

# Validation of virtual complex polymer component through test measurements on physical prototype

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**Abstract.** The work presented is an injection molding filling analysis of a complex polymer component. Assessment of accuracy and precision of the manufacturing process between a virtual prototype and a physical model is achieved by a way of a 3-dimensional laser scanning technology. Defined are basic advantages and potentialities for such an assessment as well as suggestions towards the manufacturing process for achieving the desired quality and accuracy.

## Injection molding

Injection molding is a highly effective method of producing plastic components by injecting plastic materials molten by heat into a mold, and then cooling and solidifying them. This technology is widely known for the mass production of products with complex shapes, and takes a large part in the area of plastic processing. [1]

Injection molding is preferred technology due to some crucial advantages and benefits over other methods. The ability to produce complex geometries in various intricate shapes that would consume much less time and costs to produce compared to other technologies. Plastic injection molding process produce details with high dimensional accuracy and yield. [2]

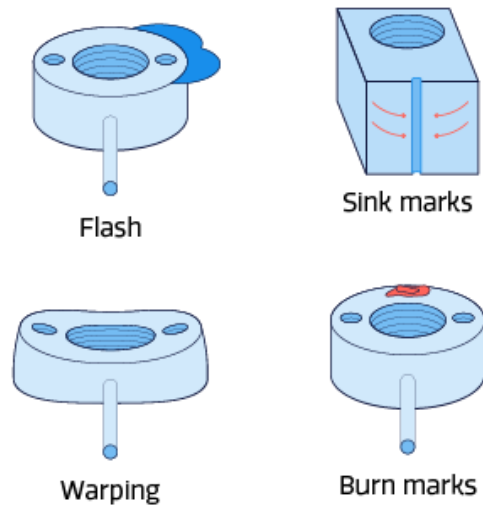
Among the advantages, a typical drawback of technology that prevents full application in the industry where higher accuracy is obligatory, is residual stresses and displacement. [3] Many defects may occur during or after the completion of the process in the products. There are several types of defects like shrinkage, warpage, voids, weld-lines etc. which usually occurs in plastic products. Defects in the products can be occurred at any step of the process. In industry, engineers have tried to minimize these defects by optimization of any of the feature like mold, plastic resin; parameters of the process. [4]

However, since the technological preparation and production of the mold tool equipment is an expensive and time consuming process, it is recommended to model a virtual prototype first. Research stage and virtual analysis of injection molding is shifted before actual production, allowing optimization and corrections of the plastic component, saving time and costs. By this way, defects and displacements could be seen and removed before creating the physical equipment. This additional step saves a lot of correction and work afterwards along with high detail accuracy.

Defects are influenced by parameters such as pressure, temperature, speed, viscosity, type of material, and others. By simulating the injection molding process in CAE software environment, most of defects can be prevented. Solutions to some defects are: [5]

- Sink marks – Melt temperature is too low/Wrong gate location/Cavity pressure is too low/Part ejected is too hot
- Flash – Excessive injection pressure/Excessive melt temperature

- Brittleness – Mold is too cold/Incorrect part design
  - Burn marks – Incorrect filling pattern
- Warping – Melt temperature is too low/Incorrect part design/Over packing near gate



**FIGURE 1.** Common defects in injection molding

The wide range of materials provide a field to engineers to improve some important properties of the injection molded component like toughness, rigidity, tensile strength, abrasion, stiffness, etc. One of the biggest advantages of this technology is the lightweight. In most cases, weight is crucial for a proper exploitation.

### 3D laser scanners

3-Dimensional scanners are machines that extract and analyze a real-world object or environment to collect data on its shape and its appearance. The collected data can be used to model virtual 3D model. They provide all purpose of metrology for multitude applications like 3D digitizing, 3D modeling, point cloud inspection, reverse engineering, rapid prototyping and other laser scanner applications. [6]

For this research, a modular high-end laser ROMER Absolute Arm 7329 SI scanning machine is used. It is designed with six rotational axes which provides very accurate and precise measurements on countless work pieces.



