Faster process at consistent quality and reduced energy input

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Often, only a few modifications of the standard procedure are needed to make a product process-reliable and economically feasible. New potential for the processing of crosslinkable materials may thus open up by implementing, for example, a plastics-oriented part design, special procedures for ventilation and mould temperature regulation right up to isolated tool systems. A reliable production then enables a subsequent automation, which seems to become indispensable today due to demographic changes and the positioning on the world market.

1 Introduction

In the near future, automation will become mandatory for all fields of plastics processing – from product development to tool design right up to the actual production of plastic parts including their assembly. This will also affect medium-sized enterprises at a growing rate. If the course is not set in good time it will be difficult to get on board later on.

2 Are products and mould tools ready for automation?

The key to addressing the resulting problems is similar as for current production processes. We need a significant improvement of the plastic parts quality. Although this is common knowledge it is not consistently put into practice. Therefore, we are describing an old problem that is tackled by only a few companies. But even then it is not thoroughly implemented from the first idea to serial production. This applies to the processing of rubber and silicones also in combination with metals (fig. 1) and thermoplastics as well as in other areas.

Frequently, focusing only on cost centres will prevent the development of consistent and comprehensible solutions from the idea to serial production that have a good cost-benefit ratio.

The first problem is that most products are not optimally developed in regard to material and production process. Then, not considering subsequent costs, people are still bargaining hard to receive the cheapest price for the tool, instead of defining an optimum design for product and tool that will always pay off during production. For smaller quantities, high-quality tool change systems can be used without any loss of quality. Today, most elastomer moulds, injection moulding tools, or thermoset moulds are not suitable for a process-reliable production on the required level. In the future, a comprehensive automation will not – or only to a very limited extent – be possible with these tools.

2.1 Product development

Instead of a complex design we will need for the future a robust design including all draft angles and mean tolerances. With regard to automated production we will need to shift these tasks that have been located within tool design until now to product development. It would be a good start to compile early on a first tool concept with separations, feed gate definition, definition of temperature regulation and definition of shrinkage with the aid of a shrinkage database. Companies that do not have the expertise in any of these fields should consider integrating an experienced tool design engineer into their product development team or purchasing this service externally.

2.2 Tool construction

In the future, tool design will concentrate on implementing the concepts and requirements drafted during product development. As far as contour-forming parts are concerned, optimisation and automation will increase. Since temperature regulation systems that are cycle-dependent and close-to-contour are becoming increasingly important, also more contour elements will be produced using additive manufacturing, vacuum brazing or diffusion welding. The toolmaker’s task is to manufacture a precise and low-wear tool with a good temperature regulation in line with the specification.

2.3 Tool construction today and tomorrow

By programming networked machining centres and measuring devices the industrial production of high-quality injection moulding tools has become possible and profitable these days. Unfortunately, very few companies make use of this new development.

Also, for smaller mould makers the first step towards the future will be an automated approach, including the planning and programming of one or more manufacturing units for the contour-forming area that are interconnected by robots. The respective sustainable and modular mould tool concepts (fig. 2) will probably be purchased completely from external partners. Manufacturing and programming processes that are assisted by knowledge databases will then run automated to a large extent. However, a high level of training will be required for the remaining staff – a small number due to demographic changes in order to identify potential errors and eliminate them.

Until the year 2030, we anticipate the following developments in mould construction:

For the development of plastic parts, moulds and machine technology, an emphasis will be placed on automation at maximum process reliability. For high-wage countries such as Germany this tendency offers opportunities for the future global market. In previous...
decades, employees had to worry about losing their job because of automation. Today, they have to worry if the company does not set the course for automation in time.

New concepts for temperature regulation combining different heating/cooling systems offer additional potential for process reliable tools suitable for automation. Tools which are not energy-efficient and thus cannot have an optimum and sustainable temperature regulation will need to be newly built as isolated tools with a lower energy demand. It is possible to make these days already a sustainable decision (fig. 3).

