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Integration Pareto Distribution and Pareto Analysis to Analyse and Diagnose Defects and the Root of Causes for the Air Cooling Motor

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Abstract

Today the interest of industrial organizations increase about the quality subject and they work seriously to satisfy the customers who consider today the main factor in the business environment, by manufacturing quality products. Pareto distribution and Pareto analysis are used where The Pareto distribution is used to analysis the data of the defective motors to find the mean, variance, and standard deviation. Pareto Analysis is used as a tool to diagnose and analyse the defects type, causes of the critical defect and the root of cause of the critical cause for the air cooling motor.

The air cooling motor is a one of the various products that produce by the state company for electrical products. Four main defects have been diagnosed through final inspection process by the Inspection team, these are dielectric (electrical circuit), sound (noise), loss (non-pass the electrical current) and tolerance (non-accurate tolerance).

The Pareto distribution was illustrated that Dielectric defect has the highest mean but loss has the highest variance and standard deviation. The Pareto analysis was identified that the dielectric has the biggest defect with 42.24% of all defects. It has been caused by four causes, and the machine are the biggest cause, it is responsible to 50% of this defect, consumption of the rolling mold is the root of the dielectric defect with 40% of this defects.

The Pareto distribution and Pareto analysis may considered an efficient tools that could use to help company management to analyse the defects data and diagnose all the causes and cause roots of the biggest defect (dielectric defect) to determine and take any necessary corrective actions that will minimize the defective products.

Keywords: Pareto Distribution, Pareto Analysis, Critical defect, cause root

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Introduction

Today, the industrial organization focuses on customers and work seriously to satisfy the customers who consider the main factor in the business environment by manufacturing satisfied quality products. The quality aspects in any Industrial organization can measure in addition to the corresponding the products characteristics with standards by:

1- Rejected products rate.
2- Rate of product returns.
3- Customer complaints.
4- Customer satisfaction that has measured by a survey.
5- Customer loyalty that can be measured by repeat purchases, or renewal rates.

Two common types of defects can be diagnosed; the first type is the Uncontrolled defects where it has due to assignable or special causes. For example, the shift of operation, procedures or raw materials and breakages have all outside influences on a process, which interrupt its normal pattern of operation and the second type is the Controlled defects where it has due to non-assignable, chance, random or common causes [1].

Many researchers have studied the product defects by using various methods: -

Dalgobind Mahto and et.al (2008) suggested methodology to identify a root- cause to eliminate the dimensional defects in cutting operation in CNC oxy flame cutting machine so a rejection has decreased from 11.87% to1.92% [2].

Neelufur and et.al (2010) developed an economic statistical design to analyse the x-control chart with the assumption that the sample average of the quality characteristic (follows a Johnson distribution and the process in-control times follow Pareto distribution. [3].

Branislav Tomic and et.al (2011) highlighted the major steps that should be taken successfully and permanently resolve any problem from problematic process by using root cause analysis and corrective action process [4].

Mohiuddin and et.al (2011) has used pareto chart for minimizing rejection of raw material in the lamp production process where the pareto chart have been used to identify critical areas, at each production stage, defects were identified and then prioritize and arrange it in decreasing order of importance and then use the cause

and effect diagram to explore possible causes of defects [5].

yonatan mengesha Awaj and et.al (2013) point out that the quality team should be aware how to use the statistical process control (SPC) tools in the problem analysis, especially to train quality team about how to hold an effective brainstorming session and exploit these data in construction the cause and effect diagram pareto analysis and control chart to provide significant productivity improvement in the long run [6].

Tanvir Ahmed and et.al (2013) show that Pareto chart and cause and effect diagram can be applied to improve the quality in the garment factory by minimizing defects in order to reduce rework and rejection rate [7].

