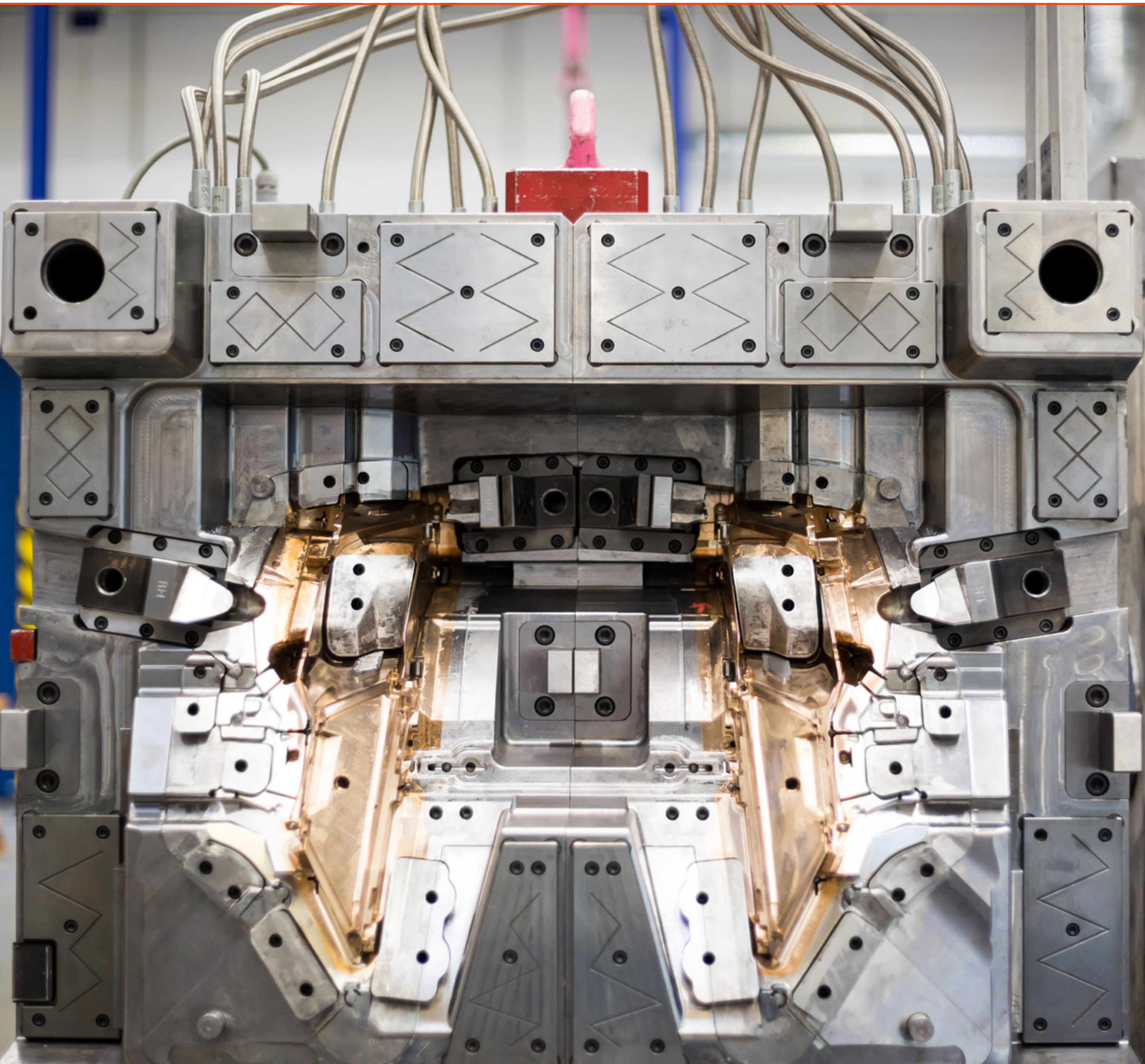
ALTAIR

EGUIDE TO INJECTION MOLDING



INTRODUCTION

Injection molding of plastics is an established, proven industrial manufacturing process for the mass production of identical components. Over the past 100 years, the basic process of forcing a molten polymer under pressure into a cavity machined in a metal tool has evolved to become highly sophisticated and is now utilized across all industry sectors to produce a wide range of complex shapes from small recyclable packaging items, consumer products, and toys to load-bearing, high-performance parts used routinely in automotive, medical, and aerospace industries.

