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Effective Material Handling System for JIT Automotive Production Line

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Abstract

Since the past two decades, small, medium and large automotive industries have grown rapidly and globally in Malaysia in line with the increasing of demand from customers. To increase market share and sustain in industry, most of the companies continuously applied world-class manufacturing techniques such as Lean Manufacturing, Toyota Production System, Just-in-Time (JIT), Kanban, Kaizen, Six Sigma and others. In order to achieve world class manufacturing status such as on-time delivery, high quality and high production efficiency, an effective material handling system is necessary to support production processes. Based on observation at a JIT automotive assembly line of a local automotive manufacturer in Shah Alam, it was found that the existing material storage system used was bulk storage called as wire mesh and trolley. Also, the material handling activities were run without referring to any standard or procedure. Therefore, the aims of this case study are to design a new storage system for an automotive component which is Air Cleaner by using computer aided design software, CATIA V5R20 and to evaluate its' effectiveness by using a computer aided manufacturing software, DELMIA Quest. Improvement will be made on the existing material handling system by introducing new standard poly-boxes and a gravity flow rack system for material handling activities. The results obtained from the computer simulation were compared to the existing performance of the line. Inventory level has managed to be reduced by 74% while space utilization reduced by 18.18%.

Keywords: Material handling system; gravity flow rack system; point of use technique; automotive assembly line

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1. Introduction

Gravity Flow Rack system (GFR) is a storage rack with metal shelves, equipped with rollers or wheels to move goods from the one end to another by using the force of gravity. The GFR was designed to be inclined along the length of the rack. This system is introduced in the assembly line as a temporary storage in order to place the components or parts as close as possible to the operators' Point of Use (POU) to make it easy for the operator to pick up parts or components for the assembly processes [1].

In Toyota Production System (TPS), GFR plays an important role in order to support the effectiveness of one of TPS principles which is Just-in-time (JIT) system [1]. Main concerns of JIT are to implement pull system and regulate and control process of manufacturing based on actual market demand by producing the right product, at the right time and in the right quantity [2]. By introducing the GFR system in JIT production line, POU technique can be implemented at the line. This technique helps to smooth the material production flow and reduce the walking distance of the operator so that the cycle time of the process can be reduced. The GFR also enables only small amount of parts or components to be refilled at one time [1], thus reducing lead time and inventory level [3]. By applying the GFR system, it will leads to the economic benefits such as reduced lead-time and higher throughput, smaller floor space requirements and lower work-in-progress [3,4,5,6].

This paper study the impact of GFR system when properly applied in a JIT assembly production line. This study utilized the case-based approach to demonstrate and document the implementation stages that were conducted at the assembly line. The study explores the design and concepts of the GFR system for an automotive component which is Air Cleaner that emphasized on manpower productivity and occupied space in the production area. Computer simulation by using computer aided manufacturing software, Delmia Quest has been conducted in order to verify and improve the design and operational rules of material handling systems before physical installation. This clearly reduces the inherent risks and enormous costs involved in any material handling project [7]. Explanations on the overall activities of the GFR implementation including design stages and layout improvement are included.

2. Methodology

This methodology is based on the PDCA cycle where the phases involved are Plan, Do, Check and Action. This project starts with understanding on the existing storage system through a series of line observation, informal interviews and data collection at the study area. The next stage is to analyze the existing performance by analyzing the data collected. Then, plan for improvement is executed based on the calculation of demand, number of poly-boxes per flow rack, quantity of Air Cleaner per poly-box and frequency of replenishment of the poly-boxes. The standard poly-boxes and the new GFR system for an automotive product which is Air Cleaner in an automotive assembly line were designed by using CATIA software V5R20. While the walking routes for the material handler and proper system for the material handler were designed by using DELMIA Quest. The practicability and the effectiveness of the new system were evaluated by using computer simulation. It covers the productivity, inventory and space of the line. Then, the conclusion was made based on the results and the data collected that has been generated using computer simulation.

3. Designing of a new storage system

The product used for this case study is an Air Cleaner as shown in Fig. 1 which is 325 (L) mm x 142 (B) mm x 47 (H) mm. The weight of the Air Cleaner is about 0.25 kg and is made from PU rubber and non-woven filter paper.

