Development of Standardized Efficiency Indicators for Plastic injection Moulds

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Abstract: Operational Efficiency, a ratio between input and output of a business, was adapted in this study to Injection Moulding process in order to create the Standardized Efficiency Indicators for Plastics Injection Moulds. The proposed indicators regards to mass and energy consumption. The input, the minimum amount of resources required, was named Baseline, and the output, the real amount of resources consumed, was named Actual Value. The values used in the calculation of the Baseline are based on theoretical and empirical knowledge. The values used in the calculation of Actual Value are obtained from injection moulding simulation software. To calculate the Baseline’s and Actual Value’s energy consumption is used an energy consumption model. To use the model is created an injection moulding machine databases in order to obtain a standard installed power/clamping force equation. The Standardized Efficiency Indicators aim is to compare moulds with different design alternatives and parts with different sizes. Sensitive analyses were performed to material variation and number of cavities. With the results obtained were developed and proposed classification labels for moulds.

Keywords: Injection Moulding; Operation Efficiency; Standardized Efficiency Indicators; Design Mould Alternatives; Mould Label;

1. Introduction

Nowadays companies want to stay competitive while reducing the environmental impact of processes and products, therefore they are realizing the financial and environmental benefits of practising sustainable manufacturing. Coupled with the concept of sustainability, methodologies like Life Cycle Assessment, Eco-efficiency, Eco-Design etc. have emerged and become the main evaluation and decision tools for process and products development focused on resource efficiency. It is mandatory that these processes become more and more resource efficient in order to be sustainable and to guarantee the desired competitiveness level.

In this thesis the concept of operational efficiency is applied to formulate the Standardized Efficiency Indicators for Plastic Injection Moulds. Injection moulding process is a manufacturing process with great prominence in the processing of polymers materials. The mould is the main tool that shapes the part to be produced. Therefore the design and the quality of the mould are very important to ensure that the consumed resources are minimized and a cyclic reproduction of plastics without defects.

To improve the efficiency of injection moulding process efforts are made to reduce the cycle time and improve the cooling, in order to produce products with quality and increase productivity.

Depending on the part to produce and on the company production volume required, the design mould alternatives can be more or less advantageous. With the several engineering solutions available for mould design, it is important to know what the best suited choice for a particular part is. The main issue is how injection moulding companies can compare moulds and moulds’ efficiency, from different potential suppliers. With the lack of a decision tool, it is pertinent to develop a metric that attempt to classify moulds, making their comparison fair, comprehensive and accurate as possible.

The Standardized Efficiency Indicators methodology are proposed in order to compare the performance of different mould designs in the injection moulding process, regarding three main aspects: mass and energy consumption, related with resources efficiency; and execution time, related with productivity. The efficiency is calculated using simple ratios between the minimum input required to accomplish the process (Baseline values) and the real or expected actual time and resources consumed (Actual value). The minimum process resources consumptions are estimated by empirical and theoretical models and the actual values can be estimated by
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numerical simulation of injection moulding (or real industrial data if available). The aims of this thesis are to propose and validate the concept behind these indicators, to assess if they can be used in the future as a standard to characterize the performance and efficiency of the injection moulds.

As an application case for the developed indicators, three plastics parts were designed with different dimensions. For each part, four mould design alternatives were considered to analyse two types of feeding system and two types of cooling systems. Additionally a sensitivity analysis to the material and to the number of cavities variation was performed.

2. Proposed Methodology
In injection moulding one of the main goals is to reduce the total cycle time, in order to increase productivity and reduce production costs. Every part design requires a different mould and even for the same part the mould can be different in terms of the design of the feeding and cooling channels, among other design features. The different possible designs of the channels across the mould influence the performance of the process and by consequence the part quality [1].

Aiming to evaluate the efficiency of the process regarding energy and material consumption in different mould designs and in different moulds sizes, Standardized Efficiency Indicators are proposed in this thesis.

The formulation of Standardized Efficiency Indicators it is based on the concept of operational efficiency. Operational efficiency is a ratio between the input and output of a business [2]. Once the matter of study in this thesis is a manufacturing process and not a business the inputs and outputs are defined as follows.