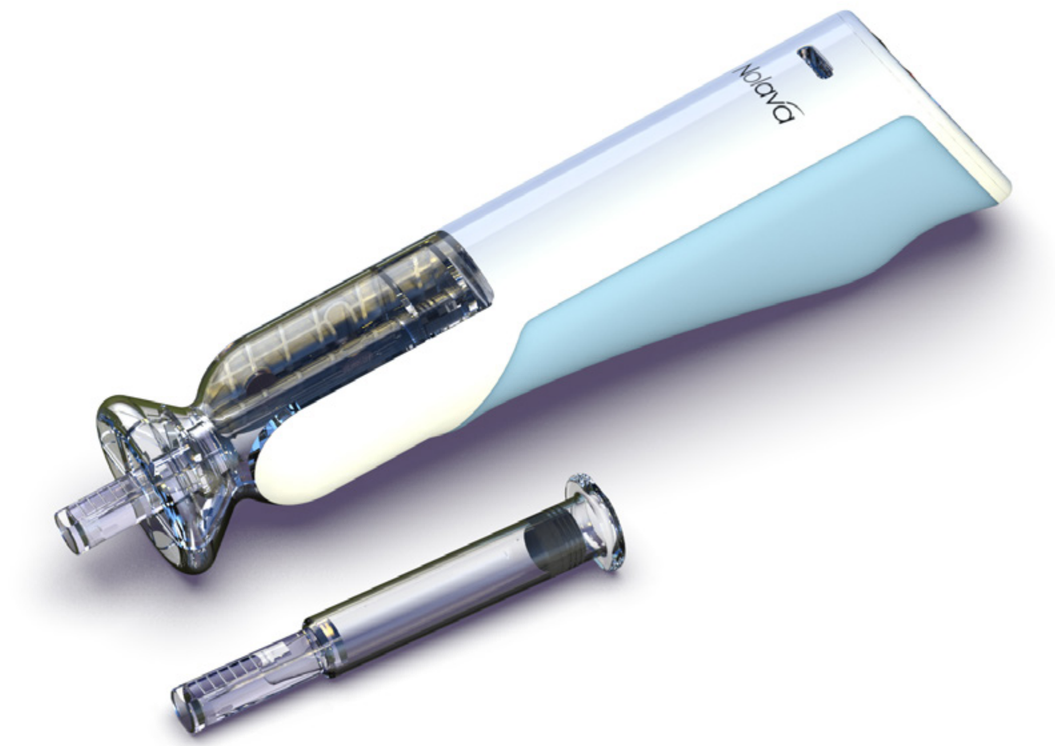
Given injection molding is such a widely used and increasingly popular manufacturing process with years of successful application, what can simulation technologies possibly bring to the party? This guide aims to answer those questions to help those taking the step into the virtual age.

The benefits and disadvantages of injection molding are established from years of industry experience. In the beginning, much of this relied on a trial-and-error approach using the experience of the engineers and toolmakers to get it as good as possible, as quickly as possible.

Injection Molding Guide

Nowadays to remain competitive, the need to constantly improve injection molding processes can benefit from modern technological advancements that simulation offers to overcome known disadvantages. With the aid of sophisticated computer-based tools, virtual product design enables engineers to look at and gain a better understanding of the entire process – from first idea through to seeing how the top clips on and stays on - all before taking the first step towards the factory floor.

This e-Guide includes illustrations from the collaborative product design study Altair developed with Nolato for "Nolava", a battery-powered medical electro-mechanical auto injector. These devices need to be robust and reliable because they are used every day around the world by people needing life-saving medication that is administered in the home by non-medically trained staff.



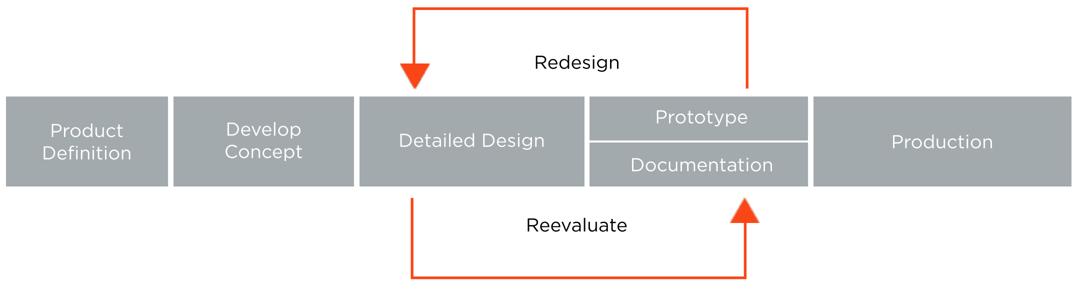
“To ensure quality and durable injection molded parts that meet their intended role relies on good part design anchored on best practices for design for manufacturing...

