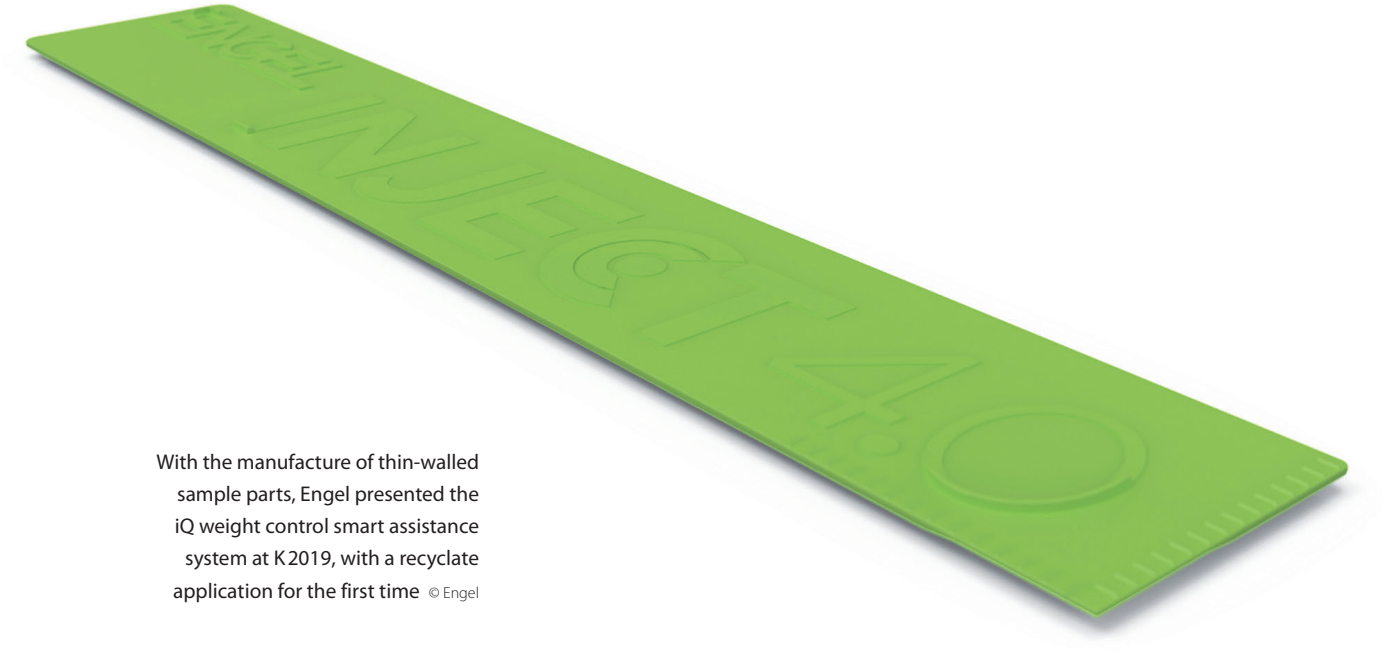
Opening up a Broader Range of Applications for Recyclates

The iQ weight control Assistance System Ensures Higher Process Stability

Smart assistance systems are paving the way for self-optimizing production. Automatic correction of quality-relevant parameters is already reality for individual phases of the injection molding process. At K 2019, Engel presented the iQ weight control with the example of a recyclate application for the first time. Extensive tests performed jointly between the injection-molding machine manufacturer and the recycling specialist Erema confirm that the system has great potential for the circular economy.



With the manufacture of thin-walled sample parts, Engel presented the iQ weight control smart assistance system at K 2019, with a recyclate application for the first time © Engel

Transport and storage boxes are predestined for the use of recycled raw materials. Several customers of Engel Austria GmbH, Schwertberg, Austria, already process recyclates in large quantities to produce various containers, with iQ weight control to improve the process repeatability. The software detects fluctuations in the raw material and in the ambient conditions, and adjusts the injection profile, switchover point and holding pressure, individually for each shot to suit the current production conditions. "We can process recyclates from different sources and, thanks to iQ weight control, minimize the reject rate. This makes it substantially easier to use recycled materials," commented, for example, a well-known internationally active processor.

