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Production Leveling System Implementation at Mixed Model Product with Heterogeneous Cycle Time for Single Operation Line

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Abstract: Production leveling is one of the main lean manufacturing principles which aims to enhance production performance and optimize operation cost. Systematic and level production of process for mixed model product is presented to study manufacturing parameter results. A required production time was synched in leveling system approach to avoid non-value-added item such as excess inventory and poor planning in production space. A few parameters were used to measure the performance of production leveling system implementation. Proper establishment production leveling schedule gained good results for manufacturers who were committed to the implementation. The most significant production area and productivity were due to balanced capacity according to actual demand. The conclusion and recommendation regarding potentials of efficient implementation were presented in a demonstration of production leveling system at mixed model product at single operation line.

Keywords: Production leveling, level production scheduling, smooth flow manufacturing

1. Introduction

Intense competition among manufacturers has grown and increased significantly. Uncertain demand situation as well as dynamic consumer expectations have pressured manufacturers to seek systematic and efficient techniques in handling the environment. The new challenge has caused many global manufacturers to adopt lean manufacturing principles and tools. Gahm et al. (year) explain that global companies now offer complex and specific orders according to customer requirements and quantity [1]. To meet these challenges, systematic scheduling and efficient production processes are crucial for the success. Systematic scheduling is discussed by Gahm et al. (year) to reduce operation cost, and to meet customer delivery deadlines [1]. Two crucial aspects (cost and customer expectation) are important to be understood by companies in order to lead the market segment.

Systematic scheduling is the main focus in lean principle, which is identified as lean production leveling [2]. Efficient production leveling in terms of volume and mix models could offer a variety of choices to customers [3]. In the current business context, small quantity production based on customer need, shorter lead time, a variety of products and on time delivery are the performance metrics that focus to meet customer expectation. Excellent performance metric results coupled with level production could show tremendous costing reduction [2]. Production leveling approach focuses to avoid over-production, and to meet customer delivery deadline. Leveled production attained by load balancing among the processes is synchronized to the customers' takt time in a smooth manufacturing manner. Information management system needs to be aligned to the level production because failure to synchronize can cause detrimental effects towards an organization's performance [4]. Just in Time (JIT) production contributes to customer

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satisfaction by shortening lead time of process and avoiding cost of non-value-added activities. Level production is one of the tools to achieve JIT in which it is aimed to level quantity order throughout working hours [1], [2], [4].

The purpose of this paper is to present an implementation of production leveling approach. This research utilizes the case-based approach to demonstrate the implementation of production leveling in the mixed products on a single operation line. The study explores the concept of level scheduling that emphasizes on improvement of manufacturing performance. As one of the JIT principles, assessing its associated cost and other lean parameter is carried out to investigate the impact of implementation. This paper ends with conclusion of the level production in manufacturing firms. Implementation of level production could offer tremendous results in productivity, saving in production space and many other parameters which provide comprehensive information prior to decision making by industrial practitioners on the best manufacturing technique.

2. Literature Review

Fulfilling dynamic changing order and request is tough and challenging. Capital commitment and system constraint have caused most manufacturers to be unable to deliver better result. However, proper arrangement and implementation gain good performance to the company, especially systematic and efficient manufacturing reaction to flexibility request. The increment of resource utilization, reduction of operation cost, quality improvement and customer service level enhancement are the results discussed by researchers [5], [6], [7].

In literature, production leveling or Heijunka is one of the concepts in lean manufacturing which presents pull signal of production based on actual request. The approach consists of supermarket replenishment to control work-in-process inventory [3], [8]. In addition, smoother pattern for daily production event is established at the manufacturing floor. Product quality and delivery reliability are keys to success stories of leveling policies, whereby limiting and controlling production process by imposing actual figure needs is due to scheduling and distribution by customers [9]. Shortened lead time in manufacturing is aimed in the production system. If the process fails and exceeds target level, unnecessary inventory or defect occurs which could affect the company financially. Production planning team must be quickly responding to market demand and the current order situation [10]. Associated small batches in mixed model production throughout daily production hour attain capacity balance and synchronization of production to customer needs. The flexibility change of demand allows production to precisely adopt to situations without any major issues such as inventory excess or delivery problem [11-12].