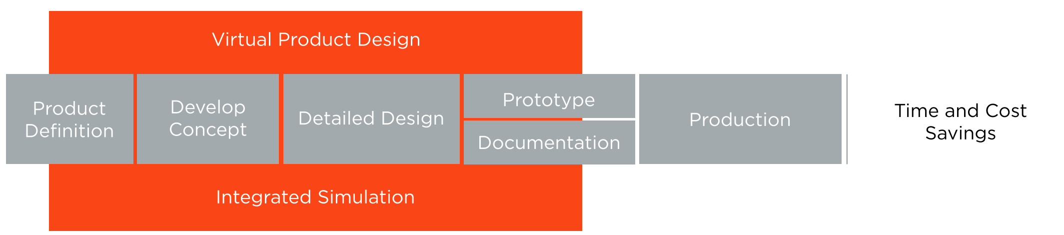
...along with a thorough understanding of the process parameters and how they interact: part material and geometry, single- or multiple cavities, tooling.”
Patrik Ingvarsson, Manager TDC EU, Nolato Medical Solution

UNDERSTANDING THE DESIGN PROCESS

Although the overall injection molding process appears straight forward, the interrelationship between the numerous variables at each step is complex. This means understanding how each process variable impacts on component design is essential.

A conventional design process is somewhat linear and moves from idea to concept design to detailed design, followed by different prototyping stages. Only once a prototype is tested and validated, which may take several attempts to get it right, does the mass production stage start.





Whereas virtual product design applies integrated simulation tools across the whole design process which means that both design and process variables can be investigated together and optimized much earlier. Fewer physical prototypes, with the physical testing needed for each, significantly reduces the time and cost to market meaning fewer scrap parts, less waste, lower tooling costs, less energy while also providing confidence of fewer in-service failures.

Simulation-driven design is a powerful tool that instigates “joined up thinking” by bringing together the different roles of designers, engineers, product development, manufacturers, process development, quality control, that all work together to deliver a reliable robust product first time. Central to this is having an integrated simulation solution to enable concepts to be explored, questions to be asked and answered, problems exposed and resolved all within a single interoperable virtual product design ecosystem.

To ensure durable, high-quality injection molded parts that perform their intended role, manufacturers rely on good part design anchored on best practices for design for manufacturing. It also requires a thorough understanding of the process parameters and how they interact: part material and geometry, single or multiple cavities, tooling.

Using Injection Molding

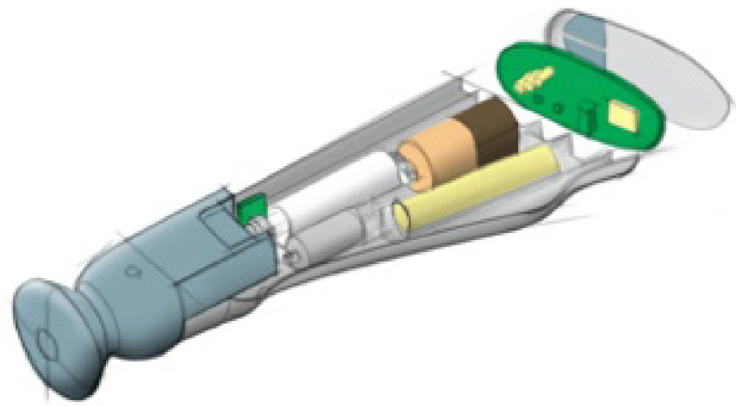
Pros	Cons
Proven industrial process	As-molded material performance
High-volume manufacturing of plastics	Part geometry limitations
Fast, high production rates	Plant costs
Multiple parts at same time	Start-up tooling costs
Wide range of materials • Cheap grades of polymers, • bio-based materials, • high-performance fiber-filled	Rework part design and tool costs
High productivity	Lead times longer compared with other manufacturing process
Repeatability and tolerances	
Aesthetic appearance	

WHAT IS VIRTUAL INJECTION MOLDING PRODUCT DESIGN?

Part Design

A common starting point in any product design is the idea, followed by a definition of what is needed (size, mechanical, environmental, life). Today, drawing boards are replaced by CAD program files to effectively define a component's geometry and dimensions. At this point, the CAD diagram does not take into account how best the item is to be manufactured, just what is needed.

Understanding the manufacturing processes, their pros and cons, efficiency and cost-drivers, aids in the correct selection for any particular component. Where decisions are not clear-cut, trade-off studies may become necessary to dig deeper into the efficiency of candidate processes.



