

# Implementation of FMECA and Fishbone Techniques in Reliability Centred Maintenance Planning

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**ABSTRACT:** The paper presents the implementation of failure mode effect and criticality analysis (FMECA) and fishbone techniques to possibility of failure occurring by studying all parts of machine and expects the failure for it and takes a preventive action for it. Fish bone is an important tool because it depends on studying by brain storming all expected possible reasons for these failures and take a corrective action for these failures. FMECA and fish bone techniques are helping maintenance team of any factory by reducing the chances of catastrophic failure that can result in injuries, and optimizing maintenance efforts by suggesting applicable and effective preventive maintenance task for potential failure modes or a corrective action for a fish bone technique. The performed application on tubing line of glass bulb factory is because of its tendency of having frequent breakdowns and mal-functioning. This in turn, has an impact on the production rates and continuity and finally affects the final product of the factory. The detection rating to the failure mode, the values of risk priority number and revised risk priority number are calculated. Global corrective actions are suggested to improve risk priority number and revised risk priority number.

**KEYWORDS:** FMECA, RPN, Fish bone, Glass Manufacturing.

## I. INTRODUCTION

Failure mode, effect and criticality analysis is called (FMECA) which is defined as a reliability evaluation technique which examine the potential failure modes with in a system and its equipment. Initially, the FMECA was called FMEA (failure mode and effect analysis). The FMECA is composed of two separate analyses, the failure mode and effect analysis (FMEA) and the criticality analysis (CA). FMECA is a technique used to identify, prioritize, and eliminate potential failures from the system, design or process before they reach the customer [omdahl 1988]. It is a technique to resolve potential problem in a system before they occur [sematech 1992]. The required information to perform an FMECA includes, in the case of design-related information, equipment and part drawings; functional block diagrams, design descriptions and design-change history, system schematics, narrative descriptions, operating specifications and limits and configuration management data [1, 2].

## II. RELATED WORK

Oldenhof et al [17] studied consistency of FMEA that was used in the validation of analytical procedures. An FMEA was carried out by two different teams. The two teams applied FMEA to suspected illegal medicines in order to detect pharmaceutical crime. Each team was free to define their own ranking scales for the probability of severity (S), occurrence (O), and detection (D) of failure modes and then calculated Risk Priority Number (RPN). They concluded that the outcome of the two FMEA clearly showed inconsistency. These differences can be partially explained by different approach chosen by the teams within FMEA frame work. The consistency can be improved by developing

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the skills of a small number of experienced facilitators who can help analysts to use FMEA more effectively on definition of failure modes and rating of severity and probability. Moreover, at least, two technical experts should be included in FMEA team to balance out significant individual differences in these crucial judgments.

Application of FMEA-FTA (failure tree analysis) in reliability-centered maintenance planning was applied to a large sized axial plunger pump in an Egyptian fertilizers production plant that was studied by Abdel-Aziz et.al [18]. The main components of the pump of ammonia plant were pump motor, stuffing box, oil tank, filter, crank shaft oil, bearing, pump nozzle, gear box, suction valve, and discharge valve. The methodology of FMEA was to define functional failure, identify the failure mode, determine causes of failure, determine effects of failure, evaluate the severity, evaluate the occurrence, evaluate the detectability and then calculate RPN. FTA was normally used to discover the root-causes of failure, determined what would happen to the system if the status of a part in it is altered. They found that the two techniques, FMEA and FTA, have complementary importance for the evaluation of potential failures in the plunger pump, and can complement each other in support of equipment reliability and availability studies.

### III. ANALYSIS TOOLS

When the problems occur, use the tools to understand and gain insight into causes before making changes based on assumption. There are many tools to help us in solving problems and making the analysis to know the root cause of each problem. To take the suitable action for preventing the problem occurrence or reducing the breakdown failure, we should use the analysis tools such as brainstorming, cause and effect diagram, Pareto chart, and five-whys [14, 15].

### IV. BRAIN STORMING

It is a simple way to generate a large number of ideas from a group of people in relatively short period of time. Brain storming is one of the most well –known tools for creative thinking. There are steps to perform brain storming, first, write the problem on a board or flip chart or a large piece of paper, choose a team of leaders which called brain storming team consisted of 8 to 12 members, then assemble the team around the chart, after that quickly write down anything about the problem that comes to your mind in the chart until all team members write all ideas in their minds, and finally organize the ideas by eliminating those that are not useful and taking note of those that are most important for our problem [15, 16].

### V. FMECA

Some of the benefits of conducting FMEA are Increase customer satisfaction by improving safety and reliability, Improve development efficiency in terms of time and cost by solving reliability and manufacturing problems during design stages. FMECA is helping maintenance team of any factory by reducing the chances of catastrophic failure that can result in injuries, and optimizing maintenance efforts by suggesting applicable and effective preventive maintenance task for potential failure modes. Generally, there are four types of FMECA; system, design, process, and service FMECA; System FMECA focuses on global system functions, Design FMECA focuses on components and sub-systems, Process FMECA focuses on manufacturing and assembly processes, and Service FMECA focuses on service functions [3].

### VI. FMECA METHODOLOGY

A typical FMECA process is a proactive methodology that follows the following typical steps; first select a high –risk process, then review the process, this step usually involves a carefully selected team that includes people with various job responsibilities and levels of experiences. After that make a brainstorm of potential failure modes, identify the root causes of failure modes, then list potential effects of each failure mode, and assign severity, occurrence, and detection ratings for each effect, then calculate the risk priority number (RPN) for each effect, then prioritize the failure modes for

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action using RPN, then take action to eliminate or reduce the high-risk failure modes, finally calculate the resulting RPN as the failure modes are reduced or eliminated as a mean of monitoring the redesigned improved product or process[2].