Varsha M. Magar and et.al(2014) illustrated that 7 QC tools can be very helpful for quality where it provide a great process tracking and analysis [8]

Ashwini. A and et.al (2015) used Some of seven quality tools to do the rejection analysis like check sheet, Pareto chart, cause and effect diagram and control charts, where the data of defects were collected for three months by using check sheet, identification of major defect percentage using Pareto chart, finding the causes using cause an effect diagram and investigating the process is in control or not by statistical control charts. The overall rejection rate in production line was reduced from 10% to 7 % and thus the production line was able to meet the required demand [9].

Many root cause analysis techniques are available like; Seven basic Quality tools (QC7) namely, check sheet, histogram, Pareto chart, Cause and effect chart, graphical tools, scatter plot and control chart in addition to Seven new quality tools (or the seven management tools; M7) have been used as a strategy to improve the quality of production include affinity diagram, relation diagram, tree diagram, matrix diagram, matrix data analysis (prioritization matrices), Process Decision Program Chart (PDPC) and procedure diagram. By using a combination of tools and techniques [10]

In This paper, integration Pareto distribution and pareto analysis can be used efficiently to analyse data and to diagnose the defect cause root into two stages:-

Stage One: - Pareto Distribution is used to analysis the defects data to find the mean, variance and standard deviation of defects.

Stage Two:- Pareto analysis is used into three steps as a tool to diagnosis and analysis the defects type, causes of the critical defect and the root of cause of the critical cause for the air cooling motor, the steps are:-

1-The types of defects were identified by collecting data and then identified the critical defect(biggest defect).
2-Analyze the causes of defect for the biggest defect by two ways; firstly, by The Root Cause Tree Diagram to find out all the causes of this defect. Secondly, by Pareto analysis to identify the biggest cause for the biggest defect.
3-Detect the roots of the biggest cause of defect and then identify the biggest cause root for the biggest defect.

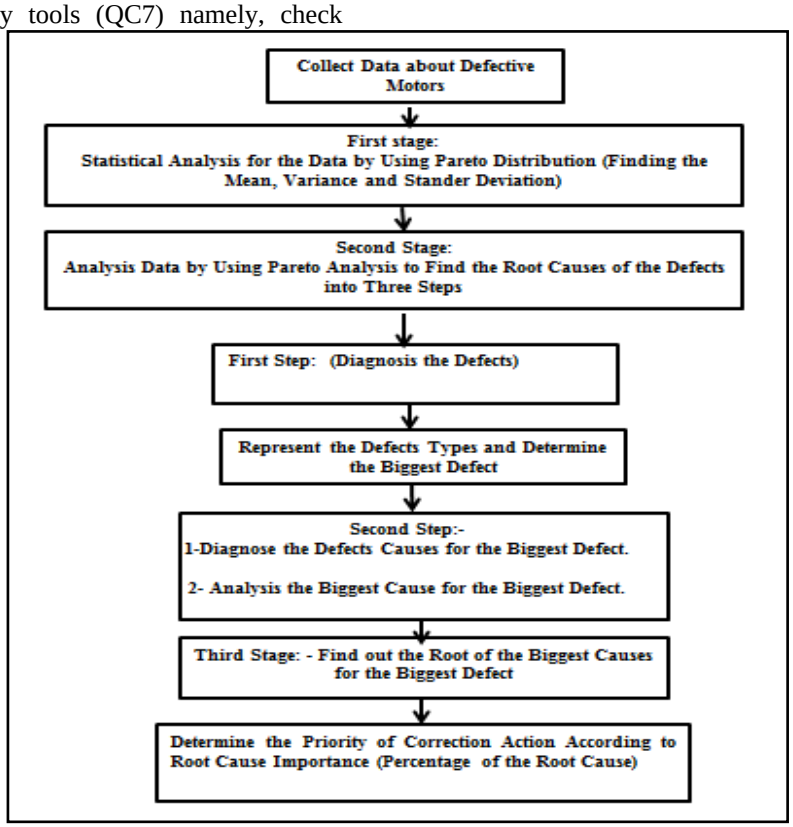

Fig 1: Methodology of the research

Many reasons can cause defects for the product; common causes are [10]-

1-Tools: process variation can occur due to the selection of wrong tool, excessive tool wear, bad tools specifications and lesser tool strength.
2- machine: process variation can occur due to bearing wear, or due to clearances between the moving parts or bad maintenance and old machines.
3- Material: process variation can occur due to lack of homogeneity in the material with sudden spots of dimensional or hardness variation, leading to excessive load on the machine**.**
4- Workers: process variation can occur due to variations in operator's skill, his training level, eyesight, physical and mental health, habits like drinking.

