From digital die design to a shared process digital twin: QForm UK Extrusion and ExtrusionLink™ for smart collaboration between die makers and extruders

Paul Mordvintsev, Ivan Kulakov
QForm Group, www.qform3d.com, market@qform3d.com

Keywords: aluminium extrusion, digital twin, QForm, die design, process simulation, ExtrusionLink, virtual trials

Aluminium profile production is increasingly driven by the need to shorten die development cycles, reduce trial extrusions and scrap, and verify process feasibility and predict product properties before the first industrial run. During the last several software generations, QForm UK Extrusion has evolved from a numerical verification tool for an already designed die into an integrated environment [1] that links die design, transient extrusion analysis, defect prediction, quenching and final-property assessment (Fig. 1). The next step is not only technical but also organisational: the same validated numerical model can become a process digital twin that is shared with controlled access between the die maker and the extruder. ExtrusionLink™ implements this concept in QForm UK Extrusion, allowing the extruder to receive a reusable process model while the die maker can protect proprietary CAD data. The model can then be used for virtual production trials under the actual plant conditions and for feedback to the die maker before physical tooling corrections are required. The model is no longer a one-off verification file: it becomes a reusable information carrier shared across die design, production and profile quality assessment.

DIE DESIGN	DIE + PROCESS	FULL BILLET	PROFILE QUALITY	EXTRUSIONLINK
QExDD parametric die model Bearings + prechamber flow optimisation	Coupled tool deformation Flow / temperature Seam & charge welds	Transient Temperature Skin contamination Waving / scrap	Quenching Distortion Mechanical properties	Flexible model Exchange Extruder virtual trials Two-way feedback

Fig. 1. Development of QForm UK Extrusion from die verification towards a reusable process digital twin.

This work summarizes the technical developments that make this workflow practical and presents ExtrusionLink as a framework for collaboration between die makers and extrusion plants. The concept connects automated die preparation and optimisation in QExDD, coupled simulation of the die and material flow, whole-billet transient analysis, prediction of billet-skin and welding-related defects, deformed-contour assessment, quenching simulation and mechanical-property prediction. Instead of repeating model preparation at each stage of the supply chain, a single validated digital model is created once and then used by the parties that need to make engineering decisions.

Technical evolution: from die geometry to the complete extrusion cycle

The first stage of the workflow is die design. QForm Extrusion Die Designer (QExDD) provides parametric die generation and automated geometry preparation, while the flow-optimisation tools allow bearing lengths and prechamber contours to be adjusted before manufacturing (Fig. 2). The resulting geometry is verified in QForm UK Extrusion by analysing material flow, profile distortion, temperature, tool stress and deformation. This makes die optimisation a simulation-driven process rather than a sequence of physical corrections after the tool has already been produced [1,3].

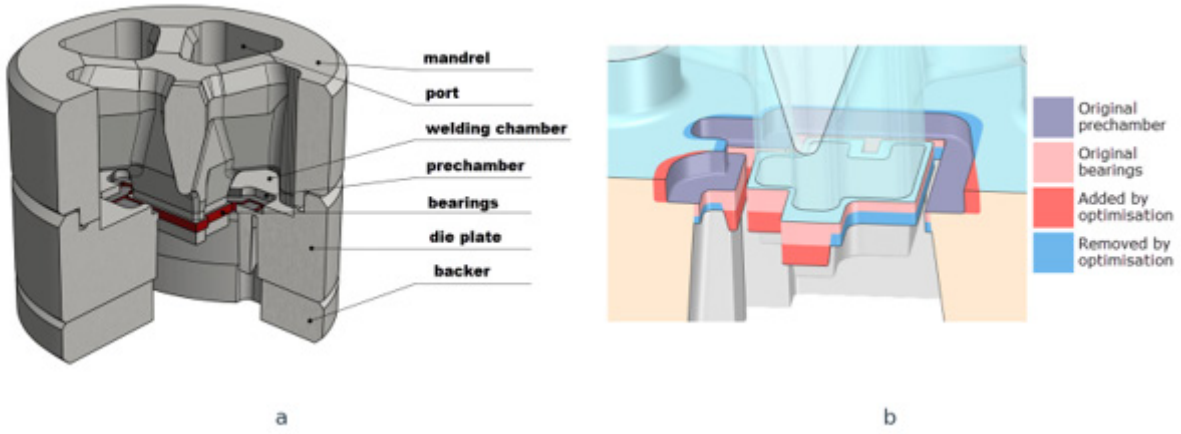
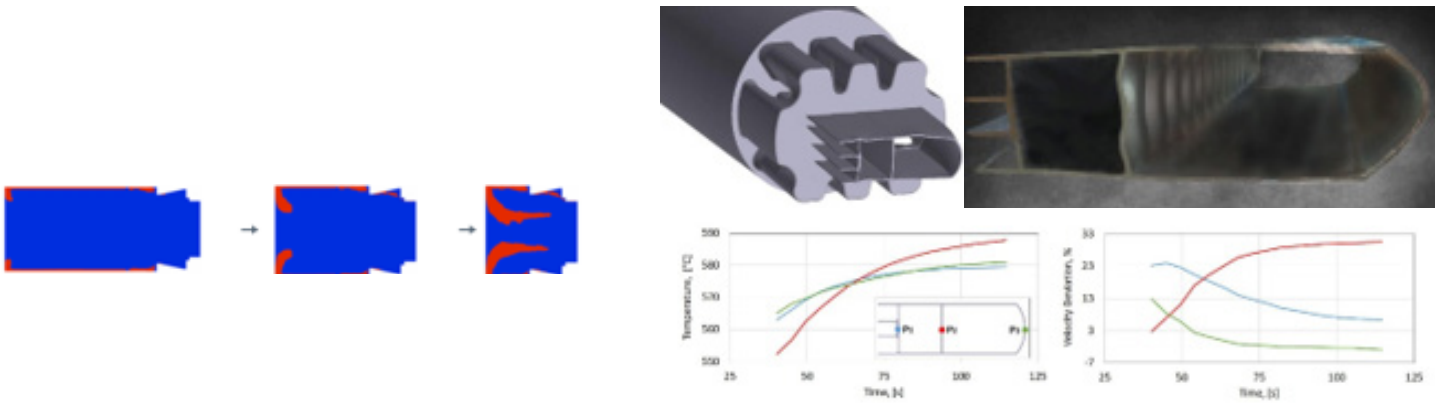


