Available online at: http://publikasi.mercubuana.ac.id/index.php/ijiem

IJIEM (Indonesian Journal of Industrial Engineering & Management)

ISSN (Print) : 2614-7327 ISSN (Online) : 2745-9063

Quality Analysis and Improvement of Nut Dragging Defects in FR S/C Side RH Bracket Products within Indonesia's Automotive SMEs

Fredy Sumasto[1*], Yogi Pangestu Saputra[1], Febriza Imansuri[1], Dewi Auditiya Marizka[1], Ahlan Ismono[2], Muhamad Fahrul Rozi[2]

[1]Department of Automotive Industrial Engineering, Politeknik STMI Jakarta, Jakarta Pusat 10510 Indonesia

[2]Department of Automotive Industry Information Systems, Politeknik STMI Jakarta, Jakarta Pusat 10510 Indonesia

ARTICLE INFORMATION

Article history:

Received: 25 October 2023
Revised: 15 March 2024
Accepted: 6 May 2024

Category: Research paper

Keywords:
Automotive SMEs
Fault tree analysis
Impact-effort matrix
Minimum cut set
Quality

DOI: 10.22441/ijiem.v5i3.23857

A B S T R A C T

This study analyses the quality of FR S/C Side RH Bracket products at PT BMI, especially concerning the nut dragging problem, which is often the main defect. This study aims to analyze and improve the nut dragging defect problem in FR S/C Side RH Bracket products, as well as provide an understanding of the effectiveness of the improvement in reducing the number of defective products. The analysis shows that FR S/C Side RH Bracket products with nut dragging problems are the most frequent defects, reaching 632 defective units or about 60% of the total defective products before improvement. The Failure Tree Analysis (FTA) method was used to identify the root cause of the nut dragging problem, which revealed that machine factors were generally the main cause, especially setting the spot welding machine parameters too high. In response, improvements were made by changing the parameters on the SW.03 spot welding machine and adding a cooling water line. The results showed a significant decrease in defective products, totaling 1320 units. After the improvement, only 141 units were defective. This research provides an in-depth understanding of product quality issues at PT BMI. It offers solutions to improve product quality and meet customer expectations in the highly competitive automotive industry.

***Corresponding Author**

Fredy Sumasto
E-mail: f-sumasto@kemenperin.go.id

1. INTRODUCTION

As one of the critical sectors in global manufacturing, the automotive industry has experienced rapid development in recent decades (Imansuri et al., 2023; McKinsey&Company, 2016; F Sumasto et al., 2020; Tan & Li, 2021). Technological improvements, intensifying competition, and ever-increasing customer expectations have driven automotive manufacturers to prioritize the quality of their products. High quality is critical to winning customer trust, maintaining brand reputation, and meeting stringent standards imposed by industry regulatory bodies (Nabiilah et al., 2018; Razak & Nirwanto, 2016; Fredy Sumasto et al., 2023). As an integral part of the global automotive industry, PT BMI shares the same commitment to manufacturing quality. Not only does the company play a role in producing critical automotive components, but it is also an essential partner for many well-known automotive brands. In this context, product quality is not just a goal but the foundation of their business success. Well-maintained product quality is essential in the relationship between automotive component manufacturers and their customers (Razak & Nirwanto, 2016; Tama et al., 2015). Customer claims are an essential indicator that can provide deep insight into the extent to which product quality is applied in practice. As a leading manufacturer of automotive components, PT BMI is not immune to challenges arising from customer claims.

This research will explore a product quality issue arising from a customer claim, specifically filed by their primary customer, PT TBINA. This claim relates to the company's FR S/C Side RH Bracket product, which has been under the spotlight. The results of 34 customer claims indicated a problem that must be addressed immediately. This research not only identifies the problems faced by PT BMI regarding the quality of its products but also explores the root causes. Our primary focus is on the 382 pcs of Nut Seret defect, which explains most claims. Outline the methodology used to analyse the FR S/C Side RH Bracket's product quality, including using tools such as Fishbone Diagram, Fault Tree Analysis, Minimum Cut Set, and Impact-Effort Matrix. The results of this analysis will provide an in-depth understanding of the nut-dragging problem and help us formulate appropriate improvement recommendations.

In addition to highlighting the importance of product quality in the automotive industry and the particular challenges faced by PT BMI, it is important to articulate the motivation behind this research and its potential contribution. This research is motivated by the urgent need for continuous production quality improvement to uphold PT BMI's reputation and meet the growing demands of the automotive market. By addressing the identified product quality issues and investigating their root causes, this research aims to fill the existing gap in the literature regarding the application of quality improvement methodologies in the context of automotive component manufacturing. In addition, the findings from this research are expected to provide valuable insights for industry practitioners, academics, and policymakers to contribute to the overall improvement of manufacturing quality standards and enhance PT BMI's competitiveness in the dynamic automotive sector.

2. LITERATURE REVIEW

Quality control is essential in the manufacturing industry to increase productivity and reduce product defects (Fredy Sumasto, Arliananda, Imansuri, Aisyah, & Purwojatmiko, 2023; Fredy Sumasto, Nugroho, Purwojatmiko, Wirandi, Imansuri, et al., 2023). One method that has been widely used is Failure Mode and Effect Analysis (FMEA), which is used to identify the causes of defects and recommend prevention methods. In the context of the paper industry in Indonesia (Nurwulan & Veronica, 2020; Fredy Sumasto et al., 2024; Fredy Sumasto, Christiani, Wulansari, Rozi, Dzulfikar, et al., 2023) explored the application of FMEA to identify the root causes of paper product defects. They calculated the Risk Priority Number (RPN) to assess the risk level of various causes of defects. The results showed that machine disorder and problems with the whitening machine were the leading causes of defects with the highest RPN. Similarly, (Pontororing et al., 2018) discussed using FTA and FMEA to reduce defects in the welding process in the automotive industry.

