Environment of Flexible Machining - Tests on the Shop Floor in Order to Minimize Setup Times

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Abstract
In 2008, during the EngOpt in Rio de Janeiro, the authors presented a paper proposing an appropriate model to reduce the setup of tools in an environment of flexible machining. Was understood as flexible machining, the production schedule with batches of small number of pieces of different materials and geometries from one to other batch. The proposed model was tested only by simulation data which were not from the real world of industry. Through simulation, many issues that could arise from the practice of the machining process in manufacturing environment were impossible to predict. The main question to be answered that depends on the practical application of the optimization model on the shop floor is the way in which the cutting process parameters and predict tool life should be selected from the tool manufacturer’s catalog. In addition, the model predicts that the cutting edge tool life informed by a catalog for the parts to be produced in a small batch is used to estimate the life of other parts of the other batches. Besides, these and other aspects related to the difficulty of validating the optimization method only by simulation, the model itself has undergone changes that mean an upgrade version. All these aspects were partly known, but were completely cleared after a first set of preliminary tests that were performed during the parts cutting process evolution in shop floor. Not only in aspects using catalog, but mainly because of the difficulties in finding the initial machining conditions for achieving full implementation of the model. The purposes of this work is analyze and eventually provide any need modification of the optimization model already developed by the authors in previous work and then validate the more recent one using data taken from practical application in shop floor of an industry that works behind the context of flexible machining.

Keywords: Flexible Machining; Presetting; Optimization.

Introduction
The authors have been working with the optimization of cutting process for some years. Studied this task is not as easy as it could sounds. They noted that tools manufacturers are called by their customers to optimize their machining processes. However, it should be noted that this optimization procedure occurs in manufacturing plant and manufacturer of tools will be based on actual data to perform this optimization. Unfortunately in these cases, the commercial interest negatively influences the results, because the tool manufacturer is interested in selling your products and not to seek further the optimized parameters of the process. This procedure is not actually incorrect, because the industries have to earn profits. Fortunately, there are researchers to examine these issues without the need for concern about the immediate financial aspects, except when the subject is part of ongoing research.

Inspired by the behavior of the tools manufacturers mentioned before, the authors decided to opt for optimization models that were validated with data extracted directly from the shop floor in real time with the production of parts by machining.

In the particular case of flexible machining, development of optimization models is even more challenging [1]. Better understand the challenge of flexible machining has been the target of other researchers. Boyle and Scherrrer-Rathje [2] proposed an empirical way to better examine the problems related with flexible manufacturing. This is because to have been statistically reliable data directly from the shop floor, it is required a reasonable number of identical parts to be produced, representing an adequate sampling [3].

This is a situation almost impossible to occur, because during the planning of a typical flexible machining workday, normally is scheduled several batches of a small number of parts each. In the limit it can be only one.

To attend this scenario the authors identified the following possible situations:

a) optimize the cutting parameters that influences the cutting time. Try to reduce non-productive time by applying concepts of lean manufacturing. This option would require tests to determine the each tool life and its respective size of each lot. This would be impossible to be applied in the industry, because it would be need, for the industry, operate as a laboratory. When the number of parts per batch is large,
the authors have developed models and operational support systems which are presenting good solutions already [3];

b) reduce the presetting time: In this case it will be need to find solutions with greater flexibility to reduce the presetting time. This is because to use specific selected tools to cut different batches, it will be need innumerous presettings. Seek for these solutions are being in course by researchers of the Uninove University team [4, 5, 6, 7];

c) reduce the presetting time as proposed and detailed following in this work;

d) explore all the above proposals at the same time after using all the above proposals after analyzing the characteristic scenery of each industry.

The purposes of this work are: analyze and eventually provide any need modification of the optimization model already developed by the authors in previous work and then validate the more recent one using data taken from practical application in shop floor of an industry that works behind the context of flexible machining.

