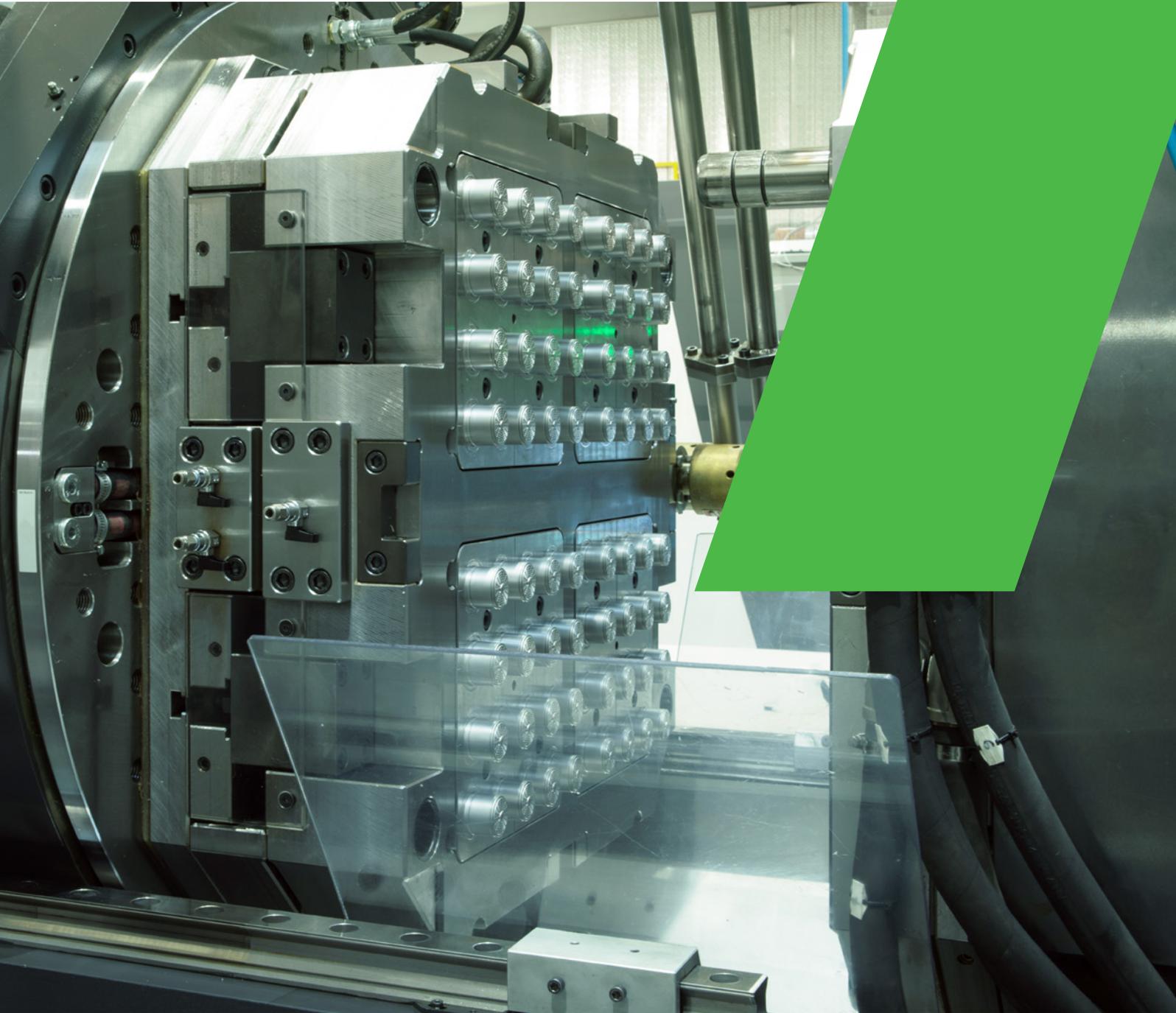


Faster & more accurate control technology with

KEBA concepts & KePlast Smart Functions



Whitepaper

KEBA[®]
Automation by innovation.

“

Continuous
improvement is better
than delayed perfection.

Mark Twain

”

Intro

Whether one calls it the heart or the brain of the machine, the control technology is a vital element of every machine's "life". The term "control technology" or "industrial control technology" refers to the devices responsible for managing, regulating, gathering data, communicating, and diagnosing various processes. In a more specific context, when we talk about "control" in automation technology, we are referring to the influencing of the flow of material or energy through a closed-loop system that processes multiple signals. Consequently, the outcome of this process affects the closed-loop system, and the input value influences the controlled output value.

In the 70ies, KEBA, led by its two founders, Mr. Krippner and Mr. Kletzmaier, already had its focus on cutting-edge control engineering technologies in the industrial automation field, and so it has stayed until now. In the last decade, the development toward I4.0 intensified, resulting in increasing demand for even faster and more precise control concepts and the involvement of artificial intelligence and predictive models.

In this whitepaper, we present the latest achievements of our control engineering experts – the newest control engineering technologies and smart functions of KEBA & KePlast – in an informative, but interactive way – with numerous measurements, curves, graphical schemes and even examples from a daily life. We hope you find it helpful and look forward to discuss with you, how can our technology paired with your know-how shape the future of the industrial machines control.



Michael Petruzelka
Vice President Plastics



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Pressure closed loop on KeDrive D3:

A secret ingredient for faster, easier & more accurate control solution for EIMMs

This year it will be 40 years since KEBA started controlling the complex injection molding process. This fact however does not make KEBA rest on their laurels, though... The same applies to the entire industry – the IMMs (injection molding machines) are continually becoming more sophisticated. Especially in sectors which require the highest process precision and parts accuracy, e.g. health care, the end-customers, had been signaling room for improvement.

“The challenge was put on the table: The improvement of process quality requires much better closed loop control quality”, outlines Michael Petruzelka, Vice President Plastics at KEBA. Slow reaction time, even when using fast closed loop control technology on industrial PCs still sporadically leads to unwanted under- or overshoots – resulting additionally in higher mold wear.

The recent KEBA developments and testing efforts revealed what our process experts have had on their minds quite for a while: there is a new, fully undiscovered potential for even better control of injection molding processes – predominantly applicable for full-electric machines, partly for hybrid ones. So if you want to get more from your new but also existing machine fleet, check this out!

Short ride around the predictive feed-forward loop

To bring everyone to the same starting line, let's start with a simple analogy illustrating and helping to understand the predictive feed-forward loop.

Imagine you are driving a sports car on a scenic highway. You want to go as fast as possible while also keeping control of the car and avoiding the over-use of the vehicle, which could have a negative effect on your bank account. What factors you need to consider and how to keep up with the execution of this task while still enjoying the view through the window? You are right, you can turn on an autopilot!

Autopilots use a variety of sensors to gather data about the vehicle and its surroundings, continuously processing and monitoring the data by the onboard computer using complex algorithms, provide real-time feedback and take corrective actions – all just in a few μ s. It can for example monitor and keep the same speed – even when the outdoor conditions change. This is how the predictive feed-forward control logic works.

What sport cars & injection molding machines have in common?

If you have assumed, that both can use predictive feed-forward concept to efficiently control their processes, you are already on the right track.

Surely we could find more similarities, like highest automation and easiest handling etc., but that is not the focus of this article.

Predictive feed-forward control is a control strategy that uses a mathematical model of the system being controlled to predict the future behavior of the system and generate a control signal that anticipates changes in the system.

In the context of an injection molding machine, the objective is to constantly monitor and optimize the process by controlling the injection pressure, speed, and position of the molds, while improving the quality of the final product, decreasing energy consumption and increasing productivity.



Pressure closed-loop on PLC (Programmable Logic Controller) – still a golden standard?

The FPGA (Field-Programmable Gate Array technologies) used in the CP05x KEBA controllers form the basis for the implementation of highly efficient control concepts directly in the controller hardware. This means fewer demands on the software, and the necessary modules are implemented in the hardware with top efficiency.

