Introduction

Translator Profile

IPC is the French Technology Transfer Institute dedicated to plastics and composites materials. As such, IPC is in charge of providing the plastics and composites industry cluster with innovative and high added value facilities and manufacturing pilot lines, cutting edge expertise and services. IPC covers the full industry value chain with its key fields of expertise including design and simulation of parts and processes; advanced injection molding and tooling; thermoplastics materials; composites materials; 3D-MID (Molded Interconnect Devices).

Main markets addressed today encompass automotive, aeronautics, health, packaging, connectors, house appliances, horology. Developing new value chains is a key strategic issue with focus e. g. on micro / nanostructured plastic parts, microsystems on plastics; smart composites; multi-materials additive manufacturing.

https://ct-ipc.com/

Client

MOPLA is an Italian SME founded in 1975 and headed by the Savoia family. They produce plastic injection parts, as well as molds and prototypes. MOPLA business mainly deals with products with high quality technical details. Therefore, MOPLA has a great and specific experience in handling production with that degree of details. Such experience has brought to the development – together with a local Software House – of an SPC control software which is now available on the market. This software has constantly been used since 1982 to certify the quality of the parts.

http://www.mopla.it/default.htm

IPC and MOPLA were partners into the FP7 MOLD4PRODE project.

Industrial/Business Case

Injection molding is the most widely used polymer processing method to manufacture plastic parts. This cyclic process can be defined in four essential stages: cavity filling, melt packing, part solidification and then ejection. A large part of the total time of the process is dedicated to the part cooling. That is why cooling system have to be design with carefulness.

Many defects such as warpage, shrinkage, thermal residual stresses, sink marks originates in a flawed design of the regulation system or unbalanced cooling. From an economical point of view, an efficient process can particularly be achieved through fast heat removal. Quality and productivity are often two conflicting objectives that optimization procedures can solve. Optimization has been used to determine optimal cooling conditions which minimize undesired effects.

MOPLA needs are directly related to this context. A molding tool use to produce body actuator parts came to its end of life. So the objectives were to develop a more efficient version of the tool regarding productivity and quality using laser melting technology.

Figure 1. Body actuator

Two quality criterion are defined. The planarity defined on Figure 2 insures the positioning of the part. The target defines in the product specification is a defect of 0.2 mm. The second criterion is the perpendicularity of the shortest cylinder axis with the bottom of the part. Perpendicularity defect influences noise and energy consumption. It has to be under the value of 0.15 mm.

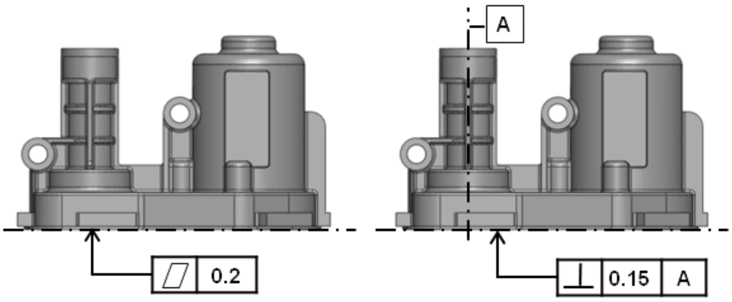

Figure 2- Part quality criteria

MOPLA came to see us only for our additive manufacturing facilities and a CAD work. We proposed him to use modelling to optimize the design for 2 reasons:

- For us, it was to validate on new approach of thermal design optimization on more cases
- For him, it was to improve design to increase productivity and quality

To convince him, we use:

- Technical argument: we showed him previous use cases (success stories)
- -Economical argument: we made an arrangement on the cost dedicated to the modelling task

Total MOPLA investment was related to the mold insert design including modelling and the manufacturing overcost of using laser melting to manufactured some parts of the new mold. That represents an amount of €10,000.

The translation process helps in

- designing a new cooling system in injection molding mold
- identifying the best location for cooling channel
- understanding heat transfer in metal during in-service behavior

Translation to modelling solution

Translation is based on an in-house modelling methodology to help designing cooling system for injection moulding. This methodology is original and has no equivalent in literature. It is illustrated in Figure 3.
In addition, we could also have modelled fluid dynamics into the channels and mechanical resistance of the mold but, according to our experience, it was not necessary.

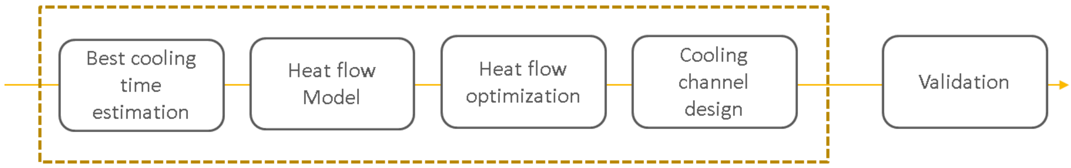

Figure 3- Modelling Workflow

Modelling strategy
The workflow that has been developed is based on the modelling of heat flow in the plastic part and the injection mold. Heat flow model has been used firstly to estimate the cooling time of the part and, secondly, to calculate the temperature fields in the mold and in the part. The main assumption of this continuum model lays in the fact that the phase change kinetics of the polymer is considered independent of thermal history of the material. Then, modelling is simplified and kinetics coupling is avoided. The problem remains nonlinear due to the dependence of the specific heat to the temperature. To model a non-perfect contact between the mould and the polymer and the resulting temperature jump, a thermal contact resistance is introduced at the interface. The cyclic aspect of the injection moulding process is taken into account through periodic conditions.

