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Statistical Process Control (SPC) and Fuzzy-Failure Mode and Effect Analysis (F-FMEA) Approaches to Reduce Reject Products in Wine Bottle Rack Production Process at PT Alis Jaya Ciptatama

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ABSTRACT

PT Alis Jaya Ciptatama (AJC) is a company engaged in the furniture industry, where the products are exported. One of the products from PT AJC is a wine bottle rack. In the production of wine bottle racks at PT AJC, many product defects were found. Therefore, it is necessary to conduct further research to determine the quality of the product, so that the correct product quality improvement is obtained. The purpose of this study was to determine the limits of statistical control and the factors causing defects in wine bottle racks so that the quality improvement provided was right on target. The methods used in this research are Statistical Process Control (SPC) and Fuzzy Failure Mode and Effect Analysis (F-FMEA). SPC method is used to determine statistical control limits and factors causing product defects. The F-FMEA method is used to determine the priority of improvement in improving the quality of wine bottle racks. The results of the research related to the statistical control limits of the SPC method were obtained that the defective data were outside the statistical control limits. While the results of research related to the causes of product failure using the SPC method are human, machine, material, environmental, method, and measurement factors. Factors causing product failure were analyzed using the F-FMEA method so that improvement priorities were obtained, namely the lack of experience of workers with an FRPN value of 269.33. Improvements that need to be made by PT AJC include providing training to mill 1 worker and splitting the logs.

Keywords: *quality control, SPC, fuzzy FMEA, wine bottle rack*

1. INTRODUCTION

Furniture products are products that are in demand by the wider community, both at home and abroad. The furniture industry is an industry that manages raw materials or semi-finished materials derived from wood, rattan, and other natural materials into a finished product called furniture which has higher added value and benefits (Salim & Munadi, 2017). PT AJC is a manufacturing company engaged in the furniture manufacturing industry. The products produced by PT AJC are export products sent to America. One of the products produced is a wine bottle rack. Based on the results of interviews conducted with the company's quality control staff, PT AJC has a reject rate quality standard of 10% of the total production carried out. PT AJC has a reject rate that exceeds the set target.

The purpose of this study was to determine the limits of statistical control and the factors causing defects in wine bottle racks, so thatthe quality improvement provided was right on target. Based on the background that has been described, this research will conduct quality control using statistical process control and fuzzy FMEA methods. The relationship between the SPC method and fuzzy FMEA is that the SPC method is used to determine whether the reject rejected within the statistical control limits and to determine the cause of the resulting reject in the production process. Meanwhile, the fuzzy FMEA method is used to analyze failures that cause defective products to be produced and provide suggestions for prevention and improvement to improve

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product quality. Some research that raises related topics are as follows:

Table 1. Resume of research related to quality control

Number	Name	Year	Research Object	The Goals
1	Huda	2018	Syrup bottle products	Knowing what factors often cause bottle damage.
2	Rimantho & Hatta	2018	Drinking water treatment production floor	Identify and analyze the risks contained in drinking water treatment.
3	Sucipto dkk	2018	Beef production floor in slaughterhouse	Identify the hazard risks that exist in the abattoir and propose preventive improvements to minimize the hazard risks.
4	Imam dan Pakpahan	2020	Folding cardboard packaging products (KFC snack box products)	Analyzing the failure modes that cause defects, finding the biggest production process failure risk, and providing suggestions for improvements for the next production.
5	Lestari	2020	Wiring harness products	To improve the quality of the products produced, reduce product failures, and reduce losses borne by PT EDS Manufacturing Indonesia (PEMI).
6	Elyas dan Handayani	2020	Furniture products	To find out the number of defectivethe furniture, the most dominant type of defect, the factors causing the defect and proposed improvements to reduce the number of defective furniture products.
7	Sri Susilawati Islam dkk	2020	Production machines at PT PLN Sector Tello Makassar	To identify damage to the machine and determine the priority of repairs on the machine that must be given immediate treatment.
8	Krisnaningsih	2020	Facial tissue products	Identify the types of defects that occur, identify the factors that cause product defects and increase the competitiveness of the tissue company at PT XYZ.
9	Hardiyanti dkk	2021	Leather products	To analyze the quality control of leather products whether it is within the control limits and to identify the factors that cause defects that occur.
10	Ezra	2021	Tempe chips product	Knowing the process capability, analyzing the factors causing the deviation of the tempe sago chip product and providing suggestions for improvement with the aim of controlling product quality.
11	Sari	2021	X roastery coffee products	To find out the description of the ongoing production process, to examine the factors that cause product failure, to know the actions that must be taken to prevent the occurrence of failed products.

