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Equivalence assessment method for the resource efficiency of equipment, technologies and production systems

Kuznetsov A.P.[a]*, Koriath H.-J.[b], Kalyashina A.V.[c], Langer T.[b]

[a]*Moscow State University of Technology "STANKIN", 127055 Moscow, Russia*
[b]*Fraunhofer Institute for Machine Tools and Forming Technology IWU, 09126 Chemnitz, Germany*
[c]*Kazan National Research Technical University, Kazan, Russia*

Abstract

The paper analyses different assessment methods for the overall equipment effectiveness (OEE), energy efficiency and productivity of equipment and production systems. The proposed model and systematic assessment approach define the total and relative resource efficiency of equipment, technologies and production systems in the form of material, energy and information efficiency. This common resource efficiency assessment method is based on the physical and mathematical equivalence of efficiency indicators including probable events for resource usability. Three typical relations, determining any kind of efficiency, are obtained from those equivalents. Examples for resource efficiency assessment types are energy efficiency, productivity and accuracy. Integrated evaluation indicators for a comparative benchmarking of equipment, technologies and production systems are provided based on the equivalence assessment method and the proposed three typical relations. This method is also applicable to process chains.

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Keywords: equipment, resource efficiency, technology, production system

* Corresponding author. Tel.: +7 499 972 9584; fax: +7 499 972 9584.
E-mail address: apk_53@mail.ru

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1. Introduction

Progress in the development of technologies, systems, equipment and production is presently largely focused on efficient manufacturing systems during the design and exploitation phases. This becomes possible through improved performance indices and an increased degree of resource use, such as physical resources (energy, material, time), information and economical resources. **Therefore, procedures are required for resource efficiency analysis, assessment and set-up of parameters and characteristics** in order to make decisions in a prescribed and trustworthy manner. Referring to [1,2,3], **efficiency** is the extent of the use of any resource and the relative efficiency is described by the terms energy-efficiency, productivity, economical effectiveness or overall effectiveness in relation to this resource.

In all of the investigated systems (technologies, systems, equipment and production) **transformations** (processes) can be found, resulting in changed element **states**: input elements are being transformed into output elements. This model, as a system, contains the start conditions, nominal resource flow values for physical processes and limiting conditions for real flow values. Therefore, the relation between output values (power, information, time, etc.) E_{out} and input values E_{inp} is equal to the criteria efficiency E_e, where the numerator characterizes a possible maximal value and the denominator - the real work value performed by the equipment (or technological machine, technological or manufacturing system).

Different authors have investigated the assessment of different resource efficiency indicators and propose complex methods for the increased resource consumption efficiency in a functioning manufacturing system. Paper [1,2] propose the term efficiency as the relation of output process values E_{out} (energy, power, information, time etc.) to the input values E_{inp} and builds a general assessment method, applicable for the analysis of technologies, systems, equipment, technological machines and manufacturing in general.

Reference [4] proposes the following equipment and system efficiency indicators:

- indicator of machine operation time as the ratio of total equipment in use time excluding standstill to the overall equipment in use time,
- indicator of technical machine in use time as the ratio of total equipment in use time excluding standstill to the sum of total equipment in use time excluding standstill and own standstill time,
- indicator of equipment capacity usage as the ratio of the sum of total equipment in use time and own standstill time to the overall equipment in use time,
- general indicator of equipment in use as the product of the indicator of machine operation time and indicator of equipment capacity usage for the equipment exploitation time.

Paper [5] proposes a quantitative assessment method for all types of manufacturing equipment as the **overall equipment effectiveness (OEE)**. OEE permits the quantitative assessment of time losses influencing efficient equipment exploitation. OEE is the starting point for the derived analysis methods. Based on the overall equipment effectiveness proposed in [5], a standard for the effectiveness calculation and measurement [6] has been established. This standard proposes the application of the basic indicator – overall equipment effectiveness **OEE, measured in units of time**. The indicator OEE is easy to use, intuitively understandable and widely used in manufacturing corporations. Paper [7] proposes an efficiency assessment as the ratio of theoretical job execution time and actual manufacturing time. Here the equipment speed may differ between manufacturing tasks, e.g., caused by different operator qualifications. Therefore, preparation time or short equipment stops are not included in the standstill time, but are considered manufacturing time. Here, in case of different equipment operation speeds, the time consumption evaluation regarding standstill depends on the overall manufacturing management. Paper [8] proposes an alternative indicator to OEE. The authors explain that OEE is not supporting a precise efficiency measurement regarding the adjustment, reconfiguration and setup time. They propose the use of an indicator for the *overall equipment productivity*, which is connected to OEE through equipment capacity usage time.

Therefore, despite common theoretical background for overall resource efficiency and overall equipment effectiveness, different assessment methods have different systematically deviations and exclusive interpretations for terms and elements leading to different resource assessment results. A common equivalence assessment efficiency method is proposed for equipment, technologies and production systems.