Quality Control Analysis Using the Grey Failure Mode And Effect Analysis Method on a Electric Batik Stove (Case Study: CV. ABC)

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Abstract

If less effective quality control is applied in the company repeatedly, the number of failed products will increase. The company can identify failures based on severity, occurrence, and detection criteria using the Failure Mode and Effect Analysis (FMEA) method. The result of multiplying the three criteria becomes the Risk Priority Number (RPN). However FMEA has a weakness that has attracted many criticisms, namely the potential for the same RPN results but not considering different failure risks. Thus, the FMEA method is integrated with grey theory to become a Grey Failure Mode and Effect Analysis (GFMEA) method that can improve RPN priority determination. Determination of the weight of importance between criteria in the GFMEA method is strengthened by the Fuzzy Analytical Hierarchy Process (FAHP) method so that the level of accuracy in determining the RPN will be better. This study aims to identify failures for each component in CV. ABC, electric batik stove company, and determine the priority of the causes of loss in the production process of electric batik stove products based on analysis using GFMEA method. However, there was no detail on the type of failure. So it was difficult to optimally determine the causal factors, root causes, and risk of loss. The analysis found nineteen failures can potentially cause failure in the company's electric batik stove production process. After that, three potential failures with critical values must be prioritized, including broken bowl heaters, uneven coloring, and slanted body folds with a Grey RPN result of 0,50001; 0,50512; and 0,51156.

Keywords
Quality control, Failure, production process, GRPN, GFMEA

1. Introduction
If less effective quality control is applied repeatedly, the number of failed products will increase. Each company seeks to maintain the quality of its products by implementing quality control to comply with the company's quality standards (Kafetzopoulos et al. 2015). CV. ABC is a company that produces electric batik stoves. Based on the results of observations and interviews with the company, it was found that the problem that occurred was the identification of failures carried out on each component, but it was not known in detail the type of failure so that it was difficult to know optimally for causal factors, root causes, and the risk of failure that occurs. Therefore, it is necessary to analyze the quality control at each stage of the production process.

The Failure Mode and Effect Analysis (FMEA) method can be applied to identify failures based on the criteria for severity, occurrence, and detection (Stamatis 1995). The result of multiplying the three criteria becomes the Risk Priority Number (RPN) (Cicek and Celik 2013). However, according to Chang et al. (2013), FMEA has a weakness that draws a lot of criticism, namely the potential for the same RPN results, but different failure risks are not considered. Thus, the FMEA method is integrated with grey theory so that it becomes a Grey Failure Mode and Effect Analysis (GFMEA) method that can improve RPN priority determination (Li et al. 2018). Determination of the weight of importance between criteria in the GFMEA method is strengthened by the Fuzzy Analytical Hierarchy Process (FAHP) method which has a wider decision-making range than AHP so that the level of accuracy in determining the RPN will be better (Chen 2020).

Thus, the main focus of this research is the failure of the electric batik stove production process in CV. ABC to identify the causes and risks of failure. The expected goal of using the GFMEA method is the suitability of the assessment results with conditions that occur in the company so that recommendations for corrective actions can be given in an effort to overcome the problems that have been determined.

1.1 Objectives

The following are research objectives based on the formulation of the problem:

a. To find out the types of failures that exist in the production process of electric batik stove products.
b. To identify the causes and potential consequences of failure on electric batik stove products based on analysis using the FTA method and cause-and-effect diagrams.
c. To determine the priority causes of failure in the production process of electric batik stove products based on an analysis using the GFMEA method.
d. Propose corrective actions based on the priority of the RPN value on the calculation results using the GFMEA method.

2. Literature Review

2.1 Failure Modes and Effect Analysis (FMEA)

FMEA is a set of procedures to identify and prevent potential failures (Barends et al. 2012). In addition, the application of FMEA can play a role in the systematic assessment of products and processes, proving the occurrence of failures, identifying failures, and documenting possible failures as product or process features that do not conform to quality requirements. standards (Li et al. 2018). An assessment of each type of failure is given to identify failures based on severity, incidence, and detection rate (Stamatis 1995). These three aspects become a priority consideration for the risk of failure in determining the RPN by multiplying it (Cicek and Celik 2013). (Tables 1, 2 & 3)

a. Severity is useful for assessing the impact of failure on the following scale.

