Faculty of Manufacturing Engineering

DEVELOPMENT OF OVERALL PERFORMANCE EFFECTIVENESS IN JOB SHOP MANUFACTURING PROCESS

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DECLARATION

I declare that this thesis entitled “Development of Overall Performance Effectiveness in Job Shop Manufacturing Process” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
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Date	:	…………………………….

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature	:	....
Supervisor Name	:	ASSOC. PROF. IR. DR. PUVANASVARAN A. PERUMAL
Date	:	…………………………….

DEDICATION

To my beloved parents and family

ABSTRACT

Overall equipment effectiveness (OEE) is implemented by the case company, an aerospace part manufacturing company, to encourage machines to operate all the time at the ideal speed and produce no quality defect in extreme case. However, integration between workstations and transporting activities, deviation of production from customer demand, and imbalanced capacity among processes are neglected under OEE implementation. The consequences include inefficient material flow, overproduction and excessive inventory level, as well as lack of interaction between workstations. Therefore, objectives of this study aim to quantify the impact of transportation efficiency onto the workstations, to synchronize capacity available among them and also to monitor the fulfillment of customer demand in terms of delivery time and production amount. The critical measures are shorter lead time and wait time, less throughput, minimal equipment utilization and less capacity incurred. Simulation results have shown that both transportation efficiency and performance of Autoclave workstation affect material flow and throughput rate respectively. Consequently, the performance of workstations they connect with are also affected. Besides, simulation also proves different production rate and imbalanced capacity throughout production system. Therefore, Overall Performance Effectiveness (OPE) is proposed to consider customer demand, historical equipment utilization and Takt time of each workstation. This promotes reasonable utilization of resource to avoid both overprocessing and overproduction issues which are invisible in OEE. Furthermore, delay propagation throughout production system and interrelationship between processes are quantified by delivery performance (DP) of OPE. The waiting time and lead time spent in each workstation are monitored under the DP. Responsibility of all workstations and transportation process in delivering demand on time are quantified. Last but not least, transportation process which serves as the connectors of manufacturing processeses is also quantified and monitored by proposed Transportation Measure (TM). TM aims to reduce the queue length at destination and the corresponding waiting time with reasonable utilization of forklift. It also promotes less capacity investment in transportation and prioritizes its scheduling according to urgency of destination workstation. In short, newly proposed Overall Performance Effectiveness (OPE) and the quantification of Transportation Measure (TM), which affect each other, help in promoting better delivery performance in terms of production amount and lead time. Besides, reasonable utilization equipment and minimal consumption of material are promoted to fulfill the demand. The effectiveness of entire production line is examined as a unity with joint responsibility under varying transportation efficiency and cycle time of each workstation. Both OPE and TM could be implemented together to optimize the production system. All of these are not quantified and provided by the OEE implemented by the case company.