Fluctuations in the material properties pose a significant challenge for the processing of recyclates. Even homogeneously collected and treated plastic wastes are subject to greater fluctuations than virgin material, since the recyclate properties are also influenced by circumstances such as how heavily the wastes are polluted and the process used to wash, shred and repelletize the wastes. In recyclate processing, such materials are generally sourced from different suppliers. Since recycling companies use different technologies, the variance is particularly high when a batch is changed.

Engel tackled this theme at K 2019. With an Engel victory 120 machine, fully recycled ABS was processed into elongated sample parts (**Title figure**). The recyclate batches came from two suppliers,

who used different treatment technologies and obtained the raw materials from different sources. The trade show visitors were able to initiate a batch change themselves and track on the display (CC300) how the assistance system adapts the processing parameters to the different melt viscosity in order to produce acceptable parts with the first shot after a batch change. To illustrate this, iQ weight was alternatively activated and deactivated on batch change (**Fig. 1**). When it was switched off, the parts were no longer completely filled following the batch change – rejects were produced.

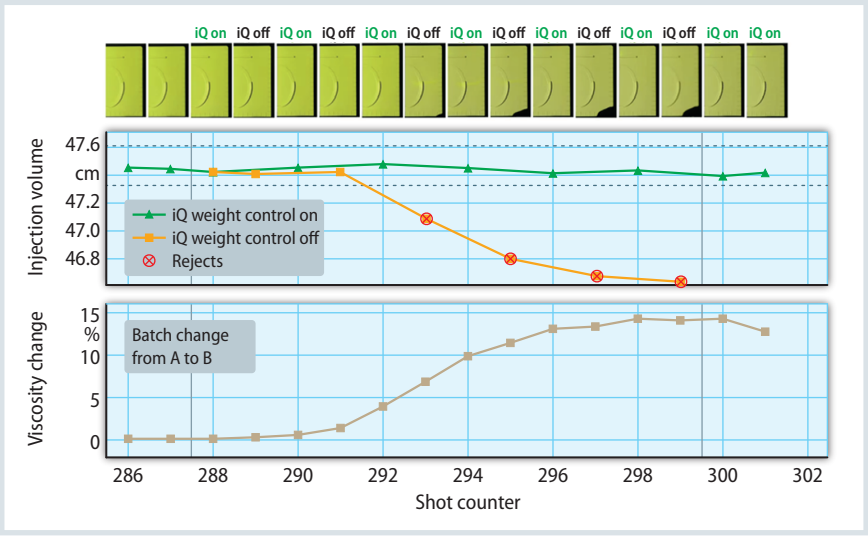


Fig. 1. The image sections of the flow-path end (top) clearly show that, with iQ weight control deactivated (black), the cavity was not completely filled after batch change. With iQ weight control activated (green), on the other hand, acceptable parts were consistently produced Source: Engel, graphic: © Hanser

Differently Processed Recycled Pellets under Test

The prerequisite for establishing a circular economy is to use processed plastic wastes more diversely for the production of new, and especially high-quality plastic products. As an injection-molding machine manufacturer, Engel makes an essential contribution to a circular economy by increasing the process stability. On the market since 2012, iQ weight control first became globally established for the processing of virgin material [1].

The trade show demonstration and the first practical examples, such as the manufacture of containers and vessels, show the assistance systems' potential in the circular economy. To put this on a sounder footing, Engel and Erema Engineering Recycling Maschinen und Anlagen Ges.m.b.H., Ansfelden, Austria, investigated the effectiveness of iQ weight control for processing recyclate.

At the Erema technical center, an Engel victory series machine was used to mold sample parts from polypropylene (PP). The starting materials for the processed recyclates were geotextiles, which had been in use as construction site fabric, and were correspondingly soiled. The textiles were washed and then processed and repelletized on Erema systems (**Fig. 2**).

