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Validation of Line Balancing by Simulation of Workforce Flexibility

Markus Pröpster[a]*, Lothar März[b], Gunther Reinhart[a], Carsten Intra[c]

[a] *Institute for Machine Tools and Industrial Management (iwb) - Technische Universität München, Boltzmannstr. 15, 85748 Garching, Germany*
[b] *STREMLER AG, Am Schönbühl 1, 88131 Lindau (Lake Constance), Germany*
[c] *MAN TRUCK & BUS AG, Dachauer Str. 667, 80995 München, Germany*

* Corresponding author. Tel.: 0049 (0)89 289 15494; fax: 0049 (0)89 289 15555, *E-mail address*: markus.proepster@iwb.tum.de

Abstract

To stay competitive and reach a high productivity, mixed model assembly lines need to handle variations in capacity requirements induced by the different variants manufactured. Therefore workforce flexibility is required, i. e. drifting, which allows workers to leave their stations to fulfill high equipped variants, and the allocation of jumpers. These support if drifting is not sufficient. This paper presents a simulation tool which simulates these aspects of worker flexibility according to the produced variants and their sequence. Furthermore an approach is introduced which validates line balancing results by using the simulation tool. Since the simulation tool is already in use at a commercial vehicle company, an example of application is also given in this paper.

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1. Introduction

The European automobile industry is distinguished by the fact that it facilitates the production of vehicles with high customer individuality and complex product structures. Programme planning therefore has the task of distributing high product variance across the day in such a way that the employees are kept consistently working and both under-utilisation and capacity peaks are avoided. Sequenced lines have proven themselves as a system for multi-variant series, in which the products are assembled in a fixed rhythm [1].

On account of the labour-intensive production structure and low level of automation, assembly (unlike body construction and painting) is the area requiring the most workforce. Apart from purchasing, assembly is therefore the area with the highest savings potentials [2]. At the same time, there is a growing trend towards relocating the point of variant development to Assembly (late configuration) in order to permit modifications at a later stage as well as mapping of a simplified product structure during the upstream production stages [2]. For Assembly, there is an increased demand for flexible mapping of various variants accompanied by rationalisation of the processes [3].

After explaining the planning of sequenced assembly lines, this paper presents a simulation tool, which takes workforce flexibility for dealing with different variants into consideration. Furthermore an approach is introduced which validates line balancing results by using this tool and an example of application is given.

2. Planning of sequenced assembly lines

One main challenge of planning the configuration of assembly lines is the assignment of assembly tasks to the stations by taking all restrictions given by the product, the assembly line and human factors into consideration. This process is called Line Balancing [1, 4]. Because of varying assembly times of different product variants, Line Balancing of mixed-model assembly lines is even more complex. Assembly lines are normally not balanced according to the maximum variant, since it results in high under-utilization for variants with little task time. Therefore a balancing of assembly lines according to a fictive average-variant, which represents an average programme, is common in the automotive

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industry. Due to this, sequenced assembly lines are considered to be very inflexible according to changes in demand, since a shift in the average variant programme leads to a variation of the average utilization on stations affected by these variants and a change of the output of an assembly line can only occur by a time-consuming modification of cycle time [5, 6].

Since the assembly line is balanced on an average programme, a successive receipt of product variants with high process times therefore leads to overloads. By considering vehicle criteria in the form of orders or precedence, sequence planning attempts to avoid such cases [7]. This is not always sufficient because the rules are not drawn up based on a preview but have been formed on the basis of past experiences.

Excessive overload peaks can arise within a group of workers as a result of the order of vehicle types or equipment variants. Such overloads can be avoided in future by specifying rules for sequencing. As there are manifold overload peaks, not all vehicle combinations can be taken into consideration by rules as otherwise calculation times would be too long or the problem could no longer be solved [8]. Furthermore, not all of the rules necessary are recognised as they only evolve during future sequencing. The reasons for this include unusual vehicle sequencing or shifts in the percentage of product types or equipment variants.

If the variant with the maximum process time in a cycle was to be applied as a benchmark, this would result in an increased cycle time or workers deployed and subsequently increased under-utilisation of easier variants. Worker utilisation is a decisive Key Performance Indicator (KPI) for assessing planning. Theoretical worker utilisation is calculated by averaging the workloads over a selected period of time and comparing them with worker capacity. This average figure is associated with some elementary problems: two vehicles each with workloads of 95 % of capacity cause a different utilisation situation to that caused by two vehicles demanding 75 % and 115 % of capacity, respectively, although the average value in both cases is 95 %. The ability of workers to compensate for the variant spreading is not apparent.

Workers are given the opportunity to perform pre-drawing or reworking in the case of more complex vehicles [9]. This process is also called drifting. Drifting can only be within process, resource and station limitations. The aim is also to avoid workers obstructing each other at upstream and downstream stations and that the respective vehicle sequence enables workers to return to their station on less complex vehicles.

Drifting must be taken into consideration in order to correctly establish utilisation of the resources. Specifying increases in capacity by drifting increases worker flexibility. If flexibilisation is insufficient, the workers will be obliged to rely on jumpers to prevent the line from coming to a standstill. Jumpers are additional workers and can be used for various reasons [10]:

- Use of a jumper to balance processing times at stations with risk of bottlenecks (see figure 1)
- Assigning jumpers to larger orders entailing high expenditures. They stay at this order for the entire assembly line or a section of it.
- Use of jumpers for processes demanding special skills and only occurring seldom (use of jumpers for technical reasons)
- The jumper as a substitute capacity during absence, holidays, illness etc.

In the first two reasons outlined above, jumpers use their free capacity at the time of occurrence, i.e. they must be available accordingly. The use of jumpers serves as an additional worker to the core workforce in order to provide support at short notice in the event of capacity bottlenecks to finish the product within the cycle time [11]. The other scenarios also increase the available capacity but are not utilised ad-hoc for bridging overload peaks. They are scheduled as early as during planning or when workers arrive at work.

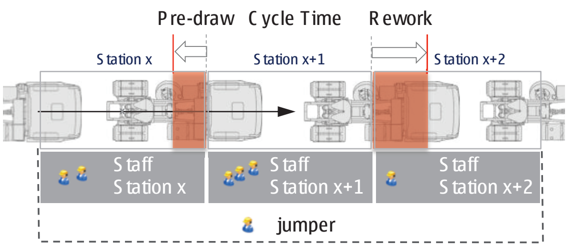

Figure 1: Use of jumpers and drift

In practice, flexible employee organisation compensates for a high share of overload cases. Against the backdrop of increasing product and therefore process time variance in Assembly and heightened efficiency, more accurate planning processes are required. They need to permit an analysis, evaluation and continuous adaptation of the capacities in line with load requirements. Static calculation of utilisation does not indicate whether the vehicle programme can be realised using the drifting flexibilisation measures or jumpers. Simulation is the only method for valid assessment of the effects of vehicle sequences on personnel utilisation.

3. Simulation Tool for Workforce Flexibility

The advantages of simulation are apparent when compared to static evaluation of staff utilisation. Only consideration of the vehicle sequence and degrees of freedom of flexible deployment of staff provides a realistic image of utilisation and the potentials of