Virtual sensor for injection molding process based on physical modeling

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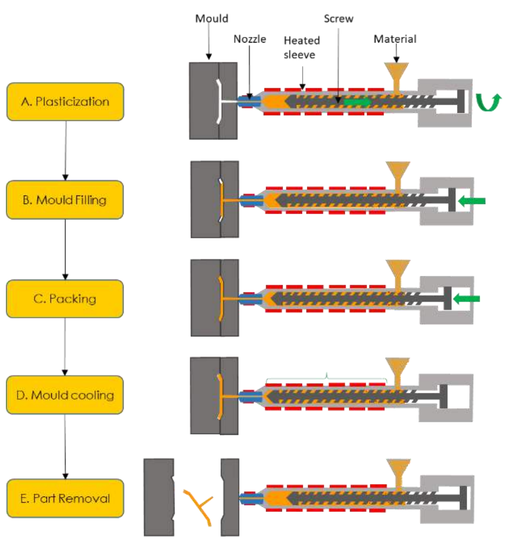
DIMOFAC — Digital Intelligent MOdular FACtories

Objective

In plastic manufacturing, the need for controlled injection molding process is crucial to produce high quality plastic products. Early detection of failure and quality prediction based on process measurement are promising approaches because it allows the correction of process before producing bad parts. When possible in line quality control of the product is set up but it could be costly according to benefit. Indeed, it is not always adapted to mass production such as for multi-cavity tools and often there is no space for new machinery.

Fig 1. Injection molding process



Consequently, prediction of quality from process parameters is an interesting approach. Final part quality depends on process and material history during manufacturing. When sensors are not capable of measurement, we propose to add a virtual sensor based on physical modelling of the process. It enables to take into account thermomechanical physics in order to be as close as possible to the processing behaviour.

Modeling Strategy

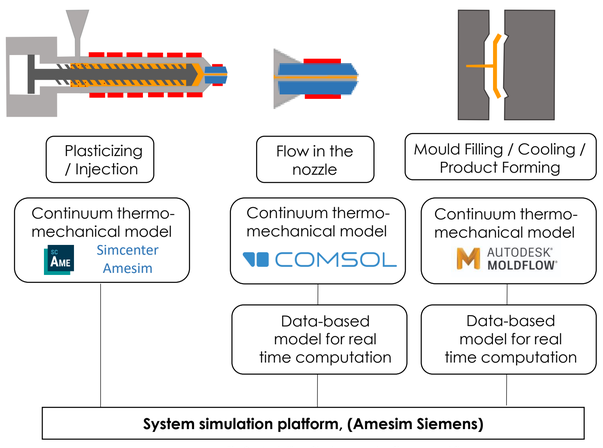
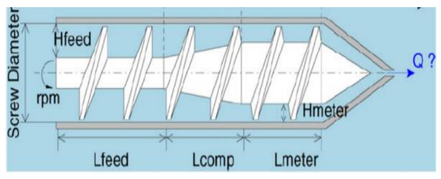


Fig 2. Modelling Strategy and software workflow

Modeling

Plasticising

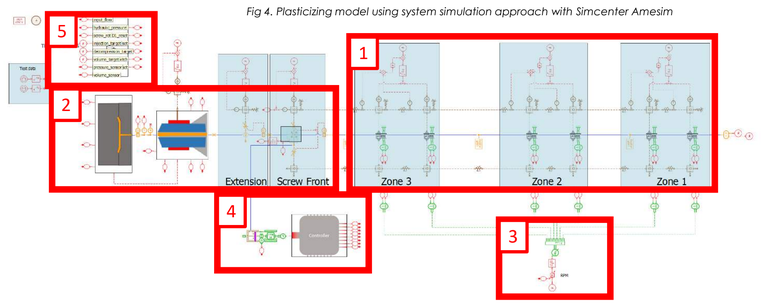
Fig 3. Injection Screw geometry



Béreaux, Charmeau and Moguedet, 2008

To simulate the preparation of molten plastic for injection by accumulating it in the front of the screw and decompression of the accumulated plastic by moving the screw back and letting the prepared dose expande.

