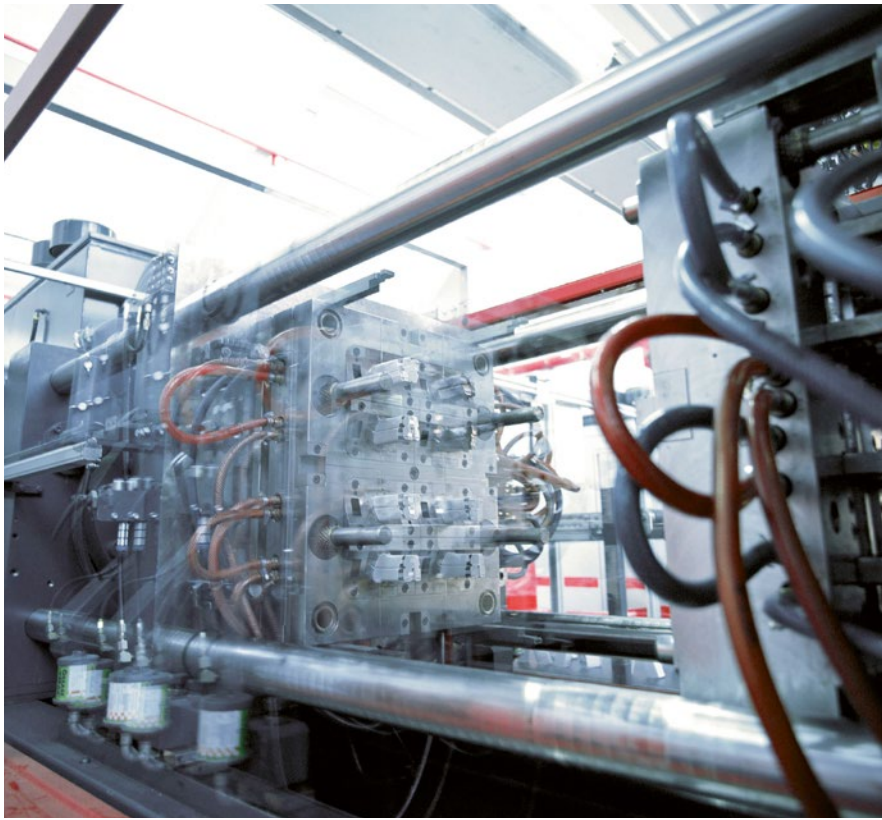
By directly controlling the flow and pressure via the pump, energy losses are minimized, resulting in ten to forty percent savings in power. It should be noted that machines incorporating servo drives and specialized pumps have higher cost than conventional hydraulic machines but are significantly less costly when compared to equivalent all-electric machines.

Plastics machines with lower performance requirements can use lower cost VFD vector drives with pumps suited for the wide range of RPM operation. This drive technology also has the potential to save energy, but there are limits on the drive dynamics. Since a large inertia induction motor is generally used, acceleration and deceleration rates are limited.

Slower reacting machines and products that require less precision



By implementing modern drive technologies into their plastics machines, operators will benefit from the advantages of reduced energy consumption and low noise operation while experiencing improved machine performance.



Certain Rexroth solutions combine hydraulic, electric and hybrid drives to cover a wide range of performance requirements with a single machine family.

may be suitable for VFD vector drive technology. Pressure control also becomes slower and less precise due to the limits of the drive dynamics and may require additional loss generating hydraulic components to improve pressure control accuracy.

Advantages of using VFD drives with “intelligent” hydraulic pumps

In order to improve machine performance when using VFD drives, the addition of an “intelligent” hydraulic pump can reduce the negative characteristics of the motor drive dynamics. One product is an “intelligent” piston pump that interfaces directly with the VFD electronics.

This technology allows electronic control of the pump’s flow and

pressure by varying the mechanical displacement of an axial piston hydraulic pump that is optimized for variable speed operations. For steady state operation the pump will command the VFD drive speed to match the needed requirements. For dynamic operation the fast-reacting pump displacement control performs the speed and/or pressure changes, while the relatively slow reacting drive “catches up” to the requirement. This combination offers system response times in tens of milliseconds, even while the drive acceleration times are in the hundreds of milliseconds.

One advantage of this technology is that it can be applied to machine rebuild and retrofits for service life extension, achieving targeted efficiency improvements that would

otherwise require replacement with servo driven machines. While costs include a VFD, potential motor replacement, specialized pump and control modifications, it can be a cost effective solution for machine upgrades, with favorable investment returns.

Other machine applications

Any machine that requires fast, precise motions that may have overlapping cycles can also benefit from modern drive technologies. One example is a blow molding machine. Parison and mold motions often overlap and must be precisely controlled at high speeds. Hydraulic systems often utilize fluid storage accumulators to supply large flows, while a pump supplies average demand.

These and other “hydraulic accumulator” based systems can use the newer drive technologies to save energy. For example, using a VFD to drive a hydraulic pump, the motor’s drive speed can be varied to match the average flow demand of a machine. Lowering the pump speed to match flow demand and minimizing RPM during idle periods can reduce electrical energy demand and noise.

Electrical considerations

All of the drive technologies discussed in this article can generate varying degrees of electrical interference into a plant’s power grid. Known as harmonic distortion, the generation of high frequency, high current and high voltage signals can cause undesirable effects on a plant’s power system.

Effects range from electronic disturbance to failure of electrical devices. These issues should be considered when selecting supplier

equipment and become more critical in plants using these technologies to retrofit or rebuild existing machines, as well plants that are adding more machines using this technology.

Newer drive technology offers long-term savings

These drive technologies generate savings on power usage that can be attractive in many applications. The cost of drive technology needs to be weighed against the expected energy savings. Utility incentives and high utility costs (many times based on geographic factors) favor these changes in drive technology. These technologies have become dominant in the new plastic injection machine market. The advantages of energy savings, combined with high performance operation, rival all-electric machines and are applicable up to the largest machine size.

While there is additional cost, return-on-investment and total-cost-of-ownership make a strong case for assessing the use of these technologies, in both new machines and retrofit/upgrade applications. Machine OEMs and users can benefit from the advantages of reduced energy consumption and low noise operation, while enjoying the advantage of improved machine performance.

Do you have technical advice worthy of an article?

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