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Integration of Ergo-Manufacturing and Simulation to Minimise Waiting Time for Cracker and Kemplang Production Process Flow (Case Study of PT. Belimo Food Industry)

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Abstract.

Background. Belimo Food Industry factory is engaged in the production of crackers and kemplang with the Belimo brand. Observations made at the packing workstation indicate that there is still a buildup or bottleneck in the press machine that is not optimal, resulting in inefficient performance that violates many ergonomic principles in the manufacturing industry (Ergo-Manufacturing).

Aims. This research explores the integration of Ergo-Manufacturing concepts with simulation. The study aims to improve performance and reduce process lead time.

Methods. The research method employed is quantitative-descriptive, utilizing primary data. Data processing utilizes the integration method of the Ergo-Manufacturing concept with Arena software-based simulation to provide solutions that optimize process waiting time, improve efficiency, work comfort, and production capacity at the packing workstation.

Result. The results of the study, after applying Ergo-Manufacturing with work environment settings, can minimize the waiting time of the initial condition process, with a process time of 58.273 minutes. Under the conditions of improvement scenario 1, the process waiting time of 26,830 minutes can reduce the process time by 60%, under the conditions of improvement scenario 2, the process waiting time of 14,562 minutes can reduce the process waiting time by 80% and under the conditions of improvement scenario 3, the process waiting time of 12,483 minutes can reduce the process time by 85%.

Conclusion. The results of the BEP decision analysis for scenario one were selected by adding one press machine to 2 press machines, which can increase production capacity by 128 products. This also reduces overtime costs incurred by the company by 1.5 hours, amounting to IDR 40,500. The BEP investment in press machines takes 3 years.

Keywords: Bottleneck, ergo-manufacturing, simulation, process time, Arena Software

INTRODUCTION

The synergy of the ergonomics approach in the manufacturing industry (Ergo-Manufacturing) and simulation to minimise production process time can simulate real situations and conditions of inefficient production processes combined with an approach to ergonomic principles can prevent and reduce the potential for occupational injuries and diseases, reduce physical and mental stress, which in turn will have an impact on improving the performance of organisations and management of industrial companies, especially the aspect of productivity in the manufacturing industry (Didik Hadiyatno, 2024; Lamers & Zelik, 2021). Considering the production trajectory in a manufacturing process to achieve the best quality is a key focus for the industry in winning the competition (Huda Nur Qodzbari & Andesta, 2023). Efforts that can be made include improving the performance of the production line system within the company. This can be achieved by increasing production output or enhancing the efficiency of the production line. In a manufacturing company engaged in food production, PT Belimo Food Industry also needs to implement these efforts to survive and compete with other companies.

The production activities of a manufacturing industry must normally align with the designed production process to prevent problems during the continuity of the production process. Queues occur because service needs exceed capacity, resulting in a service backlog. Queuing is a situation where customers wait to receive service while others wait to get service (Iqbal Alfarizi & Andesta, 2023; Situmorang & Matondang, 2020). A queuing system in the production process is a method used to organize the order and production time of various elements or stages in a limited facility manufacturing operation. The purpose of this queuing system is to increase efficiency, reduce waiting time, and maximise resource usage (Yaqin et al., 2022).

PT Belimo Food Industri is one of the companies engaged in food processing. The products produced are raw crackers and kemplang, which are still not fried using tapioca flour as the primary raw material.

Figure 1. Stacking of Packing Station

Figure 1 above illustrates that a buildup occurs at the packing workstation during its operation, resulting in a bottleneck and prolonged process time. The number of incoming orders and the ratio of unbalanced machines cause a buildup of work in the queue. The occurrence of the buildup is due to the machine's capacity, which is limited to only one press machine, resulting in a backlog of products to be packed and lengthening the product process.

As a result of the queues that occur, PT Belimo Food Industry often experiences delays in the production process, which forces the company to increase overtime, extend delivery times, and receive customer complaints about the long wait when picking up goods. Due to the lengthy process time, the company lost three customers, resulting in a loss of opportunity for profit and a decline in trust in the company. Queues are related to constraints. Based on the *Theory of Constraints* (ToC), this continuous improvement activity focuses on identifying and managing constraints within the company to optimize the use of these constrained resources and achieve ToC goals (Lidberg & Ng, 2024; Urban & Rogowska, 2020; Inayati & Wahyuningsih, 2018).

The Ergo-Manufacturing integration approach and Arena Software-based simulation have the advantage of improving workstations and work environments that are not yet ergonomic, as well as the ability of the model to represent the real system quite accurately, allowing bottlenecks to be identified and optimized accordingly. The experimental design is modeled after the real thing and then observed to determine what happens to the production process of PT Belimo Food Industry, aiming to minimize the process time, which will affect the buildup (Rahmawati & Donoriyanto, 2023; Dohale et al., 2021). The purpose of this research is to apply Ergo-Manufacturing by regulating the work environment, minimizing process waiting time, and determining the simulation of balancing model parameters to be used and forming an improvement model as an appropriate proposal scenario to increase output (Dube & Gupta, 2023).

