“Low-Cost” Tools Through Life Cycle Observation

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Abstract

In course of increasing cost pressure caused by competitors from low-wage countries and customers’ budgetary restrictions the observation and optimization of tools’ life cycle costs covers differentiation potentials for European tool making companies. In the course of the research project TEC (Total Efficiency Control) a calculation tool is developed to enable tool making companies to prognosticate and to present their customers tools’ life cycle costs transparently. Therefore they are able to justify their higher acquisition prices by the lower production costs and market an overall more cost-efficient tool.

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Selection and peer-review under responsibility of the International Scientific Committee of the 21st CIRP Conference on Life Cycle Engineering in the person of the Conference Chair Prof. Terje K. Lien

Tool and die making industry; Resource consumption; life cycle observation; calculation of life cycle costs

1. Challenges for the Tool and Die Making Industry

The tool and die making industry is one of the key industries in the manufacturing sector due to its role in the value chain between product development and series production of manufacturing goods [1, 2]. Excellent products from high-wage countries can only be manufactured at economical prices with the support of efficient and highly productive tools [3, 4].

In the global competition the European tool and die making industry faces a challenging environment. This is characterized by changing conditions of the global market for companies in high-wage countries and new competitors from Asian low-wage countries with growing technologic potential [5]. Therefore three main challenges can be identified for the tool and die making industry – increasing product derivatization, shorter product life cycles and lower factor costs of global competitors [6].

The combination of increasing product derivatization with shorter product life cycles leads to an increasing number of product variants besides decreasing production volumes concerning each variant. Consequently this ends in a significantly higher product diversity as well as product and production complexity [7]. These changes directly effect the tool and die making industry as it provides the tools for manufacturing those products. The tool and die making industry therefore appears as the enabler for managing product and production complexity [8].

Due to the decreasing production volume the tool costs take a higher share of the overall production costs [9]. Consequently the tool budget is reduced by the customers, which requires the tool making company to offer its tools at a lower price [10]. Furthermore European tool making companies compete with new market participants from low-cost countries, which distinguish through lower factor costs [11]. On account of higher costs for manufacturing of tools it is not a successful strategy for European tool making companies to differentiate over lower prices. Thus the European tool and die making industry tries to stay competitive by focusing on five fields of action [12]:

- Time-to-market: In times of high global competitive pressure, the success or failure of a product is often decided by the passed time to the market launch.
to the realization of a new product, the production of the tool is on the critical path between product development and series production (figure 1). It is often one of the last remaining factors for a significant lead time shortening. Therefore the speed of order processing in tool making and the lead time in tool manufacturing has direct impact on the product success.

- **Quality**: Besides the tool itself and the interaction of the tool and the machine, the production processes of goods and services are essential to the products quality. These factors determine the customers’ perceived quality and thus its satisfaction. In addition to technological developments various organizational measures are necessary to achieve high customer satisfaction regarding quality.

- **Innovation**: The production of a tool provides its services in both directions of the value chain. New types of processes and tool concepts enable a more economical production. Because of its expertise the tool making company can actively participate in the customers’ product development.

- **Productivity**: The productivity of a tool in use significantly determines its life cycle costs. Therefore a high level of tool availability is a crucial factor in the tool’s overall cost calculation, which affects the production of the tool. Thus the importance of the tool’s purchase price often retreats into the background when focusing on the entire life cycle.

- **Costs**: As a differentiation over lower prices is not a successful strategy for European tool making companies analyzing and optimizing the life cycle costs of the tool, from its development to its recycling, offers potentials to distinguish from low-wage country competitors. This approach seems to be even more feasible as tools amount up to 30% of the total production costs. Due to the use of the tool, planned maintenance and unplanned repairs, additional costs which are directly connected to the tool accrue over its life cycle. Hence experts assume that 60% of the total production costs are determined by the tool [13].

![Fig. 1. Position of Tool Making between Product Development and Series Production](image)

One of the strongest levers for the European tool and die making industry to develop the five action fields is to observe tools’ life cycle. The observation lets the tool making company gain transparency over time-to-market, quality, innovation, productivity and costs and illustrates the precondition for their controlling and optimization. However the pivotal measure in context of tools’ life cycle observation are tools’ life cycle costs [14].

### 2. Analysis of Prior Works on Life Cycle Observation

There are some existing approaches concerning the tool’s life cycle that mainly focus on observation of life cycle costs. The key to life cycle optimization is the efficient use of resources of a tool over its life cycle. Resources have to be defined in this context as everything which is needed to develop, manufacture, use and recycle the tool and at the same time generates costs. While the need for life cycle optimization by controlling resource consumption in the tool and die making industry has been acknowledged, no holistic solution has been proposed yet [15]. The research project LCC and its follow-up project QProLCC for instance developed a tool to prognosticate manufacturing costs, optimization costs, maintenance costs and costs of idleness depending on different tool parameters, but still cannot make a clear statement about the entire costs along the tool’s life cycle [16].

