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"LCA to go" –Environmental Assessment of Machine Tools according to Requirements of Small and Medium-sized Enterprises (SMEs) – Development of the Methodological Concept

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Abstract. The goal of the "LCA to go" project is spreading the use of LCA across European SMEs. For the sector of machine tools a webtool will be developed to help SMEs with conducting environmental assessment. First the SMEs requirements regarding environmental assessment were gathered in a survey. Second LCA case studies and third standards and legislation were studied. Out of these three sources a simplified environmental assessment methodology is developed. This resulted in a two-step approach including the life cycle phase raw materials and use phase of the machine tool. In the first step of the methodology the Cumulative Energy Demand has to be calculated to analyse the environmental hot spots. Depending on the hot spots a detailed environmental assessement using the CED or an Energy Efficiency Index is proposed in the second step. The methodology should be kept simple but lead to useful data for environmental communication. Next steps in the project are the detailed specification of the methodolgy, the data collection and the tool development.

Keywords: Environmental assessment methodology, machine tools, SMEs

1.1 Introduction

Environment is one of the leading concerns of our industrialized life. The increasing interest in environmental impacts of products over the whole life cycle is reflected by the numerous standards and activities. Large sized companies have enough budget and workforce to cope with these environmental necessities, but what about SMEs? The objective of the project "LCA to go" is to develop open source webtools for SMEs to perform a sector specific life cycle based environmental assessment. It provides tailor-made solutions to integrate simplified life cycle approaches into daily business processes. Industry machines and more specifically machine tool are in focus of the "LCA to go" project next to other sectors.

1.2 Approach

This paper shows the development of the methodology concept for the environmental assessment of machine tools. To name an appropriate assessment method (LCA, Carbon Footprint, Energy Efficiency Index etc.) a SMEs needs assessment in form of a survey, a research for current case studies of environmental assessments of machine tools and an analysis of current and future legislation and standards have been conducted (Figure 1.1.).

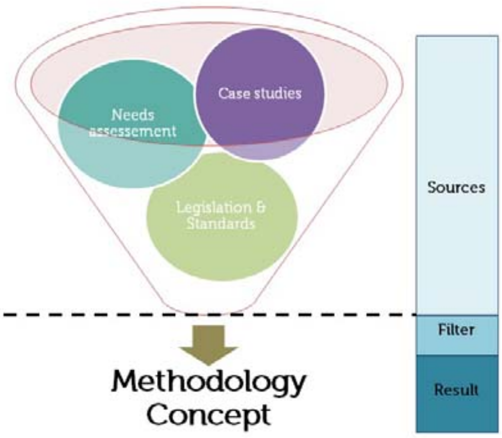

Fig. 1.1. Development of methodology concept [1]

1.2.1 Needs assessment

A survey, where 22 SMEs specialized in machine tool manufacturing responded, helped to define the needs of the European SMEs. It can be recognized that environmental issues are already anchored in SMEs but often just in form of cleaner production and theoretical knowledge around environmental assessment methods. Only 2 companies have practiced LCA once and just 36% of respondents know that machine tool are use-intensive products (because of energy consumption). 23% think that disposal is the most problematic life cycle (Fig. 1.2).

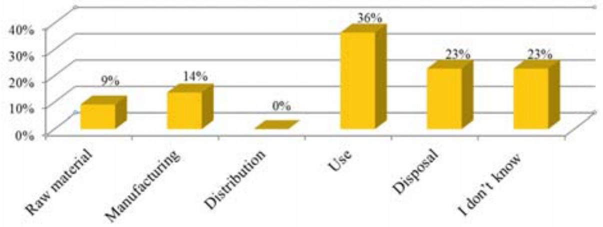

Fig. 1.2. Survey answers to the question "What is the most problematic life cycle phase of a machine tool?" [1]

Nevertheless the SMEs pointed out that the software tool should focus on energy aspects and it should support in fulfilling legal requirements. As environmental communication instrument a voluntary environmental label focusing on energy efficiency is of most interest. Additionally the tool should help improving product quality, product environmental performance should support in reducing manufacturing costs and helps to be prepared for future requests according to customers' demands. It should be possible to assess innovative products, without complete life cycle data sets.

1.2.2 Case studies

Case studies about environmental assessment of machine tools give the scientific perspective via providing environmental profiles where the most environmental aspects can be derived.

For conducting an LCA of machine tools different methods (CML, Ecoindicator 99, Cumulative Energy Demand) have been used in the case studies. Machine tools have usually a high weight (> 5 tons) and average lifetime of about 10 years running on a 2-3 shift basis. The result of the environmental assessment pointed out that the energy consumption during use phase causes 55-90% of the total environmental impact. Figure 1.3. shows the environmental profile for an injection moulding machine. Additionally the energy consumption in the use phase is broken down into its main consumer, where the tempering unit is of main importance consuming nearly 50% of the total energy consumption.