Nolava, is a battery-powered electro-mechanical auto injector. These devices are used every day across the world by people needing life-saving medication that is administered in the home by non-medically trained staff.
The key requirements include:

- *Ease of use with minimal training*
- *Load any fluid from any provider for patients to use, e.g. insulin for diabetic patients, adrenaline (epinephrine) to counter anaphylaxis (sever allergic reactions)*
- *Reliably dispense a single dose in a consistent, safe manner*

Injection Molding

With the selection of manufacturing process, the "Design for Manufacturing" begins to assess any additional demands on the original component geometry. While these could be referred as modifications to the conventional CAD drawing, today a more efficient approach is to make these within a CAE product design tool creating a design space and including constraints from the original CAD that can be modified easily as it then evolves into a product design.

Many injection molded components are used to house static or moving electro- or mechanical assemblies, these requirements can be incorporated into the overall virtual product design. By including fixing point load cases and any physical movement into the simulation, it ensures the housing does not imped movements, for example, and that the molded components themselves can be assembled successfully.

A modern approach is to disrupt the conventional "concept > detailed design > test" route and move simulation-driven design earlier in the design process. Topology optimization is a key technology when exploring designs to understand the trade-offs between different constraints enabling designers to home in on a solution that best responds to the need. By placing material only where it is needed provides not only weight efficiency but also cost efficient soultions much earlier.

Watch Injection Molding Tools through Optimization, CFD Simulation and 3D Printing

Nolava — Innovation

Taking a traditional rib-stiffened component and moving to an innovative design driven by topology that puts the material where it's needed to deliver a balanced performance-weight-cost-optimized product.

While topology optimization provides the easily recognized organic form, when it comes to ensuring cost-effective injection mold making, these are reinterpreted via CAE to ensure component design for manufacturing (draft angles, assembly points, etc.) and CNC mold machinability.

Plastic or Composite – Material Mapping?

Mechanical, environmental, processing, and cost form the basis for material selection. To fully characterize any material generally starts with manufacturers' data for their range of polymer resins and physical test results to recognized industry standards.

A complication arises for any filled resin, especially when fiber-reinforced, because the properties of these composite materials depend heavily on the fiber content (volume fraction) and the orientation of the fibers in the final molded component. Fiber orientations are influenced by the distribution and flow of the resin melt in and around features within the mold. To undertake a full physical testing program is both expensive and time consuming, which is where the ability to create a virtual material model is important especially for the kind of high-value, fiber-reinforced injection molded parts used for structural applications in the automotive and aero industries.

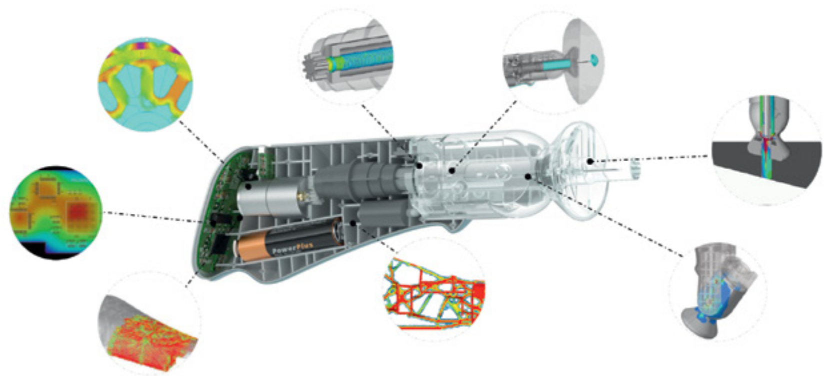
Watch Concept Design for Plastic Parts

Warpage/Strength

Understanding what happens inside the mold cavity helps ensure viable products are produced repeatedly. Traditionally this was the role of the prototyping stages. Today, mold simulation is used to provide a quick "mold fill" check on manufacturability but also to explore the plethora of material- and process-related parameters together in order to predict why, where and how defects may occur and, more importantly, resolve issues – all within the virtual domain - that could otherwise compromise the performance or aesthetics of the molded product.