In addition to improving product quality, Fault Tree Analysis (FTA) has also proven effective in evaluating safety risks in various sectors. (Zermane et al., 2022) describe the application of FTA to identify the causes of fatal falls from height accidents in the Malaysian construction industry. They used statistical data and FTA to identify the leading causes, including lack of use of Personal Protective Equipment (PPE) and lack of supervision. Meanwhile, (Nguyen et al., 2022) described how FTA was used to evaluate the operational safety of a light rail rapid transit line in Vietnam. In this case, FTA was used to identify train collision risks and develop a theoretical model to assess these risks.

Researchers in previous studies also proposed innovations in applying Fault Tree Analysis (FTA). (Niloofar & Lazarova-Molnar, 2023) Created the DDFTAnb algorithm that allows the extraction of fault trees from data generated by a system during its lifetime. They used time series data of observed defects and Naïve Bayes classification to estimate the system's future behavior. Meanwhile, (Xiao et al., 2023) developed a hybrid risk identification model that uses FTA and Bayesian networks to analyze critical risks related to uncrewed aircraft (UAV). The results showed the main risk factors in UAV safety incidents. Thus, FTA remains a powerful tool in product quality evaluation, improvement, and safety risk assessment in various industrial sectors.

FTA can identify the root cause of product defects. As illustrated in the study (Nurwulan & Veronica, 2020), FTA can be used to analyze and clearly describe the causes of defects in the production process. By identifying these causes, SME automotive companies in Indonesia can understand the factors that cause problems and take appropriate preventive measures to address them. FTA also effectively evaluates safety risks, which is relevant for this article as it relates to the automotive industry. As seen in the study (Zermane et al., 2022), FTA was used to identify the causes of fatal accidents in the construction industry. In the automotive context, FTA can be used to identify risks related to products that may have defects that could jeopardize user safety. The FTA process will involve creating an FTA tree that illustrates the relationship between risk factors that could affect the safety and quality (Purba & Deswandri, 2018; Fredy Sumasto, Arliananda, Imansuri, Aisyah, & Pratama, 2023; Xiao et al., 2023) of the FR S/C Side RH Bracket product. This FTA tree will have multiple levels, starting from the end event, such as a product defect, down to the causal or root factors of the event. During this process, validation of the FTA tree will be done by considering additional data and simulating various possible scenarios.

3. RESEARCH METHOD

This study's research object is the FR S/C Side RH Bracket Product. The selection of this research object is based on the high frequency of customer claims related to this product from January to June 2022. The claim data includes incident or defect reports related to FR S/C Side RH Bracket products manufactured by the company. The research will involve a process of observation and interviews with experts in the production of FR S/C Side RH Bracket products to gain an in-depth understanding of the production process, product specifications, and risk factors that could affect product safety and quality.

After the data is collected and an understanding of the production process is achieved, the research will continue by conducting a Fault Tree Analysis (FTA) using TopEvent FTA software. FTA is used to identify the components that cause accidents or damage to a system (Idiyanto & Surya, 2021; Nguyen et al., 2022; Yaghubpour et al., 2016). In this context, FTA will be used to identify the root cause of customer claims related to the FR S/C Side RH Bracket product, specifically those with the highest claim frequency. Not all claims will be identified at this stage, but only the most significant ones will be analyzed further in PT BMI. After successfully identifying the root causes of significant customer claims, the company will take corrective measures in the production process to improve the safety and quality of the FR S/C Side RH Bracket products produced.

4. RESULT AND DISCUSSION

PT BMI, a company operating in the industrial sector providing automotive stamping machine production services, needs help to meet customer expectations and satisfaction. One of the problems faced is the presence of products that do not meet 100% quality standards, which means that the company is still trying to achieve zero defect targets in every stage of its production. The defective products detected at PT BMI can be divided into two categories: those that can be fixed through product improvement and those that cannot. It is important to note that when customers discover defective products, this can damage customer trust and satisfaction with PT BMI. During the three-month research period, the company received 15 customer claim reports complaining about product shipments that did not meet specifications or contained defects

(Table 1.). This problem indicates a severe challenge in maintaining and improving product quality and customer satisfaction. In this section, we discuss the findings and results of the analysis related to this issue and the proposed improvement recommendations to overcome these obstacles.

Table 1. Summary recap claim customer

Part name	Month of claim	Delivery quantity (pcs)	Quantity of defect (pcs)	Problem
Angle B	January 2023	200	3	Minimal Nuts
Protector Muffler K56	January 2023	200	2	Part Baret
Bracket, Seat Track, LWR RR	January 2023	2000	1	Minimal Bending
Bracket, Seat Track, LWR FR	January 2023	1400	6	Dent
Bracket FR Seat Cushion Side RH	February 2023	500	34	Nut Seret and others
FLG FLEX, EXH	February 2023	600	1	Crack
Bracket Regulator	February 2023	3200	2	No Marking
Socket Holder JW1	February 2023	6000	2	NG Plating Rusty/Spotted
Band Exh Pipe HB20	February 2023	400	3	Loose Nut
Plate RR Seat Back Lock RH/LH	February 2022	600	1	Pitch Over
Flange Rear Comp (Bolt)	March 2023	240	1	Loose Bolt
Nut Spring	March 2023	858	1	No Thread
Flange Rear	March 2023	360	4	Pin not entered
Nut M5	March 2023	20000	4	Over Dimension
Collar	March 2023	10000	3	Burry

After examining the history of customer claims at PT BMI (Table 1.), the next step is constructing a bar chart to identify the defective products most frequently shipped to customers. This step is essential because many defective products significantly impact the evaluation of production activities at PT BMI. Figure 1, included in this article, displays a bar chart based on the claims data that has been collected.

