Preventing forging defects in aluminium and steel forgings through iterative automated preform design in QForm UK Direct

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Abstract

This paper presents a design methodology for multi-step closed die forging processes applied to complex metal components. The primary objective is to determine the optimal geometry of preforming dies to ensure a defect-free final product. The procedure begins with the generation of candidate surfaces representing the main contact shapes between the workpiece and the tools during preforming operations using the QForm UK Direct automated CAD system. Based on these surfaces, complete die geometry is developed, followed by conventional metal forming simulations to evaluate process performance and product quality.

The simulation results demonstrate that the optimized preform geometry enables complete die filling without defects, such as laps, flow-through defects, or underfilling. In addition, tool life is considered a key parameter for monitoring and optimization. Industrial production trials validated the design and simulation outcomes, confirming that this numerical approach provides an efficient and reliable alternative to traditional manual design and trial-and-error methods.

Key words: forging, preform design; isothermal surfaces method, forming, dies, tools, simulation, QForm, FEM.

1. Introduction

The determination of preform geometry represents a critical stage in the design of multistage forging processes, as it significantly influences metal flow, defect formation, and process stability. In industrial practice, preform design is predominantly based on empirical methodologies derived from accumulated production experience which have remained largely unchanged since the middle 20th century. Despite their practical utility, such guidelines are inherently qualitative and do not provide a basis for the formulation of a rigorous and reproducible algorithm for preform design. Consequently, the development of preform geometries in industrial environments is often carried out using iterative trial-and-error procedures, which are time and cost-consuming and dependent on operator expertise.

The approach implemented in QForm Direct addresses these limitations by introducing an algorithm for automated preform

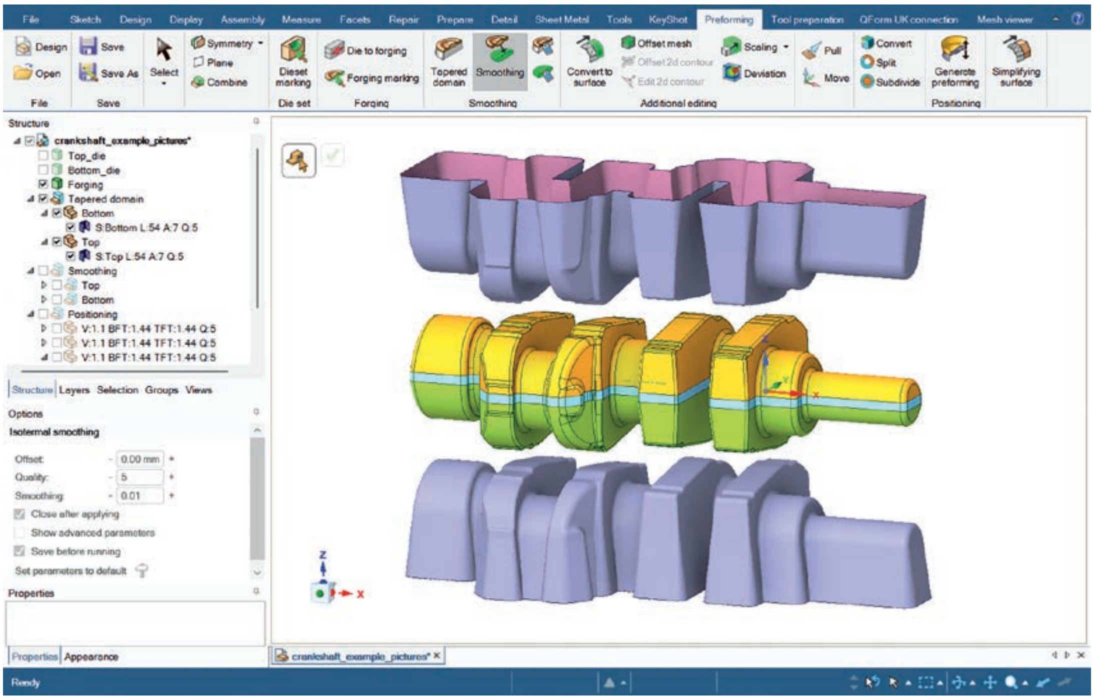


Fig. 1 Example of the interface of the QForm Direct system

generation based on smoothing the geometry of the final forging using the method of isothermal surfaces. This method enables a systematic transformation of the final shape into a technologically feasible preform while preserving key geometric and physical characteristics of the deformation process.

