PRODUCTIVITY AND ACCURACY IN PLASTIC INJECTION MOULD QUOTATION

Mikó, B. & Boór, F.

Abstract: The quotation in the field of injection mould tool manufacturing is still so difficult mission and means so great challenge that leads the manufacturers be more bottleneck providing huge differences between the results of cost and time calculation following hand-rules or experiments. The simple cause of this is the very fact they must estimate the mould’s design and manufacturing time and cost – with unknown tool structure and complexity – based on an elastic or plastic product. The aim of authors is to summarise existing quotation methods and to introduce the principle concept of an experimental cost estimation system, which can calculate the realistic cost and time demands in advance based on local design and manufacturing environment.

Key words: mould quoting, cost estimation

1. INTRODUCTION

The estimated cost and time values has a large importance from the viewpoint of company’s profitability since the minimal or concurrent production price can be determined only after estimating the self-cost of mould design and manufacture. However, based on estimated time and with consideration of free manufacturing capacities can only be defined a sustainable production’s deadline toward the costumer. In this early phase of the project there is no way to create a detailed mould design and manufacturing plan in order to gain accurate cost and time results. In case of under calculation as well as if the costumer steps back from a purchase order; the cost of quotation increases further more the deficit. On the other hand if we do not put a great deal of effort into the quotation, the price will be too high, and we lose not only an order but a general costumer. If we win the project with too low price and benefit, the design and manufacturing process will be loss-making.

The demand for a quotation is very clear: to provide estimated time and cost data so accurate and with so less effort as possible.

2. QUOTATION METHODS

There are four basic quotation methods known in mould making industry in order to estimate time and cost of tool design and manufacturing [1].

The first method is known as intuitive estimation, as it is based on the personal experiences. The application of this method needs a lot of experiences and deep knowledge in specific design and manufacturing environment. A junior expert can estimate the real data only with huge difference, it can exceed ±50% in cases.

The second one is called as analogue estimation, and uses time and cost data of the events in the past, generating from previous mould productions. This method is more reliable and consequent than the intuitive one if large case-base is available. Even with using computer program for evaluation during this method application, the cost expert needs deep knowledge in previous moulds’ construct and manufacturing structures too. The method requires a large paper- or computer-based data base.
For efficient utilisation the previously done moulds documents must have been classified and high-maintained. This method cannot be applied in case of relatively “new type” moulds estimation fitting essentially less to the past experiences. The accuracy of the analogue estimation method can usually achieve ±35% [1].

The third method is called as parametric estimation, as it utilises some selected product design parameters – considerably essential in cost and time production – and referring functions to calculate base time and cost data. Mostly the overall product mass or global dimensions are used, but there are some more complicated and sophisticated figures and calculation methods in the practice without essential benefits in estimation accuracy. This method is applicable only for raw calculation [1-2].

The forth method is the analytic estimation; in which case the object is divided into pieces and the method determines cost and time data partly for these simplified components. During this application the user must have a deep knowledge in mould design and technology in order to identify the essential features, division borders. However, the method is very time-consuming, but an expert user with special skills and huge experience can achieve the level of ±5% estimation accuracy in general, while a beginner can realise only ±15% [1].

The quality of the estimation is affected by the experience and grounding of the user in case of each methods. The estimation accuracy is determined by unknown skills and factors.

Table 1 collects the advantages and disadvantages of cost estimation methods. Based on earlier researches [3], an artificial neural network based analysis is proposed to meet the demands of an industry proven time and cost estimation for elastic-plastic injection moulds’ design and manufacturing process. The proposed expert system creates connections between the essential features of the product and the estimated time and cost data, enables to reuse post-processed cost data of complex moulds, and to determine the hidden relationships between the characteristic features of the part and overall cost by learning interdependencies and connections via artificial neural network (Figure 1.).

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intuitive</td>
<td>Fast Easy-to-use</td>
<td>Experience-based, Inaccurate, Non consistent</td>
</tr>
<tr>
<td>Analogue</td>
<td>Environment oriented</td>
<td>Time-consuming, Huge database</td>
</tr>
<tr>
<td>Parametric</td>
<td>Fast Simple</td>
<td>Inaccurate, Heuristic</td>
</tr>
<tr>
<td>Analytic</td>
<td>Accurate</td>
<td>Time-consuming, Experience-based, Sophisticated</td>
</tr>
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Table 1 Advantages and disadvantages of known cost estimation methods.