Table 1. Scale of severity

Score	Criteria
1	No effect
2,3	Low
4,5,6	Moderate
7,8	High
9,10	Very high

b. Occurrence is defined as a value that expresses the probability of failure and resulting in failure during the production process with the following scale:

Tablel 2. Scale of occurrence

Score	Criteria	Likelihood Level
1	No occurrence	1/10.000
2,3	Low	1/5000 to 1/500
4,5,6	Moderate	1/2000 to 1/200
7,8	High	1/100 to 1/20
9,10	Very high	1/10

c. Detection shows how effective it is at detecting potential failures at the following scale.

Tablel 3. Scale of detection

Score	Criteria
1	Very easy failure detection

2	Fairly easy failure detection
3	Easy failure detection
4,5,6	Difficult failure detection
7,8	Very difficult failure detection
9,10	Failure has the possibility of not being detected

d. RPN is useful for knowing the priority of failure. High RPNs are considered more critical than those with lower values (Guinot et al. 2016).

2.2 Analytical Hierarchy Process (AHP)

The AHP method is a tool in determining the influence of a part on a problem. In determining the effect, a scale comparison is made on individual abilities compared in pairs against the elements (Saaty 1990). This method is useful in making decisions in the form of pairwise comparisons. Here are the AHP steps (Saaty 2008).

a. Problems and goals are defined.
b. Determine criteria for making decisions and selecting alternatives.
c. Create a hierarchy
d. Each criterion is a pairwise comparison matrix for numerical analysis with equation 1 below:
   $aij = W_i/W_j \qquad i, j = 1, 2, 3, \dots, n$ (1)
   n = number of criteria, wi = weight of all i criteria, and aij = ratio of weights of all i and j criteria.

The numerical value given to the decision maker is based on the Saaty scale which is worth 1 to 9 with the provisions in Table 4. below (Saaty 1990):

Table 4. Paired Value Scale

Intensity interest	**Description**	**Explanation**
1	The two parts are equally important	The effect on the goal is the same
3	One part is slightly more important than the other	Ratings don't favor one section over another, but they're not convincing
5	One part is more important than the other	Rating strongly favors one section over another
7	One part is definitely more important than the other	One part is stronger to support and dominate in its application
9	One part is absolutely more important than the other part	One part supports the other and has convincing evidence
2, 4, 6, 8	The value between two adjacent assessments	Discussion is needed in the assessment

Source: Saaty (1990)

a. The column is normalized by dividing each value in the j column and y column for the total value in the i column with the following equation 2:
   $aij = a_{ij}/\sum a_i$ (2)
b. Determine the priority of each condition (w) by dividing each value of a for the specified condition by equation 3 below:
   $w_i = a_i/n$ (3)
c. Calculation of the consistency value with the following steps::
   1) The matrix for pairwise comparisons is multiplied by the weight of each criterion (Aw).
   2) Calculate the eigenvalue (λ max) obtained from the average value of Aw/W with equation 4 below:
   $\lambda max = \sum a/n$ (4)
   3) Calculate the Consistency Index (CI) value to calculate the deviation from the consistency value with equation 5 below:
      $CI = (\lambda\, max - \text{n})/(n-1)$ (5)
      n = the orde of the paired matrices.

4) Consistency Ratio (CR) is calculated by equation 6 below:

$$CR = \frac{CI}{RI} \quad (6)$$

The Ratio Index (RI) value is based on the provisions in Table 5. below (Saaty and Vargas 2001):

Table 5. RI Value Terms

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

Source: Saaty and Vargas (2001)

The pairwise comparison matrix is said to be consistent if it has a CR result of less than 0.1, so that inaccurate expert judgments are still acceptable. If the CR is greater than 0.1 then the assessment is considered inconsistent and a reassessment is required **(**Saaty and Vargas 2001).