To simulate realistic conditions and perform batch changes, four different combinations of recycling technologies and processing parameters were used. The four resulting recycled materials have different melt flow indexes (MFI) in the range between 15 and 30 g/10 min and have correspondingly different properties during processing.

Recognizing and Compensating Differences in Material Properties

In a first range of tests, dumbbell tensile bars were injection molded. To assess the process repeatability and the resulting part quality, attention focused on part filling and the mechanical properties, such as impact strength, which were determined in the lab. The mechanical properties, as well as the viscosity, depend on the molecular weight of the processed polymer. iQ weight control can recognize even minor deviations in the viscosity from a reference value. An (automatically) detected change of the viscosity is thus an indicator that something could have changed in the polymer chain length distribution.

By adjusting the injection profile, switchover point and holding pressure profile, the assistance system keeps the filling volume constant even with fluctuating viscosity, thus preventing incomplete filling of parts. The more consist- »

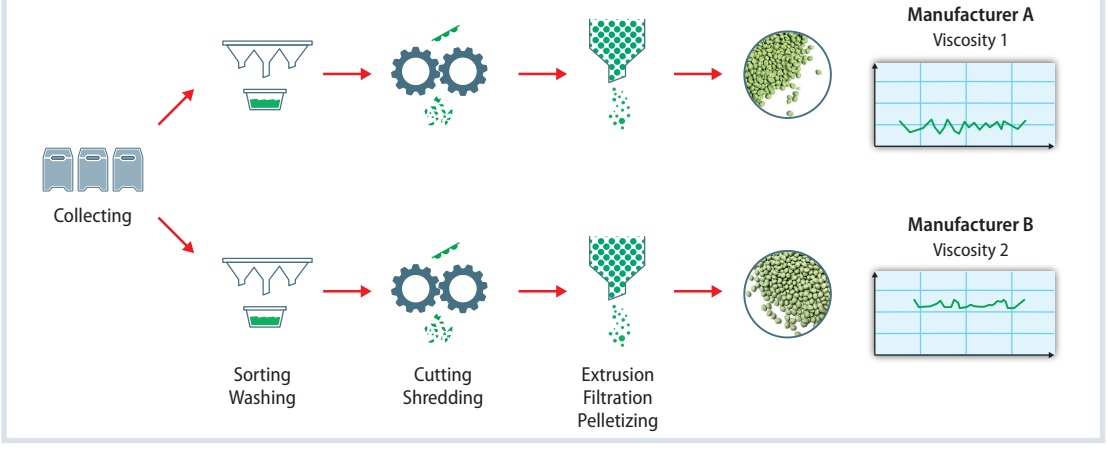


Fig. 2. Different reprocessing methods influence the flowability and other properties of the resulting pellets. To simulate a broad spectrum of different conditions, the series of experiments was conducted with four differently treated PP recyclates Source: Engel, graphic: © Hanser

