

How to Improve the Energy Balance of Injection Molding

General Consideration. With energy prices on the rise, energy consumption is growing more and more significant for plastics processors' balances – when calculating operating costs of machines and plants, as well as for the manufacturing costs of parts. Employing electric direct drives in injection molding machines provides a large potential for reducing these costs – and this is going to be one of the factors that determine purchase decisions.

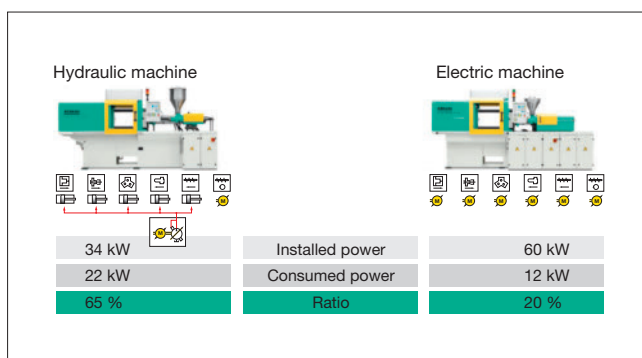


Fig. 1. Comparison between injection molding machines with electric and hydraulic drives. The installed power gives no information as to the energy consumed. This is determined by duty cycle, degrees of utilization and efficiency of the consumers employed (figures: Arburg)

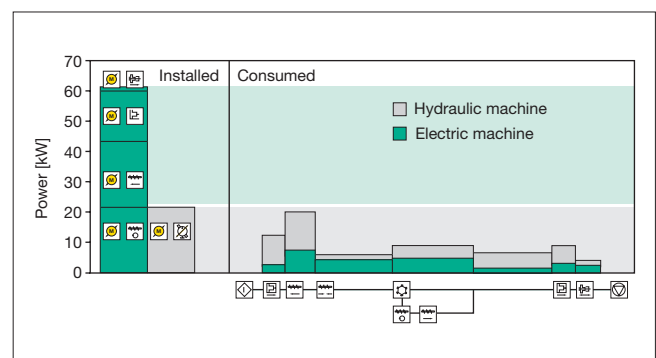


Fig. 2. Despite the fact that electric drives have a higher installed power, their average energy consumption by the individual axis movements over a cycle is lower than for hydraulic machines

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In the past, if a new machine could meet quality requirements, and provide for high productivity, this used to be a good reason for an investment. Nowadays, high energy costs compel producers to consider energy consumption as well, when selecting a new machine. This is particularly true in view of the fact that operating costs over an equipment's service life might well be above its purchase price. Reducing energy consumption in injection molding comprises a sort of multi-stage saving potential, since using less energy for molding incurs lower demand for ener-

gy during waste heat discharge and for operating the tempering unit. Each enterprise operation is aimed at keeping production costs low, and this necessarily calls for holistic consideration of the systems.

Suppliers of machines and plants are therefore required to optimize their products' energetic efficiencies, since this improves process efficiencies and reduces emissions and waste heat. In this respect, injection molding machines with electric direct drives open up considerable potentials to save energy, when used with low and average clamping forces. For large machines, sophisticated combinations of electrically driven axes on a hydraulics basis, i.e. so-called hybrid drives, provide a significant potential for improvement, too.

Installed Power Gives no Clue to Energy Consumption

Lay-out and specifications of installations to supply injection molding plants call for the existing energy flows to be estimated precisely. Frequently, this is done by deriving energy demands from the installed power, directly. Especially, when applied to injection molding machines with direct drives, though, this generates imprecise data, mostly leading to eventual overdimensioning of plant technology.

The term "installed power" means all the consumers connected to a duct. It is therefore quite an appropriate instrument to characterize the machine's performance. Consumers even comprise sockets at the machine, or hot runner controllers.

