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Machine tools — Environmental evaluation of machine tools

Part 1: Design methodology for energy-efficient machine tools

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee MTE/1, Machine tools.

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Machine tools — Environmental evaluation of machine tools —

Part 1: Design methodology for energy-efficient machine tools

Machines-outils — Évaluation environnementale des machines-outils —

Partie 1: Méthode de conception de machines-outils économes en énergie

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 39, *Machine tools*.

ISO 14955 consists of the following parts, under the general title *Machine tools — Environmental evaluation of machine tools*:

— *Part 1: Design methodology for energy-efficient machine tools*

The following parts are planned:

— *Part 3: Principles for testing metal-cutting machine tools with respect to energy efficiency*

— *Part 4: Principles for testing metal-forming machine tools with respect to energy efficiency*

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Introduction

As environmental impact is a common challenge for all products and as natural resources become scarce, environmental performance criteria for machine tools have to be defined and the use of these criteria has to be specified.

Machine tools are complex products for industrial use to manufacture parts ready for use or semi-finished products. The performance of a machine tool as key data for investment is multi-dimensional regarding its economic value, its technical specification, and its operating requirements which are influenced by the specific application. Therefore, the same machine tool can show quite different energy supplied to the machine depending on the part which is being manufactured and the conditions under which the machine is operated. Therefore, the environmental evaluation of a machine tool cannot be considered in isolation from these considerations.

This part of ISO 14955 tries to overcome this deficiency by breaking down the machine tool to machine components which come closer to a functional unit for environmental evaluation. The machine components are objects of specific improvements keeping the application of the system in mind. These improvements are subject for quantification together with the overall system design to achieve a product with an improved environmental performance. The provisions and procedures specified in this part of ISO 14955 are also intended to allow the calculation of environmental improvements on a multi-national level and across different manufacturers/suppliers and users.

Based on a list of positive environmental features, which can be built into a machine tool, the performance of this product is intended to be evaluated in order to quantify the environmental improvements achieved over a defined period.

ISO 14955 takes care of relevant environmental impacts during the use stage. Aside from the design and engineering of machine tools, the utilization of these products is also addressed.

Machine tools as manufacturing devices might have a significant influence on the environmental performance of the products being manufactured together with their final use stage. This aspect has to be treated very sensitively and might produce quite different results when an assessment is made with a broader definition of the system boundaries.

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Machine tools — Environmental evaluation of machine tools —

Part 1: Design methodology for energy-efficient machine tools

1 Scope

This part of ISO 14955 constitutes the application of eco-design standards to machine tools, mainly for metal working numerically controlled (NC) machine tools.

This part of ISO 14955 addresses the energy efficiency of machine tools during the use stage, i.e. the working life of the machine tool. Environmental relevant stages other than the use stage and relative impacts other than energy supplied to machine tools are not within the scope of this part of ISO 14955 and need a special treatment (e.g. according to ISO/TR 14062).

Elements of eco-design procedure according to ISO/TR 14062 are applied to machine tools. Reporting of results to users and suppliers and monitoring of results are defined.

Evaluation of energy efficiency implies quantification of the resources used, i.e. energy supplied, and of the result achieved. This part of ISO 14955 provides guidance for a reproducible quantification of the energy supplied. It does not suggest a methodology for quantifying the result achieved due to the lack of universal criteria. The result achieved in industrial application being machined workpieces, their properties (e.g. material, shape, accuracy, surface quality), the constraints of production (e.g. minimum lot size, flexibility), and other appropriate parameters for the quantification of the result achieved are intended to be determined specifically for each application or for a set of applications.

This part of ISO 14955 defines methods for setting up a process for integrating energy-efficiency aspects into machine tool design. It does not support the comparison of machine tools. Also, this part of ISO 14955 does not deal with the effect of different user behaviours or different manufacturing strategies during the use phase.

Lists of environmentally relevant improvements and machine components, control of machine components, and combinations of machine components are given in two informative annexes, one for metal-cutting machine tools (Annex A) and one for metal-forming machine tools (Annex B). Annex C provides an example of application of the methodology. Other machine tools, e.g. laser-cutting machine tools, material additive machine tools, and woodworking machine tools are currently not covered by informative annexes.