**FIGURE 2.** ROMER Absolute Arm 7329 SI

## Purpose of The Research

The purpose of this study is to design and simulate the injection molding process of a complex component. Assessment of accuracy and precision between the virtual prototyped component and a physical one is done.

### METHODOLOGY FOR DESIGN THE PROCESS OF SIMULATING THE FILLIGN PROCESS OF A COMPLEX GEOMETRY COMPONENT. MATERIAL SELECTION.

The model analyzed in this article is a handle with a complex geometry. The quality of this element is crucial for its mounting parts.

The research represents a comparative analysis between a virtual prototype and a physical model by a way of using a 3D laser scanning technology. The idea is to measure the displacement from the nominal dimensions' model to the real one. Minimizing warpage from the control zones is important.

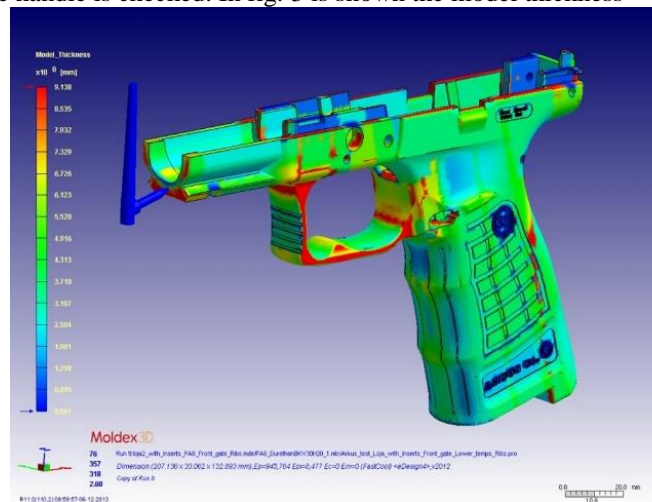
The working parameters are properly selected after being picked over by multiple of simulations and analysis. By choosing the right material, many defects and distortion from the original form would be avoided. For this specific case, Polyamide 66 with 30% Glass Fiber Reinforced is used because of the stiffness and heat resistance required. CAE software Moldex3D is used for the analysis below.

In Table 1 are given the working parameters of the injection process.

**TABLE 1.** Working parameters

Parameter	Units	Value
Filling Time	sec	5
Melt Temperature	°C	270
Mold Temperature	°C	80
Maximum Injection Pressure	MPa	155
Injection Volume	cc	87.8845
Packing Time	sec	15 (sec)
Maximum Packing Pressure	MPa	155 MPa
VP Switch by volume (%) filled	%	98 (%)
Mold Opening Time	sec	5 (sec)
Ejection Temperature	°C	140 (°C)
Air Temperature	°C	25 (°C)

Firstly, the geometry of the handle is checked. In fig. 3 is shown the model thickness



**FIGURE 3.** Model thickness



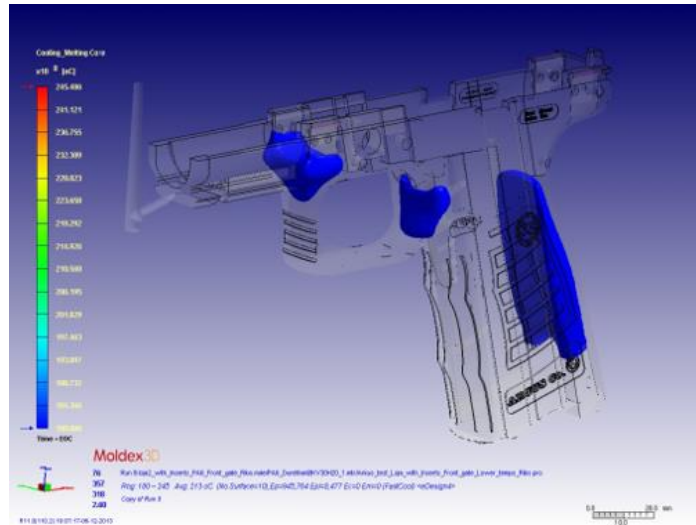


FIGURE 6. Melting core

Polymer material in zones above remains partly melted after cooling which is due to the uneven thickness. Warpage Z-Displacement in Fig. 7 shows total displacement in Z axis direction after the part is ejected and cooled down to room temperature.

