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Criteria for energy-efficiency of technological processes, technological machines and production engineering

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Abstract

At present, a large number of methods for processing and forming of parts and products, technological processes and equipment have been created for their implementation. Trends towards improved productivity, accuracy, reliability, flexibility, economy of the technological process, technological machines and machine system demand the development of new methods for the analysis of their effectiveness. A unified approach to the assessment of the effectiveness of processes, equipment and production allows considering them as energy-information model in which there is a transformation of all types and forms of energy, matter and information. This allows considering the concept of "energy efficiency" as the relative coefficient of efficiency of the collection of all kinds of transformative mechanisms and devices. On the basis of the proposed energy-information model is given the generalized method for the evaluation and comparison of the integral energy efficiency of technological processes, technological machines and production engineering. Due to the directive for the ecodesign of energy-related products (2009/125/EC) and economic factors a metal cutting machine tool has been evaluated over its whole life cycle. A methodology of Life Cycle Impact Assessment (LCIA) was used to unfold the main ecological footprint. The energy consumption of the machine tool and in particular its components was measured for the manufacturing of a defined work piece. The results state priority resource saving potentials of the machine tool. Theoretical calculations and experimental evaluation are presented and compared in order to propose methods for industrial applications.

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Keywords: machine; manufacturing process; energy-information model; energy efficiency; criteria;

1. Introduction

Material production, as a technical system, consists of two elements: first - the subject with its inherent properties, second - technologies, parameters and characteristics. Therefore, the development of such a system is in principle possible in the following ways:

- The improvement and creation of a new subject and its properties
- The improvement and development of new production technologies
- Combing these two, but in the choice of priority (with limited resources) of the second preference.

At present, there are different methods for processing, preparation and formation of parts and products, technological processes and equipment for their implementation. Tendencies towards increasing productivity, accuracy, reliability, flexibility, economic and efficiency of both the production and process equipment, require to have innovative machine systems. Thus, alternative methods for system analysis are required, especially for equipment with variable structure and a wide range of technological processes. This would allow for a deeper and more comprehensive structural and system description.

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Nomenclature

EE energy efficiency
LCIA life cycle impact analysis
U relationship

2. Life cycle impact analysis

Resource savings derived from a life cycle impact analysis will improve the environmental performance of a manufacturing system. The energy-efficiency of different processes may be compared through the energy-efficiency indicator. Figure 1 shows the lifecycles stages of a manufacturing system and manufactured products.

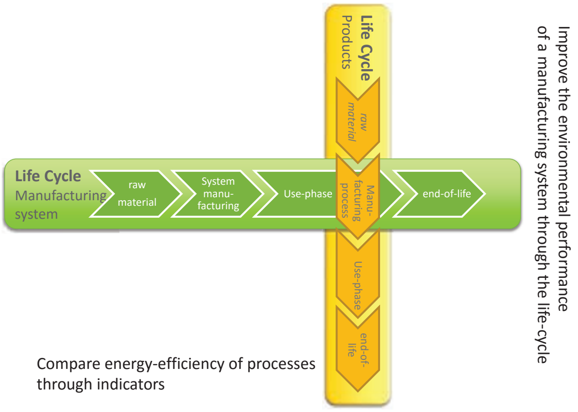

Fig. 1. LCIA of manufacturing system and products.

Following the ISO 14955 standard [1], a methodology for the evaluation of the energy- and cost-effectiveness of machine tools which is characterized by the integration of energy flow measurement, predictive energy consumption simulation of drive systems and life-cycle costing has been presented in [2]. The European Directive 2009/125/EC [3] and economic factors faces manufacturers and users to evaluate their machine tools over their whole life-cycle from an ecological and economical point of view. Based on the European Commission Methodology for Ecodesign of Energy-using Products (MEEuP) a product group study identifies and recommends solutions to improve the environmental performance of these energy-using products throughout their lifetime at their design phase [4].

A 4-axis CNC machining center, HEC 400D type, is divided into a workpiece system, tool system with clamping and handling functions. Main modules for engineering phase are: electrical system for control and mechanical purposes, control system, pneumatic system, hydraulic system, main drive, feed drives, tool and workpiece handling system, handling of support and waste materials, which have been analyzed for their resource consumption following the MEEuP. Figure 2 illustrates, that the highest impact is related to the use phase with 99.2% of the electrical energy consumption. The second most important impact is related to the materials to be used for the machine tool manufacturing.

The resulting resource consumption of the machine tool and its modules for the manufacturing of a defined workpiece was investigated.

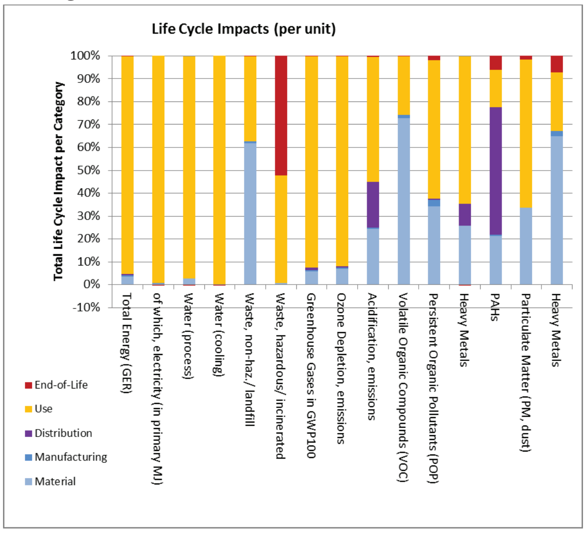

Fig. 2. Environmental assessment for 4 axis machine tool HEC400D.

Energy evaluation of the total life cycle impact per category helps to identify technically and ecologically weak points of machine tools in order to increase the energy-efficiency through low-energy consuming components or electrical energy storages. (following the first way in chapter 1)

3. Energy–information model of the processes, equipment and productions

3.1. Energy-information model

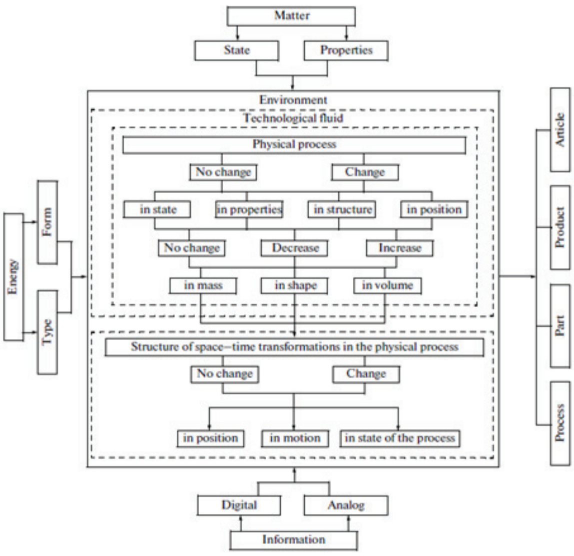

Fig. 3. Energy-information model.

Figure 3 shows a generalized energy-information model [5] for the production of goods (items). The physical manufacturing process of the product is the result / type of