

Increasing Bead Productivity with Wire Counting Tools Using Design of Experiment (DOE) Methods And Investment Feasibility at PT. RZ

Arief Suwandi^{1*}, Meli Anggita Rani¹

¹Industrial Engineering Department, Faculty of Engineering, Esa Unggul University,
Jalan Arjuna Utara No.9, Kebon Jeruk, Jakarta 11510.

Corresponding Author/E-mail: arief.suwandi@esaunggul.ac.id

Abstract - Bead is a tire component which is formed through a let off bobbin process, used as a stand so that the bobbin can rotate and wire can be used to make beads. The 2021 Bead Forming area KPI did not reach the target. The Bead Forming Machine stops during stock taking because it is still manual. The aims of this research are to analyze the design of a wire counting device using the DOE method and to analyze the feasibility of investment so that the use of wire can be monitored in real time, speeding up stock taking and preventing the machine from stopping. Optimal results with the smallest error value using a roll encoder of around 10 and 20 pulses which produce an error value of 0.0050 (0.5%). The investment feasibility results show that the required investment cost for a wire counter is 81,000,000 IDR. While the loss when the machine stops is 131,221,200 IDR for 1 year. Reducing error values can increase KPI achievements with an initial value of 2.2% dropping to 0.5%, with the help of an automatic stock taking wire counter on the monitor.

Keywords - Bobbin Process, Effectiveness, Investment Feasibility, Stock Taking.

INTRODUCTION

The rapid development of technology requires all business sectors to continue to improve the quality of service and production. Manufacturing is required to develop production equipment so that the quality of the products produced meets the standards and expectations of consumers[1]. The manufacture of tires there are several production processes such as material (bead, chaffer, tread), building (assembly) and curing. Bead is one of the tire constituent materials that is useful for gripping the rim on the tire[2]. The bead making process consists of three stages, namely bead forming, bead finishing and slittering. The bead forming process is the process of coating wire with a compound which has several processes such as let off bobbin, lap wool, wire heater, extruder, cooling drum, accumulator and wind up [2].

The bead forming process starts at the let off bobbin area. Let off bobbins are used for bobbin holders so that bobbins rotate and wire can be used for bead making[3]. At the end of each year, monitoring of

key performance indicators (KPI) is always carried out to see whether the process is running well or if there are any problems. In the Bead Forming area itself, the 2021 KPI did not reach the target because production fell at the end of each month. This happened because the Bead Forming machine stopped completely at 06.00 WIB because stock taking was to be carried out in the Bobbin area (where the wire mat was). The stock taking process itself is still done manually using a vernier caliper and roll meter, measuring the width of the bobbin and the distance between the outside and the wire, then entering it into the application so that the numbers obtained are processed using a formula and producing stock cable numbers in kilograms.

This manual stock taking process makes the bead forming machine have to stop completely so that production decreases. While the process takes 55 minutes, installing a bead forming machine takes 120 minutes. So production stopped for 175 minutes. KPI achievement for the bead forming process can be seen in Figure 1.

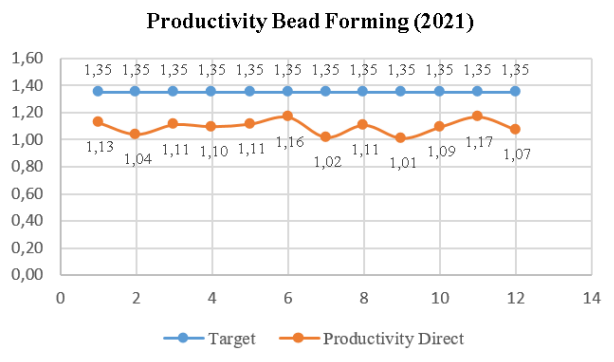


Figure 1. Productivity Bead Forming Data (2021)

From the picture above it can be seen that the achievement of the KPI in 2021 did not reach the target every month, namely with an average direct productivity achievement of 1.09.

In addition, stock taking which is done manually also requires additional time and manpower. Therefore, the design analysis of the wire counting tool is conducted using the Design of Experiment (DOE) method so that the use of wire can be monitored in real time, thus speeding up the inventory counting process and preventing the machine from stopping production. Continuous production with good quality will achieve the company's set targets and improve the company's performance[4].