Severity (S) is defined as the assessment of the seriousness of the effect of the potential failure mode. In this step, we have to determine all failure modes based on the functional requirements and their effects. Occurrence (O) is defined as the chance that one of the specific cause mechanisms will occur. In this step, it is necessary to look at the cause of a failure and how many times it occurs. Detection (D) is defined as an assessment of the probability that the current process control will detect a potential weakness or subsequent failure mode before failure mode the part or component leaves the manufacturing operation or assembly location. RPN is defined as the indicator for determining proper corrective action on the failure modes. It is calculated by multiplying the severity, occurrence, and detection ranking levels resulting in a scale from 1 to 64. After deciding the severity, occurrence, and detection numbers, the RPN can be easily calculated by multiplying these 3 numbers as shown in equation (1). S, O and D criteria is presented in tables (1, 2 and 3) according to the nature of glass industry with a simple form.

$$RPN=S*O*D \tag{1}$$

The small RPN is always better than the high RPN. Once it is calculated, it is easy to determine the greatest concern areas. The engineering team generates the RPN and focused on the solution of failure modes [4]. The objectives of FMECA are to identify potential design and process failures before they occur and to minimize the risk of failure by either proposing design changes or, if these cannot be formulated, proposing operational procedures.

Table (1) Proposed Severity criteria

| Severity likelihood                  | Severity rank |
|--------------------------------------|---------------|
| Injury or death (safety effect)      | 4             |
| System fail (company fail)           | 3             |
| System down time (production effect) | 2             |
| No effect                            | 1             |

Table (2) Proposed Occurrence criteria

| Occurrence likelihood           | Occurrence rank |
|---------------------------------|-----------------|
| Very high ( inevitable failure) | 4               |
| High ( repeatable failure)      | 3               |
| Medium (few occurrence)         | 2               |
| Low (unlikely failure)          | 1               |

Table (3) Proposed Detection criteria

| Detection likelihood                                     | Detection rank |
|--|----------------|
| No design technique available / controls with not detect | 4              |
| Design controls have a poor chance of detection          | 3              |
| High probability of detection                            | 2              |
| Easy detection   | 1              |

Essentially the FMECA is to Identify the equipment or subsystem, mode of operation and the equipment; Identify potential failure modes and their causes; Evaluate the effects on the system of each failure mode; Identify measures for

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eliminating or reducing the risks associated with each failure mode; Provide information to the operators and maintainers so that they understand the capabilities and limitations of the system to achieve best performance. The standard FMECA work sheet is shown in table 4 [5].

Table (4) Standard FMECA work sheet

| potential Failure Mode | Potential Effect(s) of Failure | Severity | Potential Cause(s) Of Failure | Occurrence | Present detection system | Detection | RPN | Results             |     |     |     |     |  |  |
|------------------------|--------------------------------|----------|-------------------------------|------------|--------------------------|-----------|-----|---------------------|-----|-----|-----|-----|--|--|
|                        |                                |          |                               |            |                          |           |     | Recommended Actions | Sev | Occ | Det | RPN |  |  |
|                        |                                |          |                               |            |                          |           |     |                     |     |     |     |     |  |  |

Failure is defined as the inability of any asset to do what its users want it to do; functional failure is defined as the inability of any asset to fulfill a function to a standard of performance which is acceptable to the user. failure mode is defined as a design failure is the manner in which a system, subsystem, or part fails to meet its intended purpose or function, effect of failure mode is describe what happens when a failure mode occurs, causes of failure is defined as root causes of the failure. Recommended action is defined as the action required to prevent the potential failure, detection mean is defined as the way to detect or predict the failure before it occurred. Revised detection (RD) is defined as a value entered in the action results detection field when the recommended action is completed and the action has improved the detection of the failure mode or cause. Revised occurrence (RO) is defined as a value entered in the action results occurrence field when the recommended action is completed and the action has reduced the likelihood that this cause will occur and generate the failure mode. Revised severity (RS) is defined as a value entered in the action results severity field when the recommended action is completed and the action had reduced the severity of the failure mode, and revised risk priority number (RRPN) is a value from 1 to 64 after completed the recommended action [6]. To fill this work sheet , there are many definitions must be known such as component that is defined as the identification of each part belonged to the system, component function is defined as an accurate description of the task that the component must execute , functional failure is defined as the description of all the possible failures to each component, potential failure mode is defined as the description of the form as the failure is observed by the operation team , potential failure effect is defined as the consequence of a failure on the operation function, or status of a component. Severity is defined as the consequence of the failure when it happens, potential causes of failure is defined as the most probable causes associated with potential failure modes, occurrence is defined as the probability or frequency of the failure occurring, detection is defined as the probability of failure being detected before the impact of the effect is realized, RPN is defined as the indicator for the determining proper corrective action on the failure mode, recommended action is defined as the action recommended reducing the possibility of occurrence of the failure mode, reducing the severity if failure mode occurs, or improve the detection capability should the failure mode occur, while the risk priority number after taken the recommended action is called RRPN [1, 7, 8].

$$RRPN=RSXROXRD$$

(2)

## VII. CAUSE AND EFFECT DIAGRAM

Cause and effect analysis helps you to think through the causes of a problem, including possible root causes not just symptoms. It is only by identifying the main causes that you can permanently remove the problem [9]. A cause and effect diagram (also known as Ishikawa diagram or fish bone diagram). In this study every effect is considered a “problem” there are likely to be several causes. They can be classified under men, methods, materials, machines, policies, procedures, plant. These categories are only suggestions. You may use any category that emerges or helps people think creatively [10].

