# "You Can See What Is Happening in the Mold"

## *Interview with Eberhard Duffner and Paul F. Filz by the Magazine* ***Kunststoffe***

The 2019 K fair focused on the fusion of digital methods with analog production processes. At the fair, Arburg and Simcon showcased a filling process proceeding in real-time, as a 3D animation, on the display of a machine control panel, for an example of sunglasses, made of PA12. All that was needed to prepare this, was to load the simulation model, as well as the geometry of the part, directly onto the machine controls. This sounds almost too easy to be true. Right?

The dream of using simulation results directly on injection molding machines has been around for decades – and has always interested Eberhard Duffner. He had already been head of development at Arburg and head of the advisory board of the injection molding section at the Institute for Plastics Processing (IKV) in Aachen, Germany, for some time, when he had a remarkable experience: "I asked, who is using simulation, and all hands went up in the circle of machine manufacturers. I then asked, who has tried to transfer these simulation results directly into basic machine settings – and this time, those same hands stayed down. I was surprised." So: how is it possible, that, in this day and age of digitization, injection molding machines still know so little about the mold and the part? "Somehow", Duffner thought, "it should be possible to take scientific insights from the IKV advisory board and apply them at Arburg. We discussed these ideas a lot: is it possible, today? How can we do it? These questions marked the beginning of the collaboration between Arburg and the simulation software experts at Simcon.

***Kunststoffe:*** *Mr. Duffner, Arburg and Simcon showcased a filling simulation, directly implemented on an injection molding machine, at the K show in 2019. What's the main idea underpinning this solution?*
**Duffner**: First, we want to simplify the job for machine setters. They should not have to analyze curves to get optimal mold filling. The fact that set curves don't directly translate to the real process is something I also experience during trials, and in the production of molded parts in our customer center. Our goal is that the setter need not observe the screw stroke or the pressure profile over time. Instead, we want to visualize the filling process in 3D on the machine, and show how it changes, depending on the parameters. This means you need to have a simulation on the machine. And that is the first stage of the filling assistant, which we have implemented from the simulation.

***Kunststoffe:*** *And what's next?*
**Duffner:** Next, we want to focus on helping our users to solve quality issues. In order to do that, we need to demonstrate the process fluctuation in a modern, interactive, three-dimensional visualization. In this way, the machine setter can see what is happening inside the machine, without needing to interpret an abstract scientific curve. That is the challenge.

***Kunststoffe:*** *Mr. Filz, that sounds like it makes sense. Why is there still a gap between product development and production in injection molding?*
**Filz**: Mainly for historical reasons: in simulation, people have typically thought in terms of physical process variables of the melt, like the volumetric flow rate, filling times, or packing pressures. But injection molding machines are set up with different kinds of parameters, like screw advance speeds, screw strokes, changeover points and so on. These approaches basically achieve the same thing, but it is not easy to convert into one another. So, in a nutshell, things get lost in translation between engineering and production.

***Kunststoffe:*** *What would you estimate: what share of companies use a filling simulation nowadays, when they are designing molds?*
**Filz**: We estimate that about 25 percent of companies use simulation systematically during product development. In those »

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## About the Interviewees

**Dr. Eberhard Duffner** (64, right) studied physics at the University of Tübingen, Germany, and received his PhD in 1986 with a thesis on the global quantum dynamics of multi-lattice systems with non-linear classical effects. Directly afterwards he started working for Arburg GmbH + Co KG, Lossburg, Germany. Initially, he worked in software development. In 1990 he assumed his current position as head of the development department.

**Dr. Paul F. Filz** (62, left) studied mechanical engineering at the RWTH Aachen University, Germany. In 1988 he completed his doctoral thesis at the IKV with the title "New developments for the simulation of injection molding processes with thermoplastics". In the same year Filz became managing director of Simcon kunststofftechnische Software GmbH, Würselen, Germany.

25 percent, I'm counting the companies who actually simulate in-house, not companies that only order a simulation as an external service every once in a while, when they have a particularly complex part.