2. Theoretical Bases

The theory bases used in this paper are based in previous author’s work [4]. The concept of cutting edge life becomes applied in a different way when compared with the traditional concept. A same cutting tool will be used to cut parts with different materials and geometries. Each batch will use a percentage of the cutting edge life in accord of its aggressiveness and depending on its number of parts. Thus, it is supposed that \( (n) \) batches are scheduled for a fraction of a workday. For the batch \((i)\) it is possible to write down the Eq.(1):

\[
Z_{ti} = \frac{T_i}{t_{ci}}
\]

where:

- \( Z_{ti} \) = number of pieces per cutting edge life of the batch \((i)\);
- \( T_i \) = life of the cutting edge for batch \((i)\) and workpiece material (previously determined or withdrawn from the catalog tool manufacturer) [min];
- \( t_{ci} \) = cutting time to cut one piece of the batch \((i)\) [min].

So, for a number of machined parts \((Z)\) less then \((Z_{ti})\), only a percentage \((PT_{ai})\) of its life is consumed. Then, the same cutting edge can continue mounted in the machine cutting new parts of the same batch or parts of the following new batch. \((PT_{ai})\) is given by the Eq.(2).

\[
PT_{ai} = \sum_{i=1}^{n} \left( \frac{Z_{ci}}{Z_{ti}} \right) \times 100
\]

Where: the relationship \((Z/Z_{ti})\) is the percentage of cutting edge life consumed to cut a number of pieces of the batch \((i)\).

When the predefined life criterion is reached, the same cutting edge accumulates percentages of tool lives utilized to cut different parts of different batches. Then, it can be considered that, when the \((PT_{ai})\) value, calculated as showed in Eq.(3) is close or equal at 100\%, the cutting edge had its life completely consumed, and must be changed by a new one. It is considered values close to 100\%, because, it is unlike that \((PT_{ai})\) results equal to exact 100\%. The \((PT_{ai})\) value could be 100\% when cutting parts only from one or from different batches.

Summarizing, the cutting edge should be changed always when:

\[
PT_{ai} = \sum_{j=1}^{m} PT_{aj} \equiv 100\%
\]

where:

\((PT_{ai})\) reaches approximately 100\% cutting edge life consumed for cut \((m)\) parts from \((j)\) different batches [%].

A second aspect followed in the author’s previous work was the way used for calculating the cutting edge life. It was based on tool’s makers catalog, more specifically, was adopted the theoretical bases developed by Sandvik Coromant [8]. This tool maker supplies a catalog that allows selecting the cutting parameters and, for them, the foreseen cutting edge life is supposed to be 15 minutes. The catalog does not inform which the cutting edge’s life criterion is.

If, for actual application, the piece material presents different hardness from that for which the catalog was built, it will be need to introduce a factor correction to calculate the new cutting edge life. For this purpose the user will find, inside of catalog, a table given the corrections factors indicated for different hardness levels. Another correction must be used in the case of changing the cutting speed to have it adjusted for the actual application: in this case, it will be need to calculate the new edge life using a factor also extract from a catalog table.
3. Theoretical Simulation of the Model

From the author’s work presented during the EngOpt 2008, it is reproduced an improved new version of the Worksheet 1 that represents the simulated theoretical scheduling to cut three different parts A, B and C. The Worksheet 1 summarizes the essence of the proposed model, which is to reduce the presetting time in flexible cutting process scenarios.

To the users it is recommended to apply the following steps:

- a). each work day must be organized to identifying batches of parts that will be cut with a same tool material and geometry;
- b). select the holder and insert geometry so that the tool could cut profiles of all the different parts of the scheduled batches, without interferences in its trajectories during the cutting process evolution;
- c). select, in the tool makers’ catalog, all the cutting conditions as it traditionally happens and also determine the respective cutting edge lives, following the catalog recommendations strictly;
- d). one batch must be considered a group of parts with same geometries and materials. In the limit the number of parts per batch could be one;
- e). the optimization model is proposed for turning operations in CNC lathes highly flexible. However, the model could be applied also to other types of cutting operations and machines;
- f). the cutting edges will be changed at each life’s end, and based on a tool edge criterion of life pre fixed. In the case or Worksheet 1 when the life of the cutting edge is reached;
- g). the moment of cutting edge exchange should be done when it reaches approximately 100% of his life, determined according tool maker’s catalog. This could occur for a number of pieces of one or for much then one batches;
- h). when the Worksheet for the theoretical model is ready, it will be the moment to verify its performance in practice;
- i). for the proposed model the setup time between one and another batch will be only to run the each batch CNC program, provide the machine references, eventually exchange devices to hold the new parts to be cut and to cut the first piece just for check if all is according with the desired part quality. It is no more necessary spent time to clean the work area, to accomplish maintenances, to provide the presetting before start to cut the new batch of parts.

