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Analytical approach for the examination of the feasibility of rework in flow assembly lines

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Abstract

Since the beginning of the 20th century flow assembly lines are a global standard for manufacturing companies to produce serial products. The standardization and the allocation of assembly jobs in certain cycle times along the assembly line ensure productivity. All work operations in each cycle are allocated ideally in such a way that every operator uses the complete cycle time for the assembly jobs.

One disadvantage of these flow assembly lines is the lack of time for possible rework operations. If a human error occurs, there is hardly any time for its correction. The alternative is to stop the line until the rework is done. These situations cause an interruption of work for the whole line, which is unproductive. Consequently most errors become evident at the end of the line and cause rework, which diminishes productivity as well.

This paper helps to examine the feasibility of rework in flow assembly lines with regard to technical and organizational restrictions.

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Keywords: *assembly, quality management, human error, rework*

1. Introduction

Flow assembly lines were first introduced by Henry Ford for the "Model T" in the year 1908. Basic considerations for systematization and rationalization of the assembly can be found in the works of Frederic Winslow Taylor and Frank and Lilian Gilbreth, published in early 1900. Due to the rapid growth of automotive industry in the US, the resultant compulsion to economic assembly and the lack of skilled workers, the division of labor in the assembly arised. To this day there have been no substantial changes [1].

Flow assembly lines were established as single-model lines, meaning that standardized and similar products were produced in flow by workers who executed a certain assembly job. Thus learning effects could be realized quickly and high qualified workers were rarely needed [2].

These days manufacturers have to respond to megatrends like globalization, sustainability or individualization with effects on the industrial production and thus also on the assembly [3]. Moreover innovations caused by new technologies come on the market sooner and the environment for production companies becomes more turbulent and more complex [4]. Therefore manufacturers are caught in a dilemma: To produce in large scale and vary products in order to meet the individual customer needs. As a solution manufacturers take advantage by using the principle of a mixed-model line. This kind of assembly line is adapted to produce similar models of a product in sequence [5]. Although there are challenges like varying equipment, different work operations and different production times it allows producing different variants of a product cost-efficiently at one line.

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New technologies help to deal with varying equipment, however quality problems due to increasing complexity of assembly processes are hard to get under control [6]. For instance, when assembly lines have a high degree of human workforce, product and process complexity have a negative influence on the quality, although quality problems (QP) are caused by human errors including psychological, physical, sensorial and mental factors [7].*

2. Quality Management in flow assembly lines

Manufacturing companies try to minimize all quality costs by proper quality management. Those costs are subdivided into four categories, which are "prevention costs", "appraisal costs", "internal failure costs" and "external failure costs"[8]. Prevention costs are costs that emerge when avoiding other costs, such as failure costs, e.g. the quality planning, new-products reviews, supplier evaluation, audits or preparing and conducting quality-related training.
Appraisal costs are costs incurred to control or spot QP. These are inspections and tests of incoming goods, in-process or final inspections of products and measurements of instruments and equipment in calibration.
Internal failure costs are quality costs that are caused by deficiencies, which are detected before delivery to an internal or external customer, e.g. scrap, rework or repair operations.
External failure costs turn up after the customer has received the product. Penalties due to poor quality, complaint adjustment, repair costs or revenue losses account to those costs.
Internal and external costs would disappear if no deficiencies existed [8]. Fig. 1 gives an overview of all QP.

Prevention	Appraisal	Internal Failure	External Failure
Design and development of equipment	Receiving inspection	Scrap	Lost profit/sales
Quality review	Laboratory inspection and testing	Rework and repair	Loss of goodwill
Maintenance and calibration of production and inspection equipment	In-process inspection (sensors and signals)	Rescheduling due to downtime	Warranty
Supplier quality audits	Final inspection (100%/sampling inspections)	Overtime to cover production losses	Product recalls
Quality training (seminars, workshops/lectures)	Field testing (performance tests and status reporting)	Downgrading	Allowances
Quality improvement programs	Inspection and test equipment		Complaint adjustment
			Cost of support operations

Fig. 1. Categorization of quality costs [6,8]

During all production steps QP occur and cause quality costs. To get an idea why the assembly plays an important role concerning the quality costs in production, an analysis of a manufacturing company is shown in Fig. 2.

* For the further understanding it is important to know what is meant by the term "quality problems". It contains mistakes, defects, failures, faults and errors, but also deviations or tolerances at the product to be assembled. System malfunction, disturbance of facilities or damage caused by wear as well as software bugs are not included. If quality problems refer to workers, they are called "human errors".

The left axis of ordinates describes the relative number of all QP, whereas the right one shows the relative time of rework (TR) caused by the problems. On the axis of abscissae the causes of the QP are depicted. QP that were not assignable to a cause are summed up under the term "others".

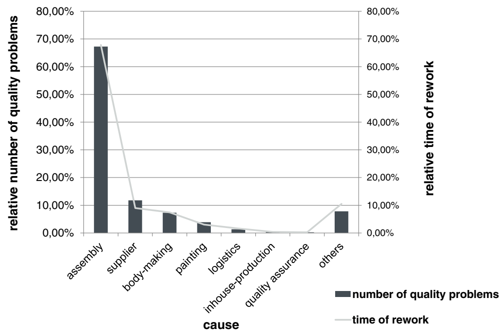

Fig. 2. Quality problems in production by cause.

It is clear to see that the relative number of QP and the needed TR correlate, whereas it is obvious that the TR above "others" is relatively high. Lacking a precise explanation for this, it is probably quite time-consuming to find the reason for QP that are not precisely assignable. In terms of painting the TR is smaller because defects in paint jobs can often be undone by hand without repainting the whole product. For suppliers the TR is visibly lower because these QP are solved by the supplier himself and do not rank among the TR of the manufacturer. Altogether the main discovery is that the assembly causes not only the highest number of QP but the biggest share of time of rework amounting to 68 %.
This example underlines why the assembly can be of great interest to reduce quality costs in manufacturing companies.
Another reason why a serious focus should be placed on the assembly is shown in Fig. 3

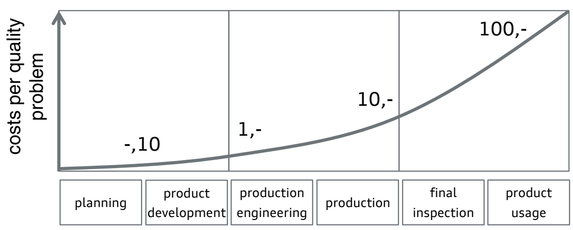

Fig. 3. The "empirical rule of ten" [9]

The importance of the correction of QP in early stages of product development is evident in the "empirical rule of ten". It reflects the experience that costs for QP increase by a factor of ten with each stage in which they are not discovered and eliminated. Since flow assembly lines stand in the field of production and final inspection, the costs for QP are already one hundred times higher than in the beginning and still increasing. This emphasizes how important and still worthwhile it is to avoid or correct QP.