3. THE ECOTEST/MOULD COST ESTIMATION SYSTEM

Based on earlier researches [3], an artificial neural network based analysis is proposed to meet the demands of an industry proven time and cost estimation for elastic-plastic injection moulds’ design and manufacturing process. The proposed expert system creates connections between the essential features of the product and the estimated time and cost data, enables to reuse post-processed cost data of complex moulds, and to determine the hidden relationships between the characteristic features of the part and overall cost by learning interdependencies and connections via artificial neural network (Figure 1.).

The artificial neural network is a tool for computational tasks, which has biological analogy. An artificial neural network is a hierarchical net of simple elements which called nodes [4].

The perceptron-based neural network is used, where the nodes summarize the weighted inputs and transform by a non-linear function. If three layer of nodes are created, where first contains the input data, the third represents output data, the relationship is determined by the learning process itself.
The learning process needs a case-base, which consists of post-calculated time and cost data of moulds. The usage of these data has several advantages. On one hand, these moulds were designed and manufactured by the given (i.e. user) firm, so they contain the in-house effects and interdependencies of design and manufacturing features. This fact ensures than actual design and manufacturing environment is considered. Production of a mould needs different time and cost calculation in different mould shops, so as the skills of employees, quality and number of machine tools end equipments are rather different. The post-calculated data has other advantages too: these moulds have already been produced, therefore the cost and time data are absolutely exact, and there is no need to use theoretical formulas, just measures and summarisation. The post-calculated data contains the cost of correction of manufacturing failures too, which can be interpreted as a disadvantage. The manufacturing failures are stochastic, theirs importance and cost cannot be prognosticated, so the correction of measured data seems to be evident in order to eliminate random effect. But if you study manufacturing processes of several moulds, the average cost of repairing is...
relatively constant. This value characterises the technical and human state of the mould shop and this is a very importance indicator, so it cannot be eliminated.

One of the most important questions for effective system work is the content of learning case base. In the installation phase of the project the system must be adjusted by systematic learning process. It is not practical to exclude the non-typical mould or that had too many manufacturing problems, because they can cause distortion in the run. We must create the most heterogenous case base, because the extrapolation skill of the net is rather weak, it can work well in the pre-defined field. The learning process needs about 80-100 implemented cases for installation, accordingly it can perform properly on an annual production of a middle size mould shop. After installing ECoTEst in the beginning period (for a year maximally) it is recommended to use the system as alternative or background solution parallel with one of above listed existing methods, and to control and to compare the results, and to complete the case base with new post-calculated data. When the system contains about 200 cases, it can learn well the future events and can work as primary system.

During the daily work it is worth to supplement the case base with new post-calculated project results, and to execute new learning process once or twice a year. This maintenance ensures the continuous evolution of the accuracy and the capacity of the system.

4. INPUT/OUTPUT PARAMETERS

One of the most important steps of the development process is the definition of input and output parameter set. The output parameter set can be defined rather simply, because it is determined by the time and cost data required.

The needed data are as follows:

- Design time of the mould,
- Time of process planning,
- Material cost,
- Cost of standard elements,
- Cost of cooperated work,
- Time of manufacturing grouped to machines (milling, turning, grinding, EDM, drilling etc.),
- Time of fitting and assembly.

The selection of input parameters is a little more difficult problem. The reason of that, the selected parameters must be satisfied with several conflicting conditions. We can use only such parameters which can be determined from any design representation type; like 2D drawing, physical model, 3D CAD model in any format, etc. Every essential property of products must be selected which has essential effect on mould’s structure, size and complexity. The concept of the mould must be developed during quotation, and some characteristic properties must be taken account for accurate results. One of the most important viewpoints in the parameter selection is the clear structure, and avoiding too huge number of parameters. Based on these rules the input parameters are as follows:

*Global/overall dimensions of product*

One of the most significant parameters is the maximal part’s dimension. The part’s height, being parallel with the mould move (open-close) direction, influences the height of mould. The dimensions being normal to the mould move have an effect on the closing force required and on the injection mould machine applied.

*Mass of product*

The mass of product determines the material cost of the elastic or plastic part and influences the mould machine selection.

*Number of cavities*

More number of cavities there is, more productivity of mould can be obtained, albeit the cost of mould making is also larger. The operation of a multi cavity mould requires such a moulding machine, which is able to ensure needed force;
following the work expense is increased as well.