Further the case studies showed that only for least intensive used machines e.g one shift operation of a press brake, the raw material use has a relevant environmental impact with 40% of the total. This indicates that the environmental impact of a machine tool is quite sensitive according to the use scenario.

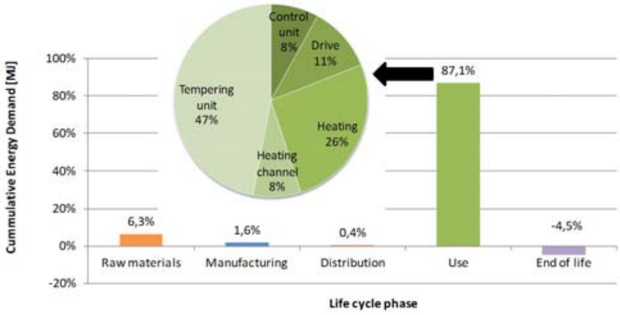

Fig. 1.3. Environmental Profile of an injection moulding machine [2]

1.2.3 Legislation and Standards

To ensure a high application rate of the developed web tool, the methodology should be in line with the actual and future legislation and standards.

Machine tools are already in focus of different environmental driven legislative initiatives. The European Commission has started a Product Group Study related to the Ecodesign Directive [3] with the aim to identify and recommend ways on how to improve the environmental performance of machine tools. This pressure from the EC resulted in two further initiatives driven by the industry. The ISO 14955 [4] and the Self-Regulation Initiative [5] concentrate on the environmental assessment of machine tool. The SRI and the ISO focus on the evaluation of energy efficiency of machine tools, where according to the functions of a component their energy consumption is allocated and the most relevant machine components can be identified. Further the German Society on Numeric Control (NCG) [6] proposed a method to measure the energy usage to calculate an Energy Efficiency Index (EEI).

All mentioned initiatives and standards are focusing on the energy consumption during the use phase of a machine tool. Additionally also Product Category Rules for preparation of an Environmental Product Declaration are under development, where the whole life cycle is considered [7].

1.2.4 Methodological concept

According to some leading questions the key aspects of the methodological concept is identified (see table 1.1). These questions are answered on the basis of the three defined sources needs assessment, the case studies and the legislation.

For machine tools the most relevant environmental aspect is the energy consumption during use as it is of major importance according to all three sources. The energy consumption represents up to 90% of the total environmental impact of a machine tool, already first attempts in legislation are seen and also the companies get more and more aware of this issue.

Table 1.1. Main questions leading to methodological key aspects (excerpt) [1]

Main questions	Sources	Key aspects for methodology
On which **environmental aspect(s)** the assessment should focus?	Case studies, Needs assessment,	Energy consumption, materials consumption
What kind of **environmental assessment** should be provided?	Case studies, Needs assessment	Cumulative Energy Demand (MJ), Energy Efficiency Index (kWh/production unit)
What kind of **environmental communication** instrument should be used?	Needs assessment, Legislation	Energy savings, EEI, CED

Additionally the raw material use is the second relevant environmental aspect to consider as they are relevant for the companies (needs assessment) and also due to some environmental assessment case studies. The relative environmental impact of the raw materials rises, especially if the machines running just a few hours a week and less energy are used during the whole life of the machine. Materials become also important, when large quantities or rare elements are addressed within machine tools or if the customer's request a material declaration. Moreover increasing costs of materials or future legislation could bring these aspects more in focus.

Therefore the environmental assessment method as well as the developed software tool will be limited on the relevant life cycle phases raw materials and use phase. Parameters such as auxiliary materials or energy consumption during manufacturing of the machine tool are excluded as this causes minor environmental impact over the full life cycle of the machine tool. For environmental communication a voluntary environmental label, focusing on energy efficiency, is of most interest. SMEs want to inform their business clients about energy savings of machines compared to reference products.

To fulfil these key requirements a two-step assessment is proposed. In the first step a hot spot assessment with applying the Cumulative Energy Demand (CED) will be conducted. Just the impacts of indicators for energy and for materials are in focus of the assessment. In the second step a detailed assessment will be conducted, either an EEI or a more specific CED will be calculated.

1.2.4.1 First step: Hot spot assessment with CED

The goal in the first step is to find the environmental hot spot of the machine tool. With only limited data input the dominant environmental life cycle phase can be highlighted. According to these results a detailed assessment can be conducted in the second step.

