Customer Integration To Gain Cost Efficiency Alongside Tool’s Life Cycle

Günther Schuh, Martin Pitsch, Thomas Kühn*

*Chair of Production Engineering, WZL, RWTH Aachen University, Steinbachstr. 19, 52074 Aachen, Germany

Abstract

Today's efforts to optimize industrial production processes exceedingly focus on tools’ life cycle costs. Toolmaker and its customer are the two entities influencing tools’ life cycle costs. Due to lack of information exchange neither life cycle assessment nor cost efficient life cycles can be realized. An effective lever for penetrating information exchange and therefore gaining cost efficiency alongside tool’s life cycle is the integration of the toolmaker into the value creation process of its customer. The so called customer integration succeeds through innovative product-service systems alongside tools’ life cycle networking the value creation processes of toolmaker and tool user. As the findings of research project TEC in this paper practical solutions for realizing customer integration are introduced and measures for gaining life cycle cost efficiency alongside tool’s life cycle are explained.

1. Introduction

Due to its key role in the value chain between product development and mass production the tool making industry is one of the most important industries in the manufacturing sector [1]. The key role is justified as the tool making industry enables the product development to realize new products as well as the series production to produce those products at a high quantity and economical prices. Efficient and highly productive tools are the bases for a high-performance manufacturing sector [2]. The tool making industry therefore largely contributes to the economic performance of major economies [3, 4, 5, 6]. However due to an increasingly global production environment the tool making industry in high wage countries stands in an aggressive competition with suppliers from Eastern Europe and China [7, 8]. Facing this challenge, the industry has to develop business differentiators to preserve international competitiveness. As differentiation over tools’ quality or price is not a successful strategy any more, low life-cycle costs and therefore cost efficiency alongside tools’ life cycle comes into play. Gaining this cost efficiency tool making companies in high wage countries would be able to justify their higher acquisition prices by lower production costs and market overall more cost-efficient tools.

To approach a solution for tool and die making companies to gain cost efficiency alongside tools’ life cycle this paper is divided into six chapters.

After an introduction in the second chapter the German tool and die making industry as well as its challenges derived from trends in the manufacturing sector are introduced.

In the third chapter prior works on life cycle assessment are analyzed and considered regarding their capability to address the introduced challenges.

In the fourth chapter an explanation model of tools’ life cycle costs is presented. Within the 11th Transnational Collective Research Project Proposals (CORNET) program, the Laboratory for Machine Tools and Production Engineering (WZL) Aachen, Germany, and its research partner IFT Vienna, Austria, set up the “Total Efficiency Control” (TEC) project to focus on this topic. From the beginning in 2011 the TEC project has been supported by 14
German and Austrian tool making companies to enhance relevance. An explanation model of tool’s life cycle costs was developed followed by a Resource Consumption Calculation Tool (RCCT) that allows the forecasting of total costs for tools over their entire life cycle. The explanation model in combination with the RCCT makes tool’s life cycle costs transparent.

Based on this transparency in the fifth chapter an approach is introduced to stimulate cost efficiency finally: customer integration. Through customer integration the tool making company is integrating into the value creation process of its customer. Thereby the toolmaker is enabled to get production process information by the meaning of field data of its tool. Getting the production process information the tool making company has access to all costs alongside tool’s life cycle, which has not become reality in the tool making industry by now. Customer integration can be realized through services alongside tools’ life cycle. In this paper these services related to the tool as the core product are explained and their influence on cost efficiency over the tool’s life cycle is clarified. These findings are results of the research project as well and were worked and verified by the 14 international tool making companies.

The conclusion in chapter six will finalize this paper.

In the following the word “tool” is used to describe tools as well as dies. Therefore companies of the industry are described by the expression “tool making company” and the industry itself by the expression “tool making industry”.