***Kunststoffe:*** *Considering those numbers: isn't integrating the filling assistant like taking the second step before the first?*
**Filz**: No, certainly not. We want to make results from engineering easily accessible to the injection molding machine user, to help close that gap between production and engineering. Production practitioners often claim that real-life results don't match what engineering has sent them. And it's easy to see why: something about the mold was modified in the interim, or a process is run differently from what was anticipated in engineering – usually, for good reasons. So, there is a disconnect between the engineering plans and the practical implementation. That's why it makes sense to take a more integrated approach, with a filling assistant that's right there, on the machine. Because that way, you can better ensure that those two things match.

***Kunststoffe:*** *So you would prefer there to be feedback loops with reality?*
**Filz**: Yes, clearly, we want that matching to happen. In many cases, people on the front lines aren't feeding those real-life observations back to engineering. This of course makes it difficult to see how well the results were realized on the injection molding machine. When people observe how well reality and the simulation results correspond if the settings match, the benefit becomes clearer. And this will continue to increase adoption of using simulation as a tool. As a result, we will eventually go way beyond the 25 percent usage rate that I just mentioned. There is still an incredible amount of untapped potential out there, and this is something that really helps customers realize and capture that value.

> *"We use the significant parameters from the simulation, as presets for the machine."*
>
> Dr. Eberhard Duffner

***Kunststoffe:*** *How are the on-screen animations linked to the real processes on the machine?*
**Duffner**: You can see in real time what is currently happening in the mold, as a live filling image displayed on the machine control screen. To bring these two things together, we compute a simulation model, which is parameterized and fully integrated into the Gestica control. The animations are then shown, synchronized with the injection process on the machine. Not only that, we also use parameters from the simulation, such as dosing volume, temperatures and pressures, as presets for the machine. On the screen, the mold filling then does not simply run linearly over the screw path, but is also linked to the compressibility of the melt and the closing behavior of the non-return valve.

***Kunststoffe:*** *That is, you could also use the screen to better understand partial filling behavior?*
**Duffner**: Yes, if we stop the injection process at a certain point, say 90 or 95 percent for a filling study, then the part from the machine should look like the simulation results displayed in the filling assistant, with a certain accuracy. That is the first function that we've integrated: a regular sample filling study. As of today, this may not yet be precise enough for all classes of molds. But it works well with the kinds of molds with which we have already tested it. We need to address this openly – otherwise we cannot win the acceptance of the machine setters.

***Kunststoffe:*** *Which kinds of tools or geometries have been left out, for the time being?*

**Duffner**: We are quite comfortable with a mold with a cold runner gate and a certain number of cavities. I wouldn't put a 96-cavity screw cap mold in this category, because the hot runner volume is three times the shot weight, and compressibility has a massive effect.

**Filz**: Such multiple-cavity molds involve considerations that are not yet tackled in the simulations. A very large hot runner with lots of branches, for example, has a life of its own in terms of how it is controlled, and that is not yet taken into account by the simulation. The simulation assumes some standard conditions. But as long as those basic requirements are met, you can reliably use simulations of the type that will be available on the Arburg machine, for both simple and more complex components.

***Kunststoffe:*** *What about materials?*

**Filz**: Here, too, at this time there are still some restrictions, as we have not yet been able to test everything down to the last detail in the short time before the K show. We are now doing this step by step, so that we will have comprehensive coverage for the filling assistant.

***Kunststoffe:*** *What does the interface between machine and simulation look like?*

**Filz**: One advantage of simulations is, that there is basically only one variant. If, for example, we were to specify an injection volume flow profile as a bar, it would work wonderfully, because there would be no mass and no control valves that needed to be regulated in some way. What is a bigger challenge, is for Arburg to take the information from the simulation, and translate them so that they are implemented physically on the actual machine.

**Duffner**: We complement each other and of course we have to create translations between several different software interfaces. For example, let's say you've got a flow rate profile with a few discrete jumps. But the machine can't do discrete jumps, and may not be able to achieve the targeted maximum speed. In such cases, we compute normalized profiles, for example by adjusting the total injection time, to translate it into something that is feasible in practice, on the machine. But that's not all: we have to transfer the model to the respective machine with its specific gear and configuration, i.e. implement it in the real physical environment. This changes the model, possibly impacting quality, and you have to take a step back in the model creation process. So, this is a recursive process – and a lot of hard work.