The input is defined as a minimum amount of a certain variable (resource) required for the injection moulding process that from now on is called Baseline. The Baseline concept intends to represent the amount of variables that would be required in an ideal process. Therefore all values assumed in the calculation of the Baseline are based on theoretical and empirical knowledge.

The output is the actual value of material or energy consumed in the process. This amount can be obtained directly from the production system (part injection moulding industrial data) or as done in this thesis, through injection moulding simulation software. To apply this concept was defined a Case Study.

To calculate the energy consumed for the Baseline and for the Actual Value the energy consumption model proposed by Ribeiro et al.[3] is used. Regarding material consumption the Mass Baseline is calculated based on theoretical and empirical knowledge and the actual value is obtained from Simulation Software.

2.2 Case Study
The Case study objective is to assess the influence of the design characteristics of the mould along with the variation of the parts size. To analyse the influences of each type of feeding and cooling system it was defined a geometry similar to a cup with three dimensions, in polypropylene PPC 3120 MU5, from TOTAL Refining & Chemicals, with 2 mm of thickness each. The geometries are denominated as Part1, Part2 and Part3 (Figure 1). Their dimensions varies proportionally (Table 1).

![Figure 1 Parts](image)

<table>
<thead>
<tr>
<th></th>
<th>Part 1</th>
<th>Part 2</th>
<th>Part 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>h [mm]</td>
<td>50</td>
<td>50</td>
<td>500</td>
</tr>
<tr>
<td>d_B [mm]</td>
<td>27.44</td>
<td>2.32</td>
<td>274.39</td>
</tr>
<tr>
<td>d_T [mm]</td>
<td>42.68</td>
<td>28.05</td>
<td>426.83</td>
</tr>
</tbody>
</table>

Table 1 Parts Dimensions

To obtain the variables and parameters of the process for Actual Value, Software Moldflow Insight was used. For each part four design mould alternatives are analysed (Table 2). The Engineering Solutions regarding feeding and cooling system, were matched resulting in the total in 12 alternatives, so 12 Actual Values. Further
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ahead will be referred using the nomenclature presented in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Cold runners</th>
<th>Hot runners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1,2,3 (CN)</td>
<td>1,2,3 (HN)</td>
</tr>
<tr>
<td>Conformal</td>
<td>1,2,3 (CC)</td>
<td>1,2,3 (HC)</td>
</tr>
</tbody>
</table>

Table 2 Design Mould Alternatives

In Figure 2 the approach to the development of Standardized Efficiency Indicator is summarized.

3. BASELINE

3.1 Mass Baseline

The mass baseline is calculated through equation (2), where \( V \) is the volume of the part and \( \rho \) material density.

\[
m = V \times \rho \quad (2)
\]

The mass baseline is the minimum quantity of material required to produce a part without accounting with the feeding system.

3.2 Energy Baseline

As mentioned before the energy is calculated using the energy consumption model proposed by Ribeiro et al.[3]. The Total Energy is the sum of the Thermodynamic Energy with the Energy Consumption of the injection machine.

The Thermodynamic Energy is the energy needed to melt the raw plastic material that is injected. The energy consumption of the injection moulding machine includes the machine and part specifications. The Total Energy is given by equation (3), the Thermodynamic Energy is given by equation (4) and the Machine Energy is given by (5).

\[
E_{\text{total}} = E_{\text{thermo}} + E_{\text{machine}} \quad (3)
\]

\[
E_{\text{thermo}} = mc_p (T_{\text{melt}} - T_{\text{ambient}}) + \lambda mH_F + pV_{\text{inj}}
\]

\[
E_{\text{mach}} = C_f M (C_f P \times P_{\text{inst}}) \frac{t_c}{C_f T} \quad (5)
\]

The values used to calculate the Thermodynamic Energy derived from the material properties and from the part characteristics. The Machine Energy, equation (5), depends on Model Coefficients, on the Installed Power and on the Cycle Time of the process. In order to estimate a theoretical cycle time for each part, the cycle time is defined as the sum of: injection + cooling + open/close times times.[4][5].