ABSTRAK

Keberkesanan Peralatan Keseluruhan (OEE) telah dilaksanakan oleh syarikat kajian, iaitu sebuah syarikat yang terlibat dalam pembuatan bahagian aeroangkasa, untuk menggalakkan mesin-mesin beroperasi sepanjang masa pada kelajuan yang ideal tanpa menghasilkan produk yang cacat kualitinya. Walau bagaimanapun, integrasi antara stesen-stesen dan pengangkutan dalam sistem pengeluaran, perbezaan antara pengeluaran dengan permintaan, dan ketidakseimbangan kapasiti mesin sering diabaikan dalam OEE. Akibatnya, pengangkutan yang tidak cekap, lebihan penghasilan dan inventori serta ketidakadaan interaksi antara stesen-stesen didapati dalam produksi. Oleh itu, objektif kajian ini ialah untuk mengukur impak kecekapan pengangkutan atas performasi stesen-stesen, mengimbangkan kapasiti mesin-mesin dan menggalakkan pemenuhan permintaan pelanggan dengan unit masa dan pengeluaran yang minimal. Sasarannya termasuk masa tempoh yang singkat, pengeluaran yang munasabah, pnggunaan mesin dan bahan yang minimal untuk memenuhi permintaan pelanggan. Ini adalah untuk mewujudkan keseimbangan antara kepenuhan permintaan pelanggan, penggunaan munasabah dan isu-isu pengeluaran berlebihan yang sering diabaikan dalam OEE tradisi. Simulasi menunjukkan bahawa kecekapan pengangkutan dan prestasi Autoklaf menentukan pengaliran bahan, serta prestasi mesin-mesin dan juga stesen-stesen. Tambahan pula, ketidakseimbangan kapasiti antara mesin-mesin dalam syarikat kajian telah dibuktikan oleh simulasi. Oleh itu, Keberkesanan Prestasi Keseluruhan (OPE) telah dicadangkan untuk merangkumi permintaan pelanggan, penggunaan peralatan yang munasabah dan masa Takt untuk semua stesen untuk mengelakkan situasi lebihan pengeluaran dan pemprosesan yang tidak diukur dalam OEE. Prestasi Penghantaran (DP) dalam OPE yang mengukurkan masa penungguan dan masa 'Lead' *telah meliputi kelewatan yang disebarkan dan perhubungan antara stesen-stesen. Oleh itu, tanggungjawab stesen-stesen dan pengangkutan dalam memastikan pengaliran produk yang lancar telah digalakkan. Akhir sekali, penggangkutan dalam produksi sistem diukurkan dengan Ukuran Penggangkutan (TM) memendekkan barisan bahan dan masa penungguan serta penggunaan kenderaan yang minimal. Dengan adanya TM, pelaburan dalam pengangkutan dapat dikurangkan dan penjadualan kenderaan ialah berdasarkan kecemasan bahan diperlukan di destinasi berikutnya. Pendek kata, Keberkesanan Prestasi Keseluruhan (OPE) dan Ukuran Pengangkutan (TM) yang saling berhubung kait meningkatkan penghantaran produk tepat pada masa dan kuantiti pengeluaran. Tambahan pula, penggunaan sumber dan bahan yang munasabah atau minimal telah digalakkan untuk memenuhi permintaan pelanggan. Keberkesanan seluruh barisan pengeluaran telah dinilaikan sebagai unit dalam situasi berlainan. Kedua-duanya dapat meningkatkan prestasi sistem pengeluaran yang tidak diliputi oleh OEE.*

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CHAPTER 1

INTRODUCTION

1.1 Background

There are different kind of data available in manufacturing industry nowadays for improvement of production system. However, manufacturing company faces difficulty to utilize and process the data in such a way that could provide context and meaning, such as insight into future performance and estimation of the time to failures, so that the right personnel could respond accordingly (Lee et al, 2013). Besides, things could be different in daily performance because high system complexity and data volume have compromised the predictive capabilities during production planning. This could be seen from mass production which is preferable due to the economies of scale, however, would lead to overproduction if the customer demand is not taken into consideration carefully.

In addition, inability in selecting the appropriate measures which adapt and suit the nature of manufacturing process would cause lean wastes in production not being quantified and monitored. Therefore, focus on the environment of manufacturing is necessary so that rightful decision could be made accordingly for lean improvement. Performance measurement is the fundamental principle of management that it identifies the gap between current performance and desired performance and enables company to initiate progress towards closing the gaps (Samad, Hossain, and Major, 2012).

Customer demand, for instance, is crucial because it is one of the data to consider at the very first step to ensure smooth flow of production. Only by then, production plans are carefully prepared and executed on a shop floor where performance indicators are measured and used for parameter optimization, minimization of the impact from uncertainties and proactive implementation of solution to prevent performance loss (Lee et al, 2013; Mugwindiri et al, 2013; Gansterer, Almeder, and Hartl, 2014). Therefore, it is crucial to ensure every operation within manufacturing environment is carried out with respect to customer demand.

Utilization of the manufacturing facilities has been selected as the Key Performance Index (KPI) to be considered at most of the time to attain optimum operation of plant (Gansterer, Almeder, and Hartl, 2014; Ponsignon, and Mönch, 2014; Helo, 2000). Management concentrates on the important data generated such as the available capacity and fulfillment of customer demand and excel to the benefits of company (Mugwindiri et al, 2013). It is understandable that companies emphasize on the capacity of their manufacturing facility which is available to fulfill customer demand because this helps to reduce the buffer inventories which are normally required to protect its downstream production from any possible breakdown. Utilization of manufacturing facility and fulfillment of customer demand, therefore, are related to each other.

