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Gravity Flow Rack's Material Handling System for Just-In-Time (JIT) Production

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Abstract

Effective and efficient material handling (MH) system is crucial in any Just in Time (JIT) production system. A Gravity Flow Rack (GFR) system is one of the very well adopted MH system and very practical in order to optimize the effectiveness of the JIT production system. This paper presents a review on the actual implementation of a GFR system at an automotive component's assembly line in an accord to improve its existing MH system. The main purpose of this implementation is to reduce the material transfer activities while reducing the occupied space; hence reducing the overall production cycle time (CT). The implementation outcomes show significance improvement on the productivity and not to mention the material handling's time. It is proven that the GFR system is still relevant and can be regarded as one of the most effective tool in JIT production.

Keywords: Automotive Industry Malaysia; Case study; Just In Time (JIT); Material handling (MH) system; Gravity Flow Rack (GFR) system.

1. Introduction

Nowadays, major, medium as well as small local automotive manufacturing companies are experiencing rapid development in terms of technology and system applied, resulted by stronger domestic and global market demands. As the companies grows, the need for efficient MH system also arises especially in the manufacturing area.

Material handling (MH) system is one of the basic components that complement the whole manufacturing operation. This system basically refers to any activities, equipment and procedures related to the moving, storing, protecting and controlling of materials flow in a manufacturing system [1]. It provides the manufacturing system with smooth material flow without excess in-line and out-line inventory. The MH system is categorized as non-value added (NVA) activities which implying that the less MH involved is the better [1]. However it is impossible to totally eliminate the MH activities in any manufacturing operation. Hence an effective and efficient MH system is always the ultimate objective by many companies. Research by Allen, J., Robinson, C. and Steward, D. [1] confirms that efficient MH system helped to reduce 15% to 30% plant's operating cost. Kasul, R. and Motwani, G. [2] supported this statement by highlighting that systematic MH system could increase the material flow's efficiency and it's effectiveness. Others than that, there are several research affirm that systematic MH system promises several advantages to the manufacturing system such as efficient part picking during the assembly process [3], improving operators' ergonomic factors [4], reduction in operators' walking distances, NVA activities and CT [4], reduction in product cost [5], and reduction in WIP stock as well as product's lead time [6].

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MH system is synonymous with JIT production area which requires supply of right and proper materials for the system in the right quantity, place, time, position, sequence and cost. This is to ensure that the products are produced at the right time consuming and fulfilling quality requirements [5]. However, the process of handling and supplying materials can be simple or fairly complex with the increasing of quantity, size and weight of the materials to be supplied. The effectiveness of this system strongly depends on many aspects such as types of conveyance used, temporary storage methods, routes of the material delivery, frequency of the delivery and quantity per delivery. Therefore, the system must be properly designed and tested before applied into the manufacturing line.

This research utilized the case-based approach to demonstrate and document the implementation of a project aimed at improving the MH system of a real JIT automotive assembly line with application of GFR system. It was conducted at a plastic manufacturing plant owned by XYZ Manufacturing Sendirian Berhad. The study explores the design and concepts of the GFR system that emphasized on the productivity per man hour and occupied space in the assembly area. Detail explanations on the overall activities of the GFR implementation including GFR design stages and layout improvement were included. Hence, this paper revealed the actual implementation of a GFR system at an automotive company assembly line. Actual data on the existing assembly area were collated. Summary of the research findings and some suggestions for maintaining the stability of the GFR system presented in the end of this paper.

2. Methods

2.1. Review and Data Collection

Review is conducted to investigate the existing method of materials feeding assembly processes. It was carried out by direct observation on the actual manufacturing activity and reviewing the existing production documents such as Standard Operating Procedure (SOP) and production report. After that, previous manufacturing data were collected from computer data base system called Production Control System (PCS). Average figures, for the past 5 months were calculated to establish baseline for the analysis. For comparison purpose, the data were compared to standard target as registered by the company in their Bill of Material (BOM). Next, line observation was conducted to understand the present conditions of the assembly line as well as to identify types of wastes in the process. Time study was also conducted according to J. Haizer and B. Render [7] and S. A. Lawrence [8]. Time Measurement Sheet (TMS) was used to record all elements process and cycle times (CT) for each process. In the TMS, process time was separated between hand time, transportation time and machine time to clearly picture the process. Along the process, it also includes a number of periodical tasks. Periodical task is a set of tasks that is infrequent but periodically performed by operators along the production process. This task must be separated from the work cycle as it is classified as NVA activity where for this; Periodical Task Check Sheet (PTCS) was used to run the analysis. Last but not least, study on the existing layout; movements of operators inside the line and size of the assembly line were also conducted by using Standard Work Chart (SWC).