2. The German Tool Making Industry

2.1. Overview over the German Tool Making Industry

The German tool making industry has about 54,000 employees [9]. 80% of the produced tools are either injection and compression molding or forming tools. After the global crisis in 2009 and 2010, the industry has recovered very quickly and is almost back at pre-crisis sales. Most of the 4,800 German toolmakers are medium-sized companies with less than 20 employees [10] (Figure 1). The market access of toolmakers can either be external or internal. An external tool shop offers customers tools as its final product. Internal tool shops, on the other hand, build tools for their companies’ own production. They are therefore a supporting unit within a producing company.

![Figure 1: Key Facts about the German Tooling Industry](image)

However German toolmakers are still facing margin losses even after the crisis and consistently increasing sales. The reason for this development is the upcoming competition especially from Eastern Europe and Asia. The quality of their tools has increased enormously but their prices are still low. Thus the German tool making industry tries to stay competitive by focusing on the five fields of action costs, time-to-market, quality, innovation and productivity [11]:

- **Costs:** Depending on the sector, tools account for up to 30% of the total production costs [12]. Due to the use of the tool, planned maintenance and unplanned repairs, additional costs which are directly connected to the tool accrue over the lifetime. Experts assume that 60% of the total production costs are determined by the production tool [13]. Innovative tool concepts enable the customers to realize significant cost-saving potentials over the life cycle of the product because of the tools high productivity. Therefore tools’ life cycle costs become the most important lever.

- **Time-to-Market:** Product life-cycles shorten continuously in most industries. 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. Referring to the realization of a new product, the production of the tool is on the critical path between product development and mass production. 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:** Beside the tool by itself and the interaction between 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, caused by the high complexity of the tool manufacturing, are necessary to achieve high customer satisfaction through 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 toolmaker 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.

2.2. Challenges for the German Tool Making Company

In the global competition the European tool 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 labour-cost countries with growing technologic potential. Therefore three main challenges can be identified for the tool making industry – increasing product derivatisation, shorter product life-cycles and lower factor costs of global competitors.
The combination of increasing product derivatisation with shorter product life-cycles leads to an increasing number of product variants besides decreasing production volumes concerning each variant [14]. Consequently this ends in a significantly higher product diversity as well as product and production complexity. These changes directly affect the producing industry as well as the tool making industry as it provides the tools for manufacturing the products. The tool making industry therefore appears as the enabler for managing product and production complexity. Due to the decreasing production volume the tool costs take a higher share in the overall production costs [15]. Consequently the tool budget is reduced by the customers, which requires the tool manufacturer to offer the tools at a lower price. Furthermore European toolmakers compete with new market participants from low-labour-cost countries, which distinguish through lower factor costs.

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 [16]. Rather analyzing and optimizing the life-cycle costs of the tools and therefore reducing the production costs offers potentials to distinguish from low labour-cost country competitors. Nevertheless the tool making industry has not made any satisfactory efforts to optimize tools’ life-cycle costs and gain a win-win situation for toolmaker and tool user yet.

In the conventional distribution of roles the toolmaker is only responsible for developing and manufacturing the tool. A cooperation with its customer, the tool user, comprising the exchange of information or communication beyond the traditional interfaces does not occur. TEC revealed the fact, that toolmakers do not have access to information within the utilization and recycling phase of their tools (phases whereas the tools are physically at their customers). A study by WZL and Capgemini Consulting in 2013 confirmed these findings [17]. Thus about 90% of problems occur on interfaces between toolmakers and their customers what is considered as the top priority interface-problem in the study. Another WZL study concentrating on toolmakers identified that less than 10% of the toolmakers get performance information about their tools in their customers’ production. Furthermore less than 20% get informed about maintenance activities of their tools. As a disadvantage the toolmaker has no access to process data and costs caused by the tool during its use, which forecloses a life-cycle cost analysis, respectively optimization. To make life-cycle costs transparent the integration of the toolmaker into the customer’s value chain and therefore a collaborative value creation is forcefully necessary. This collaboration would allow the tool making company to create specific knowledge about life-cycle costs, which would make it possible to draw conclusions about life-cycle costs regarding current tool developments as well.