Root cause analysis is a process of tracking down the sources of variation to identify the key sources that are causing the problem. These root causes when eliminated or changed, will make the biggest impact toward solving the problem. To apply the cause and effect diagram we must take many actions such as: Also draw a long line with a large arrow pointing it. Then develop a list of factors that could be causing or contributing to the problem and recording the

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possible causes of the problems. Then select the major categories that are appropriate for the team's diagram. The standard categories that are generic to most problems are 4Ms or 4Ps or a combination of them. The 4Ms are machines, methods, materials, and manpower (people). The 4Ps are policies, procedures, people, and plant (equipment) [11]. Cause and effect diagram is an effective tool for problem solving process, also known as the Ishikawa diagram or fish bone diagram. As shown in figure (1), the effect is written in a rectangle on the right hand side, and the causes are listed on the left side. 5M1E is a method of constructing cause and effect diagram consisting of (man, machine, material, method, measurement, and environment) [12].

## VIII. ROOT CAUSE FAILURE ANALYSIS (RCFA)

RCFA is a step by step method used to analyze failures and problems down to their root cause. Every equipment failure happens for a number of reasons. There is a definite progression of actions and consequences that lead to a failure. A root cause analysis investigation traces the causes and effect trail from the end failure back to the root cause in order to determine what happened, why it happened, and more importantly figure out what to do to reduce the likelihood that it will happen again. The process of analyzing the root cause of failures and acting to eliminate these causes is one of the most powerful tools in improving plant reliability and performance [1]. RCA is a tool designed to help to identify not only what and how an event occurred, but also why it happened. Only when investigators are able to determine why an event or failure occurred will they be able to specify workable corrective measures that prevent future events of the type observed. Usually, RCA has got mixed with the accurate description of what happened and how it happened. However, if the analysis stop there, it is not enough to understand the reasons for the problem. Therefore, it is not known what to do to prevent it from occurring again. Identifying root causes is the key to preventing similar recurrences. Corrective action is an action that organization should take to eliminate the root cause of nonconformities in order to prevent recurrence.

In other words, corrective action is a process of identification and elimination of the root causes of a problem, thus preventing its reoccurrence.

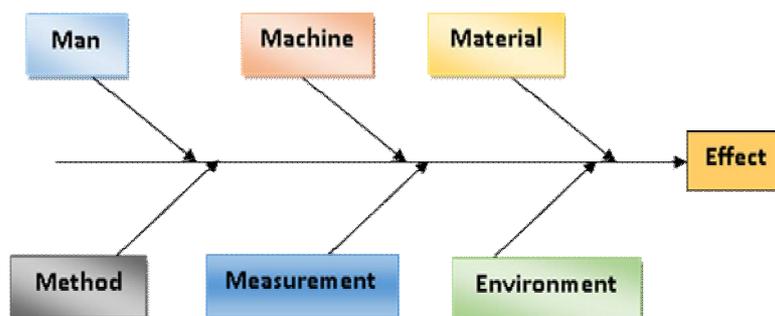


Fig. (1) Fish bone Method (5M1E).

## IX. RELIABILITY CENTERED MAINTENANCE (RCM)

RCM is a method for maintenance planning, developed within the aircraft industry and later was adapted to several other industries and military branches [15]. RCM combines reactive, preventive, predictive, and proactive maintenance practices and strategies to maximize the life of a piece of equipment that functions in the required manner at minimal cost [16]. The RCM analysis may be carried out as a sequence of activities or steps, some of which are overlapping in time. These steps include FMECA and RCFA, so RCM is the integrated methodology which connects the FMECA and Fish bone techniques in its steps of application [13].

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## X. CASE STUDY

This present study has been applied for Toshiba El-Araby bulb glass factory – Quesna-Kofor El-Raml –Moubark Industrial City-3rd Zone-Monfiya-Egypt. The product of the company is glass bulb (florescent tubes) with many sizes and specifications. The final product is florescent tubes for a bulb glass factory as a transparent bulb glass, after that is transferred to the lamp factory to charging, coating it and finalized the florescent lamp as a final product. It is the first line for production the florescent tube, it produces a semi product. Tubing line is consists of many processes such as

- Rough cutting process & cooling process.
- Re cutting process.
- Glazing process.
- Cooling process.
- Center cutting and glazing process.
- Inspection process.

The process flow diagram of tubing line is illustrated in figure (2).

