Resource Consumption Calculation Tool to Enhance Efficiency in Production Processes

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Abstract
Today, the overall price of a production process, in particular the price of resources, energy and labour, is increasing. This affects the whole European industry, especially tool-makers, their suppliers and customers. This development jeopardizes their competitiveness against industries from low-wage countries and increases the importance of recycling. This has an impact on both tool-makers and producers, since tools are an integral element in each production system. Thus the tool industry’s efficiency needs to be improved in order to meet future challenges. While there are many approaches optimizing resource management in general, none of them particularly regard tools. Thus their tremendous potential is left untapped. Given the competitiveness in the international field of tooling, there are four major scopes to improve upon: Development, the tool-making process, utilization and recycling. To this end, WZL Aachen, Germany and its research partner IFT Vienna, Austria are developing a Resource Consumption Calculation Tool (RCCT) which will allow for a prognosis of resource consumption, relating to a tool’s entire life cycle. To ensure significance, as a first step a tool’s life cycle is analyzed. Afterwards, all identified interdependencies between parameters along the life cycle are stored in a knowledge base. On the one hand the development of new manufacturing technologies is supported, and on the other hand the functionalization of materials and surfaces is facilitated. The RCCT offers competitive advantages to the European tool industry, as it provides a calculation of possible savings based on input data, i.e. certain limits or usage conditions such as frequency or life-time. This leads to an overall costs reduction regarding all four major scopes and helps tool-makers distinguish themselves from their competitors, especially from those from low-wage countries. In particular, tool manufacturers are able to sell products of higher value while tool-users have more information concerning resource consumption.

Keywords
Resource Consumption, Tool Life Cycle, Tool Improvements, Competitiveness of Tool Manufacturer, Calculation of Resource Consumption

1 GLOBAL TRENDS AND ASSOCIATED CHANGES OF BUSINESS ENVIRONMENT
Over the last decade the scarcity of resources has become highly visible. Several newly industrializing populous nations e.g. China have raised the global demand for numerous resources [1]. The consequences have been, among others, surging and volatile prices e.g. for energy and raw materials [2].

Beside the monetary aspect, ecological awareness has become – especially in the EU – more significant. Companies have to operate in a sustainable manner. The Europe 2020 strategy with its flagship initiative “Resource-efficient Europe”, for instance, aims to form a more competitive low-carbon economy that makes efficient, sustainable use of resources [3].

Furthermore, new competitors with steadily improving technical abilities enter the global market. Their relatively low labour costs – compared with those of existing high-wage industrialized countries – are one of their main advantages [4]. Consequently there is an immense pressure on pricing. In addition, an upsurge in customer demands leads to increased complexity in production. Shorter product life cycles and higher quality requirements are examples for this development [5]. Many customer demands necessitate continuously reliable processes.

Particularly the tool-making industry, with its key role within the industrial value creation process, has to address the aforementioned changes of the business environment. In order to compete sustainably on the global market, resources need to be used as efficiently as possible. Additionally, tool-makers need to be able to fulfill their customers’ requirements to the highest standard, with the objective of allowing for differentiation[6].

In order to achieve this goal, a holistic approach has to be applied, that identifies the relevant parameters on the resource consumption in this specific industry
and helps to set up structures to manage them in a more sustainable way.

2 CURRENT BUSINESS ENVIRONMENT IN THE EUROPEAN TOOL-MAKING INDUSTRY

The European tool-making industry faces a growing competitive environment. With more than 16,000 companies and an average annual turnover of over 20 billion euros it represents a high value-added industry branch. Tool-makers hold a key position in the value chain of production industries, because almost every ramp-up of a production line depends on the completion of vital tools and their integration into existing production facilities [7]. In summary, the tool-making industry is the enabler for high value and high-technology production in Europe.

2.1 Challenges caused by increasing globalization

Globalization challenges tool-makers in a number of ways. One of the most apparent challenges is the strong competition with companies from low-wage countries. It is commonly known that competition through low-cost pricing is not a successful strategy for European tool-makers. Offering better prices than e.g. Asian tool-makers is in the long run ruinous, because of their relatively higher costs in Europe [8].

