Automated bearing and prechamber optimization based on simulation

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Extrusion of aluminium profiles is one of the most common and efficient technological processes in metal forming. Currently, there is a wide range of difficulty levels of extruded profiles: from simple solid forms to complex hollow shapes for automotive, railway and other industries. Even complex tools have to be designed in a short time. In this case decisions are made based on the experience of the designer. In some companies, specialized design assistance tools developed internally are employed, too. QuantorForm now offers an integrated solution, which combines a design system for extrusion dies (QExDD) and a powerful finite element package for extrusion (QForm Extrusion) with an automated optimization procedure.

QForm Extrusion

In the meantime, the ever-growing power of workstation computers allows companies to effectively use FEM-based simulation, namely QForm Extrusion, during the tool designing process. QForm Extrusion is the only program specialized on profile extrusion that can perform simulations of material flow with thermal and mechanical coupling of the tool deformation – even for very complicated thin-walled profiles. Having this simulation tool, the typical designing process is presented as follows: 2D and/or 3D designing using any CAD system, then mesh generation and simulation in QForm Extrusion. Thus, the last two steps (Fig. 1) are performed in cycle until acceptable results are achieved.

However, using non-specialized CAD systems, the process of adjustment of the tool design requires advanced skills in 3D designing, as well as simulation results interpretation. This can be made easier with a software that has an advanced interface with the simulation engine and which allows to automate routine actions, simplify the modification process and finally speed up the designing stage itself. Such software is QForm Extrusion Die Designer (QExDD).

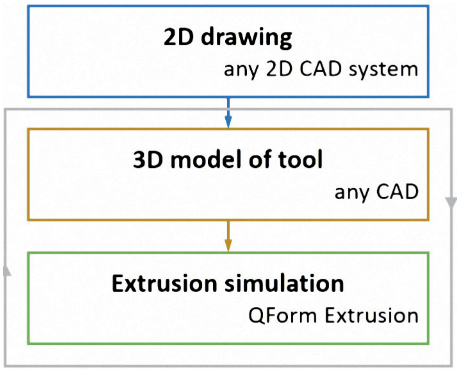

Fig. 1: Design flow for extrusion tools

QForm Extrusion Die Designer

QExDD is an automated system for 3D creation of dies, mandrels and other parts of the tooling set for extrusion of aluminium profiles. This system helps create the 3D model of a tooling set step-by-step using special parametric design tools. The user controls the design process by specifying the geometry and basic dimensions of the model. This automated design process is several times faster than conventional die design. Since the routine part of the work is automated by the software, the user can concentrate his attention on more important tasks.

QForm Extrusion Die Designer provides the highest quality 3D models that can be used for simulation, particularly in QForm Extrusion. If the simulation shows some problems with the material flow, then any kind of alteration of the die design can be easily implemented in the die model and re-simulated. This makes the simulation and analysis of a designed die set much faster and more effective. Such effect is even more accelerated with help of in-built optimizers for bearings and prechamber (Fig. 2).

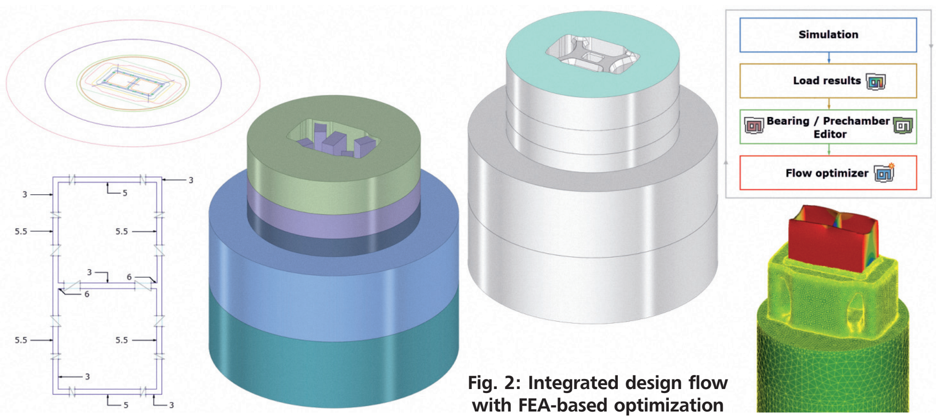

Fig. 2: Integrated design flow with FEA-based optimization

Prechamber and bearings

The prechamber is a part of the die plate which is located right before the metal entering the calibration zone of the tool. It controls and balances the profile flow by varying the distance between the bearing entry edge and the prechamber wall. Thus, this distance can be made shorter in case of locally slow flow and longer in the opposite situation.