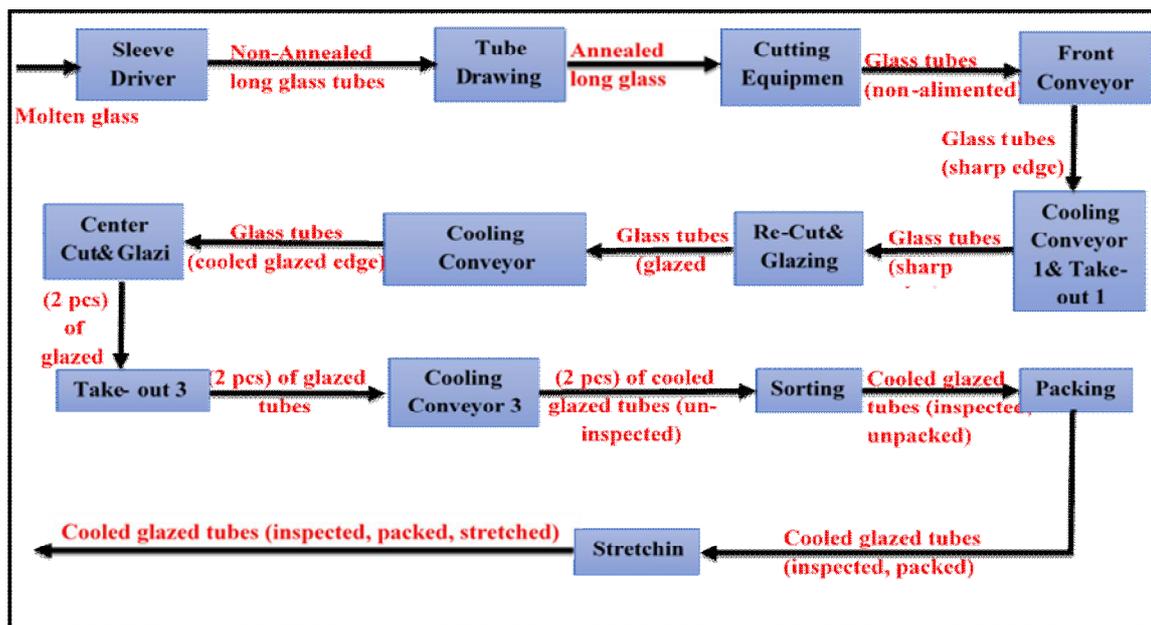


Fig. (2) Process flow diagram for tubing line.

## XI. FAILURE CODING SYSTEM

Failure coding system is very important to build a full data base for all failures which occurred with an accurate description for failure. Coding system must be easy understand. To make this coding system should be known first the structure of the machine and divide it into sub-system and then divide sub system into mechanism then divide mechanism in components then divide component into parts , and finally divide parts into small items to cover all item in the machine by this coding system.

## XII. CRITICALITY ANALYSIS

Criticality analysis is a tool used to evaluate how equipment failures impact organization performance as it systematically ranks plant for the purpose of work prioritization by using TPM method of calculating the criticality of

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equipment. Table (5) shows the criticality of tubing line (TL). In this method, dividing the machines into group has the same properties and has the same effect on safety, production, and quality. Group (1) includes sleeve driver only, Group (2) includes tube drawing, and cutting equipment. Group (3) includes machines from front conveyor to take out 3. Group (4) includes sorting, packing, and stretching machine. Group (5) includes all utilities that serve the tubing line.

Table (5) Ranking of criticality for tubing line

| Classification                                     | No | Evaluation   | Evaluation points |   |   |   | G1       | G2       | G3       | G4       | G5       |
|--|----|--|-------------------|---|---|---|----------|----------|----------|----------|----------|
|  |    |  | 5                 | 4 | 2 | 1 |          |          |          |          |          |
| <b>Production (PD)</b>                             | 1  | Average level of operation   | 5                 | 4 | 2 | 1 | 5        | 5        | 5        | 5        | 5        |
|  | 2  | Availability of a spare machine or alternate machine, and the easy of switchover |                   | 4 | 2 | 1 | 4        | 4        | 4        | 2        | 2        |
|  | 3  | Impact of a failure on other equipment   | 5                 | 4 | 2 | 1 | 5        | 5        | 5        | 1        | 5        |
|  | 4  | Frequency of failure   |                   | 4 | 2 | 1 | 1        | 1        | 1        | 1        | 1        |
|  | 5  | Down time for repairing failures   |                   | 4 | 2 | 1 | 2        | 2        | 1        | 1        | 2        |
| <b>Quality (Q)</b>                                 | 6  | Product fabrication process capability   | 5                 | 4 | 2 | 1 | 2        | 2        | 2        | 2        | 2        |
| <b>Cost (C)</b>                                    | 7  | Failure cost   |                   | 4 | 2 | 1 | 4        | 1        | 1        | 1        | 4        |
|  | 8  | Total repair cost  |                   | 4 | 2 | 1 | 4        | 1        | 1        | 1        | 2        |
| <b>Safety (SM)</b>                                 | 9  | Risk of a failure causing injury   | 5                 | 4 | 2 | 1 | 5        | 1        | 1        | 1        | 5        |
|  | 10 | Risk of a failure causing pollution  | 5                 | 4 | 2 | 1 | 4        | 1        | 1        | 1        | 4        |
| Total points                                       |    |  |                   |   |   |   | 36       | 23       | 22       | 16       | 32       |
| Total evaluation                                   |    |  |                   |   |   |   | <b>A</b> | <b>B</b> | <b>B</b> | <b>C</b> | <b>A</b> |
| Note General equipment A=45-29 & B=28-19 & C=18-10 |    |  |                   |   |   |   |          |          |          |          |          |
| Note Integrated line A=41-27 & B=26-18 & C=17-10   |    |  |                   |   |   |   |          |          |          |          |          |

### XIII. EXPERIMENTAL RESULTS

Table (6) showing the FMECA applied on the case study. The main causes and sub causes are identified usually using brain storming such as in Fish bone applied on figures from (3) to (9).