There are a few research papers that examine the potentials of leveling concept through modeling approach and mathematical technique [1-2], [5], [12-13]. This is demonstrated in measuring responsiveness of system and customer flexibility order. Synchronized manufacturing flow to the next process leads to establishment of quality and control policy which results in higher performance and cost optimization [2]. The work presented in this paper demonstrates the real case study on production leveling approach in glassware manufacturing which results in the improvement of production performance.

3. Methodology

The concept of implementation is based on Plan, Do, Check, Act (PDCA) cycle which is also known as the Deming cycle [14]. The concept in Figure 1 was adopted and modified to incorporate the mechanism of the company situation.

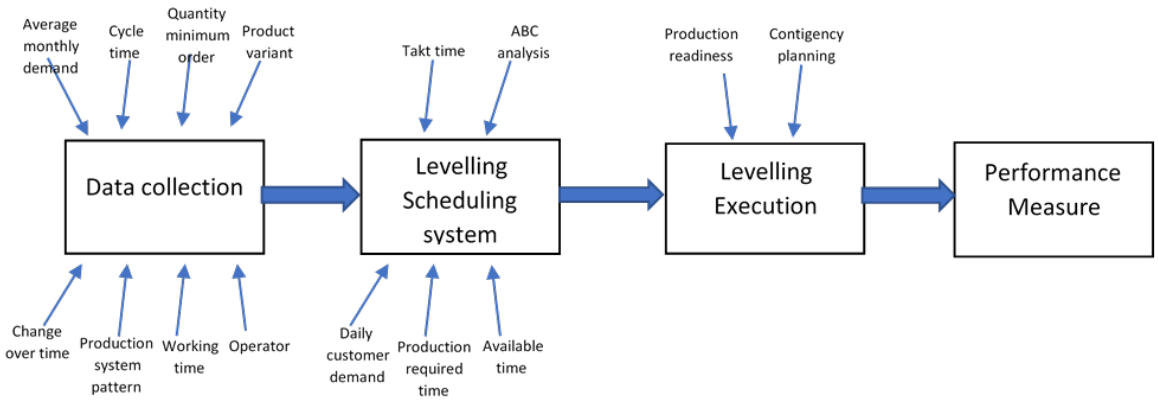

Fig. 1 - Implementation concept of production leveling at manufacturing process

The first phase was data gathering activity. It was conducted to understand the production activity and system on how the process was run to the end. Basic data such as average of customer order, cycle time, change over time,

working time, product variants and operators' working days were collected. This data was essential to be used for the next phase.

The second phase was to establish production leveling schedule. A few parameters were defined such as takt time, daily order, production required time and available time. ABC analysis was used to set the trend of production order for scheduling. The following list is the equations used in establishing production leveling schedule [15].

$$\text{Talk time} = \frac{\textit{Total Available time per day}}{\textit{Daily order}} \quad (1)$$

$$\text{Daily order} = \frac{\textit{Average monthly demand}}{\textit{monthly working days}} \quad (2)$$

$$\text{Production required time} = \textit{Cycle time} \times \textit{quantity order} + \textit{number of change time} \quad (3)$$

The next phase was execution activity. However, two factors needed to be reviewed and identified, which are production readiness and contingency plan. The criteria for contingency plans were a sufficient buffer to cater to minor stoppages and additional time to cover capacity losses during the production process. Both factors were crucial in which it affected the progress of production leveling schedule for this situation. The last phase was performance measurement of implementation. This analysis was then conducted by comparing performance of the line between the current state and future state maps. Productivity and production area were the parameters used to determine performance result of production leveling approach.