The difference between this study and previous research lies in the calculation of the fuzzy FMEA. The use of fuzzy logic in this study is used to weight each failure mode that exists in the production process of mill 1 wine bottle rack products. Calculations using fuzzy logic can minimize the results of the same priority weighting.

2. METHOD

The reject data contained in this study is the reject data obtained in the mill 1 process.

Mill 1 process is the process of forming wooden boards into rough components of wine bottle rack products. This process is the first component formation process, causing many reject components to be generated. The types of rejects produced in the production of wine bottle rack components include knots, cracks, holes, fibers, bends, colors, pith, wrong measurements, and mildew. Therefore, it is necessary to carry out quality control to reduce losses borne by the company and deliver products according to a predetermined schedule. Quality control can be done by using Statistical Process Control (SPC) and Fuzzy Failure Mode and Effect Analysis (F-FMEA) methods. The study was conducted using a sample with a population of 35 employees. The sample is part of the characteristics and quantities possessed by the population use (Sugiyono, 2018).

Data processing is carried out aiming to find answers to the formulation of the problem that has been made. In this study, product defect data will be processed using the SPC method with the use of 6 quality control tools. Furthermore, questionnaires will be distributed to workers and quality experts in mill 1. The distribution of questionnaires is carried out to weight each value of S, O, and D in each failure mode. The results of the questionnaire obtained were then tested for validity and reliability using the minitab application. If the results of the questionnaire are valid, then the FRPN value will be calculated using Fuzzy FMEA. The calculation of Fuzzy FMEA will result in which deviations need priority improvement. The advantages of Fuzzy FMEA include (1) the possibility of using linguistic values, (2) it can be used for qualitative and quantitative data, and (3) it can take into account the experience and knowledge of experts (Khasha et al., 2013). The use of conventional FMEA has several drawbacks, namely the weighting of interests in the preparation of the RPN can produce the same value (Chanamool & Naenna, 2016). The difference between the RPN in Fuzzy FMEA and the conventional FMEA method lies in the value of the three components in Fuzzy FMEA using fuzzy numbers that pay attention to the weight of the respondent along with the weight assessment based on the respondent (Mansur & Ratnasari, 2015). FRPN gains are displayed on a scale of 0.1-10 in nine categories starting from very low to very high (Supriyadi et al., 2017).

The analysis and discussion stage is an analysis of the results of data processing that has been carried out based on the SPC and Fuzzy FMEA methods. The analysis and discussion include check sheet analysis, histogram analysis, control chart analysis, Pareto diagram analysis, scatter diagram analysis, analysis of causes of defects, and proposed improvements. This step aims to get a complete picture of the research and as a basis for drawing conclusions and suggestions.

3. RESULT AND DISCUSSION

Data processing in this study was carried out using the Statistical Process Control (SPC) method to determine whether the defective product was still within the statistical control limits or not and to determine the factors causing the rejection of the wine bottle rack product. Furthermore, data analysis and processing will be carried out using fishbone diagrams and the Fuzzy Failure Mode and Effect Analysis (F-FMEA) method in making suggestions for improvements. The use of fuzzy logic in research will produce more accurate results when compared to traditional FMEA (Keskin & Özkan, 2009).

