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RESEARCH ARTICLE

THE IMPLEMENTATION OF FUZZY FAILURE MODE AND EFFECT ANALYSIS (FFMEA) IN REDUCING THE RISK OF RUBBER AUTOMOTIVE SPARE PARTS.

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Abstract

Reducing a risk cannot be separated from the implementation of an integrated production systems quality control, so that, the output is marketable. Hence, the implementation of Fuzzy Failure Mode and Effect Analysis (FFMEA) will generate many problems especially in terms of increasing the cost, time and work as existences of the problems in the implementation of FFMEA in reduced the risk. Rubber automotive SME's needs to apply a method of FFMEA that is easy to apply and give good results to reduce and prevents the occurrence of such damage. Furthermore, to explore the impact of the implementation FFMEA in quality control and reducing production risk of SMEs, a total of 8 rubber automotive spare parts companies in Bandung, West Java, Indonesia. It found, that in Indonesian SMEs, the implementation of FFMEA is not an easy task to give good results. Some problems faced by SME's are still high damage on Rubber Seal production process. The results of the discussion show that the biggest problem experienced by the injection forming process section because it has the highest Fuzzy Risk Priority number (FRPN) value of 717. This method has advantages, which can prevent or detect earlier from the damage experienced and can determine which type of damage should be prioritized to be given the solution gradually.

Introduction:-

In the era of globalization, all industrial sectors and organizations collaborate to achieve competitive advantage. For that one thing to do is improve the quality of the products. Currently there are many ways and methods that can be used to improve a products quality, one of which is Failure Mode and Effect Analysis (FMEA) and the use of fuzzy logic. FMEA is a systematic method of identifying and preventing problems that occur in products and processes [11]. PT CDM is one of manufacturing SMEs in Bandung, West Java that produces Rubber Seal. In this study investigated is the damage that often occurs in every process.

This structured method provides essential information for predicting reliability and design of a product or process. FMEA is a reliability analysis technique that tries to identify the failures affecting on the functionality of a system in its defined range. Fuzzy logic is a technique to perform and manipulate uncertainty information [15]. Fuzzy logic is one of method for representing uncertain system analysis [9]. The Fuzzy FMEA (FFMEA) can determine the Risk

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Priority Number value of the failures which solution should be prioritized for the production process to minimize the occurrence of production failures. Therefore The SMEs needs to apply this method in order to improve the quality of its production so as to satisfy consumers A failure cause is a weakness of failure result. The wind turbine systems have some Typical causes of failures are: connection failure, using incorrect material, corrosion, poor welding, error systems in assembly and calibration, icing, maintenance fault, forming of cracks, being out of balance, over stressing, overheating, and etc [4].

Visual inspection, oil analysis and ultrasonic testing for online condition monitoring techniques are to detect FMEA [12], and time-based preventive maintenance actions. Their definitive impact should be controlled by a cross-useful group which is typically shaped by pro from different capacities (e.g., plan, activity, upkeep, and power creation) for distinguished disappointment and mode. As the after effect of disappointment mode, a disappointment impact is characterized on the capacity of the framework as seen by the client. A portion of the impacts of a disappointment in elastic extra parts are loss of power generation, poor power quality to the network, and a noteworthy capable of being heard noise. Likewise, the impacts of a disappointment in one part can be the reason for a disappointment mode in another segment.