4. Case Study

The case study selected was at Set Packing (SP) line at a glassware manufacturing company in Pasir Gudang. This production line consists of packaging assembly line in which glassware is produced for overseas market. The line is run on a mass batching approach in which items are produced in a big quantity before stored in the finished goods storage for a month before delivered to customers. By practicing, the production team has to produce the low volume of order items more than customers' orders just to reduce workers' idle time. There were 12 operators involved, and each operator worked at different workstations in the SP line. Every operator performed his/her task according to the predetermined cycle time set by the company. The line was working 24 hours a day and 6 days a week. Two teams were assigned to cater to two shift patterns. Each shift was supposed to run 11 hours with 1 hour of break.

During the Gemba and data gathering sessions, the production floor was congested with child parts and materials supplied due to mass batching production approach. Pallets were widely used on the floor to place child parts, material supplies as well as finished goods. The reason the production management allowed such practice was because they were running the operation in huge quantities. With the practice of palletizing system on the floor, they believed that the material transportation time could be reduced. However, the floor was congested and not safe.

The objective of production leveling scheduling was to create smooth production order throughout the months to minimize congested area and improve the production performance with the introduction of balance capacity based on demand. This was done by taking a minimum order to run based on customer takt time with specific requirements from the company. Data collected is shown in Table 1.

Table 1 - Manufacturing data collected for Set Packing line

Item variant	A	B	C
Cycle time	90 seconds	120 seconds	280 seconds
Working hour		22 hours	
Number of shifts		2 shifts	
Number of working days in a month		24~26 days	
Change over time		600 seconds	
Number of operators	12	12	12
Average monthly customer order	11,440	4,160	780

In order to establish smooth production flow and minimize inventory, production leveling approach was set up. Total required production time was calculated by including change over time allocated in daily working time and total production time. In this case study, the decision of production time allocation was decided by the company based on their ABC analysis in which 50% of production time was allocated for group A items, while 30% and 20% production time was planned for the production of group B and C items, respectively. Available time was defined as real working time by operators excluding the break. Then, essential parameters were gathered to prepare production leveling schedule. Takt time for that assembly line and cycle time for each group were calculated to ensure that both figures

synchronized, and able to cater to customers' orders. Daily production order was defined as the minimum quantity to produce with mixed model production. Since all important data was obtained, leveling schedule was established to create balance and event production quantity for each item at daily time. The rule for the scheduling was that every item must be run based on daily production order, unless the quantity did not achieve the minimum quantity per order. For this case, the company remained to run for at least a minimum quantity due to traceability issue, and to avoid overstock of loose supplied part. The fluctuation factors by customers' orders were excluded by providing specific inventory buffer at the finished goods storage. The figure was defined by the company based on the marketing and delivery data.

In order to ensure the consistency of production level, all wastes were eliminated. In this case study, the company had implemented kaizen activities which focused on eliminating seven types of wastes as well as to create continuous production without obstacles between workstations. The production leveling schedule was executed to introduce more even and balanced flow of process. Figure 2(a) shows the planning items run at the Set Packing line for that month. It began with the quantity of each item, followed by the schedule and time. The high-volume items were scheduled first, followed by middle and low volume items as shown in Figure 2(b). Total required schedule production time of product should be less than the total available time. If there was any obstacle or problem occurred, such as quality issues or worker availability, the production team had prepared a contingency plan to cater to the daily demand. Actual total production required time must be monitored closely by the production team because timing was crucial. Figure 2(c) shows the monitoring table used by the production team to follow up on the current status against target. If the production time exceeded the required time, it would be jeopardizing the leveling approach. The critical element was production readiness such as change over time, material availability on time, and consistency of worker performance. If these factors were not sustained, the objective of the production level cannot be achieved. However, efficient buffer at the last processes and additional working overtime would be considered as contingency plan in order to fulfill customers' orders.

