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Improving Production Line Performance: A case study

Wan Hasrulnizzam Wan Mahmood[1,2,a], Mohd Nizam Ab Rahman[2,b], Baba Md Deros[2,c] and A.G. Jaharah[2,d]

[1]Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[2]Advance Manufacturing Research Group, Faculty of Engineering and Build Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

[a]hasrulnizzam@utem.edu.my, [b]mnizam@vlsi.eng.ukm.my, [c]hjbaba@vlsi.eng.ukm.my, [d]jaharah@vlsi.eng.ukm.my

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Abstract. A case-based research method was chosen with the aim to provide an exemplar of practice and test the proposition that the use of simulation can improve productivity. Three alternatives were performed by considering the aspects of operator, machine, and workstation to define productivity improvement alternatives for operation optimisation. The research determines the optimum result to improve the current operation system. The experiments on simulated and real data clearly indicate that the productivity improvement in the current performance can be achieved by re-allocating the number of operators and machines effectively instead of a combination. The paper presents a novel example of the use of simulation to estimate the production line performance. The paper highlights this method by addressing this operational issue and the likelihood of the success of the strategic decision to improve productivity.

Introduction

At present, the manufacturing industry is growing more technical and complex. Therefore, the margin for error is shrinking. The industry can no longer afford to make educated guesses regarding complicated system design. That is why a reliable and stable technique or tool is required to prevent costly mistakes and changes. One of these approaches is simulation.

A simulation is the replication of the operation of a real-world process or system overtime [1-3]. It is practical for studying how a production system will behave without having to experiment with the system itself [1,4]. By using a simulation approach, a schedule is created by simply simulating the execution of the factory and taking the recorded execution history as the schedule [5]. However, the simulation model in itself does not provide solutions [6]. Many simulation software packages, such as WITNESS, AutoMod, ProModel, Arena, and Quest, therefore contain tools for finding input parameters that give the desired outputs. These software packages can come up with best value for single parameters or optimal combinations of values for a limited number of parameters. Because scheduling problems are computationally difficult, finding an optimal schedule is beyond the abilities of these standard simulation packages.

Simulation is an important area of research, including the clarification of the different types of simulation with respect to their areas of specialty for providing solutions to industry [7-9]. Moreover, Turner and Williams [10] used simulation to develop and implement a production distribution system for the automotive industry. The simulation model assisted in improvement and integration of the supply network and test processes with a focus on customer behaviour, demand seasonality and ageing of stock. On the other hand, to test a new concept or system through simulation before implementation also makes the simulation important for the decision maker. Uncertainty is removed and replaced with certainty about the expected operation of a new system or the effects of changes to an existing system [11-12]. Hence, it provides clear perception and easy decision-making to the management level to decide whether the investment is worth for it or not. In additional, the lower cost to simulate the new system can ensure that a higher cost investment manufacturing process is worth it.

Kumar and Phrommathed [13] also found that the results of a simulation showed that the revised process, sheeting by combining paper of all grades with same size to cut at a sheet cutter, gave a better outcome, in terms of productivity, cost savings and efficiency, than the original process in the sheeting operation at Advance Agro, Thailand. The process improvement can be effectively accomplished with an integrated approach using the proposed computer based tools. In addition, Marvel *et al.,* [14] proved that the simulation application provided a complete planning solution for a tier two automobile supplier in the manufacturing industry. The simulation model was able to validate the sequencing and scheduling of the top 30% of the product line that generated 80% of the business. The simulation also took into consideration the logistical issues with customer supplied materials that were used in the production process. The production planners were also able to use the model to perform "what-if" scenarios to determine where to focus their continuous improvement efforts.

This paper reviews a case study that was conducted to model and simulate a current production system through simulation software, to analyse the current production system, to define a productivity improvement alternative for operation optimisation, and to give awareness of simulation effectiveness for a particular manufacturing firm. The case study was performed at a manufacturing firm located in the Industrial Zone of Bayan Lepas, Pulau Pinang, Malaysia. On the other hand, the global supplier of automotive and industrial technology and of consumer goods and building technology is a worldwide operating group and comprises 270 subsidiary companies, of which more than 230 are located outside Germany. It started mass production of "Made in Malaysia" power tools in 1994. It launched different types of drills, grinders, planers, jigsaws and sanders. Yet, the company has been in Penang for more than 10 years, and it was over 2000 employees. Furthermore, it was a well-known manufacturing firm, and its extensive range of products had a wide domestic and global market. In the factory, one of the production lines for the power tool plan was selected and taken for analysis. Afterwards, the information data such as process flow and cycle time for each workstation in the production line selected were gathered. The production system was simulated by using the simulation software, WITNESS. The performance of the selected assembly line was evaluated through comparison between the simulation results and the actual system. Finally, some alternatives for the production line were proposed.