Especially when considering electric injection molding machines, it has been the state-of-art closed-loop control practice since a few years to connect the inject pressure sensor directly as well as the 3rd party drives with EtherCat (e.g. with 500 μ s) to the PLC in order to achieve the fastest and most accurate control using predictive feed-forward technologies. The results are generally satisfying, it usually takes 3 cycles (each ca. 500 μ s long) from reading the sensor data, through calculation, to sending the output to the drive, amounting in 1,5 ms. However, the “times are changing”.

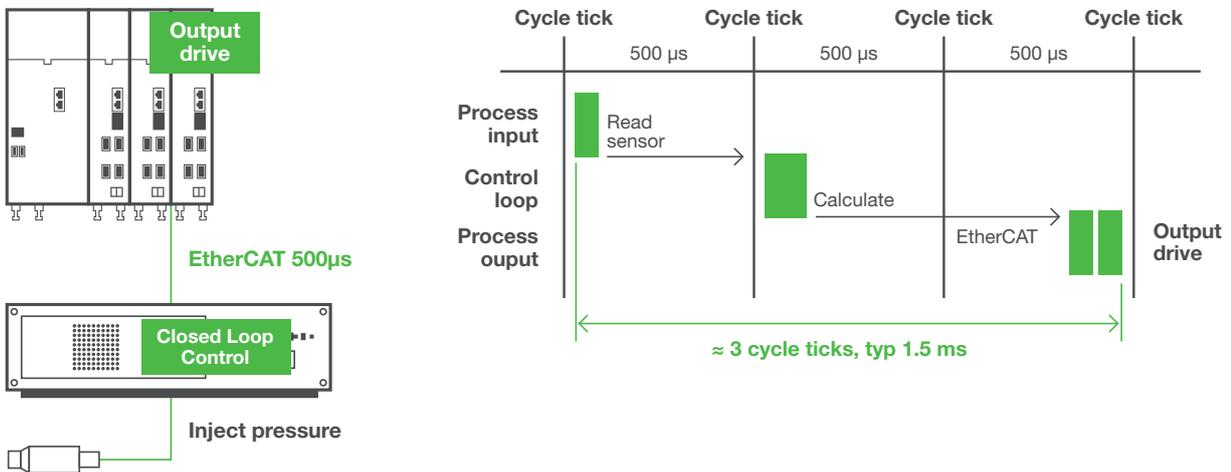


Figure 1.1: Pressure closed-loop on PLC



KeDrive D3 – The new benchmark in control technology for high-end requirements

The latest comprehensive tests on real machines conducted by KePlast experts revealed striking synergies between KEBA's PLCs & drives and shifted the control technology at KEBA to a new dimension. In this case, the inject pressure sensor is connected to the drive, where the pressure close loop functionality runs (Figure 1.2). This grants the cycle time of 125 μ s, the maximal reaction time of 500 μ s and minimal dead-time.

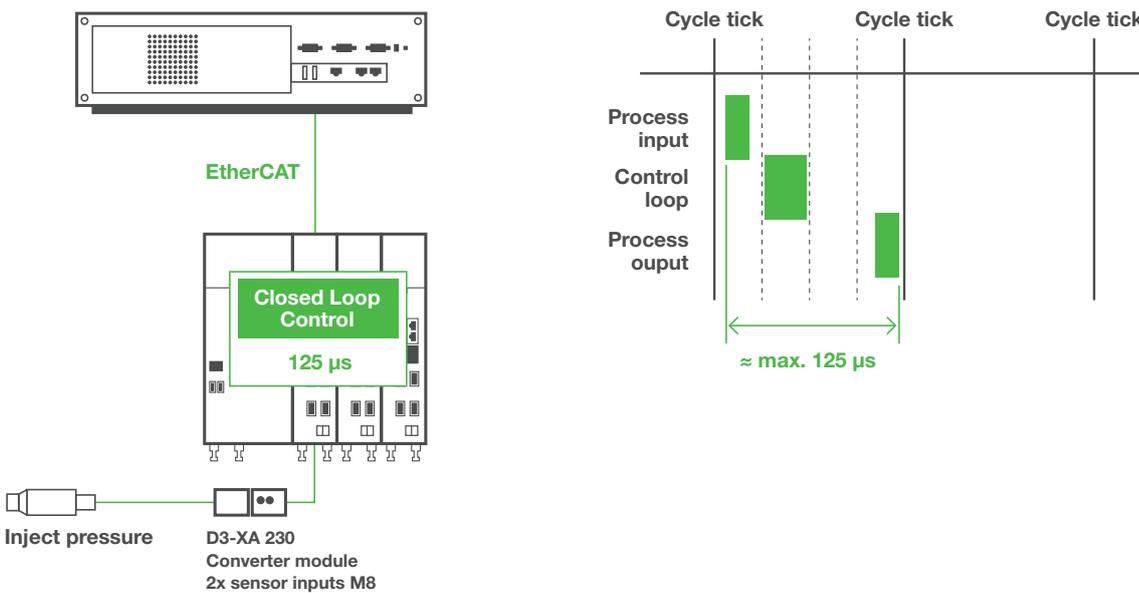


Figure 1.2: Pressure closed-loop on KeDrive D3

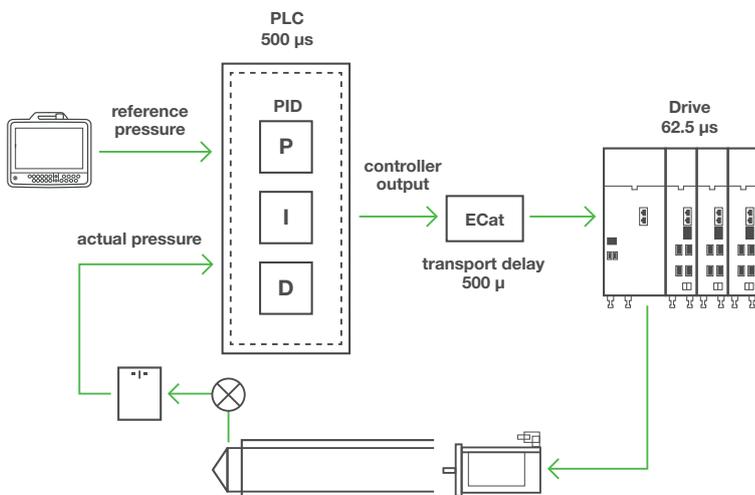


Figure 1.3: Standard technical schemes of pressure closed-loop on KEBA PLC

Comparison of different scenarios

The figure 1.4 provides insights to measurements of pressure (p) and velocity (v) in various circumstances..

The scenario with a 3rd party drive showed an overshoot of over 650 bar and a rising time of 400 ms to reach the needed pressure.

The scenario with pressure closed-loop on KeDrive D3 achieved overshoot of 225 bar and the rising time 125 ms (slow due to the test machine type in this case, however a minimal-possible rising time can be 30 m).