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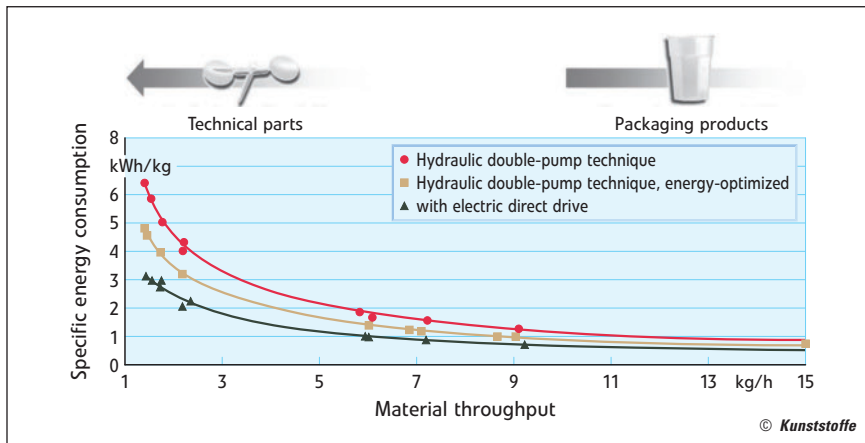


Fig. 3. Consumption of specific energy with various drive technologies for a defined component size in relation to processing technique. This 15 kg/h throughput corresponds to approx. 80 % of the maximum value for this machine size

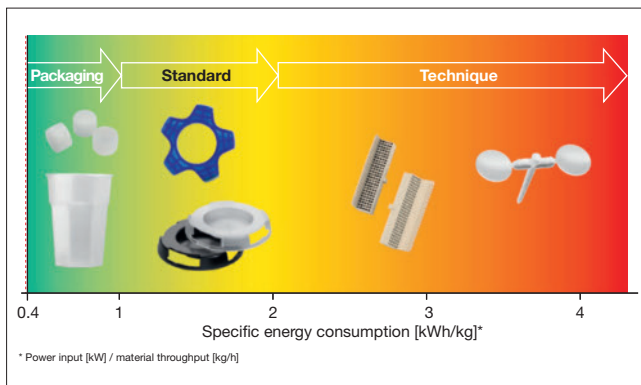


Fig. 4. Producing technical parts requires additional peripheral devices, due to demanding material compounding. This steps up specific energy consumption, if compared to other types of articles

A production plant's installed power merely rules the fuse and diameter of the duct and is therefore a figure significant for e.g. plant construction.

An ideal electromechanical machine features an individual drive for each of the axes, tuned to the individual load case, whereas equipment with a hydraulic drive usually has a central main drive to move the axes. For electrically driven injection molding machines, the individual axis' driving power safeguards the processability required, and leads to a high figure of overall installed power. The installed power therefore represents the work capacity and maximum output of an injection molding machine. Energy consumption is however related to duty

cycle, degree of utilization and efficiency of the consumers that are employed or required (Fig. 1).

The center drive of a hydraulic machine works on long duty cycles or is constantly operated by the electrically driven pump motor, respectively. By nature, the hydraulic pump motor's degree of efficiency is lower than that of a combined electric direct motor. Conse-

quently, its energy consumption is correspondingly high, as a result of the pronounced variations in utilization cycles. Even if the machine runs idle, and the pumps barely convey any oil, the hydraulic center drive consumes some energy – and open-circuit losses occur. Obviously, such systems and drives are superior here, that consume only the amount of energy needed for the actual task.

Vast Deviations in Efficiencies

Interrelations might become clearer, when analyzing the way in which an electric machine's energy consumption behaves throughout a cycle, if compared to that in a hydraulic equipment. Average energy consumption for an individual axis movement is significantly lower with electric drives. Selection and layout of motors employed in electric machines is however in line with the required maximum load for each of the moving axes, and this initially leads to the fact that the sum of the individual motor's figures of drive power is above the figure for a center drive in a hydraulic machine (Fig. 2).