Customer demand is one of the vital elements which influent the capacity utilization of manufacturing facilities. In order to understand the customer demand thoroughly, the approach of demand division is sometimes implemented in industry nowadays by dividing the demands into segments to make them more predictable for reduced volatility or fluctuation. This enables company to adjust their lot sizes and safety stock level with respect to the demand and seasonal cycle of that particular demand. Besides that, several initiatives had also been done by suppliers to customers so that they could confirm and place their order in advance for the better production planning (Colares, n.d.). All these require some incentives to ensure large amount of reservation of demand so that stability in term of the economies of scale could be achieved, at the same time its amount does not create any discomfort to the supplier itself in case of cancellation.

However, shorter waiting time of jobs in queues results from the shortage of buffer inventories and its corresponding shorter lead time will increase the competitiveness of company in term of flexibility and delivery (Afefy, 2013). This is one of the examples demonstrating the trade-off exists between buffer inventory and the performance of demand fulfilment. Therefore, big picture of the information flow and importance of focusing on the overall performance and availability of capacity are required especially when the market is full with fluctuation of demand on multiple version of product.

Consequently, historical events had been analyzed so that relationship could be established between theory, interview and the historical events to find out the strategies in terms of demand management and capacity management (Colares, n.d.). Most of the time company focuses more on the capacity management. This is because most of the strategies depend on the aspects controllable by company such as assignment of resource, scheduling of production and capacity planning. Since the ultimate goal of any manufacturing companies is to make profit from the production, the performance measurement is sometimes evaluated in term of energy consumption or competitiveness, instead of capacity utilization, with the help of simulation model (Barletta et al, 2014).

On the other hand, for the uncontrollable aspects such as the variation of customer demand, it is the standard in manufacturing nowadays to use simulation tool as the analytical tool because of its capability of predicting the possible future events and identifying the area that would have gone wrong during a certain period of time (Mugwindiri et al, 2013). Besides, simulation-based framework is used to model the market behavior and production system so that demand and execution uncertainty could be considered during assessment

(Ponsignon and Mönch, 2014). Discrete Event Simulation (DES) has been widely implemented by companies to identify of production waste such as waiting, work in progress, inventories and transportation so that optimum values for a manufacturing resource can be defined. (Badiger and Gandhinathan, 2008; Heilala et al, 2008).

Simulation method is also extensively used by industry to test different scenarios, model any abnormal situation and drive recommendation based on the results once the desired target is attained in the model (De Carlo, Arleo, and Tucci, 2014; Zhou et al, 2009). Last but not least, it is a common practice to emphasize solely on the manufacturing environment which is controllable and internal within a company in order to minimize the error of estimation.

1.2 Background of case company

The case company is an aerospace part-manufacturing company located in Malaysia. It is part of global supply chain for major aircraft manufacturers and also in the composite industry. Five main manufacturing processes within the company are layup, autoclave curing, demolding, CNC trimming and NDT inspection processes as illustrated in Figure 1.1.