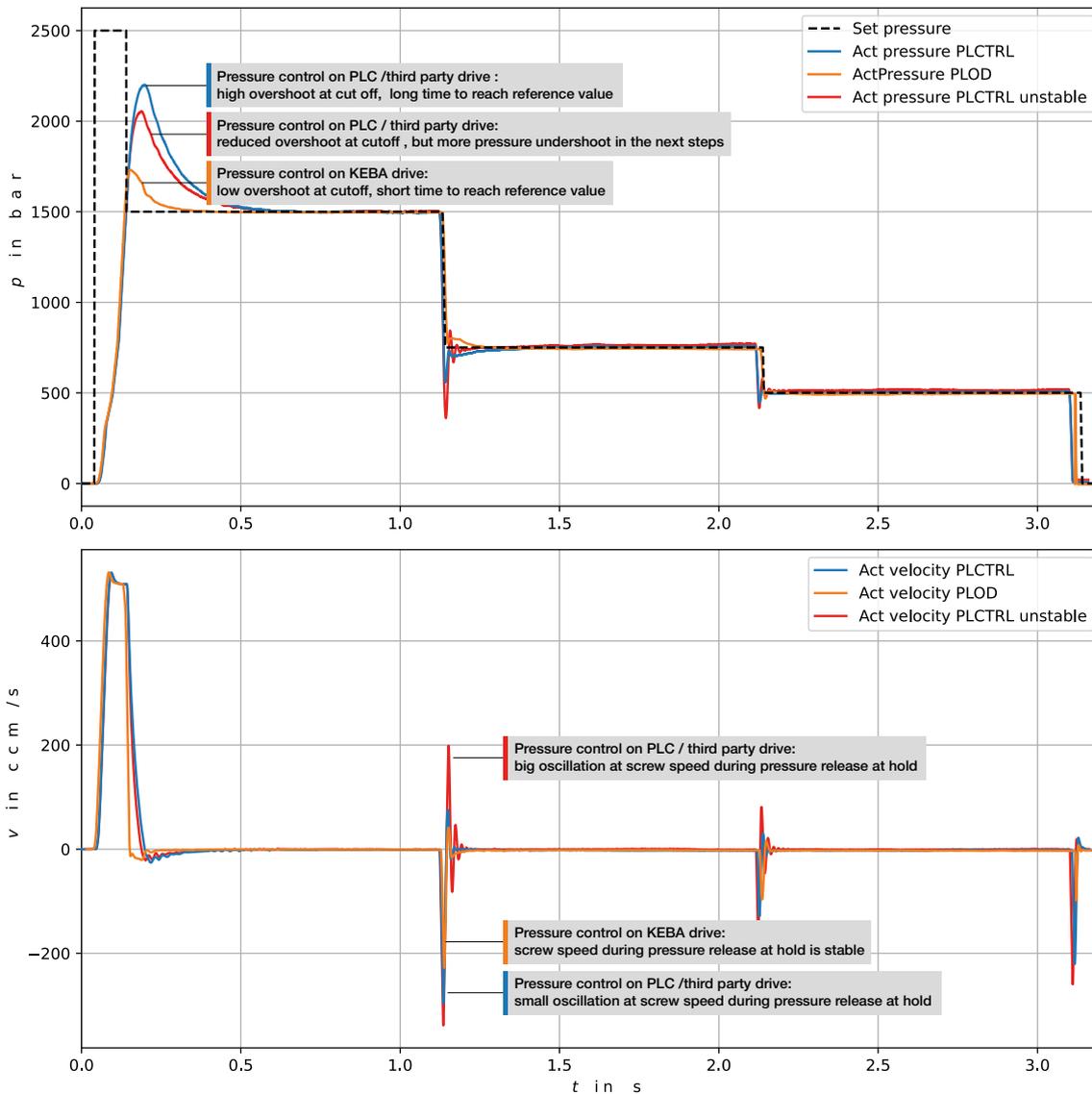


Figure 1.4: Comparison of different scenarios of pressure closed-loop – a real machine measurements

The main learnings from the measurements are:

- // With pressure control on the KEBA drive, a pressure peak can be reduced without oscillation at screw speed during pressure release at hold.
- // With pressure control on PLC and 3rd party drive, the pressure peak cannot be reduced very much without getting screw speed unstable (noise, temperature of motor and drive is increasing which results in a reduced lifetime of drive).

The implications for a daily business of plastics producers

“Today, lot of end-customers classify machines due to repeat accuracy,” explains Günther Weilguny, Product Manager Plastics at KEBA. “The highest requirements come especially from the manufacturers in health care or automotive industry, which produce complex parts. In order to succeed in these sectors, the manufacturers need exceptional parts quality” adds Weilguny.

The KePlast Process Expert Gerald Reindl dives even deeper to the root of the issue. “If the reaction time is not fast enough, the filling is not complete, the parts quality is inconsistent and the whole process is considered unstable.”

Here are the most common implications of such an unstable process:

- // Part defects: The high pressure pulse during overshoot can cause overpacking, sink marks, or warpage in the molded part as well as affect the strength or functionality.
- // Mold damage: The high pressure can damage the mold surface or cause wear and tear on the mold components.
- // Machine damage: The repeated overshoot can cause damage to the injection molding machine components, such as nozzles, barrels, or screws.
- // Drive utilization: a more stable closed-loop control requires less energy and leads to reduced heating of drives and motors. This enables the machine to operate at higher pressures without increasing the size of the drives.

“Monitoring the pressure signal during the molding process with the pressure closed loop on the drive helps to detect and to correct any overshoot faster to reach the required parts quality,” summarizes Reindl.

Advantages of seamless integration between PLC and drives

Additional perks for both OEMs & end-customers are hidden in the integration of the controller and servo drive. The two mostly benefit from quick commissioning – meaning less down-time for the machines in use due to simple drives exchange process and the fact that no additional tools are required.

An extra help for the machine producer is the easy diagnostics thanks to integrated tools at PLC. Moreover, tuning of controller parameters becomes uncomplicated.

Summary

The new solution provides room for process, material and maintenance cost-saving as well as profit generation in form of new product and market possibilities.

Position balance & fast reaction control technology:

Enabling synchronized EIMM movements

After explaining the advantages of the KeDrive D3 pressure closed-loop control technologies from KEBA's servo drives portfolio, more innovative and, for full electric (EIMM) and hybrid machine beneficial technologies will be elaborated on next.

Commonly seen in the praxis, there is not only one single-axis controlling certain movement but based on the required power or torque, numerous multi-axis drive modules are in use. As a simple example, imagine an electric injection molding machine with two single-axis servo drives and two motors. Did you know that running them at the same voltage does not necessarily mean they will move exactly the same and may cause costly machine damage? The extensive pressure on one side can mechanically damage the machine parts like molds, ejectors, and injectors, or it can be sent back and damage not only the motor itself but also the machine's electronics.

Therefore, fast communication and synchronization between these devices are crucial to avoid machine parts damage and unwanted machine downtime.

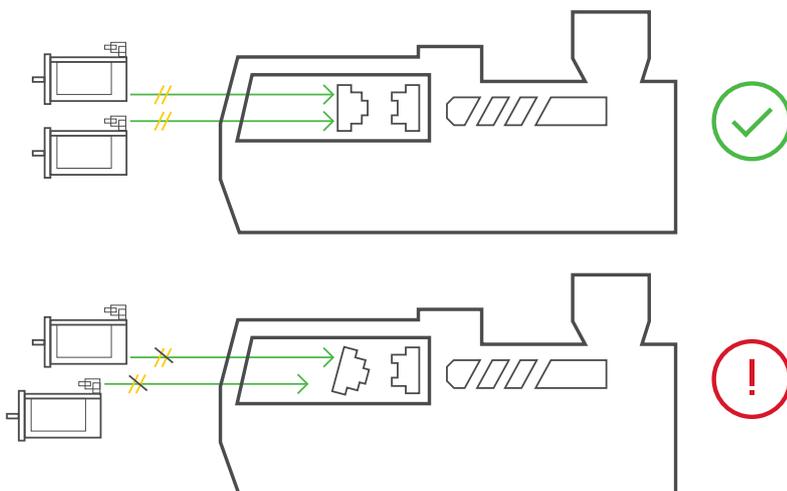


Figure 2.1: Synchronized & unsynchronized EIMM mold movement & possible cause

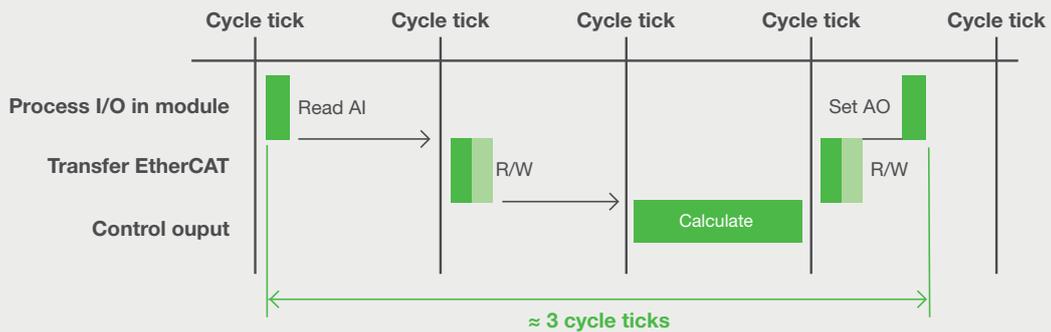


Fast, “3in1” reaction control technology for the shortest possible dead time

Fast communication and reaction between the devices is a door opener for successful & high-speed position balance control as well as controlling other processes.