NOTE Certain machining processes and specific machine tools can allow significant changes in the environmental impact of machined workpieces, e.g. material reduction for aluminium cans by application of special press technology, higher performance of compressors by machining on precision form grinders.[3][5] The environmental impact of such processes or machine tools might be less important compared to the environmental impact of the machined workpieces and their application. These changes in the environmental impact of machined workpieces are not subject of this part of ISO 14955 but might be important if different machining processes or different machine tools have to be compared related to environmental impact of products. For instance, the accuracy of a machined workpiece might be a significant parameter for the environmental impact of the workpiece in its use stage, and any attempt to compare machine tools is intended to take this into account necessarily.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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ISO 14021:1999, *Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)*

ISO 14031, *Environmental management — Environmental performance evaluation — Guidelines*

ISO/TR 14062:2002, *Environmental management — Integrating environmental aspects into product design and development*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 14062 and the following apply.

3.1
design and development
set of processes that transforms requirements into specified characteristics or into the specification of a product, process, or system

Note 1 to entry: The terms "design" and "development" are sometimes used synonymously and sometimes used to define different stages of the overall process of turning an idea into a product.

Note 2 to entry: Product development is the process of taking a product idea from planning to market launch and review of the product, in which business strategies, marketing considerations, research methods, and design aspects are used to take a product to a point of practical use. It includes improvements or modifications to existing products or processes.

Note 3 to entry: The integration of environmental aspects into product design and development may also be termed Design for Environment (DFE), eco-design, the environmental part of product stewardship, etc.

[SOURCE: ISO 9000:2005, 3.4.4]

3.2
environment
surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation

Note 1 to entry: Surroundings in this context extend from within an organization to the global system.

[SOURCE: ISO 14001:2004, 3.5]

3.3
environmental aspect
element of an organization's activities, products, or services that can interact with the environment

Note 1 to entry: A significant environmental aspect is an environmental aspect that has or can have significant environmental impact.

[SOURCE: ISO 14001:2004, 3.6]

3.4
environmental impact
any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects

[SOURCE: ISO 14001:2004, 3.7]

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3.5
life cycle
consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to the final disposal

Note 1 to entry: The stages of a product's life cycle are raw material acquisition, manufacture, distribution, use, and disposal (Introduction of ISO/TR 14062 based on 5.2.3 of ISO 14040:2006).

[SOURCE: ISO 14040:2006, 3.1]

3.6
mode of operation
type of operating and controlling a machine tool, whereby different modes of operation are defined by safety standards for machine tools

Note 1 to entry: Examples for modes of operation are manual mode, automatic mode, and setting mode.

Note 2 to entry: Different machine activities require certain modes of operation as laid down in safety standards for machine tools.

3.7
operating state
defined combination of ON, HOLD, OFF, etc., states of mains, peripheral units, machine control, machine processing unit, and machine motion unit including machine activities when operating state is other than OFF

Note 1 to entry: Peripheral units are for example units for machine cooling, process cooling, workpiece and tool handling, recyclables, and waste handling.

Note 2 to entry: Machine processing units are for example main spindle of a turning machine, tool spindle of a machining centre, generator for electro-discharge machine, slide of a press, and draw cushions of a press.

Note 3 to entry: Machine motion units are for example linear axes of a turning machine, linear and rotary axes of a machining centre, and linear axes of a wire electro-discharge machine.

Note 4 to entry: For measurement and testing energy efficiency of machine tools, operating states such as OFF, STANDBY, EXTENDED STANDBY, WARM UP, READY FOR OPERATION, PROCESSING, and CYCLING, have to be defined. An example for such a definition for a metal-cutting machine tool is given in Table D.1.

Note 5 to entry: Examples for machine activities are tool loading, workpiece loading, axes movements, waiting, machining or cycling, or complete test cycles.

Note 6 to entry: Depending on the operating state and the machine activities, a mode of operation is selected as defined by relevant safety standards of machine tools.

3.8
environmental claim
statement, symbol or graphic that indicates an environmental aspect of a product, a component or packaging

Note 1 to entry: An environmental claim may be made on product or packaging labels through product literature, technical bulletins, advertising, publicity, telemarketing, as well as through digital or electronic media such as the Internet.