***Kunststoffe:*** *Mr. Duffner, you said earlier that you transfer some parameters from the simulation into the process. Which parameters are those?*

**Duffner**: With Arburg, development is based on the principle "machine knows part" – i.e. it knows itself and its special equipment, and it knows the molded part. The machine gets its 3D geometry from the filling simulation, so it knows the shot volume and can calculate the metering volume, taking into account the screw speed, the pvT curve and the nonreturn valve parameters. For certain materials, we have stored settings that can be obtained through the material selection. And we have a clear philosophy for the changeover point, which is set at 98 percent filling. »

**Filz**: Arburg takes all of the results from a regular simulation, such as temperature settings for the melt or the injection volume flow profile, and converts them into what the machine needs. It's really a symbiosis of what we can do in the simulation and what Arburg are able to do with their know-how, to influence the behavior of the machine so that realizes the optimal simulation results.

***Kunststoffe:*** *The original focus of simulation is actually to calculate shrinkage and warpage, right?*
**Duffner**: Yes, that has been in focus. And we will also take this aspect into account in the future, in order to optimize the parameters for this. But right now, we're prioritizing other aspects. If you want to support a machine setter efficiently, you've got to focus different things than when you are supporting the part designer who uses simulations for tool design. Today, it still takes too long to calculate the full simulation inline on the machine itself. Solving this requires close cooperation, understanding from both sides and a willingness to constructively deal with failures along the way. Because it's less useful if you've got time to go get a coffee while the machine is running the calculations for a simulation model. Our goal is for the 3D representation to run in real-time.

## Project CoSiMa

In addition to collaborating on the filling assistant, Arburg and Simcon are involved in a project funded by the German Federal Ministry of Education and Research (BMBF). The aim of the research project "Connecting simulation and machine to optimize the production process of injection molded parts – CoSiMa" is to realize seamless communication between process simulation and injection molding machines. The coordination of the cooperation is in the hands of the Institute for Plastics Processing (IKV) at the RWTH Aachen University.
Together with an international consortium of German and Slovenian companies, as well as the Slovenian research cluster Tecos (Slovenian Tool and Die Development Centre), they are developing a function that transfers simulation-based setting data directly to the injection molding machine. With the help of an MES as a mediator between simulation and machine, it should also be possible to support the operator at the machine in the adjustment process by providing the simulation results of a relevant process window.
Other participants besides the companies mentioned above are GRP, Kolektor and Tehnomat.

***Kunststoffe:*** *What do you think: will your customers embrace the filling assistant?*
**Duffner**: The filling assistant is an essential tool for sampling, for the mold designer – provided that the results are reliable, and the machine setter can trust their accuracy. This is our first priority. Of course, this what we believe. For example, let's take a technical part with leaps in wall thickness. In order to fill this part with a constant flow front speed, as theory would suggest, you've got to accelerate at thicker points and reduce speed at thinner ones. Up to now this has been a black box for the setter. With the filling assistant, on the other hand, they can see exactly when a jump is coming, and can respond accordingly. Running a simulation gives you mathematically rigorous results, based on the geometry of the part and the volume flow profile. The setter doesn't need to guess anymore.
**Filz**: Above all, you need to eliminate transfer errors, which happen because things are lost in translation between engineering and the machine operator. If the operator obtains the basic settings in an automated way, that helps. Efficiency automatically increases, because setup times are reduced, and typical ambiguities and translation errors can be avoided. It's like having a car navigation that considers traffic jams and thus avoids unnecessary stress. This makes it much less likely that the machine setter will be woken up by a WhatsApp in the middle of the night because a machine is at a standstill.

***Kunststoffe:*** *In your developments, are you thinking in the direction of machine intelligence?*
**Duffner**: I would say, let's see. It's conceivable, for example, that the system realizes that it has processed a part with a similar geometry before. And then it remembers that last time, the setter ran the process with parameters that are different from the values that the simulation suggested. That would be a learning process, something like machine intelligence – a first stage, at least. But we're not there yet. Current research projects, such as CoSiMa (**see Box**, editor's note), are moving in this direction.

***Kunststoffe:*** *What is your next ambition?*
**Duffner**: We are aiming towards data transfer, i.e. that we deliver scientifically optimized machine setting parameters inline, based on a computational model. This is the next big step that we're working on. We have a lot planned! ■

***Interview: Dr. Clemens Doriat, Editor***