The recently finished government-funded research project EnHiPro focused mainly on optimizing energy and auxiliary use. EnHiPro’s fundamental approach intended to integrate consumption measuring in existing ERP systems aiming to combine ecological and classical production-related goals. EnHiPro generated a certain degree of transparency regarding specific consumption and cost drivers. Furthermore interdependencies with manufacturing efficiency have been identified. EnHiPro’s outcomes might be capable of continuously increasing energy and auxiliary efficiency [17].

The life cycle observation proposed in this paper wants to take the next step forward and investigate not only energy efficiency but overall resource respectively cost efficiency.

### 3. Customer Integration to Gain Transparency over Tools’ Life Cycle

According to the position in between the customer’s production process the tool and die making process is the central enabler of an efficient production process. In contrast to series production a tool making company can not rely on repeating an established process routine. It rather has to account for all requirements and characteristics of the customer and its orders on a single-time basis. Therefore a continuous cooperation between the tool making company and its customer is inevitable. This way of collaboration allows the tool making company to create specific knowledge about life cycle costs, which makes it possible to draw conclusions about life cycle costs regarding current tool developments as well.

In the conventional distribution of roles the tool making company is only responsible for delivering the tool. A cooperation comprising the exchange of information or communication beyond the traditional interfaces does not
occur. As a disadvantage the tool making company has no access to process data and costs caused by the tool during its use, which forecloses a life cycle cost analysis. To make life cycle costs transparent the integration of the tool manufacturer into the customer’s value chain is necessary.

3.1. Upstream Customer Integration

The upstream customer integration, which is also called frontloading, enables a collaboration among the tool making company and its customer during the product development process. Therefore the tool making company is able to contribute his know-how already in the design phase of the product. Hence a reallocation of his resources into the upstream customer process is required.

Frontloading creates additional customer benefits such as shortened time-to-market, significantly higher adherence to schedules and reduced development complexity. The tool making company is empowered to recognize the customers’ demands regarding the product specifications, which leads to an appropriate tool design.

3.2. Downstream Customer Integration

The downstream customer integration is realized by services over the entire life cycle of the tool. These services cover tools’ maintenance and repair up to take-over of entire process steps like manufacturing of small series. The most accomplished characteristic of downstream integration is the use of intelligent tools. Being equipped with modern sensor technology these tools collect and analyze process data and transmit it to tool making company and customer. This data is the pre-condition for gaining life cycle transparency.

By downstream customer integration the tool making company reduces the perceived complexity of the production process for its customers on the one hand. On the other hand he is able to collect process data from the series production and to create cost transparency over the tool’s life cycle.

4. Reference Model for Life Cycle Observation

Based on the transparency realized by customer integration a descriptive reference model can be developed which reveals detailed information about the life cycle of the tool, the cost positions over the life cycle, the influencing factors on the life cycle costs of the tool and their correlations. In the following sections the reference model for injection molding tools developed and verified by the tool making companies within the research project TEC (Total Efficiency Control) is explained step-by-step.

4.1. Life Cycle Phases of a Tool

As a first step the relevant stages in a tool’s life cycle have been defined as detailed as possible in order to grant a transparent inclusion and analysis of the phases’ cost parameters. The life cycle of the tool is defined by the following generic phases:

- development
- manufacturing, assembly and start-up
- use in production
- recycling

These four main-phases are extended to ensure a closer look at each phase. Therefore the phases are divided into 22 sub-phases which are shown in figure 2.

The development phase is initiated by the customer’s request and finished by the handover of the engineering drawings to the tool manufacturing divisions. In the manufacturing, assembly and start-up all steps of the manufacturing process, the assembly and the successful finishing of the try-out are included. After giving the tool to the producing company the customer starts the production. This phase also comprises maintenance and repair activities. The recycling of the tool starts after the series production is finished.

![Fig. 2. Phases and subphases of tools’ lifecycle](image-url)

4.2. Cost Positions along the Tool’s Life Cycle

Each sub-phase has associated cost positions. A cost position is defined by a cost type which is caused in a sub-phase and occurs in it. Thus the same type of costs can occur within several sub-phases and represents different cost positions. Cost positions can be classified as material and personnel costs. During the project work it could be discovered that the personnel costs take a noticeable high share particularly in the development phase. In the other phases both kinds of costs could be recognized in equal measure.