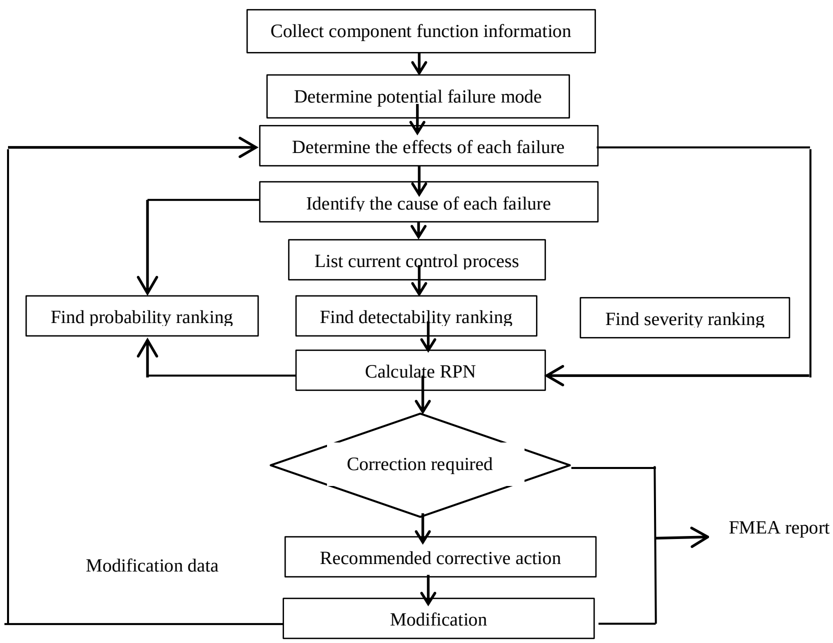

Figure 1:-The FMEA technique

The procedure for completing a FMEA can be separated into a few stages as appeared in Fig. 1[14],. Essentially, every disappointment mode in the FMEA strategy is assessed by three factors as severity (S), occurrence (O), and detection (D). A number somewhere in the range of 1 and 10 (with 1 being the best and 10 being the most pessimistic scenario) is given for every one of the three components, and a Risk-Priority Number (RPN) is acquired, which is RPN = SOD. The RPN esteem causes the FMEA group to recognize the segments or subsystems that require the need activities for development. Contingent upon the breeze cultivate director's choice, diverse criteria are utilized to trigger the enhancement activities. For example, activity could be required if the general RPN surpasses a predefined limit, or for the most astounding RPN paying little heed to an edge. At long last, at the last advance, some equipment, programming or structure alterations are made in the framework to limit the disappointment impacts. Despite the fact that FMEA is likely well known instrument for dependability and disappointment mode examination in wind turbine frameworks, a few impediments are related with its execution in seaward wind ranches:

The disappointment information assembled from monitors, vibration sensors, and the SCADA system is frequently absent or inconsistent. Subsequently, the evaluation data of three risk factors (severity, occurrence, and detection) is for the most part dependent on specialists' information and ability;

Contrasting and coastal breeze control, the historical backdrop of offshore wind turbine systems is genuinely later. Subsequently, it is troublesome or even unthinkable for specialists to absolutely assess the three hazard factors S, O and D. The risk factors are frequently communicated semantically (such as 'likely', 'important', 'very high' and etc);

In the conventional FMEA technique, the three risk factors are accepted to have a similar significance [2]. Be that as it may, it is seen that numerous O&M specialists give more inclination to the 'blame identification' factor. Along these lines, the consequences of the conventional FMEA strategy may not really speak to the genuine hazard needs in offshore wind turbine systems, and this can involve a misuse of assets and time. To defeat the above downsides and enhance the viability of the conventional FMEA technique, we build up a fuzzy-FMEA approach to determine with decide the impacts of disappointment on failure on offshore rubber seal. For the first, a fuzzy inference approach is considered to perform the evaluation data utilizing etymological terms. At that point, by utilizing the weight vector of three risk factors, a grey hypothesis investigation is proposed to rank the failures modes. As far as anyone is concerned, this paper is the main endeavor to make the customary FMEA methodology increasingly for offshore wind turbine systems, particularly when the failure information is inaccessible or questionable. The rest of this paper is organized as follows. In Section 2, we give a brief overview of FMEA methodology so as to set the background for the main contribution of the paper. Section 3 describes the rubber seal process considered in this paper. In section 4, the proposed fuzzy approach which utilizes the fuzzy IF–THEN rules and grey relation analysis. Finally, in section 5, the results obtained from the proposed approach are compared with the traditional FMEA.