In the past, European tool-makers have been able to satisfy customer demand through superior tool quality. Tool users have been willing to pay premium prices for an additional value. Since competitors from all over the world steadily enhanced the quality of their tools the former lead is almost caught up.

Furthermore, booming economies in Asia with an enormous market potential attract manufacturers from all over the world. Strict regulatory frameworks for foreign direct investments e.g. in China force foreign manufacturers to establish joint ventures, which might further advance knowledge drain [9].

2.2 Needs of small and medium enterprises (SME)

In the long run, the tool-making industry – in particular SMEs – needs business models in order to succeed in this time of difficulty. As the sole focus on price does not lead to a sustainable competitive advantage, SMEs have to find novel alternatives to differentiate themselves from low-price competitors. Otherwise they will find themselves easily replaced by their customers [10]. In order to establish comparable criteria for European tool-makers, successful products are characterized by a unique selling point (USP).

Offering superb quality is no longer an exhaustive USP. Thus new ways to gain customers are necessary. Being able to offer an exclusive additional value will distinguish European SMEs from low-cost competitors [11].

2.3 Existing approaches to enhance resource efficiency and process reliability in production processes

There are already many approaches concerning the tool’s life cycle that mainly focus on the calculation of life cycle costs. The research project Life Cycle Costing (LCC) and its follow-up project concerning the quality oriented prognosis of tool’s life cycle (Qualitätsorientierte Prognose des Lebenszyklus von Werkzeugen und Formen, QProLCC) 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 consumption of resources such as raw materials, energy and commodities during the tool’s life cycle [12].

The recently completed government-funded research project on energy and auxiliary material optimized production (Energie- und Hilfsstoffoptimierte Produktion, 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 [13].

The aim of the research project Total Efficiency Control (TEC) is to take the next step forward and investigate not only energy efficiency but overall resource efficiency. Furthermore, TEC aims at considering the whole life cycle of a tool, not only parts. None of the present approaches is based on a knowledge base, as these are all associated with productivity.

3 ENHANCEMENT ENABLED BY TEC

The TEC project’s overall aim is to enable European tool-makers to differentiate from their competitors by offering tools that are more resource efficient. Since all existing approaches do not meet the SME’s needs regarding productivity and stability in production processes a holistic research approach is necessary. Tool-makers in Europe should be able to offer tool-users a forecast on the tools’ consumption of resources as an innovative customer-specific and value added service to distinguish from competitors, especially from those of low-wage countries. That will secure Europe as a sustainable production site for tool-makers in the long term.
3.1 Tool-makers’ benefit
Most tool-makers in the EU are SMEs with limited research resources. A joint project actually provides the capacity to carry out a project like TEC.

Generally the whole European tool industry will profit from further knowledge with the purpose of differentiating from competitors – especially from low-wage countries.

In particular, tool-makers will benefit by being able to provide value adding services for their customers (such as individually adjusting and customizing a resource efficient process). This competitive advantage obviously strengthens the tool-makers’ strategic position within the market by merging both productivity and stability through resource efficiency. Furthermore, tool-makers will be able to demonstrate that their tools are superior when considering the whole tool life cycle. The European tool-makers will gain a promising one-of-a-kind capability to convince potential tool-users.

In addition, the Europe-wide knowledge transfer might establish a network which could be used for joint future projects. The TEC project’s results might serve as the basis for further future research and development of innovative tools.

3.2 Tool users’ benefit
The main benefit for tool-users is the access to additional information regarding resource consumption over the whole life cycle.

The TEC project makes it possible to classify the tool’s parameters right from the beginning. The tool-user will be able to use the right adjusting levers based on the TEC project’s outcomes to improve efficiency.

As that information will be accessible for a tremendous number of alternative tools, better purchase decisions will be possible. The availability of more efficient tools helps to reduce costs and improve process reliability.

4 KNOWLEDGE-BASED RESEARCH APPROACH
In order to build a solid foundation for this holistic approach, data about the tools needs to be collected. This implies prior identification and analysis of a tool’s life cycle. After describing and analyzing the main interdependencies between the different parameters of several tools, the outcome will be stored in a knowledge base, which will serve as the basis for further research. Activities, such as the Resource Consumption Calculation Tool (RCCT), will benefit.