KEBA controllers can realize the shortest possible dead time, meaning the time needed until a change in the input causes a change in the output, with fast control feature. Usually, the industrial PC would use three cycle ticks to read, calculate and send an answer. KEBA controllers, with the Fast Reaction Control feature, can fit all of these steps into one control cycle. At the beginning of the frame, the controller reads input signals, then calculates the output values immediately and writes the output signals at the end of the scan frame. The feature works with EtherCAT and IO-Board IOs. The function influences the pressure control in the controller and improves the communication between the drives.

→ Standard Communication



→ KEBA Fast-Reaction Control

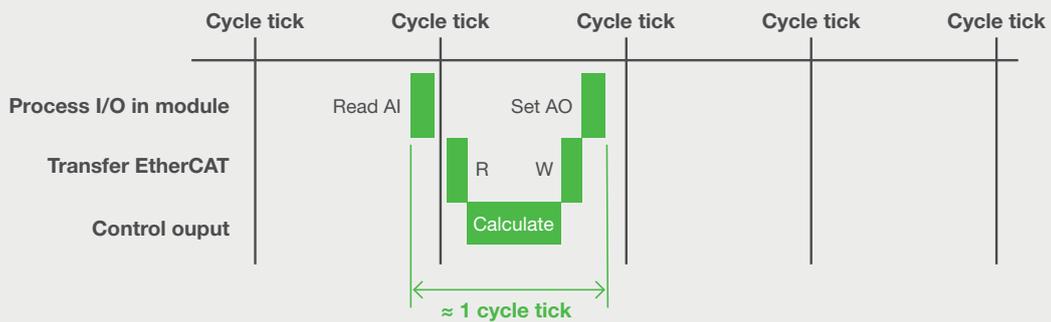


Figure 2.2: FPGA-supported Closed Loop with Fast Reaction Control

Reduced dead time improves process quality, saves CPU performance, and guarantees the best results thanks to minimized jitter.

Synchronizing any IMM movement controlled by any drive type

As explained in our first article about pressure closed loop, pressure control, as well as now a position compensation control, can be carried out on the controller, and this used to be a golden standard in the IMM process controlling for many years (still the state-of-art solution for hydraulic machines). In comparison, the new concepts, when the pressure & position control are integrated into the servo drive, lower dead times (due to fast control features), faster pressure control behavior, and advantage of error reactions directly on the drive seem to be the reasons many OEMs make the shift.

This being said, one may ask if KEBA pressure and position balance control assistants function with 3rd party drives and the answer is positive. However, the combination of KEBA controllers, servo drives, and even motors provides unlimited benefits of one-source hardware & software, resulting in the best possible performance indicators.

By using the pressure control and the position balance control at the drive, our smart function KePlast Position Balance Control can synchronize all movements required by the customer, depending on the application. A distinction on which movements should be controlled (e.g., ejector, mold, injection movements) is made at a set-up phase, as they all have different requirements. For instance, injection movements will require most of the time two single-axis drives because of the high-pressure control. However, mold movements could be possible with one double-axis controller since no extremely high torques are expected.

Both KEBA Fast Reaction Control, as well as KePlast Position Balance Control smart function effectively run on any servo drive – with 1, 2, or 3 axes which also means on all KeDrive D3 servo controllers.

Our technology provides perfect cross-communication between master and slave axis in the pressure and position balance control – it does not only correctly controls pressure, but also control the position difference between the two motors at almost zero. This guarantees the 100% utilisation of the drives and motors. Another benefit on top is, that the position compensation functions even in the event of an error.

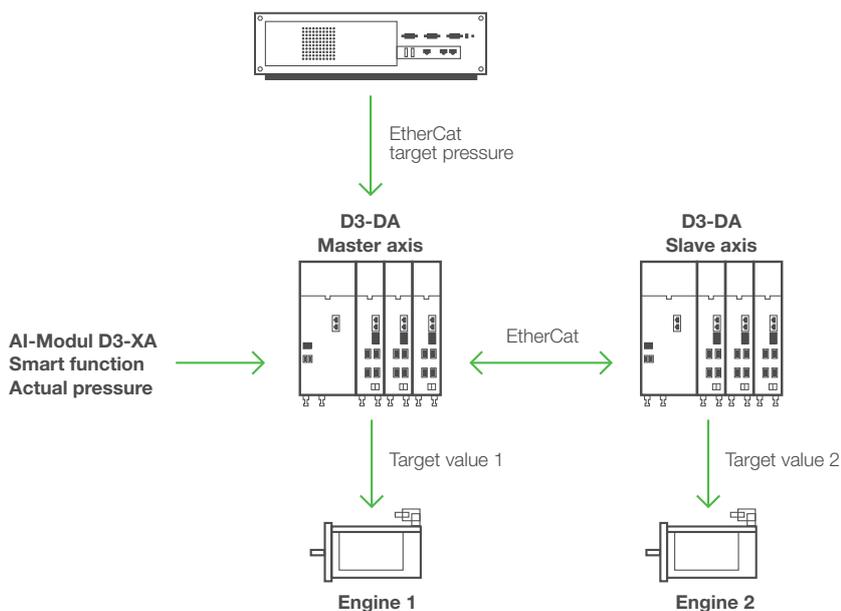


Figure 2.3: Communication scheme – an example with two single-axis controllers

Use Case of KePlast Position Balance Control: customer measurements

Details about the measurement:

- // In the figure 2.4, graphic “Inject Pressure (A)”, we can see that the Injection pressure of 1800 bar is controlled stable with an overshoot of about 3%.
- // Additional we can see in the graphic “Position difference (B)” that the maximum position difference between the axis is about 0.02 mm. During the whole injection process the position balance controller try to reduce the gap to 0.0 mm. This prevents mechanical damage of the machine.
- // The influence from the pressure loop on drives can be seen in the two curves “Velocity Axis1 (C)” and “Velocity Axis 2 (D)” of the motor. The pressure controller reduces the velocity before the reference pressure is reached to control the high pressure.
- // In the whole figure also the advantages from pressure loop on drive is visible. The pressure is controlled with low overshoot and short reaction time, the actual speed of the motors are stable and have less oscillation which extends the lifetime of the machine.
- // With two KeDrive D3 axis highest requirements on pressure and speed can be controlled with good quality.