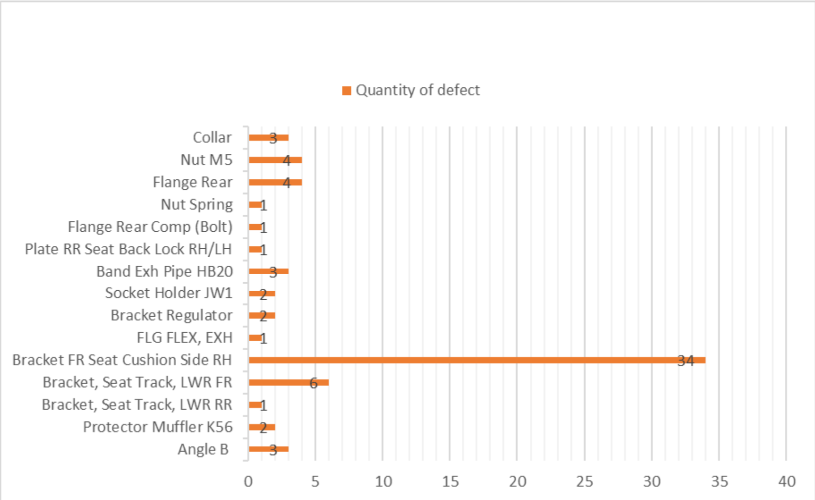


Figure 1. Product defect data for each claim

From the bar chart, it can be concluded that during the three months, the product that experienced the most defects in customer claims was the FR S/C Side RH Bracket from the February production lot, with 34 units shipped to PT TBINA. Defects in this product were related to nut dragging and thread defect issues. Furthermore, it was found that the thread defect was caused by the repair process of the drag nut part performed using a tapping machine when the product was exchanged with the existing stock of the defective drag nut at PT TBINA. Therefore, in this analysis, the data collected and the research's primary focus is the FR S/C Side RH Bracket product.

The data used in analyzing the causes of defects in the FR S/C Side RH Bracket customer claim is data on the number of defective products found at PT TBINA. Based on Table 2, defective product findings data, the next step is to calculate the damage value in the form of % and calculate the cumulative defect. Table 3 is the result of calculating the data on the findings of defective products at PT TBINA. After calculating the cumulative number of defects, a Pareto Chart is then made to more clearly compare the highest number of defects sent by PT BMI.

Table 2. Data on defective product findings

Part name	Sort	Total Sort Results (Pcs)	Type of defect		Number of Defective Products (Pcs)
			Nut-dragging	Defective Threads	
Bracket FR S/C Side RH	Sort by PT TBINA	500	32	2	34
	Sort by PT BMI	788	350	248	598
Total		**1288**	**382**	**250**	**632**

Table 3. Data on defective in the FR S/C side RH bracket product

No	Type of defect	Number of Defects (Pcs)	Percent of Defects
1	Nut-dragging	382	60%
2	Defective Threads	250	40%
	Total	**632**	**100%**

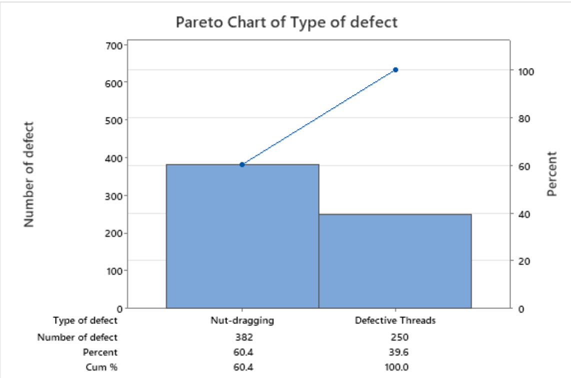


Figure 2. Pareto chart of defect in in the FR S/C side RH bracket product

Figure 2 shows that nut dragging has the highest defect frequency, and the cause must be found. The number of defects totaling 632 Pcs is detrimental to the supplier and the customer. From the supplier's side, when that many defects are found, they must incur additional costs to send people to sort directly to PT TBINA and increase production costs to repair products or waste production costs because the product cannot be reused. From the customer side, it reduces satisfaction and trust in PT BMI. It disrupts the production course because products that should be able to enter the following process are hampered because they have to wait for replacement products from PT BMI. So, to prevent defective products from being sent back. Next, a Fishbone Diagram will be made to determine the root cause of products with nut dragging defects.

Based on the Pareto Chart, the most significant number of defective products from the FR S/C Side RH Bracket is the nut dragging problem. To minimize these defective products, it is necessary to identify the factors that cause nut dragging in the FR S/C Side RH Bracket product. The Fishbone Diagram is one of the structured methods used to conduct detailed analysis to identify the causes of non-conformity or problems that occur. In the research, it is only devoted to tackling Nut-Dragging because the handling is carried out in collaboration with the QCC Team. The following is Figure 3. Fishbone Diagram of the FR S / C Side RH Bracket product with the problem of Nut Dragging.

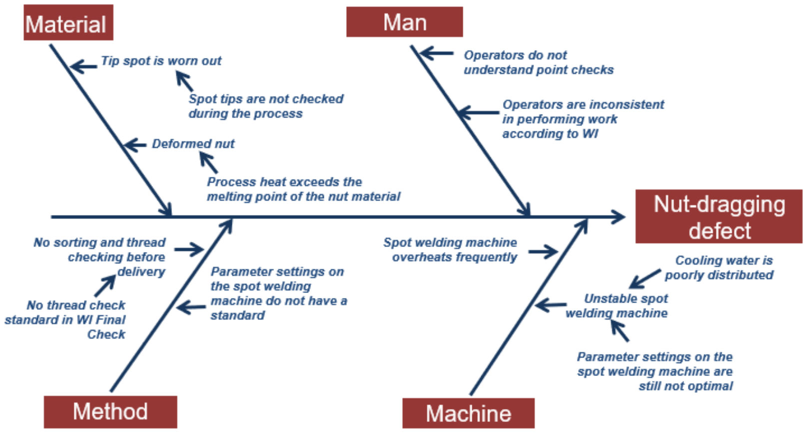


Figure 3. Fishbone diagram of nut-dragging defect

Figure 3 shows four factors that cause the FR S/C Side RH Bracket to experience nut dragging: Man, Material, Machine, and Method. After knowing the common factors that can cause nut-dragging defects, a Fault tree analysis (FTA) is made to find out the root cause of products that have nut-dragging defects. In making a Fault Tree Analysis (FTA), general factors that can cause the nut dragging defect are identified. After these common factors are found, the next step is to identify more specific factors from these common factors to determine the primary factors or essential events that underlie the problem. Figure 4 shows the Fault tree analysis based on the fishbone diagram using TopEvent FTA software.