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Table (6) FMECA for tubing line

| Potential Failure Mode                                  | Potential Effect (s) of Failure                         | Severity | Potential Cause (S) of Failure                                | Occurrence | Present Detection System | Detection | RPN | Results   |      |      |      |      |
|---|---|----------|---|------------|--------------------------|-----------|-----|---|------|------|------|------|
|   |   |          |   |            |                          |           |     | Recommended Actions   | Sev. | Occ. | Det. | RRPN |
| Broken attachment (PR-TL-FC-BK-B)                       | Produce a product with defect                           | 2        | No training in maintenance methods                            | 2          | Visual                   | 1         | 4   | Training on maintenance program and production method                             | 2    | 1    | 1    | 2    |
| Stopping of plain belt (PR-TL-RCG-PB-ST)                | Bad product produced                                    | 2        | Motor overload  | 2          | Visual                   | 1         | 4   | Measuring the current every shift and make cooling for motors                     | 2    | 1    | 1    | 2    |
| Clogged of piping line of rough cutter (PR-TL-RC-P-PLC) | Bad production (product effect)                         | 1        | Bad maintenance performed. Impurities or wear in piping line. | 2          | Visual                   | 1         | 2   | Make chemical treatment for water   | 1    | 1    | 1    | 1    |
| Air in piping line of pump (PR-TL-RC-P-A)               | Bad production (product effect)                         | 1        | Bad check list performed                                      | 2          | Visual                   | 1         | 2   | -Make a tightening cycle. Change a frequency of tightening in maintenance program | 1    | 1    | 1    | 1    |
| Sound in alignment motor (PR-TL-FC-AM-S)                | Produce a product with defect                           | 2        | Bearing failure of motor                                      | 2          | Visual                   | 1         | 4   | Make a frequency for bearing change   | 2    | 1    | 1    | 2    |
| Bearing failure of plain belt (PR-TL-RCG-PB-B)          | Plain belt stopped overload or plain belt motor stopped | 2        | Impurities with grease of bearing or surrounding              | 2          | Visual                   | 1         | 4   | Installation of dust collector in production area                                 | 2    | 1    | 1    | 2    |
| Elongation plain belt (PR-TL-RCG-PB-E)                  | Overload or plain belt motor stopped                    | 2        | - High temperature of surrounding.<br>- Over tension of belt  | 2          | Visual                   | 1         | 4   | Make ventilation in production area   | 2    | 1    | 1    | 2    |

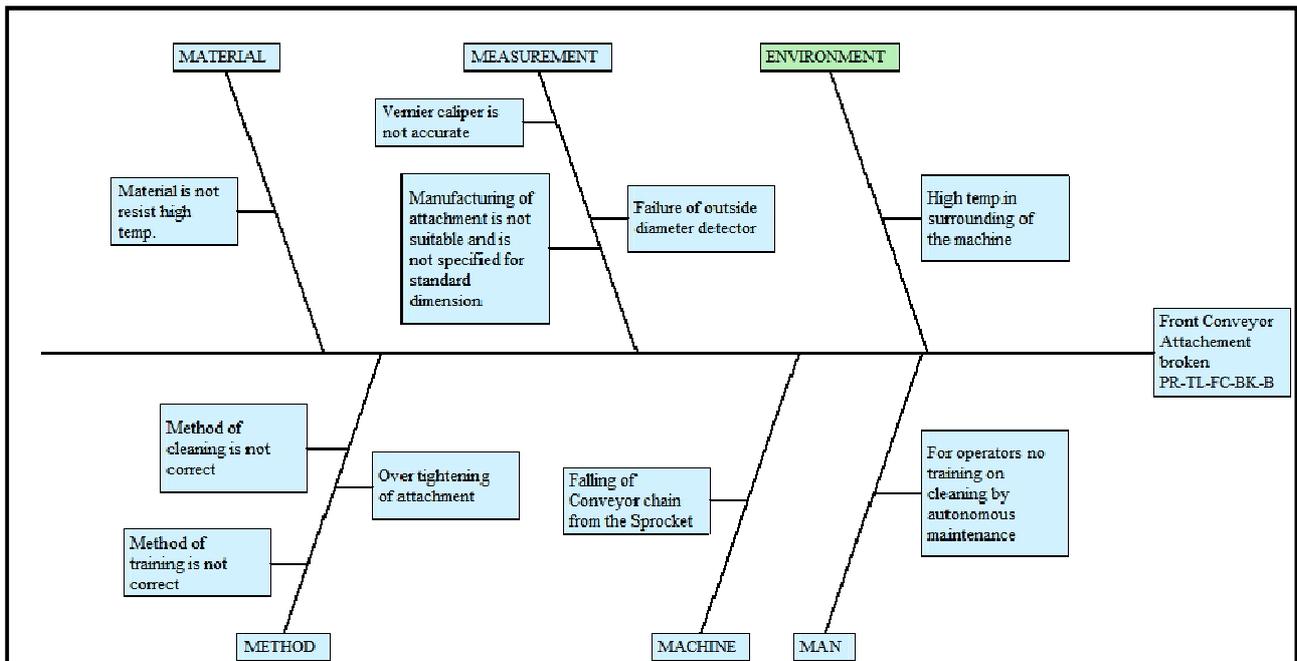


Fig. (3) Fish bone of failure code (PR-TL-FC-BK-B)

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Figure (3) shows the fish bone diagram of the failure code (PR-TL-FC-BK-B), so many reasons for this failure must be studied, such as material is not resist high temperature or manpower did not perform autonomous maintenance or man power did not train on maintenance practices.