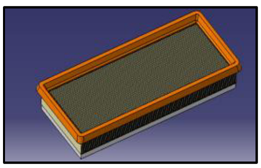

Fig. 1. The air cleaner

3.1. Identify Existing Storage System

From the current practice, the existing material storage system at the line is a bulk storage called as PU trolley and the material handling activities are running without referring to any standard document. This trolley can store up to 154 pieces of Air Cleaner at any one time. The size of the trolley is 1340 mm length, 380 mm width and 1770 mm height. Due to its size, it requires more space in the assembly line. The trolley was translated into CATIA drawing in order to show the geometric view of the trolley as shown in Fig.2.

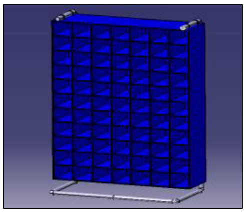

Fig. 2. PU element trolley used in the assembly area

The bulk size of the trolley requires a large space in the assembly area. During replenishment by material handler, short stoppages were frequently occurred as the operator was asked to help the material handler to rearrange the trolley at the line. Since the trolley is bulk in size, the operator required to take the part at a certain position. In this situation, the operator has higher chances to get back pain due to non-ergonomic design of the trolley. Once the inventory runs out, the material handler has to walk further to the store room to replenish the inventory of the trolley. Due to this, the walking distance of the material handler has increased. Minor stoppages and long walking distance are the wastes that must be eliminated in order to adhere to the philosophy of the TPS. These wastes may reduce production output and productivity as well.

3.2. Design New Storage System

Before starting to design the new storage system, it is necessary to set the target of inventory. The target is referring to the line cycle time and the size of the poly-boxes and the GFR system. Table 1 shows the details of the target amount on the standard poly-boxes and the GFR system.

Table 1. Target amount of air cleaner to be placed on the new storage system

Model	BLM
Cycle time	60 sec/pc
Frequency of replenishment of the poly-boxes	Every 30 minutes
Number of Poly-box / flow rack	4
Quantity per poly-box	10
Number of poly-box required per cycle	3

With the line cycle time is 60 seconds per piece; the frequency of replenishment is set for every 30 minutes with maximum 3 poly-boxes will be carried per cycle. One extra poly-box is required on the rack as safety stock in order to avoid shortage at the line as clearance is given to the material handlers for personnel matters such as to go to toilet or drink water. Therefore, maximum number of poly-box on the rack is set to be 4 with a total of 40 pieces of air cleaner at one time.

3.3. Standard Poly-box

Based on the dimensions of the Air Cleaner, the standard poly-boxes have been designed by using CATIA. The size of the poly-boxes is 515 mm length, 399 mm width and 460 mm height with the weight of 1.2 kg. The estimation weight for the overall poly-boxes including the 10 pieces of air cleaner is 3.7 kg. This new poly-boxes have 10 partitions where each of them is for 1 piece of air cleaner. Therefore, each poly-box can store 10 pieces of air cleaner at one time. These poly-boxes are designed to maintain proper part presentation and orientation. Therefore, it can be integrated with a partition to increase protection by preventing contact between parts which can cause damage on the part's surface.

These poly-boxes are made up from polyethylene corrugated plastic material. The advantages of using polyethylene corrugated plastic are it is easy, cheap and cost-effectively customized and can achieve perfect fit for unconventionally shaped components or products. Moreover, it is lighter by 50% than a conventional container made from metal or wood. In addition, this material is fully recyclable and can be found in recycled materials. However, limitations of this material are that it is not durable and not suitable for products that are too heavy. To solve the limitation, it is suggested that the poly-boxes should be injected so as to last longer though the price of poly-boxes from plastic injection may be costly but it is able to withstand a longer period of time.

In addition, these poly-boxes used rivets instead of adhesive for joining process. Rivet has several advantages over other fastening methods. First, the cost of rivets is inexpensive and easy to assemble. Also, it is strong, lightweight and durable. Whereas adhesive is not a preference as a joining mechanism as it is not strong, takes time to harden and weaken over time.

Address system or also known as labelling system is also applied. It is placed on each side of the poly-boxes in order to avoid wrong part to be replenished at the line with information such as product name, model, quantity, product orientation also product positioning. Product orientation and product positioning are crucial in order to ease the operator to take the product and assemble with other parts without having to reorient the part's position.