**Determination of cycle time**

**Injection time**

The injection time, time in which the material is injected in the cavity mould, is estimated by equation (6) as reported by [4].

\[
t_{\text{fill}} = \frac{2V_{\text{cavity}}}{Q_{\text{max}}} \quad (6)
\]

\( Q_{\text{max}} \) is the maximum flow rate of the material from the nozzle. To find the value of the maximum flow rate, it’s required the selection of a machine available on the market with the nearest installed power regarding the theoretical value. The theoretical installed power, \( P_{\text{inst}} \), is determined by the linear regression equation that relates the installed power of the machine and its clamping force, Figure 3.

![Figure 3 Installed Power vs. Clamping Force - ENGEL MACHINES][1]

The clamping force required for each part is given by equation (7) according [1], where the \( P_{\text{inj}} \) is the injection pressure and \( A_{\text{proj}} \) is the projected area. The projected area was calculated using equation (8).

\[
y = 0.1585x + 19.771
\]

[1]: https://example.com/figure3.png
Clamping Force \( = A_{proj} \times P_{inj} \) \hspace{1cm} (7)

\[ A_{proj} = \pi r_t^2 \] \hspace{1cm} (8)

As mentioned by [8] the clamping force required for PP is 2 to 4 tonnes per square inch of projected area. So 2 tonnes per square inch were assigned to the smallest part, 3 tonnes per square inch to the medium part and 4 tonnes per square inch for the biggest part.

In equation (9) the \( x \) is the Clamping Force and \( y \) is the installed power.

\[ y = 0.1585x + 19.771 \] \hspace{1cm} (9)

Though equation (9), replacing the \( x \) with the value of the Clamping force, the value of the installed power is determined. With the value of installed power is possible to select a machine available on market that best suits the installed power and clamping force calculated. From catalogues or databases of machines is it possible to find the maximum flow rate of the material from the nozzle for the selected machine.

Cooling time

The cooling time, is the most relevant time of the total cycle time. Since the concept of baseline is the minimum amount of the variables, the cooling time to take into account is the cooling time for hot runners that minimizes the cycle time. The equation (10) allows to calculate the cooling time for hot runners. The set of temperatures needed to calculate \( Y \) depends on the selected material. The \( s \) is the part thickness, \( \alpha_{ef} \) is the thermal diffusivity and \( k \) is the thickness coefficient of the part and is given by equation 11.

\[ t_{cooling} = \begin{cases} \frac{s^2}{\pi \alpha_{ef}} \ln(kY), & \text{hot runners} \\ \frac{D^2}{23.14\alpha_{ef}} \ln(0.692Y), & \text{cold runners} \end{cases} \]

\[ Y = \frac{T_{inj} - T_{mould}}{T_{est} - T_{mould}} \] \hspace{1cm} (10)

\[ k = \begin{cases} \frac{4}{\pi} & \text{if } s \leq 3 \text{ mm} \\ \frac{8}{\pi^2} & \text{if } s > 3 \text{ mm} \end{cases} \] \hspace{1cm} (11)

Mould open/close time

Mould open/close time is the time that wherein the mould opens to eject the part and then closes to a new injection cycle. Mould open/close time can be estimated through equation (12) according [4].

\[ t_{open/close} = 1 + 1.75 \times \left( \frac{L_{stroke}}{L_{stroke \ max}} \right) t_d \] \hspace{1cm} (12)

\( T_d \) is the dry cycle time of the machine and \( L_{stroke} \) is the opening stroke of the machine. The dry cycle time and \( L_{stroke} \) are obtained from the catalogue for the selected machines.

Determination of the coefficients

CfM- Machine Type Coefficient

- Electric vs. Hydraulic

For the Case Study it was assumed that the machines are Hydraulic, so the CfM=1

CfPe- Machine Power Coefficient

\[ CfP_e = \frac{P_{therm}}{P_{inst}} \times 1.5079 + 0.084 \] \hspace{1cm} (13)

The theoretical installed power, \( P_{inst} \), is calculated through equation (9). The calculation of thermodynamic power, \( P_{therm} \), is given by equation (14),

\[ P_{therm} = \frac{E_{therm}}{1000 \times t_c} \] \hspace{1cm} (14)

where \( t_c \) is the cycle time for each part previously calculated and Thermodynamic Energy values are the ones calculated according equation (4) also for each part.

CfT- Thickness Coefficient

The thickness coefficient is given by the following equation, where \( s \) is the thickness part.

\[ CfT = 0.0884 s + 0.7629 \] \hspace{1cm} (15)

With all coefficients, installed power and cycle time values it is possible to calculate the machine energy for each part, equation (5) and finally the total energy, equation (3).

