Energy cost optimization is not just about minimizing the energy requirements of individual consumers. Capping of energy peaks and the distribution of regenerative energy are a growing focus of the injection molding industry (© Engel)

Reliably Avoiding Power Peaks

Industry 4.0 Paves the Way to Smart Energy Management

In the past, reductions in the energy consumption of injection molding machines have come about through numerous advances in drive technology. Today it is no longer just about the energy consumption of individual consumers. Instead, the spotlight is increasingly being trained on capping energy peaks and distributing regenerative energy. Progressive machine networking under Industry 4.0 is opening up new horizons in the future of smart energy management.

Injection molding machine-makers have concentrated on energy efficiency for more than three decades. Thus, back in the 1980s, Engel Austria GmbH, Schwertberg, Austria, developed an energy-saving concept for its hydraulic injection molding machines that was centered on avoiding energy loss. However, very few customers expressed an interest at that time. It was only when energy prices started rising and sustainability became an emerging trend that energy efficiency came under the 'radar' of converters.

Servo-Hydraulics Increasingly Standard

Engel launched its "ecodrive" servo-hydraulic system onto the market in 2008. This drive solution lowers the energy consumption of hydraulic injection molding machines by 30 to 70 %, the precise amount depending on the type of machine and application. Although ecodrive represents the state of the art in energy-optimized hydraulic drive technology, it does not differ in its basic principle from the solution developed back in the 1980s. The speed of a drive is regulated according to the instantaneous speed needed by the axes of the injection molding machine. When there are no movements, e.g. during cooling, the drive comes to a standstill and does not use any energy.

In ecodrive, Engel has managed to even make hydraulic machines fit for purpose in the future. Should the molds require a hydraulic unit anyway, e.g. for actuating core pulls, a hydraulic machine fitted with ecodrive can consume less energy than an all-electric machine with hydraulic add-on unit. What counts is the overall efficiency. Servo-hydraulics was originally offered as an option but is now increasingly a standard feature of hydraulic and hybrid machines. More than 80 % of the hydraulic machines sold by Engel worldwide are fitted with ecodrive. For a long time, it was mostly the main drives for mold opening and closing as well as for metering and injection that were targeted, but Engel is increasingly looking at secondary movements, such as core pulls, and equipping hydraulic add-on units with ecodrive.

All-Electric Machines Meet Specific Sector Requirements

The e-motion series of all-electric machines was developed by Engel at a very early stage for high-performance ap- »

Fig. 1. The Engel e-speed 500/90 injection molding machine produces 16 cartridges at once. At K2016, Engel will combine its large high-speed machine with IML automation for the first time (© Engel)

plications. It has been continuously refined and optimized for specific industry requirements over the years. In the area of high-speed caps and closures production, this culminated in the Engel e-cap, which combines high performance with energy efficiency. An Engel e-cap 4200 kN machine with a 96-cavity mold and a 2-second cycle produces more than 170,000 beverage closures per hour, yet needs roughly just 45 % of the estimated energy consumption of hydraulic machines used hitherto.

It should be noted that the Engel electric drives are not reserved for just small and medium-sized machines. The machine-builder can optionally equip almost all its large machines with electric drives, with just one exception: the drive concept for building up clamping force. The Engel e-duo is the first large-scale dual-platen machine on the market to feature electric drive technology.

Energy Stores for Constant Connected Load

The e-speed injection molding machine from Engel was developed for high-speed applications involving high shot weights and high clamping forces. It combines a purely servo-hydraulic injection unit with electric metering and an electric clamping unit (**Fig. 1**), because these performance requirements still cannot be implemented economically with a servo-electric injection stroke.

A typical application is the manufacture of cartridges for the construction and DIY retail sector. Molding the long hollow bodies with a wall thickness of just 1.2 mm requires very high dynamics and injection performance. Starting at K2016, the entire Engel e-speed series will be offered with ecodrive servo-hydraulics on the moving mold half as standard. The high energy efficiency is contributing substantially to the great success of the Engel e-speed on international packaging markets. Without the novel electrical clamping concept, it would not have been possible to achieve the level of performance that machines in this high clamping force class with electric drives need for continuous high speed operation.

