

論文の要旨

題目 A STUDY ON WORKER COLLABORATION FOR BUCKET BRIGADE PRODUCTION LINES
(バケツリレー型生産ラインにおける 作業者協調に関する研究)

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The development of production line continued during industrial revolution which was stimulated by the invention of steam engine technology by James Watt. Moreover, the productivity of workers at that time increased multiple time since the concept of interchangeable parts in production systems had been introduced. The fundamental of the mass production line was introduced by Henry Ford in 1913. He installed an assembly line that driven by conveyer belt where components will be moved from one station to next station while workers remain stationary at their respective stations. Nowadays, manufacturing companies are constantly trying to increase their productivity with the same amount of resources. The main challenge to manage the production line is to balance the work assignments, so there is no idle time due to the bottleneck in order to obtain low cost and high productivity. The bottleneck in a production line can cause the entire line to slow down or stop, and it affects the capacity of the whole production line. Balancing a production line is a procedure in which workloads are distributed evenly to each assembly station in the line so that each workstation has the same amount of the work. It can decrease the unused idle station capacity by reducing the operator idle time over the takt time.

One way to increase productivity in the serial or U-shaped assembly line is by increasing the number of workers. As the consequences, if more workers are added in the line, then more workers have to wait, and bottleneck will occur. Assembly line balancing problem (ALBP) is the term commonly used to refer to the decision process of assigning workloads to workstations in a serial production system. If the ALBP is utilized to balance the line, then the assembly line needs to be configured. Moreover, it is not guaranteed that a perfect balance line will be obtained.

The flexibility of the assembly system is used to improve the throughput rate of non-perfectly balance assembly line through work-sharing. The same task may be accomplished in different stations in different cycles when applying work-sharing. As a result, the division of workload among the stations is improved, and the cycle time is reduced. Work-sharing is closely related to the cross-trained studies since the tasks must be performed by cross-trained works due to the overlapping in the workers' capabilities. The Toyota Sewn System (TSS) and bucket brigades are the most common work-sharing system.

The bucket brigade is a self-balancing line in which each worker can move from one station to the next to continue working on a given part. Sequencing worker from slowest-to-fastest is the best policy for maximizing throughput on a continuous line. Meanwhile, throughput at discrete workstations may decrease due to blocking even though workers are properly sequenced. Most studies of bucket brigades in serial line and U-shaped line have been carried out based on the assumption that the work content is distributed continuously and uniformly over the entire line. However, for many assembly lines, the work content is neither continuously nor evenly distributed but is grouped in various proportions into discrete workstations.

The maximum possible throughput is not always achieved due to blocking conditions, although preemption or simply handing over task is allowed is the main problem of bucket brigade at discrete workstations. Workers may block each other, as each workstation can only accommodate one worker at one time. By utilizing cellular bucket brigades (CBB) to coordinate workers in a U-shaped line with discrete workstations, the throughput is significantly improved when the number of stations at each stage increases from one to two, but that there are diminishing returns if each stage is divided into more stations, then the performance may vary according to the situation.

The most famous application of bucket brigades is to coordinate workers to pick products for customer orders in distribution centers. The results show more effective work-sharing where the pick rates increase as a result of the absence of zone restriction by using bucket brigades. A case study of order picking by CBB, using data from a distributor of service parts in North America, and compares the average throughput of cellular and serial bucket brigades using a computer simulation. CBB can not only boost productivity but also save costs in terms of labor and wireless technology.

Teamwork or collaborative work can also be used to improve the performance of an assembly line that relies on workforce flexibility. A scenario at Compaq where teams of three workers built, tested and shipped computers at a single workstation and showed productivity and quality improvement as much as 25%. A prior study had compared assembly line design without collaboration to the parallel cell-based design of two single tasks with collaboration and introduced an inefficiency factor that rates the efficiency due to collaboration. Other study had compared four different worker coordination policies (no helping, floater, pairs, and complete helping) on a parallel assembly line under the assumption that the collaborative inefficiency reduces the productivity. The study tested collaborative efficiency factors at minor collaborative inefficiency in pair-working as 10% (with a collaborative coefficient of 0.9) and major inefficiency as 30% (with a collaborative coefficient of 0.7).

A method to counter halting, blocking, and starvation condition in serial line and U-shaped line by integrating bucket brigades and worker collaboration is proposed in this thesis. Since the increase of task speed can be obtained by using worker collaboration, then by integration of worker collaboration may decrease the idling of workers in some cases, and increase the performance of the production line. Prior assumptions are utilized to investigate and compare the performance of a production line in which the collaboration velocity is proportional to the sum of the individual worker velocities and is influenced by the collaboration coefficient under additive conditions ($\alpha=1.0$) and inefficient collaborative condition ($\alpha=0.7$ and $\alpha=0.9$).

The aim of this thesis is to determine the possible extended conditions for improvement and a procedure for achieving possibly higher throughput through worker collaboration. The performance of bucket brigades with and without worker collaboration can be compared at the serial line and U-shaped line. Moreover, a case study on migration from craft manufacturing to assembly line by integrating bucket brigade and worker collaboration based on prior assumption of serial-continuous line has been performed. Based on this thesis, worker collaboration can preserve the characteristics of self-balancing line and obtained performance improvement.

Keywords: bucket brigade, worker collaboration, collaboration coefficient, serial line, U-shaped line