3.1 Statistiqal Process Control (SPC)

Statistical process control (SPC) is a process carried out to monitor standards, take measurements, and determine appropriate corrective actions when products or services are being produced (Jay et al., 2016). This study uses 6 tools used in the SPC method, including:

a. Check Sheet
   The initial step in controlling the quality of the wine bottle rack product is to collect production data and defect data into a check sheet. The types of rejects include cracks, holes, colors, knots, fibers, fungus, pith, bends, and wrong measurements. The largest type of reject is cracked reject with a total of 600 units with an average reject of 166 units.

b. Histogram
   Normal distributed data means that the data has been perfectly distributed. The following is a histogram of Based on the histogram, it was found that all reject data

were normally distributed. This is indicated by the presence of a bell-shaped line on the histogram crack rejects:

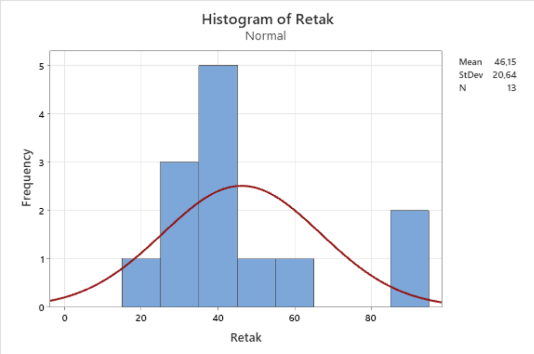

Figure 1. Histogram of crack reject

c. Pareto

The next step is making a Pareto diagram. In the Pareto diagram, reject data will be displayed from the largest to the smallest number of rejects. By using the Pareto diagram, the most dominant type of reject can be identified. Pareto reject diagram can be seen in Figure 2:

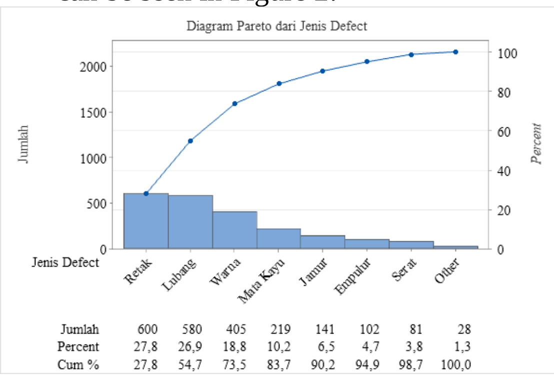

Figure 2. Pareto of crack reject

d. Scatterplot

The scatter diagram in this study is used to determine how strong the relationship between two variables is. The two variables are the number of production variables (x) and the number of reject types (y). The results of calculations using Minitab can be seen in the following figure:

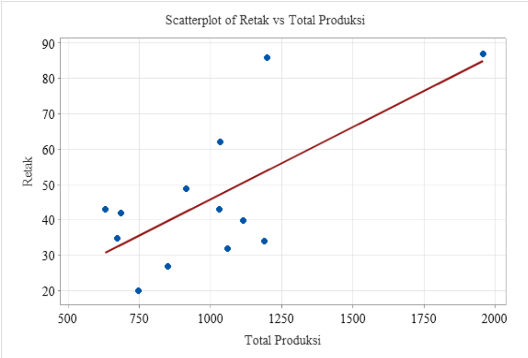

Figure 3. Scatterplot of crack vs total production

This is indicated by the movement from the lower left to the upper right, which means that the higher the number of production, the higher the number of rejects.

e. P-Chart

The next stage is the creation of a map of the vehicle. The control chart used is the p control chart, where the purpose of using the p control chart is to determine the proportion of deviations that occur in reject products. The reject data will be declared still within the control limits if the reject data is still between the Upper Control Limit (UCL) and Lower Control Limit (LCL). The following is the result of the calculation of the P control chart which can be seen in Figure 4:

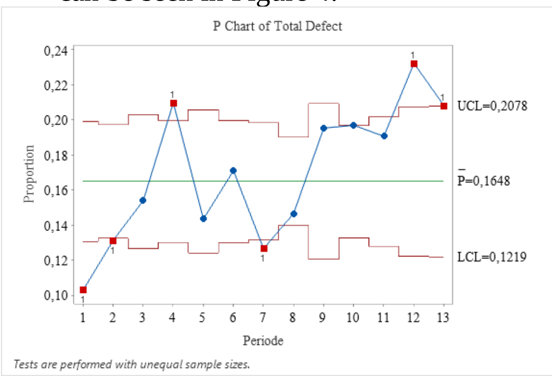

Figure 4. P Chart of total reject

In Figure 4, it is known that there are still data that are outside the control limit, namely 6 periods. Periods that exceed the upper control limit are week 4, week 12, and week 13. While the periods that are outside the lower control limit are the 1st week, 2nd week, and 7th week. With data that is still outside the statistical control limits, it can be concluded that PT Alis