To support electrical operation at up to 6500 kN, Engel has developed an energy storage concept based on the flywheel principle. The storage system absorbs the braking energy of the platen movements, which would otherwise be converted into heat and released into the environment, and transfers it back on demand, e. g. when the platen accelerates again. The machine itself is thus able to

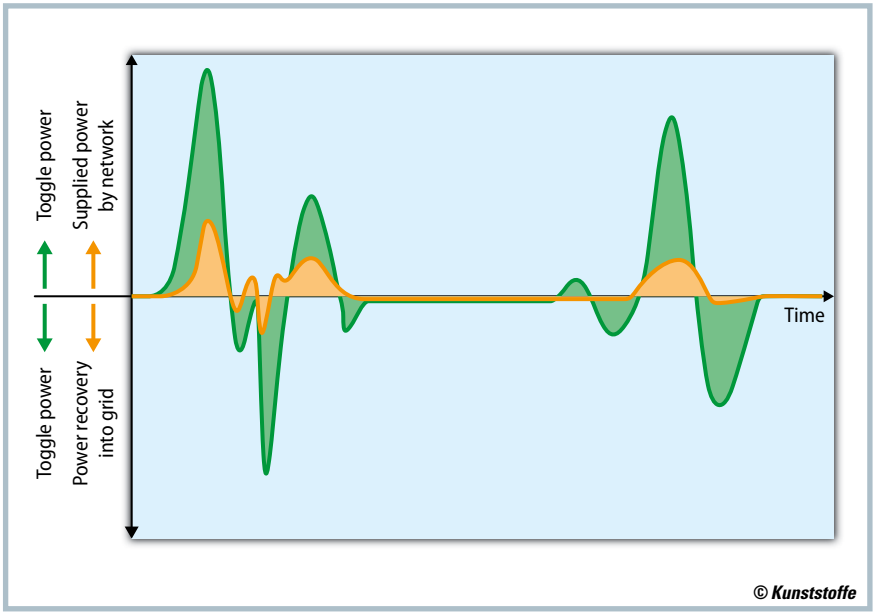

Fig. 2. Power demand over a production cycle. The filled green curve represents the electrical power requirement along the positive y-axis. This compares to the power both drawn from the grid and recovered (yellow). The e-speed is thus able to operate continuously at high-speed under a constant connected load (source: Engel)

On the Way to the Smart Factory

E-factory is Engel's own MES (Manufacturing Execution System), which is tailored to the requirements of the plastics conversion industry and achieves deep vertical data integration down to the level of individual cavities. E-factory is modular to allow adaptation to individual requirements. New at K2016 will be the "energy" module, which supports detailed presentation, evaluation and optimization of the energy consumption by individual consumers. Energy enables the Engel e-factory to control startup of machines and production cells automatically and to reliably avoid energy peaks. This can help lower the electricity costs of the machinery.

MES is an important component of the smart factory, which is the focus of industry 4.0. Engel already has a suite of products and solutions ("inject 4.0") for all three areas of smart production, smart machine and smart service. By virtue of the networking and integration of production systems, the systematic use of machines, process and production data and the use of decentralized, intelligent assistance systems, the manufacturing processes in a smart factory are continuously self-optimizing and so allow a flexible response to rapidly changing requirements. The outcome is greater efficiency, productivity, availability and quality.

↘ www.engelglobal.com/en/inject-4-0

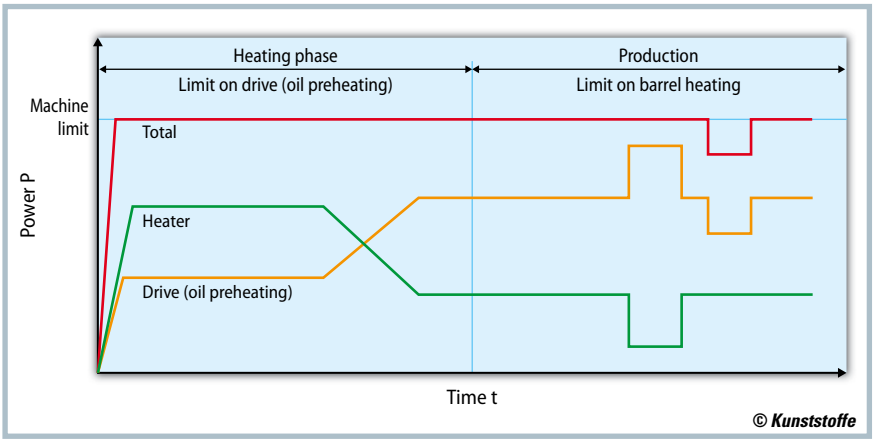

Fig. 3. Ecobalance caps energy peaks by assigning a particular priority to the individual energy consumers within a machine or production cell. During startup, the power limit of the heaters is fully utilized but, after that, the drives have the highest priority (source: Engel)