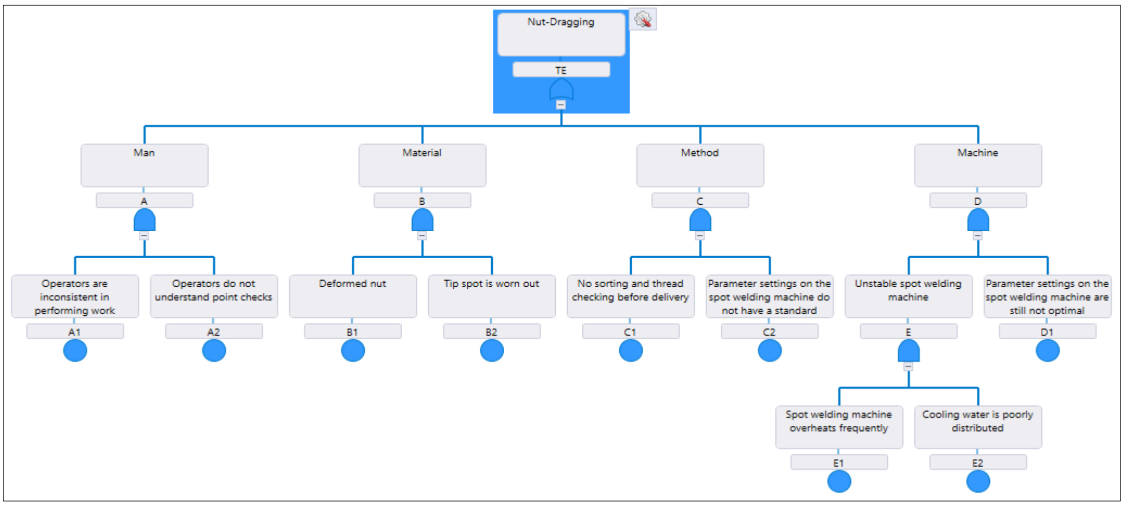


Figure 4. Fault Tree of nut-dragging defect

Figure 4 is a fault tree analysis of the problem of nut-dragging defects in FR S/C Side RH Bracket products. A name is given to each basic event and intermediate event to facilitate the calculation of the value weight of each basic event. Later, the most significant value weight is the leading root cause that must be fixed immediately. Table 4 shows the probability of occurrence of each basic event.

Table 4. Frequency of occurrence of each basic event

Basic Event	Frequency of occurrence per month
A1	3
A2	2
B1	2
B2	1
C1	2
C2	2
D1	6
E1	6
E2	6
Total	**30**

Table 4 is the frequency of occurrence within a one-month time frame where the data taken in February 2023 corresponds to the month of Claim Customer PT TBINA. The following is an explanation of each frequency of occurrence of the basic event. (1) Basic Event A1 is taken from the last lot of production, where this lot is sent to PT TBINA. It is estimated that the operator did not do sampling in the process of 3 events because the standard check is carried out at the process's beginning, middle, and end, (2) Basic Event A2 is taken based on two lots before the customer claim by PT TBINA, (3) Basic Event B1 is two times production activities before the claim occurs with a total production of 6000 pcs, (4) Basic Event B2 obtained one tip spot finding that has been AUS used during the process at the time of the incident, (5) Basic Event C1 was two times delivery activities the last time before the claim occurred with a quantity sent to the customer of 1638 pcs, (6) Basic Event C2 is taken from the production lot after the PT TBINA customer requirement, which requires the Part and Nut to be Burnt, which is two lots, (7) Basic Event D1 is six times production activities before a claim occurs with a production quantity of 6000 pcs, (8) Basic Event E1 as many as three times machines overheat in one production. Based on two times production activities, (9) Basic Event E2: As much as six times, cooling water must be distributed correctly to the machine. This event is based on the occurrence every time the machine is unstable while in production.

Based on the basic events described, a Fault tree Analysis of the Nut Dragging problem is made by entering data on basic events according to the model type and frequency of occurrence in Table 4 Frequency of occurrence of each Basic Event. Figure 5 shows the Fault Tree Analysis according to the frequency of occurrence that has been described.

From the results of the Top Event Evaluation in Nut Dragging Problem using TopEvent FTA Software above, it can be concluded that the most significant root cause is event D, namely the machine with a probability value of 0.993. The following is the calculation of the weight of each basic event based on the probability value per month in TopEvent FTA Software:

A = A1 x A2
= 0.950213 x 0.864665
= **0.822**
B = B1 x B2
= 0.864665 x 0.632121
= **0.547**
C = C1 x C2
= 0.864665 x 0.864665
= **0.748**
D = (E) x D1
= (E1 x E2) x D1
= (0.997521 x 0.997521) x 0.997521
= **0.993**
TE = A + B + C + D
= 0.822 + 0.547 + 0.748 + 0.993
= **3.108**

Minimal Cut Set Contribution:

A = 0.822 / 3.108
= **0.264**
B = 0.547 / 3.108
= **0.176**
C = 0.748 / 3.108
= **0.241**
D = 0.993 / 3.108
= **0.319**

The machine gets the most considerable Minimal Cut Set contribution value of 0.319, so this factor must be improved immediately. Furthermore, an effort impact matrix will be made (Table 5.) to determine the improvement decision according to the root cause of the problem. Based on Table 5, the proposed improvement plan will be mapped into the Impact-Effort Matrix to determine how much effort is required to make improvements and the resulting impact. Figure 6 shows the Effort Impact Matrix based on the proposed improvement plan.