The bearing is one of the most important parts of the tooling set designed on both, die plate and mandrel, in case of a hollow profile and only on the die plate in case of solid profile. The quality of the bearing surface defines the quality of the profile surface. It is possible to vary the height of the bearing along the profile contour in order to balance the flow. So, the idea is to make longer bearings in the areas where there is a need to slow down the profile and shorter bearings in the areas where the velocity should be increased.

Both described components of the die set have some limitations in influencing the profile flow. In some cases, there is no chance to eliminate the imbalance of flow in case of poorly designed tools by varying bearing heights or prechamber shape. This is because bearings should not be too short to ensure required tool life. On the other hand, they should not be too long, since they have an effective length that depends on the tool deformation in practical conditions. Therefore, the bearings practically only affect the flow within some limits. Same applies to the prechamber: its contour is limited by the welding chamber contour from one side and by the profile contour from the other side. However, considering the existing experience and knowledge of companies involved in die design, both prechamber and bearings play a significant role in the tool adjustment.

Optimization

One of the goals of tool design as well as the goal of optimization is a balanced profile flow. Quantitatively, the goal of optimization is the minimum of profile velocity deviation (*VD*), where

$$VD = \frac{V_i - V_a}{V_a} \cdot 100\%$$

V_i – velocity of a particular point (node) of the profile and
V_a – average profile velocity.

Positive value of deviation indicates areas of the profile with higher-than-average velocity and negative value indicates the opposite. Therefore, the goal is to get a velocity deviation as close as possible to zero along the whole profile contour.

Another similar parameter that may define profile imbalance is relative velocity of profile, where

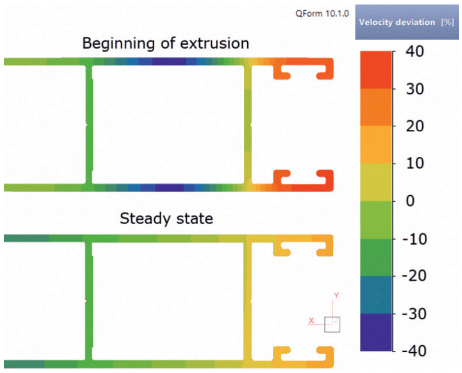

Fig. 3: Velocity deviation at the beginning of the extrusion process and at steady-state-condition

$$VR = \frac{V_i}{V_a}$$

So, values over 1 indicate areas of the profile with higher-than-average velocity and values below 1 indicate opposite. The goal of optimization in this case is to make relative velocity equal to 1.

It is well known that the initial profile flow right at the beginning of the extrusion process is usually quite different compared with the flow trend at steady-state velocity conditions. For example, the velocity distribution at the beginning of the real extrusion process or simulation sees no relative impact of slow profile areas on fast ones and vice versa. Meanwhile, at steady conditions the flow trend is much clearer and defines the main vision on what can be improved in the design (Fig. 3).

On the other hand, elimination of flow imbalance at the beginning of the process at certain conditions ensures uniform flow further. Moreover, by eliminating the initial imbalance of the profile flow we guarantee the minimization of risks to have any contact of profile front end with the tools and consequent possible problems. Therefore, the final idea is to minimize *VD* and *VR* at the very beginning of the process. To achieve this there are two basic types of optimization approaches that might be applied to the design within the mentioned combination of QExDD and QForm Extrusion: subsequent and batch optimization.

Subsequent optimization

Subsequent optimization is generally used when there is the requirement to make sure

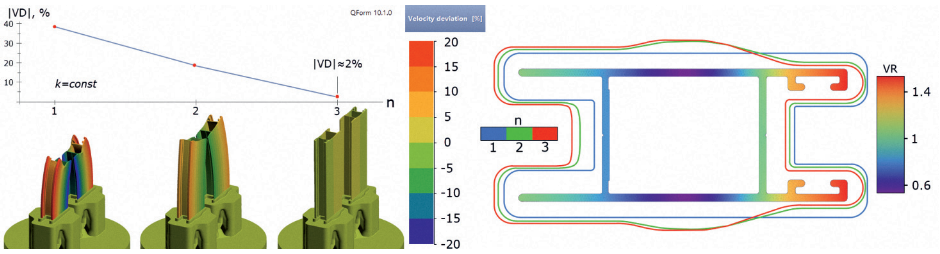

Fig. 4: Automatic prechamber optimization for balanced profile flow

that each new simulation leads to improvement in the design in terms of profile flow. This approach is reasonable for complex and/or very demanding designs or when there are no tough deadlines to finish the design work. In this case the same coefficient of the correction formula (k) is subsequently applied to the new prototype of initial design (n) until convergence. Thus, such kind of optimization allows to subsequently get closer to the minimum of velocity deviation (Fig. 4) by automated changing of the prechamber contour step by step in an easy-to-understand way: making prechamber greater where the flow is slower than average and smaller where the flow is faster than average.