3. Prior Works on Life Cycle Cost Assessment

There are some existing approaches concerning the tool’s life cycle that mainly focus on assessment of life cycle costs. The key to cost efficiency 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 tooling and die industry has been acknowledged, no holistic solution has been proposed yet [18]. 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 consumption of resources like raw materials, energy and commodities during the tool’s life cycle [19].

The 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 [20].

None of these works is capable to address the introduced challenges of the tool making industry. Still an approach to explain resource consumption alongside tools life cycle is missing as well as measures to gain cost efficiency. The life cycle optimization proposed in this paper wants to take the next step forward and investigate not only energy efficiency but overall resource respectively cost efficiency. Furthermore it wants to discuss measures for gaining cost efficiency alongside tools’ life cycle.

4. Description Model of Costs alongside Tools’ Life Cycle

4.1. Tools’ Life Cycle

As a first step in research project TEC 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 stages’ cost parameters. The life cycle of the tool is defined by the following generic stages: development, manufacturing, usage, recycling. These four main-stages are extended to ensure a closer look at each stage. Therefore the stages are divided into 21 sub-stages which are shown in figure 2.
The development stage is initiated by the customer’s request and finished after the construction by the handover of the engineering drawings to the tool manufacturing divisions. In the manufacturing stage all steps of the manufacturing process, the assembly and the successful finishing of the try-out are included. After delivering the tool the customer starts the series production using the tool. This stage also comprises maintenance and repair activities. The recycling of the tool starts after the series production is finished.

4.2. Costs Alongside Tools’ Life Cycle

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

The completed model of life cycle costs enables the tool making company as well as its customer to consider all emerging cost over the entire life cycle of tools. To even optimize the life cycle cost and therefore gain cost efficiency over the life cycle specific measures are needed. In the next chapter potential measures to gain cost efficiency are presented.

5. Life Cycle Oriented Customer Integration

According to the position in between the customer’s production process the toolmaking process is the central enabler of an efficient production process and therefore life cycle cost efficiency. However, in contrast to a company of 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.

In the conventional value chain a cooperation comprising the exchange of information or communication between toolmaker and tool user does not occur. As a disadvantage the tool making company has no access to process data during the tool’s usage stage, which forecloses a life cycle cost optimization. To enable a life cycle cost optimization the tool making company needs a login into the customers’ processes. The so called customer integration succeeds through innovative product-service systems alongside tools’ life cycle networking the value creation processes of toolmaker and tool user. Derived from the position of the toolmaker in the value chain there are opportunities for customer integration upstream (into the product development) and downstream (into the series production)(Figure 3).

Customer integration can be realized in different degrees. A low degree of integration is realized through consulting services by the toolmaker. The tool making company is transferring information to the customer without getting an equal quality of information by the customer. A medium degree of integration means at least an exchange of information. The tool making company is also getting valuable information by the customer. A high degree of customer integration means the total adoption of the customer’s process. The process step is transferred from the area of responsibility of the customer to the area of responsibility of the toolmaker.

5.1. Upstream Customer Integration

The upstream customer integration 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 its know-how already in the design stage of the product. Thereby the degree of integration into the value creation process of the customer may vary. Following three services to be offered in a product-service system in combination with the tool itself are introduced – from low integration degree up to high integration degree: Consulting of product development, rapid prototyping of products and adoption of product development.