Average energy consumption is low in moving axes with an electric direct drive, and this is partly due to another principle-related benefit: Efficiency of the individual components and drives employed is usually much higher than for hydraulic drive components. In addition, efficiency of electric drive components is less submitted to power input. Most of all, hydraulic pumps and motors, unlike electric motors, in some cases show vast variations in their efficiency maps – with the highest degree of efficiency usually ▶

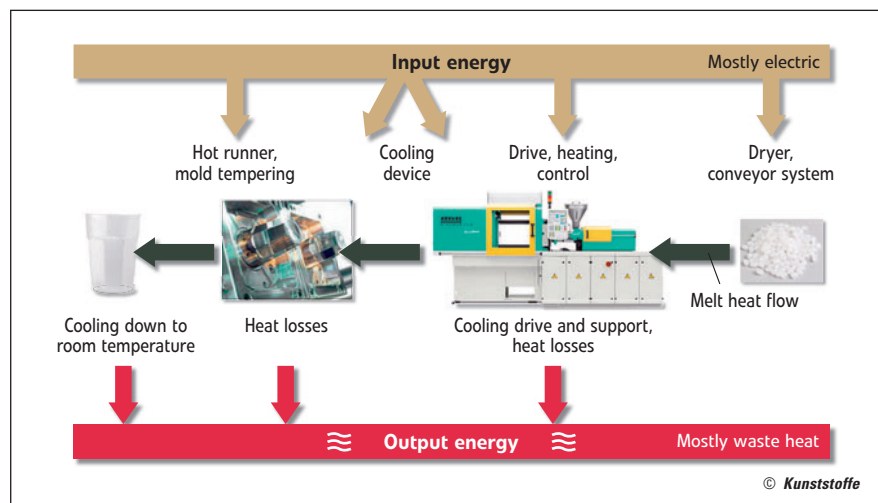


Fig. 5. Energy flow during injection molding: The input energy passes through several conversion processes, finally to disperse into the environment or the tempering water

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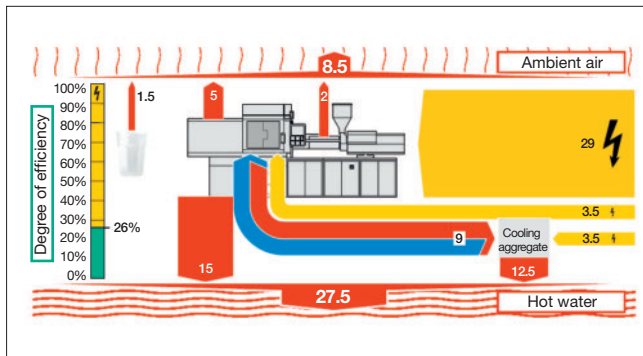


Fig. 6. Output balance [kW] of a production cell with a hydraulically driven machine for a packaging article

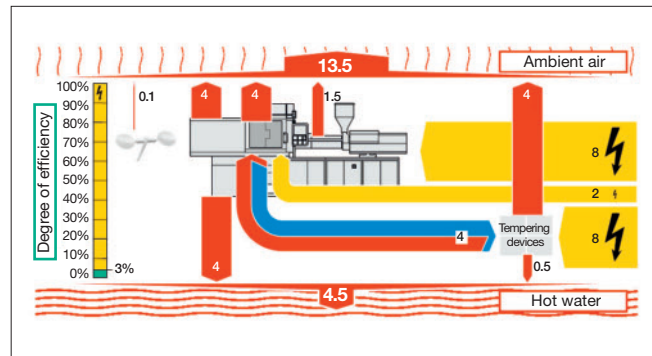


Fig. 7. Output balance [kW] of a production cell with a hydraulically driven machine for a thick-walled technical part