The same approach can be applied to the bearings where the variable parameter is the bearing height along the profile contour. As well as for the prechamber, in this case subsequent optimization allows to step by step get closer to the required result in terms of profile flow.

Batch optimization

The idea of batch optimization is to find an optimal design by varying the coefficient of the correction formula (k). In this case there is a possibility to create a number of new designs with different coefficients based on simulation results achieved using the initially created tool. Such approach allows to run plenty of simulations simultaneously in parallel thereby speeding up the optimization process and shortening total designing time. However, the computational power needed for this procedure is significantly higher than in the subsequent optimization approach.

Once the simulations are performed, the goal is to find the best coefficient of the correction formula, so the best design with the minimized velocity deviation can be chosen (Fig. 5).

Such kind optimization is a good starting point within the global optimization process with the aim to find an optimum coefficient for the initial design. If acceptable flow results cannot be found, the results can be used for further optimization using combined type.

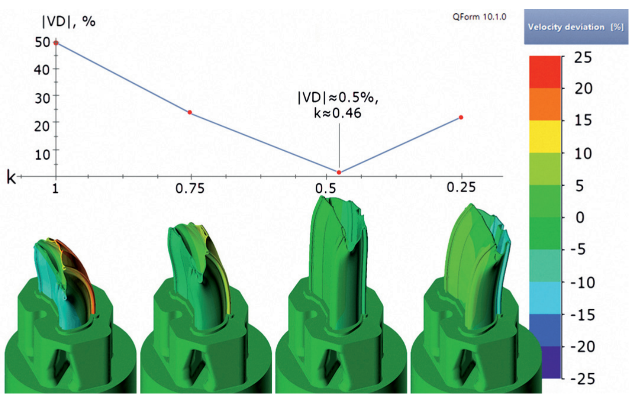

Fig. 5: Finding the best solution in batch optimization approach

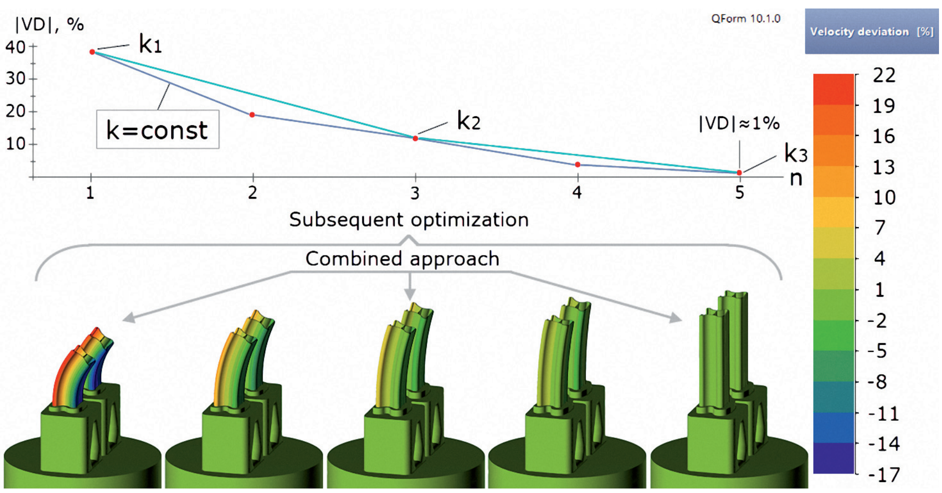

Fig. 6: Comparison of subsequent optimization and combined approach

Combined approach

The combined approach combines the advantages of the two mentioned types of optimization approaches available in QExDD. Thus, based on simulation results calculated with an initial 3D design, a new batch of different designs can be generated, from where the best one is the basis for the next iteration. Such an approach allows to obtain good results in a most effective way, since it considers the best optimization coefficient for each particular iteration. This leads to much faster convergence compared with just subsequent optimization especially for complex designs (Fig. 6).

Summary

Nowadays, the development of extrusion technology of aluminium profiles involves the use of special FEM-based software for technology and tool design. For extrusion simulation it is necessary to create a 3D model of the tooling set containing several components with not always trivial shapes. This requires advanced skills in 3D designing, basic knowledge of FE analysis of the extrusion process and deep understanding of simulation results. The presented combination of QExDD and QForm Extrusion including an optimizing tool supports the design process greatly with an additional bonus of increased reliability of the designed technology. This leads to minimization of design iterations and speeds up the process within one iteration. Finally, it allows to get high quality 3D models in an automated way using an in-built metal flow optimizer. Furthermore, the two types of optimization contribute to time savings when designing complex shapes. With this advanced method, a profile flow quality can be achieved which would be impossible (for cost and time) with real-life tool and extrusion trials. The cost invested in simulation (license, training, computer) will be amortized quickly by savings of hardware cost (tools and trial material) and of trial time on the extrusion press.

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