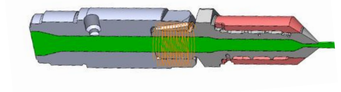
Fig 4. Plasticizing model using system simulation approach with Simcenter Amesim



1- Screw model
2 -Volume Chamber
3 -Rotation Control
4 -Screw Linear Displacement
5 -States Control

Flow in the nozzle

Fig 5. Nozzle Geometry



To simulate the polymer state before entering the mold (temperature, pressure, viscosity and shear).

Fig 6. Mesh

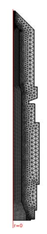
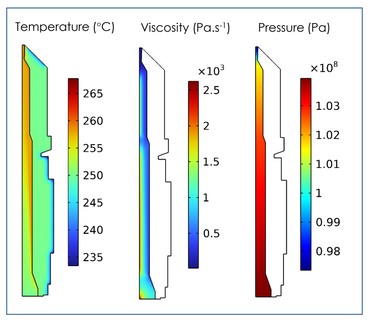


Fig 7. Different results obtained by simulation polymer flow in the nozzle with Comsol



Flow rate →
Pressure →
Pressure Loss →
Shear rate →

Computation time reduction approach to run model within a production cycle (20s)

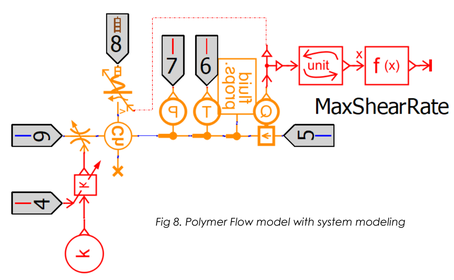
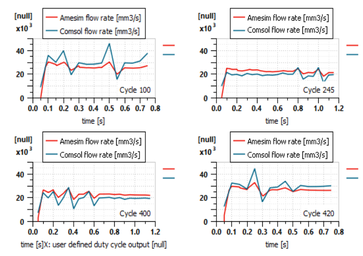


Fig 8. Polymer Flow model with system modeling

Model optimization →

Fig 9. Comparison between Comsol and Amesim resuts after optimization



Molding

To simulate the mold filling, polymer packing and cooling and final part shrinkage

Fig 10. Fill time in mold cavity

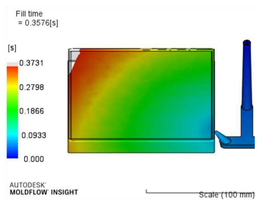
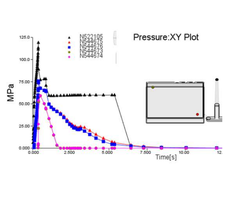


Fig 11. Injection Pressure and pressure on polymer

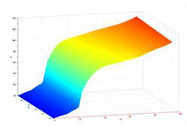


Computation time reduction approach to run the model within a production cycle (20s)

Numerical DOE

Material Tre
Flow rate
Water Tre
→ AUTODESK MOLDFLOW →
Pressure
Screw position
% of Filling
Flow rate

→ Data-based model →



P(Filling, Tcoolant, Tinlet, Filling

→

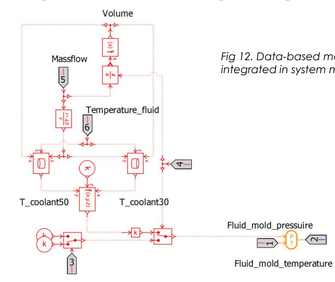
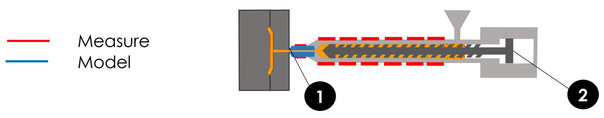
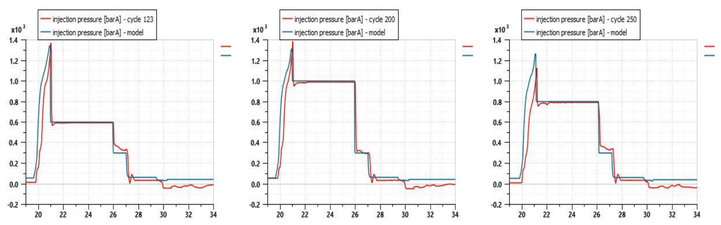