Causes of Fail of Quality Improvement Efforts

Many causes can fail the quality improvement such: - [1]

1- Managers may focus excessively on short term financial results.
2- Managers may blame the employees instead of themselves for quality failures.
3- Managers may believe that quality cannot be done without sacrificing the schedule or the costs.
4- Managers interfere with true teamwork. Either they do not really delegate decision-making to the team or they do not encourage the teamwork therefore the quality issue is a team responsibility.
5-Some companies fail to realize how inefficient industrial procedures and processes can affects about quality.

Practical Application

The practical Part was applied at the State Company for Electrical Industries, where the motor of air Colling was chosen Figure 2. and Table 1 show its specifications

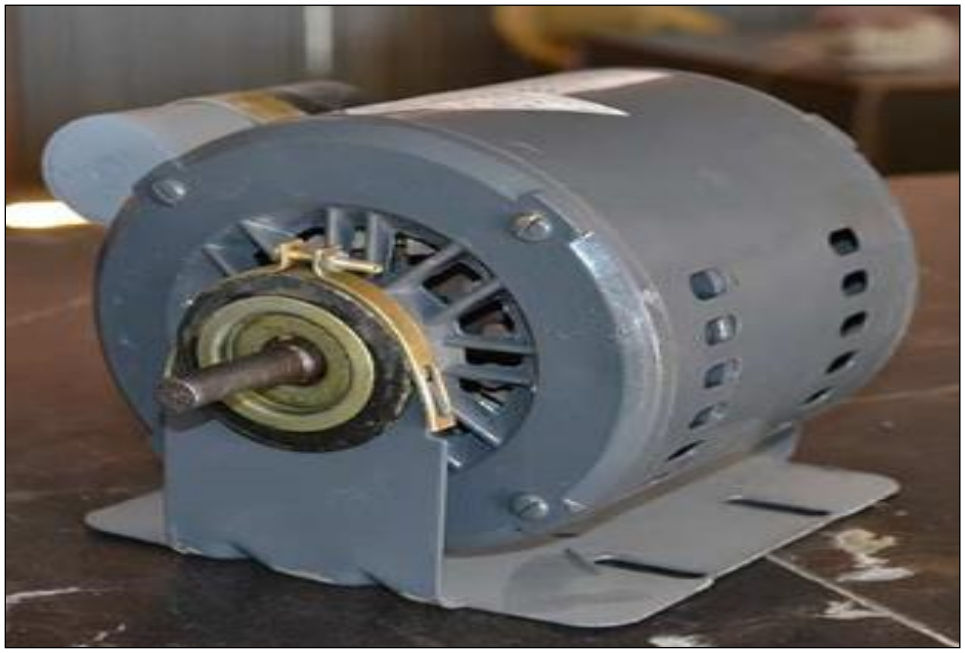

Figure 2: The motor of air Colling

Table 1 The motor specifications

Current (Amp)	(1- 1.7)
Speed(r.p.m)	1285-1370
Electricity	220v/ 50Hz
Rating	Continuous
Efficiency %	61%
Insulation class	B
Relative humidity%	95%
Power factor	More than 0.9

Power(Watt)	120-170

The motor passes through different manufacturing stages and may occur manufacturing defects in each of these stages. The company management identified four major types of defects, these are dielectric, sound, loss and Pitch as a basis for the final inspection of the product, these are:-

1- Sound defect, it is occurred by collision the router (rotated part) with the inner diameter of the stator (fixed part) during the rotation because of the difference in measurements between the bearings and the axle.
2- Dielectric defect , it is a loss of insulation material from coils wire lead to small electrical circuit.Dielectric can inspect by pass an electrical current.
3- Loss defect, it is a lack of the current flow in the primary and secondary coils because of cutting the primary and the secondary coils therefore the motor non- functioning and this defect can detect it by pass the electric current.
4- Tolerance(pitch), it is a Mismatch between the design tolerances and the design limits between the hub and the chairs or the chairs and its installation area in the cover lead to this kind of defect.