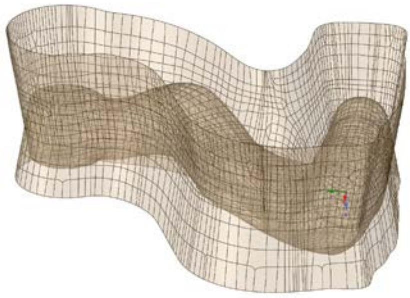
QForm Direct provides advanced capabilities for geometric modeling and transformation (**Fig. 1**). The integration of this functionality allows for a high degree of automation in preform design. The application of the proposed methodology has demonstrated its effectiveness in solving a range of industrial problems.

2. Methodology for preform geometry design in QForm Direct

The design of preform geometry in QForm Direct is based on smoothing the die cavity of the final forging stage (i.e., the geometry of the finished part) using the method of isothermal surfaces. Routine procedures for calculating isothermal surfaces and generating smooth 3D geometry based on these results are fully automated within the software.

The process design of hot forging operations can be fully implemented in QForm Direct for two-stage processes (preforming and final forging) as well as three-stage processes (upsetting or preforming stage – preforming – final forging). For more complex processes requiring significant metal redistribution in preforming stages, the use of QForm Direct makes it possible to substantially reduce the time required for preform design. The software is also effective for improving existing technologies, particularly in cases where forgings produced in the final impression exhibit surface defects such as underfilling, incomplete die filling, laps and flow through defects.

The primary output of QForm Direct is the generation of master surfaces for die cavities and their positioning in a manner that ensures defect-free forging in the final impression. The master surface of a die cavity is represented as a piecewise spline surface, the imprint of which in the die block defines the geometry of the forging cavity (**Fig. 2**). This surface can be readily modified both globally and locally, by adjusting small regions of the geometry.



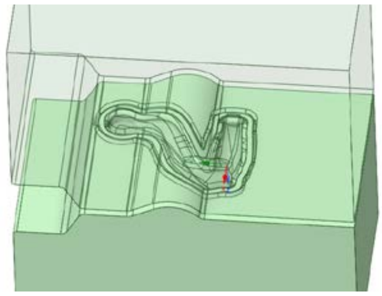


Fig. 2 Master surfaces of the top and bottom dies designed in QForm Direct (a) and the corresponding dies (b)

The preform design procedure using QForm Direct is illustrated in **Fig. 3**. The initial input data for the calculation is the CAD model of the final impression. Following the definition of reference features, a computational forging model is automatically generated; alternatively, a hot forging model may be used for this purpose.

The die cavities of the upper and lower impressions are used to generate a computational domain, within which the isothermal surface calculation is subsequently performed. The procedure includes a set of adjustable parameters that control the degree of smoothing of the final die geometry. The resulting mesh-based (faceted) master surfaces of the upper and lower dies are then positioned relative to each other in such a way as to ensure complete filling of the final die cavity while preventing flow defects.

The software defines the volume of the forging between the generated surfaces. Subsequently, a geometric subtraction operation (imprinting) of the die cavity surface from the die block model is performed (with a flash gutter created beforehand, if required), resulting in a die model for the preforming stage that is ready for simulation in QForm UK. The designed die cavity surfaces can be exported in Parasolid or STEP format to external CAD systems for die modeling. However, this process can be carried out more efficiently directly within QForm Direct, as the software provides a direct interface with QForm UK, thereby simplifying subsequent model preparation and verification of simulation results.

3. Results of industrial validation of the methodology

Industrial validation of the developed technologies confirms the high efficiency of the proposed approach and the software implementation (**Fig. 4–7**).