Fig 12. Data-based model integrated in system model

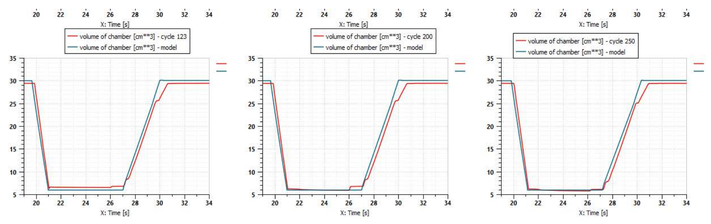
Experimental Validation



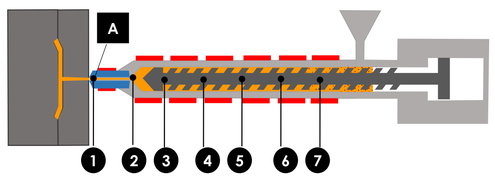
1 Injection Pressure of polymer for 3 process settings



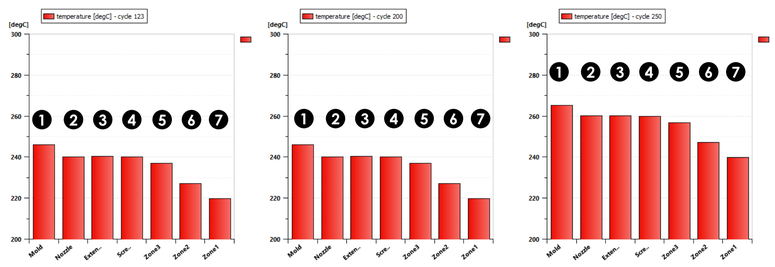
2 Screw position for 3 process settings



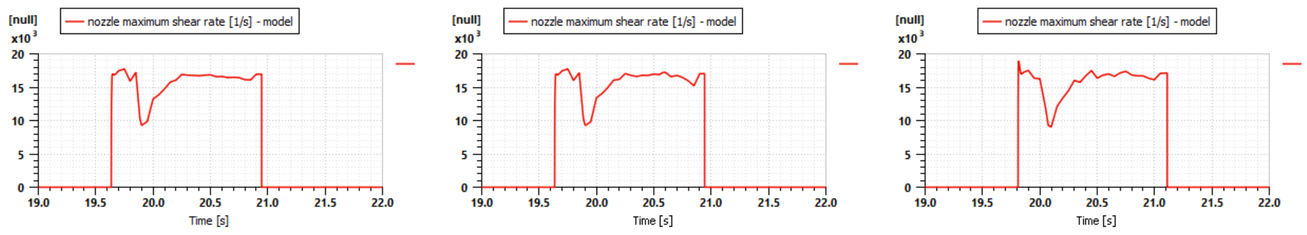
Virtual sensor



Temperature along the screw and in the nozzle



Maximum polymer shear rate in front of the nozzle A



Integration

Integration of the virtual sensor uses Asset Administration Shell. The AAS consists of a series of submodels that describes all the data and functions of a particular asset. In our case virtual sensor is composed of 3 submodels corresponding to input data, output data and execution script. In that way virtual sensor AAS is directly connected to machinery and product via their own AAS. As injection moulding is a cyclic process, the virtual sensor is executed at each cycle and results are stored to be displayed on specific dashboard easily understandable for plastic domain workers.

Conclusion

The physics-based models developed in DIMOFAC to simulate the injection molding process can be combined to compose a virtual sensor. Thanks to their ability to simulate all process steps, provide reliable results and operate in real time for some of them. This model could be used to go further in the control of the process and can be adapted to be a digital twin of the production workcell.

DIMOFAC project received funding from European Union's Horizon 2020 research and innovation program under agreement n° 870092