2.2. Design the GFR system

To design the GFR system according to scale, Computer aided system called Auto-Cad was utilized. The GFR system was designed by considering the following guidelines [9][10][11]:

i. Present the parts and components as close as possible to the point of use of operators so they can use both hands simultaneously. This is to reduce walking distance of the operators.
ii. Applying First in First out (FIFO) system.
iii. To design the rack by ensuring it can only be occupied by not more than 2 cycles of delivery quantities at one time, by referring to standard line CT. This is to minimize inventory in the assembly line.
iv. Kitting area to be located near to the assembly line. This is to reduce walking distance of the material handlers.
v. Parts and components are replenished from outside of the assembly area by material handler. By this, the material handler will not freely enter the line which could disturb the operators.
vi. Empty poly-boxes are returned from inside of the assembly area by operators by using gravity feeding system, where for this the rack is inclined to outward.
vii. Size of poly-boxes on the flow rack must be convenient to handle individually by the operators and material handlers without assistance and also must be standardized.
viii. The GFR is designed with appropriate degree of inclination so that process of storage is more ergonomic.
ix. Proper address system at feeding in and feeding out the flow rack to avoid wrong parts supplied to operators.
x. For small components, the GFR should designed according to the size of the boxes.

2.3. Implementation and kaizen activity

Right after the implementation of the GFR system in the assembly line, a set of *kaizen* activities was implemented to optimize the effectiveness of the GFR system. Subsequently, de-bugging process was carried out to monitor stability of the system. During the process, corrective actions were made immediately on abnormalities that were found along the evaluation. They were then monitored to ensure the effectiveness of the action taken and stability of the standardized process.

2.4. Performance analysis:

This analysis was conducted by comparing performance of the assembly line with the existing system. The parameters used are productivity per man hour and occupied assembly area.

3. Case Study

The case study area is BLM assembly line, producing air cleaner for local automotive manufacturers in Malaysia. It is a semi-automated production process with manual loading and unloading at the start and the end of the process for producing air filter module. This assembly line consists of two workstations; workstation 1 at assembly machine and workstation 2 at inspection machine. There are two operators who carry out all the assembly processes; operator 1 at workstation 1 operates the assembly machine and operator 2 at workstation 2 operates the inspection machine. During the assembly processes, the product is carried from first workstation to next workstation manually by hand. Operator assembled a set of components on the plastic case manually, and then fitted them by using the assembly machine. Inspection on the completed part is performed by using the inspection machine.

Both operators performed their tasks according to predetermined cycle time given by the company. The production outputs are monitored on hourly basis by the production line leader. BLM assembly line runs on a one-shift operation for 12 hours a day all year long except for public holidays and major shutdowns. The production runs with 2.5 hour overtime during the weekdays and 12 hours of overtime over the weekend. This is to cover daily backlog that occurred due to incompetence of the line to fulfil daily production target given by the planner.

The production system at this company is practicing conventional MH system with bulk of materials supplied to the line without any standard procedure or system to refer. Materials loading and unloading is carried out by material handlers according to the production order. For large components, wire-meshes are used as storage equipment in the assembly line. The wire-meshes are supplied by using pallet trucks. Large quantity per wire-mesh of around 100 to 250 pieces helped reduce the frequency of loading and unloading processes. The material handler has to walk from kitting area and then hand carries the poly-boxes periodically into the assembly line. While small components such as hook, gasket, and stickers are supplied in large quantity and then stored in one poly-box that is placed close to the line operators so that the operators can load the components into small poly-boxes by themselves whenever they need it. For the quantity of finished goods (FG) poly-boxes, they are supplied according to the size of pallet where there are two pallets permanently located near the line for temporarily storing the FG poly-boxes. The poly-boxes then transferred to the outgoing area by the material handler using a pallet truck repetitively according to the size of the pallet used. Usually, 1 pallet could carry about 20 poly-boxes equivalent to 40 pieces of FG at a time. These conditions caused the assembly area congested with large size of poly-boxes, pallets and wire-meshes which required extra space and additional operators' movements as well.

3.1. Data collection from existing manufacturing data

Data from previous manufacturing performance are summarized in Table 1.0 below.