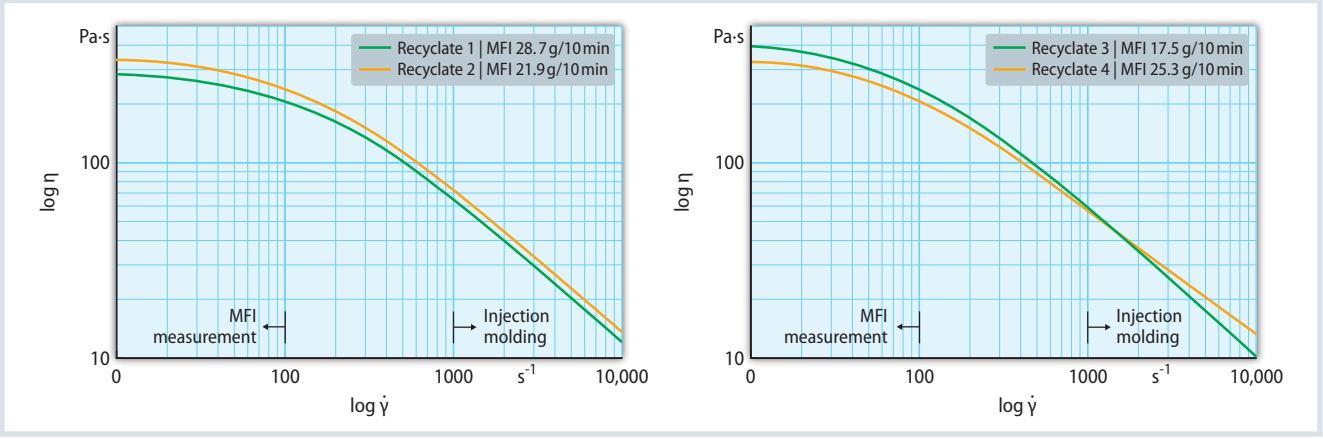


Fig. 3. The two diagrams show shear-rate-dependent viscosity curves measured in the high-pressure capillary rheometer (HCR) for different recyclates in double-logarithmic presentation. MFI measurements are made in the range of low shear rates, which significantly higher shear rates occur during the actual injection molding process. The viscosity change determined from process data is therefore often much more relevant than a pure MFI comparison Source: Engel, graphic: © Hanser

Fig. 4. Stepped panel with four different wall thicknesses. The center web is 3 mm thick. The side arms have wall thicknesses of 2, 1 and 0.5 mm, with the thinnest regions located at the end of the flow path © Engel

iQ weight control

With the injection of plastic melt into the cavity, the filling quantity is influenced by a diverse range of factors, which can have a negative effect on the part quality. Besides fluctuations in the raw material batch, they also include changing ambient temperature and atmospheric humidity, fluctuations in the closing behavior of the non-return valve and operating fluid supply, as well as a long run-in phase, e.g. after production downtime.

The iQ weight control assistance system from Engel analyzes the pressure change in real time during injection and compares the measured values with a predetermined reference cycle. If the software detects deviations, it adapts the injection profile, the changeover point and the holding pressure profile to current process conditions in the same shot. In the case of parts that are filled in a cascade via multiple gates, iQ weight control additionally corrects the opening and closing of the individual shut-off valves according to the progress of filling. In this way, the software ensures high process constancy and maximizes the production of acceptable parts.

↘ www.engelglobal.com/inject-4-0

ent filling also helps the same compression to be ensured. Strength deficits caused by the degradation of the molecular weight in the raw material cannot be compensated by means of process control.

More Useful than the MFI

The MFI is often used as an indicator of the flowability; however this neglects the influence of shear rate on viscosity. With increasing shear rate, the viscosity is reduced by the pseudoplastic behavior of plastic melts, which improves the flowability. Since significantly higher shear rates occur in injection molding than in MFI measurement, MFI has only limited suitability for assessing the flowability under processing conditions. iQ weight control determines the change of viscosity based on the shear rates that are actually effective in the process, and thus permits a more precise statement (**Fig. 3**).

The MFI measurement at lower shear rate agrees well with the measurement in the high-pressure capillary rheometer (HCR) in showing a difference of 23.7 % in the flowabilities of the two materials under consideration. In the actual injection molding process, iQ weight control, on the other hand, calculates a viscosity difference of only +11.7 %, which agrees very well with the difference of 12.4 % determined with the HCR measurement at the correct effective shear rate (**Fig. 3, left**).

If the curves of the shear-rate-dependent viscosities cross, a material that flows poorly in the MFI measurement may even flow more easily under the actual process conditions. Here, too, iQ weight control provides the correct result of –5.4 % (**Fig. 3, right**).

Moldings with Complex Geometries as Test Objects

To be able to assess the mode of operation of the software with complex geometry, a test mold for manufacturing branched stepped panels with multiple wall-thickness steps was used for a second series of experiments (**Fig. 4**). The panels have a wall thickness of 3 mm along the center web. The side arms are 2, 1 and 0.5 mm thick, with the thinnest regions located at the end of the flow path.