Results & Discussion

For discussion, the production line of 'PRODUCT X' was chosen. The production line involves a manual assembly process and semi-automated process, and these processes are controlled or handled by the operators. The flow orientations of product start from the first workstation, then go through each workstation and finally finish at the last station. Fig.1 shows the general layout for the 'PRODUCT X' production line. There are two sections in the production line: the pre-assembly process and the main assembly process.

Analysis of simulation model. From the simulation results, there are two main bottleneck areas in the whole production line, which are the workstations for balancing and milling. The buffer quantity at the balancing workstation is the highest: 1312 units. Meanwhile, the buffer at the milling workstation are 1221 units. The remaining workstations ran through smoothly without any buffers. The main reason that the balancing workstation becomes a bottleneck is that its cycle time is longer than that of other workstations. However, the bottleneck of this area does not affect to the production line much because the operation cycle ending before and after the balancing workstation is not much different.

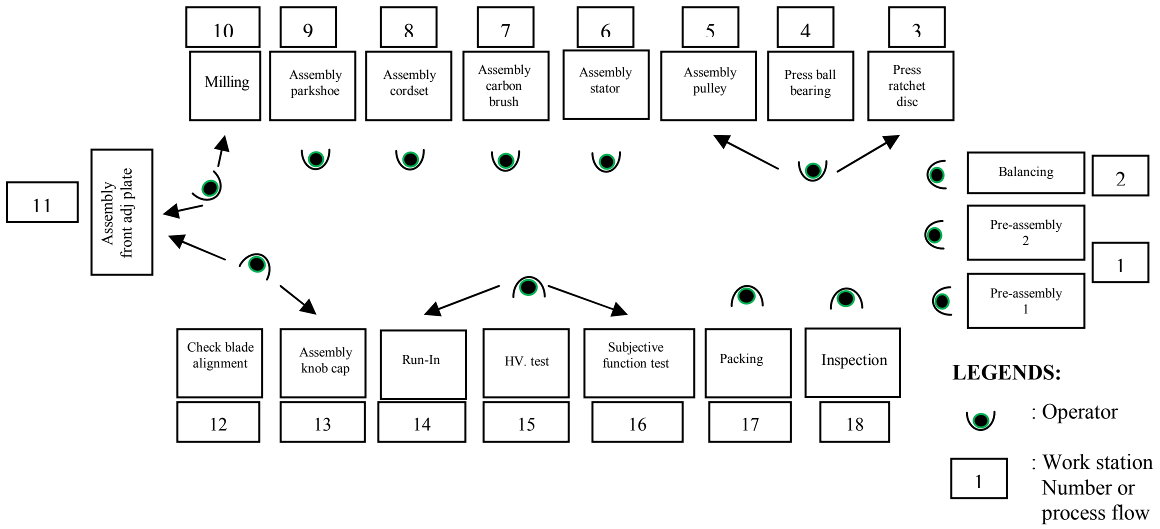

Fig. 1: The layout of ‘PRODUCT X’ production line

On the other hand, the milling workstation’s cycle time is not longer than that of other workstations, but it still is the bottleneck station. This is because the milling workstation needs the operator (opr#9) to set it up at the start of each cycle. At the same time, the operator #9 needs to handle the process in the next station (assembly front adjustable plate). Therefore, the milling workstation wastes some time waiting the operator to set up and causes a bottleneck station indirectly. The percentage of waiting for the operator is 21.38%. Moreover, it was found that the percentage of busy time for some workstations is not above 50%, meaning that the workstation utilities are low. One of the reasons is that these workstation are controlled by one operator at the same time. However, this low percentage of busy time does not affect the production line. There are 9 workstations in the situation mentioned above, such as the workstations for pressing the ratchet disc, pressing the ball bearing, assembly pulley, assembly front adjustable plate, checking the blade alignment, assembly knob cap, run-in, HV test and subjective function testing. The another reason for the workstation having the low percentage of busy time is that the task of operator is not well organised, such as tasks for packing and inspection. These caused the high idle time and production waste.

Model verification and validation. Validation is the determination of whether the simulation model is an accurate and reasonable representation of the actual system under study. The quantitative comparison between the output performances was involved in this phase. Thus, the output of the simulation model and the actual system were compared using the historical records of the company. The simulation results show that the output is higher than the actual output by 0.20%. Therefore, the simulation model is considered validated [6] and reliable for further analysis.