3.3 Actual Value

Like the Baseline the Actual Value for Mass and Energy Consumption are calculated. The variables and parameters of the process required to calculate the Actual will be obtained from injection moulding simulation software Moldflow Insight.

Each part and design alternatives will be simulated on Moldflow Insight. Through Moldflow results and log files it is possible to obtained the mass, cycle time,
clamping force, the injected volume, the injection pressure etc. These parameters and variables will be used to calculate the energy consumption, using the same energy model used in the Baseline (Equation 3). The material properties required to the energy model are taken from Moldflow Database’s. Beside the processing conditions and parameters of the process, the characteristics of the part are also provided by Moldflow analysis.

In the calculation of the machine energy, the value of the installed power will be a real installed power, from a machine available on market (Table 3) and not the theoretical value as used in the Baseline.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Clamping Force [ton]</th>
<th>Total Power [KW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engel DUO 23050/2000</td>
<td>2000</td>
<td>334</td>
</tr>
<tr>
<td>Engel DUO 16050/1700</td>
<td>1700</td>
<td>283</td>
</tr>
<tr>
<td>Engel DUO 16050/1500</td>
<td>1500</td>
<td>274</td>
</tr>
<tr>
<td>Engel DUO 16050/1500</td>
<td>1500</td>
<td>239</td>
</tr>
<tr>
<td>Engel DUO 11050/1300</td>
<td>1300</td>
<td>204</td>
</tr>
<tr>
<td>Engel DUO 11050/1000</td>
<td>1000</td>
<td>199</td>
</tr>
<tr>
<td>Engel DUO 5550/900</td>
<td>900</td>
<td>163</td>
</tr>
<tr>
<td>Engel DUO 7050/800</td>
<td>800</td>
<td>149</td>
</tr>
<tr>
<td>Engel VC 3550/600 Tech</td>
<td>600</td>
<td>143</td>
</tr>
<tr>
<td>Engel 600 HL-V</td>
<td>600</td>
<td>115</td>
</tr>
<tr>
<td>Engel VC 3550/350,400</td>
<td>400</td>
<td>104</td>
</tr>
<tr>
<td>Engel VC 2550/400 Tech</td>
<td>400</td>
<td>89</td>
</tr>
<tr>
<td>Engel 300 HL-V</td>
<td>300</td>
<td>73</td>
</tr>
<tr>
<td>Engel 300 HL-V</td>
<td>300</td>
<td>64</td>
</tr>
<tr>
<td>Engel VC 1350/300 Tech</td>
<td>300</td>
<td>66.3</td>
</tr>
<tr>
<td>Engel VC 1800/260</td>
<td>260</td>
<td>62.3</td>
</tr>
<tr>
<td>Engel VC 1050/180 Tech</td>
<td>180</td>
<td>46.3</td>
</tr>
<tr>
<td>Engel 150 HL-V</td>
<td>150</td>
<td>48</td>
</tr>
<tr>
<td>Engel VC 650/120</td>
<td>120</td>
<td>37.3</td>
</tr>
<tr>
<td>Engel VC 650/120</td>
<td>120</td>
<td>35.3</td>
</tr>
<tr>
<td>Engel VC 650/110 Tech</td>
<td>110</td>
<td>31.8</td>
</tr>
<tr>
<td>Engel VC 330/80 Tech</td>
<td>80</td>
<td>24.2</td>
</tr>
<tr>
<td>Engel 75 HL-V</td>
<td>75</td>
<td>22</td>
</tr>
<tr>
<td>Engel 45 HL-V</td>
<td>45</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 3 Machines Available on Market – ENGEL [6] [7]

4. Alternative Mould Design Solutions

4.1 Influence on performance

The mould is the main tool of injection moulding process. The mould may have several cavities and it may vary in amount of the various constituent elements and their arrangement. The mould has feeding and cooling systems that are constituted by several elements and channels. The variants of feeding and cooling systems influence the quality part and the process itself. The part geometry, the part material and the quality required, delineate and guide the design of the mould.