For the tests, two of the four recyclates reprocessed by Erema were molded. One of the two materials was defined as reference (recyclate 1). With the change from the reference material to the other material (recyclate 2), it was found that, without the smart process controller, the shot weight decreases significantly and the cavity can no longer be completely filled (**Fig. 5**). When iQ weight control was switched on, the

shot weight was increased to the region of the values obtained with reference material, and completely filled parts were consistently produced.

This result was supported by the analysis of the recorded cavity pressure curves (**Fig. 6**). In this case, the control was nevertheless performed using the injection pressure transducer in the machine, since this is the typical case in practice. In the filling phase, the required pressure is significantly increased with the poorer flowing recyclate 2. The switchover point – marked by a vertical line – and the holding pressure level are correspondingly adjusted with iQ weight control (**Fig. 6, top**).

Two marked pressure rises are noticeable in the cavity pressure curve, which are emphasized in the figure by means of vertical dotted lines. The first pressure rise takes place at the point at which the flow front reaches the cavity pressure sensor, and the second pressure rise takes place as a result of the complete volumetric filling of the cavity or during premature freezing of the flow front in the incompletely filled parts.

Without iQ weight control, the filling is time delayed, which is manifested as the delayed pressure rise in the mold, a significantly lower pressure in the holding phase and ultimately in incomplete filling of the cavity. With iQ weight control, on the other hand, due to the adaptation of the switchover point and the holding pressure level, the cavity pressure curve was almost identical to that achieved when processing the reference material (**Fig. 6, bottom**).

Reliably Assessing the Potential before Investment

The smart assistance system from the "Inject 4.0" program is available for all Engel injection-molding machines, both with electrical and hydraulic injection units. iQ weight monitor helps with an assessment of the potential before the investment is made, [2]. This software is part of the standard scope of all injection-molding machines. Like iQ weight control, it recognizes deviations from a reference state and allows the processor to recognize fluctuations and assess the quality of the respective raw material batch. It differs from iQ weight control in that iQ weight monitor does not make corrections to the process.

Engel is continually developing its assistance systems further. At K 2019, iQ weight control was not only presented with a recyclate application for the first time, but also with a new function. In cascade injection molding with iQ weight control, the quality-relevant process parameters can now be adapted for multiple gates connected in series. After filling at the first gate, it switches first to the second, then to all further gates, and only to holding pressure at the end of the cascade.

In the process, in addition to the injection profile, changeover point and holding pressure, the software additionally adapts the respective opening and closing points to the current process conditions. The elongated sample parts of recycled ABS were filled via three gates. Thus, in the injection molding of large-area parts with long flow paths – with both virgin material and recyclate – the potential of iQ weight control could be completely exploited. »

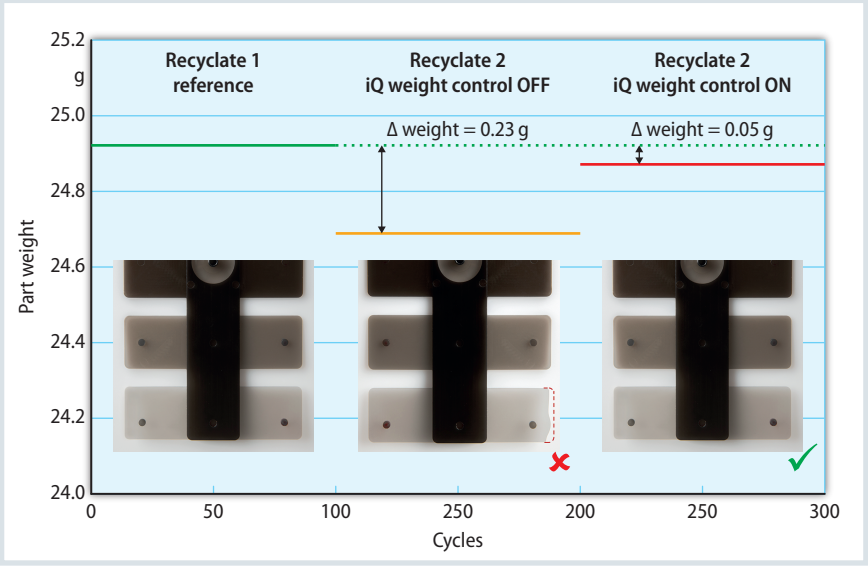


Fig. 5. On recyclate change, the shot weight sinks significantly with the consequence that defective parts are produced. With the activation of iQ weight control, the shot weights are increased to the range of the reference material Source: Engel, graphic: © Hanser