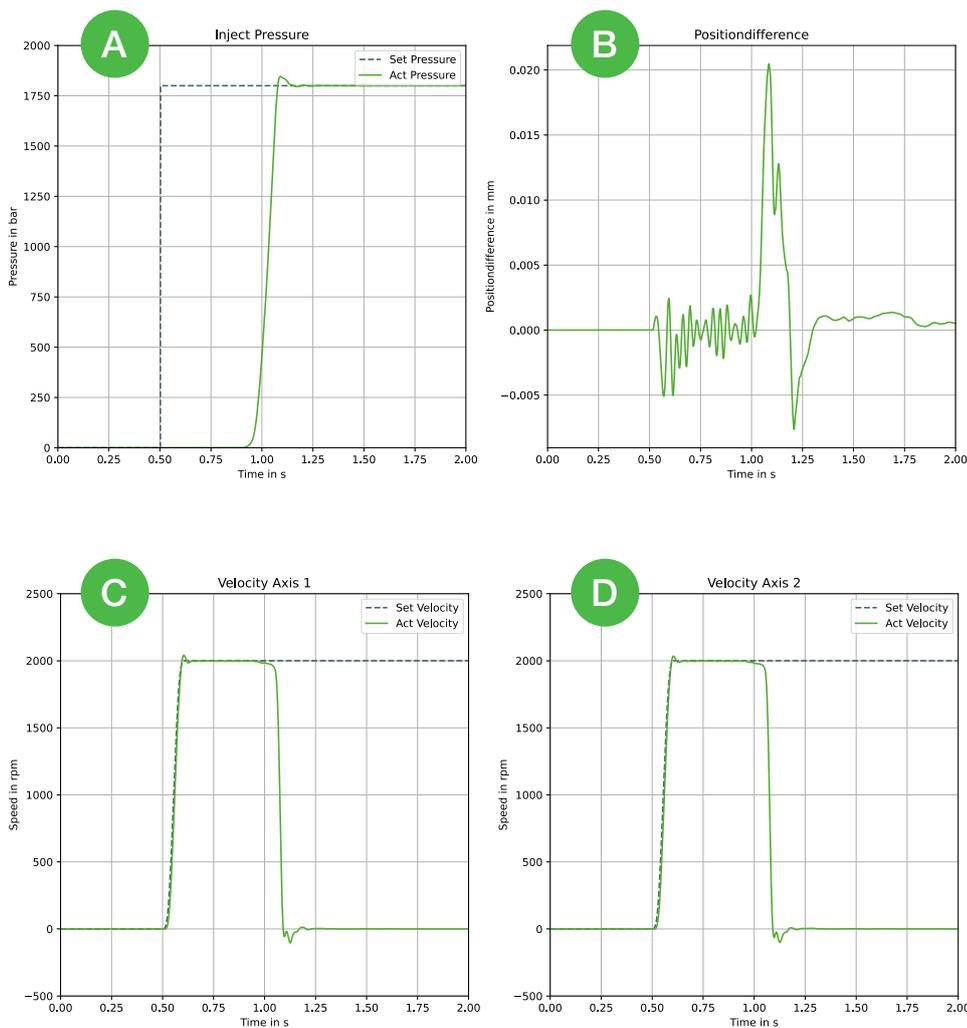


Figure 2.4: Injection // all variables // 2 seconds

Comparison of position balance control on KeDrive D3 and on KEBA PLC

We have tested the dynamical behavior of the controller in the laboratory. To rate the control reaction we used a fictional disturbance during the Inject process using the same control settings. One example shows the control loop is in the PLC and the second one in our KeDrive. In the following picture you can see the comparison.

Although the position balance on the PLC meets the highest requirements on reaction time and overshoot, the result at the drive is even better because of minimal possible dead time. This leads to an optimal control behavior, which prevents the machine from being damaged.

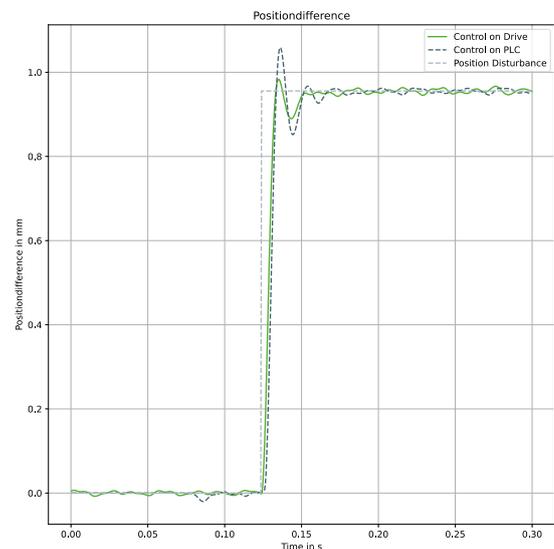


Figure 2.5: Comparison of position balance control on drive and on PLC

Benefits Summary

- // The pressure control takes place at the drive with 125us = an industry benchmark value for a cycle length
- // The drive reacts directly in case of error and thus avoid damage and minimize downtimes
- // Set the max-braking capacity quickly and easily without adverse effects on the machine
- // 100% Utilization of the drives / motors up to the torque limit
- // Position compensation even in the event of an error
- // Due to Fast Reaction Control, the dead times caused by the cross-communication are also minimized, as the whole controller cycle only requires one cycle tick instead of three.

New feature in use: "Fast cross-communication on EtherCAT"

As already explained, there are movements that have to be executed with several axes due to the required torque and speed. To ensure that both axes behave in the same way and no mechanical distortions occur, we use the option of copying data directly from one axis controller to another axis controller via EtherCAT.

With the new feature and correct EtherCAT communication, an axis controller stores data as an EtherCAT slave in a separate EtherCAT frame, and a second axis controller takes the data from this frame. The position compensation control in KePlast serves as an application example here. With the help of a modified control structure, it is only necessary to transfer position and speed from the master axis to the slave axis - this is possible in 125µs with the fast cross-communication on EtherCAT – in order to ensure precise synchronization.



Ramp calibration assistant helps

extend the mold lifespan and speed up the mold exchange process

Call off the search! Automatic Ramp Calibration assistant will look for the optimal ramp of the mold movements, prevent breakage and prolong the mold's life.

Mold damages can be a significant concern for plastics manufacturers as they can lead to production delays, scrap or rework of defective parts, and increased maintenance costs.

Furthermore, calibrating a machine after a mold exchange can be a very long and expert-demanding process, machine type independent, because calculating and testing manually requires lots of time and expertise, including many trial-error situations – something the plant's owners want to avoid for sure in times of qualified workforce shortages.

One alternative for automatically identifying how quickly the mold should close and open at these different stages is the Automatic Ramp Calibration feature commonly available as a part of KePlast Software.

Man vs. machine

A short analogy of this function to daily life is car parking. When thinking of the last curve one needs to take to get to the final parking position, the driver decides at what velocity and with which acceleration the car should move to achieve the smoothest possible movement.

Stepping on the gas and directing the steering wheel in a specific direction to reach the final position too fast leads to problems with immediate need of braking, resulting in pressure overload on brakes, and may move the car slightly forward because of shaking. However, we also do not want to park the car too slowly because there are simply better things to do.

We, humans, learn from our experiences and are able to adapt the parking velocity to protect our vehicles. The same applies to open and close movements of injection molding machines, it is, however, not so straightforward to imagine.

Impact of multi-stage mold profile movements on the mold lifespan

The injection molding process's open and close movements usually have three to five velocity stages for mold close and two to five for mold open, each requiring the molds to move at different velocities and with different acceleration or deceleration to avoid unnecessary mold damage caused by excessive braking and shaking.

On KePlast screen view, the horizontal lines show constant velocity, and the steep lines show the change in velocity. Acceleration refers to a change of velocity in time – being that a speed up or slow down. And as a ramp, we consider the linear change of velocity, which can be adjusted with “Start %”, “Mid %” and “Stop %” parameters.

Molds under control – also without active brake control

The changes in velocity and acceleration are usually executed through a manually-configured active brake control mechanism. It changes the brake valve or servo valve position, the cross-section where oil flows through, after (and before) the cylinder that moves the mold. So depending on the desired case, the cross-section is either smaller, resulting in higher resistance to the flow of oil and stronger braking effect, or the cross-section is larger, meaning reduced resistance and lower braking effect.

Since the prices for active brake controls are pretty high, not all machines are equipped with them. If there is no active brake control mechanism, therefore, without the valve, the cross-section is either completely open or closed, not usable for active braking. The mold is then only braked by friction or due to the toggle lever. Thus, soon enough, too much oil must stop being pumped.

The good news is that the Auto Calibration feature is working perfectly in both cases and is a preferred option for standard or low-end machines without active brake control.

At the right time, at the right place

Let's look closer at what actually happens with an injection molding machine when we want a mold to stop at a particular spot at a specific time. The graphic below shows the desired velocity of the open movement (black curves) and the actual measured values of the velocity (green curves). When focusing on the braking, the last and crucial phase of the opening process, we can clearly see the negative velocity followed by a positive one – which is a sign of machine shaking.

