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Assembly line balancing and group working: A heuristic procedure for workers' groups operating on the same product and workstation

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Abstract

In this paper, we examine an assembly line balancing problem that differs from the conventional one in the sense that there are multi-manned workstations, where workers' groups simultaneously perform different assembly works on the same product and workstation. This situation requires that the product is of sufficient size, as for example in the automotive industry, so that the workers do not block each other during the assembly work. The proposed approach here results in shorter physical line length and production space utilization improvement, because the same number of workers can be allocated to fewer workstations. Moreover, the total effectiveness of the assembly line, in terms of idle time and production output rate, remains the same. A heuristic assembly line balancing procedure is thus developed and illustrated. Finally, experimental results of a real-life automobile assembly plant case and well-known problems from the literature indicate the effectiveness and applicability of the proposed approach in practice.

Keywords: Assembly line balancing; Heuristic methods

1. Introduction

Assembly is a process by which subassemblies, manufactured parts and components are put together to make the final products. In the most common statement of the assembly line balancing problem, a set of

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work elements having fixed duration times is to be assigned to a set of sequential workstations [1]. A set of precedence relationships indicates the restrictions on the performing order of each work element. The amount of time available at each workstation is called cycle time and it is predetermined by the desired production rate. The objective is to assign the work elements in such a manner so as to minimize the number of workstations on the assembly line, without violating the precedence constraints and without having the work element times at any station exceed the cycle time. The difference between the cycle time and the sum of the work element times assigned at any workstation is called the workstation's idle time. The total idle time of the assembly line is the sum of workstation's idle time over all stations. Minimizing the number of workstations is equivalent to minimizing the total idle time of the assembly line.

2. The problem under study

In this paper, we discuss paced assembly lines with multi-manned workstations, which are widely used in practice, typically in producing large-sized products such as in the automotive industry [2,3,5,6], but almost unmentioned in the academic literature [4]. The product stops during the cycle time at each multi-manned workstation where there are several workers simultaneously performing different assembly work on the same individual product. Each worker starts performing assembly work as soon as it is technically feasible, regardless of whether the product is available exclusively to him. The goal of such an assembly line configuration strategy is to reduce the length of the assembly line while the total effectiveness of the assembly line, in terms of total number of workers working on the line and total idle time, still remains optimized.

This kind of parallel operation of workers, allocated to the same multi-manned workstation, requires the product to be of sufficient size. This is, for example, the case of vehicles' final assembly, where workers do not block each other during their assembly work [5,6]. The product is released from a multi-manned workstation when all workers have completed their work. In a traditional assembly line, if precedence constraints are considered appropriately, all the work elements assigned to a worker can be carried out continuously without any interruption. However, in a multi-manned assembly line, some work elements assigned to a worker of a specific workstation can be delayed by the work elements assigned to some other worker of the same workstation. In other words, idle time is sometimes unavoidable even between work elements assigned to the same workstation. Therefore balancing multi-manned assembly lines needs to consider the sequence-dependent finish time of work elements, which is a feature specific to multi-manned assembly lines. Thus, the decisions involved in balancing assembly lines with multi-manned workstations include the following questions: (a) how many workers should be allocated to each multi-manned workstation, working together on the same individual product, without exceeding the maximum feasible 'worker concentration' per product, i.e. without workers blocking each other during the assembly work, and (b) which work elements' subset should be assigned to each worker.

The maximum feasible 'worker concentration' per product, i.e. the maximum number of workers at any multi-manned workstation is an important external decision variable and can be prefixed by the system designer depending on the case, provided that certain preconditions are fulfilled. Such preconditions are, for example, product's structure and size that enable workers working together on the same individual product, without blocking each other during the assembly work, a sufficient number of tools available for the workers in order to minimize waiting time, a workstation design and the materials flow pattern that facilitate communication between the workers, etc.