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Evaluating the Performance of a Multipart Production System Using Discrete Event Simulation (DES)

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Abstract. This paper aims to demonstrate the ability of Discrete Event Simulation (DES) in detecting bottlenecks. A DES model was developed based on the logic and using data collected from a manufacturing plant in the northern region of Malaysia that specializes in producing aircraft composite parts. Attention was given to the operational activities of laminating the multipart of an aircraft composite part. The detection of bottlenecks in this study was based on resource utilization and work in process (WIP). From the study, it was found that the DES is capable of analyzing complex and sophisticated systems over the more conventional analytical approach.

Keywords: Discrete Event Simulation, Manufacturing, Multipart, Aircraft's Composite, Bottleneck.

1. Introduction

Manufacturing industries are one of the leading industries that contribute heavily towards Malaysia's economic growth. These industries are expected to continue to grow and expand in line with Malaysia's development agendas. The aerospace manufacturing industry, although quite young, has been identified as one of the industries that can spearhead and contribute to Malaysia's research and development (R&D) activities. Malaysia's aero-manufacturing industry starts in 1970, an initiative taken by the Malaysia's government in order to transform Malaysia into one of the world's leading aerospace nations by 2015 [1]. To fulfil this aspiration, this manufacturing industry is constantly seeking for technologies that can help to maximize its production and productivity. However, this is not a straight forward task because this manufacturing industry consists of very complicated systems which are very difficult to monitor and study without the help of mathematical and statistical models [2].

At present, analytical methods such as queuing theory, linear programming and differential equation methods are being employed. However, these techniques are only effective for simple system. Because of its lesser flexibility and detail results, the analytical techniques are not suitable for complicated systems especially those found in the aerospace manufacturing industry. A simulation technique is one of possible ways of modelling complex systems. It can help to improve performance in terms of productivity, cycle time improvement, resource utilization and most importantly it can help to identify and detect bottlenecks in production [3].

Simulation has been used to study the behaviour of real systems in order to identify and understand problems associated with the systems. One of the many simulation approaches is known as discrete event simulation (DES). This particular simulation gives picture of each individual event that occurs through a series of processes in a system. DES has been proven to be the most powerful simulation modelling tool that helps and allows decision makers to analyze and evaluate simple to complex processes [2]. It has been successfully applied in many different areas such as manufacturing, healthcare, transportation, military and supply chain [4]. DES found its most application in manufacturing.

This paper discusses the application of the DES to multipart laminating activities in an aircraft composite part manufacturing industry. The main aim is to detect and identify bottlenecks based on resource utilization

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and work in process (WIP). Arena Simulation software version 13.9 was employed to model and analyze the multipart laminating activities.

2. System Descriptions

Figure 1 shows the process flow of the operational activities in the chosen plant. The chosen process for the DES model; i.e., the layup process is highlighted. The layup process consists of six teams that operate simultaneously to produce different types of products. Each layup team has different number of operators. Therefore, the developed model mainly focused on the operations in six layup teams that simultaneously operate to produce different types of products since each team has their own complexity in the operational activities.

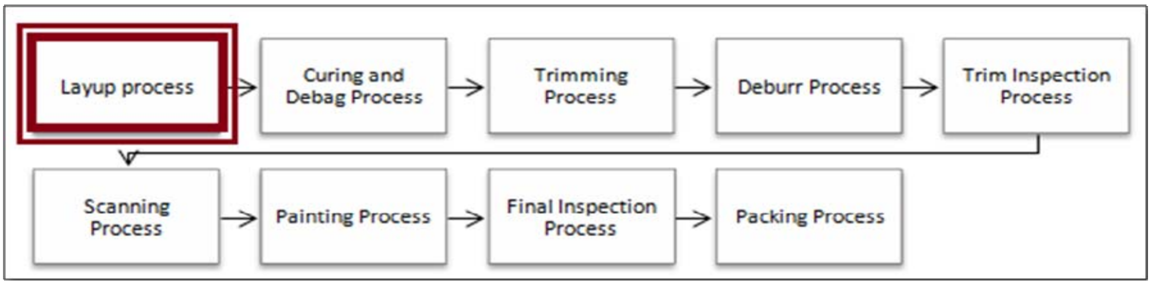

Fig. 1: Highlighted Process and General Production Process Flow

3. DES Model Development

The model was simulated and analyzed to measure the performance of the layup process. The chosen plant has six layup teams; with each team has its own complexities. Thus, multipart of the aircraft's composite were considered in this model with six product programs, namely as product 1, 2, 3, 4, 5 and 6. The process which was done manually consisted of number of steps. The main challenge in developing this model was to determine the arrival of products. The variability of production rates is different from day to day. Due to these, an array concept was used in developing the model logic.

Different attributes, variables and expressions were used in developing the DES model. A batching module was applied since several composite parts were produced using the same mould. Figure 2 shows a part of the DES model logic for the chosen process. Data input was processed by using the Arena Input Analyzer. The analyzer allows the user to process raw data and fit it into a statistical distribution. In the model, the multiparts of aircraft's composite product were the entity that moved throughout the system. The model was developed based on several assumptions which were:

- Each process consists of skilful workers and work in a shift per day
- Simulation run time is one month and 24 hours per day include break time
- Travel time between all processes is assumed to be constant