The CED is an appropriate approach to assess impacts due to energy and material consumption leading to aggregated results in MJ. The results are easy understandable for SMEs. In the material section a rough estimation of the CED will be calculated. Just knowing the total weight of the machine tool the CED is calculated using a general material data set, including an average material mix. Then the main focus lies in the definition of the use scenario. Therefore the operating hours of the machine tool over the full life time have to be assessed. It has to be declared if the machine is used in 1-shift, 2-shift or 3-shift operation and what is the targeted lifetime. Within one shift different machine modes (operating, stand-by, idle) have to be considered. For all this machine modes the energy consumption has to be measured according to a defined measuring standard. As result the environmental performance just focusing on raw materials and the use phase, calculated in MJ is given. If the CED shows a significant environmental impact of both raw materials (>10% of the total CED) and the use phase than the CED should be used for further environmental considerations – step two. If the CED of the materials represents less than 10% of the total energy the detailed environmental assessment should focus just on the use phase. In this case an Energy Efficiency Index (EEI) will be calculated.

1.2.4.2 Second step: Detailed assessment with CED or EEI

To get accurate results in the second step the environmental assessment will be conducted in more detail. If the accuracy rises to a certain level e.g. 95% of the environmental impact, the results can be used for environmental communication as well. Additionally the results should help and give advice on how to environmentally improve the machine tool.

In case of significant environmental impact of both the materials and the use phase the CED will be calculated in more detail. Therefore the specific materials have to be declared. For each material a dataset is available. The more materials are declared the higher the accuracy of the results. In the use phase the energy consumption is measured according to the energy measurement standard giving the energy consumption for all main components.

This will help at the analysing stage when it comes to product improvement.

In comparison to other environmental assessment methods the advantage of the CED methodology is manageable data and time effort, which was a main criterion for SMEs using an environmental assessment method. Moreover it delivers easy to understand results, even for users which have low experience in the field of environmental assessment.

If the use phase is dominating an EEI should be calculated instead of the CED. An EEI has the purpose to assess the energy efficiency of products and to show the efficiency performance in comparison to other products. The EEI is also very much favoured as business to business communication from the SMEs, as it provides clear and short information about energy consumption of a machine tool during the use phase. In comparison to other communication instruments like the product carbon footprint (PCF) the EEI methodology is easy to calculate and to understand. Moreover the value of the EEI is the same for a specific product in every country. Considering a PCF (calculated with CO_2-equivalents) the value for one and the same product is different due to the different energy mixes.

In developing an EEI, the challenge is to get comparable results. This has to be secured by defining a suitable energy measurement standard. For example, NCG has proposed a standard where the machine has to run through a 15 min test cycle without producing a work piece. This leads to a method applicable for a broad range of machine tools, but on the other side the productivity and the energy consumption during production are not included. Another approach to define specific test pieces like it is foreseen in the ISO/CD 14955-1 Part 3. This lead also to comparable results but a test piece for each product type is needed.

In figure 1.4 a model on how to display the energy efficiency of a product is shown. The energy efficiency is defined as the relation of the energy consumption to the production unit per hour. Within this model the energy efficiency of a machine tool can be compared with other machine tools and additionally the energy class (A, B, C, etc.) can be defined. For example machines with the Best Available Technology (BAT) represent the energy class B or machines with Best Not Yet Available Technology (BNAT) are defined as class A. This energy classes can then also be used within an Energy Efficiency Label for environmental communication.

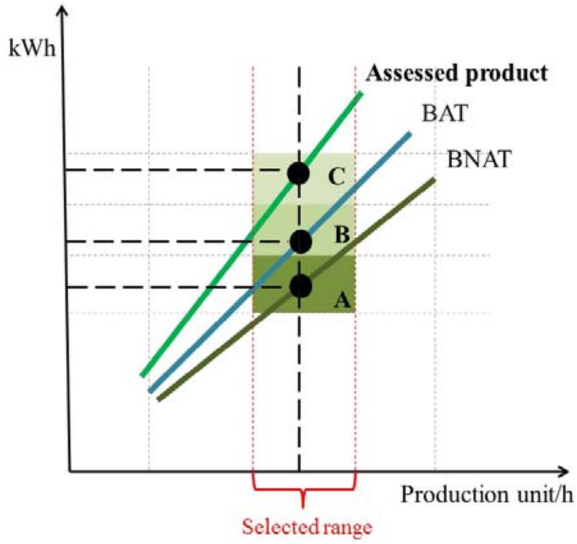

Fig. 1.4. Model of Energy Efficiency Index

1.3 Outlook

In the next step a simplified operating method is generated including compiling environmental profiles and developing Product Category Rules (PCR). To define the EEI the challenges will be the definition of the measurement standards and the data collection for reference products (BAT, BNAT).
More aspects to clarify are the definition of the use scenarios and the energy measurement standard. Defining the details of the tool and the methodology will be conducted in collaboration with the later users, the SMEs.

1.4 References

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