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Jaya Ciptatama has problems in the production process. So it is necessary to do an analysis of quality control in order to find the causes of defective products produced in order to improve product quality.

f. Fishbone

Fishbone diagram is a diagram that is used to analyze what problems exist in a production process and to find out the causes and effects of these problems. In the wine bottle rack production process, there are 9 types of rejects, including cracked rejects, holes, colors, knots, fungus, pith, fibers, bends, and wrong measurements. The following is a fishbone diagram of 9 types of defective wine bottle racks:

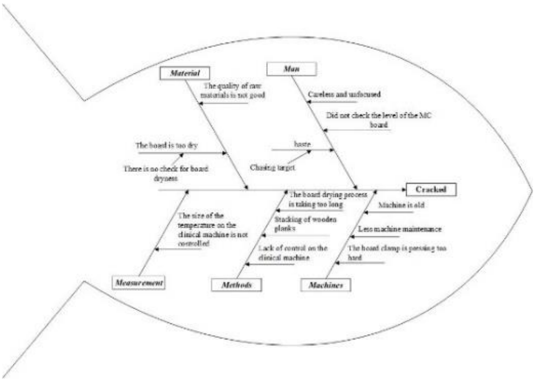

Figure 5. Fishbone diagram of cracked reject

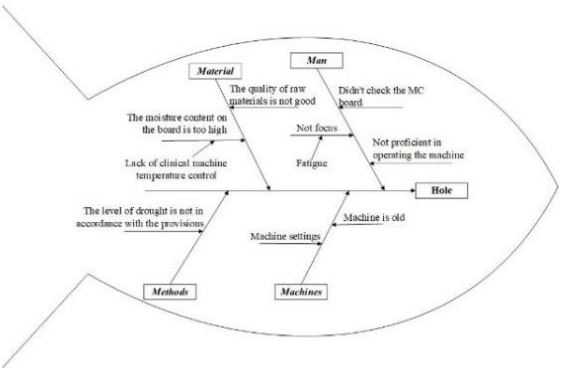

Figure 6. Fishbone diagram of hole reject

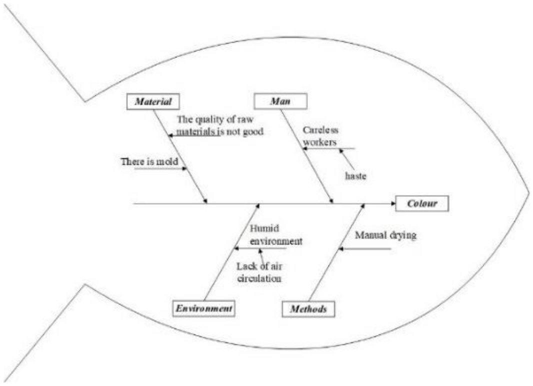

Figure 7. Fishbone diagram of color reject

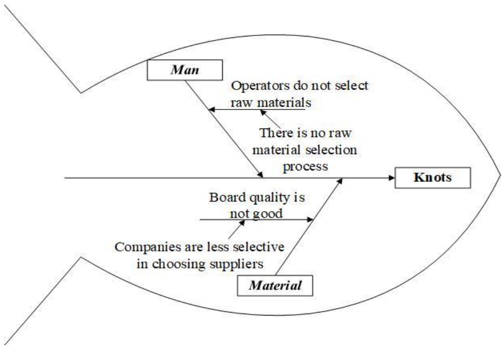

Figure 8. Fishbone diagram of knot reject

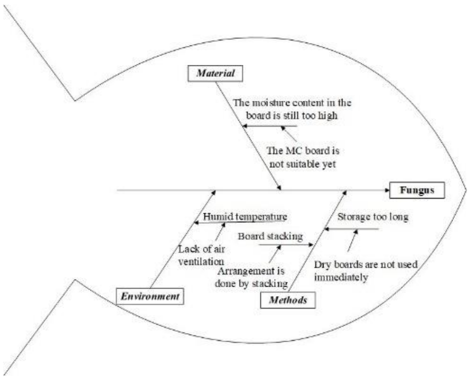

Figure 9. Fishbone diagram of fungus reject

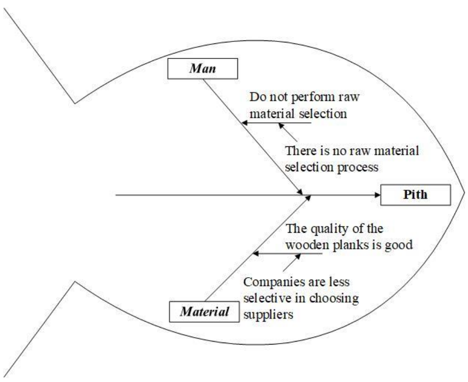

Figure 10. Fishbone diagram of pith reject