Methods:-

Fuzzy Methodology

The fuzzy set hypothesis proposed by Zadeh (1965) which is a vital idea to manage vulnerability based data. The parameters for example Severity (S), Occurrence (O) and Detection (D) which are utilized in FMEA are fuzzified utilizing suitable enrollment capacities [7]. Fuzzy system is an information based system which is developed from ability and involvement as fuzzy IF-THEN standards [19]. Through building learning based model, master information and judgment can be used to make the FMEA evaluation strategy increasingly sensible and advantageous. The fluffy end is then defuzzified to get hazard need number. The fundamental parts related with fuzzy are:

1. Fuzzification
2. Fuzzy rule base
3. Defuzzification.

Fuzzification

Fuzzification alludes to change of crisp as inputs to an enrollment degree which communicates how well the information has a place with the phonetically characterized terms (Rajiv Kumar Sharma 2005). Experts judgement and experience can be used for define degree of membership function for a particular variable. Amid fuzzification, a fuzzy logic controller gets input information, otherwise called the fuzzy variable, and breaks down it as indicated by client characterized outlines called membership function

Fuzzy rule base

The standard base depicts the criticality level of the system for every mix of input variables. Regularly communicated in 'If Then', they are defined in semantic terms utilizing two approaches (i) Expert information and atitude (ii) Fuzzy model of the procedure [20]. Experts judgement and experience can be used for define degree of membership function for a particular variable.

Defuzzification

The defuzzification process analyzes the majority of the standard results after they have been legitimately included and afterward figures an esteem that will be the last yield of the fluffy controller. Amid defuzzification, the controller changes over the fuzzy output into a genuine information esteem [16]

The Capability Process

The Capability process shows the range of a process variation or a quantity that shows the ability of production equipment to produce product specifications. Measurement of process capability is carried out after the process is considered to have been controlled, in other words the variations that occur are only due to natural factors. Process capability shows how far a process is able to meet the desired specifications. The Cpk value 1.34 based on the product classification value Cp, the process capability value is good, process results are the products that meet specifications, but still have defective products.

Fuzzy FMEA Input Variable Value

Inputs used in fuzzy logic are severity, occurrence, and detection indexes which are categorized into 5 levels of number importance. Category for the Severity (S) input variable, Occurrence (O), and Detection (D) are found in table 1.

Table 1:-Crisp Number Index Category Severity, Occurrence, Detection

Categories	Curve type	Parameter
VL	Trapezoid	[0 0 1 2.5]
L	Triangle	[1 2.5 4.5]
M	Trapezoid	[2.5 4.5 5.5 7.5]
H	Triangle	[5.5 7.5 9]
VH	Trapezoid	[7.5 9 10 10]

Source: Puente, 2002

Associated with a is o. Notation A = {x | P (x)} indicates that A contains item x with P (x) correct. If XA is a characteristic function of A and property P, then it can be said that P (x) is correct, if and only if XA (x) = 1. If in the set of crisp, the membership value is only two possibilities, namely 0 and 1, in the fuzzy set the membership value lies in the range 0 and 1. If x has a fuzzy membership value µA [x] = 0, it means that x is not a member of the set. Similarly if x has a fuzzy membership value µA [x] = 1, it means that x becomes a full member of the set A.

Table 2:-Crisp Number Index Category Severity, Occurrence, Detection

S	O	D	Categories
1	1	1	VL
2.3	2.3	2.3	L
4.5.6	4.5.6	4.5.6	M
7.8	7.8	7.8	H
9.10	9.10	9.10	VH

Source: Puente, 2002

For membership function parameters and curve types, the output variables are in table 3 below.