[SOURCE: ISO 14021:1999, 3.1.3]

3.9
environmental claim verification
confirmation of the validity of an environmental claim using specific predetermined criteria and procedures with assurance of data reliability

[SOURCE: ISO 14021:1999, 3.1.4]

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3.10
explanatory statement
any explanation which is needed or given so that an environmental claim can be properly understood by a purchaser, potential purchaser, or user of the product

[SOURCE: ISO 14021:1999, 3.1.6]

3.11
functional unit
quantified performance of a product system for use as a reference unit in a life cycle assessment study

[SOURCE: ISO 14021:1999, 3.1.7]

3.12
machine tool function
machine operation (machining process, motion and control), process conditioning and cooling, workpiece handling, tool handling or die change, recyclables and waste handling, machine cooling/heating

Note 1 to entry: Any machine tool function may be realized by one machine component or by a combination of machine components. Some machine components may realize more than one machine tool function.

Note 2 to entry: Figure 7 shows an example relation between machine components and machine tool functions.

Note 3 to entry: Machine tool functions may be used for identifying machine components (3.13) relevant for energy supplied to the machine tool.

3.13
machine component
mechanical, electrical, hydraulic, or pneumatic device of a machine tool, or a combination thereof

3.14
qualified environmental claim
environmental claim which is accompanied by an explanatory statement that describes the limits of the claim

[SOURCE: ISO 14021:1999, 3.1.12]

3.15
self-declared environmental claim
environmental claim that is made, without independent third-party certification, by manufacturers, importers, distributors, retailers, or anyone else likely to benefit from such a claim

[SOURCE: ISO 14021:1999, 3.1.13]

3.16
machine tool
mechanical device which is fixed (i.e. not mobile) and powered (typically by electricity and compressed air), typically used to fabricate metal components by the selective removal or mechanical deformation

Note 1 to entry: Machine tools operation can be mechanical, controlled by humans or by computers. Machine tools have also a number of peripherals used for feeding, safety, waste and chip removal, lubrication, and other tasks connected to their main activities.

3.17
energy efficiency
relationship between the result achieved and the resources used, where resources are limited to energy input

Note 1 to entry: Efficiency is defined as the relationship between the result achieved and the resources used (ISO 9000:2005, 3.2.15).

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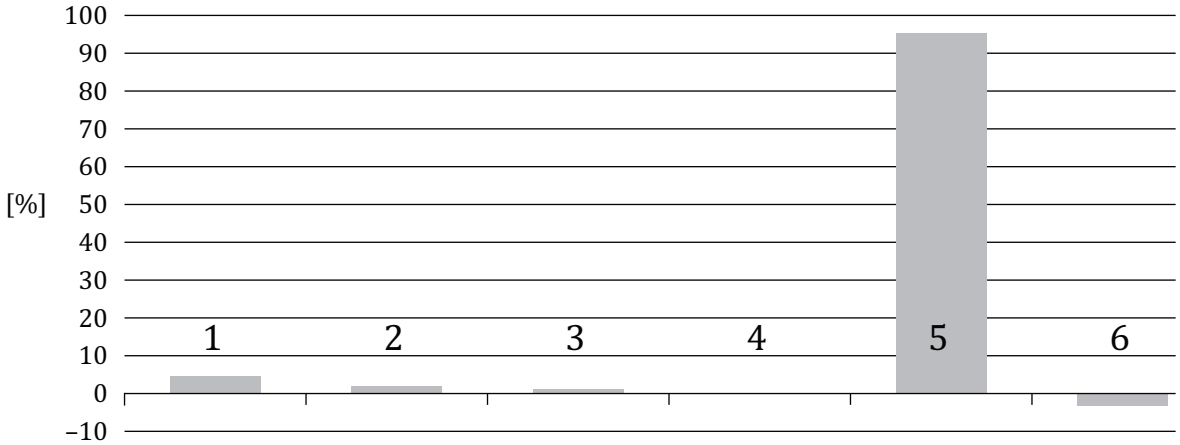
Note 2 to entry: Statements of energy efficiency can be given e.g. in cycle per total energy supplied, in workpiece per energy supplied. If machining of test pieces is involved, specification of workpiece machining and quality of workpiece are part of the definition of the result.

4 Restriction to energy efficiency during use stage

For the environmental impact of a machine tool, different stages of the product life cycle shall be investigated: acquisition of raw material for the machine tool, manufacturing of the machine tool, transportation of the machine tool, installation of the machine tool, use of the machine tool, and recycling of the machine tool (for more details on life cycle assessment, see ISO 14040).