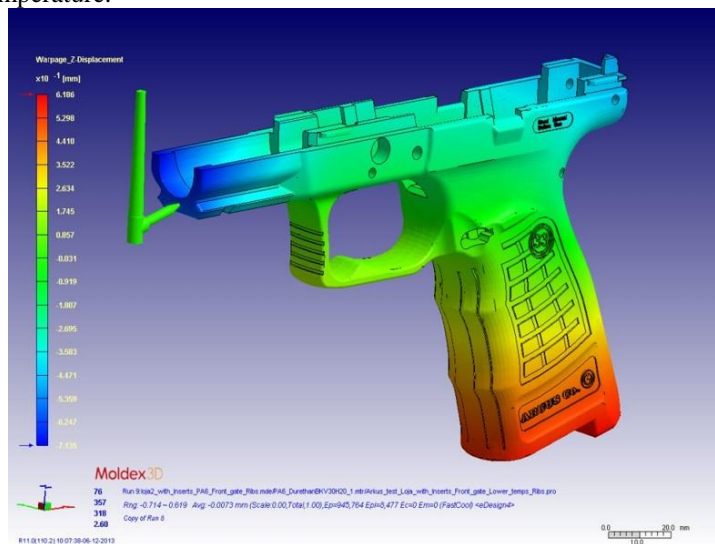


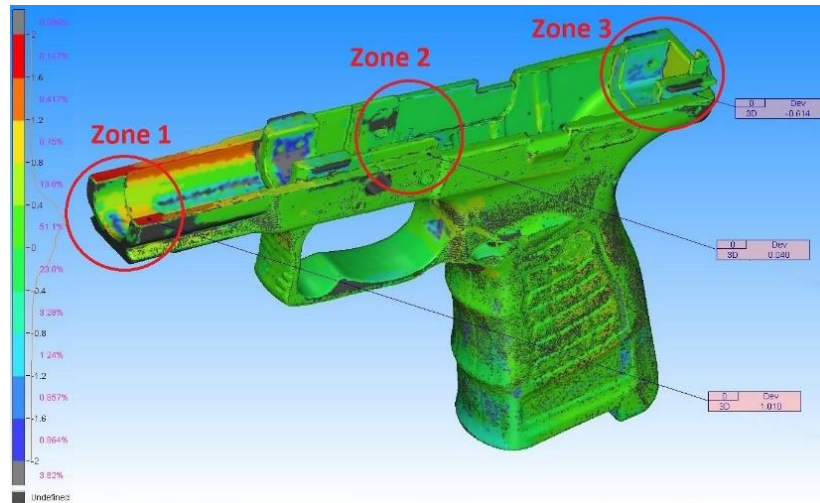
FIGURE 7. Warpage Z-Displacement

### Comperative analysis between virtual prototyping model and a physical model

Based on simulated results provided by Moldex3D, a verification is made with a physical model.

The comparative analysis between virtual prototyping model and a physical model is done by 3DReshaper software. Meshing is done based on point cloud which is brought by non-contact laser measurement device ROMER Absolute Arm 7329 SI.

In Fig. 8 are shown zones with the biggest deviation based on the physical scanned model and virtual simulations.



**FIGURE 8.** Scanned model Z-Displacement

In Table II is shown displacement in Z-axis in three control zones in percentage.

**TABLE 2.** % displacement difference

Parameter	Zone 1	Zone 2	Zone 3
Virtual Prototype	1.01	0.045	0.64
Scanned model	0.9	0.04	0.7
Percentage (%)	11.5%	11.7%	8.9%

## CONCLUSION

There is a high matching between virtual prototype and the physical model.

The result of the study shows that virtual model is highly accurate with the physical model.

Virtual prototypes can be used to predict process issues of newly designed plastic components.

Contemporary 3D scanners allow faster comparison between virtual and physical prototypes.

## ACKNOWLEDGEMENTS

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