cover a large part of the power requirement of the drive motors. In addition, any energy that is not required is fed back into the power grid and not converted into heat via braking resistance, as is usually the case. Overall, then, the Engel e-speed is thus able to run with a relatively low and, above all, constant connected load.

The usual power peaks that arise when large electric injection molding machines are operated at high dynamics are reliably avoided. The chart of power consumption over a production cycle clearly shows that the drawn electric power is only 30 % of peak power, with the difference being provided by the integrated energy storage system (**Fig. 2**). It is not just in countries with an under-developed power grid that solutions which place caps on energy peaks are increasingly in demand.

Machine Energy Management through Smart Distribution

Energy peaks are expensive. Even if maximum power demand is rarely reached, the public utility must make constant provision for it. Added to which, installation of the electrical connectors is more expensive, because all the lines must be designed for peak performance. If the maximum connected load is exceeded, penalties are levied. For a medium-sized plastics converter in Germany, the additional monthly costs amount to EUR 10,000.

The Engel ecobalance energy management system seeks to prevent energy peaks, to limit energy consumption and thus to lower energy costs, in a different way from the e-speed machines. Ecobalance reflects the fact that an injection molding machine or a production cell has a different power requirement at startup than during operation, and that individual consumers do not need constant power during the injection cycle. Startup requires a lot of energy, especially for heating. During production, however, mold opening and closing and injection require the most energy.

To cap the energy peaks, ecobalance assigns a specific partial consumption value to each consumer in a machine or production cell and then prioritizes each partial consumption value. After each cycle, those consumers which received a lot of power in the preceding cycle are moved down the priority list while those consumers which received little or no power are moved up. One cycle roughly comprises four steps:

- Query power data,
- calculate power limits,
- transmit power limits, and
- comply with power limits.

This cycle takes place within a few seconds.

What happens in practice is as follows. At startup, the power limit of the heaters is fully utilized. They receive the calculated level of power, provided that this does not exceed the overall power requirement. During this time, the »