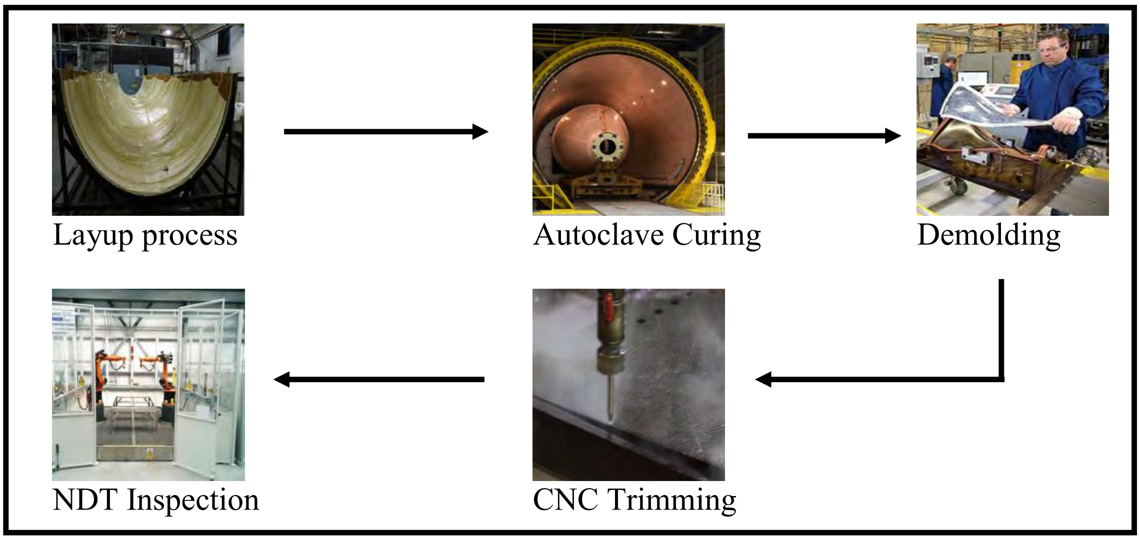

Figure 1.1: Process flow of the main processes in company under study

Production system of the company under study starts from layup process which is to stack the ply materials layer by layer manually which will be cured and hardened in autoclave curing process. The harden materials will then be separated from its mold and transferred into suitable trimming mold during demold process before its excessive portion will be removed in the CNC trimming process. It is followed by Non Destructive Testing (NDT) section where inspection is carried out to ensure there is no void and crack within the product. In addition to 5 main processes as shown in Figure 1.1, there are transporting activities carried out within the production system to ensure smooth material flow.

Among the aforementioned job shops, 2 of them namely layup and demold are manual process whereas the other three are automated process. Each job shop consists of varying number of man power, either as the operators to operate machine for automated process or as the technicians to perform manual process. The capacity of each job shop are shown in Table 1.1 below:

Table 1.1: The capacity available in each job shop of the production system

Process	**Capacity and Nature**			**Cycle Time (Hour)**		
	Process type	**Unit Available**	**Capacity Type**	**Min**	**Mod**	**Max**
Layup	Manual	20	Man power	14.0	16.0	18.0
Autoclave	Automated	2	Fixed Capacity	9.0	14.0	28.0
Demolding	Manual	12	Man power	0.5	1.0	1.5
CNC Trimming	Automated	2	Fixed Capacity	18.0	20.0	21.0
NDT Inspection	Automated	1	Fixed Capacity	16.0	24.0	32.0
Transportation	Manual	5	Forklift			

The production system of the company produces 27 sets of aerospace part per month with fixed routine since the process flow is constant and unchanged as per specification. The variation of cycle time for each process are shown in Table 1.1. The cycle time is plotted in upper and lower limit with the mod value because the data collection is time consuming and there is lack of operator to collect the data at the meanwhile performing operation during daily production. Note that in addition to the 5 main processes as shown in Figure 1.1, transporting activities within production system is supported by 5 forklift available. The company strives to achieve better delivery performance via shorter lead time and less consumption of materials in demand fulfillment.

1.3 Problem statement

The company under study implements Overall Equipment Effectiveness (OEE) to monitor its production system due to its simplicity and efficiency. However, company focuses on individual equipment and process separately rather than integrating and improving the performance of overall production system. Consequence of that, issues such as unreliable downstream capacity and inefficient flow of Work In Progress (WIP) within production system have impeded the company in achieving the mission of Just-In-Time (JIT). Most of the time, company experiences excessive consumption of materials and delayed delivery of product to customer site. This happens even though the operation of machine in each process completes within the standard duration without any delay.

In addition, joint responsibility is not promoted among processes in the company under study due to absence of appropriate measure. Consequence of that, supportive activities which are carried out between processes could not be quantified and improved by company. One of the examples includes the transportation of WIPs within production system. There are five forklift shared among processes which are more than enough for the transporting activities. However, process such as demolding process to wait for incoming materials whereas other processes such as curing and inspection process are having long queue. Company wishes to resolve it via improvement on the transportation process.