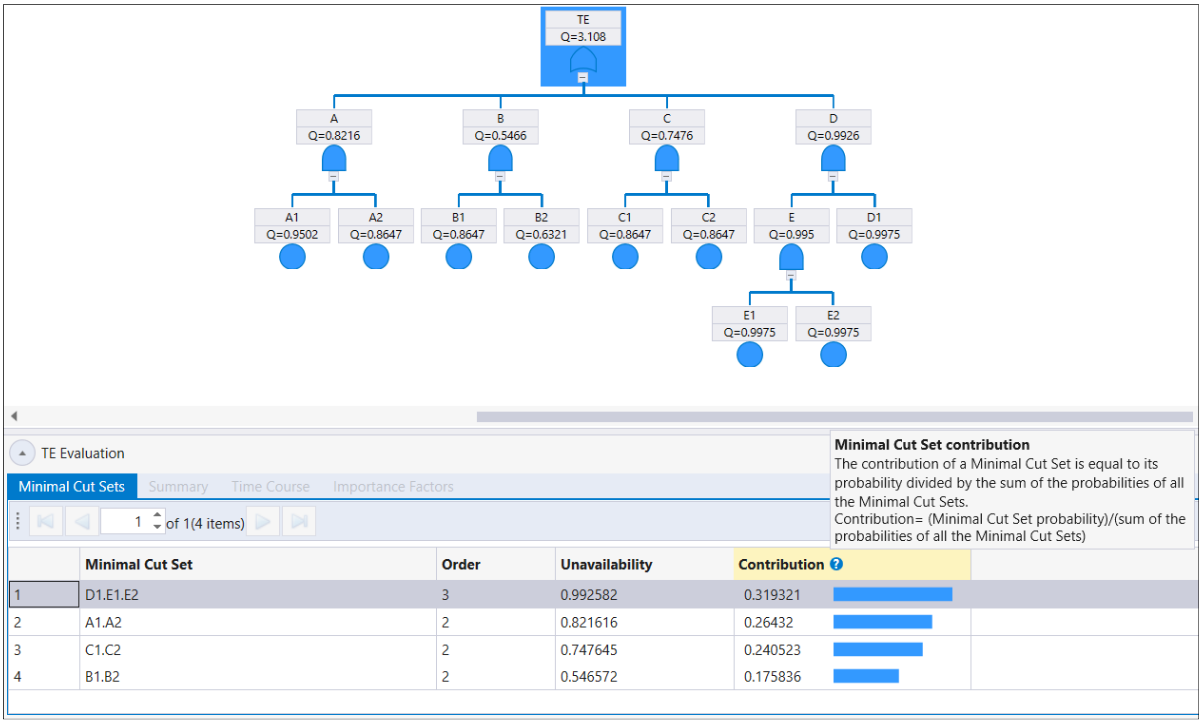


Figure 5. Fault tree analysis evaluation of nut-dragging defect

Table 5. Improvement proposal plan

Code	Suggested Improvements	Impact	Weight	Effort	Weight
S1	Purchase a new Spot Welding Machine	New engines are not sure to prevent overheating in the long run	2	It is costly and time-consuming.	4
S2	Looking for a type of nut material that is not easily deformed	The nut is not easily deformed due to the high heat resistance of the nut material.	4	It takes a lot of time and increased costs to buy the nut.	3
S3	Changing the spot welding machine parameters	Nut not deformed.	4	It is not costly and time-consuming to search for the right parameters.	2
S4	Added cooling water pipe lines and water flow indicator	The spot welding machine does not overheat easily and the operator can know the flow of water because it is equipped with a water flow indicator.	3	Low cost and short time to add cooling water lines and water flow indicator.	2

Figure 6 Impact-Effort Matrix shows that the proposed improvement plan is to change the parameters of the spot welding machine (S3) and add cooling water pipelines and water flow indicators (S4). It was chosen because the Quick Wins chart requires little effort and produces a significant impact. After obtaining the root cause of the nut-dragging problem and deciding to propose improvements, an improvement or repair is carried out to avoid repeating the mistake in the next lot. However, before the improvement is made, there is a nut strength standard related to the problem in the FR S/C Side RH Bracket product. Figure 7 Check Sheet FR S/C Side RH Bracket.

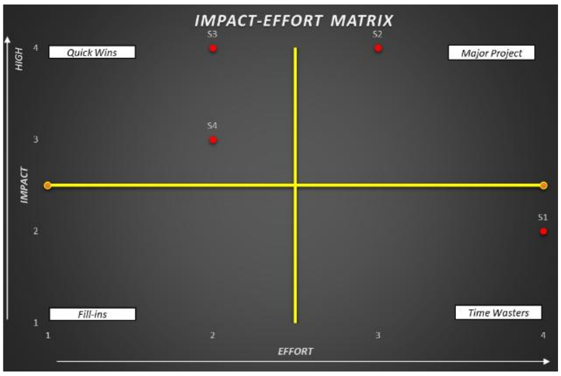
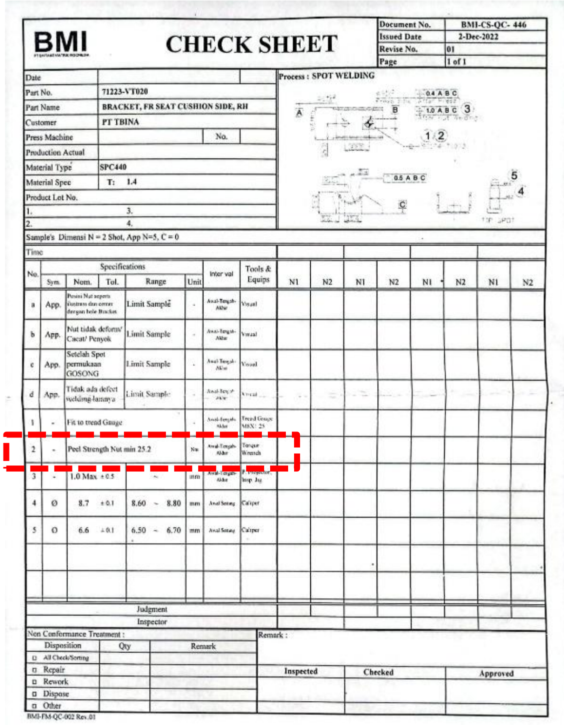


Figure 6. Impact-effort matrix of proposed improvement

Figure 6 Impact-Effort Matrix shows that the proposed improvement plan is to change the parameters of the spot welding machine (S3) and add cooling water pipelines and water flow indicators (S4). It was chosen because the Quick Wins chart requires little effort and produces a significant impact. After obtaining the root cause of the nut-dragging problem and deciding to propose improvements, an improvement or repair is carried out to avoid repeating the mistake in the next lot. However, before the improvement is made, there is a nut strength standard related to the problem in the FR S/C Side RH Bracket product. Figure 7 Check Sheet FR S/C Side RH Bracket.