2.3 Fuzzy Analytic Hierarchy Process (FAHP)

The FAHP was first introduced to Chang (1992) which contains TFN number and syntetic extent values matrix for pairwise comparisons. FAHP is an approach method of AHP and fuzzy logic. The difference between the FAHP method and the AHP method lies in the scoring between criteria in pairwise comparisons (Kabir and Hasin 2011). In the FAHP method, the conversion process from AHP to TFN is carried out so that its importance can be known. The TFN number is denoted by M. TFN is expressed in a variable consisting of three, namely the variable l which means the lowest value, m means the middle value, and u means the highest value (Hsieh et al. 2004). So, *M = (l, m, u)* which is defined as l m u. The weighting of values in pairwise comparisons becomes TFN numbers with the provisions in Table 6. below (Chang 1992): (Table 6)

Tabel 6. TFN Terms

Paired Comparison Value	**Fuzzy Scale**	**Inverse of Fuzzy Scale**	**Value Description**	**Paired Comparison Value**	**Fuzzy Scale**	**Inverse of Fuzzy Scale**	**Value Description**
1	(1, 1, 1)	(1, 1, 1)	Same priority	6	$(\frac{5}{2}, 3, \frac{7}{2})$	$(\frac{2}{7}, \frac{1}{3}, \frac{2}{5})$	Middle
2	$(\frac{1}{2}, 1, \frac{3}{2})$	$(\frac{2}{3}, 1, 2)$	Middle	7	$(3, \frac{7}{2}, 4)$	$(\frac{1}{4}, \frac{2}{7}, \frac{1}{3})$	Highly prioritized
3	$(1, \frac{3}{2}, 2)$	$(\frac{1}{2}, \frac{2}{3}, 1)$	A little more priority	8	$(\frac{7}{2}, 4, \frac{9}{2})$	$(\frac{2}{9}, \frac{1}{4}, \frac{2}{7})$	Middle
4	$(\frac{3}{2}, 2, \frac{5}{2})$	$(\frac{2}{5}, \frac{1}{2}, \frac{2}{3})$	Middle	9	$(4, \frac{9}{2}, \frac{9}{2})$	$(\frac{2}{9}, \frac{2}{9}, \frac{1}{4})$	Absolute priority
5	$(2, \frac{5}{2}, 3)$	$(\frac{1}{3}, \frac{2}{5}, \frac{1}{2})$	More priority				

Source: Chang (1992)

The provisions for calculating the TFN used are if there are two TFN numbers, namely $M_1 = (l_1, m_1, u1)$ and $M_2 = (l_2, m_2, u_2)$.

The following are the steps in determining the weight of the FAHP method (Chang 1996).

a Determination of the value of fuzzy synthetic extent (Si) with the following equation 7:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (7)$$

with,

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (8)$$

Meanwhile, in determining the value of $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{i}^{j}\right]^{-1}$ all TFN numbers are added up using equation 9 below:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} \sum_{j=1}^{m} l_{ij},\ \sum_{i=1}^{n} \sum_{j=1}^{m} m_{ij},\ \sum_{i=1}^{n} \sum_{j=1}^{m} u_{ij}\right) \quad (9)$$

So, resulting in the following equation 10:

$$a_{ij}^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) = \frac{\mathbf{1}}{\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}} = \frac{\mathbf{1}}{\sum_{i=1}^{n} u_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} l_i} \quad (10)$$

b. Calculation on probability level ($S_i \geq S_k$)
Calculation of the level of probability comparison between two TFN numbers, namely if the acquisition results of each fuzzy matrix $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ with a probability level of M_2 and M_1 then determine the vector value with equation 11 below this:

$$V(M_2 \geq M1) = \sup\left[\min\{\mu_{M1}(x)\}, \min\{\mu_{M2}(y)\}\right] \quad (11)$$