If the environmental impacts are compared in the different stages of a machine tool, the typical profile is as shown in Figure 1, which gives the profile of an NC milling machine. The largest impact is in the use stage, and the largest contributor in the use stage is the energy supplied to the machine tool. This is the result of many life cycle assessments for machine tools [1][4][5][7] if the machine tool is used for 8 h a day/5 d a week or more, which is typical for the use of machine tools in an industrial manufacturing environment.



Key

1	raw material	4	set-up
2	production	5	use
3	transport	6	recycling

Figure 1 — Example of an eco-profile for a milling machine

Therefore, this part of ISO 14955 concentrates on the environmental impact, and specifically on the possibility of improving the energy efficiency during the use stage.

If the machine tool is not used in a typical industrial manufacturing environment, a complete life cycle assessment, e.g. according to ISO 14040, might be needed in order to identify the relevant environmental impacts. Measures other than increasing energy efficiency during the use stage to change the environmental impact might be of importance.

5 Integrating environmental aspects into machine tool design and development (design procedure for energy-efficient machine tools)

5.1 General

This is the application of ISO/TR 14062 for achieving energy-efficient machine tools in the use stage.

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5.2 Goal and potential benefits

The goal of integrating environmental aspects into machine tool design and development is the reduction of adverse environmental impacts of machine tools, especially the increase of energy efficiency during the use stage of the average machine tool in an industrial manufacturing environment.

Benefits for the machine tool supplier/manufacturer and user may include the following:

— energy efficiency during use stage;

— cost reduction in machine tools operations;

— increased competitiveness of the metal working sector;

— stimulation of innovation and creativity;

— enhancement of organization image and/or brand;

— attraction of financing and investment, particularly from environmentally conscious investors;

— enhancement of employees' motivations;

— increased knowledge about the product;

— improved relations with regulators.

5.3 Strategic considerations

Strategic considerations that are taken into account for integration of environmental aspects into machine tool design and development may include the following:

— organizational issues (e.g. competitor's activities, machine tools user's needs, requirements and demands), organization's environmental aspects and impacts, activities of regulators and legislators, activities of industry associations;

— product-related issues such as early integration (i.e. addressing the environmental aspects early in the design and development process), functionality (i.e. how well the product suits the purpose of the machine tool user in terms of usability, useful lifetime, productivity, accuracy, etc.), multi-criteria concept (i.e. consideration of all relevant impacts and aspects), and trade-offs (i.e. seeking optimal solutions);

— communication (e.g. internal communication to employees on product-related environmental impacts, training courses on environmental issues, programmes, and tools, site-specific impacts on the environment, and feedback from employees), external communication on product properties (performance and environmental aspects), and proper use of machine tool.

5.4 Management considerations

Top management support and action should enable effective implementation of procedures and programmes to integrate environmental aspects in design and development of machine tools, including allocation of sufficient financial and human resources and time for the tasks involved. An effective programme should engage those involved in product design and development, marketing, production, environment, procurement, service personnel, and machine tool users. More detailed aspects on the multidisciplinary approach are given in ISO/TR 14062:2002, 6.5.

Details on how to formalize management's commitment and how to establish the organization's framework to integrate environmental aspects into machine tool design and development are given in ISO/TR 14062:2002, 6.2.

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The integration of environmental aspects in machine tool design and management can be supported by existing management systems, e.g. management systems according to ISO 14001 or ISO 9001. This integration can also influence the supply-chain management; for details, see ISO/TR 14062:2002, 6.6.

5.5 Machine tool design and development process

An overview of integrating environmental aspects into the design and development process of machine tools is given in Figure 2.

NOTE Additional details are listed in ISO/TR 14062:2002, Clause 8. Eco-performance indicators, e.g. according to ISO 14031 might be rather useful for formulating measurable targets and transferring the targets into specifications.