Figure 7 shows the Check Sheet Bracket FR S/C Side RH nut strength standard (Peel Strength Nut 25.2 Nm), and the standard is multiplied by 2 to 50.4 Nm. PT BMI does this to ensure that the nut on the part in the spot welding process cannot be separated or strong. The improvement is given as follows:

1. The root cause of the nut dragging problem, namely the spot welding machine parameters that are too high, which causes deformation of the nut, an improvement is made by changing the parameters of the spot welding machine on the FR S / C Side RH Bracket product so that in the future the nut does not drag again. Figure 8 is the spot welding machine used on the FR S/C RH Bracket part.


BMI CHECK SHEET

Document No.	BMI-CS-QC- 446
Issued Date	2-Dec-2022
Revise No.	01
Page	1 of 1

Date	
Part No.	71223-VT020
Part Name	BRACKET, FR SEAT CUSHION SIDE, RH
Customer	PT TBINA
Press Machine	No.
Production Actual	
Material Type	SPC440
Material Spec	T: 1.4
Product Lot No.	
1.	3.
2.	4.

Process : SPOT WELDING

Sample's Dimensi N = 2 Shot, App N=5, C = 0

Time

No.	Sym.	Nom.	Tol.	Range	Unit	Inter val	Tools & Equips	N1	N2	N1	N2	N1	N2	N1	N2
a	App.	Posisi Nut seperti ilustrasi dan center dengan hole Bracket		Limit Sample	-	Awal-Tengah-Akhir	Visual								
b	App.	Nut tidak deform/ Cacat/ Penyok		Limit Sample	-	Awal-Tengah-Akhir	Visual								
c	App.	Setelah Spot permukaan GOSONG		Limit Sample	-	Awal-Tengah-Akhir	Visual								
d	App.	Tidak ada defect welding-lannya		Limit Sample	-	Awal-Tengah-Akhir	Visual								
1	-	Fit to tread Gauge			-	Awal-Tengah-Akhir	Tread Gauge M8X1.25								
2	-	Peel Strength Nut min 25.2			Nm	Awal-Tengah-Akhir	Torque Wrench								
3	-	1.0 Max	± 0.5	~	mm	Awal-Tengah-Akhir	P. Projector, Insp. Jig								
4	Ø	8.7	± 0.1	8.60 ~ 8.80	mm	Awal Sesang	Caliper								
5	Ø	6.6	± 0.1	6.50 ~ 6.70	mm	Awal Sesang	Caliper								
Judgment															
Inspector															

Non Conformance Treatment :

Disposition	Qty	Remark
◻ All Check/Sorting		
◻ Repair		
◻ Rework		
◻ Dispose		
◻ Other		

Remark :

Inspected	Checked	Approved

BMI-FM-QC-002 Rev.01

Figure 7. Check sheet bracket FR S/C side RH (spot welding)

Figure 8. Spot welding machine (SW.03)

Based on Figure 8, the Spot welding machine used on the FR S/C Side RH Bracket is SW. 03. Before making changes to the parameters, it is advisable to understand the function of the spot welding machine parameters first. Here is the function of each parameter of the spot welding machine: (a) SEQUENCE is a welding sequence that includes the squeeze stage until the end of the program, (b) SQUEEZE is the duration required for the upper electrode to meet the lower electrode and a waiting time of 3-5 cycles before the welding time is activated, (c) UP-SLOPE is when the welding current is gradually reduced so that the outgoing current does not increase immediately but rises slowly. Its value ranges from 1 to 3 cycles, (d) WELD TIME 1 is the duration required for the first weld, (e) WELD CURRENT 1 is the ampere current used to melt the material to be welded first, (f) WELD TIME 2 is the duration required for the second welding. (note: if required), (g) WELD CURRENT 2 is the ampere current used to melt the material to be welded second. (Note: If needed, (h) COOL TIME 1 is the pause time between weld 1 and weld 2. (note: if needed), (i) HOLD TIME is the time used to hold the plate after it is melted so that it does not change its position, (j) OFF TIME is the pause time used for SEQUENCE repetition. (Note: If needed)

Table 6 is an improvement to the FR S / C Side RH Bracket—changes in welding time and welding current parameters on the spot welding machine. The welding time parameter before improvement is 0.07 S (Second), and after improvement is reduced to 0.06 S (Second). Furthermore, the welding current parameter before the repair was 12.5 A (Ampere) and reduced to 12.3 A (Ampere) after the repair. This improvement is done to reduce the potential for deformation of the nut, which will cause the nut to drag. Table 7 shows the results before and after improvement.

Table 6. Before improvement and after improvement parameters

Before Improvement	**After Improvement**
 *Welding Time = 0.07* (S)	 *Welding Time = 0.06* (S)
 *Welding Current = 12.5* (A)	 *Welding Current = 12.3* (A)

2. Furthermore, improvements were made to the problem of engine cooling water needing to be distributed appropriately. The basic event is an unstable spot welding machine. Although the percentage value is insignificant, improvements are also made because it has a significant enough number of events. If improvements are made, it will further minimize the potential for nut-dragging defects to occur again and not interfere with productivity. Table 8 shows the improvement of the unstable spot welding machine. Based on Table 8. The first improvement is adding the cooling water line to two lines. Furthermore, the second improvement is adding a water flow indicator that detects that the cooling water works correctly during the process. This improvement is done to eliminate errors in the basic event of an unstable machine.