The Worksheet 1, as mentioned before is a process planning simulation of three pieces A, B and C that illustrate the proposed model. The Worksheet 2, on the other hand, illustrates the simulation of a traditional process planning for the same parts of the Worksheet 1. The purpose of these simulations is to make easier to understand the discussion of the proposed optimization model and its comparison with the traditional model.

Worksheet 1. Proposed optimization model application simulating three pieces A, B and C to be machined based on the proposed model (1 US$ = 1,893 R$).

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts</td>
<td>Z_{batch}</td>
<td>( s_{cut} ) [m/min]</td>
<td>( T_i ) [min]</td>
<td>( t_{ci} ) [min]</td>
<td>( t_{st} ) [min]</td>
<td>( Z_i )</td>
<td>( PT_{ai} ) [%]</td>
<td>( PT_{ci} ) [%]</td>
<td>( N_t )</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>16</td>
<td>216</td>
<td>12</td>
<td>1,5</td>
<td>3,0</td>
<td>8,2</td>
<td>8</td>
<td>97,3</td>
<td>97,3</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>216</td>
<td>12</td>
<td>1,5</td>
<td>3,0</td>
<td>8,2</td>
<td>8</td>
<td>97,3</td>
<td>97,3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>216</td>
<td>15</td>
<td>1,7</td>
<td>3,0</td>
<td>8,6</td>
<td>8</td>
<td>92,8</td>
<td>92,8</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>216</td>
<td>15</td>
<td>1,7</td>
<td>3,0</td>
<td>8,6</td>
<td>8</td>
<td>92,8</td>
<td>92,8</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>216</td>
<td>20</td>
<td>0,9</td>
<td>3,0</td>
<td>22,2</td>
<td>17</td>
<td>76,5</td>
<td>99,7</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>216</td>
<td>20</td>
<td>0,9</td>
<td>3,0</td>
<td>22,2</td>
<td>17</td>
<td>76,5</td>
<td>99,7</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Total value of \( t_c \) plus \( t_{st} \) multiplied by \( Z_i \) [min] \( 85,8 \)

Passive time (piece load/unload, tool change time, etc...) [min] \( 34,2 \)

Total number of cutting tool edges \( N_t \) to machine all the batches \( 4,6 \)

Total cost to machine all batches [$] \( 168,0 \)

Cost reduction compared with the traditional cutting process routine [%] \( 28,8 \)
Where:

1st – part code;
2nd – batch’s size;
3rd – cutting edge life (for the simulation accomplished in this work it was used the procedure adopted by Sandvik Coromant tool maker. Such procedure foresees that if the selection of operational conditions is that suggested in the catalog, the cutting edge life will be 15 minutes. The simulation suggests that the material A is the worst to be cut when compared with the others, in terms of their hardness. Material B is easier than material A and material C is the easiest one. In this way, first was chosen the cutting speed of the material with an intermediate hardness between the others, for a cutting edge life equal to 15 minutes. This same cutting speed was used for the other two materials and their cutting edge lives were recalculated based on their hardness;
4th – cutting time per part;
5th – time independent of the cutting speed used to load the new CNC program when a new batch is going to be machined, exchange the cut edge every time it fails and make small adjustments before to cut the first part of the new batch under the specified quality. The suggested time was supposed to be enough to take care about these tasks. It is appropriate to remind the fact that there is no presetting time, because is predicted by the proposed model that all the batches prepared to be cut will be using the same edge tool ever;
6th – is the cutting edge life in number of machined parts;
7th – is the number of machined parts;
8th – is the cutting edge percentage life consumed for effective number of machined parts;
9th – is the edge life percentage of life accumulated until 100% of it is consumed.
10th – is the cutting edge percentage of life consumed;
11th – is the number of tool cutting edge consumed;

Worksheet 2 represents the planning process to machine the same three parts of Worksheet 1, however, using the traditional cutting process routine. In this case, each pair of tool and part is selected through the catalog, however, the cutting speed indicated is adopted and therefore, the tool life is always 15 minutes, instead the tools could be completely different each others.