Table 1.0: Previous Manufacturing Data from PCS and BOM for BLM Assembly Line

Manufacturing data	Target	Actual					
		April 11	May 11	June 11	July 11	August 11	Average
Output per man hour (pieces)	60.0	56.0	55.4	56.0	56.5	57.0	56.18
Target production output (pieces)		12,915	13,220	13,530	13,660	13,530	13,371
Actual production output (pieces)		12,394	12,880	13,121	13,180	13,075	12,230

With the average production output is 56.18 pieces per man hour, this line is not capable fulfilling daily production target of 60 pieces per day that resulted with daily backlog.

3.2. Line Observation (Gemba / Walk the floor)

Standard Work Chart (SWC) is used to illustrate the existing and improved layout as shown in Figure 1.0. The existing assembly line is designed in close U-shaped with operators moving around their own working areas. The production flow is not considered continuous as there are excess in-process stocks in on the WIP table between workstations. There are also large amount of components inventories stored in large storages in the line. This resulted with numerous back and forth movements by the operators. With current size of 22ft^2, the assembly line congested with two wire-meshes, one trolley, two pallets, and lots of components' poly-boxes and also one WIP table as shown in Figure 1a. These conditions increased the amount operators' movements and product's cycle times as well. It was found that, operators frequently stopped the production due to material shortage and NVA activities such as re-arranging wire-meshes and poly-boxes and loading small components. The new improved layout then introduced as in Figure 1b. It is designed with the main targets to reduce the NVA activities, production area and ultimately the product cycle time.

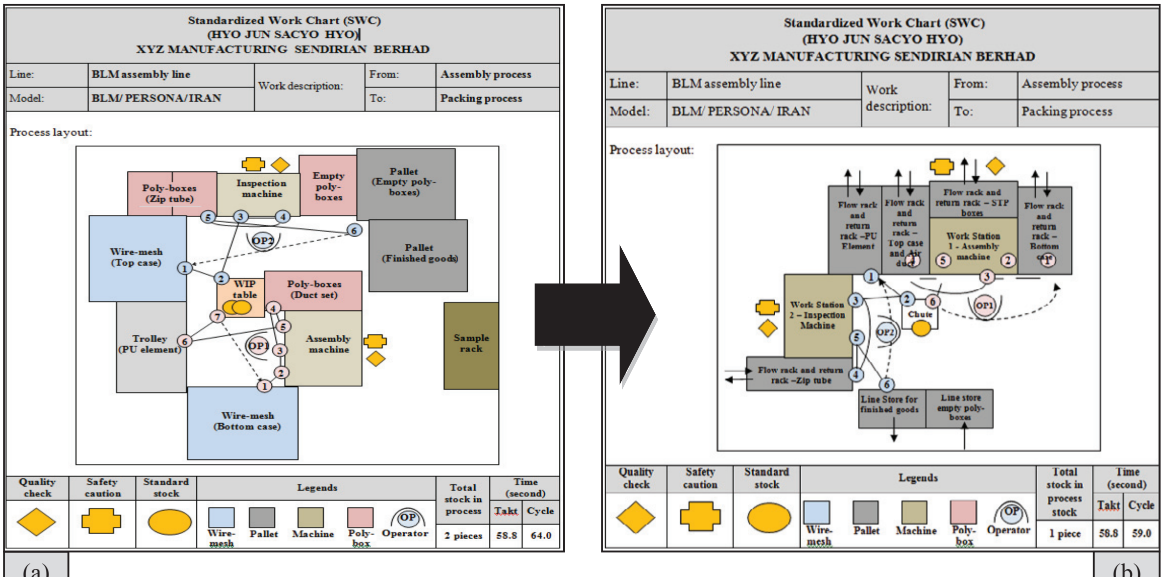

Figure 1.0: Schematic Layout: a) Existing layout, and b) Improved layout

3.3. Work Measurement – Time study

Results from the time study are summarized in Table 2.0. Mode time is used as actual cycle time to run the analysis. This is due to large variant between minimum and maximum time as observed in the assembly line. Therefore, for workstation 1, actual CT is 57.0 seconds. The operator used 12.3% from the CT for walking and 87.7% for hand time. While for workstation 2, actual CT is 55.5 seconds. The walking time covered 8.11% from the total time with 91.89% is for the hand time. Machine times for both workstations did not included in the actual CT due to no idle hand by the operators when operating the machines. Even though the actual CTs observed are lower than the target CT, the actual output times are much higher than the target caused this line failed to fulfil hourly target which is 60 pieces per hour. The main factor is due to high NVA times from the periodical tasks, which are 5.5 and 9.2 seconds at workstation 1 and workstation 2 respectively.