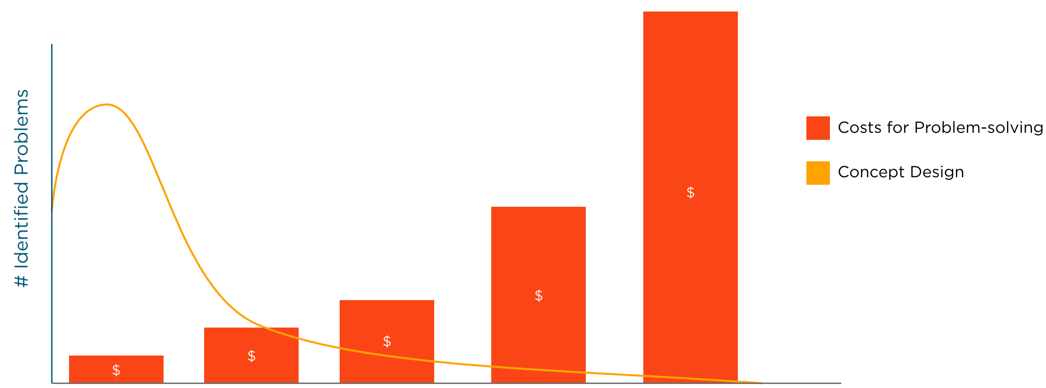
Strength and Durability

In the virtual world, the performance of a component, relative to its expected static and dynamic load cases, can be simulated to see if it meets the needs and, more importantly, locate and resolve any weaknesses in the design. Additional load cases, accidental use or misuse, can be explored and problem solved prior to making the mold. Who has not dropped their mouse, reversed into a plastic dumpster, or stood on a plastic garden chair?



Virtual Product Design Checklist

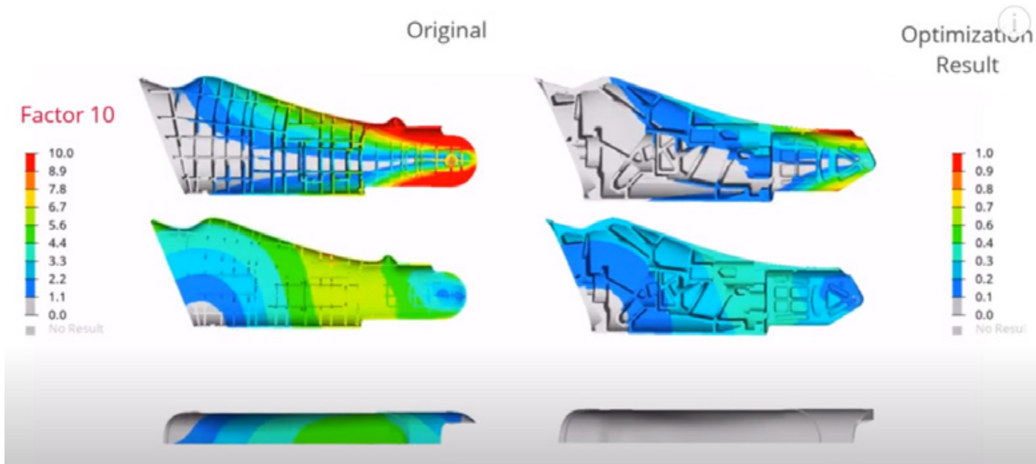
Virtual product design avoids unexpected costs later in the process. Making changes during the design phase is much more cost effective than at any injection molding production phase.



- During design, keep the end-use requirements in mind not to neglect a specific characteristic or function.
- Avoid surface defects to ensure aesthetics are met.
- Robust product design consider component wall thickness, drafts, cores, ribs, bosses, undercuts, fillets and assembly processes during design.
- Design to reduce shrinkage and warpage.
- Increase injection molding strength and stiffness.
- Part service life, longevity and recyclability.
- Need to disassemble or permanent joining of components.
- Design to optimize strength and stiffness characteristics.

REDUCE COSTS

The main cost drivers in injection molding are:
Component: Total cost to design component for successful manufacturing.
Tooling: Total cost of designing and machining the mold.
Material: Volume of the material used, its price per kilogram and waste.
Production: Total time the injection molding machine is used.



Nolava — Optimized Design for Manufacturing
Good product design is key to cost saving across the whole product life cycle. In the virtual world, product design – from idea to having a part ready to manufacture – enables ideas to be explored, innovations made all within the comfort of knowing that something missed, insufficiently specified or a new requirement can all be corrected before stepping onto the factory floor.

Component costs can be significant if design for manufacturing is ignored during the initial design and process-related factors have to be revisited later. A major advantage of working in the virtual domain is that modifications can be made, and their effect easily determined prior to embarking on tool making.

While tooling costs are independent of the total number of parts manufactured, they can contribute around 70% of overall costs for low production runs. By modifying the component, easily done within the virtual product design cycle, a simplified mold design can reduce its manufacturing time and cost.

At larger production runs >10000, tooling costs contributions become less important than material and production costs. By minimizing both the component volume and molding cycle time, the overall cost is reduced.