Part No	Group	Cycle Time	Takt Time	Av. Demand/ Day (pcs)	Monthly Demand	total planned
1098434	A	**90**	**121**	58	**1,500**	1508
1098428	A	**90**	**121**	31	**800**	806
1098417	A	**90**	**121**	107	**2,780**	2782
1098444	A	**90**	**121**	83	**2,150**	2158
1098420	A	**90**	**121**	108	**2,800**	2808
14ED-OG-CS	B	**120**	**121**	50	**1,300**	1300
14ED-KE-CS	B	**120**	**121**	31	**800**	806
A-423C-JW	B	**120**	**121**	115	**3,000**	2990
52K-PU-KS	C	**280**	**121**	4	**100**	100
40V-LN-P	C	**280**	**121**	12	**300**	312
40V-DL-P	C	**280**	**121**	8	**200**	200
40V-RQ-P	C	**280**	**121**	8	**200**	200
52K-STR-KS	C	**280**	**121**	8	**200**	200
52-SW-KS	C	**280**	**121**	15	**400**	395
52-STR-KS	C	**280**	**121**	15	**400**	395
52-SM-KS	C	**280**	**121**	4	**100**	80

Fig. 2 - (a) Schedule of items of product run at Set Packing line

SET PACK LEVEL PRODUCTION SCHEDULE SYSTE Month : **JUNE** Year : **2016**

Average Change Overtime 3 min No of Working Days : **26 days** Hour/shift: **11** Number of shift: **2**

IMPORTANT : Pls ensure weekday column header is located correctly to the day of the month :

							WED	THU	**SAT**	**SUN**	MON	TUE
Part No	Group	Cycle Time	Takt Time	Av. Demand/ Day (pcs)	Monthly Demand	total planned	1	2	3	4	5	6
1098434	A	**90**	**121**	58	**1,500**	1508	58	58	58		58	58
1098428	A	**90**	**121**	31	**800**	806	31	31	31		31	31
1098417	A	**90**	**121**	107	**2,780**	2782	107	107	107		107	107
1098444	A	**90**	**121**	83	**2,150**	2158	83	83	83		83	83
1098420	A	**90**	**121**	108	**2,800**	2808	108	108	108		108	108
14ED-OG-CS	B	**120**	**121**	50	**1,300**	1300	50	50	50		50	50
14ED-KE-CS	B	**120**	**121**	31	**800**	806	31	31	31		31	31
A-423C-JW	B	**120**	**121**	115	**3,000**	2990	115	115	115		115	115
52K-PU-KS	C	**280**	**121**	4	**100**	100			10			
40V-LN-P	C	**280**	**121**	12	**300**	312	12	12	12		12	12
40V-DL-P	C	**280**	**121**	8	**200**	200	10	10			10	10
40V-RQ-P	C	**280**	**121**	8	**200**	200	10	10			10	10
52K-STR-KS	C	**280**	**121**	8	**200**	200	10	10			10	10
52-SW-KS	C	**280**	**121**	15	**400**	395	15	15	15		15	15
52-STR-KS	C	**280**	**121**	15	**400**	395	15	15	15		15	15
52-SM-KS	C	**280**	**121**	4	**100**	80			20			

Fig. 2 - (b) Production Leveling Schedule for Set Packing line

	WED	THU	SAT	SUN	MON	TUE
	1	2	3	4	5	6
TOTAL REQ. SCHEDULED PDN TIME (sec):	**78510**	**78510**	**78510**	**0**	**78510**	**78510**
TOTAL CHANGEOVER TIME (sec):	**42**	**42**	**39**	**0**	**42**	**42**
TOTAL REQ.PDN TIME (W. C/OVER) (sec) :	**78552**	**78552**	**78549**	**0**	**78552**	**78552**
TOTAL AVAILABLE TIME (sec)	**79200**	**79200**	**79200**	**79200**	**79200**	**79200**
OVERTIME REQUIRED (sec) :	**0**	**0**	**0**	**0**	**0**	**0**
EXTRA TIME (sec) :	**648**	**648**	**651**	**79200**	**648**	**648**
Additional OVERTIME REQUIRED (hr) :	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Max OT allowed :						

Fig. 2 - (c) Available time and total required production time in Production Leveling Schedule

Table 2 presents the data of performance before (Mass Production Approach) and after (Production Leveling Approach) the implementation of production leveling schedule. Five spaces of production floor were measured to evaluate the implementation effectiveness. Productivity per man hour was collected to be compared with previous data.

