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Criteria for assessment of basic manual assembly complexity

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Abstract

Tough competition force companies to develop and increase their product assortment in order to maintain their market share. This has resulted in numerous product variants with more features and build options. The complexity and risk of quality errors will increase. Managing complex product and installation conditions will result in distinct competitive advantages. Research has shown that sustainable and more cost-efficient assembly solutions can be obtained by proactive improvement of the working environment and installation conditions for the operators. Significant reduction of costly corrective measures can be made. The objective of this paper was to demonstrate criteria for proactive assessment of manual assembly complexity, which have been developed and verified in several studies. A further objective was to clarify and quantify included criteria as far as possible to enable a more general application in manual mass production of complex products.

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Keywords: Assessment; Basic complexity criteria; Manual assembly complexity; Quality; Error; Cost

1. Introduction

Increased competition for customers in the international market have forced manufacturing companies to increase and diversify their product range. This has led to numerous product variants and build options such as in the automotive industry. In a typical assembly plant the numbers of different vehicles, variants and options can thus reach numerous combinations of build options. A huge amount of variants and build options is a major challenge in production planning and for the operator who is supposed to manage many different assembly tasks in paced assembly lines. There are many choices to make often under time pressure, e.g. pick the right material, the right tools and make things in the right order etc. [1]. As a result cognitive and physical factors often put high demands on human performance, which cause mistakes, quality deficiencies and other assembly-related errors. There is a clear relationship between task variables and perceived assembly difficulty [2] and the more assembly options that are available to the operator, the more assembly-related errors are likely to occur [1]. Decisions taken during early design phases of product and production development have been found to have a major impact on assembly conditions in automotive manufacturing [3]. The higher the degree of basic assembly complexity the higher were the reactive action costs for correction of assembly-related quality errors. A big part of the quality errors were due to loose parts, parts in wrong position or wrong fitting, which was considered to be geometry-related errors. For those reasons, a model for geometrical robustness analysis considering manual assembly complexity was developed [4]. However, the assembly complexity criteria used need to be further described in order to facilitate application.

Nomenclature

Basic manual assembly complexity includes the basic design of products, components and system solutions developed and decided in early design phases. Basic assembly complexity includes both physical and cognitive factors.
HC: High manual assembly complexity
LC: Low manual assembly complexity

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TMU: Time Measurement Unit: 1/26th of a second

1.1. *Assessment of assembly complexity*

Several attempts have been made to comprehensively explore the meaning of the complexity concept in design and manufacturing context [e.g. 1, 5, 6, 7, 8 and 9].Very few studies of complexity impact on assembly quality have to date been made in current production context. However, researchers [6] identified seven task variables for prediction of object assembly difficulty that was based on operators´ view. Further studies [10, 11 and 12] focused on assembly complexity as perceived by operators and individual operator factors in order to support operators *at station level* in building the right quality in mixed-model assembly lines. Another study [3] in the automotive industry had a different approach focusing on how *basic* manual assembly complexity affected operator performance, assembly quality and productivity. The results clearly showed that the higher the complexity level the higher were the reactive action costs in manufacturing due to assembly-related errors and scrapped parts and components. The criteria used for assessing assembly complexity were obtained from an earlier interview study [13] with very experienced engineers in design, manufacturing engineering and production development in Swedish manufacturing companies. Based on their answers about high and low assembly complexity sixteen criteria characterizing high manual complexity and sixteen criteria characterizing low manual complexity were identified. In this paper the criteria of both high and low assembly complexity are shortly presented and the procedure for complexity assessment is described.

1.2. Objective

The objective of this paper is to concisely present method criteria for predictive assessment of manual assembly complexity. A more detailed method description will be published elsewhere. The overall objective is to prevent costly assembly-related errors and create sustainable manufacturing conditions in early concept phases of new manufacturing solutions.

2. Criteria description and assessment approach

There are sixteen criteria for high manual assembly complexity (HC) and sixteen criteria that characterize low manual assembly complexity (LC). The HC criteria could be considered as “tricky and demanding” and the LC criteria as “easy and fast”. These criteria are intended for assessment of individual assembly tasks or elements. All criteria should always be assessed for each assembly task and each criterion must be *either* HC *or* LC. For example when criterion **4** is to be assessed it must be decided if the task conditions complies with **No clear mounting position of parts and components** meaning **HC** or ***Clear mounting position of parts and components*** meaning ***LC*** **.** After assessment of all HC and LC criteria the results could be for instance nine LC and seven HC or three HC and thirteen LC criteria. The HC and LC criteria are not meant to be each other´s opposite but function as control questions for improved assessment of each assembly task. This approach aims at identifying potential assembly difficulties in early development stages of product and assembly concepts when it is still possible to change to other solutions.

The information required in basic complexity assessment is an assembly task or operation description of how the work should be performed, with what components and parts, with what tools and equipment and how long time the work is expected to take.

2.1. Checklist for evaluation of basic manual assembly complexity of assembly tasks.

A checklist is being developed and tested for evaluation of assembly tasks according to the HC and LC criteria below. The filled in checklist will illustrate which of the criteria that are problematic and which are not for each assembly task. Filled in HC criteria will require actions in order to remove risks of poor quality. The goal is to reduce the number of met HC criteria and increase the number of LC solutions in order to ensure as flawless assembly as possible. The complexity criteria are intended to be used by engineers in manufacturing engineering for identification of potential quality issues in development of assembly solutions.

2.2. Sixteen HC and sixteen LC criteria

1. **HC: Many different ways of doing the task.**
LC: Standardized (accepted) way to do the task.

Interpretation/Evaluation: Is it possible to assemble the parts/perform the task in different ways for instance with or without hand tools? If yes: The complexity is high (HC); If no: The complexity is low (LC).

2. **HC: Many individual details and part operations.** ***LC: Few parts/components to mount; preassembly; module solution (integrated assembly).***

Interpretation/evaluation: There is a difference between details and part operations. Both have to be taken into account: The number of part operations (normally described in the operation description) and individual details should be counted separately. (Note that some operation descriptions may be split up on several stations).

Clarification: Individual details (ID)**:** All parts to be mounted/fastened should be counted. However, pre-mounted details should *not* be counted and included. Example: 4 screws = 4 details but (built-in) reference pins should not be included because these were already mounted.

Part operations (PO)**:** All operations that consume /assembly/ time (TMU, sec. or other time units) should be counted.

The limit values should be calculated based on the average number of details and sub-operations of a large number of task instructions as shown in the example from car manufacturing:
Low amount of ID + PO (0-6): Low complexity = LC
High amount of ID + PO (7<): High complexity = HC

3. HC: Time demanding operations.