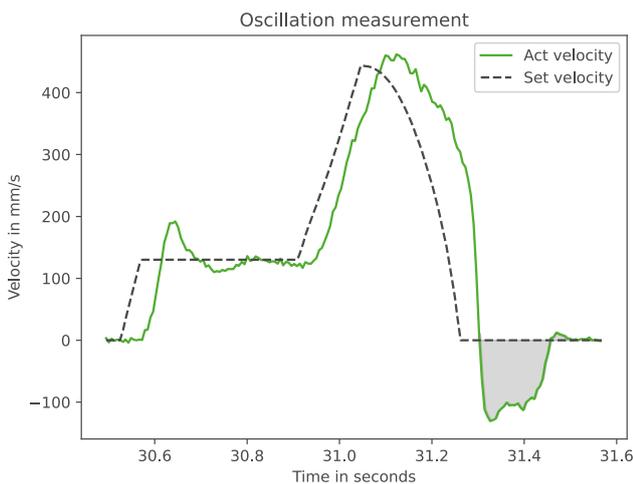


Figure 3.1: A typical mold open stop ramp evaluation (the movement time values start at 30 s, because we used actual data from a real measurement)

Now, the machine's options to avoid extensive shaking are to use an active brake control mechanism with the help of a brake valve or a more expensive servo valve for which the process experts need to find the correct values and set them up in the control system manually – or use the algorithm calculated and tested values from the KePlast Automatic Ramp Calibration feature.

A PLC from KEBA with KePlast Software has a precise, intelligent auto-calibrating function, which answers the question of how much shaking shall be allowed and adapts the processes accordingly.

By evaluating the optimizing criterium, which is, in this case, the oscillation, defined as the shaking at the end of the movement, the robust algorithm identifies the “trade-off” ramp values with the help of numerous auto-calibration movements like the idle, reference & validation ones.

KePlast Automatic Ramp Calibration AI assistant in 3 steps

- 1 Algorithm evaluates the oscillation at the end of the movement (Figure 3.1),
- 2 uses the oscillation of a slow movement as a reference (A), and
- 3 performs numerous auto-calibration movements to identify the most suitable value based on the optimal “Max (B) & Stop (C)” values

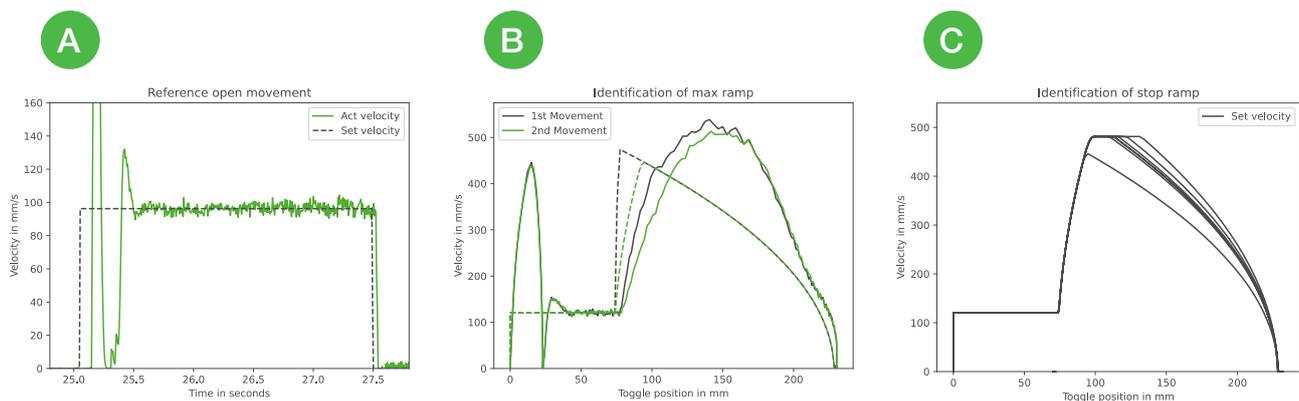


Figure 3.2: Mold open auto-calibration – the overview of all steps the algorithm executes
(A: the movement time values start at 25 s, because we used actual data from a real measurement)

As a result, the algorithm finds the highest possible Max and Stop ramp values highest acceptable oscillation.

Benefits Summary

- // Smooth movements & smooth braking for longer mold life
- // No or fewer experts needed as well as saved time by the mold exchange process
- // Set the max-braking capacity quickly and easily without adverse effects on the machine
- // For any hydraulic machine type, also suitable for braking with servo valve

The KePlast Smart Movement:

The right mold movement position – on a millimeter exact & without any servo valve

The KePlast Smart Movement, is a simple AI assistant that ensures the highest movement accuracy of an injection molding machine's mold without using an expensive method of active braking.

Position accuracy is an essential characteristic of any injection molding process, and here applies, the more constant the position, the more constant the process. Not to mention that many processes have an integrated take-out robot, which requires the molds always to have the same position to take out and further process the parts.

The machines always have tiny deviations to initial states, for example, when the oil temperature changes or as the effect of lubrication after 1000 produced pieces, leading to slight tuning out of the machine.

To repeatedly reach specified target under changing external conditions for every phase of the movement, especially for the crucial last (or intermediate) bit, when the mold slows down to stop, is not common for all machine types. Indeed, a popular option for premium segment machines is velocity control through active braking with a servo or a proportional valve. However, it is neither space nor cost-saving and absolutely unfeasible for economic as well as standard machines.

Parking without brakes – would you dare?

We love analogies in explaining our features. In our previous article about the KePlast Automatic Ramp Calibration feature, we already got the velocity (speed and direction) as well as the acceleration of the "parking movement" right.

Imagine driving on an empty country road, seeing the train crossing from a long distance, switching its lights to red, and signaling that the cars should stop. You know the driving direction and can imagine the final parking position. The issue is that you would not be allowed to use the brake pedal.

By getting the feet off the gas pedal at the right time, experienced drivers may bring the car close to the desired parking position, even without brakes. When they repeat the process every day, they might even fine-tune it and always get better and better at it. But they also may not.

To get the parking under full control, one either needs to use brakes or theoretically design some intelligent assistant to calculate the position deviation. Based on the actual results, get the driver's feet off the gas pedal a bit earlier or later to finally stop at the right position.

Go with the flow

Injection molding machines have different technology behind movements and braking, characterized by managing the oil flow in the hydraulic system, but the logic of the issue is the same.

The scenario explained above especially challenges economic and standard injection molding machines with simple hydraulics with an on-off hydraulic transmission system. Because of their attractive price/performance ratio, having an active brake function with a proportional valve or a servo valve is not feasible. The quality standard of products produced by these machines is generally well-received by the end users, primarily because of the simple nature of these products, and therefore, many manufacturers simply accept using the affordable technology without active brake.

This is how the simple hydraulic of such machines works. As the electric motor turns the hydraulic pump on, the fluid from the tank is driven through the filter into the pipes. The pump's function is to create flow and is set up using two parameters – oil flow and pressure, but actually, only one of these is achieved in the process. Pressure in a hydraulic system is created by the resistance to flow. The directional valve position (open or closed) specifies the direction of the oil flow and moves the mold. After the fluid passes through, it returns to the tank.

In this case, it is not possible to fully control slowing down the mold. Also, if the flow of the pump is reduced with a ramp, the speed of the mold may not follow at the same deceleration rate because of the heavy mass of the mold.

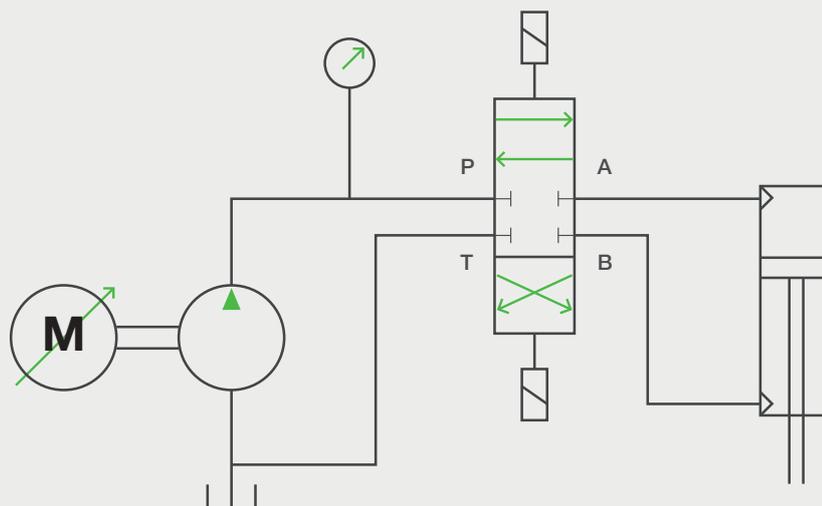


Figure 4.1: A basic directional on-off hydraulic transmission system used in eco and standard machines

Active braking

On the other hand, premium machines require much more accuracy. They may produce products where even a minimal deviation of mold position may lead to catastrophic quality issues. Such machines commonly use active braking, which can be achieved with a proportional or a servo valve.