Read Altair for Manufacturing

Tips and Tricks

- **Reduce Part Counts:** By combining different parts into one molded component design, production costs are reduced. While a more complex molded component is more expensive, cost savings come from faster production rates, reduced component assembly costs.

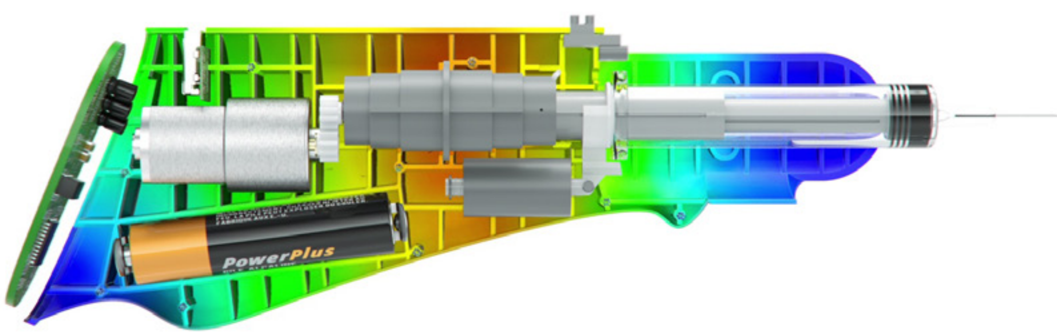
- **Reduce Tooling costs:** By simplicity of design because a simple mold is cheaper. By avoiding complex features, the tool can be straight open and close. Components needing more complex features, e.g. threads, can be molded or machined afterwards.

- **Multi-cavity Tool:** Despite the initial higher tooling cost, multi cavity tools to produce high numbers of identical parts or the same quantities of different but similar parts, can be more cost effective.

- **Reduce Cooling Cycle:** By designing thin walled parts, cooling is faster which can simplify cooling the tool and reduce production costs by increasing production rates.

- **Select the Correct Material:** Choose a resin that meets the requirements. Optimized design improves strength and stiffness without resorting to thicker sections.

- **Step Into Virtual Product Design:** Choose a flexible, integrated software solution that covers the end-to-end workflow – from idea to factory floor – saves time and money wherever your engineering staff are based.



FROM THE DESK OF MARTIN SOLINA, DIRECTOR OF PRODUCT MANAGEMENT, MANUFACTURING

How to assure robust design and manufacturing of injection molded products.

Injection molding is an established manufacturing technique used across numerous industries, so what competitive advantages do simulation technologies offer to the design and manufacturing of injection molded products?

1

Better decision making ...

In general, when it comes to questions about design and manufacturing, simulation helps customers make better decisions because as a designer you have to consider not only structural performance but also the manufacturability of the part. Applying simulation early in the design stage leads to better products that are also easy to manufacture and defect-free. By making these better decisions early can only help you save time and money, leading to better products.

2

Robust design with lower reject rates ...

Across most manufacturing industries, not only injection molding, component reject rates tend to be around 5% to 10% but can be even higher in some complex shaped parts. Using simulation technologies can effectively reduce reject parts to considerably lower values. By detecting defective parts at an early stage, changes to the part or processes can be made easily, whereas if companies only detect these defects very late when they are already in production, it becomes very expensive situation to recover from both in terms of time and cost. That's why reducing reject rates is so very important.

3

Faster products to market ...

Using simulation techniques can significantly reduce the number of iteration loops between design and manufacturing teams which is important because, in so many cases, it's these loops that are responsible for delaying the time to market. If we design a part and send it to be manufactured, but the production team says we cannot make this part as it is, then it has to be redesigned. That doesn't only involve manufacturing, it can involve revisiting other analyses that also cause delay. Using simulation to check a part can actually be manufactured before sending it to be produced saves a lot of time.

How important is design for manufacture?

For me it's a key point. To implement simulation early into the design stage is putting these technologies directly into the hands of the designers. It is really important to avoid iterations loops between design and manufacturing, as I said, to help reduce the time to market. But it also gives designers the opportunity to learn how to design for manufacture to reduce time and costs by understanding more about the manufacturing processes and constraints. We've seen that many companies' designers are beginning to use simulation techniques not only to check manufacturability but also to modify the design. "Think manufacturing" early in design adds in quality and part performance factors that can improve manufacturability.

Analysis software is often thought of as virtual testing, can you explain a little more about how simulation reduces cost and drives better decisions?