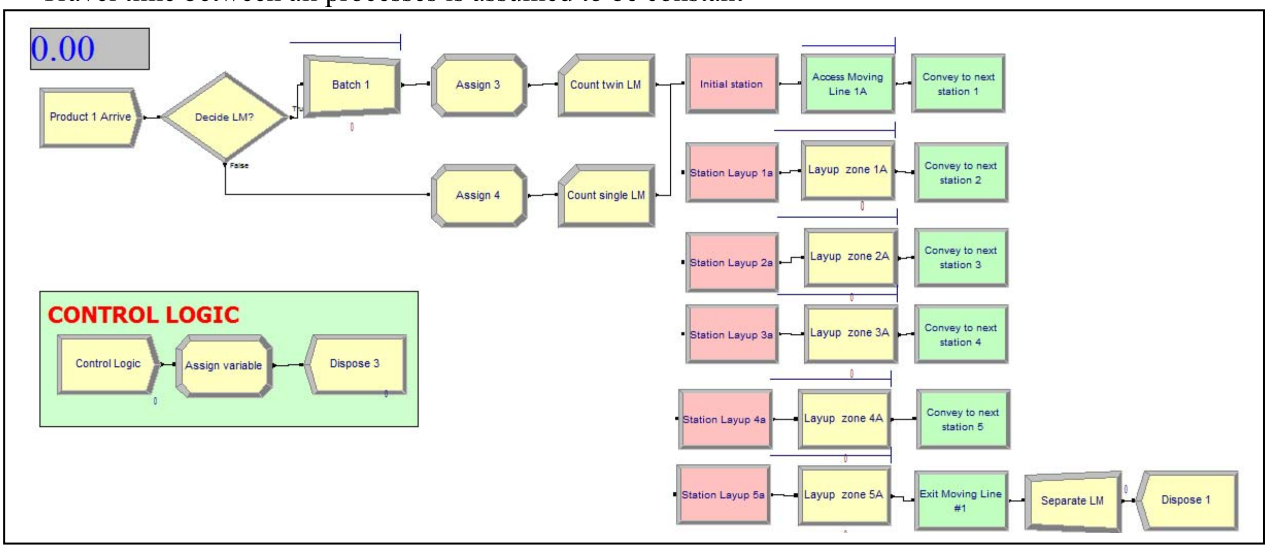

Fig. 2: A Part of DES Model Logic of the Layup Process

4. Model Verification and Validation

Model verification and validation are two important steps in a simulation study. Verification is the task of ensuring the developed model behaves as intended. For verification requirement, the developed DES model was checked with the system's expert to confirm that the model mimic or emulate the actual system. A validation stage on the other hand involves comparing the performance of the developed model (under known condition) with the performance of the actual system. The difference between the two system outputs must be around ±10% or less. For validation requirement, the development model was analyzed five times and its output was computed and compared with the outputs of the actual system [6].

5. Simulation Result and Discussion

The outputs collected from the simulation model were parts throughput, resource utilization and work in process quantity (WIP). In order to obtain the accuracy of the result, [7] recommended running the simulation model at least 5 times and the average of performance of the runs is recorded.

5.1. Parts throughput and WIP

The plant throughput represents the capacity of the plant to produce the product. The value of throughput is useful to the management in forecasting the demand of each product produced at the plant. The average plant throughput of the simulation model is compared to the historical data. As shown in Table 1, the validity levels of the plant throughput are very close to the actual system. Meanwhile, WIP defines a partial product waiting for completion as a finished product. Product 1 and Product 4 shows higher WIP compared to other products.

Table 1: The Values of Accepted Validity Level.

Products	*Historical Data (part)*	*Average Simulation Output (part)*	*Validity Level (%)*	*WIP (part)*
Product 1	206	186	9.7	11
Product 2	89	81	8.9	8
Product 3	44	41	6.8	6
Product 4	842	854	1.4	11
Product 5	167	184	10.1	2
Product 6	1191	1296	8.8	10

5.2. Resource Utilization

Table 2: The Values of Resource Utilization in the Production Plant.

Resource Name	*Resource Utilization (%)*	*Resource Name*	*Resource Utilization (%)*
Operator Product 1-1	89	Operator Product 5-1	86
Operator Product 1-2	86	Operator Product 5-2	90
Operator Product 2-1	79	Operator Product 5-3	90
Operator Product 2-2	72	Operator Product 6-1	29
Operator Product 2-3	89	Operator Product 6-2	36
Operator Product 2-4	92	Operator Product 6-3	29
Operator Product 2-5	98	Operator Product 6-4	29
Operator Product 3-1	83	Operator Product 6-5	36
Operator Product 3-2	90	Operator Product 6-7	43
Operator Product 3-3	86	Operator Product 6-8	29
Operator Product 4-1	71	Operator Product 6-9	35
Operator Product 4-2	91	Operator Product 6-10	36

Resource utilization measures the level of how busy a resource in performing its task in a system. The value of 70% indicates busy resource [8, 9]. The values of resource utilization in the production are presented in Table 2. Operator product 2-4, operator product 2-5, operator product 3-2 and operator product 4-2 has been utilized for more than 90% and this is a typical indicator for the system's bottleneck. The underutilize resource meanwhile were operator product 6-1 to operator product 6-10. The utilization for the operator has been verified with the system's expert and the simulation model's outputs were also agreed by them. This proved that our DES model has replicated the system behaviour correctly.

6. Conclusion

The main objective of this paper is to demonstrate that a DES model can be used to deal with complex multipart aircraft's composite produced in the layup process. From the preliminary analysis it shows that the DES model is capable of analyzing a complex multipart manufacturing system. The DES model developed in this study was aimed to understand and improve the performance of the layup production system. Further works on investigating the causes of underutilization resource need to be done and additional analysis are required before this DES model can be further employed for 'what-if' analysis. The developed DES model can be used as a decision making tool by the plant's management. Investigations on planning and changes can be tested on the model without disrupting the existing operations. This enhances the ability to manage the system, control its capacity, and make better decisions regarding its operation, which in turn improves the ability of the company to deliver quality product to customers.

7. Acknowledgements

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8. References

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