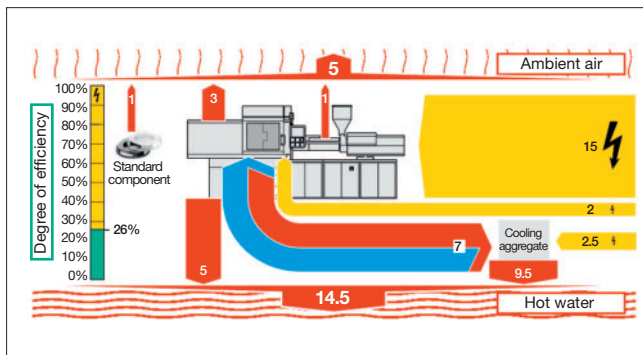


Fig. 8. Output balance [kW] of a production system for a standard component with an electric injection molding machine at its center

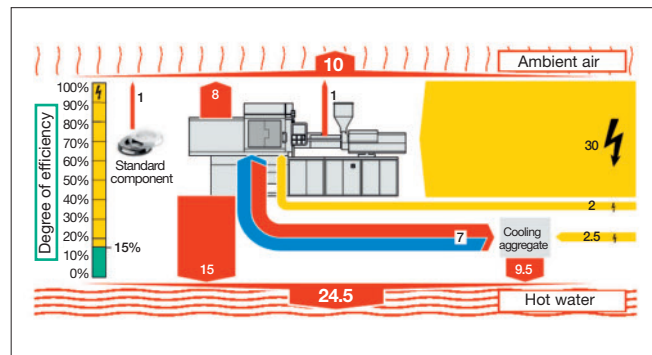


Fig. 9. Output balance [kW] of a production system for a standard component with a hydraulic injection molding machine at its center. If compared to Figure 8, direct electric drives show a potential for energy saving

achieved under nominal load. Actually, drives rarely run under nominal load, which further reduces the efficiencies of hydraulic drives.

A Machine's Energy Consumption is Determined by the Process

What eventually determines energy consumption – and thus a production system's costs – is the power actually retrieved. As a result, it is significant to keep absolute consumption as low as possible or to maximize the system's efficiency, alternatively. The reference value employed to determine the efficiency of an injection molding machine, or of an entire injection molding system, is the specific enthalpy of the polymeric material. This term describes the amount of energy required, in theory, to melt a specified amount of plastic pellets. Making up a comparison between the plant's absolute energy consumption and the specific enthalpy then provides the system's actual degree of efficiency.

While measuring an injection molding machine's energy consumption at different operational points and for process variants, it showed that absolute energy

consumption – and thus efficiency – is severely affected by the process. So as to utilize, in an optimum way, the energy employed, it is therefore necessary to know the energy-efficient operating points of a production system – including those with the highest efficiencies. An injection molding machine's efficiency is thus highly submitted to mass throughput, i.e. the quantity of plastic material processed per time unit. In concrete terms, this means that if a machine is highly utilized, this clearly improves efficiency. This is due to the fact that power loss, which is latent and independent of throughput, is allocated to a larger amount of material.

Nevertheless, engineers must pay account to the portfolio of products. When producing, for instance, packagings, high mass throughputs are achieved, usually incurring excellent efficiencies. Manufacturing of technical parts, however, mostly fails to reach such figures, as a result of high wall thicknesses and high process temperatures of the technical plastics. These factors lead to longer cycle times. In this context there is another striking feature: The difference between energies consumed by the two drive techniques over the operating range remains

virtually constant. Electric direct drives may therefore save the user up to 50 % of energies over the entire operating range (Fig. 3).

Including Additional Consumers in Overall Considerations

Subject to the actual application, certain energy consumers are involved in the production process, too, apart from the injection molding machine. Some of them significantly contribute to overall energy consumption. Among them are dryer, devices for tempering and cooling, vacuum and compressed air units and not least hot runners in the mold. Inevitably, additional peripheral devices step up overall specific energy consumption. Production of technical plastics parts is particularly demanding, in terms of additional peripheral devices, as a result of the higher process temperatures and complex material compounding techniques involved. For the production of packagings, the specific energy required usually lies clearly below 1 kWh/kg, whereas some technical articles, especially thick-walled or micro parts, consume far more than 5 kWh/kg of specific energy (Fig. 4).