Table 1 shows the motor specifications and Table 2 types and frequency of defects during five peak months.

Table 2 Types and frequency of defects for five peak months during 2012

Defect type	Defect frequency between (1/4- 31/8)- Quantity of production= 3102 engine					
	April	May	June	July	August	Total
Sound	30	49	33	86	76	274
Dielectric	69	121	65	100	113	468
Loss	224	141	10	29	17	421
Tolarance(Pitch)	-	-	-	-	-	-
	323	311	108	215	206	1163

Data Analysis by Pareto Distribution

Data analysis by pareto distribution was done[12] by Suppose that X has the Pareto Distribution with shape parameter α >0. The density function f is given by:

$$f(x) = \begin{cases} \frac{\alpha}{X^{\alpha+1}} & x \geq 1 \\ 0 & elss\ where \end{cases}$$

And the **mean** and the **variance** can give as:

$$E(X) = \frac{\alpha}{\alpha-1} \quad if\ \alpha > 0 \qquad (1)$$

$$var(X) = \frac{\alpha}{(\alpha-1)^2(\alpha-2)} \quad if\ \alpha > 2 \qquad (2)$$

We can find the standard deviation from the variance as the following:

$$\sigma = S(x) = \sqrt{var(X)} \qquad (3)$$

The parameter α of the Pareto distribution can find it by using relationship between mean and α as the follow:

$$E(x) = \bar{X}$$

Calculations of the Pareto Distribution

Calculations of the Pareto Distribution have been done by calculate:-

Firstly, the mean of the five peak months for each defect as follow:-

$$\bar{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

Form equation 1 we can find α as the following:

$$\therefore \quad \frac{\sum_{i=1}^{n} Xi}{n} = \frac{\alpha}{\alpha - 1}$$

$$where \quad \alpha n = \sum_{i=1}^{n} Xi \ (\alpha - 1)$$

$$\alpha n = \alpha \sum_{i=1}^{n} Xi - \sum_{i=1}^{n} Xi$$

$$\alpha n - \alpha n\bar{X} = -n\bar{X}$$

$$\alpha = \frac{\bar{X}}{\bar{X}-1} \qquad (4)$$

$$\bar{X}_{sound} = \frac{X_1+X_2+X_3+X_4+X_5}{5} = \frac{274}{5} = 54.8$$

$$\bar{X}_{Dielectric} = \frac{X_1+X_2+X_3+X_4+X_5}{5} = \frac{468}{5} = 93.6$$

$$\bar{X}_{Loss} = \frac{X_1+X_2+X_3+X_4+X_5}{5} = \frac{421}{5} = 84.2$$

Where:-

$\bar{X}$ = The mean of sound, Dielectric and loss defects.

x_1 = defects number at April.
x_2= defects number at May.
x_3 = defects number at June.
x_4 = defects number at July.
X_5 = defects number at August.

Secondly, Alfa α parameter was calculated as follow

$$\alpha_{sound} = \frac{\bar{X}_{sound}}{\bar{X}_{sound}-1} = 0.982 \approx 1$$

$$\alpha_{Dielectric} = \frac{\bar{X}_{Dielectric}}{\bar{X}_{Dielectric}-1} = 0.981 \approx 1$$

$$\alpha_{Loss} = \frac{\bar{X}_{Loss}}{\bar{X}_{Loss}-1} = 0.988 \approx 1$$

Finally, the standard deviation and variance are calculated

$$\sigma_{sound} = \sqrt{\frac{\sum_{i=1}^{5} Xi^2 - n\bar{X}^2_{sound}}{n-1}} = 25.233$$

$$\sigma_{Dielectric} = \sqrt{\frac{\sum_{i=1}^{5} Xi^2 - n\bar{X}^2_{sound}}{n-1}} = 25.45$$

$$\sigma_{Loss} = \sqrt{\frac{\sum_{i=1}^{5} Xi^2 - n\bar{X}^2_{sound}}{n-1}} = 94.66$$