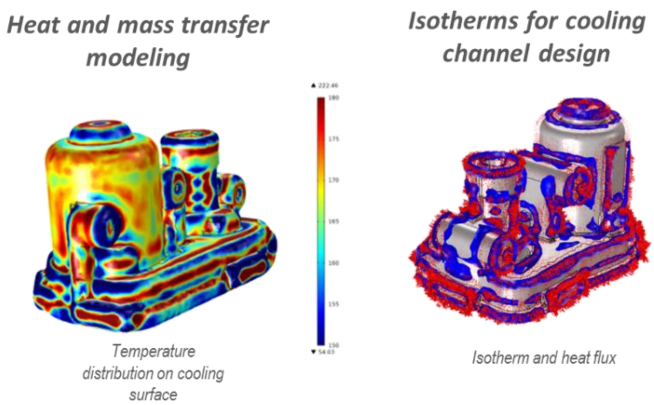

Figure 4 - Heat flow results

The cooling channel position is deduced from a bi-objective optimization strategy to determine the distribution of coolant temperature into the mold. The optimization strategy was achieved thanks to the minimization of the cost function by means of a gradient method. The cost function represents a weighted combination between the cooling efficiency and the fact that the part is uniformly cooled. Indeed, it is supposed that a uniform temperature along the part surface highly reduced deflection through warpage and shrinkage

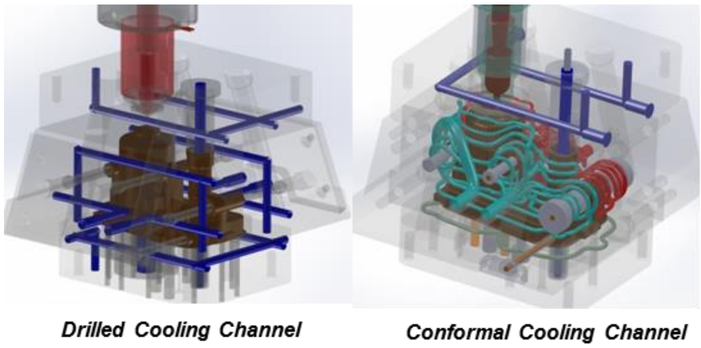

Figure 5 – Comparison in cooling channel design: former mold with drilled cooling channels and new mold with conformal cooling channels

Validation
To validate efficiency of the new version of the mold cooling channels, simulation of injection molding process have been performed in order to compare the effect of each cooling channel design regarding cycle time and quality criterion.
The mold has been tuned and tested before being send to production plant. A 42 s cycle time has been obtained that represent a decrease of 36% compared to the former mold. Some parts manufactured during that step had been sent to metrology to measure perpendicularity and planarity criterion.
All numerical and experimental data are sum up in Table 1.

		Drilled cooling channels		Conformal cooling channels		Outcome
		Production	Numerical	Production	Numerical	Production
Productivity	Cycle time[s]	66	64	42	42	-36%
	Cooling time [s] (Packing included)	50	50	32	32	-35%
Quality	⏥ [mm]	0.48	0.13	0.25	0.13	- 48%
	⊥ [mm]	0.30	0.32	0.18	0.29	- 40%

Table 1 - Numerical validation compared to production data and final outcome

Client's benefits from the modelling

Direct benefit:
Direct benefit is related to the reduction of the cycle time that have impact on the product cost.

Annual product quantity to be produced	400 000
Life time of the mold	4 year
Gain on the product cost	0.03 €
Direct Benefit	**48 000 €**

Indirect benefit

Optimisation of the regulation channels enables a reduction in the thermal inertia of the mold. Then production set up has been improved and sped up. Benefit is related to a better tuning and a decrease in the number of set up.
Another indirect benefit relies on the enhancement of the product quality but it has not been quantified.

Cost of a set up	3000 €
reduction of number of set up	3
Indirect Benefit	**9000 €**

Total ROI

Direct benefit	48 000 €
Indirect Benefit	9000 €
Investment	10000 €
ROI	**4,7**

Evaluation of the translation case

The main challenge encountered in the translation process is to include a modelling step inside a product design workflow without delay in the logistic chain. That is why modelling was adapted to time to market needs in term of deadline and budget.

The overcost generated by modelling needed to be explained clearly to the client and a ROI needed to be estimated before the work.