Table 1 - Manufacturing data collected for Set Packing line

Space used m^2	Mass Production Approach	Production Leveling Approach
Production Area	389.58	272.58
Kitting Area	198.66	118.25
Set Pack Touch Zone Area	94.35	36.23
Finished Good Preparation Area	173.56	63.55
Total Area	**856.15**	**490.61**

Through the performance measurement activities, two significant elements were improved. Figure 3 and Figure 4 show the improvement gained after the establishment of production leveling schedule system on SP line.

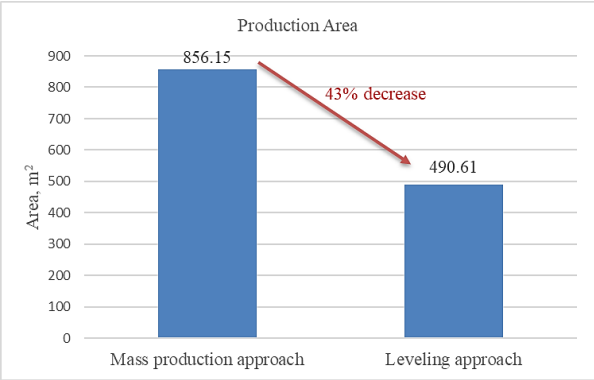

Fig. 3 - Reduction in production area

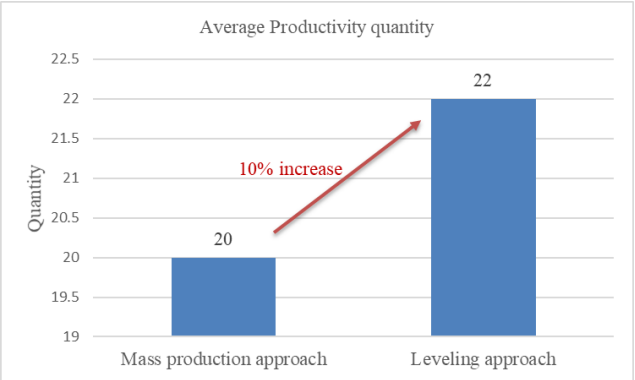

Fig. 4 - Increased in productivity

In the production area, there was a significant improvement in which the occupied area reduced 43%. It was due to the practice of small lot parts supplied on the line approach. There was no large quantity of parts or products remaining on the floor. It was moved based on the takt time flow to avoid scheduling congestion. Pallets on the floor were removed since a small lot quantity was introduced in the production leveling approach. Thus, SP line and other areas on production floor were more organized and less congested.

The average productivity quantity showed increment by 10%. During mass production approach, average productivity was 20 units, but it increased to 22 units after the leveling method was introduced. Working in organized and less congested area have boosted the morale of the workers as to work in a more conducive environment. Less movement and less searching part at workplace had increased capacity of production. As a result, productivity has improved compared to previous practice. The workers just needed to continue with the routine activities in order to follow the production schedule.

5. Conclusion

This case study proves that the Production Leveling Scheduling has given a positive impact to SP line for JIT production. Significant achievements in terms of space saving and improved productivity are the results from this case

study. The production leveling schedule has successfully improved JIT concept in which a small lot production is able to eliminate waste of transportation, movement and production as well as balanced quantity of the items manufactured based on orders. Moreover, it helps to enhance 5s by providing systematic manufacturing scheduling.

To sustain the effectiveness of production level schedule, some recommendations need to be considered:

i. The continuous flow concept must be established around working process in order to avoid obstacles in the production flow. Thus, it will be easier to run the level quantity of products with mixed model schedule based on the takt time.
ii. The fluctuation of customer demand must be minimized or is needed to create an effective buffer system at the finished goods storage in order to cater to the real demand from customers.

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