4.3. Influences on Life Cycle Costs

To analyze and rate the life cycle costs of a tool, their influencing factors have to be identified. The TEC project focuses on those costs which can be influenced by the tool making companies themselves, especially in the phases of
development, manufacturing, assembly and start-up. However, the most significant influence on the tools quality and thereby the life cycle costs were identified during these phases. Therefore the main influencing factors can be described as quality criteria and summarized to quality clusters. Besides three basic quality clusters seven clusters referring to tools’ complexity were identified:

- Volume
- Material Properties
- Surface Properties
- Complexity of Product Geometry
- Complexity of Molding Technology
- Complexity of Tool Geometry
- Complexity of Tool Mechanics
- Complexity of Injection Concept
- Complexity of Ventilation
- Complexity of Temperature Control
- Degree of Standardization

The degree of standardization is determined by the number of installed standard parts as well as the number of company-specific standard parts and components.

The tool making company’s ability to influence the quality criteria is increasing with the integration degree into the upstream customer processes. Consequently the tool making company’s leverage on life cycle costs rises proportionally with a higher degree of integration.

4.4. Correlations between Influencing Parameters and Cost Positions

The final step of developing the reference model is to link the identified cost positions to the influencing quality criteria. The links are defined by quantified correlations between the cost positions and quality criteria. In TEC project the correlations were identified and verified by the consortium (figure 3) and are based on long-term expertise in tool making.

It became apparent that the costs are affected by the complexity of tool mechanics and the complexity of the geometry at the most. The complexity of ventilation only takes a marginal part in this context. Apart from the product’s volume the costs generated in the recycling phase are not influenced by the quality clusters.

Based on the identified cost positions, quality criteria and their correlations the reference model for tools’ life cycle cost observation was developed. It describes the connections between the tools’ attributes and the resulting life cycle costs and therefore enables a comprehensive analysis and evaluation of tools’ life cycle costs.

5. Calculation Tool for Marketing Cost-Effective Tools

Based on the reference model for life cycle observation a software tool (RCCT – Resource Consumption Calculation Tool) was developed, to forecast tools’ life cycle costs and thereby market high-quality tools of European tool making companies on global markets.

5.1. Functionality of the Calculation Tool

The RCCT lets the user individually configure a molding tool by varying its quality parameters and finally predict the costs along the defined phases and sub-phases of the tool’s life cycle. Hence cost saving potentials are disclosed and support for an appropriate tool design is provided. The RCCT enables a configuration of up to three tools simultaneously, which lets the user compare its own tools or the ones of competing companies.

The RCCT is based on the reference model for life cycle observation and has been supplemented by mathematical functions to ensure an accurate description of the interdependences between quality criteria and life cycle costs. Default settings regarding the interdependencies verified by the consortium are taken as a basis but can be adjusted according to the user’s requirements.

To configure a tool the targeted quality cluster can discretely be set on a scale from 0 to 10 (figure 4). The standard configuration is adopted by the first tool configured and represents the reference tool. Furthermore up to two more tools can be configured for comparison. Simultaneously the life cycle costs of all configured tools are calculated by the defined interdependences of the reference model.

As a result the RCCT illustrates the distribution of costs of all configured tools over all phases and sub-phases of their life cycles. The costs are constituted numerically in a table...
and graphically in a bar chart (Picture 4). As the life cycle costs of the standard configuration are automatically indicated with 100 percent, a direct cost comparison of all calculated tools with the reference tool is enabled.

![Fig. 5. Exemplary Visualization of Results of RCCT](image)

5.2. Application of the Calculation Tool

The RCCT supports the tool making company during the design phase providing information about cost influencing design parameters. The tool and die making company is delivered with high-value knowledge about the resulting life cycle costs. But the tool is not meant to be only used for in-house purposes. It also supports the tool making companies and the customer simultaneously in the integrated product and tool development phase. Discovering tools’ life cycle costs enables the European tool and companies to justify higher acquisition prices over lower costs in the phase of production.

The transparent illustration of tools’ life cycle costs and the possibility to design a tool generating customized life cycle costs represents a differentiation criteria for the tool and die making industry in Europe. Therefore the RCCT supports European tool making companies to market their high-quality tools.

Acknowledgements

The presented results were worked out in the ongoing research project “TEC - Total Efficiency Control” at the Laboratory for Machine Tools and Production Engineering, RWTH Aachen, and the Institute for manufacturing technology and high performance laser technology, TU Wien (Vienna). Altogether 14 companies from Germany and Austria (10 tool making companies) are part of the consortium. The research project is supported by means of the German Ministry for Economy and Technology by the Consortium of Industrial Research Associations „Otto von Guericke“ e.V. (AiF).

References