3.4. Gravity Flow Rack system

Below are the guidelines that have been considered before designing the GFR system [1, 2]:

- Reducing walking distance by placing the parts and components nearest to the point of use of the operators so that they can use both hands at the same time.
- Applying First in First out (FIFO) system.
- Minimizing inventory by designing the rack with only one cycles of delivery can be placed at the same time plus with minimum safety stock based on the standard line cycle time.
- Reducing walking distance of material handlers by locating the kitting area near to the assembly line.
- The rack should be inclined inwards by using the gravity feeding system so that the material handlers can replenish the poly-boxes onto the rack from outside of the line without disturbing the operator.
- The rack also should be inclined outwards by using the gravity feeding system so that the operator can returned the emptied poly-boxes from inside of the assembly area.
- Standardizing the size of the poly-boxes on the rack and ensure it could be easily handled individually by the operator and material handlers without assistance.
- The process of storage will be more ergonomic if the gravity flow rack is designed with a suitable degree of inclination.
- In order to avoid wrong parts being supplied to operators, the address system at the feeding in and feeding out section must be written properly and accurately.

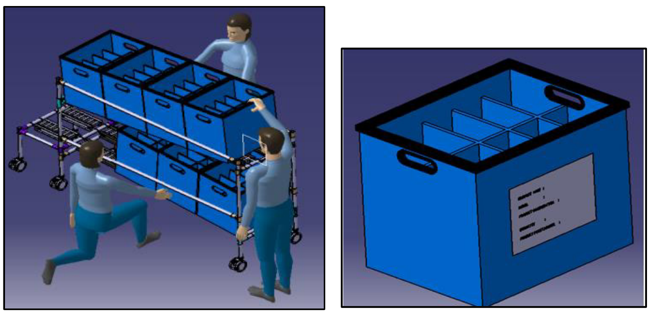

Fig. 3. New standard poly-boxes and Gravity flow rack system

Fig. 3 shows the 3D model of the new standard poly-boxes and the new GFR system that have been designed. In this system, the poly-boxes are flow from one end to another end by gravity force on the rollers. The emptied poly-boxes at the gravity feed out rack will be taken out of the assembly line by the material handler. This system implements First-In First-Out (FIFO) sequence workflow which means the stock rotation is always achieved. This system also leads to ergonomic issue as the inventory is always at the eyes level of the operator. The height for this GFR system designed is based on the standard height of Asian people.

This GFR system is lightweight, low cost and ergonomically designed to move materials and proved to be economical. The main components of the GFR are roller, stopper, wheel and also the inclination of the rack. In designing GFR system, there must be at least three rollers to support the poly-boxes at any particular time for easy rolling or otherwise the poly-boxes will tumble. For this system, the channel frame that has been assembled with the rollers was hooked to the main structure or pipe. The relevancy of doing this is for easier disassembles of the channel frame from the main structure or pipe. A stopper is needed at the end of the gravity feed out in order to stop or guide the poly-boxes from flowing out. Based on the design, the height of the stopper will not be too high in order to ease the operator to take out the empty poly-boxes. In addition, this system also uses wheel with a locking system at the bottom of the GFR so that the GFR can be moved easily if there is a need for re-layout or relocation at the production floor.

3.5. Computer Simulation

In this case study, the computer simulation used is DELMIA Quest. This software has a complete 3D digital factory environment for process flow simulation and analysis, accuracy and profitability. This software can analyze the impact on material handling equipment and labour by integrating the actual production variables. It can also determine the total time spent by operators walking between work stations in the production line. In order to simulate an accurate material movement system, the available templates in this software have been applied.