METHODS

This research was conducted at PT. RZ with the aim of analyzing the design of a wire counting device using the Design Of Experiment (DOE) method and analyzing investment feasibility so that wire usage can be monitored in real time, thus speeding up the stock taking process and preventing the machine from stopping[5]. Experimental Design Methods are widely used in industry to obtain optimal parameters for performance improvement with the aim of

improving manufacturing processes (Figure 2). Data processing using statistics is needed to analyze the occurrence of experimental errors[6]. The basic principles in designing experiments are replication, blocking and randomization.

Data collection and processing begins with observation on the research object, the observations made aim to describe the current conditions in the field[7]. Furthermore, monitoring key performance indicators (KPI) in the bead area which has been recapitulated for the last 1 year, the data is in the form of Productivity Bead Forming Data (2021). The stock taking process is carried out with 7 work activities, namely measuring bobbin width using a roll meter, inputting results to the application, measuring bobbin height using a vernier caliper, inputting results to the application, calculating process, recording remaining weight and moving from line 1 area to line other.

Taking Motion Data and Working Time in The Bobbin Area

Retrieval of motion data and work time on work activities carried out by the operator. In the data collection process, several measuring instruments and supporting tools are needed for the process to be carried out, such as: Stopwatch and minitab applications.

Determining Work Activities and Determining the Level of Effectiveness

After collecting data in the counting wire area, then pay attention to the movements made by the operator to see how effective the movements carried out during the stock taking process and record the things that are analyzed. Based on the data, then begins to determine how high the level of effectiveness of the wire counting tool is by using the design of experiment (DOE)[8]. The level of effectiveness is able to make the wire counting tool in the bobbin area effective.

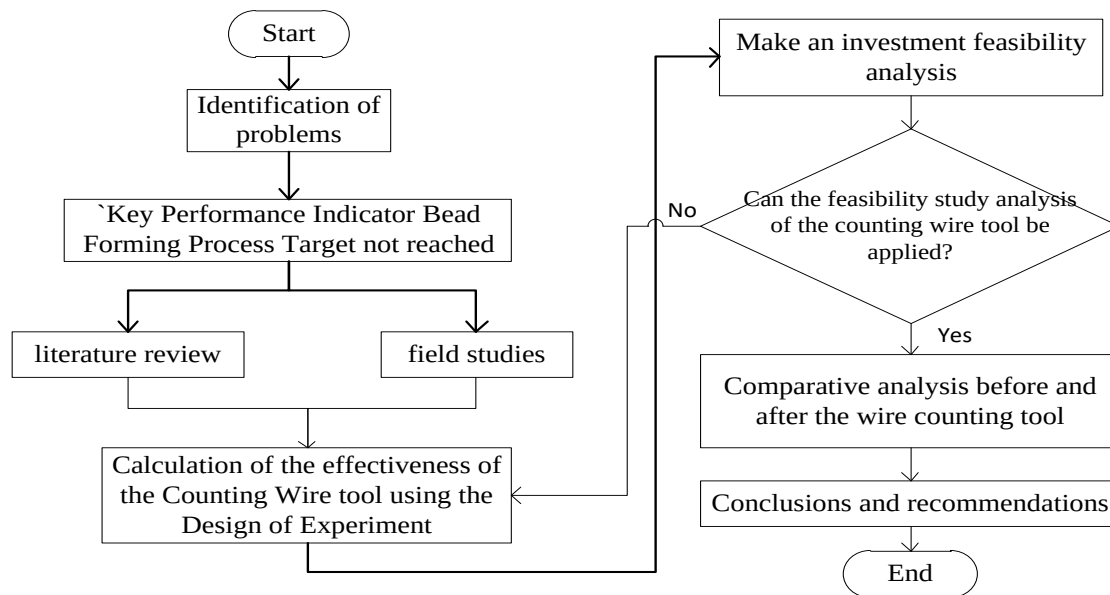


Figure 2. Research Flow Chart

Tool Specifications

The specifications of the wire counting tool used are as follows, (1) The wire counting tool uses a microcontroller, (2) How the wire counting tool works using a rotary encoder sensor, (3) The data generated from the wire counting tool is stored in a database in real-time and can be viewed on a monitor screen, (4) A tool for counting wire used for the Kiswire brand.