Have conformity with the following 12 equations:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \begin{cases} 1 & , \textit{jika } m_2 \geq m_1 \\ 0 & , \textit{Jika } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & , \textit{lainnya} \end{cases} \quad (12)$$

c. It is calculated which level of probability of a fuzzy convex is better than a fuzzy convex number k so that the results of the Si ≥ Sk value are compared for each criterion and are expressed by the following equation 13:

$$d'(A_i) = \min V(Si \geq Sk) \qquad k = 1,2,\ldots,n;\ k \neq i \quad (13)$$

description:
Ai = decision element; *Si* = fuzzy synthesis value; *Sk* = synthesis value on another fuzzy.
Thus, the local weight vector is obtained by the following equation 14:

$$W' = (d'(A_1), d'(A_2) \ldots d'(A_n))^T \qquad Ai = \{1,2,\ldots,n\} \text{ are elements of n} \quad (14)$$

d. Normalized localized fuzzy weight vector (w)
Normalization of fuzzy numbers is done by geometric mean and ordinary average. Then the weight vector is obtained which becomes a local vector. The calculation of the normalization of vector weights with equation 15 is as follows:

$$W = (d(A_1), d(A_2) \ldots d(A_n))^T \qquad Ai = \{1,2,\ldots,n\} \quad (15)$$

Therefore,

$$DF = \frac{d(A_n)}{\sum_{i=1}^{n} d(A_n)} = \frac{x_l + x_m + x_u}{3} \quad (16)$$

description:
DF = Defuzzyfikasi; $x_l = l$ value; $x_m = m$ value; $x_u = u$ value; w = Localized weights that have been normalized to non-fuzzy numbers; $d(A_n)$ = Local weight of each criterion

2.4. Grey Theory

In 1982, the grey theory was first introduced by Juling deng. To overcome the weakness of FMEA in determining risk priorities, Li et al. (2018) stated that traditional FMEA methods can be integrated with grey theory which is useful in solving uncertain problems with limited information. The results of the integration of these methods into the GFMEA method can improve the prioritization of the RPN with more realistic results. The steps for calculating RPN using gray theory are as follows (Chang et al. 2001).

a. The row comparison calculation is carried out using the matrix rule, namely in equation 17:

$$X_j = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ \vdots \\ X_n \end{bmatrix} \begin{bmatrix} X_1(1) & X_1(2) & X_1(3) & \cdots & X_1(k) \\ X_2(1) & X_2(2) & X_2(3) & \cdots & X_2(k) \\ X_3(1) & X_3(2) & X_3(3) & \cdots & X_3(k) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ X_n(1) & X_n(2) & X_n(3) & \cdots & X_n(k) \end{bmatrix} \quad (17)$$

n = Total of failure and k = Total factor of failure. Three failure factors in FMEA, namely severity, occurrence, and detection.

b. Standard rows are shown with all the minimum potential failures for each factor. In the following equation 18 represents the standard row.

$$X_0 = X_0(1), X_0(2), X_0(3), \ldots X_0(k) \quad (18)$$

X_0 as the minimum value of each factor in all possible failures

c. Calculation of the difference between the standard row and the comparison row by subtracting the value of the comparison row by the standard row. According to Chang et al. (2001), it can be seen in the following equation 19 matrix:

$$D_0 \begin{bmatrix} \Delta_1(1) & \Delta_1(2) & \Delta_1(3) & \cdots & \Delta_1(k) \\ \Delta_2(1) & \Delta_2(2) & \Delta_2(3) & \cdots & \Delta_2\,(k) \\ \Delta_3(1) & \Delta_3(2) & \Delta_3(3) & \cdots & \Delta_2\,(k) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \Delta_n(1) & \Delta_n(2) & \Delta_n(3) & \cdots & \Delta_n\,(k) \end{bmatrix} \quad (19)$$

With, $\Delta_{0j}\ (k) = \|X_0(k) - X_j(k)\|$; X_0 = standard row and Xj = comparison row.

d. Calculates the grey relational coefficient of the decision factor for each failure by comparison on the standard row. Here are the calculation steps:.
   1) Find the largest and smallest values in the difference between the standard row and the comparison row.
      Δ_{max} = The difference with the largest number
      Δ_{min} = Difference with the smallest number
   2) Determine the grey relational coefficient from equation 20 below:
      $$\gamma_{0i}(k) = \frac{\Delta_{min} + \zeta\Delta_{max}}{\Delta_{oj}(k) + \zeta\Delta_{max}} \quad (20)$$
      ζ = Identification that can only affect the relative risk value and be the highest without change, usually 0.5 (Chang *et al*., 2001).