Table 7. Results before and after improvement

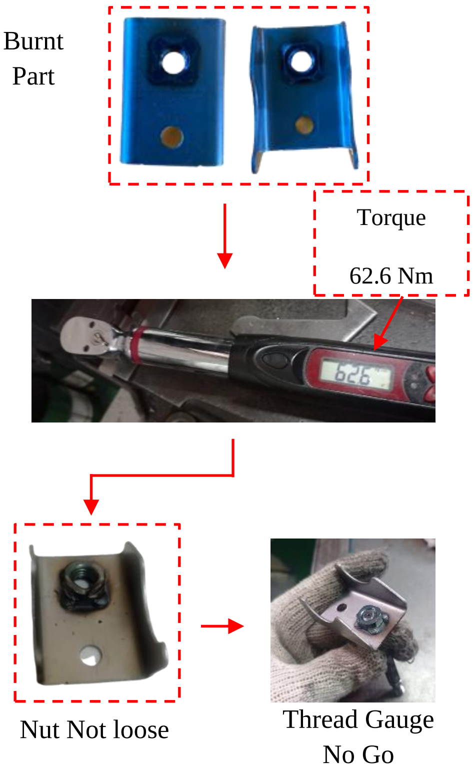
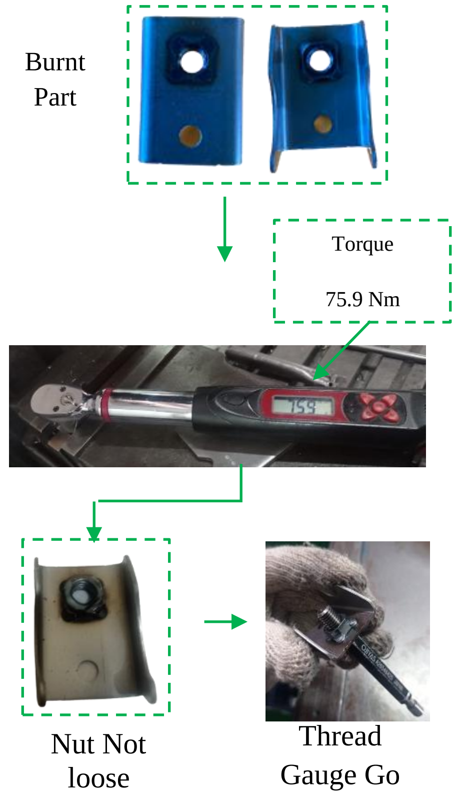
Result	
Before Improvement	After Improvement
	
Burnt Part, Torque 65 Nm (OK) & Nut Drag	Burnt Part, Torque 75.9 Nm (OK) & Nut not dragging

Table 8. Improvement of unstable spot welding machine

Before Improvement	After Improvement
 Water pipeline circuit only 1 line	 Added water pipe circuit line to 2-lines
 There's no water flow indicator	 Added water flow indicator

Table 9. Data on defective product findings after improvement

Part name	Sort	Total Sort Results (Pcs)	Type of defect		Number of Defective Products (pcs)
			Nut-dragging	Defective Threads	
Bracket FR S/C Side RH	Sort by PT TBINA	486	2	3	5
	Sort by PT BMI	834	10	126	136
Total		**1320**	**12**	**129**	**141**

Table 9 shows the defective product finding data after implementing the improvement on the FR S/C Side RH Bracket component. This data records the sorting results from two factories, PT TBINA and PT BMI, and the details of the defect types found, including Nut-dragging and Defective Threads. After implementing the improvement, the total sort results from PT TBINA reached 486 units, with only 5 products found to have defects, consisting of 2 cases of Nut-dragging and 3 cases of Defective Threads. Meanwhile, in the sorting by PT BMI, out of a total of 834 units, 136 defective products were found, of which 10 were related to Nut-dragging and 126 were related to Defective Threads.

Overall, the sorting results from both factories totaled 1320 units after implementing the improvements. Of these, only 141 units were found to be defective, with 12 cases related to Nut-dragging and 129 cases related to Defective Threads. This data gives an idea of the effectiveness of the improvement in reducing the number of defective products, showing a significant improvement in quality control after implementing appropriate improvement measures.

5. CONCLUSION

This study investigated and analyzed the product quality problems faced by PT BMI, focusing on the FR S/C Side RH Bracket products delivered to the customer, PT TBINA. The analysis concluded several important points that provide a deep understanding of the problem. First, it was identified that the FR S/C Side RH Bracket product with nut dragging was the most frequent defect, with 632 defective units, or about 60% of the total defective products before repair. In addition, the thread defect in this product, which accounted for about 40% of the total defects, originated from the repair process of the drag nut part using a tapping machine during the exchange with the existing defective drag nut stock at PT TBINA.

Secondly, the analysis involved the Fault Tree Analysis (FTA) method to identify the root cause of the nut-dragging problem. The results showed that machine factors were generally the main cause, with a high probability of Minimal Cut Set. Setting the spot welding machine parameters too high was one of the main causes of deformation in nut dragging. Third, in response to these findings, improvements were implemented by changing the parameters on the SW.03 spot welding machine and adding a cooling water line with a water flow indicator. These improvements proved effective, with positive results seen in the delivery of three consecutive lots without any cases of nut dragging.

Furthermore, comparing the results before and after the improvement provides a better understanding of the effectiveness of the corrective action. Before the improvement, 632 defective units were found, whereas, after the improvement, the number of defects decreased drastically to only 141 units. This comparison shows a significant improvement in quality control after implementing appropriate remedial measures.

Finally, in response to the research objectives, further research themes are recommended to explore product quality issues in the automotive industry. This research theme could include further analysis of other possible root causes of the problem and the implementation of more proactive prevention strategies. The practical implication of this research is that it provides valuable guidance for automotive companies, especially PT BMI, in improving their product quality and meeting customer expectations in this highly competitive industry. Theoretically, this research contributes to understanding the application of product quality analysis methods in the automotive industry and broadening the insight into the importance of strict quality control in achieving competitive advantage.

REFERENCES

Idiyanto, B., & Surya, A. (2021). Implementation Of Fault Tree Analysis Techniques To Reduce Work Accidents In The Department Of Rebuild Center PT. X. *Jurnal Terapan Tekniik Mesin*, *2*(April), 17–26.

Imansuri, F., Wirandi, M., Sumasto, F., Aisyah, S., & Kautsar, A. (2023). Investment feasibility study of implementing electric conversion motorcycle in Indonesia : A sustainable development perspective. *Journal Industrial Servicess*, *9*(2), 81–86. https://doi.org/http://dx.doi.org/10.36055/jiss.v9i2.19996

McKinsey&Company. (2016). Automotive Revolution & Perspective Towards 2030. In *Auto Tech Review* (Vol. 5, Issue 4). https://doi.org/10.1365/s40112-016-1117-8

Nabiilah, A. R., Hamedon, Z., & Faiz, M. T. (2018). Improving quality of light commercial vehicle using PDCA approach. *Journal of Advanced Manufacturing Technology*, *12*(1 Special Issue 2), 525–534.