Fig. 2. Examples of QExDD die construction (a) and simulation driven prechamber/bearing optimization (b).

The scope of simulation has subsequently expanded beyond the initial steady-state flow. Full-billet calculations are essential when the defect mechanism depends on the evolution of temperature and flow during the whole extrusion process. Studies of waving [4] show that a profile can remain well balanced at the beginning of extrusion and become unstable later because local heat generation accelerates selected parts of the section (Fig. 3). Similar full-cycle simulation is required for billet-skin contamination and back-end defects [2], where the critical question is not only whether contaminated material can enter the profile, but at what ram position this occurs and therefore what discard length is required.



Tracked billet surface layer (red) progressively enters the profile; its onset position defines the required scrap length

a

Local heating changes the flow balance during the billet stroke, creating a late-cycle velocity deviation that can initiate waving

b

Fig. 3. Full billet analysis:(a) progressive billet-skin propagation and (b) transient temperature/velocity evolution associated with waving, adapted from [2,4].

Quality indicators available inside the digital twin

The current extrusion model can carry substantially more engineering information than a conventional die report. In addition to velocity deviation and front-end shape, the model can be used to assess longitudinal seam-weld location and quality, charge-weld propagation, billet-skin inflow, profile temperature, die deformation, tool-life indicators and dimensional changes of the profile [1,2,5]. Recent software development has also strengthened multi-profile analysis, charge-weld evaluation for individual profiles and deformed contour analysis [7]. These functions convert simulation results into quantities that can be discussed directly between a die maker and an extruder rather than interpreted only by an FEA specialist.

Stage	Digital-twin information	Engineering decision
Die design	Geometry, flow balance, tool deformation	Bearings, prechamber, ports, tool strength
Full billet extrusion	Temperature/velocity evolution, skin flow, charge weld	Productivity, taper heating, billet length, scrap
Profile quality	Seam welds quality, distortion, streaking lines, dimensional change	Acceptance criteria and die/process correction
Quenching	Cooling history, bending/twisting, strength/hardness, microstructure	Spray/air strategy and final properties

ExtrusionLink: secure collaboration between die maker and extruder

In the traditional workflow, a die maker may deliver a die together with a report, while the extruder receives only the final design and must perform industrial trials under plant specific conditions. This separation creates a gap: the die maker cannot anticipate every combination of billet temperature, extrusion speed, container temperature, alloy condition or discard policy, while the extruder usually does not have access to the original die CAD model needed to rebuild an accurate simulation. ExtrusionLink closes this gap by transferring the prepared numerical process model itself.

QForm provides the technical basis for protected yet flexible exchange of process digital twins. Depending on the cooperation model, the die maker may transfer a full project with geometry, a project with limited geometry access, or a viewer-oriented results package. The key principle is that the validated numerical model, process parameters and quality indicators can be reused by the extruder without rebuilding the project from scratch, while the level of geometry access is agreed between both sides (Fig. 4).

DIE MAKER	SHARED PROCESS DIGITAL TWIN	EXTRUDER
QExDD / CAD die design	QForm project / viewer package	Virtual production trials
Flow balancing	Process parameters + model	Productivity / billet temperature
Tool stress and life	Simulation results + quality indicators	Full billet analysis
Digital certification by accurate process twin	Geometry access defined by cooperation level	Skin, welds, waving, scrap Quenching and properties

Die model and results ⇄ Shared digital twin ⇄ Plant specific virtual analysis

END CUSTOMER

Receives profile quality information: dimensional accuracy, mechanical properties and process traceability

Fig. 4. Proposed ExtrusionLink workflow and two-way engineering analysis between die maker and extruder.