Where the variance is the square of standard deviation:

$$Var_{(sound)} = (\sigma_{sound})^2 = 636.7$$

$$Var_{(Dielectric)} = (\sigma_{Dielectric})^2 = 647.8$$

$$Var_{(loss)} = (\sigma_{loss})^2 = 8959.7$$

Table 3 The mean, variance and standard deviation for the types of Defects.

Scales	Sound	Dielectric	Loss
Mean	54.8	93.6	84.2
Variance	636.7	647.8	8959.7
Standard Deviation	25.23	25.45	94.66

Pareto Analysis to diagnose roots cause of defect

The defect type, cause and root analysis was done into three steps, these steps are:-

Stage one: - (Diagnosis the defects types), table (3):-

1 - Percentage of defect % (for each defect):- this can b e done by using percentage formulation.

Percentage of defect % = [Frequency of Defect / summation of defect]*100%

Percentage of sound defect %= 274/1163=36.1
2-Cumulative of the Percentage defects can calculate as follow:-
Cumulative of defects =cumulative of current percentage + cumulative of the Previous percentage
Cumulative of loss defects= 36.19+40.24=76.45
Figure 3. is shown the result of this step

Table 4 Show defects types

Defect type	Percentage %	Cumulative %
Dielectric	40.24	40.24
Loss	36.19	76.45
Sound	23.55	100
Pitch	0	100

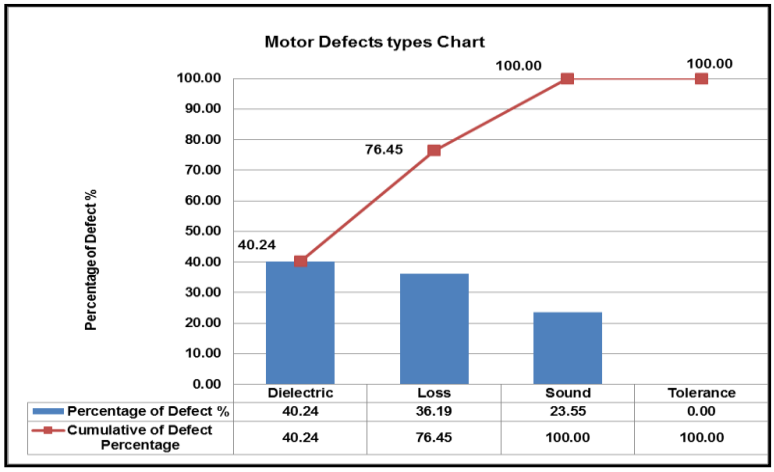

Figure 3: Diagnose the defects types

Step two: - (Diagnosis the causes). it was done by two tools:-

1- The Root Cause Tree Diagram was used to identify all causes roots that causes of the Dielectric defects to help company to propose the possible corrective actions, Figure 4.

2- Pareto Analysis was used to find out the biggest cause root for the biggest defect by calculate:-

1- Percentage of cause% (for each cause) = [Frequency of cause / total cause]*100%

2- Cumulative =cumulative of current percentage + cumulative of the Previous percentage.

The result of this stage is shown in Table 4.