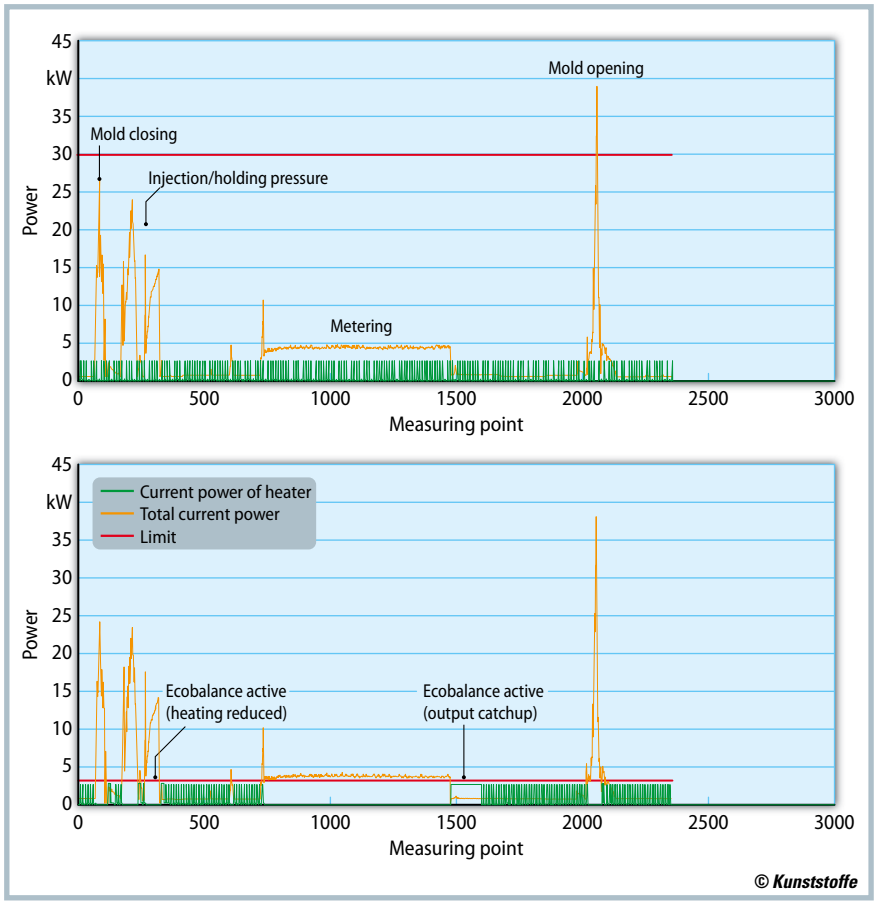

Fig. 4. The Engel e-victory 440/120 injection molding machine illustrates how ecobalance can be used to lower the energy limit from 30 kW (above) to 3 kW (below) (© Engel)

Fig. 5. Machine networking also benefits energy management. The new "energy" module of the MES solution e-factory renders the instantaneous energy needs of individual consumers transparent (© Engel)

machine drives make do with the remaining energy. Only when the set temperature has been reached are the drives for the machine movements supplied with the calculated power which they need. In production mode, this order is reversed. Then, the drives have top priority, with the heaters receiving the power that is left over after the drives have been supplied. Thus, during the cooling phase, when no machine movements are required, heating occurs. If the sum of all instantaneous machine consumption values is less than the maximum permissible value, no restrictions are imposed on the machine or production cell. It is important to configure the overall performance so that sufficient power is available for all receivers/consumers that alternately draw more and less power and that the temperature never falls below the setpoint (**Fig. 3**).

Ecobalance directly accesses the energy consumption data which has been gathered in the Engel CC300 machine controller by the ecograph tool. This enables the consumption of individual machine components to be identified and displayed, including the movements of the mold fixing platen and nozzles, the injection and holding pressure, metering and cooling, ejector movements, demolding and dry cycle times. Ecobalance uses this information to distribute the total power demand defined for the particular machine or manufacturing cell over the entire injection molding cycle and so ensures that the total energy requirement will never exceed the limit (**Fig. 4**).

Energy Management System for All Available Machines

The rapid growth in networking of injection molding machines and manufacturing cells that is occurring under Industry 4.0 also benefits energy management. Thus, in the future, ecobalance will coordinate the energy consumption values not just in one injection molding machine or production cell, but also across all available machines. This will prove especially beneficial when, for example, all the machines are started up together after a weekend or a factory shutdown. The dynamic allocation of machine-specific consumption limits ensures that production hall management can avoid power peaks in these cases too (**Title figure**).

After warm-up, the management system then continues with the consumption limits in production mode. The machines can be grouped arbitrarily to facilitate the optimal consumption limits for different production halls or hall areas. Production hall management forms part of the new "energy" module (**Fig. 5**), which will extend the functionality of the Engel e-factory MES (Manufacturing Execution System). Energy will be unveiled for the first time at K 2016.

The more consumers and energy sources that are available to the energy management system, the more effective distribution can be. Communication among production cells will soon considered state of the art under Industry 4.0.

Machine networking also opens up new prospects for energy recovery during operation. Engel is investigating how to make recovered, stored braking energy available to other machines so as to cover power peaks. Ideally, in the future, the public utility company will only have to compensate for the losses of individual energy consumers.

Outlook: Transferring Stored Energy to Other Machines

The choice of storage technology that will be used for this will vary with the machine size and the application. Directly connected electrical storage is easy to install and yields high efficiency, but has a sizable footprint. To keep the storage compact, it should be closely matched in size to the demand. If the storage is oversized, cost efficiency will suffer. Thus, provision must be made, too, for dissipating surplus energy that cannot be stored. One possibility is to feed it back into the power grid.

Where substantial amounts of power are involved, it would be worthwhile investing in kinetic memory storage. Engel is therefore in the process of transferring the energy storage concept developed for the e-speed series to other series as well. ■

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