The feeding system can be with cold runners or hot runners. Cold runners system can accommodate a wide variety of polymers and allows quick colour changes. The removal of the feeding system usually leaves a mark on the part. With cold runners there is a waste of plastic. In a cold feeding system the cooling time is dependent on the cool of the runners because the runners’ thickness is bigger than the thickness of the part. So even if the part is already frozen, it only can be ejected when 50 % to 80 % of the runners are frozen.

In hot runners system the material stays melted, keeping a balanced melt flow at a constant temperature throughout all the system to fully fill and pack the cavities [9]. Hot runners allows to take full advantage of the highly accurate cavities and therefore plastic parts can be produced with great dimensional accuracy and quality [9]. Hot runners are adequate for medium and large part volumes [10]. Usually with hot runner systems are used lower injection pressures, which will reduce the mould deflection. With hot runners system there is no wasted material and isn’t necessary an additional operation to remove the runners.

The design of the cooling system is a very important step in mould design. The cooling phase influences significantly the quality of the part and the productivity. A conformal cooling system can improve the efficiency and quality of the production comparatively to the conventional cooling [11][12].

4.2 Modelling Mould Design Alternatives

Modelling in Moldflow requires knowledge about the injection moulding process. It is important to know the different phases of the process, the parameters and the processing conditions. The Figure 4 is an overview of the analyses and tasks performed in Moldflow Insight software for the three parts. In this overview are also included the results of each analysis that were checked, improved and validated according the parameters and the processing conditions ranges.
In Figure 5 are presented the two types of cooling systems designed, as example, and in Figure 6 are presented two of the several results that were checked (Figure 4) in the modelling of the parts. The parameters obtained from Moldflow required to calculate the Actual Value are the following: part mass, the injection pressure, the injected volume, the cycle time and the clamping force.

5. Standardized Efficiency Indicators

With the values of Baseline and Actual Value were calculated the Standardized Efficiency Indicators regarding mass and energy consumption.

5.1 Mass Indicator

The Mass indicator is calculated with equation 16 (Figure 7). The indicator is calculated for the three parts, for the four design mould (Table 2).

\[
\varepsilon_{mass} \% = \frac{\text{Mass Baseline}}{\text{Mass Actual Value}}
\]
The efficiency of hot runners systems is over 100%, so the mass baseline is higher than the actual values. This result is justified by the final part volume. When the parts are ejected they are at a temperature that allows ejection but not necessarily at the ambient temperature, so the part continues to cool and volumetric shrinkage occurs. This volumetric shrinkage represents the decrease in local volume, so the parts simulated on Moldflow have smaller volumes and by consequence smaller mass values. The model parts should have a bigger volume to compensate this volumetric shrinkage.

Comparing the three parts, it is possible to affirm that the material efficiency isn’t drastically affected by the dimension of the part. The range of efficiency values is similar for the three parts. To notice that using cold runners system in Part3, the efficiency decreases a little bit, so it wastes more material than the others. The Mass Efficiency Indicator distinguishes the efficiency of cold runners to hot runners as expected. For a part with big dimensions, like Part3, efforts should be made to improve the feeding system in order to minimize the waste of material.

5.2 Energy Indicator

The Energy Indicator is calculated with equation (17) (Figure 8). The indicator is calculated for the three parts, for the four design mould (Equation 17).

\[
\varepsilon_{\text{energy}} \% = \frac{\text{Energy Baseline}}{\text{Energy Actual Value}} \quad (17)
\]

Was assessed the contribution and evolution of the Thermodynamic and Machine Energy in the Total Energy along the three parts, either for Baseline and Actual Value (Figure 9).

5.3 Material Variation

The aim of this assessment is to analyse how the Standardized Efficiency Indicators behave for different materials. This assessment was performed only in Part1, because the results would be similar for the other parts. Four thermoplastics were defined, two of them semi-crystalline, PP and Polyamide 6 (PA6) and the others amorphous, Polystyrene (PS) and Polycarbonate (PC).
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5.4 Cavities Assessment

In this assessment moulds with different number of cavities regarding their energy consumption are compared. As analysed before, the cycle time is the variable that controls the machine energy, so is proposed a sub indicator related to time (Equation 18). Regarding the Thermodynamic Energy it is expected a linear behaviour increasing with the number of cavities since the Thermodynamic Energy depends on the mass and injected volume.

\[
Time\ Indicator(\%) = \frac{Time\ per\ part}{Cycle\ time}\ 
\]

(18)

This indicator measures the times that a mould with more than one cavity is faster relatively to a mould with a single cavity.