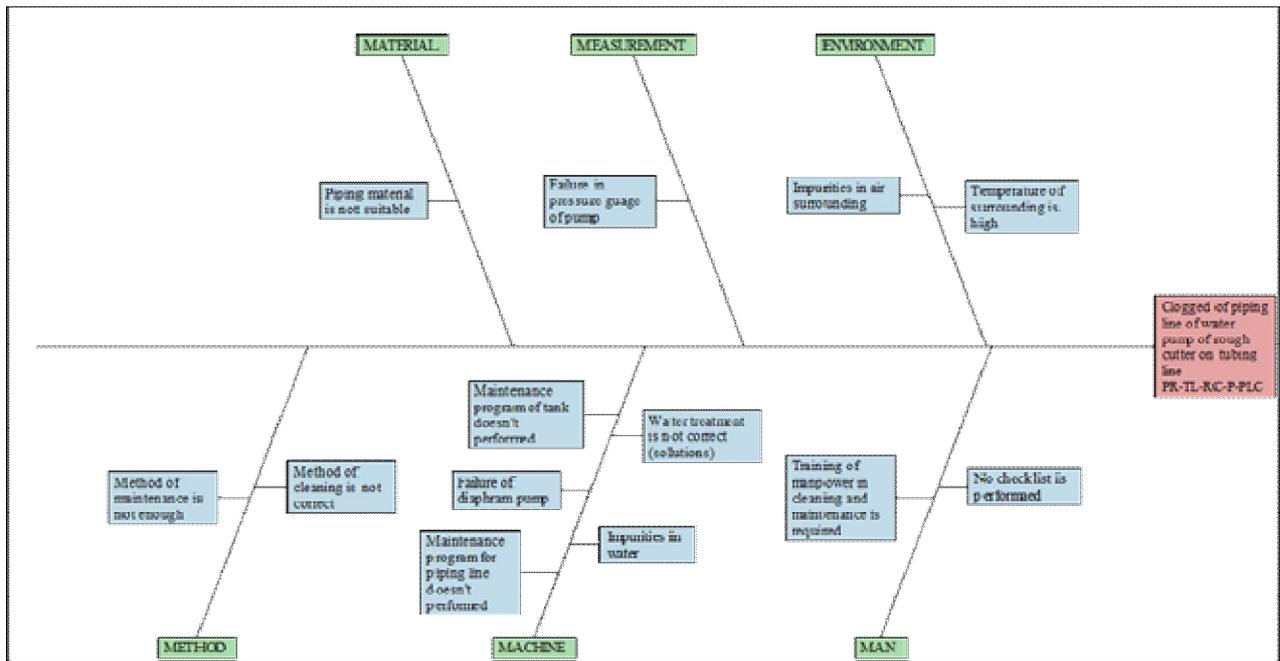


Fig. (4) Fish bone of failure code (PR-TL-RC-P-PLC)

As observed in figure (4), by applying fish bone for the failure code (PR-TL-RC-P-PLC), this failure can occur for many reasons such as pressure gauges failure occurred, or impurities found in water, maintenance of water tank does not perform, or bad maintenance or bad maintenance program for this zone is performed.

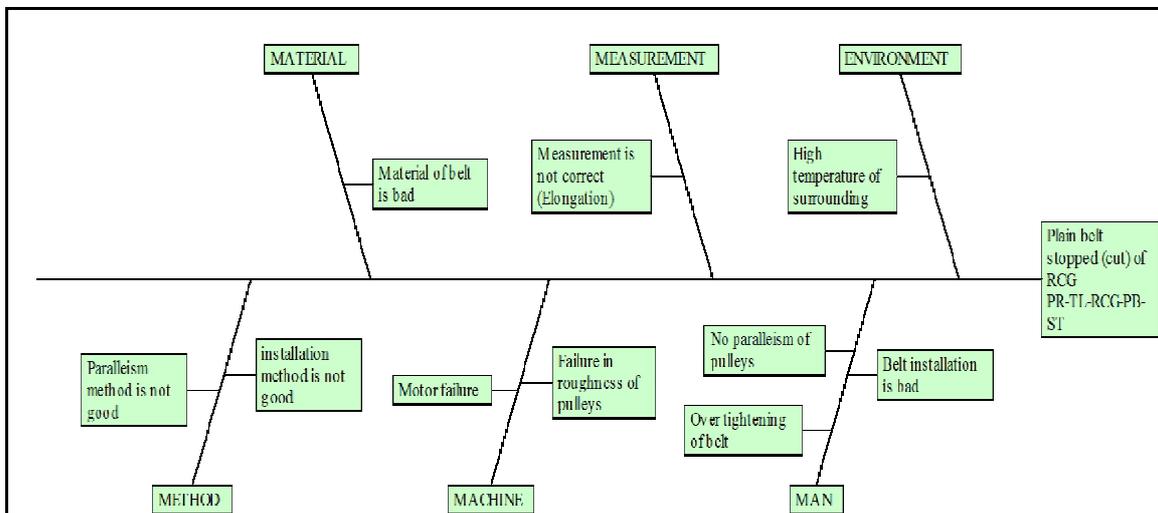


Fig. (5) Fish bone of failure code (PR-TL-RCG-PB-ST)

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As shown in figure (5), by applying fish bone for the failure code (PR-TL-RCG-PB-ST), this failure can occur for many reasons such as belt installation is bad, or material of belt is bad or motor failure.