Traditionally simulation has been used as virtual testing to answer, for example, "what if" I change this? Virtual testing consists of creating the whole system – the part, the entire mold with runner system and cooling lines, with everything defined exactly as we have been doing in the real life. Then, simulation is performed to check if the part has any problems, if the cooling system works fine, etc., and this is what we call virtual testing. To test exactly the same things that we do in real life, but in a digital world brings huge benefits because it is so much faster and cheaper to make a mold in the virtual world. And the real benefit can be observed by bringing together different teams, the customer, the designer, the manufacturing process people, and getting them all using simulation tools early cuts through time wasted on iterations.

It lets everyone work together to predict problems and resolve them at the start of processes and not find them in late stages. We are changing how design and manufacturing work and have many use cases where integrating simulation in the early stage of structural component design is becoming a key step in their design stage. We reduce costs by basically applying simulation techniques earlier to avoid having to duplicate processes and redo things when we make a change. The idea is simple: identify and make changes as early in the design chain as possible.

You worked with customers in many different industries. Have you developed a standard workflow that translates across different organizations?

Over the last 10 to 15 years, I've been working in different industries with different processes, not only polymer injection molding but also metal casting. We realized that although designers and CAE analysts have different goals, but both require easy-to-set-up and use simulation. Originally, say 10 years ago, simulation was only for specialists, only people who knew about simulation techniques and had that type of expertise could use simulation. Today, we are putting advanced simulation technologies in the hands of designers who don't need to be experts in simulation techniques. We've been changing the way we design our simulation software so that users no longer need to know about complex parameters, meshing and this kind of thing. What we have created is a 5-step simulation workflow that leads the user to easily define, set-up and run a simulation.

What our injection molding technology offers is two different flavors of simulation: We can run a "fast" simulation, or a quick analysis to let the user understand the basics of the injection molding process or a "detailed" simulation, which provides much more information from a more complex analysis.

Watch the Inspire Mold Overview Video

What is the one take-home message you want everyone to consider when embarking on an injection molding manufacturing project?

First off, I've probably said this many times already, use simulation as early as you can. Whereas in the past it was used only to virtual test or to validate, now simulation has really become my new "workplace buddy" that's there to help when we have a design for a part and when we ask: Where do I put the gate so it fills properly? What and where will my part have a possible defect? How can I change my design to avoid these types of defects? Can my part be manufactured? How can I change my design to improve the manufacturability, reduce cost, etc.? All before we get to the factory floor.

Integrating simulation in our end-to-end full workflow design process, or within the entire life of the part, is very important for the future. Having the means to connect optimization, motion analysis, with manufacturing is already being applied in some forward-thinking industries to create really robust, high-performance components

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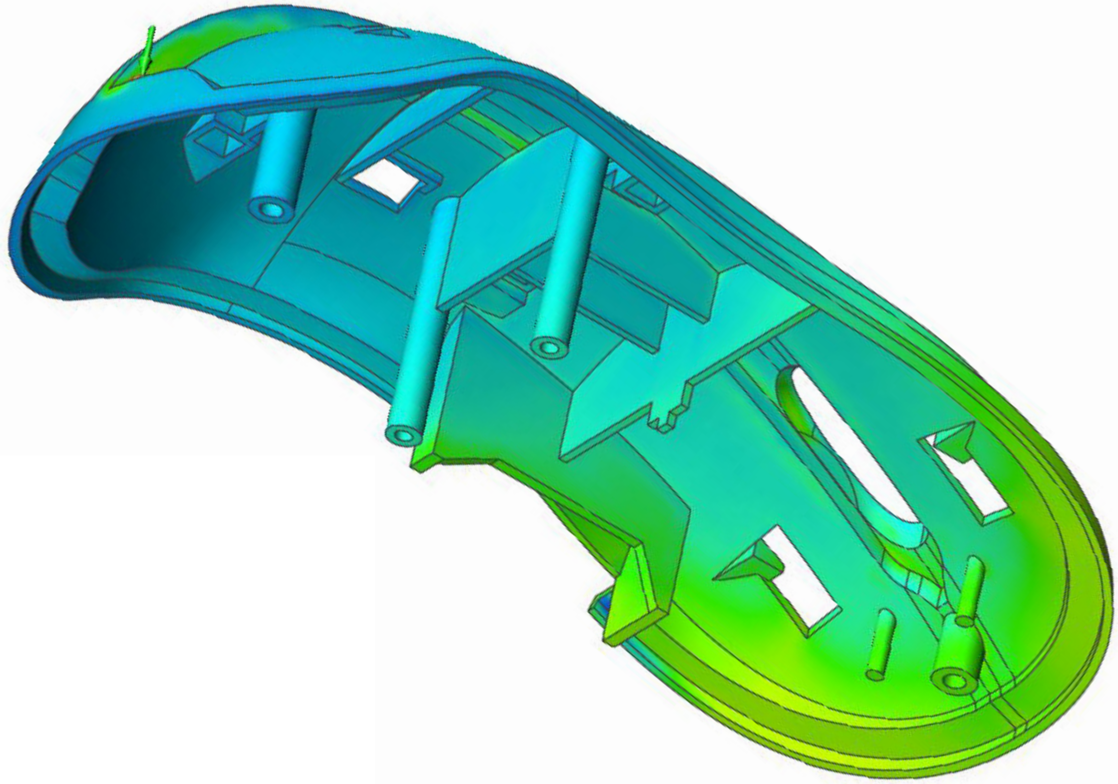
One final thought: Don't be afraid of simulation! Some people still have the idea that it's complex, hard to use, something that they don't know enough about, don't know how or lack the confidence to use. Today simulation can be used by anyone dealing with real parts, be they a designer, manufacturer, QA, structural analysts, estimators or sales teams.