2.4 Future production

An important change will be that in addition to large quantities of the same part, smaller quantities and many variants will increasingly have to be produced at a high quality in automated systems. Currently, systems are available (such as Varimos) that are able to compensate for dimensional deviations, defects and batch variations. Temperature regulation will also become an issue of even greater importance. All sins in relation to an insufficient product development and "cheap" tools will become apparent during production and have detrimental effects in the long run. Since these problems are often allocated to a cost centre different from tool construction the system is not yet designed to be capable of learning.

All aspects mentioned here aim at a product that can be produced process-reliably in a process that can be automated with an optimally designed tool in a short cycle time. Implementing the results of a simulation (e.g., LSR) the first parameters can be entered at the machine; the optimum settings should then be elaborated in the technical centre.

Likewise, temperature regulation will be implemented according to a heating/cooling design or according to specification using isolated fixed tubing in the technical centre and then constant monitoring will verify whether target values and tolerances are obtained. For temperature regulation, an appropriate inoculated medium will be used that prevents clogging of temperature regulation channels (even at 1 mm) or extreme corrosion due to hot water (>100 °C), and that ensures a turbulent temperature regulation (from 3.5 mm on). Sensors such as pressure sensors near the gate and temperature sensors away from the gate provide the necessary information, for example, for filling or further settings.

Transponders on tools ensure that tool history, maintenance, allocation and availability at the machine and during work preparation are both transparent and reliable.

3 Reducing overflow: ventilation versus evacuation

When parts from crosslinking materials are produced, the formation of overflow (leading to flash or skin formation) may require extensive post-production finishing. Similarly, an overflow that remains in the mould may require extensive cleaning of the mould (e.g., by brushing). A more comprehensive process control including cycle-dependent temperature regulation at a high temperature, sensors, and a design with defined overflow ventilation will open up completely new ways regarding overflow reduction.

Today, evacuation is often used in order to allow for a complete filling without air traps. This can definitely be a successful solution for reducing overflow if the evacuation is limited to the cavity. However, if the evacuation is done in the mould’s separation in an area closed by sealing, the vacuum will draw the overflow into the separation.

An evacuation only in the cavity – such as in IsoForm tools – is possible by using a quick ventilation with conical ejectors. The

Fig. 1: Rubber part oscillation element (source: KB Hein/MBS UG)

Fig. 2: IsoForm-rubber tool ejection side – four cavities, three inserts per cavity (source: KB Hein/MBS UG)
ejection box may then be used as pressure storage.

When processing crosslinking materials the lowest viscosity is typically reached in the first phase of the crosslinking process. Therefore, the exact volume of filling (controlled by sensor technology) is as important as a possible compensation of a merely negligible variation. Instead of an evacuation this could be a self-detaching overflow ventilation (e.g., HeiNo overflow ventilation, fig. 4), which is defined with regard to filling and the necessary ventilation.

Thus, in addition to conventional evacuation methods there are at least two other variants that allow for the control of the overflow and hence will make the post-treatment and mould cleaning of the respective part and the need for sliders manageable. This will aid in the future a cost-effective production of parts from crosslinking materials that are ready for automation.

4 Temperature regulation – a key to a process-reliable production

For the processing of crosslinking materials, temperature regulation has frequently been carried out using oil, electric heating rods or pressed-in heating coils. These allow for temperature regulation at a high level. For example for rubber a mould surface temperature between 160 and 180 °C is needed in order to ensure a controlled crosslinking process.

As the melt quickly reaches the crosslinking temperature when a gate system is used for filling the mould, premature scorching may easily occur close to the gate. These defective areas will then flake off and move during the filling process and may thus lead to visible inhomogeneities influencing the part’s strength. If the mould surface temperature in the contour area would (depending on the cycle) be reduced by approximately 20 °C during filling, scorching would not yet occur.

The same influence on the temperature of the mould surface could also affect the timing of the lowest viscosity and thus influence on the one hand the crosslinking profile and on the other hand the resulting overflow.

The homogeneity of crosslinking in several cavities could be better controlled using a temperature regulation that is close to the contour (e.g., using diffusion-welding, see fig. 5). Since electric or oil temperature control are much too sluggish they are not suitable for a cycle-dependent temperature regulation. As the viscosity of oil is much higher in comparison to water, a small-scale temperature control close to the contour is hardly feasible. Additionally, working with hot oil is both dangerous and environmentally unfriendly.