METHODS

The stages of this research are as follows: field studies and literature studies, problem identification, problem formulation, determination of objectives, data collection (work environment data, time data between each production process, data on the number of existing machines, and data on the choice of machine direction), data processing (improving the work environment with the Ergo-Manufacturing approach, determining system boundaries and assumptions, performing distribution fitting, developing conceptual models with Activity

Cycle Diagrams, problem solving with ToC, building system models with Arena software, determining the number of replicas and running simulations and verifying and validating simulation models), formulation and selection of alternatives for improving the physical environment based on Ergo-manufacturing and Arena software, analysis and discussion, and conclusions (Setyaningrum & Sari, 2023; egral Ergo-Value Stream Mapping in a Metal-MechaDomínguez-Alfaro et al. , 2023). This research focuses on the production process of crackers and kemplang; 1 storage warehouse, one inventory, and five workstation sequences according to the work order.

DISCUSSION

The Ergo-Manufacturing approach enhances workplace design, product innovation, and system development to suit users better. Ergo-Manufacturing aims to provide a comprehensive overview of ergonomics practices in manufacturing, highlighting the importance of ergonomics practices in improving worker well-being and increasing operational efficiency (Mohammed et al., 2024; Erwanda, 2023). Ergo-manufacturing focuses on applying ergonomic principles in the design of production systems to minimize the risk of injury and improve work comfort. At the same time, Arena is a simulation software used to analyze and optimize production systems through process modeling and simulation. The application of Ergo-manufacturing at PT Belimo Food Industry, a manufacturer of crackers and kemplang, has increased efficiency and productivity, particularly in terms of production capacity. Ergonomic workplace design through work environment settings; additional light with a transparent roof, and additional air ventilation in the production process area (Aulia Chafifah Wulandari et al., 2023).

Goodness of fit test results for determining the distribution of time data for each process with the help of fit-all in Arena software and distribution fitting results using input analyzer are presented in Figure 3 (Mohammed et al., 2024) (Javadi et al., 2023).

Table 1. Doughing Process Time

Waktu Penggadonan (Menit)									
1	2	3	4	5	6	7	8	9	10
11	13	13	11	12	11	11	13	11	11
12	12	11	12	11	11	13	12	13	11
11	13	12	11	12	13	11	13	11	13
11	11	12	11	13	11	13	11	12	11
12	11	13	13	12	12	11	12	11	13

Table 2. Packing Process Time

Waktu Packing (Detik)									
1	2	3	4	5	6	7	8	9	10
6	5	9	6	9	5	5	6	9	7
7	5	7	5	5	3	4	5	4	6
3	6	3	3	4	4	8	7	5	10
4	5	6	5	7	6	7	6	5	3
4	6	10	8	6	5	4	4	3	5

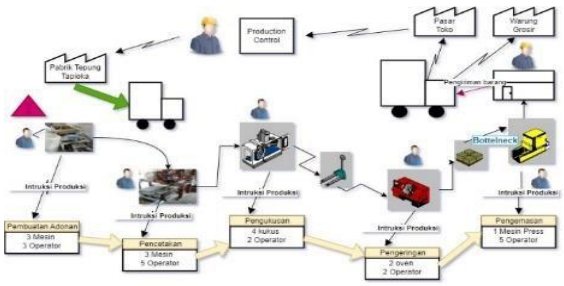

Figure 2. Current State Mapping

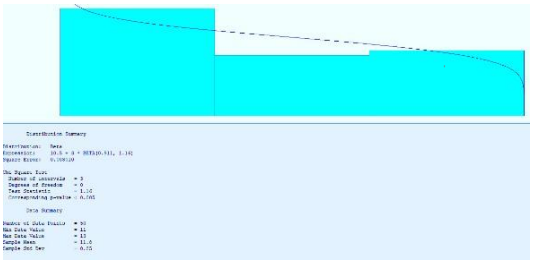

Figure 3. Distribution Fittings

Production Process of PT Belimo Food Industri From the distribution fitting results using the input analyser, it can be seen that the data is uniformly distributed (UNIF(11,13.8)).

The conceptual model of the Activity Cycle Diagram (ACD) and simulation modeling for several processes involved in making crackers and kemplang, including kneading, molding, steaming, drying, and packing, is illustrated in Figures 4 and 5. The following (e.g., Ergo-Value Stream Mapping in a Metal-MechaDomínguez-Alfaro et al., 2023; Ramawisari et al., 2023; Dina Rachmawaty, 2021).