Each Worksheet 2 column has the same meaning of the Worksheet 1, but the final results are different because the values of cutting speed, tool life, cutting time and independent time are different too.

The last line of Worksheet 1, in gray color, shows the drastic reduction in the cost to machine all the batches, when using the proposed model instead of the traditional cutting process routine. It is observed that the main influencing factor in reducing the cost is the lowest time presetting the machine.

Worksheet 2. Proposed optimization model application simulating three pieces A, B and C to be machined based on traditional routine (1 US$ = 1,893 R$).

<table>
<thead>
<tr>
<th>Piece</th>
<th>( Z_{tot} )</th>
<th>( s_{cut} )</th>
<th>( T_i )</th>
<th>( t_{ci} )</th>
<th>( t_{ai} )</th>
<th>( Z_{di} )</th>
<th>( Z_i )</th>
<th>( PT_{ai} )</th>
<th>( PT_{a} )</th>
<th>( N_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>179</td>
<td>15</td>
<td>1,8</td>
<td>15,0</td>
<td>8,3</td>
<td>8</td>
<td>96,0</td>
<td>96,0</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>179</td>
<td>15</td>
<td>1,8</td>
<td>3,0</td>
<td>8,3</td>
<td>8</td>
<td>96,0</td>
<td>96,0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>216</td>
<td>15</td>
<td>1,7</td>
<td>15,0</td>
<td>8,6</td>
<td>8</td>
<td>92,8</td>
<td>92,8</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>216</td>
<td>15</td>
<td>1,7</td>
<td>3,0</td>
<td>8,6</td>
<td>2</td>
<td>23,2</td>
<td>23,2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>220</td>
<td>15</td>
<td>0,9</td>
<td>15,0</td>
<td>16,7</td>
<td>17</td>
<td>102,0</td>
<td>102,0</td>
<td>0,8</td>
</tr>
<tr>
<td>C</td>
<td>220</td>
<td>15</td>
<td>0,9</td>
<td>3,0</td>
<td>16,7</td>
<td>13</td>
<td>78,0</td>
<td>78,0</td>
<td>0,8</td>
<td></td>
</tr>
</tbody>
</table>

Total value of \( t_c \) plus \( t_{st} \) multiplied by \( Z_i \) [min] \( 127,2 \)

Passive time (piece load/unload, tool change time, etc...) [min] \( 4,2 \)

Total number of cutting tool edges \( N_t \) to machine all the batches \( 5,8 \)

Total cost to machine all batches [$] \( 235,9 \)
4. Material and Method

The method can be considered exploratory as regards the development of the research and applied and quantitative from the standpoint of its objective [9, 10].

The proposed model mentioned before to reduce the presetting time was applied in a company that manufactures parts within the concept of flexible machining. It was machined several parts with different geometry and three different steels (SAE 4140 (A), 6150 (B) and 4340 (C)). The materials were not subjected to heat treatment and had a hardness of approximately 180 HB. The parts and the process used to machine then were those of the routine of the company. The concept of cutting process flexibility goes the limit, because their batches tending to have only one part each.

The machining operation was performed on the same CNC lathe used to machine the mentioned parts during regular production. The tool holder and insert was chosen using the first suggestion of a tool marker catalog: tool holder: ISO - C5-DDJNL-35060-15, and insert - DNMG 15 06 12-PM 4225. Only a rough turning was used to follow the performance model in shop floor.

For the theoretical model the criterion adopted to exchange the cutting tool edge was its on life selected and determined from tool maker catalog. This means that was considered the same cutting speed for all the geometries and materials parts because they have the same hardness. The cutting speed of 325 m/min selected from the catalog for a life of 15 minutes was changed to 280 m/min because some machine constraints. Because of that was need to calculate the new edge life of 29,42 min, as will be presented further.