4.1 Identification of relevant stages in a tool’s life cycle
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 stages’ parameters. Therefore the stages have been defined preferably specific and complementary. A first life cycle model was designed. Afterwards, to ensure significance and consistency to the tool-maker’s point-of-view, the results were considered by the consortium and statistically analyzed. Finally, all relevant stages in a tool’s life cycle were found [Figure 1]. In the first two phases the tool is within the tool-maker’s physical possession until it is handed over to the customer. Within the Production phase the tool is used by the customer until it is sorted out in the Recycling phase.

![Figure 1 - Phases of a tool’s life cycle](image1.png)

These four main-phases are extended to ensure a closer look at each phase. This is crucial for the future annex of parameters to the stages.

4.1.1 Phase 1 – Development
Starting off with the development phase, all necessary tasks are to be accomplished before the start of production.

![Figure 2 - Development](image2.png)

The phase is divided into four sub-phases: assignment, draft, construction, and simulation. Following a successful simulation the tool production starts.

4.1.2 Phase 2 – Assembly and start-up
The second phase is assembly and start-up. Within this phase, the tool is produced and tested.

![Figure 3 - Assembly and start-up](image3.png)

It starts with the project planning and supply management, followed by the tool’s production, measurement and assembly. Afterwards, the try-out phase begins. The first batch is produced followed by samples. The second phase ends with the products maturity and the tool is handed over to the tool-user.

4.1.3 Phase 3 – Production phase
In the third phase the actual production is initiated. Important sub-phases are: manufacturing, wear
parts, stock, maintenance, process modification and product modification.

Figure 4 - Production phase

The main problem faced by the European tool-making industry is the lack of information within this phase.

Until now, there has been a lack of communication between tool-users and tool manufacturers. There are only a few exceptions; especially when it comes to disturbances that are reported to the manufacturer in the form of complaints. The tool producer usually has to cope with the complaint not having the required information. No structures for continuous data exchange have yet been implemented. This inhibits the potential for optimization on both involved sides.

Figure 5 - Tool-makers balance sheet

4.1.4 Phase 4 – Recycling

The life cycle ends with the recycling phase, which comprises all possibilities once the production is phased out. Normally, it starts with storing the tool.

Figure 6 - Recycling

After recycling all usable components, the carryover is scrapped. Either the tool-maker or the tool-user handles the recycling process. Generally recycling is more resource efficient, but definitely needs a well-organized process infrastructure.

4.2 Identification of parameters according to the identified stages in a tool’s life cycle

The TEC project strives to measure almost every kind of resource consumption. Throughout the different stages in a tool’s life cycle a considerable quantity of parameters need to be identified. Relevant parameters can only be those, which are adaptable. They can refer to tool design (geometrical data, surface coating, surface treatment, processing technique), operating conditions (cooling lubricant, conditions of use, operating speed), quality (rework, defects, deviations), maintenance (intervals, measures, critical dates), resource consumption (compressed air, power, heat/cold, raw materials, operating supplies, measures due to legal requirements), or recycling (amount, outcome, procedure). That information is, to assure practical relevance, generated in close cooperation with the participating SMEs.

4.3 Analysis of the stages parameters’ interdependencies

The next step, after identifying all relevant parameters in a tool’s life cycle, is to analyze the parameters’ interdependencies. This is done in terms of functional correlations using existing knowledge and the experience of the participating companies. The underlying thesis is that an increase of resource consumption within the beginning of the tool’s life cycle (Development and Assembly) might lead to a higher price for the tool-makers customer. However, it will definitely lead to an even higher reduction of resources in the following phases, when the tool is in use by the customer [Figure 7].

Figure 7 - Overall resource consumption

In the end, the overall resource consumption – regarding the whole life cycle – will be lower. Figure 7 illustrates this thesis.

This example shows on the one hand, the vast potential which is offered by the TEC project. On the other hand, it illustrates the importance of a holistic approach that focuses on a long-term perspective. Only by considering the whole life cycle and analyzing the interdependencies of all parameters throughout the life cycle can a comprehensive solution be found. The interdependencies of parameters out of different life cycle phases appear to be especially promising. The overall aim, by
identifying possible trade-offs, is to design more resource efficient tools.