At the die-maker side, the model is created and verified using the nominal die geometry and recommended process parameters. At the extruder side, the same digital twin can be reused for virtual production trials under actual plant conditions. The extruder can investigate speed windows, billet-temperature strategy, taper heating, whole-billet behaviour, expected process scrap, weld quality and quenching settings without rebuilding the model from the beginning. If an unacceptable result is found, the outcome becomes a precise engineering feedback package: both sides can analyse the same case, identify the responsible condition and agree on die or process corrections before manufacturing.

Three levels of data exchange

The concept can be introduced progressively. At the entry level, the extruder receives results and uses QForm Viewer for detailed analysis without running new simulations. At the medium level, the extruder receives a simulation project without accessible CAD geometry and can create new process variants. At the highest level, trusted partners may exchange the project together with geometry, allowing the extruder to test limited die modifications, for example bearing corrections, and send these proposals back to the die maker. The key point is that all three levels use the same digital model and can evolve as cooperation and trust increase.

Level	Model access	Extruder capability	Typical use
Entry	Results / Viewer	Review supplied results	Acceptance and technical discussion
Medium	Restricted project, no CAD export	Change process parameters and recalculate	Plant-specific virtual trials
High	Project + trusted geometry access	Process and selected die modifications	Joint die/process optimisation

From zero-trial die design to zero-trial process introduction

ExtrusionLink changes the role of simulation in the aluminium extrusion supply chain. The objective is no longer only to certify that a die should work under one nominal condition. The digital twin becomes a reusable engineering asset for defining the operational window of the complete process. This is especially important for defects that appear only during later stages of the billet, for quality characteristics such as seam-weld integrity, and for downstream operations in which the extrusion temperature field directly affects quenching distortion and mechanical properties (Fig. 5) [6].

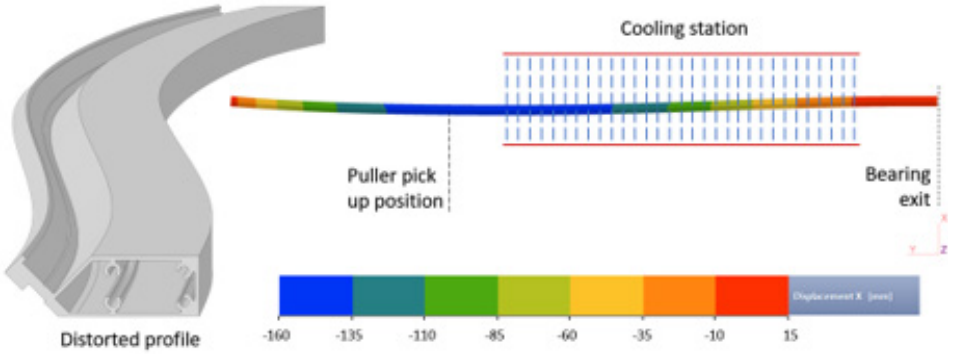


Fig. 5. Example of downstream digital-twin use: prediction of profile distortion during quenching and puller action [6].

This extended workflow also supports digital certification. Instead of a static report containing only selected screenshots, the transferred model can preserve the assumptions, process parameters and calculated quality indicators behind the conclusions. The extruder can verify whether the original conditions are applicable to a particular press and can quantify the effect of changes before an industrial

trial. The same information can be further communicated to the profile customer when requirements concern integrity, geometrical accuracy or mechanical properties.

Conclusions

The development of QForm UK Extrusion can be viewed as a transition from isolated numerical checks to a connected digital workflow. Automated die design and optimization, coupled tool simulation, full-billet transient analysis, billet-skin and weld-quality prediction, deformed-contour assessment, quenching and final property prediction now form complementary parts of one process model. ExtrusionLink extends this technical development into a collaboration model: the digital twin is created once, protected according to the required level of intellectual property access, and reused by the die maker and extruder for their respective engineering decisions. The expected result is fewer physical trials, earlier detection of die and process limitations, faster feedback between companies, lower scrap and a more transparent route to first-time-right production.

References

[1] N. Biba, I. Kniazkin, “Digital Certification of Extrusion Dies Based on Simulation,” Light Metal Age, April 2022, pp. 26–28.

[2] I. Kniazkin et al., “Investigation of the Skin Contamination predictability by means of QForm UK Extrusion code,” Materials Research Proceedings, 28 (2023), pp. 543–552.

[3] L. Rauscher, R. Backert, J. Sloboda, D. Wanat, “Productivity Increase and Process Optimisation for Profiles Using Coated Die Concept,” Light Metal Age, April 2024, pp. 24–29.

[4] I. Kniazkin, I. Kulakov, N. Biba, “Comprehensive Analysis of Waving Defects in Aluminium Profile Extrusion,” Materials Research Proceedings, 54 (2025), pp. 725–734.

[5] I. Kulakov et al., “Industrial Implementation of Simulation-Based Tool Design to Ensure High-Quality Seam Welds in 6082 Automotive Profiles,” ET Foundation, 2024.

[6] I. Kniazkin, I. Kulakov, A. Shitikov, H.-W. Raedt, “Quenching of extruded profiles – finite element simulation as a tool to minimize profile distortion,” Aluminium, 4/2022, pp. 34–35.

[7] QForm Group, QForm UK Release Notes, versions 11.1–12.0.5, 2024–2026.