The Future of Injection Molding:

How the "Digital Mold" is Revolutionizing Medical Device Molding Development

End-to-end data streams, system-supported calculations and methods, alongside advanced simulations and digitalization, ensure maximum process stability and a shorter time-to-market in a highly regulated market environment. Virtual mold and process development creates new opportunities for quality, transparency, and efficiency throughout the entire mold lifecycle.

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innovating for a better life

The global medical technology industry is continuously under increasing pressure to innovate and deliver quality. Products such as insulin pens, inhalers, or diagnostic systems demand the highest level of precision, as patient health directly depends on their flawless functionality. At the same time, regulatory requirements – such as the European Medical Device Regulation (MDR) or US FDA guidelines – mandate seamless traceability and the validation of all manufacturing processes.

In this challenging market environment, the digitalization of molding development is rapidly gaining importance. Traditional, purely empirical approaches in mold making are increasingly reaching their economic and technical limits given today's tolerance requirements and highly complex component geometries. To achieve the required zero-defect tolerance cost-effectively, new data-driven and system-supported approaches are essential.

As a global partner to the pharma and healthcare industry, Gerresheimer recognized this need early on and is consistently positioning itself as a technological pioneer in the field of digital mold making through visionary concepts. By strategically linking virtual engineering with real production data, the company is raising molding development to a whole new level.

The Target Image: The Vision of the "Digital Mold"

At the heart of the digital roadmap for molding development at Gerresheimer is the pioneering concept of the 'Digital Mold.' Driven by the Global Engineering & Innovation Center Molds, this concept describes an end-to-end, data-driven, and structured approach to the development, optimization, and subsequent operation of injection molds. The goal is to digitally map the entire lifecycle of a mold.

The foundation of the Digital Mold is the virtual representation of the mold — a precise digital twin. However, this digital twin is not intended to remain an isolated 3D model; it will later be merged with real production data from the injection molding machines. This linkage creates the 'digital shadow,' establishing a consistent, dynamic data foundation for the entire molding development process.

Through this holistic approach, physical effects and the interactions of process parameters can be analyzed before any steel is machined. Gerresheimer thus achieves increased transparency, enabling well-founded decisions based on valid data rather than estimates.

Virtual Injection Mold and Process Development and Optimization as an enabler **for Digital Molds**

procedure

System and development environment

START

1	Mold design for manufacturing	VIRTUAL
2	VIRTUAL process development	VIRTUAL
3	VIRTUAL mold development	VIRTUAL
4	Mold manufacturing	REAL
5	Injection molding process development	REAL
6	VIRTUAL Mold and process optimization	VIRTUAL
7	Mold optimization	REAL
8	Mold acceptance test	REAL

END

DIGITAL MOLD

digital representation of the real mold

Virtual Injection Mold and Process Development & Optimization

real use cases

MOLD ENGINEERING

- Mold Temperature Analysis
- Mold Material & Element Analysis
- p.e. FEM analysis

PROCESS ENGINEERING

- Injection molding process development
- Virtual DoE
- Process Target Optimization

VIMP as a Technological Enabler for the Digital Master

A key and already well-established building block on the path to the Digital Mold is the concept of “Virtual Injection Mold and Process Development and Optimization,” or VIMP for short. VIMP combines simulation-based, system-supported, and systematic approaches to simultaneously develop and optimize both the injection molds and their corresponding processes.

Throughout the entire creation process, the focus remains squarely on the mold – from the initial feasibility assessment, through conceptualization and design, to manufacturing and continuous use in series production. VIMP enables engineers to create a “Digital Master.”

This Digital Master serves as the primary starting point for all subsequent digital evaluations. In the spirit of a Digital Twin, it is utilized for the continuous development and refinement of the mold. The sequential data flow supports this transformation process from the initial design to the optimized series production mold.

Practical Use Cases for Maximum Quality

At Gerresheimer, VIMP is deployed deliberately on a demand- and risk-based basis to drive injection molding-optimized mold and process development specifically where it generates the greatest customer value. Initial successful use cases already demonstrate the immense potential of this methodology in a real-world project environment. For instance, VIMP is utilized in complex feasibility assessments within the framework of "Design for Manufacturing Molds".

Another main area of application is the targeted optimization of temperature management and tempering within the injection molds. In practice, uneven cooling of thermoplastic materials often leads to warpage and dimensional accuracy issues in the plastic component. Through virtual analyses regarding mold design and the mold materials used, these effects can be identified, described, and influenced in advance.