5. Determine the degree of gray relationship that is useful in determining the highest value for each potential failure. The following in equation 21 is a formula that is useful in determining the degree of relationship.
   $$\gamma_{0i}(k) = \frac{1}{n}\sum_{k=1}^{n} \gamma_{0i}(k) \quad (21)$$
   n = Total of decision factors

The risk level is sorted by the degree of relationship or grey RPN (GRPN) to determine the priority of failure based on the smallest GRPN value.

3. Methods

3.1 Research respondents

Respondents in this study were selected based on their knowledge and experience related to the electric batik stove production process, namely the head of the stock production division, operational manager, and stock production division employees.

3.2 Data

In an effort to overcome the problems that have been formulated, the data used include data on the types of failures that may occur in the production process of electric batik stoves which are the results of interviews; second, namely data on the causes of failure and their effects on the production process of electric batik stoves; third, namely data on severity, occurrence, and detection based on potential failure of electric batik stove products; and the last is data to assign importance weight value for each failure factor on severity, occurrence, and detection.

3.3 Flow chart of research method

The following is a flow chart Figure 1 used in this research so that it is carried out in an orderly and structured manner:

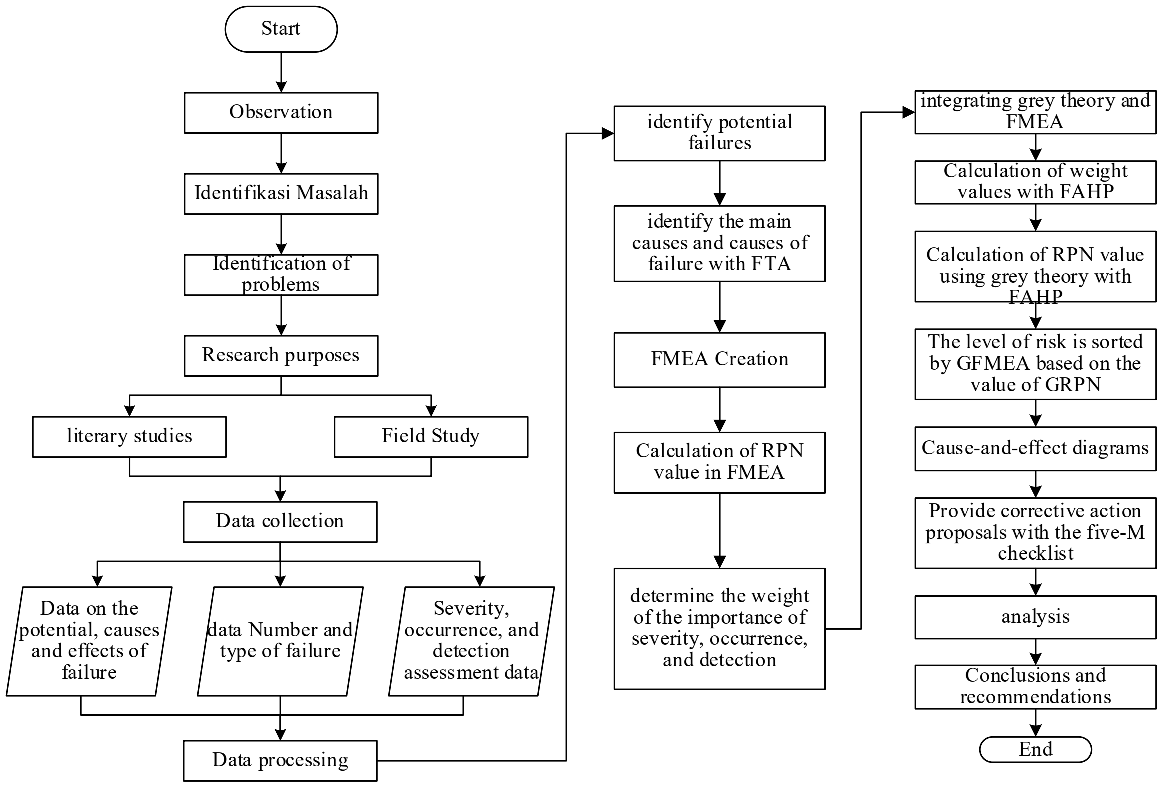

Figure 1. Research Flowchart

4 Data Collection

The data collected in this study are as follows:.

4.3 Failure Type Data

Based on the results of data collection that has been carried out by conducting observations and interviews with the head of the stock production section and employees of the stock production section regarding the production process of making electric batik stoves in the body-making process and assembly process, the types of failures included in product failure are: (Table 7)

Table 7. Failure Type

Process Name	Component Name	Failure Type	Description
Body and cover making	Stove body	Oblique body fold	The crease does not follow the mall line and results in tearing
		Body shape doesn't fit	Folds are not neat so that the diameter of the sides of the body is not the same
		Angled ventilation holes	The position of the hole does not match the mold
		dented body	Tube body shape is not perfect
		Wrong Bor	Borehole position changed
		Wrong lid fold	The diameter of the fold circle is not centered
		Torn sticker	The cut doesn't match the shape of the sticker
		Tilt panel sticker	Installation of sliding panel stickers from panel holes
		Broken plastic handle	The bolt hole on the handle is broken