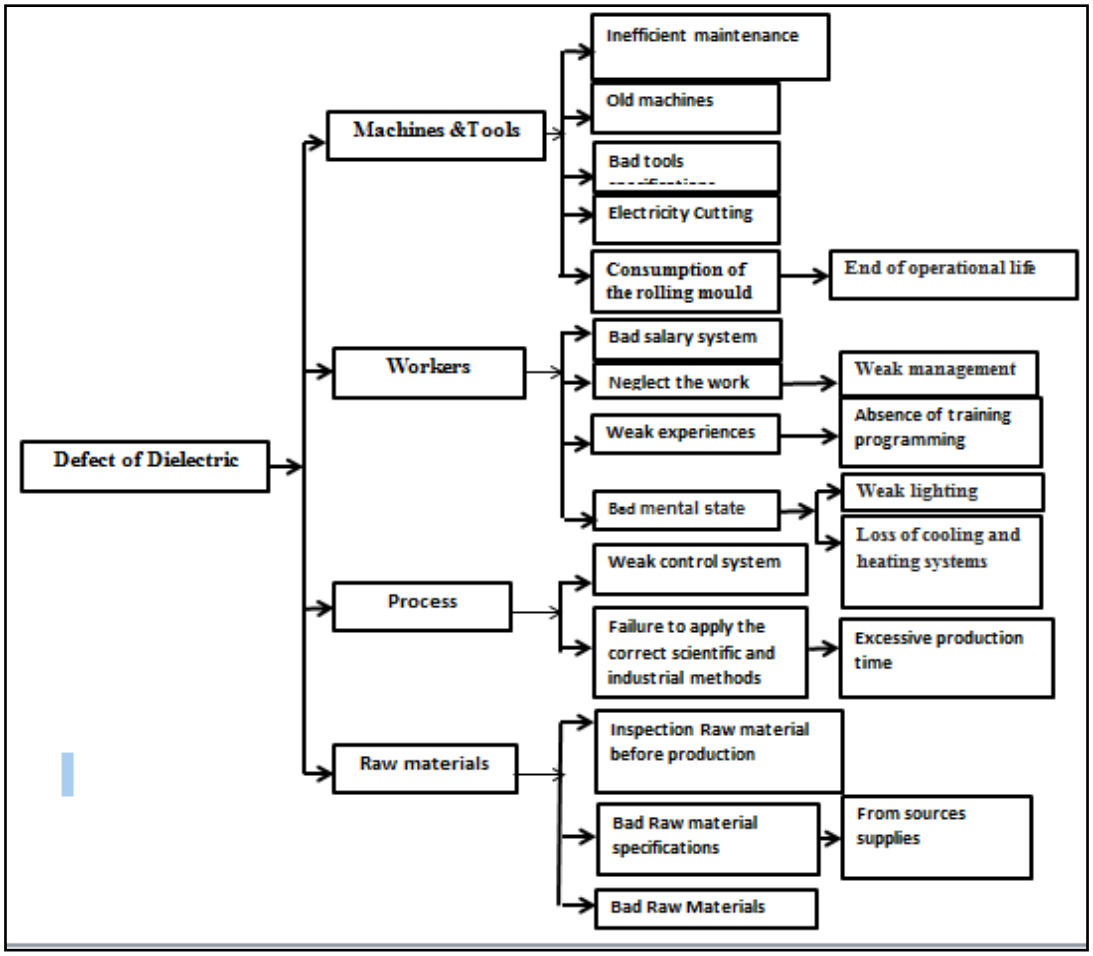

Figure 4: The root causes of Dielectric Defect

Table 4: Show defects causes for crucial defect

Defect Causes	Percentage %	Cumulative %
Machine	**50**	**50**
Process	**25**	**75**
Workers	**15**	**90**
Raw Material	**10**	**100**