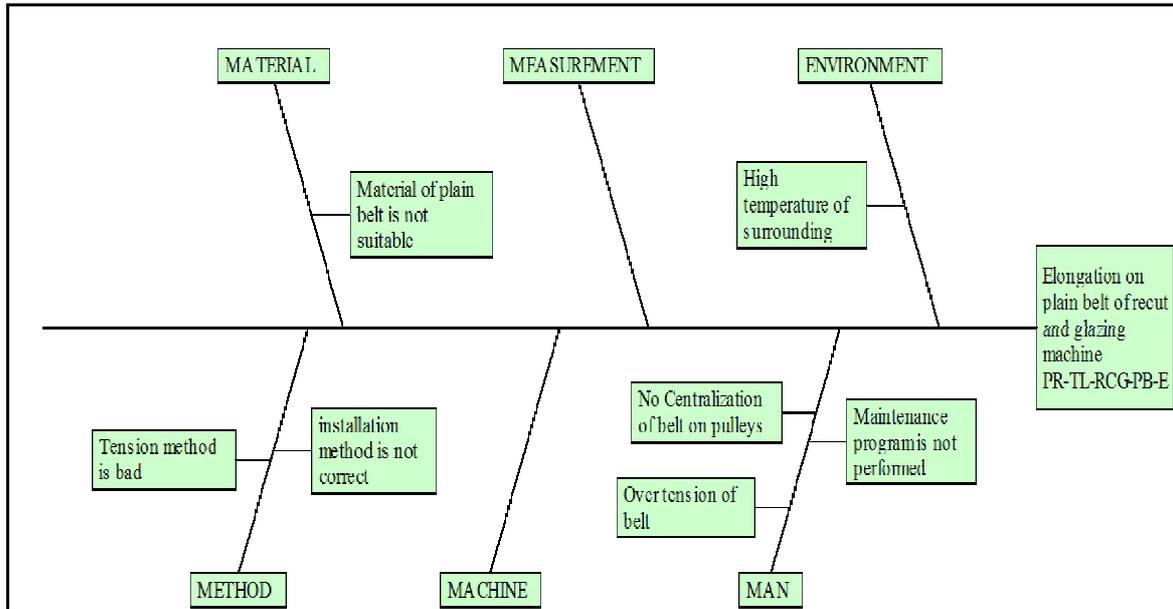


Fig. (6) Fish bone of failure code (PR-TL-RCG-PB-E)

As observed in figure (6), by applying fish bone for the failure code (PR-TL-RCG-PB-E), this failure can occur for many reasons such as bad manufacturing of attachment, or material of bearing is not suitable, or bad maintenance program for this zone is performed.

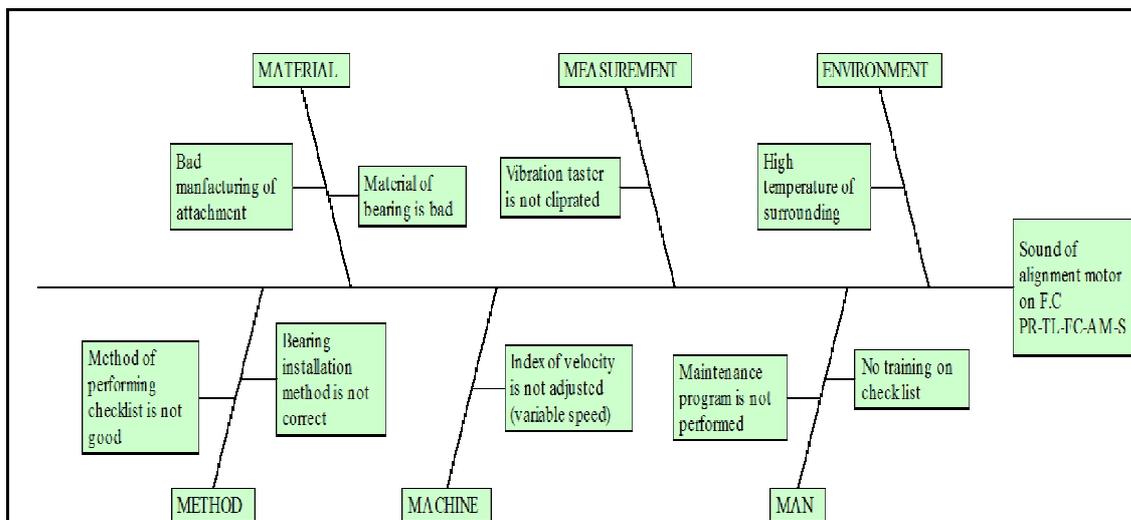


Fig. (7) Fish bone of failure code (PR-TL-FC-AM-S)

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As shown in figure (7), by applying fish bone for the failure code (PR-TL-FC-AM-S), this failure can occur for many reasons such as bad manufacturing of attachment bearing, or material is not suitable, or bad maintenance program for this zone is performed.