Comparing the Level of Effectiveness with Tool Specifications

The level of effectiveness obtained from calculations using the design of experiment (DOE) will then be compared with the investment feasibility analysis[9]. This is done to see whether the tool used is able to increase effectiveness when applied to the Let off bobbin area according to the results of the calculations that have been carried out.

Time Study

Time measurement is an activity in observing and recording the time of the elements or the work cycle of the operator by using a time measuring device such as a stopwatch. Time measurement is done to get to know the time of the work elements, so that it can be known.

Data Adequacy Test (1)

$$N' = \left[\frac{\frac{\beta}{\alpha} \sqrt{N \sum (Xi^2) - \sum (Xi)^2}}{\sum Xi} \right]^2 \quad (1)$$

N = Number of actual observation data

N' = The amount of data theoretically

β = Confidence Level = 95% = 2

α = Accuracy Level = 5% = 0.05

$$\text{Then, } \frac{\beta}{\alpha} = \frac{2}{0,05} = 40$$

Where $N' < N$, then the data is declared insufficient and measurements are carried out again until the data is sufficient.

RESULTS AND DISCUSSION

Data adequacy test

Calculation of the data adequacy test serves to determine whether the data obtained is sufficient or not for research (Table 1).

No.	Data	N	N'	Description
1	Around Roll 10, Pulse 16	30	0,08	Enough
2	Around Roll 20, Pulse 16	30	0,07	Enough
3	Around Roll 25, Pulse 16	30	0,06	Enough
4	Around Roll 10, Pulse 20	30	0,06	Enough
5	Around Roll 20, Pulse 20	30	0,05	Enough
6	Around Roll 25, Pulse 20	30	0,03	Enough

The table shows that the amount of data on each factor has sufficient results so that further analysis can be carried out.

Calculation of the Effectiveness of the Wire Count Tool uses DOE analysis.

DOE calculations using minitab produce the following image.

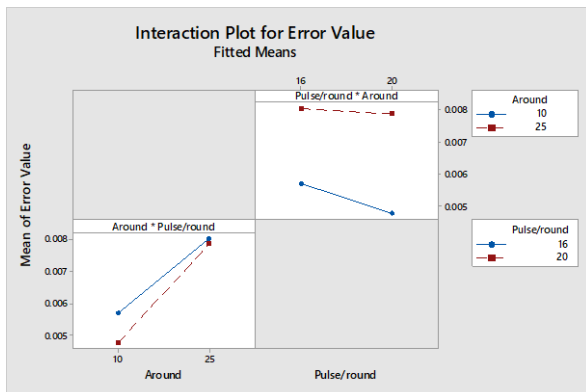


Figure 3. Interaction Plots

Figure 3 shows the interaction between Diameter and pulse which produces an error value. where it can be seen that the highest error results are from Diameter 25 with a pulse value of 16 which has an error value of 0.0084.

Each line appears to represent the diameter values (10, 20, 25) against the error values for pulse variations (16 and 20). The interaction chart shows that there is an interaction between diameter and pulse that affects the error values. The highest error occurs at a diameter of 25 and a pulse of 16, with an error value of 0.0084. Larger diameters, especially at a fixed pulse value, tend to increase the error value. However, for the combination of diameters 10 and 20, the error values are lower, indicating an inconsistency in the effects of pulse at each diameter level. The interaction analysis shows no perfectly parallel lines, indicating that there is an interaction between the factors (diameter and pulse). This indicates that the effect of pulse on error depends on the diameter value, and vice versa. The importance of this interaction factor means that in quality control or processes, diameter and pulse should not be optimized separately, but rather simultaneously.

The implications for process improvement are shown by the combination of process parameters that need to be optimally determined to minimize the error value. Based on the graph, the combination of diameter 10–20 with pulse 20 yields a relatively lower error value, and can be considered as a candidate for a more stable process setting.