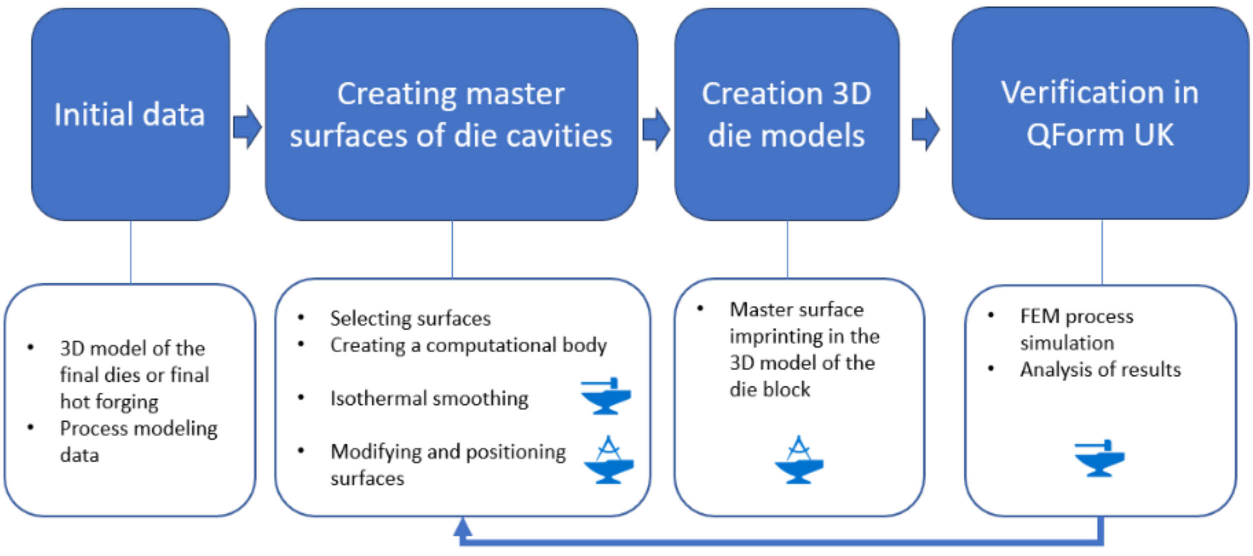
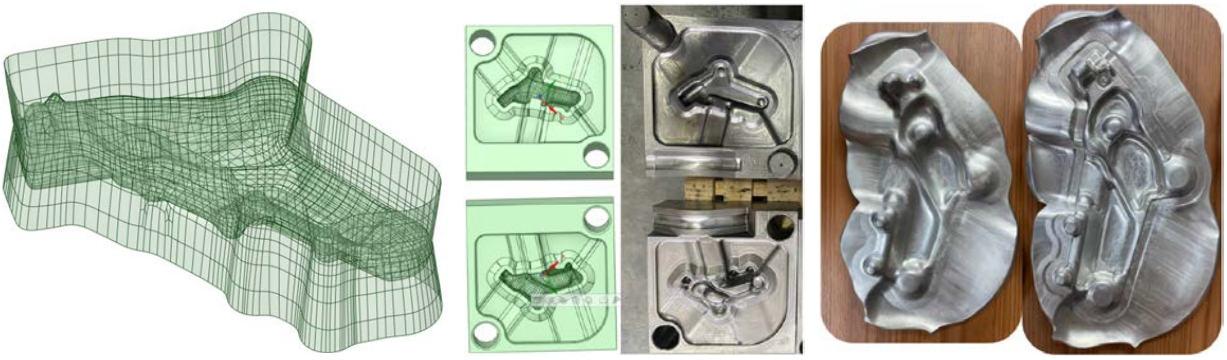
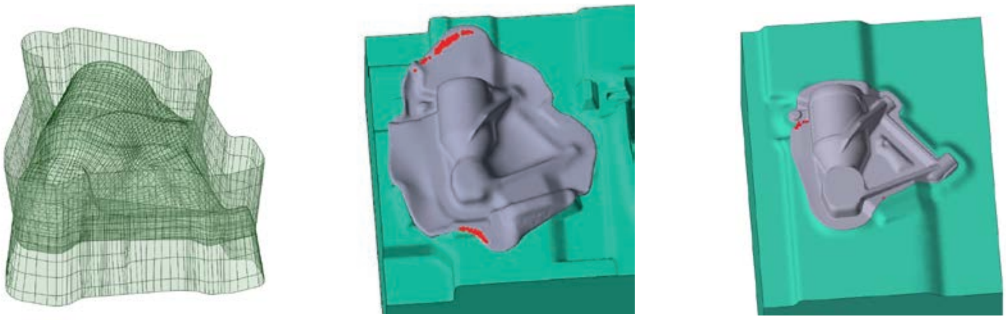