Table 2.0: Summary from Time Study at Existing BLM Assembly Line

Workstation	Total Cycle Time (Seconds)									Periodical Time (Seconds)
	Hand time	Transportation time	Machine time	Mode	Minimum	Maximum	Periodical time	Target line CT	Actual output time	
Workstation 1	50.0	7.0	4.0	57.0	55.5	59.2	5.5	60.0	64.0	5.5
Workstation 2	51.0	4.5	4.0	55.5	53.9	58.8	9.2	60.0	64.0	9.2

From Table 2.0, it reveals that, the actual output CT for BLM assembly line is 64.0 seconds. This CT is far exceeded the target CT of 60 seconds.

4. The Concept of Gravity Flow Rack System (GFR)

Gravity Flow Rack system (GFR) is a storage rack that utilizes metal shelves, which are equipped with rollers or wheels to move items on it by using gravity force. The main function of this system is to transfer the parts and components as close as possible to the operators' point of use, thus it could be reached ergonomically by the operators. The GFR allows only small quantity of parts or components to be replenished at a time; hence it does not require bigger storage area and save space. At the same time, it also ensures the right material with the right quantity and orientation supplied into the line.

Figure 2.0: Operator use Both Hands to Pick-up Parts

Figure 3.0: Gravity Flow Rack System for Small Poly-boxes

There are different sizes of poly-boxes for different sizes of components, thus the GFR was designed according to the following details; i) location size, ii) poly-boxes weight, length, width and height, iii) standard quantity per poly-box, iv) number of poly-boxes used per hour, v) delivery frequency and quantity vi) cycle time for each delivery process, and vii) maximum poly-boxes quantity on the GFR at one time. This is mainly to allow minimum quantity of components to be supplied at the same time and to reduce size of the flow rack. This system is also extended to the line storage area so that the FG poly-boxes could be replenished from off line. With this implementation, the pallet system which was used previously permanently discarded from the assembly line. Figure 4.0 show examples of the GFR system for different types of components and FG poly-boxes in the assembly line.

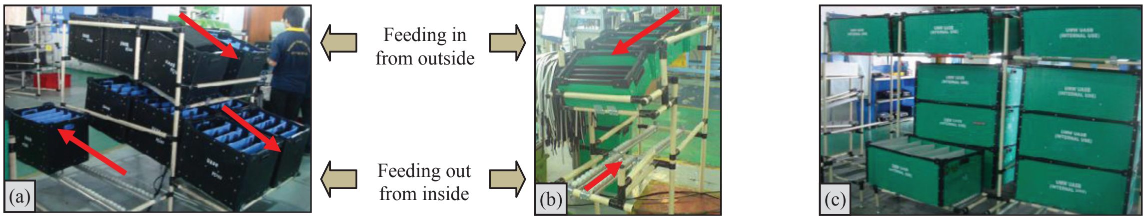

Figure 4.0: GFR System: a) Large Components, b) Medium Components, and c) FG Poly-boxes

To optimize the effectiveness of GFR system, a series of *kaizen* activities were conducted as follows [12]:

i. Simplify and re-arrange the assembly processes:

Current assembly processes were simplified and re-arranged by combining the process elements and movements where possible, as well as rearranging the process sequence and simplifying the processes.

ii. Elimination of NVA activities:

The NVA activity such as loading the components has been replaced by the GFR system. While, transferring of FG poly-boxes onto the line store which were manually done by operator 2 has been improved by a special designed trolley as in Figure 5.0. The trolley is designed according to the size of the FG poly-boxes and at the same height level with the line store. From this, the transferring process could be carried out without the operator having to pick-up and carry the poly-boxes hence prevent work-related back pain and back injury due to repetitive heavy lifting.