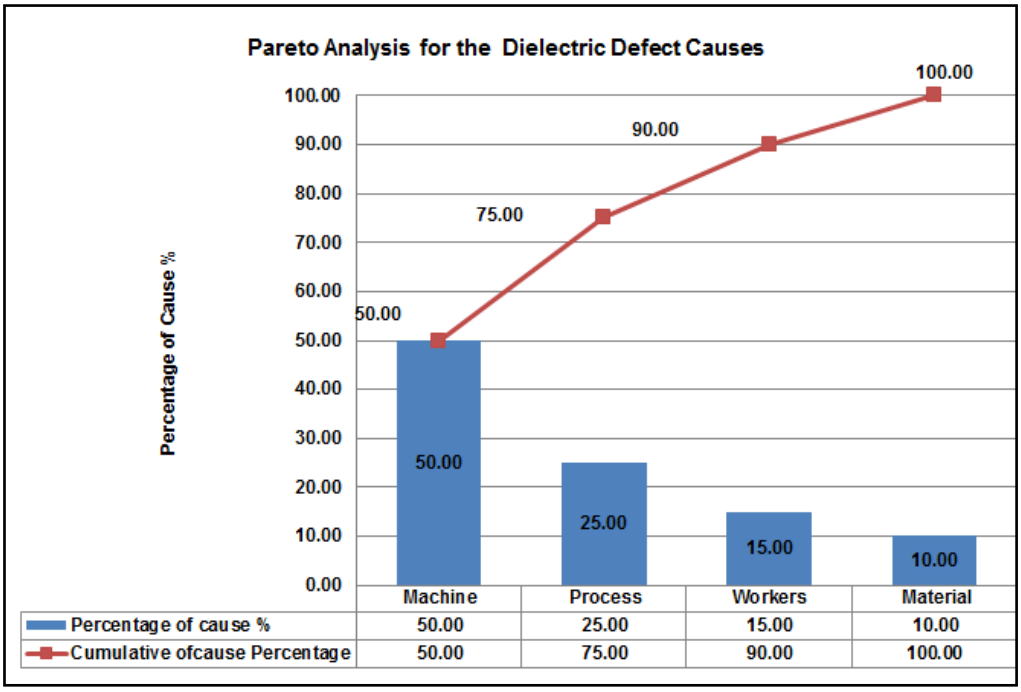

Figure 4: The dielectric defects causes

Step three: - (Diagnosis the Roots of the crucial cause), Table 5, Figure 5.

Pareto Analysis was done to find out the biggest cause root for the biggest defect by calculate

1- Percentage of cause% (for each cause) = [Frequency of cause / total cause]*100%

2- Cumulative =cumulative of current percentage + cumulative of the Previous percentage

The cause roots analysis was shown at fig (5).

Table 5 Show Roots cause for crucial cause

Cause Roots of dielectric Defect	Percentage %	Cumulative %
Consumption of roll mold	40	40
Old Machine	25	65
Inefficient Maintenance	15	80
Bad Tools Specifications	15	95
Electricity cutting	5	100

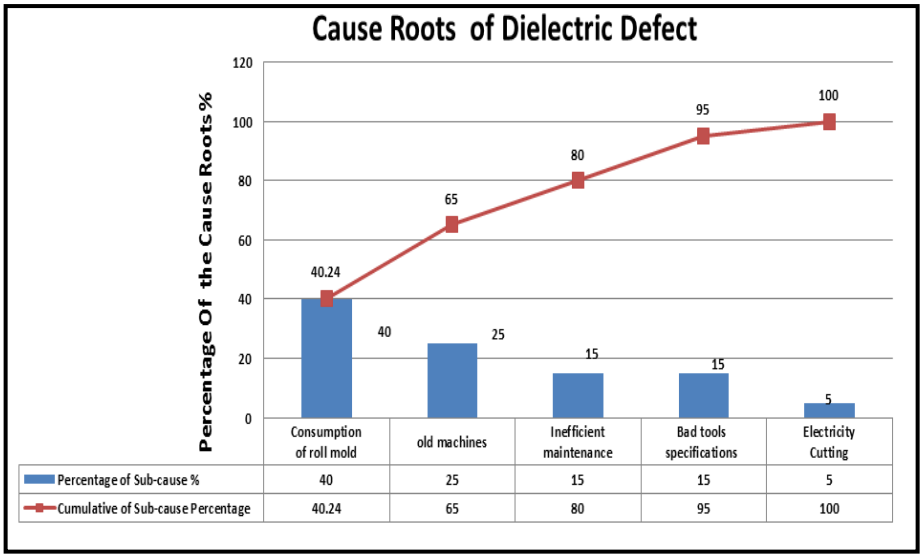

Figure 5: The cause roots of dielectric defect

Discussions the results

The inspection and quality control department in the state company for electrical products has been determined four main defects as a base to accept or reject the final products, these defects are: Sound, Dielectric, Loss and Tolerance.