For a proportional valve, the percentage of openness of the valve is specified, what creates certain desired resistance and controls the mold movements.

One higher level is active braking with a feedback device, which is most commonly a highly-responsive servo valve. Servo valves operate with very high accuracy, high repeatability, and high-frequency response and are able to handle small flow changes rapidly and accurately over a broad range of flow rates.

The disadvantages of this technology are high costs and lots of space required for the valve itself as well as its accessories and related devices.

More for less with Smart Movement

KePlast Smart Movement, an intelligent assistant of KePlast software, provides an efficient alternative to active braking with a brake or a servo valve. The solution is not only comparably accurate but also significantly more energy-efficient than the use of a servo valve.

The main idea is that the Smart movement algorithm constantly analyses the actual mold position and calculates a deviation between target and actual mold position values. It then makes corrections for the movement profile and, in the last ramp, lets the mold's deceleration start earlier or later in order to achieve the ideal end position (see Picture 3). The tool allows adapting in manual, half-automatic, and full-automatic modes.

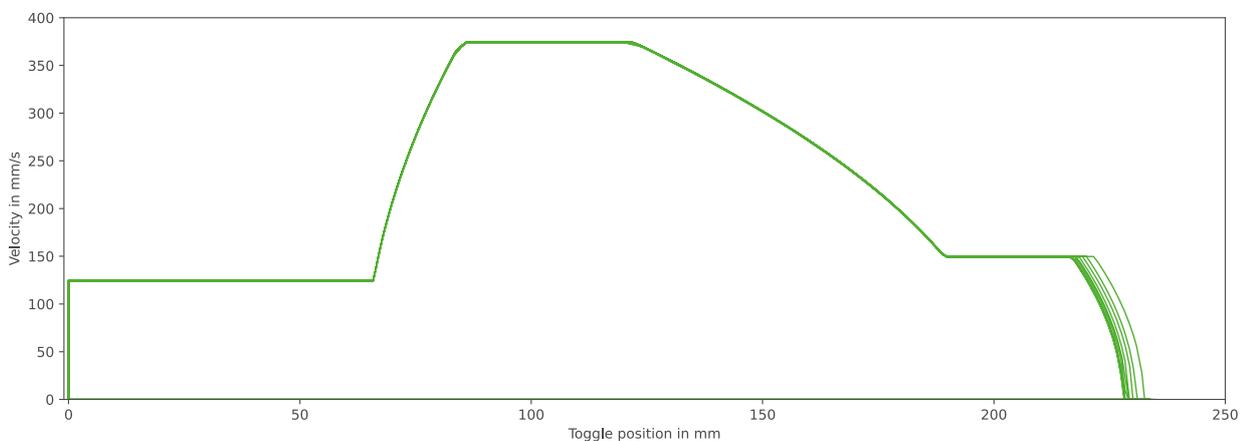


Figure 4.2: Smart Movement of the mold open movement

KePlast Smart Movement for intermediate positions

Many, especially the complex plastic parts, require accurate intermediate positions in addition to open & close mold positions because there are often robots involved in a process. Intermediate positions can be, of course, also improved by KePlast Smart Movement. A unique correction is needed for each intermediate position, and there is a convergence after a few cycles. The machine will keep high precision of its mold movements, resulting in lower wear of the mold as well as less damage to robots.

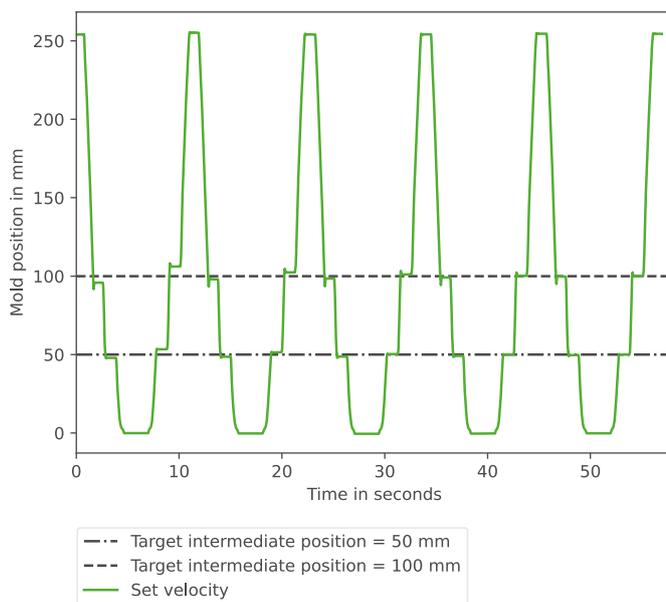


Figure 4.3: Smart Movement of the intermediate positions

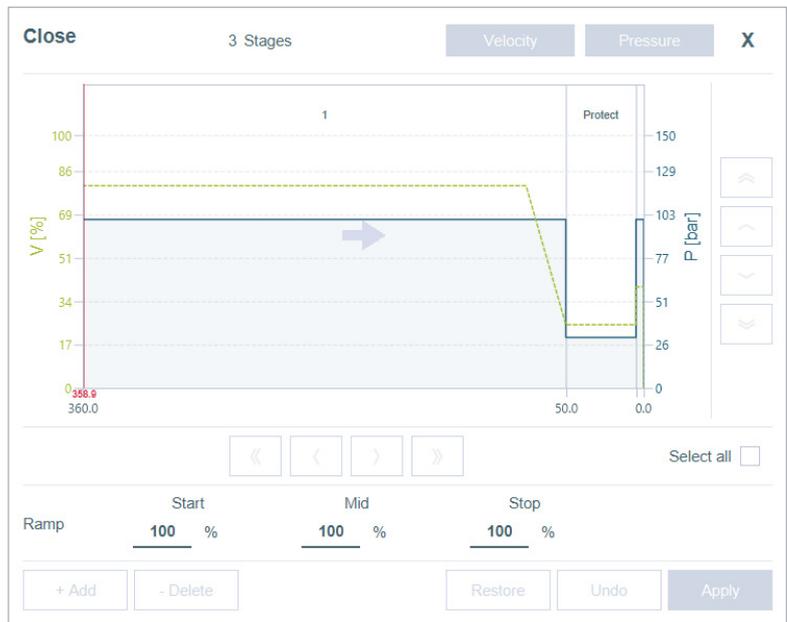
Benefits Summary

- // Smart Movement compensates for the disadvantage of inaccuracy in positioning the mold with a directional valve
- // Saves the space in the cabinet
- // For any hydraulic and hybrid injection molding machine type
- // Very favorable energy-consumption performance