Table 3:-Parameter of output variable membership function

Categories	Class Interval FRPN
VL	1-49
VL-L	50-99
L	100-149
L-M	150-249
M	250-349
M-H	350-449
H	450-599
H-VH	600-799
VH	800-1000

Source: Puente, 2002

The object of this research is the Rubber Seal problems that is the cause of production failure from production process in the manufacture components. Based on data defects that occur during the observation period. As for the types of defects that often occur in the injection process. FMEA use several stages for problem analysis:

1. Determine the potential failure mode in each process.
2. Identify processes that have the potential to fail to meet process or design requirements.
3. Identification of failure effects.
4. Identify the effects of failure on both internal and external customers. Identify the effects that occur from each process and its impact on the next process.

5. Determine the severity value.
6. Determine severity value based on the effect / effect of failure.
7. Identify the causes of failure based on priority ranking of existing problems so that later it will be easier to solve problems. The FRPN category can be seen in table 3.

Table 3:-Parameter of Output Variable Membership Function

Categories	Curve Types	Parameter
VL	Trapezoid	[0 0 25 75]
VL-L	Triangle	[25 75 125]
L	Triangle	[75 125 200]
L-M	Triangle	[125 200 300]
M	Triangle	[200 300 400]
M-H	Triangle	[300 400 500]
H	Triangle	[400 500 700]
H-VH	Triangle	[500 700 900]
VH	Trapezoid	[700 900 1000 1000]

Source: Puente, 2002

Identify potential causes for each process failure by using a causal diagram. The causal diagram is a diagram that shows the relationship between cause and effect. The diagram is used to determine the consequences of a problem for further corrective action. This diagram is also called the fishbone / Ishikawa diagram.

1. Determine the value of occurrence.
2. Determine the value of how often the cause of failure occurs.
3. Identify process control.
4. Identifying control methods that can prevent the occurrence of potential failure / cause or detect the occurrence of failure / cause.
5. Determine the detection value.
6. Determine the value of the system's ability to detect failure.
7. Calculate the RPN value.RPN is a number that states the priority scale for quality risk that is used for guidance in making improvement plans. The RPN value is obtained from the multiplication result between severity x occurrence x detection.
8. Perform the fuzzification process.That is a process that converts the crisp input in the form of severity, occurrence, and detectability to fuzzy input in the linguistic form of the variable with the membership value using the Mamdani method. After that, we can find out the fuzzy output in the form of fuzzy risk priority number (FRPN).
9. Determine ratings and categories based on FRPN values. That is to determine the ranking of the FRPN and its categories to find out which areas need to be prioritized for attention so that an improvement plan can be made.

Results and Discussion:-

The rubber seal process through several stages that are interconnected between one to the next process. The process are incoming material, bending, spot welding, spring frame , injection foaming, trimming, grinding, sanding, bonding, finishing and visual processes inspection and packing. The complete process of Rubber Seal can be seen in the following table 4:

Table 4:-The Rubber Seal process

No	Code	Next opr.	Process	Facility
1	2	3	4	5
1	IQQ1	O-1	inspection material (insert frame)	Scales, ruler, calipers
2	O-1	O-2	bending	Bending machine
3	IQQ2	O-2	inspection material (insert holder)	calipers
4	IQQ3	O-3	inspection material (spring upper)	calipers
5	IQQ4	O-4	inspection material (MDI)	Manual
6	IQQ5	O-4	inspection material (poly ol)	Manual
7	IQQ6	O-8	inspection material (paper washer)	Ruler
8	IQQ7	OI-2	inspection material (carton box)	Ruler

12	O-2	O-3	spot welding	Welding, jigspot machine
13	O-3	O-4	spring frame	spring machine
14	O-4	OI-1	forming injection	PU injection machine, mold
15	OI-1	O-5	trimming contact piece	cutter
16	O-5	O-6	grinding	Grinding machine
17	O-6	O-7	sanding	sandpaper
18	O-7	O-9	bonding	putty, sandpaper
21	OI-2	WH	visual inspection and packing	cutter

Source:PT CDM

The quality control activities at PT CDM are carried out on the entire system, starting from the receipt of customer requests and the implementation of the production process, incoming material, until the response is made if there is a complaint from the customer for the products.