Furthermore, VIMP makes a value-adding contribution to injection molding process development. By means of virtual Design of Experiments (virtual DoE), relevant process parameters can be digitally analyzed and optimized. This creates valuable synergies for subsequent real-world injection molding trials, as the machine's starting window can already be mathematically narrowed down. For particularly challenging geometries, Gerresheimer also integrates reverse engineering methods to make mold qualification highly efficient and to reduce costly real-world optimization loops.

Tangible Added Value for Global Medical Technology Customers

For Gerresheimer's customers, this innovative strength results in a well-founded, holistically conceived development of injection molds. The primary focus is always on achieving process-reliable and high-performance component production that effortlessly meets the strict regulatory requirements of the medical technology industry.

Furthermore, the Digital Master guarantees end-to-end transparency across the entire lifecycle of the mold. Should deviations occur later in production or if mold modifications become necessary, the digital database enables an extremely fast, data-driven response. Downtimes are minimized, and the global scalability of production processes can be significantly enhanced.

As a result, VIMP is already far more than just the mere use of software – it is a fundamental enabler that lays the foundation for the data- and system-driven future of mold making. Through this, Gerresheimer impressively demonstrates how digitalization is deployed in a targeted manner to generate measurable economic and qualitative advantages.

Overview Molds

- **Planning & Controlling:**
  Global scheduling and cost control.
- **Mold Engineering:**
  Global support of injection molds from specification to successful validation.
- **Mold Design:**
  Centralized design and engineering of equipment.
- **Process Engineering:**
  Global support for injection molding. Statistical design of experiments.
- **Mold Making:**
  From planning to final assembly.
- **Advanced Technology Engineering:**
  Technology scouting and analysis. Process optimizations
- **Mold Optimization:**
  Ensuring robust injection molds.
- **Metrology:**
  Tactile and optical measurement. Additive manufacturing of measurement fixtures.
- **Measurement Engineering:**
  Development of IPC measuring programs.
- **Lifecycle Management & AI Engineering:**
  Virtual mold and process development. Date-analytics & AI use cases.
- Over 130 employees
- 100 – 150 molds per year

Focus on:
Lifecycle Management & AI Engineering Molds

The specialized department "Lifecycle Management & AI Engineering Molds" at Gerresheimer is responsible for these technological milestones. Its primary focus is on "Design for Manufacturing Molds" to prepare injection molds and processes optimally – both technically and economically – for subsequent qualification and serial production.

The team contributes its many years of experience and dedicated expertise, playing a leading role: it establishes the foundation for successfully implementing and continuously evolving innovative technologies in the first place. Through the close integration of engineering competence, process understanding, and data-driven approaches, the department makes a significant contribution to the sustainable optimization and future viability of mold development.

By step-by-step integrating virtual mold and process development techniques, the department ensures that decisions are derived in a structured, system-supported, and data-driven manner. A central core project in this regard is the implementation of a comprehensive "Mold Lifecycle Management" system. The goal here is to continuously digitalize data, information, and the knowledge built up over decades from the mold creation process.

This structured database serves as an essential foundation for future data analytics and AI use cases. The goal of these initiatives is to provide employees with crucial support systems in their daily work environment and to realize significant efficiency gains. The expanded responsibilities within this department include, among others:

- **Technology Identification:**
  Continuous identification of new technologies and optimization potentials in injection molding, mold technology, and digitalization.

- **Research Collaborations:**
  Close cooperation with leading institutes, universities, and external service providers, such as OTH Amberg-Weiden, RWTH Aachen, the IKV, the WZL, FAU Erlangen, as well as industry partners.

- **Talent Development:**
  Practical and agile technology development through the targeted involvement of student professionals, reflected in a track record of forty-three supervised students within fourteen semesters to date.

The author

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Stronger as a team

The "Lifecycle Management & AI Engineering Molds" department is headed by Stefan Schumann. Now 34 years old, he began his professional career with a dual study system: from 2011 to 2016, he successfully completed his dual bachelor's degree in Plastics Engineering at the Ostbayerische Technische Hochschule (OTH) Amberg-Weiden, combined with a traditional apprenticeship as a Process Technician for Plastics and Rubber Technology. Following this, from 2016 to 2017, he pursued a master's degree in Innovation-Focused Mechanical Engineering, also at OTH Amberg.

After completing his academic degrees, he started his career directly in industrial practice at Gerresheimer: from 2017 to 2020, he served as an Expert Injection Molding within the Process Engineering department. He then transitioned to the Molds department from 2021 to 2025 as an Advanced Technology Molds Engineer, where he played a key role in digital pre-development. Since 2025, Stefan Schumann has been leading the "Lifecycle Management & AI Engineering Molds" department as Team Lead, driving the implementation of the "Digital Mold" concept for Gerresheimer alongside his team.

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