Everyone can make use of simulation because we have transformed simulation to be easy to use for everyone - don’t be afraid of simulation, use it and use it early!

SO, WHAT DOES SIMULATION TECHNOLOGY BRING TO INJECTION MOLDING?

At the start of this guide, the disadvantages of injection molded were listed as:

- As-molded material performance
- Part geometry limitations
- Start-up tooling costs
- Rework part design and tool costs
- Lead times longer compared with other manufacturing processes
- Plant costs

By bringing together a multidisciplinary team of engineers all using the same virtual product design approach centered on sophisticated, but easy-to-use, simulation tools enables the "joined-up-thinking" needed to investigate, highlight problems and resolve them very much earlier than in the traditional product design-development stage.

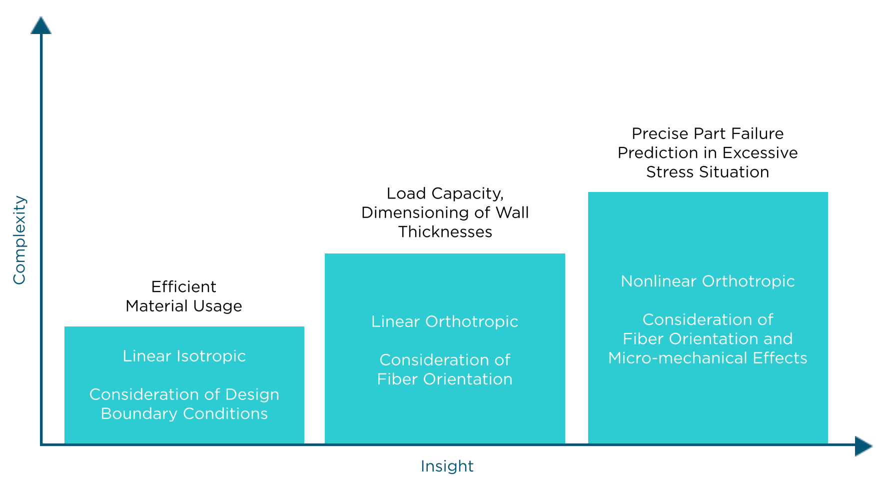
By creating an accurate material model, for unreinforced resins but also complex fiber-reinforced composite materials provides the understanding and accurate prediction of as-molded material properties, hence component performance.

Applying design for manufacturing to the component design, along with understanding the processing limitations through accurate mold simulations, can identify weaknesses in both component design and mold-related issues and resolve them earlier, so reducing verification by prototyping.

Virtual product design provides the confidence when taking the step into manufacturing, that the component can be produced successfully without incurring tooling costs for reworking the mold.

Together, these savings reduce significantly the product design-development cycle delivering a faster time to market.

Conclusion: How To Simulate When?



What about start-up plant costs? A growing feeling is that simulation enables more understanding about the entire injection molding process which gives confidence when selecting suitable plant with a capacity to meet the needs rather than a more expensive over-specified machine, or under-spec working at its limits that may need more costly care and attention long-term.

Nolava — Saving lives
Every day around the world people need life-saving medication that can be administered reliably and repeatedly in the home by non-medically trained staff.

WORKING WITH ALTAIR

Altair simulation tools provide a modern integrated approach for streamlining "design for manufacture" of injection molded components. From the initial design of the part, understanding the injection molding process, to material mapping of reinforced engineering polymers, the structural and fatigue performance of parts are efficiently analyzed and optimized. Designers and engineers are enabled to easily explore options and deliver improved products, reduce scrap and tooling rework costs.