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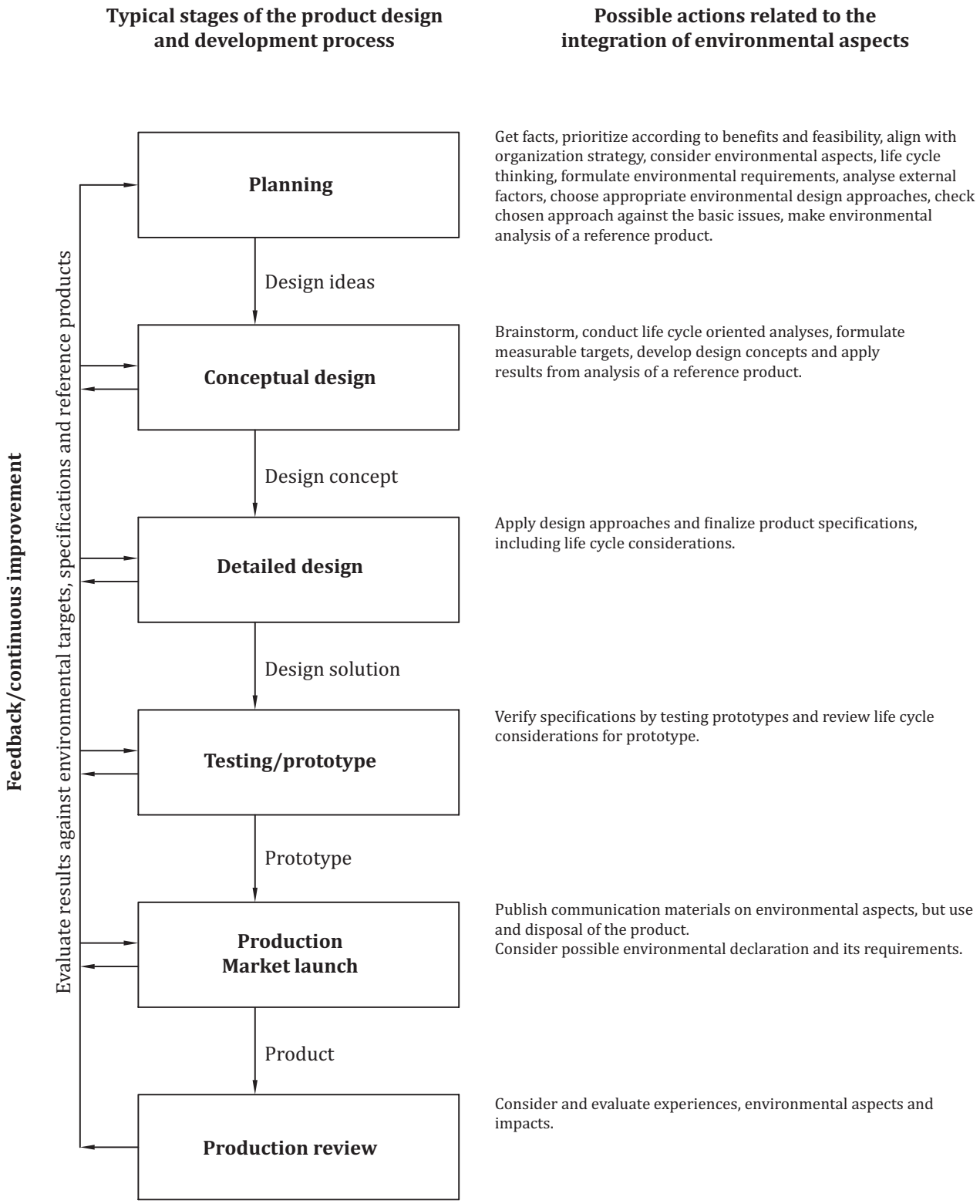

Figure 2 — Example of a generic model of integrating environmental aspects into the machine tool design and development process (Source: ISO/TR 14062)

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6 Machine tool and machine tool functions

6.1 General

The functional description of a machine tool (see 6.3) shall identify which machine tool function(s) are relevant for energy supplied to the machine. The functional description of machine tools is general and independent from the design of the machine tool and independent from the machining process implemented. Generalized functions of a machine tool, as given in 6.3, allow a general approach for identifying relevant energy flows of machine tools.

For a specific machine tool, the machine tool functions shall be assigned to machine components. This assignment is specific to each machine tool and corresponds to a transition from total energy supplied to the machine tool via machine tool functions and functional mapping to machine component level. This procedure is shown in an example in 6.3 and results in identifying energy relevant machine components (see 6.4).

Important parameters for this observation are the operating states of the machine tool and their duration in time, the accuracy of machined parts, and productivity of the machine tool, e.g. expressed by workpieces per hour. When comparing machine tools, these parameters shall be defined clearly.

Often measurement of power instead of energy is carried out. In these cases, times defined together with operating states have to be taken into account.

Some machine tools are equipped with internal compressors for pressurized air, hydraulic fluid, and/or for lubricant supply; other machine tools use centralized supply units for these. When comparing a machine tool using internal compressor(s) with a machine tool using centralized supplies, any comparison shall be made on the same basis, i.e. for both machine tools including all supplies. For this aim, system boundaries (see 6.2) shall be defined.