On the other hand, the criterion adopted to exchange the cutting tool edge in shop floor during the theoretical model validation, was the dimensional variation of the machined part in 0.2 mm, the same criterion and routine used by the machine operator during regular production of the parts. Furthermore, and still under the tradition of the company, one cutting edge was replaced by a new one, always that the percentage of your remaining life was not quite enough to machine the next part. The others parameter was the depth of cut of 3,0 mm and feed rate of 0,35 mm/rot. The cutting time for each part was measured running the CNC program with no part hold in the machine using block to block movement of the tool.

5. Results and Discussion

Following the Sandvik Metal Cutting Technical Guide [8], was not need to make cutting speed or tool life corrections because all the steels SAE 4140 (A), 6150 (B) and 4340 (C) have the same Hardness. However, the cutting speed of 325 m/min, forced by some machine’s constraints, had to be replaced by 280 m/min. So to calculate the new tool life it was used the correction factor presented in the Table 1.

Table 1. Factors to correction the tool edge life for cutting speed different from that selected in the catalog [8].

<table>
<thead>
<tr>
<th>Tool Life [min]</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>45</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correction Factor</td>
<td>1,10</td>
<td>1,0</td>
<td>0,95</td>
<td>0,90</td>
<td>0,87</td>
<td>0,80</td>
<td>0,75</td>
</tr>
</tbody>
</table>

It is possible to write:

If 325 [m/min] - original cutting speed corresponds to → 1 (correction factor because tool life is equal to 15 min.)

So, 280 [m/min] new cutting speed corresponds to → y (new correction factor to be found)

The correction factor can be given by

\[ y = \frac{280 \times 1,0}{325} = 0,86 = 0,87 \]

Table 1 shows that the tool life for a cutting speed of 280 m/min is approximately 30 min.

The results of the proposed model simulation and experimental application in industry shop floor are showed in Table 2, where the parts were decoded by a letter followed by a number. The letter states that the material part is identified as: SAE 4140 (A), or SAE 6150 (B) or, finally SAE 4340 (C). The numbers following the letters means that the parts are geometrically different between each others.

As the tool edge life was not measured for the part size dimensional variation criterion of 0,2 mm, only the tool life from catalog criterion of 30 min was informed in Table 2.
Table 2. Simulation of the model and experimental test in regular production shop floor of a typical flexible machining industry

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Z_{int}</th>
<th>s_{cut}</th>
<th>(T_1)</th>
<th>(t_{cut})</th>
<th>(t_{st})</th>
<th>(Z_{it})</th>
<th>(Z_{st})</th>
<th>(PT_{ai})</th>
<th>(PT_{ai}')</th>
<th>(N_{t})</th>
<th>(PT_{ai})</th>
<th>(PT_{ai}')</th>
<th>(N_{t})</th>
</tr>
</thead>
<tbody>
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<td>A1</td>
<td>4140</td>
<td>1</td>
<td>280</td>
<td>0,2</td>
<td>0</td>
<td>0,0</td>
<td>137,1</td>
<td>2</td>
<td>1,5</td>
<td>1,5</td>
<td>0,0</td>
<td>1,5</td>
<td>1,5</td>
<td>0,0</td>
</tr>
<tr>
<td>B1</td>
<td>6150</td>
<td>1</td>
<td>280</td>
<td>0,7</td>
<td>0</td>
<td>0,0</td>
<td>43,5</td>
<td>1</td>
<td>2,3</td>
<td>3,8</td>
<td>0,0</td>
<td>1,5</td>
<td>3,8</td>
<td>0,0</td>
</tr>
<tr>
<td>A2</td>
<td>4140</td>
<td>1</td>
<td>280</td>
<td>1,1</td>
<td>0</td>
<td>0,0</td>
<td>26,6</td>
<td>1</td>
<td>3,8</td>
<td>7,5</td>
<td>0,0</td>
<td>1,5</td>
<td>7,5</td>
<td>0,0</td>
</tr>
<tr>
<td>A3</td>
<td>4140</td>
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<td>23,1</td>
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<td>0,0</td>
<td>1,5</td>
<td>16,2</td>
<td>0,0</td>
</tr>
<tr>
<td>B2</td>
<td>6150</td>
<td>2</td>
<td>280</td>
<td>2,9</td>
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<td>0,0</td>
<td>10,3</td>
<td>2</td>
<td>19,4</td>
<td>35,6</td>
<td>0,0</td>
<td>1,5</td>
<td>35,6</td>
<td>0,0</td>
</tr>
<tr>
<td>B3</td>
<td>6150</td>
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<td>280</td>
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<td>0,0</td>
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<td>3</td>
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<td>0,0</td>
<td>1,5</td>
<td>49,0</td>
<td>0,0</td>
</tr>
<tr>
<td>C1</td>
<td>4340</td>
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<td>280</td>
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<td>0,0</td>
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<td>0,0</td>
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<td>1</td>
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<td>27,1</td>
<td>0,0</td>
<td>1,5</td>
<td>27,1</td>
<td>0,0</td>
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<td>B4</td>
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<td>0,0</td>
<td>127,3</td>
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<td>7,9</td>
<td>7,9</td>
<td>0,0</td>
<td>1,5</td>
<td>7,9</td>
<td>0,0</td>
</tr>
<tr>
<td>B5</td>
<td>6150</td>
<td>7</td>
<td>280</td>
<td>0,3</td>
<td>0</td>
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Where:
- \(12^{th}\) – is the real total number of tool cutting edge consumed;
- \(13^{rd}\) – is the theoretical edge life percentage consumed for effective number of machined parts;
- \(14^{th}\) – is the theoretical cutting edge percentage of life accumulated until 100% of it is consumed;
- \(15^{th}\) – is the theoretical number of tool cutting edge consumed.

