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Evaluation Of The Human Error Probability In Cellular Manufacturing

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Abstract

Referring to Gutenberg there are three elementary production factors: material, equipment and human workforce. They all have a significant influence on the product quality. Nevertheless, in machining research they have been given differing attention, depending on the focused scope. This paper presents the results of an empirical study of the human error probability (HEP) in a Cellular Manufacturing environment. First, it is shown that the influence of human work on the resulting product quality in machining so far has only been given little attention. Therefore a content analysis according to MAYRING has been conducted on publications in the domains of production technology and ergonomics. Second, various schemes for the classification of human errors are presented and evaluated in terms of their applicability to human tasks in machining. Finally the design and results of an empirical study which has been conducted at the Cellular Manufacturing reference line, consisting of two lathes and four milling machines, in the Center for industrial Productivity (CiP) at TU Darmstadt are presented. Overall 2700 human-machine interactions have been observed and evaluated in terms of their influence on product quality. Results show that there is a significant influence of the human worker as three percent of these interactions incorporated a spurious action.

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Keywords: human error; cellular manufacturing; quality

1. Introduction

Cellular Manufacturing, as a concept for designing lean and efficient production processes, has proven to be an economic approach, even in high-wage countries [1]. In contrast to a done-in-one concept which tends to integrate all necessary manufacturing technologies in one machine, Cellular Manufacturing aims at reducing complexity and increasing flexibility by distributing the work content to several right-sized machines, using an operator for material handling and transport [2]. In consequence, the number of human-machine interactions is relatively high and human errors are more relevant regarding their influence on product quality.

The goal of the research presented in this paper is to identify the importance of human errors in Cellular Manufacturing environments and show that this topic has been neglected in discussing the influence factors on product quality so far. Therefore, the following assumptions are discussed:

A1. In investigations that regard the product quality in machining, human workers are not considered an important cause factor.
A2. Human errors are a relevant cause factor regarding product quality in Cellular Manufacturing.
A3. The amount of human errors which affect a workpiece depends on the number of machines used for its machining.

In order to investigate these assumptions, first, a short summary of existing human error taxonomies and methods for Human Reliability Assessment (HRA) is given in section 2. The results of a content analysis regarding the importance of human error as an influence factor on product quality in machining research are presented in section 3 whereas section

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4 describes an experiment for quantifying the human error probability (HEP) in a Cellular Manufacturing reference line. The statistical tests used for the investigation of the assumptions A1-A3 in section 3 and 4 are based on the instructions of BAMBERG et al. [3] A final conclusion is given in section 5.

2. Human reliability

Human error and human reliability describe two complementary aspects of human action. In VDI 4006 human reliability is defined as the "capability of human beings to complete a task under given conditions within a defined period of time and within the acceptance limits", whereas an error is a "human action which exceeds the defined acceptance limits". Accordingly, the human error probability (HEP) and human reliability probability (HRP) are indicators for the relative occurrence of errors and respectively faultless actions and defined as [4]:

$$HEP = \frac{number\ of\ observed\ errors}{number\ of\ the\ possibilities\ for\ an\ error} = \frac{n}{N} \qquad (1)$$

$$HRP = 1 - HEP \qquad (2)$$

In order to evaluate the human error probability a classification of possible errors as well as an appropriate methodology is needed. The following paragraphs present an overview on taxonomies for the classification of human errors and existing HRA.

2.1. Taxonomies of human error

For the differentiation of certain types of human error taxonomies have been developed. These can either be cause oriented, occurrence oriented or a combination of both types. An overview on existing classification schemes for human error types can for example be found in [5].

NAKAJO and KUME present three categories to classify human errors and describe each one with several examples: The first category involves those errors that occur when the worker does not remember the finished or remaining steps of a process. Errors of perception are further divided into perception of types and quantities, states as well as motions which all can be perceived incorrectly. Finally, errors of motion are errors which describe the situation when the execution of a task is false even though the task is memorized and the situation is perceived correctly. [6] SONDERMANN seizes the examples mentioned by NAKAJO and KUME and further subdivides their categorization into 16 types of errors (see fig. 1) [7].

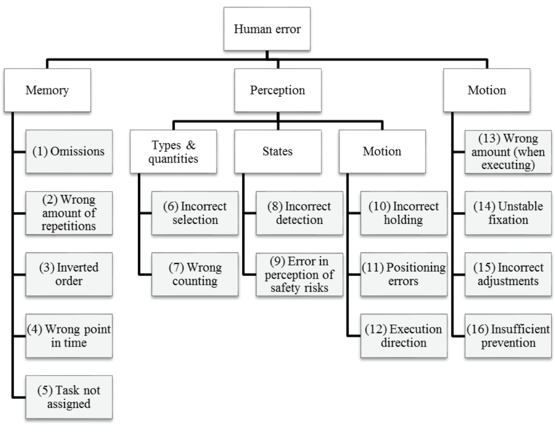

Fig. 1. Classification of human error (according to [6, 7])

2.2. Human Reliability Assessment

HRA techniques enable the quantitative or qualitative evaluation of human reliability. Their application is well-established in the design of control systems for nuclear power plants. Swain explains and evaluates 14 different HRA methods. The main criteria for his evaluation, which is based on an expert survey, are usefulness, acceptability and practicality. The methods which gain the best result in this evaluation are the Systematic Human Action Reliability Procedure (SHARP), the Accident Sequence Evaluation Program (ASEP) and the Technique for Human Error Rate Prediction (THERP). [8] Further summaries of various HRA methods can be found for example in [9–12]. Additionally, THERP is named as the most important HRA technique by several authors [10,11,13,14]. It estimates human errors and evaluates the related effects on the entire human-machine-system. As a basic tool a probability tree is used to model decision steps including wrong and correct choices. Additionally, a comprehensive set of tables links certain types of actions to a corresponding error probability.

One major issue with the quantitative evaluation of human error is the availability of reliable data. They can for example be determined via field study, experiment, statistics, estimation by experts or interviews [15]. Generally, data which has been derived from measurements should be preferred over subjective estimations [12].

3. Existing research of influences on the part quality in machining

In order to investigate the importance of human workers as influence factor on product quality in machining research a content analysis has been conducted. This research technique is a data acquisition procedure which can be used to analyze communication content in texts, pictures or films [16]. For the research presented in this paper the approach of MAYRING [17] has been used in order to facilitate the representation of the analysis material content in a category system.

The procedure to define convenient categories and assign papers to them is described in the following section. The goal has been to identify papers which present findings regarding the product quality in machining, classify these by the investigated cause factors and identify the main areas of research so far. As this topic includes two main elements, the influence of human error and the product quality in machining, two areas of research are found to be relevant: Production engineering and ergonomics.