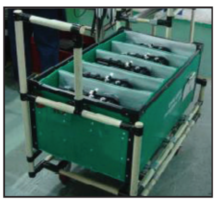

Figure 5.0: FG Trolley used by Operator 2

iii. Line re-layout:

Line re-layout is carried out to introduce the GFR system in the BLM assembly line. It began with the preparation of a layout proposal to the management for their approval. The proposed layout promised 18.18% reduction in the production floor area. Subsequently, re-layout activity is conducted at the assembly area. The assembly area is designed with application of the GFR system, continuous flow manufacturing system and in open U-shape cell to improve line balancing and avoiding miscommunication between operators. As a result, the space utilization of the assembly area is managed to be reduced by 18.18% (22ft^2 to 18ft^2). A chute is introduced to replace the existing WIP table. The chute is designed to allow minimum standard in-process stock at the line, and to allow the assembly process to flow continuously. While, the components will be supplied at fixed delivery time and quantities according to line CT. In-addition, a trolley is introduced as the main mode of delivery for the material handler. The trolley is designed according to the sizes and quantities of poly-boxes to be supplied in one delivery from kitting area to both workstations. It is placed at the on-line store area which allows the material handler to replenish the poly-boxes off-line. Refer to Figure 3b for the schematic layout of improved BLM assembly line.

5. Results and Evaluation

Through time study, new improved CT and periodical times for both workstations are calculated and summarized as in Table 3.0 below.

Table 3.0: Summary of New Improved Cycle Times at BLM Assembly Line

Workstation	Total Cycle Time (Seconds)									Periodical Time (Seconds)
	Hand time	Transportation time	Machine time	Mode	Minimum	Maximum	Periodical time	Target line CT	Actual output time	
Workstation 1	48.5	5.5	4.0	54.0	52.5	55.5	2.0	60.0	57.0	2.0
Workstation 2	49.5	3.5	4.0	53.0	51.0	54.0	3.1	60.0	57.0	3.1

Table 3.0 observed that the actual CT of workstation 1 is now 54.0 seconds with 5.26% reduction. The reductions came from the reduction of handling time by 1.5 seconds and transportation time 1.5 seconds. While the new periodical time for this workstation is 2.0 seconds or equal to 63.64% reduction. This is as a result of the elimination of NVA activities of loading and un-loading components as well as re-positioning the wire-meshes and bulk poly-boxes.

For the workstation 2, there is 4.5% improvement was recorded resulted from the reduction of existing time which is from 55.0 to 53.0 seconds. This achieved from the reduction of handling and transportation times by 1.5 seconds respectively. The machining time is not considered in the total CT because the operator is occupied with other tasks while the machine is running. New periodical time is now 3.1 seconds or equal to 66.3% reduction from the existing time. Main reductions came from the elimination of NVA activities such as loading and unloading components and re-arranging pallets, components' poly-boxes and empty poly-boxes. Table 4.0 shows summary of the results after two months de-bugging process. As revealed, daily productivity increased by 100% from 56.3 to 63.2 pieces per hour or equal to 647 pieces per shift. With daily planning of 615 pieces per shift, the assembly line is now capable to fulfil their daily production demands and at the same time reducing operators overtime. While the shop floor area reduced by 18.18%, which is from 22ft^2 to 18ft^2.

Table 4.0: Manufacturing Data from Improved BLM Assembly Line

Manufacturing data	Average (before improvement, February to June 2011)	After improvement		
		September 2011	October 2011	Average
Output per man hour (pieces)	56.18	62	62.5	62.25
Output per shift (pieces)	576	633	635	634
Attainment (%)	95.97%	100%	100%	100%
Shop floor area	22ft^2	18ft^2		

6. Conclusion and Recommendation

This research proved that the Gravity Flow Rack (GFR) system to improve material handling system for efficient implementation of JIT system in an assembly line at XYZ Manufacturing Sendirian Berhad has the productivity impact. Significant achievements relevant to the semi-automated and flexible assembly area at the BLM assembly line were generated from this research study. Therefore, the following conclusions are essential to conclude the accomplishment of this research study against the objectives set.

i. The material handling activities of the BLM assembly line was successfully improved by introducing the GFR systems. Hence, smooth delivery system for efficient implementation of JIT system can be promised by the production operation. Moreover, it helped to enhance 5S activities, provide systematic and proper materials delivery system and equipment used, and at the same time reduced NVA activities at the assembly line.
ii. Review on the improved process revealed that, productivity per man hour of the line was successfully increased by 9.75% which is from 56.18 to 62.25 pieces per man hour. With this new capacity, this line is now fully capable of fulfilling daily requirement given by the production planner without requiring for any unplanned overtime as practiced before.

To maintain the stability of the improved case study area, some recommendation needs to be considered are:

i. It is highly recommended that the company to adopt common and proven effective handling system known as Milkrun system. This is to further improve the existing material supplying system of the assembly line.
ii. To prepare Standardized Work Combination Chart (SWCT) for this system. The SWCT is used to document the new system and display it near to the assembly line as a main reference for material handlers and operators to perform their tasks.

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