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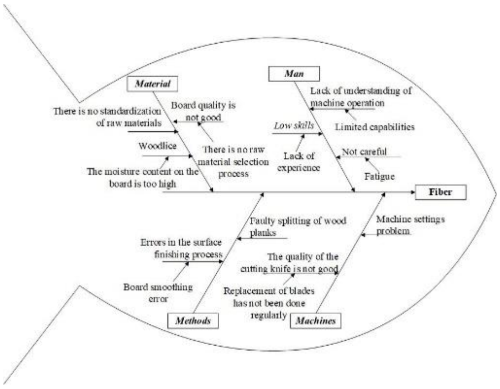

Figure 11. Fishbone diagram of fiber reject

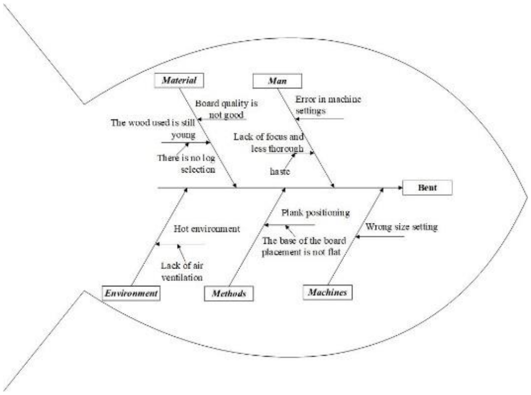

Figure 12. Fishbone diagram of bend reject

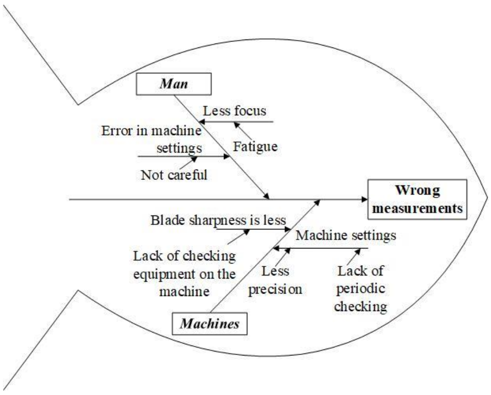

Figure 13. Fishbone diagram of wrong measurement reject

By using fishbone diagram analysis, it ca n be seen the factors causing the reject in the wine bottle rack production process. The following are the factors that cause the rejection of the wine bottle rack production process:

1. Human factor

The cause of rejects in the wine bottle rack production process is that there are mill 1 operators who are less focused on work, resulting in parts of the wine bottle rack being rejected. In addition to this, the lack of accuracy and haste in working due to being chased by targets also has an impact on the occurrence of rejects for wine bottle rack parts.

2. Method Factor

The cause of the reject was due to an error in the arrangement of the wooden boards in the storage section, causing the wooden boards to become moldy and bent. Rejects in mill 1 were also caused by drying the wood planks directly under the sun, thus causing color rejection on the wood planks.