The data about defected products were collected for five peak months , namely April, May, June, July and August in 2013 for Quantity of production=3102 motors.

Integration Pareto distribution and Pareto analysis have been used to analysis data and to diagnosis the defect cause root into two stages.

The Pareto Distribution is used at stage one to analysis the defects data to find the mean, variance and standard deviation, where at stage two the Pareto analysis is used into three steps as a tool to diagnosis and analysis the defects type, causes of the critical defect and the root of cause of the critical cause for the air cooling motor.

The Pareto distribution was illustrated that Dielectric defect has the highest mean between (54.8-93.6),this indicate that the number of defects may increase during next months if the defects causes and roots of defect cause are not eliminated, corrected or if possible decreased. But the Variance of defects is between (636.7-8959.7) so, this means the defects were occurred decreasely and increasly in variant form during these months. The loss defect has the highest variance and standard deviation, table (3).

The α parameter of Pareto distribution is calculated and it is approximately one (1) so, this mean the defects are approximately fixed during the five months in addition to the defects causes are not eliminated or corrected.

Firstly, the data about types and frequency of defects was presented by using pareto Analysis, fig (3) where the Dielectric defect is the biggest defect that appears during the product final inspection 40.24% then 36.19% for sound then 23.55% for loss and finally 0% for tolerance (pitch).

The second step was illustrated that the causes that lead to occurred the biggest defect (Dielectric). The Roots Cause Tree Diagram was used to clarify all the causes of Dielectric defect and Finally, pareto was used to find out the biggest cause root for the Dielectric defect, where each cause took numerical number as a weight to show the impact of each one. The main causes of Dielectric defect were Machine, Process, Workers and Material. The defect cause root analysis show that the machines are responsible for 50% of the biggest defect that determine at Step one and the consumption of the rolling mold is the cause root of this problem as shown at fig (5). The rolling mould in the rolling machine was used to rollthe primary and secondary copper wire and any problems in this mold will lead to occur defect.

The Root Cause Tree Diagram was illustrate deeply all causes roots of the Dielectric defect to help the company to know more about all causes roots for the biggest defects.

Conclusions

1- The industrial organization work seriously to produce satisfied quality products to satisfy the customer needs.
2- The Pareto distribution is used to analysis the data about the defective motors to find the mean, variance, and standard deviation.
3- Dielectric defect has the highest mean but loss defect

has the highest variance and standard deviation.

4- The parameter of Pareto distribution is calculated and it is approximately one (1).

5- Pareto analysis as an analytical tool can be Helped Company to determine the defects types and then diagnosis the biggest defect causes and the roots cause of it.

6- Production of five peak months was chosen because the customer needs increase during summer months, so these months represent the peak production that may clearly clarify the defects size.

7- Dielectric, sound, loss and Pitch have been identified as four major types of defects basis for the final inspection of the product.

8- The tolerance (pitch) defect did not occur during took data for this research, so it did not consider and calculate both by Pareto distribution and Pareto analysis.

9- The Root Cause Tree Diagram can help company to know all the causes and cause roots of the biggest defect (dielectric defect) to take any necessary corrective actions that will minimize the defect products for biggest defect.

10- The rolling mould in the rolling machine was used to roll the primary and secondary copper wire and any problems in this mould will lead to occur defect.

Recommendations

1- Using the modern quality procedures to measure the product quality at the company to avoid defective products like seven quality tools, statistical tools and TQM.

2- Maintain the machine and use suitable maintenance police to avoid or minimize any incorrect machine work and check continuously the rolling mold.

3- Work as a team and make the product quality responsible all level of company.

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