4.4 Development of a reference model of tool's life cycle stages and parameters regarding resource consumption

To combine the received results, the life cycle analysis on the one hand and the parameter analysis on the other, a holistic reference model will be formed. It will be based on the verified model of a tool's life cycle and on the resource consumption affecting parameters. Inappropriate parameters will be eliminated. This reference model will be the foundation of all further steps.

4.5 Construction of a knowledge base

Once the major parameters’ interdependencies are defined and analyzed, their impact on the resource consumption along a tool's life cycle is determined, the data needs to be stored in a specifically designed knowledge base. This consolidates the gathered information into one single pool. The knowledge needs to contain all relevant information, such as functional as well as qualitative correlations. Since it will be difficult to capture all the expertise of relevant specialists and transfer it to the knowledge base, the design of the knowledge base is not yet decided. It will be especially adapted to the acquired information regarding the reference model of a tool’s life cycle. The knowledge base will contain the information gathered while identifying and analyzing the resources affecting parameters and their interdependencies. Another important step is to communicate the knowledge base and to grant access to the participating SMEs. This will enable a critical discussion for further improvements of the knowledge base.

5 OPTIMIZATION OF PRODUCTION COSTS AND ENHANCEMENT OF TOOL EFFICIENCY

Built on the knowledge base, containing correlations between creative leeway in tool designing and parameters of tool’s life cycle, new approaches to optimize tool production costs will be analyzed. This is supported through the deployment of new manufacturing technologies by analyzing new production technologies, e.g.: HPC technology, adaptive high performance gun drill, hybrid manufacturing, 5D-laser discharge machining, electrochemical milling or generative procedures in terms of resource consumption. Further, the application of new materials, e.g.: ceramics or new heavy duty tool steels, is analyzed. The results will complete the knowledge base.

6 CALCULATION TOOL FOR THE PROGNOSIS OF RESOURCE EFFICIENCY

Founded on the knowledge base, an (RCCT) will be designed. This is a software tool that allows the prognosis of resource consumption on the basis of the parameters’ interdependencies within the whole life cycle of a tool. The aim is to optimize the tool-makers strategies with regard to the resource efficiency. As a first step the requirements and expectations have to be identified that should be met by this tool. Based on this the tool will be developed and tested. Up to now, the requirements have not been finally set. It has to be ensured that further developments can be implemented as updates to the RCCT. The major requirements will be described soon after consulting the SMEs.

Overall, the RCCT’s construction will be an iterative process, to grant highest quality and continuous improvement. That being said, once the software is developed it will be tested again and adjusted if necessary.

7 BUSINESS MODEL FOR TOOL-MAKERS AND TOOL-USERS CONCERNING RESOURCE EFFICIENCY

In chapter 3 the aim of the TEC project was described. It emphasizes the importance of European tool-makers in distinguishing themselves from their competitors. In order to support tool-makers, a business model needs to be invented to find new ways of distribution. This will be based on the results of the RCCT and the knowledge based approach. This will be done within three steps:

7.1 Analysis of existing business models

First, existing business models are analyzed and discussed to define the general requirements that have to be met by the business model using the Resource Consumption Calculation Tool. As a second step the consortium of SMEs will be involved in defining additional specific requirements of tool-makers.

7.2 Definition of value proposition and added value

Based on the existing business models and the capabilities of the software tool, the value proposition of the business model is defined. This will clarify the benefit for the customers. Afterwards, it will be possible to define the processes of value creation including organizational and operational structure.

7.3 Analysis of financial structure

In a final step, to ensure the profitability of the business model, the cost structures of the tool-makers’ value-added processes and the revenue streams that can be realized are analyzed and compared. Besides being able to offer an increased benefit to the customer, being able to communicate this capability is also essential for the sustainable success of European tool-makers.
8 CONCLUSION
The TEC project has as its aim the development of the first holistic approach in order to create an overview of the resource consumption throughout the whole life cycle of a tool. By knowing the influencing parameters along the life cycle and - even more importantly – their interdependencies, the RCCT will be setup. This gives full transparency to the manufacturer and therefore the missing sales arguments. In the end the RCCT will be integrated into a business model to achieve the goal of a holistic approach that is tailored to tool-maker’s needs.

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11 BIOGRAPHY
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