Fig. 3 Design methodology in QForm Direct



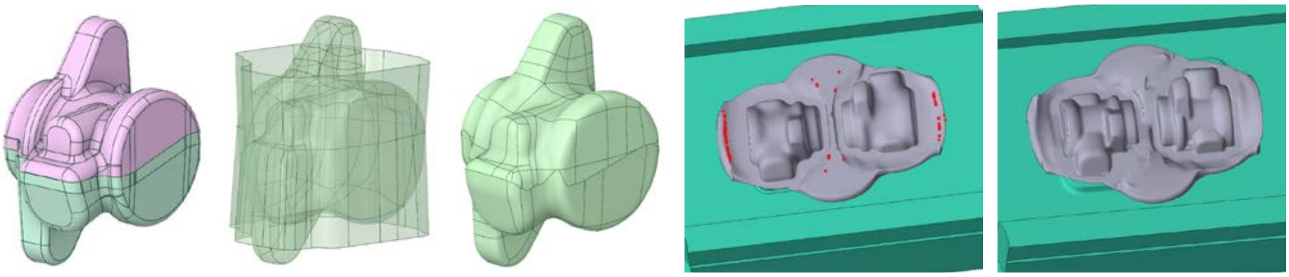
a b c

Fig. 4 Practical case of AA6082 forging design process in QForm Direct:
a – generation stage, b – 3d modeling and production of the dies, c – preforming and final forging



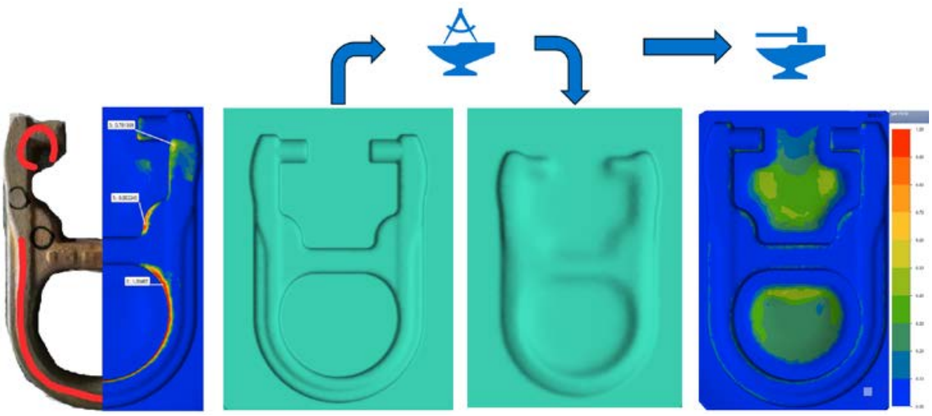
a b c

Fig. 5 Surfaces generation (a), blocking (b) and finish operation (c)



a b c d e

Fig. 6 Design process in QForm Direct:
a – final forging geometry, b – generated surfaces for the blocking operation, c – generated pre-forging, d – preforming simulation, e – final forming



a b c d

Fig. 7 Design and confirmation by simulation:
a – real defects confirmed by simulation, b – finishing operation, c – generated blocking operation, d – defect-free technology

QForm Direct enables the design of preforming die cavities that ensure the production of defect-free forgings in the final stage. Practical experience with QForm Direct demonstrates a significant increase in process engineer productivity, particularly in the design of two- and three-stage hot bulk forging processes.