Commonly the customer designs a product without being consulted pro-actively by the tool making company. As a result after the product design it may happen that the designed product can not be produced by the tool concerning to technological reasons. A circumstance which is neither time nor cost efficient and leads to an increased time-to-market. To shorten the time-to-market the product design has to be aligned with the technological capabilities of tool making. The integration of product and tool development, realized by consulting the product development by the tool making company, would ensure this alignment. Therefore consulting of product development has to be executed already between the stages of request and offer. While consulting the product development the tool making company is transferring tool and design specific know-how to the customer. On the contrary in practice the customer only discloses that information which is relevant to design and develop the tool. Therefore the degree of integration is rather low. The alignment of product and tool design covers cost potentials in every sub-stage of tool’s life cycle from production planning up to continuous improvement process (CIP). Both cost types, material and personal costs, are affected due to a more resource efficient and faster tool development process because of less trial and
error loops in tool development and usage. However the know-how transfer is just one way. Tool making companies consult their customers commonly in advance before the official order. If the project is not realized the tool making company is not paid for the consultancy service. Rapid prototyping is an opportunity to make the consulting of the product development process even more efficient. Using generative manufacturing like 3D-printing the toolmaker is enabled to produce a prototype of the product already in the product development stage. The prototype illustrates the functionality, haptics and optics of the final product. Thereby toolmaker and customer are enabled to discuss possible challenges concerning the realization of the product’s series production. Sources of technical difficulties are uncovered and can be eliminated in advance. Like consulting of the product development also the rapid prototyping service has to be executed between the stages of request and offer in the context of an integrated product and tool development. By rapid prototyping the tool making company itself realizes prototypes of products which are traditionally produced by its customer. Therefore an exchange of information e.g. in terms of design drawings between toolmaker and customer is inevitable. However the toolmaker is not adopting entire process steps of the traditional value chain. Hence the degree of integration into the value creation of the customer is medium. Eliminating sources of technical difficulties already during the product development leads to a shorter and more resource efficient ramp-up of series production and therefore usage stage. Hence cost potentials regarding personal and material costs in all sub-stages from series production up to warehousing can be leveraged. However the technological equipment for realizing rapid prototyping is expensive and therefore has to be utilized with high occupancy rates. Otherwise life cycle costs would rise extraordinarily.

As mentioned above the alignment of product and tool design is a big lever regarding cost efficiency. Traditionally the alignment is disrupted by inefficiencies concerning the interface between customer and tool making company. Avoiding this interface would eliminate these inefficiencies and thus would enable an ideal alignment of product and tool design. The only possibility to avoid the interface is to shift the whole responsibility for product and tool design to either the customer or the tool making company. Due to the increased technological complexity of tools over the last years and an increased concentration of tool users on their core competencies the logic consequence should be shifting this responsibility to the toolmaker. Therefore the adoption of product development by the tool making company as a service covers cost potentials. Being realized parallel to the life cycle stage development the relevant cost positions are equivalent to the customer integration trough consulting of product development. However in this case the degree of integration is not low but high as the tool making company is taking over a process step of value creation which is traditionally being executed by its customer. Barriers for adoption of product development could be of strategic origin: the adoption would lead into diversification and therefore would counteract a commonly intended focus on core competencies.

Figure 4 gives an overview over the measures of upstream customer integration, the particular life cycle stage, the degree of integration and the sub-stages of influenced cost positions as described above.

| Measure of Upstream Customer Integration | Life Cycle Phase | Degree of Integration | Sub-stages of Influenced Cost Positions |
|----------------------------------------|------------------|----------------------|----------------------------------------|
| Consulting of Product Development      | Assignment       | Low                  | Planning up to Product Modification     |
| Rapid Prototyping of Products          | Construction/ Simulation | Medium              | Manufacturing up to Wear Parts          |
| Adoption of Product Development        | Draft            | High                 | Planning up to Product Modification     |

Figure 4: Overview over Measures of Upstream Customer Integration

5.2. Downstream Customer Integration

The downstream customer integration is realized by services after the tool manufacturing stage. These services cover tools’ maintenance and repair up to adaption of entire process steps like manufacturing of small series. The most accomplished characteristic of downstream integration is the use of intelligent tools. Following these three measures for backward customer integration are introduced.