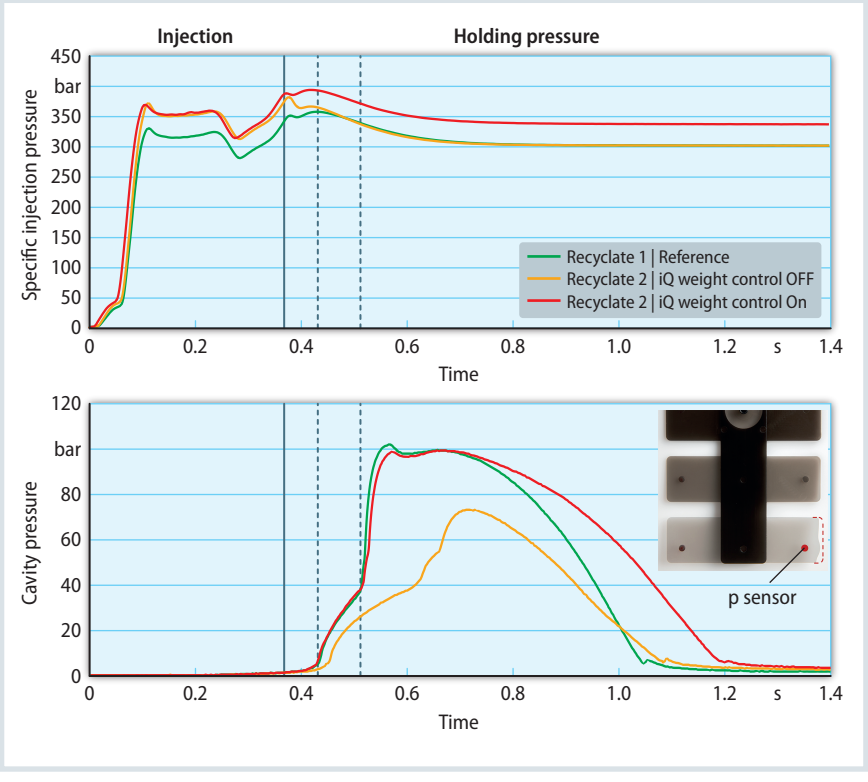


Fig. 6. Pressure curves after batch change from recyclate 1 to recyclate 2. The upper diagram presents the specific injection pressure profile. The plot of the cavity pressure curves (bottom) supports the result of the part weight measurement and also shows the more uniform fill front progress with iQ weight control Source: Engel, graphic: © Hanser

Conclusion

Batch fluctuations due to different starting materials and recycling technologies represent a major challenge to the circular economy. The practical suitability of the iQ weight control process controller for recyclate processing were confirmed in joint trials by Engel and Erema, as well as in a live demonstration at K 2019. The assistance system can thus contribute significantly to the functioning of a circular economy. ■

The Authors

Dipl.-Ing. Dr. Georg Pillwein is Head of Process Technology Development at Engel Austria GmbH in Schwertberg, Austria; georg.pillwein@engel.at

Dipl.-Ing. Philipp Willnauer is development engineer in process technology at Engel; philipp.willnauer@engel.at

Prof. Dr.-Ing. Georg Steinbichler is Senior Vice President Research and Development Technology at Engel Austria GmbH and Chairman of the Institute of Polymer Injection Molding and Process Automation at Johannes Kepler University in Linz, Austria; georg.steinbichler@engel.at

Service

References & Digital Version

- You can find the list of references and a PDF file of the article at *www.kunststoffe-international.com/2020–5*

German Version

- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*