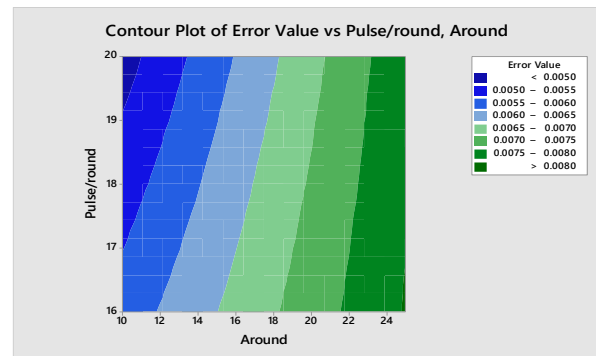


Figure 4. Contours plot

In figure 4, shows the contour plot of the results of this optimization. In the graph, the darker areas indicate higher errors. As a result, figure 4 shows that the highest value of the error is in the right corner in dark green. And for the lowest error value is the upper left corner with light blue to dark blue. In addition, it can be seen that an increase in the number of pulses will result in a decrease in the error. Thus, the contour results were found to be more informative than the interaction plots.

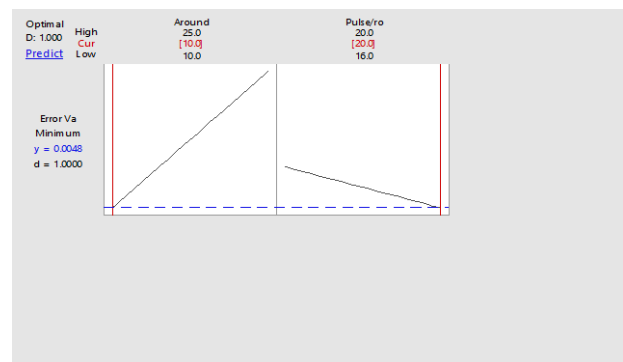


Figure 5. Optimization plot

In figure 5 it can be seen the results of the optimization plot, namely the smallest error value can be obtained using a Roll Encoder Diameter 10, with 20 pulses which produces an error value of 0.0050 (0.5%). This is certainly able to increase the achievement of bead-forming KPIs.

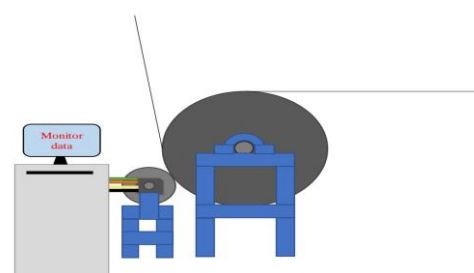


Figure 6. Wire Counting Tool

Wire Counting is a tool used to calculate how much wire has been used during the production process (Figure 6). In addition, the existence of a wire counter can facilitate the stock taking process by viewing the monitor screen automatically without having to stop the production process.

From the results of the ANOVA tests that have been carried out, it can be concluded that circumference and pulse can affect the error value so that in the doe test experiments were carried out at different circumferences, namely circumference 10, 20 and 25 and pulse 16 pulses and 20 pulses. This aims to produce the best variable (smallest error value) which will then be used in the wire counting tool.

Investment Feasibility Analysis

In this investment feasibility analysis, it can be seen that any investment made will have a good impact (give profits to the company) or a negative impact (give losses to the company). This analysis is able to determine what decisions will be taken so that the company continues to grow.

Table 2. Investment Costs

No	Goods Items	Qty	Freq	Price/ Unit/Man	Total Price
1	Inverter	8	1	3,000,000	24,000,000
2	Sensor Rotary	5	1	1,400,000	7,000,000
3	PLC	5	1	10,000,000	50,000,000
Total Cost					81,000,000

It can be seen the costs required to invest in a wire counting tool in the bobbin area which will later change the stock taking process from manual to automatic. In the table, the total cost to be incurred by the company is 81,000,000 IDR. The average bead making is 92 seconds. The following is an analysis when the machine is in a stop condition.

Loss when Machine Stopped (Per Month)

10,500 (second) : 92 (second) = 114 (pcs bead)
 114 (pcs) x 17,430 IDR = 1,987,020 IDR (per line)
 = 9,935,100 IDR (line total)
 200,000 IDR x 5 (man) = 1,000,000 IDR (per month)
 = 10,935,100 IDR

Loss when Machine Stopped (Per Year)

9,935,100 IDR x 12 = 119,221,200 IDR (line total)
 200,000 IDR x 5 x 12 = 12,000,000 IDR (Cost TSO)
 = 131,221,200 IDR
 (TSO = Cost of Team Stock Opname)

The results of the calculation show the cost losses incurred by the company every month and every year. The following analysis is converted into Rupiah units. So we can see that the loss experienced by the company due to the condition of the machine stopping during the stock taking process is 10,935,100 IDR (Per month). Meanwhile, when viewed within 1 year 131,221,200 IDR. Research results can solve problems that occur and obtained significant cost savings for the company.