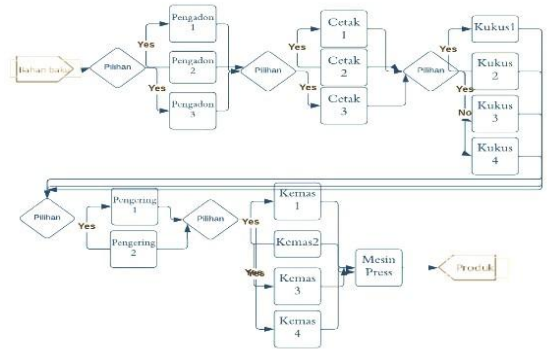

Figure 4. Activity Cycle Diagram Cracker and Kemplang Production Process

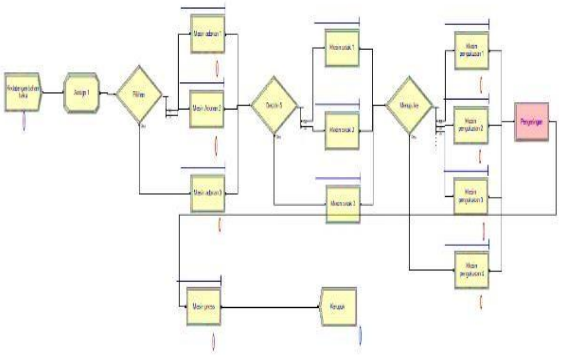

Figure 5. Process Arena Model

Problem-solving with ToC, the identification of constraints is characterized by the presence of overtime hours at the workstation of the cracker and kemplang production system (Kisanjani et al., 2023; Dube & Gupta, 2023). A lack of capacity causes the constraints that occur at the packing workstation, as the machine used is a single-press machine, resulting in product accumulation. 3) Subordination of constraints. At this stage, perform bottleneck workstation optimization by performing several alternative solutions, namely: bottleneck workstation optimization with the first solution adding one press machine, and the second solution adding two press machines + 1 labour, so that the waiting time of the process can decrease. Bottleneck workstation optimisation by increasing the work

shift from 1 shift to 2 shifts, so that production capacity increases (Rohmawati, 2023; Daffa' Muhammad Amjad et al., 2023; Suwandi et al., 2022).

Furthermore, the determination of replication calculates the standard error and percentage as follows: standard error = 2.693 and percentage error = 4.621%. Based on the Arena software simulation running, the number of replications of 5 is sufficient because it does not exceed the *error* limit of 5%. The improvement scenario used in improving performance with the initial condition of a buildup with a process time of 58,273 minutes from the service system consists of 3 improvement scenarios which will be explained as follows: (1) improvement scenario one can be done by adding one press machine with a process waiting time of 26,830 minutes capable of reducing the process time by 60%, (2) improvement scenario two can be done by adding two press machines to 3 by adding more, the process can be adequately accelerated with a process waiting time of 14,562 minutes capable of reducing the process waiting time by 80%, (3) improvement scenario three can be done by combining scenario 2 with scenario 3 adding 1 number of employees in the packaging section because the worker's utility is very busy so that adding 1 can also speed up the process waiting time with a process waiting time of 12,483 minutes capable of reducing the process time by 85%. The results of the BEP decision analysis for scenario 1 were selected by adding one press machine to 2 press machines which could increase production capacity by 128 products and reduce overtime costs incurred by the company for 1.5 hours by IDR 40,500, if the number of products produced in one month is 8000 packs, then according to the calculation of the break-even point of BEP investment in a press machine it takes 3 years to be able to recover investment costs (Fauzi et al., 2024; Ibrahim & Djamaludin, 2022; Nabilasari et al., 2022). The application of Ergo-Manufacturing involves regulating the work environment. The increasing awareness of ergonomics in the manufacturing industry of kerupuk and kemplang producers has led to the emergence of specialized manufacturing practices aimed at improving worker comfort, safety, and productivity (Nizam & Ramlee, 2024; Flor-Unda et al., 2023; Mellasanti Ayuwardani, 2022).

CONCLUSION

Based on the results of the research conducted, the following conclusions are drawn: (1) the simulation model of the production process and the packing process is created using a conceptual model with an ACD diagram. (2) The results of the simulation of the production process of queues that occur are found at the packing process workstation. In the initial

condition, there is a buildup with a waiting time of 58.273 minutes, resulting in 63 products being produced. According to the proposed scenario, the changes to the three improvement scenarios can reduce the waiting time of the most extensive process in Improvement Scenario 3 by 85%, in Improvement Scenario 2 by 80%, and in Scenario 1's waiting time process by 60%. (3) Based on the results of the analysis of the BEP calculation, the right decision is in scenario 1, a change is made by adding one press machine to 2 press machines, which can initially be processed from 58.273 minutes to 26.830 minutes, which can reduce the process waiting time by 60%. With the application of scenario one improvements, there is an increase in production capacity, resulting in 128 additional products, and a reduction in overtime costs incurred by the company of 1.5 hours, amounting to IDR 40,500. BEP investment in press machines takes 3 years to recover investment costs. The application of Ergo-Manufacturing carried out is the regulation of the work environment through the installation of a transparent roof, the addition of lights, and the addition of air vents in the production process room. The increasing awareness of ergonomics in the workplace of the manufacturing industry, particularly among crackers and kemplang producers, has led to the emergence of specialized manufacturing practices aimed at improving worker comfort, safety, and productivity.

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