A state-of-the-art water temperature control unit would thus be a reasonable decision. Currently, static water temperature regulation is possible up to 220 °C. Many cycle-dependent temperature control devices are already available by numerous manufacturers for up to 180 °C. Project concepts based on the Isoform technology and which have a short distance from the temperature control unit to the tool allow even a cycle-dependent temperature regulation for crosslinking materials.

Temperature regulation close to the contour may already be very homogeneous with a static water temperature control over many cavities. Long heating times and preheating
stations will thus be history – at least when using the IsoForm technology. State-of-the-art water temperature regulation systems thus allow for considerably increased process reliability, especially if combined with other technologies mentioned here.

It is very important that the rules for liquid flows are observed (fig. 6, 7). This means, for example, that neither baffle plates, sputters, nor other flow brakes are used in the tool. This also applies to connections between the temperature control unit and the tool. The popular water stop fitting in the coupling is usually a bad decision as it again impedes the flow and causes sometimes a high pressure loss. If a turbulent temperature regulation in the contour area can no longer be achieved due to these unnecessary flow impediments, then the effect of temperature regulation can rapidly be reduced by 90 %.

In order to ensure a really homogeneous energy input for the crosslinking process a temperature regulation close to the contour is required. Usually, specially inoculated water will be used as pure water becomes very aggressive at temperatures above 100 °C. To prevent that water changes to the gaseous state of matter at temperatures above 100 °C, pressure must be applied to the system which again leads to higher demands on the tubing and connection technology. At 120 °C, the required pressure is 1 bar, at 160 °C it is 5 bar and at 225 °C even 30 bar are needed. Closed systems with a tank for the inoculated water connected to the temperature control unit have done that trick in the past.

For water temperatures above 100 °C, special attention should be paid to the seals used in the temperature control system. Seals that have proven effective for oil at high temperatures will fail at water temperatures of more than 100 °C. It makes sense to consult seal suppliers for recommendations and to request test certificates from laboratories that tested the seal with inoculated water under the required conditions. As you can see, many aspects have to be considered. Nevertheless, many companies take this course in order to make use of the advantages water has to offer compared to heat transfer oil (a factor of 5 - 8 regarding the heat transfer properties) for a more economic and reliable production.

5 Reducing the energy demand for crosslinking: isolated mould inserts

Depending on the mould size, it may take over an hour to heat a complete mould for producing parts of crosslinking materials to a target temperature of for instance 160 °C. During start-up, many parts may already have been rejected before a homogeneous temperature profile is reached for production. It quickly becomes obvious that this procedure does not reflect process-reliability or up-to-date automation processes.

Some people might say it’s good that this field does not offer optimum possibilities for automation and that production requires the constant skills and intuition of a few adepts. However, if we consider demographic

Fig. 5: Mould insert produced by diffusion welding (source: KB Hein)

Fig. 6: Illustration of pressure loss due to redirection of heating/cooling channels (source: KB Hein)

Fig. 7: Mounted HeiNo-element for redirection of heating/cooling channels to overcome pressure loss (source: KB Hein)
changes, early retirement programs and the many open trainee and apprenticeship positions it becomes clear that companies that do not start with automation in time will be at risk tomorrow.

Therefore, we need robust processes that quickly and reproducibly render high-quality parts without a long start-up phase.

In order that the temperature control acts only where high temperature for crosslinking is required, the mould structure in IsoForm tools is isolated from the contour-forming inserts. Thus, the steel volume that will be thermally affected is considerably smaller than with standard tools. The main isolation takes place within the tool and not around it. IsoForm is suitable for any conventional temperature control system, as electric heating and systems using oil (fig. 8).

Due to the isolation of the temperature-controlled contour area IsoForm tools offer an improved basis for any application using elastomers, thermoplastics, thermosets, die casting and multiple-component applications.

Cycle-dependent temperature regulation requires a control system close to the contour that preferably only controls the temperature of small masses (mould contour areas) (fig. 9).