3. Engine Factor

The cause of rejects is due to the setting of the machine clamping the board that is too strong, causing the wooden boards to crack and the old age of the machine causing the machine to experience a decrease in machine reliability in the mill 1 process.

4. Material Factor

The cause of the reject is the quality of the wooden boards that are not good so that many wooden boards have rejects due to the absence of selection of wooden boards.

5. Environmental factor

The cause of rejects is that a humid environment can cause mold to grow on wooden boards, which can cause black spots on the wooden boards. In addition to humid temperatures, a hot environment can also cause wooden planks to shrink, so an environment with the right room temperature is needed.

6. Measurement Factor

The cause of the reject is the uncontrolled temperature measurement on the kiln machine. This is due to the absence of control over the temperature of the kiln machine.

3.2 Fuzzy Failure Mode and Effect Analysis (F-FMEA)

FMEA is an analysis which, if done correctly and at the right time, will yield great results in assisting engineers in the decision-making process during design and development (Leitch, 1995). The FMEA method begins with analyzing the evaluation results in order to identify possible problems that occur based on

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historical data, consumer complaints, and other supporting data (Walser, 2012). Based on the results of the causal factor analysis using a fishbone diagram related to the rejects produced in the wine bottle rack production process, then an analysis of the FRPN calculation is carried out on each causative factor based on the fishbone diagram. The following are the steps taken to obtain the Fuzzy RPN value.

a. Fuzzy Value Input

In the fuzzy input stage, the data used is the value of each severity, occurrence, and detection. Fuzzy logic input can be seen in Table 2.

Table 2. Input fuzzy

Failure Identification	Failure Code	S	O	D
Cracked	P1	8	8	3
	P2	8	8	4
	P3	6	8	4
Hole	P4	6	8	3
	P5	8	8	3
Colour	P6	6	8	3
	P7	8	8	4
Fiber	P8	8	8	4
	P9	6	8	3
	P10	6	8	4
Knot	P11	8	8	4
Bent	P12	7	8	3
Pith	P13	8	8	3
Mold	P14	8	8	3
Wrong size	P15	6	8	4
	P16	6	8	4

b. Fuzzy Number

Based on the fuzzy input data in Table 4.14, the membership of the fuzzy values is inputted for each of the existing S, O, and D values. the following is a fuzzy membership function which can be seen in Table 3.

Table 3. Fuzzy number

Failure Code	*Fuzzy Number*								
	S			O			D		
P1	7	8	9	7	8	9	2	3	4
P2	7	8	9	7	8	9	3	4	5
P3	5	6	7	7	8	9	3	4	5
P4	5	6	7	7	8	9	2	3	4
P5	7	8	9	7	8	9	2	3	4
P6	5	6	7	7	8	9	2	3	4
P7	7	8	9	7	8	9	3	4	5
P8	7	8	9	7	8	9	3	4	5
P9	5	6	7	7	8	9	2	3	4
P10	5	6	7	7	8	9	3	4	5
P11	7	8	9	7	8	9	3	4	5
P12	6	7	8	7	8	9	2	3	4
P13	7	8	9	7	8	9	2	3	4
P14	7	8	9	7	8	9	2	3	4
P15	5	6	7	7	8	9	3	4	5
P16	5	6	7	7	8	9	3	4	5

c. Defuzzyfication

The next step is to calculate S, O, and D to get the FRPN value from each predetermined failure mode. FRPN results are obtained from the multiplication of each fuzzy number from S, O, and The following is an example of FRPN calculation.