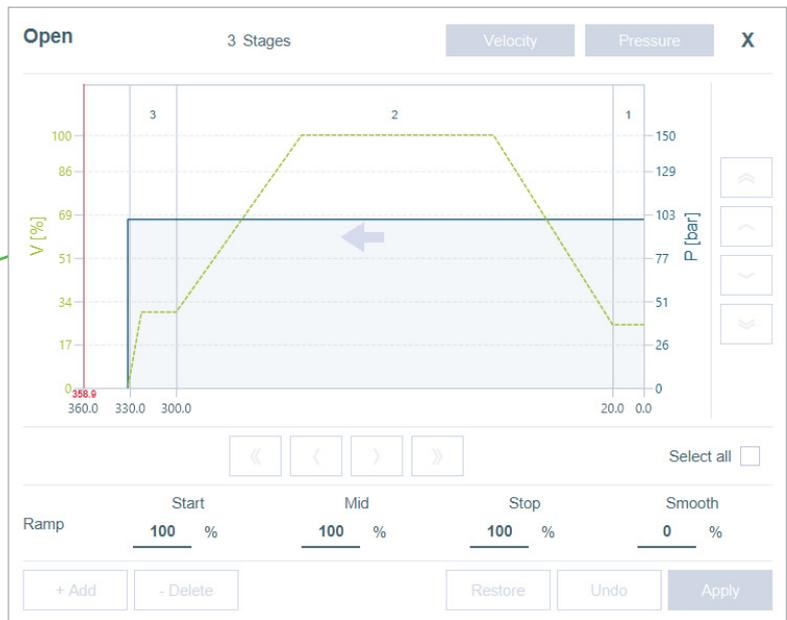
HMI visualization of various scenarios I. Ramp calibration

Before ramp calibration

// Movement ramps

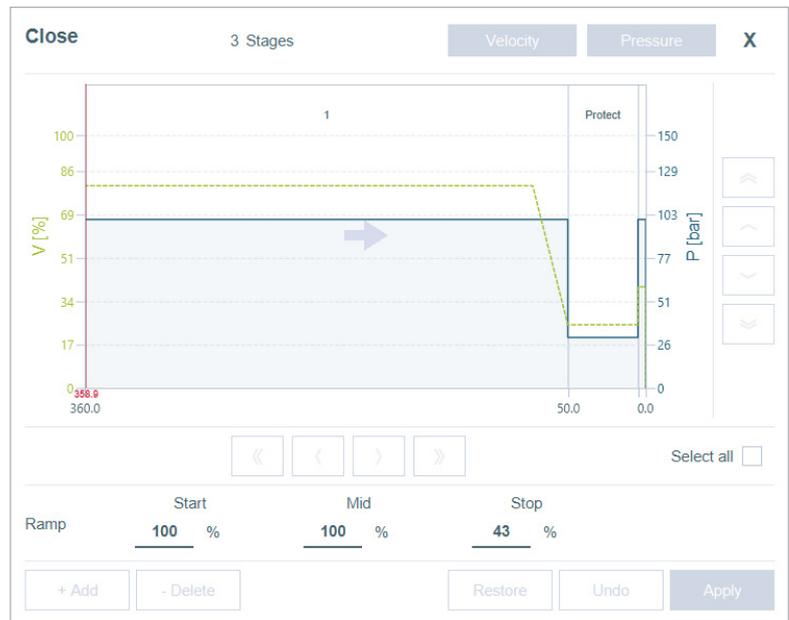


// Mold close & mold open

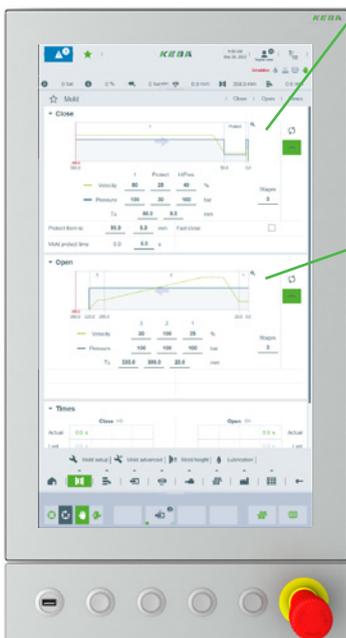


After ramp calibration

// Movement ramps



// Mold close & mold open



After ramp calibration is finished, smart movement can/should be enabled to further improve the mold movement.

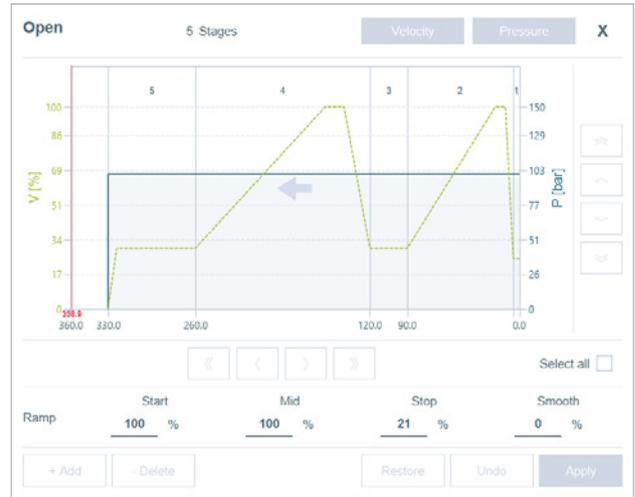
HMI visualization of various scenarios II. Deceleration stop ramps of Smart Movement

The specified stop ramp values (e.g. from ramp calibration) are then used for intermediate decelerations as well.

// Smart Movement disabled



// Smart Movement enabled



The image of "Smart Movement enabled" shows that the two intermediate decelerations are also scaled depending on the stop value (and not on the mid value anymore).

Ramps are scaled depending on toggle lever characteristic, see the following figure. The transmission of the toggle lever (derivative, second graph) at a specific toggle position is used to scale the ramps: different slew rate for ramp at e.g. 90 mm than ramp at 260 mm.

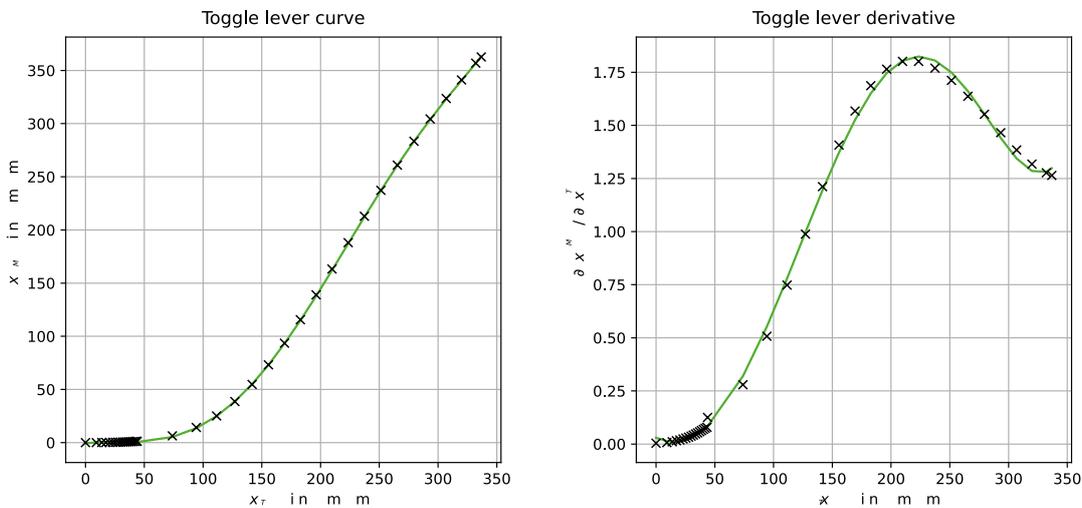


Figure 4.4: Toggle lever curve & toggle lever derivative



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Over 40 years of experience in controlling complex processes with KePlast

Due to constant improvements and innovations, KePlast is a state-of-the-art control system solution perfectly designed for various types of plastics & die casting machines.

KePlast belongs to the leading automation solutions in the injection molding field with more than four decades of continuous improvement of our products and services.

This enormous amount of knowledge and expertise provided a solid base for the developments in other branches, thanks to which we can now provide an inside out consulting, control intricate operations, and invent not only new products, but also effective work procedures, like the KEBA engineering workflows.

So whether one needs a cost-friendly turnkey, lightly customized, or utterly new solution, we are ready to realize the vision.

Benefits with KePlast:

- // Comprehensive consulting & branch process expertise
- // For all plastics machine types and price ranges
- // Close R&D cooperation with customers globally
- // KePlast software platform framework for a short time to market
- // Future-proof high-end technologies

KePlast industries:

- // Injection molding
- // Extrusion
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