Alternative Solutions For The Production Line

In order to improve the production line, some recommendations or alternatives for the production line were developed. There were a total three alternatives in the following sections, where the alternatives #1 and #2 try to enhance the current production line without adding any operators, machines or workstations. Meanwhile, the company wondered whether adding a milling machine would increase the productivity. Thus, alternative #3 will show the simulation model for this event.

Alternative #1: Reduce quantity of idle machines. Because the percentage idle time of all machines in run-in workstations is quite high, the quantity of machine was reduced in order to increase the utility of each machine. Currently, there are 8 units of machines in the run-in process, where the average percentage of idle time is 64.73%. Therefore, the quantity of machine was reduced one by one in order to maximise the machine utilities. Except for the output of the current situation (2986 units), which using 8 machines, the highest output (2979 units) comes from using 2 machines. The percentage of busy time for 2 machines is 96.36%. Although the operation done (2096 cycles) by 2 run-in machines is lower than that using 3 machines, it does not affect the total output of the production line. In order to maximise the machine utilities and minimise the output reduction, the choice of 2 machines was chosen. Meanwhile, the percentage of idle time for 1 machine is lower than for two. However, with this choice, the buffer increases, and the run-in workstation becomes a new bottleneck area. At the same time, the output of the production line also decreases dramatically as the number of operations that can done by the run-in machine decreases. Thus, two machines were chosen even though the percentage of idle time is a bit higher than that for one machine. Through this recommendation, the output for the production line did not increase, but the production cost was dramatically lowered because the machines were reduced from 8 units to 2 units. However, the percentage of this change in terms of output decreased the original throughput by -0.23%.

Alternative #2: Reorganise tasks for operators and reduce operators. Some operators are quite efficient in the production line because the cycle time of the workstation is shorter than that of the others, which caused the percentage of busy time to be lower. Thus, alternative #2 reorganises the tasks for operators or reduces the number of operators. Firstly, the task of operator 13 was taken over by operator 12. Therefore, the production line decreased the number of operators from 13 to 12. Then, operator 8 was assigned to the milling workstation, too, in order to reduce the time waiting for the operator. After the changes, the output of production line was increase from 2986 units to 3272 units. Furthermore, the percentage of idle time was decreased. In fact, the number of operators was reduced through this recommendation, which also means reducing the production cost directly. It allows a 9.58% increase in the production output.

Alternative #3: Add new workstation at the bottleneck area. The third recommendation is to add a new workstation at the bottleneck station in order to reduce the buffer quantity. There are two bottlenecks in the results of the simulation model, which are the workstations for balancing and milling. If compared with the milling workstation, the balancing workstation, in fact, does not affect the production output. The company wondered whether adding another milling machine into the production line would help. Thus, one more milling machine was added to the simulation model in order to simulate the new production system. As a result, the output was stimulated from 2986 units to 3824 units with an approximate increase of 28.06%. However, the next station after the milling workstation, the assembly front adjustable plate, becomes the new bottleneck area. By using this alternative, the output of the production line increases the most. Nevertheless, at the moment, before adding the new workstation, there are some considerations still that must be addressed before implementing this recommendation, such as the cost of adding the new workstation, the setup cost and machine cost. Is there is enough space in the production line for adding the new workstation? Lastly, by spending all these costs, will it return as profit? Thus, all of these factors must be considered before implementing this alternative.

Conclusion

This simulation was conducted using a real case from a power tool manufacturing firm. The purpose of this paper is threefold. First, the model of the current production system was developed. Second, the results show that the developed model is valid and able to analyse using the simulator-WITNESS. Third, three alternatives were developed in order to enhance the production line, which were to reduce quantity of idle machine, reorganise tasks for operators and reduce operators, and add a new workstation at the bottleneck area. To enhance the current production line productivity, the company can implement alternative #2, where this alternative can increase the production output by 9.58%. Besides, alternative #2 can reduce the production cost because the number of operators is reduced from 13 to 12. On the other hand, alternative #1 reduces the number of run-in machines from 8 units to 2 units. This can be the proposal for ramping up a new production line. Thus, alternative #2 can save costs of machines and save space. Meanwhile, alternative #3 proved to the company that adding a machine can inrease the productivity as much as 28.06%.

On the other hand, the simulation results indirectly convinced the management of the manufacturing firm about the effectiveness of simulation in productivity improvement. Simulation is believed to be one of the useful methodologies by industrial engineers, and it has become a necessary problem solving methodology. Furthermore, insight into the behaviour of an actual manufacturing system can be provided through simulation. The experiments on simulated and real data clearly indicate that the productivity improvement on the current performance can be achieved by re-allocating the number of operators or machines effectively.

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