6.2 System boundaries

For evaluating the environmental impact of a machine tool, the machine tool is looked at, not the product(s) machined on the machine tool (see also Clause 4).

In this part of ISO 14955, the energy efficiency of machine tools in the use stage is addressed (see also Clause 4), whereas different forms of energy are looked at, e.g. electrical energy, pneumatic energy, hydraulic energy.

In order to deal with the energy efficiency of a machine tool during the use stage, system boundaries shall be defined in such a way that a system that is capable of a machining process is considered (see Figure 3). System boundaries are chosen in order to be able to measure energy flows with reasonable effort.

The machine tool and peripheral units are within the system boundaries. In general, electrical energy and compressed air are relevant energy inputs to the system. In some cases, air exchange is a relevant input and/or output. In cases where liquid heat exchangers are applied, heat exchange can be a relevant energy input and/or output of the system. If there is no mist filtering system within the system boundaries, any treatment of contaminated air will need energy that has to be considered, if relevant. If a centralized lubrication system is applied, cooled and filtered lubricant will be an input to the system and contaminated, hot lubricant will be an output; any energy used for lubricant treatment has to be considered, if relevant. Input of raw parts, new tools, new lubricant, auxiliary substances and output of machined parts, used tools, chips, and any other aspects do not have to be considered if it does not represent a relevant energy flow across the system boundary.

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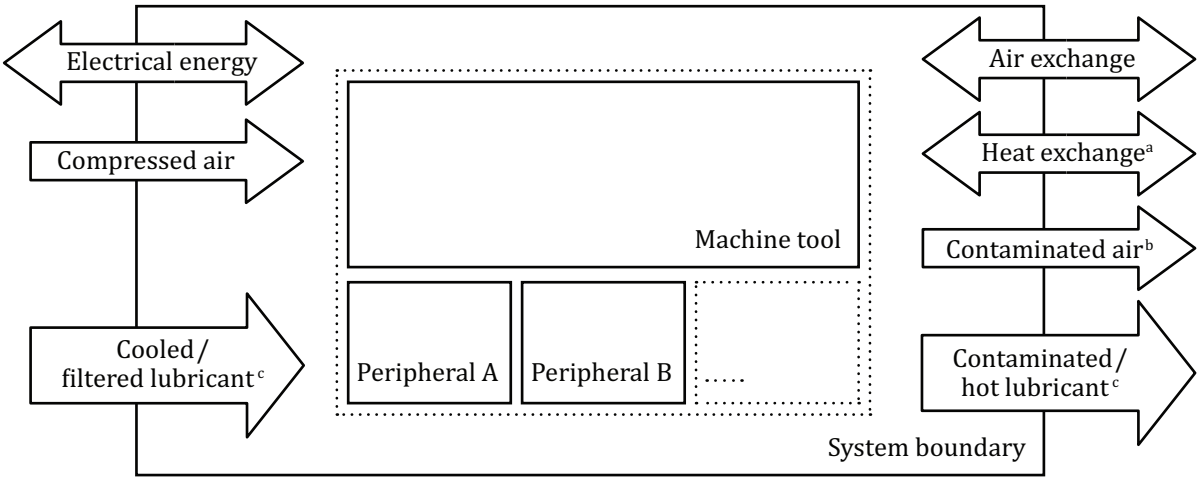

a Applies to cases with liquid heat exchangers.

b Applies to cases without internal mist filtering.

c Applies to cases with centralized lubricant management only.

Figure 3 — System boundaries related to relevant energy flows of a machine tool

6.3 Generalized functions of a machine tool

6.3.1 General

As metalworking machine tools cover a wide range of different types, subtypes, and sizes, a machine tool is described by its functions (see Figure 4), which might be realized by different machine components. This allows a generalized approach for a wide range of machine tools in order to evaluate environmental impacts of machine tools and the change of environmental impacts over time.

A machine tool should be described by the functions machine operation (machining process, motion and control), process conditioning and cooling, workpiece handling, tool handling or die change, recyclables and waste handling, and machine cooling/heating as shown in Figure 4, in relation to energy efficiency during the use stage. These generalized functions cover the vast majority of machine tools in a generalized view, independent from the implemented machining process and/or design of the machine tool.

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