Coloring	Stove body	Uneven coloring	The result of the coloring is not perfect
Assembly	Dimmer Machine	LED off	The LED light does not indicate the condition of the stove
		turn off	The switch doesn't work when the stove is turned on

Process Name	**Component Name**	**Failure Type**	**Description**
		Potential not working	Unable to show stove heat level
		Power cord not working	The cable cannot conduct electricity to the stove
		PCB chipped	The material attached to the PCB strip is peeling off
		Combustion Resistor	The resistor burns and burns out, can't be used
	Heating element	Electric current leakage	There are components that contain shock, the voltage exceeds the standard

Source: Observation (2021)

4.4 Data of Quality Control
The quality control data used for analysis by type of failure are as follows:. (Table 8)

Table 8. Data of Quality Control

Component Name	**Failure Type**		**Component Name**	**Failure Type**
Stove body	Oblique body fold		Stove body	Uneven coloring
	Body shape doesn't fit		Dimmer Machine	LED off
	Angled ventilation holes			turn off
	dented body			Potential not working
	Wrong Bor			Power cord not working
	Wrong lid fold			PCB chipped
	Torn sticker			Combustion Resistor
	Tilt panel sticker		Heating element	Electric current leakage
	Broken plastic handle			

Source: Observation (2021)

4.5. Respondent's Assessment
Data were obtained from the results of interviews, observations, and filling out questionnaires by research respondents. The data are as follows. (Table 9)

Tabel 9. Respondents' Assessment on the AHP Questionnaire

Criteria (A)	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria (B)**
Severity											√							Occurrence
Severity										√								Detection
Occurrence								√										Detection

5. Results and Discussion
In the FMEA method, to consider the most important failures are used from the largest to the smallest RPN. However, the calculation of RPN with traditional FMEA has a weakness that invites a lot of criticism because it has the potential to produce the same RPN, but different failure factors are not considered. Thus, to increase reliability and accuracy in determining the RPN value, the GFMEA method is used to assist decision making with limited and uncertain information. The advantage of integrating the grey theory and FMEA method with FAHP in determining the RPN is that it can consider the weight of importance of each failure factor. In addition, the results of calculations using the GMEA method produce varying RPN values so as to minimize the occurrence of similarity in RPN values and can be used in determining failure priorities. In its application in companies, the similarity of the results of the RPN results in confusion in placing the priority order of failure and results in a mismatch in representing the potential risk of failure.