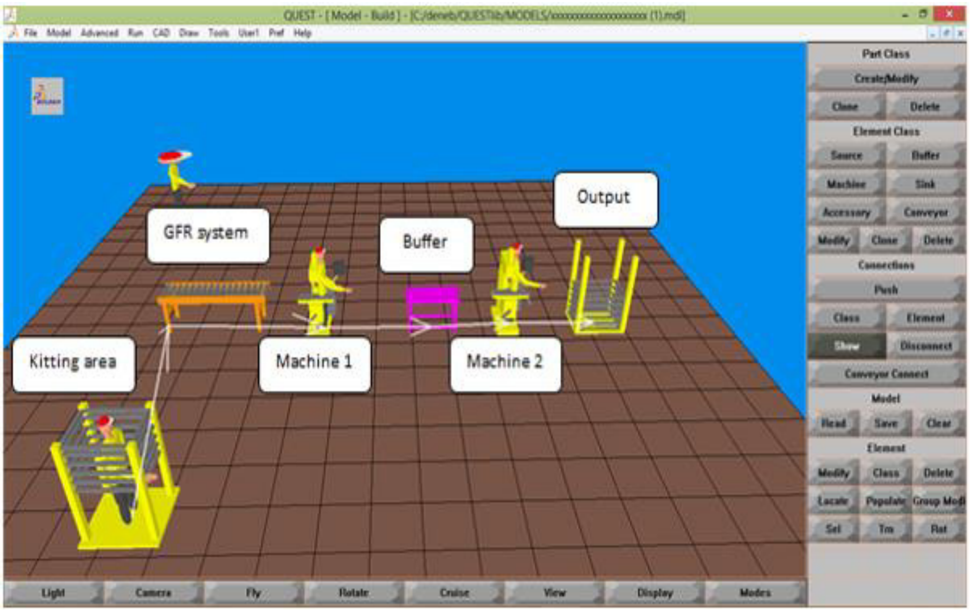

Fig. 4. Model layout for air cleaner

Fig. 4 shows the model layout for the assembly line with the logic connection between elements from start (kitting area) to the output area (output). All the elements were designed based on the cycle process time and the real process sequence. Machine 1 refers to the first process which is assembly process, while machine 2 refers to the second process which is inspection process. After the inspection process, the product will be transferred into a finished good poly-box. Process cycle time to complete one cycle of the process is 60 seconds.

4. Discussion and Results

The case study results have been evaluated based on the performance analysis of the production line through computer simulation. A comparison between before and after implementation of GFR was carried out in order to ensure that the manufacturing performance had improved or otherwise. The results show significant improvement on cycle time as well as the inventory level.

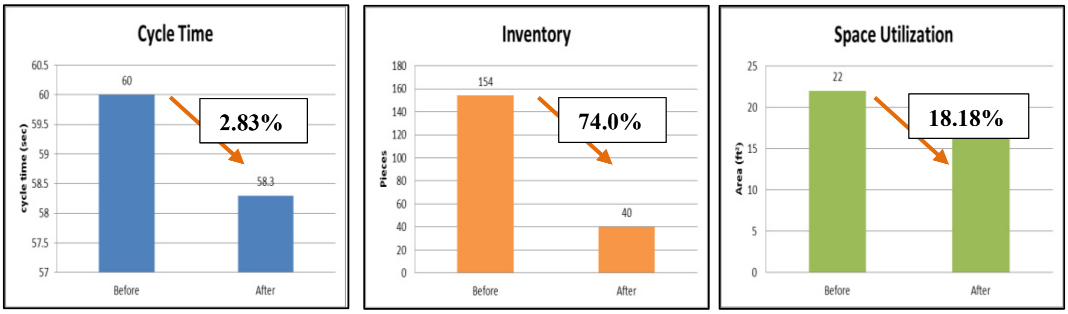

Fig. 5. Percentage of improvement after implementing new GFR system to the production line for cycle time, inventory level and space utilization

Based on the results obtained as shown in Fig. 5, the cycle time at the workplace is targeted to be reduced by 2.83%. This reduction may come from elimination of the minor stoppages at the line after the application of GFR system. Then, for the inventory level, it is targeted to be reduced by 74% through elimination of the trolley. While for the space utilization, it is targeted to be reduced by 18.18% through the application of GFR system in the line. These results proved that by introducing the GFR system, it can definitely improve the material handling system by eliminating the non-value added activities in the assembly line and hence optimize the line productivity.

5. Conclusion and Recommendation

This paper is based on the existing manufacturing operation line of an Air Cleaner. The result shows an improvement in the assembly line in terms of reduction in cycle time, inventory level as well as space utilization. The implementation of the new storage system offered advantages to the production line by eliminating waste of unnecessary motion and also waiting time when replenishing the product. By introducing the GFR system in the production line, the material handling activities can be improved. Good storage system is crucial for effective material handling system in order to achieve on-time delivery and improve efficiency.

Further study is recommended to carry out simulation of the GFR system in order to identify the smooth flow of poly-boxes by adjusting the inclination angle of the rack. In addition, a detail analysis on the material handler in terms of his route or path taken on the assembly line cycle time, tasks and job efficiency can also be analyzed.

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