*Complexity of product*
The complexity of a part is so sophisticated term; it is not so easy to define. By the ECoTEst system’s concept this parameter is defined in a scale from 1 to 10, where 1 means the simplest and 10 the most complicate mould structure. These categories can mean different mould structures in each mould shop, so during installation the case studies must be drawn up to support users. Do not use the minimum and maximum values of the scale practically, because in the future we may make cost estimation for more simple or more complicated moulds as we have ever made.

![Figure 3. Overall size of mould (Meusburger)](image)

*Estimated overall size of mould*
Based on parameters mentioned above the overall size of mould is estimated, appropriate to use the standard plate dimensions of material manufacturers, in order to reduce material cost.

*Complexity of mould structure*
Complexity of mould structure is scaled from 1 to 10 similarly as mentioned in the former case. A mould structure is simple if it consists of only core and cavity plates and the dividing surface is flat, while a multi-cavity mould with sliders, lifters, two step ejections and threaded insert means very high complexity.

*Runner system*
An injection mould has a standard runner surface or a hot runner system. A standard runner surface is more simple and cheaper to manufacture, but the time of an injection cycle is longer and provides significantly more material wastes. Although applying a hot runner system leads to shorter cycle time and nearly zero material waste, it indicates considerably more costs and purchase time.

*Complexity of sliders and lifters*
These parameters characterize the geometric complexity of sliders and lifters in a scale from 1 to 10.

![Figure 4. A slider and a lifter (DME)](image)

*Quantity of sliders and lifters*
Sliders and lifters form undercut surfaces, which cannot be only core and cavity. Application of more sliders means higher mould complexity, more components, and so the cost of design, process planning and manufacturing will be higher (the parameter is also scaled from 1 to 10).

*Quantity of deep ribs and cavities*
Deep ribs and cavities increase determinately the cost of mould as they can not be machined on milling but on EDM, which indicates additional cost in both planning and manufacturing (the parameter is scaled from 1 to 10).

*Quantity of EDM-ed surfaces*
You have to provide solid quantity, which cannot be manufactured on milling machine, but only on EDM, because of its shapes (weak walls) or material structure (also scaled from 1 to 10).

There are several reasons why the application of EDM technology increases the manufacturing cost. First of all EDM technology requires electrodes, which
indicates additional tool design and process planning and manufacturing. Secondary the EDM process has low productivity. Thirdly if the product’s surface requirements do not allow EDM-ed surface quality, the surface finishing brings additional manual manufacturing.

Quality of product’s surface
The product surface must meet design requirements, functionality and manufacturability. A surface structure and quality depends on the mould’s manufacturing process. If necessary this structure can be eliminated by manual manufacturing, however super-finishing can also be applied. In several cases the customer requires special surface structure like leather design. This structure can generally be manufactured by EDM. The natural like design can be machined by electrochemical machining, which needs many manual pre processes, e.g. the milling paths or EDM-ed hard surface layer must be removed.

Heat treatment requirements
The number of product parts and the abrasive effect of the product material generate heat treatment demands, and so additional manufacturing requirements. The effects of heat treatment indicate additional cost and production time as well as the increased transportation, if the heat treatment cannot be managed in the mould shop.

There are three types of heat treatment parameters distinguished. The first type means exact numeric values such like overall dimensions of the part. The second type data can be generated from mould’s requirement list, i.e. heat treatment requirements or types of runner system. The parameters of the third set have subjective values, like complexity of mould structure. Although the last type of parameters indicates uncertainty, use of them is unavoidable. The effect of uncertainty can be reduced by a personal user’s manual, where the selected values can be illustrated by examples.

Interpretation and specification of input parameters require perfection in mould design. The conceptual mould design is also required in advance, as the overall size of the mould, the number of lifters and sliders can not be defined without.

5. CONCLUSIONS

In case of conventional cost estimation methods the accuracy and the productivity are somehow contradictory. The artificial neural network is not a mere mean of estimation, but suitable for resolving conflicts. Based on local case base the ANN can create tailor-made relationship between the product and the manufacturing time and cost required.

6. CORRESPONDING AUTHOR

Dr MIKÓ Balázs, PhD, Assoc. Professor, Head of department, Budapest Polytechnic Bánki Donát Mechanical Engineering Faculty Department of Manufacturing Engineering,H-1081 Budapest, Népszínház u. 8. e-mail: miko.balazs@bgk.bmf.hu

7. REFERENCES

1. W. Dealey : Mold quoting: The magic, art and science, Modern mold & tooling, Vol.3 No.3 2001 March pp.10