The following table is the foaming injection defects:

Table 5:-The Injection Foaming defects

days	**Products (units)**	**Defects (units)**	**days**	**Products (units)**	**Defects (units)**	**days**	**Products (units)**	**Defects (units)**
1	173	2	9	152	0	17	157	6
2	164	4	10	68	0	18	178	5
3	174	1	11	163	4	19	158	8
4	185	0	12	154	7	20	180	2
5	158	0	13	152	1	21	160	6
6	176	3	14	138	1	22	166	5
7	169	1	15	180	4	23	147	3
8	172	4	16	175	1	24	184	0
						25	179	7
						∑	**4062**	**75**

The Pareto

The Pareto diagram is used to identify or defect type of injection processing, and also to identify or select the main problem (type of defect) that occurs in the injection foaming process. The data regarding of number and defects product type can be seen in table 6. The next Pareto diagram is as follows:

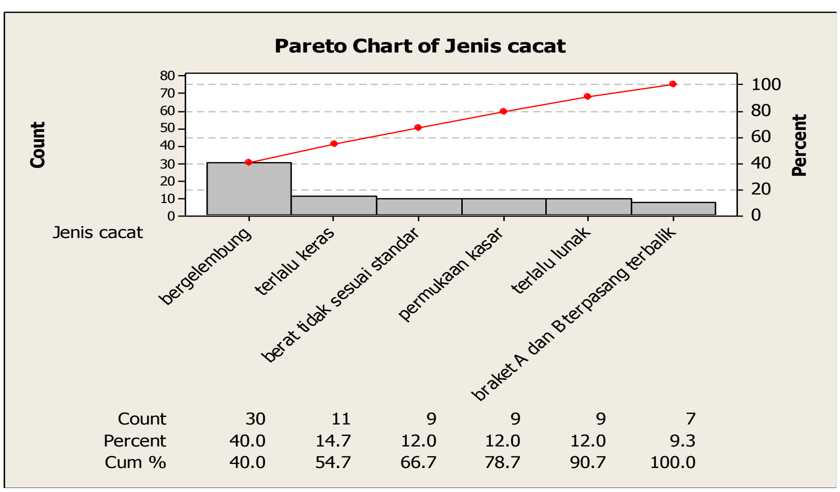

Figure 2:-The Pareto diagram injection foaming defects

The P Control Chart

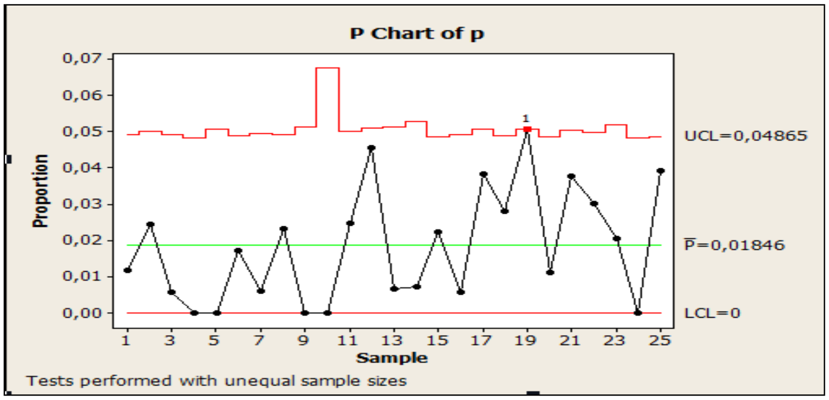

Figure 3:-The Injection foaming P control Chart

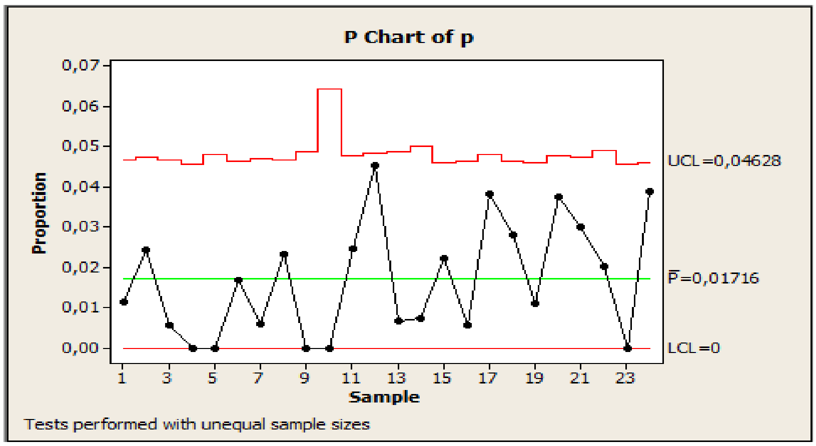

Figure 4:-The Injection foaming P control chart (proposed)

Table 6:-The cummulative of defects

Defects	**Quantity**	**(%)**	**cum (%)**
Excess rubber	30	0.40	0.40
Broken parts	11	0.15	0.55
Thick flash	9	0.12	0.67
cracks	9	0.12	0.79
nonstandard weight	9	0.12	0.91
missmatch	7	0.09	1.00
Total	**75**		

The table of defects results from injection process can be explained the types and the number of defects, then can be made by pareto diagrams that determine the type of defects that often occur and must be resolved in the data processing section of the injection foaming is as follows:

Defects	**weeks**				**Total (units)**
	I	**II**	**III**	**IV**	
Excess rubber	4	6	11	9	30
Broken parts	2	2	3	2	9
Thick flash	1	2	4	4	11
cracks	1	2	3	3	9
nonstandard weight	1	2	3	3	9
missmatch	2	2	1	2	7

Total	11	16	25	23	75

Table 7:-The types of defects

The Capability Process