The proprietary tool concept IsoForm is nowadays very popular – especially for production – mainly because of the many advantages of significantly higher process reliability.

5.1 Implementation with IsoForm tools

The individual concept for standard elements that goes with the IsoForm tool concept renders a wide range of constellations possible: from one cavity in an isolated mould insert to many small cavities in one or numerous mould inserts with specific solutions for sliders and ejection.

The applicability might be specific, but the thermal isolation from the surrounding tool and the consistent hub-centring remain unaffected. For the mould inserts, insulating centring elements are used while hub-centred lugs are used on the outside of the tool.

The innovative design of the ejection frame results in maximum support of the intermediate plate as well as of the mould plate and thus considerably reduces deflection. An unwanted flash or overflow formation (skin) due to premature ageing and deflection in the tool is therefore mostly history.

5.2 IsoForm tool change systems

Certainly, multiple use also offers an interesting perspective for the current trend to model diversity with small quantities. For certain sizes/variants with sliders or lifters only one standard mould structure is required for several applications. The IsoForm program includes variations of standard elements for multiple use, in which the inserts may be exchanged from the separation
level, or entire mould plates including their corresponding ejector system are exchanged (fig. 10, 11).

These inserts benefit from the precise IsoForm centring, are always thermally separated, and can be exchanged in a simple and quick manner. There is also a significant time advantage if mould inserts for an existing exchangeable principal mould are manufactured using generative technology.

Universal thermally separated tool changing systems allow quick change of individual applications on injection moulding machines either manually or by a robot. The advantages are convincing: always at optimal temperature and thermally separated, feasible with sliders and lifters. The principal tool is often included within the investment of the machine resulting in lower costs for the isolated contour-forming exchangeable inserts. The system is reliable and ready for automation.

6 Outlook

The shortage of resources, the declining population in some areas (currently particularly in Europe), global climate change and an anticipated increase in energy costs are all huge challenges that will force us to rethink in many areas. If in the years to come we intend to maintain the current productivity with a smaller workforce, then automation is unavoidable in all areas for reasons of sustainability. Moulds for crosslinking materials, injection moulding tools, die-casting moulds and forming tools need to meet these requirements as automation in plastics processing will only be possible in the long run if mould tools can be automated in such a way that both retooling and start-up at the machine can be carried out process-reliably. In case the mould tools need to be utilized after a few years, then this should be taken into account already in the current design. The constantly increasing demand for products made of plastics allows and requires a reasonable investment in a future in which we use our natural resources for the production of sustainable products instead of pushing them through the chimney or the exhaust.

“Europe Rubber Processing Education Week” preview

TechnoBiz Europe is organising the third edition of the Europe Rubber Processing Education Week, which will take place from 7 – 11 November 2016 at the H10 Marina Hotel in Barcelona, Spain. During this event, five educational training courses will be held in English language by well-known and experienced specialists in the field of rubber processing.

The following courses – aimed at engineers and managers – will be offered:

• 7 – 8 November 2016, "Rubber Compounding: Principles & Formulation Development", instructor: Dr. Hans-Joachim Graf
• 9 November 2016, "Rubber Mixing Plant – Design & Layout", instructor: Bruno Milanese
• 10 November 2016, "Rubber Injection Molding", instructor: Dr. Hans-Joachim Graf
• 11 November 2015, "Adhesion of Rubber", instructor: Dr. Hans-Joachim Graf

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Call for Papers: Europe Rubber Industry Forum – ERIF 2017

TechnoBiz Europe has issued a “Call for Papers” for the third Europe Rubber Industry Forum – ERIF, which will be held from 9 – 10 May 2017 at the Gartenhotel Altmannsdorf in Vienna, Austria. The theme of this event will be “All about Rubber Compounding”. The conference language is English. The organiser is inviting prospective presenters to submit an abstract on latest technological developments in the area of rubber compounding. Focused topics are:

• Advancements in raw materials and additives
• Rubber mixing plant and effect on compounds
• Rubber compounds for upcoming regulations and specifications