5.1 FTA
FTA is used to determine the cause of each failure so that it can be continued with the FMEA method. The following is an example of an analysis with FTA on oblique body fold failure. (Figure 2)

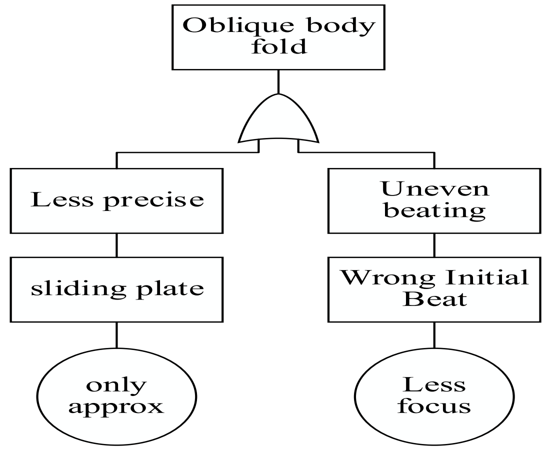

Figure 2. FTA result of Oblique Body Fold failure
Source: Analysis (2022)

5.2 GFMEA

The stage before calculating the RPN value with grey theory begins with determining the weight of importance for each failure using the FAHP method. The weighting is determined based on the respondent's consideration in giving an assessment. The following are the steps in determining the priority of failure.

4.5.1. Do a pairwise comparison with AHP to find out the value of Critical Ratio.

$$CR = \frac{CI}{RI} = \frac{0,0046}{0,58} = 0,0079$$

The result of CR 0,0079<0,1 means that inaccurate expert judgments can still be accepted or considered consistent.

4.5.2. Change the weight value of pairwise comparisons from the AHP scale to TFN numbers in fuzzy logic. Based on the results of determining the weight of the severity, occurrence, and detection criteria using the FAHP method, the weighting of the criteria is carried out as follows: (Table 10)

Table 10. Percentage of Weights Between Criteria

Criteria	Weight	Percentage
Severity	0,2999752	30%
Occurrence	0,3693554	37%
Detection	0,3306694	33%

4.5.3. Determining the priority of RPN values using the grey theory method.

After analyzing the data using the traditional FMEA and GFMEA methods, here are the results of the comparison of the resulting RPN values on the potential failure of the electric batik stove production process: (Table 11)

Table 11. RPN Results Comparison

Priority	FMEA		GFMEA	
	RPN	Potential failure	GRPN	Potential failure
1	**250**	**Broken bowl heater**	**0,500006**	**Broken bowl heater**
2	**240**	**Oblique body fold**	**0,505116**	**Uneven coloring**
3	**240**	**Uneven coloring**	**0,511563**	**Oblique body fold**
4	200	Combustion Resistor	0,531562	Wrong lid fold
5	192	Wrong lid fold	0,535183	Combustion Resistor
6	180	PCB chipped	0,544273	PCB chipped
7	160	Broken plastic handle	0,551497	LED off
8	160	LED off	0,555181	Broken plastic handle

Priority	FMEA		GFMEA	
	RPN	Potential failure	GRPN	Potential failure
9	160	Electric current leakage	0,566675	Electric current leakage
10	144	dented body	0,575765	dented body
11	128	turn off	0,586673	turn off
12	120	Power cord not working	0,595586	Tilt panel sticker
13	120	Tilt panel sticker	0,615922	Power cord not working
14	108	Nickel is broken	0,619854	Torn sticker
15	108	Torn sticker	0,625012	Nickel is broken
16	90	Potential not working	0,64701	Wrong Bor
17	75	Wrong Bor	0,660012	Potential not working
18	54	Angled ventilation holes	0,710007	Angled ventilation holes
19	48	Body shape doesn't fit	0,753881	Body shape doesn't fit

Source: Analysis (2022)

In Table 11. it can be seen the results of the comparison of the RPN and GRPN values for each potential failure of the electric batik stove production process. Sequencing 19 potential failures in the two methods has results that are not much different. This does not affect the use of the GFMEA method in this study because the GFMEA method has the advantage of considering the importance of each failure factor.