Targeted Reduction of Heat Emissions

Regarding the energy balance of injection molding, energy input, which is mostly electric, is opposed by energy output. The input energy passes through conversion processes, some of which consist of several stages, finally to disperse into the environment or the tempering water (Fig. 5).

The higher demand for energy mentioned reduces the degree of efficiency and increases the amount of waste heat discharged into the environment. Of all input energy, a large share is consumed by peripheral devices, as opposed to packaging applications. This reduces the share of energy consumed by the injection molding machine. Yet, at the same time, significantly more heat emerges into the environment, as a result of the higher process temperatures and the named additional peripheral devices. In air-conditioned production sites such as clean rooms, it is therefore recommended to deduct as much heat as possible into the tempering water, since this type of heat may quite easily be transported, reused and disposed of (Figs. 6 and 7). Using electric direct drives with water-cooled motors can be of considerable advantage for solving this problem, too.

To show the saving potential of electric machines, compared to hydraulic injection molding machines, identical components were produced and manufacturing processes compared (Figs. 8 and 9). Not only do electric direct drives reduce energy consumption and heat emission.



Fig. 11. Water-cooled electric drive of a metering unit

They moreover cause less noise and dust – if water-cooled motors (Figs. 10 and 11) and low-noise spindle drives are employed. Threaded-spindle drives are superior to belt drives and ball bearing screws for their lower values of noise and dust emission.

Small Details, Strong Impact

Some little details concerned with injection molding can open up another potential to improve energy efficiency, if considered adequately. When the hot plastic melt meets the cooled or tempered mold, this leads to steep temperature differences within a small space. On the one hand, the heat that enters the cavity must therefore be discharged as fast as possible, in order to provide for short cycle times, while, on the other hand, the melt must be conveyed in the cooled mold – sometimes by a hot runner – or the cavity be tempered, respectively.

Along with frequent restrictions to design options, this problem often allows for nothing else than solutions which are often extremely unfavorable in energetic terms. Therefore, it is of major significance to isolate the hot runner well from the cool area of the mold, as well as the (tempered) mold from the machine clamping plates. If isolation of hot runner and mold is poor, then this may lead to the hot runner heating up the cooling water directly, similar to a flow heater, or the mold may emit large quantities of heat to the environment, through the machine clamping plates.

Broad media ducts and short supply channels also reduce energy consumption in and around the mold and peripheral devices. Further action should be considered so as to e.g. optimize process safety and reject rates, including start-up processes; these measures are often neglected. Qualified process assessment is of crucial importance. Only if this prerequisite is fulfilled, a stable process can be identified, and product qualities safeguarded, in order to enable documentation of the process. After all, making appropriate amendments to the machine and optimizing operation cycles through improved scheduling of manufacturing help reduce energy consumption.

High Precision in Electric Drives

Electric injection molding machines are at the forefront, with respect to energy saving and noise reduction. But these are not the only profits involved. These ma-



Fig. 10. Main drive – water-cooled, operated electrically and frequency-controlled – of a hydraulic injection molding machine

chines also provide several benefits regarding production technology – particularly concerning dynamics and precision of axis and traveling motion. This makes the process more stable and improves reproducibility of the movements, not least reducing cycle times. Merely regarding the precision of directly driven axes such as clamping unit or ejector, the figure is ten times the value for hydraulic axes. Combined to automation systems for e.g. handling, further benefits will be obtained.

Conclusion

The configuration of an injection molding plant substantially determines energy consumption and emissions of a production unit. Employing state-of-the-art drive technology, in particular axes with electric direct drives – possibly in connection with hydraulic drives – may reduce energy consumption by up to 50 %, as against conventional machines with fully hydraulic drives. Choosing the appropriate machine size is of crucial importance here, while, generally speaking, there is an optimum solution for each application. The final target is to integrate the clamping unit, a matching injection unit, and a suited drive technology, to form a system that works energetically efficient and produces low emissions, while guaranteeing the required process accuracy. ■

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