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Procedia CIRP 63 (2017) 527 – 532

www.elsevier.com/locate/procedia

The 50th CIRP Conference on Manufacturing Systems

Comparative Integrated Manufacturing Efficiency in Production Engineering

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Abstract

At present a plurality of manufacturing methods, different manufacturing processes and manufacturing equipment are known in order to produce and customize work pieces and products. A new systematic approaches for the analysis and evaluation of manufacturing methods bases on the energy-information model as a conceptual approach to the comparative integrated manufacturing efficiency in production engineering. The integrated manufacturing efficiency is equal to the product of the efficiencies of matter, energy and information. The Comparative Integral Manufacturing Efficiency is the product of Quality rate, Effectiveness, Availability, devided by the product of (used Energy, used material, Emission ratio). A case study compares additive and removal process efficiencies for the production of a hollow cylinder. Proposed method for comparative integrated manufacturing efficiency will offer resource-efficient strategies for the creation and optimization of processes and technology applications.

Peer-review under responsibility of the scientific committee of The 50th CIRP Conference on Manufacturing Systems

Keywords: manufacturing; efficiency; technological process

1. Introduction

Material production, as a system, consists of two elements: the object with its inherent properties and technology, with its inherent parameters and characteristics. Therefore, the development of such a system is possible (in essence) in two ways: -the improvement and creation of a new object and its properties; -improvement and the creation of new production technologies. It is obvious that the selection of the first direction of development is less efficient and competitive in the long term (because the new object and its properties (obvious and foreseeable set) are rather quickly reproduced with the help of existing technologies). The selection of the second direction is more efficient and competitive (because its reproduction is less obvious and achievable in the short term due to a number of parameters and characteristics, which form and define the conditions of development of new technology). Of course, if we analyse the system, there is a third direction (this direction requires significantly more resources, which are needed for development). Third direction is a combination of above mentioned two directions. Nevertheless, when priority is selected (taking into account the limitedness of resources), preference is given to the development of the second direction.

Currently, a plurality of methods for machining and forming parts and products, processes and equipment is known for their implementation. Modern tendencies towards improvements in productivity, accuracy, reliability, flexibility, efficiency and effectiveness influence both the production and processing equipment and machinery systems. In order to influence the production object, the development of new systematic methods of analysis is required, which applies for the implementation of these objectives and the development of new machine structures, and which can fully implement the various physical processes.

That is why a deeper and more comprehensive structural and systematic description, which can analyse technologies

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doi:10.1016/j.procir.2017.03.135

and equipment, and the analysis of system elements, their connections and relationshipsare required.

From this point of view, the most comprehensive and systematic model, which can analyse technology and machines and equipment, which are based on this technology, was offered by Russian scientist I. Artobolevsky: "The machine is a device that performs mechanical movements to transform matter, energy and information" ie based system put elements (matter, energy and information) without specifying the type of relationship between them. ***So, the basis of this system are elements (matter, energy and information); the type of their interactions is not defined.***

In German standard DIN 8580-2003-09 (Fertigungsverfahren - Begriffe, Einteilung) the following classification of technological processes (technologies) is given: 1 – Primary Shaping and/or Original Forming (blanking operations : mainly, casting operations), 2 – Forming, 3 – Separating (3.1- cutting with geometrically defined cutting edge, 3.2 – abrasive machininga, 3.3 – separating and chopping operations), 4 – Joining, 5 – Coating and Finishing, 6 –change of material properties.

So the basis of the system is architecture of material connections, which is viewed as a system:

1 – connections, which create new material object;

2 – preserving connections;

3 – destroying connections;

4,5 – increasing connections;

6 – connections, which change the properties of material internal connections.

In other words, the basis of this system are types of internal connections and their interactions; atomic or molecular structure of the matter substance are adopted as elements.

Unit manufacturing processes are classified into five families of physical processes [1]:

1 – *Mass-change processes* involve material removed or added by mechanical, electrical, or chemical means. These include plating, machining, grinding, as well as nontraditional removal processes such as electro-discharge and electro-chemical machining;

2 – *Phase-change processes* involve producing a solid part from material originally in the liquid or vapor phase. These include casting of metals, infiltration of composites, and injection molding of polymers;

3 – *Structure-change processes* involve altering the microstructure of a workpiece, either throughout is bulk or in a localised area, such as ist surface. These include heat treatment and surface hardening processes;

4 – *Deformation processes* involve altering the shape of a solid workpiece without changing its mass or composition. These include processes of rolling and forging, and sheet-forming processes of deep drawing and ironing;

5 – *Consolidaton processes* involve combining materials such as particles, filaments, or solid sections to form a part or component. These involve powder metallurgy, ceramic molding, and polymer-matrix composite pressing. Joining processes, such as welding and brazing, also belong to this process family.

So, manufacturing process as a system is defined as a type of physical changes (only elements are analysed, not their connections).

2. Integrated manufacturing efficiency approach

Architecture of technological process, physical processes and part properties interactions is shown in Fig.1.

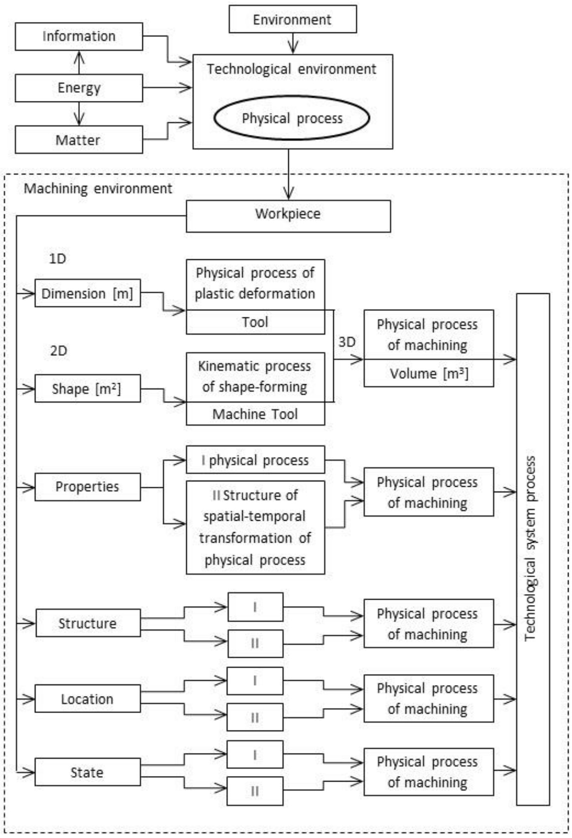

Fig.1. Architecture of technological process, physical processes and part properties interactions

System elements, ensuring the forming of part dimension (physical process, implemented by the tool) and the forming of part surfaces (physical process of surface forming, implemented by operating elements of the machine), are highlighted here. Other characteristics and parameters, that describe the information image of the part, are formed by other methods of processing in accordance with the technological image of the part [7]. Technological process is performed through the manufacturing equipment with use of material, energy, information. The result of the technological process is the product, which shall meet the customer's expectations. Consequently, the manufacturing process consists of two parts: a set of items of physical processes I