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Quantitative Analysis of the Impact of Inter-Line Conveyor Capacity for Throughput of Manufacturing Systems

Priyanka Raosaheb Dhurpate, Eastern Michigan University, USA
https://orcid.org/0000-0002-3444-289X

Herman Tang, Eastern Michigan University, Ypsilanti, USA
https://orcid.org/0000-0001-6609-7851

ABSTRACT

The objective of this study is to identify the impact of an inter-line conveyor on the throughput performance of manufacturing systems and determine the capacity of an inter-line conveyor to improvise productivity. First, manufacturing system for an automotive assembly line is modeled by adopting the methodology of two lines with an inter-line conveyor system. A quantitative analysis of an inter-line conveyor capacity is carried out under different conditions and capacities using discrete event simulation (DES). The initial results are obtained to justify the purpose of an inter-line conveyor followed by introducing a random failure of a station for the duration of 10 minutes, 30 minutes, and catastrophic breakdown of two hours at upstream and downstream line separately. The case study outcomes show that, 20 unit is an optimum capacity resulting in improved productivity. The findings of the different stoppage and catastrophic breakdown study show the buffering of an inter-line conveyor may serve as a new approach and guideline to the buffer stack design and scheduling maintenance.

KEYWORDS

Catastrophic Breakdown, Discrete Event Simulation, Inter-Line Conveyor, Manufacturing System, Work in Process (WIP)

1. INTRODUCTION

1.1 Research Background

A manufacturing system can be in different configurations, such as serial, parallel, hybrid (a combination of serial and parallel). A serial configuration is widely used for mass production, such as vehicle assembly manufacturing. In a series manufacturing line, a line is often designed with an intermediate buffer between two workstations to transfer WIPs. In a manufacturing system, two serial lines are connected with a conveyor. The inter-line conveyor transfers WIPs from the upstream to the downstream line. In addition, the conveyor system plays an important buffering role in helping the continuous operation during the downtime of a workstation in a line and improves the productivity of a manufacturing system.

Cycle time and reliability of the workstations, are crucial factors that affect the productivity of a manufacturing line. Moreover, unpredictable events in production, such as small and catastrophic breakdowns, can affect the throughput of a line. Some significant studies have been done over

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the past for the throughput performance of a system using the two-machine-single-buffer model. However, the real-world manufacturing system is more complex, consisting of a different numbers of production lines and stations. Thus, it is important to understand a complex manufacturing system performance throughput under different conditions. This study provides a substantial understanding for the selection of an inter-line conveyor capacity by introducing a random breakdown at a station and studying the WIPs on an inter-line conveyor for different capacities and effect of the same on the throughput performance.

A manufacturing system is comprised of multiple serial lines connected by an inter-line conveyor between any two lines. In principle, when a failure occurs in the downstream line, an inter-line conveyor can reduce the blocking of an upstream line, until the WIP occupies the full capacity of the inter-line conveyor. Similarly, when a failure occurs in the upstream line, an inter-line conveyor can reduce the starving of the downstream line until all the WIPs are used. Several factors are to be considered while designing such a large production line, where the capacity of an inter-line conveyor directly affects the inventory cost of production as well as throughput (Conway et al., 1988). However, such impacts on blocking and starving have not fully quantitatively studied.

1.2 Literature Review

Research has carried out in past decades and found a perfect design for the manufacturing system to improve the system performance for maximum throughput using different approaches. Li et al. (2009) performed throughput analysis for serial lines, implementing empirical law by considering the coefficient of variation of the machine's up and downtimes. Gede & Hui (2011) developed two models with random machine breakdown viz. stochastic and fix repair time in order to get optimal production rate. Qi et al. (2007) performed stochastic analysis for a single machine subjected to random job processing time which showed that the optimal schedule must be 'V' shaped. While, Gu et al. (2014) proposed a study with a preemptive – repeat model, where breakdowns are independent of process time in order to minimize the total completion time for all the jobs. Kiran et al. (2013) performed root cause analysis in order to identify major breakdowns that affect the production.

Different analytical and mathematical models have been conducted by researchers for throughput analysis to investigate the effect of downtime. Some of the researchers used the approach of considering scheduled maintenance as downtime for throughput analysis. Sembiring & Nasution (2018) concluded that high downtime cause in the industry is due to corrective maintenance which impacts unscheduled maintenance activity. Resulting in the loss in production process time. Zhu et al. (2019) used Online Task Allocation for scheduling maintenance where permanent production loss is considered to analyze the effect of disruption in the production line which led to the conclusion that permanent production loss is likely to happen when the last slowest machine starves or blocks.

Studies were performed for production loss by identifying the bottleneck stations, and some devoted to study the effect of a buffer in a manufacturing system have shown a significant improvement in productivity. Roser et al. (2004) studied the effect of the buffer on the system using starving and blocking analysis in order to create a prediction model for the allocation of a buffer. Imseitif & Tang (2019) used a strategic approach where manufacturing stations are replaced by an idle station which can act as a buffer. Their result showed the improvement in the throughput. Kavusturucu & Gupta (1999) implemented a method of a queueing system with finite buffer assigning a server to each station and investigated the effect on throughput. Liu et al. (2012) performed throughput analysis for a two-stage manufacturing system, considering independent unreliable machines at every step decoupled with a finite buffer.

The development of a manufacturing system, however, does not rely solely on the study of a single machine or a buffer, rather it involves the possible impact of these constraints on one another. Singh & Jatinder (2019) measured the whole manufacturing system performance, considering a possible change either or both machine or system by introducing Composite Performance Matrix (CPM) in two ways first by Analytical Hierarchy Process approach and second by considering data

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