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Target-oriented Analysis of Resource Consumption in Manufacturing Process Chains

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Abstract

Nowadays, manufacturing companies have to view their resource consumption as a cost driver in order to identify efficient and economical processes. Methodologies for investigating, assessing and comparing process chains are vital in order to gain an accurate insight into cost drivers over the course of the entire process chain [1]. Scrutiny of this nature enables cost drivers to be identified via the parameters process time, machine and staff costs in addition to costs related to energy, material and consumables. A review of the usage phase permits elevated costs during manufacture to be justified by reduced costs during operation. The allocation of costs to resources within individual cost-driving process steps ensures target-oriented derivation of improvement measures.

The methodology has been designed to serve as basis for production planning, for example, with regard to (energy and resource) efficiency and applied to low-pressure turbine blades made of nickel-base alloys and titanium aluminide. A dedicated analysis of process chain costs provides an insight into the development of individual production costs. This information forms a basis on which to make decisions regarding output quantity or the most appropriate time for investment in new machines. In conjunction with the process chain comparison, this serves as a basis for the integration of the results obtained into a data base which allows the user to select a goal-oriented process chain selection. The data base can provide information regarding the organization of production chains in order to ensure that the product is manufactured accordingly to reduce resources, energy consumption, process times or overall costs.

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Keywords: Energy efficiency, Manufacturing process, Production planning

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1. Methodology with results

Key aspects of the holistic process chain assessment described in this paper were the mapping of a particular process chain with regard to different aspects like material and geometry of reference parts, scope definition and consideration of alternative process chains or steps. On that basis the resource efficiency of single process steps but also entire process chains have been evaluated considering resource drivers and their data acquisition. Overall goals were the first-time assessment of energy and resource demands along the entire process chain, the development of easy-to-handle tools for a holistic assessment in terms of economically and ecologically manufacturing and use phase resources as well as some derivations of improvements for technical as well as production planning purposes, c.f. Figure 1. Thus, the questions to be answered were about the best improvement alternatives from a resource perspective and the implementation of a resource-oriented mind-set in production planning.

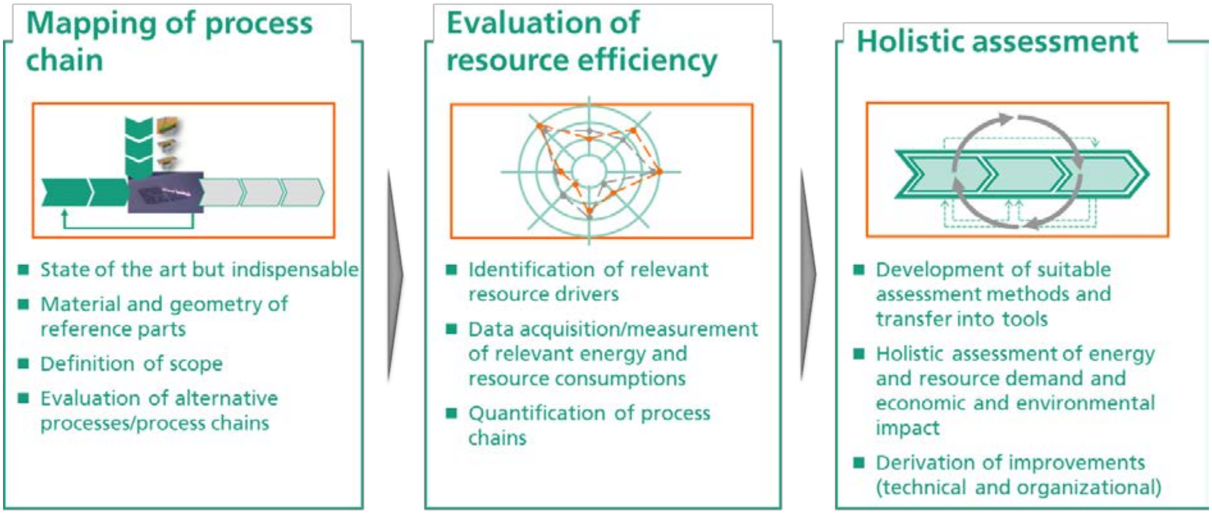

Fig. 1. Key aspects of the process chain assessment.

Two alternative process chains (conventional investment casting of low pressure turbine blades/investment casting extended by additive manufacturing of molds) were of interest to the investigation described. Although the results obtained and presented in this paper relate to the conventional process chain for low pressure turbine blades only, they bear comparison with those relating to innovative technologies, using additive manufacturing, for example as a substitute process [2], [3], [4].

1.1. Low pressure turbine blade manufacturing

The conventional process chain consists of six value adding process steps; however, the investigation focuses on the five major ones, c.f. Figure 2. The investigation focuses on the steps tool making, wax modeling, ceramic molding, the casting process itself and last but not least post machining. A detailed evaluation of the process steps and their contribution to the process chain has been discussed by Klocke et al. [1].

Due to that the conventional process chain is not very flexible e.g. for every new development it is necessary to produce a new expensive tool for the wax model. Considering this a wax-similar model could be manufactured by 3D-Printing which will also lead to a reduced number of process steps. The methodology presented here was used in detail for the assessment of the conventional process chain for casting low pressure turbine blades made of titanium aluminide. Since its generic approach, it could be applied for different process chains using single innovative process steps as well. Pre-condition in all cases is the fulfillment of the flow path already shown in Fig. 1.