5.3 Cause effect Diagram

The use of cause-and-effect diagrams in this study is to analyze the causes of failure based on the influencing factors and to make it easier to propose corrective actions on prioritized potential failures. The following is an example of a cause-and-effect diagram for oblique body fold failure obtained from discussions with companies that have knowledge and experience related to the production process.(Figure 3)

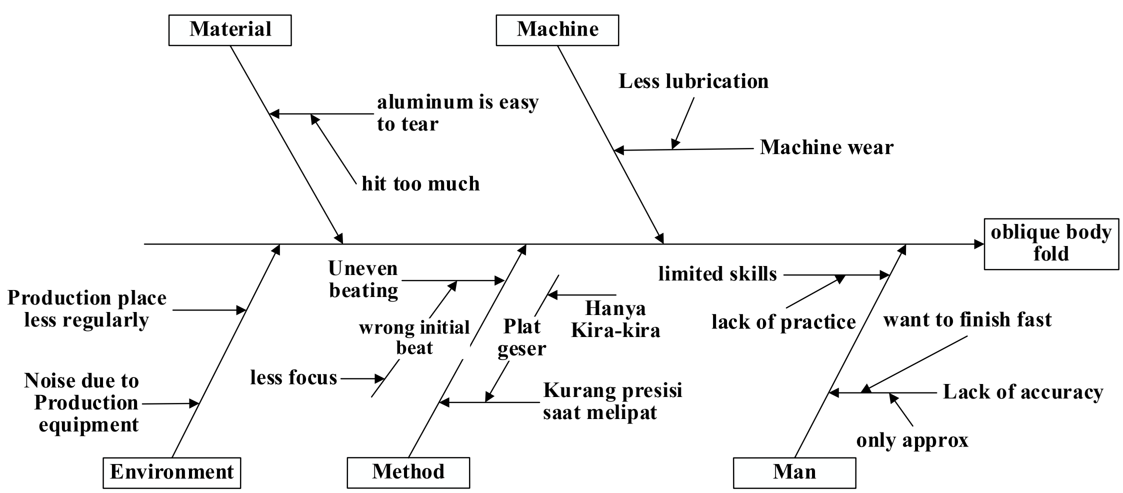

Figure 3. Cause and Effect Diagram of Oblique Body Fold failure
Source: Analysis (2022)

5.4 Suggestion of improvement

The following are suggestions from the results of the research conducted.

1. The results of the identification of the type of failure, the definition of each failure, and the causes of failure can be used as a reference in making company documents so that the quality control process carried out becomes more optimal and failures can be avoided or overcome.
2. Proposed corrective actions are given for priority failures so that failures that occur in the electric batik stove production process can be minimized, including ensuring suppliers provide raw materials according to standards, checking tools before production takes place, and making routine machine maintenance schedules.

3. Proposed corrective actions from researchers are expected to be considered for companies to overcome failures that may occur in the production process of electric batik stoves.

6. Conclusion

In the FMEA method, to consider the most important failures are used from the largest to the smallest RPN. However, the calculation of RPN with traditional FMEA has a weakness that is widely criticized because it has the potential to have the same RPN result, but different failure factors are not considered. Thus, to improve reliability and accuracy in determining the value of the RPN, the GFMEA method is used to assist decision making with limited and uncertain information with assessments in the form of relationship analysis and modeling. Determination of the weight of importance between criteria in the GFMEA method is strengthened by the FAHP method so that the level of accuracy in determining the RPN will be better.

In this study, based on the results of observations and interviews at the company, it was found 19 types of failures that have the potential to cause failure in the production process of electric batik stoves at CV. ABC. After that, there are 3 potential failures with critical values and must be prioritized. The determination is based on the calculation of the value of the GRPN. Priority 3 potential failures, including broken bowl heater, uneven coloring, slanted body folds with a GRPN result of 0.50001; 0.50512; and 0.51156. Proposed corrective actions are given for priority failures so that failures that occur in the electric batik stove production process can be minimized, including ensuring suppliers provide raw materials according to standards, checking tools before production takes place, and making routine machine maintenance schedules.

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