Total number of cutting tool edges: 10,0
However, if a systematic monitoring similar to this work is performed, it will be possible to forecast the consumption of cutting edges with a greater coincidence between simulation and real data. Furthermore, such continuous monitoring of the process will allow, at some point, batches with sufficient number of parts, enough to determine the cutting edge life specifically for this case. This would be the ideal situation for application of the proposed model and its monitoring in practice.

Then, it will be possible also use the proposed method to make predictions about the number of cutting edges to be consumed for whatever is the mix of parts to be machined. This kind of knowledge will be very useful to manager efficiently the process, first because it will be possible to make more precisely planning process, and second, because it will be easier to follow how the process is running in shop floor.

Another aspect to be discussed concerns the discrepancy between the theoretical model and the practical experience carried out in this work. This fact can be explained by:

- tool makers probably provides an approximate value for the cutting edge life (15 min) taking in account larger cutting edge wear then part’s dimensional variation equal to 0.2 mm;
- the criterion used to exchange the cutting edge even with a high percentage of edge life to be consumed just to not have to change the cutting edge during the machining of a next part was also a very important factor causing the discrepancy found. Unfortunately, this criterion is adopted by the company and at least in this research, it was not possible change. To illustrate this fact, consider the pieces from C3 to C9. The sum of the percentages of life of the cutting edges is 295.7%. This value corresponds to the use of approximately three cutting edges (100% per cutting edge) in total instead of seven, which would mean a reduction in the final four edges. Obviously in fact this criterion means that money is throwing out just what is to be prevented with the use of the proposed model.

6. Final Considerations
Relying on the development of this work is possible to present the following closing remarks:

- the corrections provided for the theoretical model that was proposed during EngOpt 2008, allowed the comparison between the theoretical and practical model becomes fair to the concept sought by the proposal. The cutting speeds for different batches of parts were kept constant and only the correction of the cutting edge lives due to possible variations in the hardness was provided;
- still on the proposed model is observed, after simulation, that the reduction in cost to machine all the batches, achieved in about 30%, was mainly due to reduction of the presetting time;
- the simulation followed by the validation in shop floor showed to be discrepant. The main reason for this discrepancy is the cutting edge life criterion not declared by tool makers. Without this information it is very difficult to make forecasts to construct the planning process and it is impossible to follow up the process in manufacturing plant;
- the systematic monitoring of the proposed model on the shop floor with the recording of data related to the tool’s performance, allowed the determination of the tool lives for a given parts mix machined in actual production condition. Also will be possible to have more realistic cutting edge exchange criterion;
- based on actual data the planning process will be more realistic and the process management in shop floor will be easier to be done.

REFERENCES