The toolmaker provides customer benefits in terms of productivity and stable series production. As tools are one of the most common origins of down times in production continuous maintenance and immediate repair of tools is inevitable. Due to the mentioned increased complexity of tools the tool user mostly has not enough know-how to execute the maintenance and repair job adequately by its own. The more complex the tool, the more depended the tool users are on the toolmaker concerning productive and stable series production. Therefore the toolmaker can offer preventive maintenance and immediate repair services performed on-site at the customer based on the tool specific know-how he has. Due to quantitative less down times and therefore less set-up times of tools the consumption of resources and time is decreasing. Due to qualitative less down times the productivity is increasing. Hence cost potentials in terms of material and personal costs during the entire use in production stage are unfolded. During maintenance and repair services the flow of information is directed especially from toolmaker to its customer. Therefore the degree of integration is low. However especially repair orders are not predictable. Therefore those projects disturb the long-term production plan of a tool making company. As a result also the process flows respectively material flows are disturbed. The due date reliability may decrease.

For tool users the production of a few and special small series beneath the common series production raises the complexity of production management and planning. Focusing on their core competencies the tool users therefore need to outsource those small series. Because of an increased efficiency due to the elimination of interfaces particularly the tool making companies may adopt those projects. For this reason cost potentials regarding tool’s life-cycle costs result from the sub-stage of try-out up to the sub-stage of CIP. Those eliminated interfaces lead to reduced personal and material costs. But there are also disadvantages, that may occur adopting small series production. Again strategic
reasons may lead to these disadvantages. Thus widening the production range is not compatible with a focusing strategy.

Traditionally the actual performance capability of the tool cannot exactly be measured and its monetary relevance cannot be quantified. One measure for gaining transparency over those issues are intelligent tools. Being equipped with modern sensor technology intelligent tools collect and analyze process data and transmit it to both tool making company and customer. Hence the toolmaker is enabled to data interpret the characteristics of a tool in use and execute a preventive maintenance service. Furthermore it can support the determination of the actual quality of the tool as all damages, repairs and maintenance is being documented. The results can be exploited in the design of new tools as well. Due to a complete intervention of the toolmaker into the production process and holistic transparency the degree of customer integration is high. Intelligent tools offer a promising opportunity to decrease the life cycle costs of a tool intensively. But barriers for using intelligent tools prohibit their common usage in the producing industry. Thus there are still reservations concerning data security. Furthermore tool users do not want to be monitored or controlled by toolmakers.

Figure 5 gives an overview over the measures of downstream customer integration, the particular life cycle stage, the degree of integration and the sub-stages of influenced cost positions as described above.

**Table: Measures of Downstream Customer Integration**

| Measure of Downstream Customer Integration | Life Cycle Phase | Degree of Integration | Sub-stages of Influenced Cost Positions |
|------------------------------------------|------------------|-----------------------|----------------------------------------|
| Repair and Maintenance of Tools          | Maintenance      | Low                   | Manufacturing up to Product Modification |
| Manufacturing of Small Series            | Manufacturing    | Medium                | Try-out up to Product Modification      |
| Usage of Intelligent Tools               | Manufacturing/ Modification | High             | Construction up to Product Modification |

**Figure 5:** Overview over Measures of Downstream Customer Integration

**6. Conclusion**

As findings of research project TEC in this paper practical solutions for realizing customer integration in the tool making industry through product-service systems are introduced. Customer integration through product-service systems is a big lever for gaining life cycle cost efficiency. Firstly it was identified that while resource and energy consumption have been addressed extensively, a holistic approach to gain transparency over life cycle costs and to optimize those costs still needed to be developed. Therefore six successful measures for customer integration according to different degrees of integration were introduced. Their incidence alongside tools’ life cycle was explained as well as their positive effect on tools’ life-cycle costs. Furthermore possible challenges respectively barriers realizing those measures where discussed.

**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). 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).

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