The limitation of this research is that it does not discuss how to manufacture wire counting aids, and only focuses on kiswire type wire. For further research development using other methods such as FMEA in process improvement.

Recommendations are suggested for implementing this wire counting tool, so that stock taking is more effective and increases company productivity.

CONCLUSION

Based on the results of the research that has been done, it can be concluded that (1) The results of the analysis using the Design of Experiment, it can be seen that the smallest error value can be obtained using the Diameter roll encoder 10, and pulse 20 which produces an error value of 0.0050 (0.5%). (2) The results of the investment feasibility analysis that has been carried out, it can be seen that the investment cost required for the wire counting tool is 81,000,000 IDR. Meanwhile, the loss when the machine stops is 131,221,200 IDR for 1 year. (3) The results of the before and after comparison of the stock taking process in the Bobin area, before the existence of a wire counting tool, the stock taking process was originally carried out manually by the team, and after the wire counting tool was available, it was carried out automatically by looking at the monitor.

ACKNOWLEDGEMENT

We would like to thank PT RZ for its support and cooperation in this research by providing opportunities and guidance in conducting the research, as well as Esa Unggul University for its support.

REFERENCES

- [1] A. Suwandi, T. Y. Zagloel, en A. Hidayatno, "Conceptual model of failure risk control on raw materials inventory system", *IOP Conf. Ser. Mater. Sci. Eng.*, vol 453, no 1, 2018, doi: 10.1088/1757-899X/453/1/012007.
- [2] Y. Li, X. Sun, J. Song, S. Zhang, en S. Han, "Topological structure and experimental investigation of a novel whole tire bead", *Mater. Des.*, vol 203, bl 109592, 2021, doi: 10.1016/j.matdes.2021.109592.
- [3] S. Olbrich en J. Lackinger, "Manufacturing Processes of automotive high-voltage wire harnesses: State of the art, current challenges and fields of action to reach a higher level of automation", *Procedia CIRP*, vol 107, no 2021, bll 653–660, 2022, doi: 10.1016/j.procir.2022.05.041.
- [4] L. Bauer, L. Stütz, P. Beck, W. G. Kleppmann, en M. Kley, "Improved design of experiments method for machine-learning-based modelling of gearbox efficiency in a test rig environment", *Procedia Comput. Sci.*, vol 207, bll 1124–1133, 2022, doi: 10.1016/j.procs.2022.09.168.
- [5] A. Pozzi, X. Xie, D. M. Raimondo, en R. Schenkendorf, "Global sensitivity methods for design of experiments in lithium-ion battery context", *IFAC-PapersOnLine*, vol 53, no 2, bll 7248–7255, 2020, doi: 10.1016/j.ifacol.2020.12.558.
- [6] N. Pandey, A. A. Patwardhan, en S. Rao, "Four decades of new product development research: An integrative review", *Int. J. Prod. Dev.*, vol 23, no 1, bll 1–14, 2019, doi: 10.1504/IJPD.2019.098385.
- [7] A. Suwandi, T. Y. Zagloel, en A. Hidayatno, "Minimization of pipe production defects using the fmea method and dynamic system", *Int. J. Eng. Res. Technol.*, vol 13, no 5, bll 953–961, 2020, doi: 10.37624/ijert/13.5.2020.953-961.
- [8] A. Sannö en M. Ahlskog, "Integrating knowledge for manufacturing technology development", *Int. J. Prod. Dev.*, vol 23, no 1, bll 65–83, 2019, doi: 10.1504/IJPD.2019.098399.
- [9] Y. Guo en Y. Xiang, "Cost–benefit analysis of photovoltaic-storage investment in integrated energy systems", *Energy Reports*, vol 8, bll 66–71, 2022, doi: 10.1016/j.egyr.2022.02.158.