Nguyen, T. H. A., Trinckauf, J., Luong, T. A., & Truong, T. T. (2022). Risk Analysis for Train Collisions Using Fault Tree Analysis: Case Study of the Hanoi Urban Mass Rapid Transit. *Urban Rail Transit*, *8*(3–4), 246–266. https://doi.org/10.1007/s40864-022-00181-y

Niloofar, P., & Lazarova-Molnar, S. (2023). Data-driven extraction and analysis of repairable fault trees from time series data. *Expert Systems with Applications*, *215*(November 2022), 119345. https://doi.org/10.1016/j.eswa.2022.119345

Nurwulan, N. R., & Veronica, W. A. (2020). Implementation of Failure Mode and Effect Analysis and Fault Tree Analysis in Paper Mill: A Case Study. *Jurnal Rekayasa Sistem Industri*, *9*(3), 171–176. https://doi.org/10.26593/jrsi.v9i3.4059.171-176

Pontororing, P. P., Gilbert, S., & Andika, A. (2018). Welding Products Defects Analysis with Fault Tree Analysis and Failure Modes and Effects Analysis. *Innoscape 2018-Jakarta*, 38.

Purba, J. H., & Deswandri, D. (2018). The Implementation of Importance Measure Approaches for Criticality Analysis in Fault Tree Analysis: A Review. *Jurnal Pengembangan Energi Nuklir*, *20*(1), 1. https://doi.org/10.17146/jpen.2018.20.1.4257

Razak, I., & Nirwanto, N. (2016). The impact of product quality and price on customer. *Journal of Marketing and Consumer Satisfaction*, *30*(2012), 59–68.

Sumasto, F, Imansuri, F., Agus, M., Safril, & Wirandi, M. (2020). Sustainable development impact of implementing electric taxis in Jakarta: A cost-benefit analysis. *IOP Conference Series: Materials Science and Engineering*, *885*, 012027. https://doi.org/10.1088/1757-899x/885/1/012027

Sumasto, F., Arliananda, D. A., Imansuri, F., Aisyah, S., & Pratama, I. R. (2023). Fault Tree Analysis: A Path to Improving Quality in Part Stay Protector A Comp. *Journal Européen Des Systèmes Automatisés*, *56*(05), 757–764. https://doi.org/10.18280/jesa.560506

Sumasto, F., Arliananda, D. A., Imansuri, F., Aisyah, S., & Purwojatmiko, B. H. (2023). Enhancing Automotive Part Quality in SMEs through DMAIC Implementation: A Case Study in Indonesian Automotive Manufacturing. *Quality Innovation Prosperity*, *27*(3), 57–74. https://doi.org/10.12776/QIP.V27I3.1889

Sumasto, F., Christiani, J., Wulansari, I., Rozi, M. F., Dzulfikar, A., & Ismono, A. (2023). Application of Failure Mode and Effect Analysis (FMEA) for Defect Reduction: A Case Study on Scratch Defects in Oil Separator Parts in Machining Line. *IJIEM (Indonesian Journal of Industrial Engineering & Management)*, *4*(3), 632–643. https://doi.org/10.22441/ijiem.v4i3.22768

Sumasto, F., Maharani, C. P., Purwojatmiko, B. H., Imansuri, F., & Aisyah, S. (2023). PDCA Method Implementation to Reduce the Potential Product Defects in the

Automotive Components Industry. *Indonesian Journal of Industrial Engineering & Management*, *4*(2), 87–98. https://doi.org/10.22441/ijiem.v4i2.19527

Sumasto, F., Nugroho, Y. A., Purwojatmiko, B. H., Wirandi, M., Imansuri, F., & Aisyah, S. (2023). Implementation of Measurement System Analysis to Reduce Measurement Process Failures on Part Reinf BK6. *Indonesian Journal of Industrial Engineering & Management*, *4*(2), 212–220. https://doi.org/10.22441/ijiem.v4i2.20212

Sumasto, F., Nugroho, Y. A., Solih, E. S., Arohman, A. W., Agustin, D., & Permana, A. K. (2024). Enhancing Quality Control in the Indonesian Automotive Parts Industry: A Defect Reduction Approach Through the Integration of FMEA and MSA. *Instrumentation Mesure Metrologie*, *23*(1), 43–53. https://doi.org/10.18280/i2m.230104

Tama, I. P., Azlia, W., & Hardiningtyas, D. (2015). Development of Customer Oriented Product Design using Kansei Engineering and Kano Model: Case Study of Ceramic Souvenir. *Procedia Manufacturing*, *4*(Iess), 328–335. https://doi.org/10.1016/j.promfg.2015.11.048

Tan, X., & Li, T. (2021). Analysis of challenges and opportunities in the development of new energy vehicle battery industry from the perspective of patents. *IOP Conference Series: Earth and Environmental Science*, *632*(3). https://doi.org/10.1088/1755-1315/632/3/032049

Xiao, Q., Li, Y., Luo, F., & Liu, H. (2023). Analysis and assessment of risks to public safety from unmanned aerial vehicles using fault tree analysis and Bayesian network. *Technology in Society*, *73*(March), 102229. https://doi.org/10.1016/j.techsoc.2023.102229

Yaghubpour, Z., Esmaeily, L., Piran, H., & Behrad, A. (2016). Public Transport Risk Assessment through Fault Tree Analysis (FTA) Case Study: Tehran Municipal District 1. *Bulletin de La Société Royale Des Sciences de Liège*, *85*, 1039–1048.

Zermane, A., Mohd Tohir, M. Z., Baharudin, M. R., & Mohamed Yusoff, H. (2022). Risk assessment of fatal accidents due to work at heights activities using fault tree analysis: Case study in Malaysia. *Safety Science*, *151*(February), 105724. https://doi.org/10.1016/j.ssci.2022.105724