Table 4. Examples of FRPN calculations

S			O			D		
7	8	9	7	8	9	2	3	4

FRPN = Severity x Occurence x Detection
Defuzzyfikasi=(Severity+Occurence+Detectio n)/3

d. Analysis of Fuzzy FMEA

Table 5. Analysis of fuzzy FMEA

Identification of Failures	Effects (S)	Causes of Failure (O)	Improvement Plans (D)	FRPN	Ranking
Cracked	Board Condition	The board is too dry	Checking the board before milling 1	204,67	5
	Pressure from the board clamp	The board clamp is too pressing	Adjusting the board clamp so as not to put too much pressure on the board	269,33	1
	Lack of control on the kiln machine	Board dryness does not match the set MC	Schedule regular clinch machine control	204	9
Hole	There is no selection of wood boards before the milling process 1	Many wooden boards with wood lice	Perform the selection process for raw materials before the milling process 1	155,33	14
	The wooden boards are not in accordance with the predetermined MC	Rotten wood boards	Select a good quality wooden board	204,67	5
Colour	The wooden board is too pale	The wooden board is too dry	Re-control the temperature on the clini machine	155,33	14
	There are mushrooms	The wooden board is too wet	Re-control the temperature on the clini machine	269,33	1
Fiber	Inexperienced workers	The surface of the wooden planks is not good	Provide training to workers in the surface smoothing of the board	269,33	1
	The blade is not sharp enough	Defects in the wood grain	Regular replacement of blades	155,33	14
	Wood splitting error	The fiber on the wooden board is not good	Conduct training for employees in the division of logs	204	9
Knot	No selection of wood planks before milling 1	Wood quality is not good	Selecting wood planks	269,33	1
Bent	The boards are made of young wood	The quality of the wooden boards is not good	Select a good quality wooden board	180	13
Pith	There is no selection of wooden boards before the milling process 1	The quality of the wooden boards is not good	Selection of wooden boards of good quality	204,67	5
Mold	There are black spots on the board	The dryness level of the board is less	Carrying out re-control of the temperature on the clinic machine	204,67	5
	Workers do not check the dryness level of the wooden planks	Wooden boards still contain high water content	Checking the wooden MC	204	9
Wrong size	Workers pay less attention to machine settings	Machine settings are less precise	Carry out supervision of operators carried out by SPV mill 1	204	9

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Based on the results of the Fuzzy FMEA analysis that has been carried out, the highest FRPN value is obtained in the failure mode of clamping board pressure, fungus on wood, lack of skills of workers, no selection of wooden boards with an FRPN value of 269.33. For the failure mode that occupies the second position is the condition of the board, the MC of the board is not suitable, there is no wood pith selection with an FRPN value of 204.67. Furthermore, in the third rank there is a failure mode of lack of control on the kiln machine, wrong wood splitting, workers not checking the boards, incorrect machine settings with an FRPN value of 204. In the fourth rank there is a failure mode for boards that come from young wood. with an FRPN value of 180. At the last level there is a woodlice failure mode, wood plank color, and a blade that is less sharp with an FRPN value of 155.33.

4. CONCLUSION

Based on the results of data processing and analysis in this final project, the following conclusions can be drawn:

a. It is known that the production of wine bottle racks has 9 types of defects, namely cracks, holes, color, fibers, bends, knots, fungus, wrong measurements, and pith which are still out of control with 13 periods. The data has a value of UCL = 0.199 and LCL = 0.1306 so that a revision is carried out by eliminating data that are outside the control limits with the results of 7 periods being within the statistical control limits.
b. Factors that cause reject products at PT AJC are poor quality wood, there are boards that are not in accordance with the predetermined MC standards, workers who are less focused, workers who do not check the quality of wooden boards, there are wooden boards that have a surface the wood is not good, the fibers on the wooden planks are not good, the workers do not change blades regularly, the use of young wood, the inexperienced workers, the occurrence of errors in the process of splitting the logs, the pressure fro m the clamping of the boards is too strong, and the lack of control on the clin machine.
c. Based on data processing using the SPC and Fuzzy FMEA methods, it was found that the priority improvement proposals for reject products were obtained, among others by providing training to workers, controlling the temperature on the kiln machine periodically, and selecting wooden boards before entering the mill 1 process.

Based on the research conducted, the advice given to PT Alis Jaya Ciptatama is to conduct training for log splitting operators, to add a wood board QC process and to carry out temperature control on the kiln machine. Then, for research that will be carried out in the future, it can be done by integrating the Fuzzy FMEA method with AHP. The AHP method can be used to consider better decisions in determining proposed improvements to existing problems at PT Alis Jaya Ciptatama.

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