The Energy Indicator is very sensitive to the selection of the machine, specifically regarding the clamping force value. In the Baseline the empirical and scientific range used for the clamping force doesn’t consider the part dimensions. Therefore there isn’t a criteria that relates the clamping force with the part’s dimensions, being the Baseline Clamping Force higher than the Actual Value Clamping Force.

6. Proposed Methodology for Standardized Efficiency Indicators

The Figure 15 is an overview of the energy model, applied to the Baseline and to the Actual Value. In the scheme is also presented the required inputs, and shown which ones differs from Baseline to the Actual Value.

Through the calculated Indicators and performed analysis were elaborated mould labels that characterize the performance and efficiency of the injection moulds. This labels are a suggestion how the results of the methodology may be presented and used as a future standard (Figure 14).

![Figure 11 Energy Indicator for each material](image1)

![Figure 12 Time Indicator](image2)

![Figure 13 Energy Indicator](image3)

![Figure 14 Mould Label- Cavities comparison](image4)
5 Conclusions

This work was performed in order to develop Standardized Efficiency Indicators for Plastic Injection Moulds. The proposed Standardized Efficiency Indicators are calculated using simple ratios between the minimum input required to accomplish the process (Baseline values) and the real or expected actual time and resources consumed (Actual value). These indicators allow the comparison between different types of mould design, different mould sizes, different number of cavities and the efficiency of the mould for different polymers.

The Standardized Efficiency Indicators are in regard to mass and energy consumption, related with resources efficiency; and execution time, related with productivity. For the energy consumption estimation a published energy model was used. To use this energy model was necessary to elaborate an injection moulding machine database with available machines on market, to establish a linear equation that relates the machine Installed Power with the machine Clamping Force. In a future use of the Standardized Efficiency Indicators, this machine database should be updated according the machines available on market.

For the defined Case Study, first was analysed the Mass Efficiency Indicator. Through this indicator it was noted that cold runners have lower mass efficiency than hot runners, as expected, due to the material that is wasted in the feeding system. Between the cooling systems, the differences were very small, being the conformal system more efficient. Regarding the dimensions of the part, it was observed that the dimensions do not drastically influence the Mass Efficiency.

Some Mass Efficiencies were above 100% due to the final part volume being smaller than the value calculated on Baseline. This result is caused due to the fact that volumetric shrinkage was not considered in the initial part design, as is usual in every mould design process. If the shrinkage effects are considered, this indicator will be only a measure of the wasted material in each shot.

For the Energy Efficiency Indicator analyses, the total energy was divided in the Thermodynamic Energy and Machine Energy. By going backwards on the energy model was identified that the Machine Energy is the
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predominant energy, and the variable that influences it is the Cycle Time.

In the Materials assessment, the comparison of the Baselines allowed to understand that each material has its own level of mass and energy consumption, depending on the materials properties. Once again in the Energy Efficiency Indicator analysis, the Cycle time is a variable that greatly influences the efficiency. When is intended to compare moulds with different design alternatives the material should be the same, once the material conditions the level of mass and energy consumed.

Regarding the Cavities assessment, was calculated the energy per part of the several moulds concluding that with the increase of the number of cavities, the energy per part decreases. The proposed Time Indicator allows to measure the times that a mould with more than one cavity is faster relatively to a mould with a single cavity. In this assessment it was analysed that the variable that influences Energy Efficiency the most is the selection of the machine in the Baseline and in the Actual Value, depending on the Clamping Force defined for Baseline and obtained from the simulation, for the Actual Value.

In the several assessments performed some fluctuations values were negative, which indicates that the Baseline is higher than the Actual Value. This occurred for some values of injection pressure and clamping force. To improve these results it is recommended a review and a more extensive research of information regarding the material properties and processing conditions for the Baseline, to better adjust the available ranges of values to the part sizes.

Finally the proposed labels gather and relate the several studied Standardized Efficiency Indicators, representing how the indicators can by implemented in moulds. A data collection during the testing mould phase, allows that the final Standardized Efficiency Indicators Label is

References