The Capability process shows the range of a process variation or a quantity that shows the ability of production equipment to produce product specifications. Measurement of process capability is carried out after the process is considered to have been controlled, in other words the variations that occur are only due to natural factors. Process capability shows how far a process is able to meet the desired specifications. The Cpk value 1.34 based on the product classification value Cp, the process capability value is good, process results are the products that meet specifications, but still have defective products.

Table 8:-The RPN Value

No	Products Characteristics	S	O	D	RPN	Cat.	Rank
1	**Incoming Material**						
	Material according to customer						
	(spec dimensions, colour, appear.)	8	1	5	40	VL	4
			1		40	VL	4
2	**Bending**						
	Result of bending acc. to drawing	8	1	5	40	VL	4
			1	5	40	VL	4
			1	5	40	VL	4
3	**Spot Welding**						
	Holder position is attached acc. to						
	drawing	8	1	7	56	VL – L	3
	Holdings must be completed	5	1	7	35	VL	4
4	**Injection foaming**						
	Perfect mixing material (colour and						
	hardness according to standards)	8	2	8	128	L	2
	Smooth injection surface	1	8		64	VL – L	3
	Injection results are not bubbly	7	2	7	98	VL – L	3
		2	7		98	VL – L	3
	Weight according to standards	4	7		196	L – M	1
	Match	7	2	8	112	L	2
		8	1	4	32	VL	4
		8	1	7	56	VL – L	3
	Finishing						
5	**Trimming Contac Piece**						
	Trimming contact piece results						
	must be clean	2	2	8	32	VL	4
6	**Grinding**						
	Grinding results are not overcut	2	2	8	32	VL	4
	Grinding results are flat	2	1	8	16	VL	4
7	**Sanding**						
	Sanding results must be smooth	2	2	8	32	VL	4
			2	8	32	VL	4
8	**Bonding**						
	Bounding results flat and neat	2	1	8	16	VL	4

			2	8	32	VL	4
9	**Visual Inspection and Packing**						
	Trimming contact piece in clean						
	condition	2	2	8	32	VL	4
	Smooth sanding	2	2	8	32	VL	4
	Bounding conditions flat and neat	2	2	8	32	VL	4
	Packing according to standards	2	2	8	32	VL	4
	Outgoing Inspection						
	The shaft hole area must be clean	2	2	8	32	VL	4
	Flat surface	2	2	8	32	VL	4
	Trimming contact piece clean	2	2	8	32	VL	4
	Smooth Sanding	2	2	8	32	VL	4
	Bounding flat and neat	2	2	8	32	VL	4
	Packing according to standard	2	2	8	32	VL	4

In table 8, it can be seen that the highest category is Low moderate (L-M), therefore this category is ranked 1st. Furthermore, for the low category, VL-L and Very low (VL) were ranked 2.3 and 4.