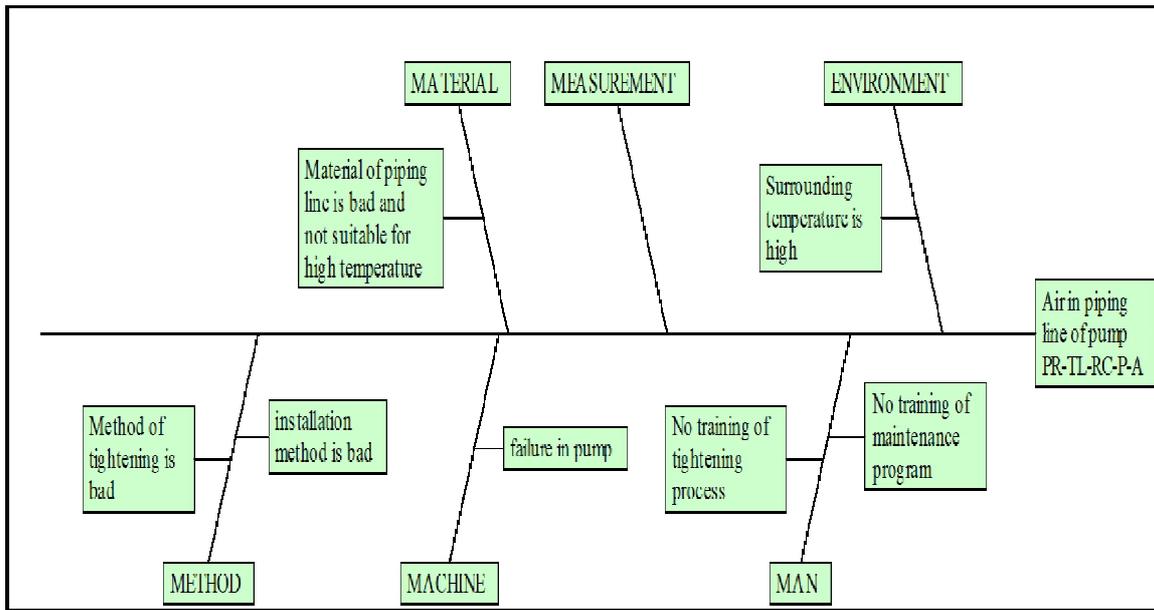


Fig. (8) Fish bone of failure code (PR-TL-RC-P-A)

As observed in figure (8), by applying fish bone for the failure code (PR-TL-RC-P-A), this failure can occur for many reasons such as method of tightening is bad, or material of gaskets of piping line is bad, or bad maintenance program for this zone is performed.

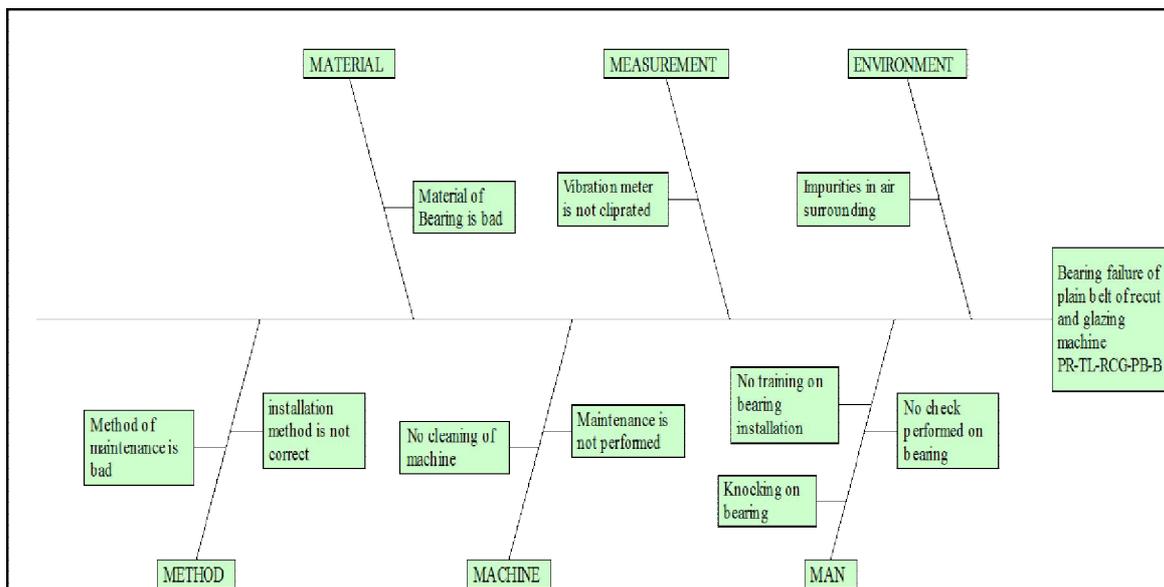


Fig. (9) Fish bone of failure code (PR-TL-RCG-PB-B)

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As observed in figure (9), by applying fish bone for the failure code (PR-TL-RCG-PB-B), this failure can occur for many reasons such as vibration meter is not cliprated, or material of bearing is bad, or bad maintenance program for this zone is performed.

## XIV. CONCLUSIONS

In this study, FMECA and fishbone techniques are suggested to failure analysis and reducing the chances of catastrophic failure that can result in injuries for the industrial processes. FMECA is improved know how for all team inside the organization. It is helped us in brain storming for any potential failure and is concerned with root cause of all potential failure and helped us to prevent it before occurring.

FMECA helped us to increase the reliability and availability by making us expect the failure before occurring and make a prevention action. FMECA is enhancing the level of know-how and competency. Fish bone is an important tool because it depends on studying by brain storming all expected possible reasons for these failures and take a corrective action for these failures. So fish bone and FMECA is an integrated tool for failure analysis and they have an effect of decreasing break down time.

This study describes an application in Toshiba El-Araby bulb glass factory – Quesna-Kofor El-Raml –Moubark Industrial City-3rd Zone-Monfiya-Egypt. As a global result of these techniques, the failure analysis is carried out based on fishbone analysis. Moreover, Corrective actions are suggested to improve RPN and RRRPN.

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