Determination of Ratings and Categories Based on FRPN Values

Ranking and categories based on FRPN values obtained from the fuzzification process can be seen in table 9 below.

Table 9:-The FRPN Value

No	Products Characteristics	S	O	D	RPN	Category	Rank
1	**Incoming Material**						
	Material acc. to customer (spec dimensions, colour, appear.)	8	1	5	671	H-VH	2
			1		671	H-VH	2
2	**Bending**						
	Result of bending acc. to draw.)	8	1	5	671	H-VH	2
			1	5	671	H-VH	2
			1	5	671	H-VH	2
3	**Spot Welding**						
	Holder position is attached acc to drawing	8	1	7	717	H-VH	2
	Holdings must be completed	5	1	7	371	H-VH	2
4	**Injection foaming**						
	Perfect mixing material (colour and hardness acc. to standards)	8	2	8	128	VH	1
	Smooth injection surface						
	Injection results are not bubbly	7	1	8	64	H-VH	2
	Weight according to standards match	7	2	7	98	H-VH	2
		8	2	7	98	H-VH	2
		8	4	7	196	L – M	4
			2	8	112	H-VH	2
			1	4	32	H-VH	2
			1	7	56	H-VH	2
5	**Finishing** **Trimming Contac Piece** Trimming contact piece results must be clean						

		2	2	8	229	L-M	4
6	**Grinding** Grinding results are not overcut Grinding results are flat	2 2	2 1	8 8	229 173	L-M L-M	4
7	**Sanding** Sanding results must be smooth	2	2 2	8 8	229 173	L-M L-M	4 4
8	**Bonding** Bounding results must be flat and neat	2	1 2	8 8	173 229	L-M L-M	4 4
9	**Visual Inspection and Packing** Trimming contact piece in clean condition Smooth sanding Bounding conditions flat and neat Packing acc. to standards Outgoing Inspection The shaft hole area must be clean Flat surface Trimming contact piece is clean Smooth Sanding Bounding flat and neat Packing according to standard	2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2	8 8 8 8 8 8 8 8 8 8	229 229 229 371 229 229 229 229 371 229	L-M L-M L-M L-M L-M L-M L-M L-M M-H L-M	4 4 4 4 4 4 4 4 3 4

Based on Table 9, there is a difference between values, categories and ratings between RPN and FRPN. This is due to calculations using RPN only done by multiplying S, O, and D only and not paying attention to the degree of importance of each input. While the FRPN value obtained from the fuzzification results, produces a value by paying attention to the degree of importance of each given input. The fuzzification calculation process has included rules that prioritize handling more problems to the cause of the defects that occur. Whereas in the RPN calculation, the RPN value is generated only by multiplying the S, O, and D values only, causing the calculation with RPN to be less accurate and different

Conclusion:-

Based on data processing and problem analysis it can be seen that:

1. The process capability of the Rubber Seal manufacturing process is 1.34 in the good category
2. The defect categories that often arise are bubbly defects with a percentage of 40%.
3. There are differences in rank between RPN and FRPN. This is because the FRPN obtained from fuzzification results in the value of each input given.
4. The highest value of RPN calculations is found in each type of failure, which causes difficulties to determine the type of failure to be repaired. The highest rating value of Fuzzy Risk Priority Number (FRPN) is found in the Injection Forming process. So the plan to do the improvement plan is for the Injection Foaming process because it is the highest ranking of FRPN.

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