Elimination of Sporadic Defects in Polyurethane Lining Process by using Quality Maintenance Methodology

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***Abstract*— Quality Maintenance also known as QM is one of the essential pillars of Total Productive Maintenance (TPM). The main objective of Quality Maintenance is to achieve Zero Defects. It does this by understanding and controlling the process interactions between manpower, material, machines and methods that may enable the defects to occur or generate. In this research paper the defects occurring in Polyurethane Lining Process are considered. This research paper reflects into the occurrences and analysis of defects occurring in Polyurethane Lining (PU) Process by using QM Methodology on Sporadic Defects or A-type of defects. The efficient use of the seven steps of QM methodology is implemented so that the defects are eliminated and the process is defect free. Moreover, it would also enable for the sustenance of the Zero Defects in PU Lining process.**

Keywords*— Quality Maintenance (QM), Polyurethane (PU) Lining Machine, Total Productive Maintenance (TPM), Nominal Diameter (DN), Zero Defects, Autonomous Maintenance (AM), Plant Maintenance (PM), Continual Improvement Process (CIP)

I. INTRODUCTION

Polyurethane Lining Machine is used for lining of Flow-tubes with Polyurethane material which is generally used for measuring the flow of the medium passing through it. Every Flow-tube ranging from size DN 15 – DN 1200 needs to be lined with a specific material in order to provide the insulation. These insulations are necessary in order to allow the effective working of Flow-tubes so that there is no generation of short circuit if in case any conductive fluid passes through the Flow-tube. In this, the Flow-tube is applied with primer and then placed into the Lining Machine for lining operation. The machine uses and forms a mixture from various components by mixing in a defined ratio. This mixture is in fact the Polyurethane (PU) chemical which is poured into the Flow-tube with the help of a stored program. Later the Flow-tube along with PU chemical is allowed to dry and thus this results into Flow-tube with PU lining. By implementing Quality Maintenance Methodology, it is possible to prevent defects from being produced in the first place, rather than installing rigorous inspection systems to detect the defect after it has been produced. Moreover, it would also enable to carry out a defect free operation that would lead to the sustenance of Zero Defects.

II. QUALITY MAINTENANCE METHODOLOGY

A. Quality Maintenace

Quality Maintenance (QM) also known as Hinshitsu Hozen is one of the eminent pillars in TPM and it aims to assure zero defect conditions. It is also called as QM pillar. And this can be achieved by understanding and controlling the process interactions between manpower, material, machines, methods and tooling (4M+T). The main objective is to prevent the defects from being generated rather than adopting various methods or inspection systems after its generation or occurrence. QM leads to a transition from Quality Control to Quality Assurance [1]. It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformance in a systematic manner much like the focused improvement [2]. Quality Maintenance activities are to set the equipment condition that preclude quality defects, based on the basic concept of maintaining perfect equipments to perfect quality products [3].

B. Quality Maintenace Pillar Methodology

In order to attain the zero defect condition, the QM Pillar methodology needs to be implemented in all the processes set across the organization. The QM Methodology includes the following steps [3]:

i. Step 1: Understanding of actual condition of defect
ii. Step 2: Understanding of equipment mechanism and sequence of operation
iii. Step 3: Survey and analysis of 4M+T condition
iv. Step 4: Problem countermeasures study and restoration of Sporadic Defects (A-type)
v. Step 5: Problem countermeasure study and restoration of Chronic Defects (B-type)
vi. Step 6: Setting ideal conditions for zero defects
vii. Step 7: Sustenance of Quality Maintenance towards Zero defects

C. Step 1: Understanding of actual condition of defect

In this step, the following sub-processes are carried out:

i. Selection of Model Machines & Processes
ii. Preparation of Quality Control Processes
iii. Preparation of Quality Defect (QD) Matrix
iv. Preparation of Pareto Analysis for occurred defects

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v. Prepare list of processes involved in each operation (Preparation of Process Map / Quality Assurance Matrix / QA Matrix)

- *Selection of model machines & processes*

Here in this paper, we have selected the Polyurethane (PU) Lining Process which is one of the most important processes in manufacturing of Magnetic Flowmeters. Moreover the Polyurethane Lining Machine is one of the model machines.

- *Preparation of Quality Control process*

This sub-step is related to knowledge sharing between the three pillars in the circle. The member of Quality Maintenance pillar explains the existing Quality Control / Quality Assurance process to the AM and PM members so as to make them aware of the quality required in the particular process. This included explaining the work documents like Quality Assurance Plan (QAP), Inspection Plans (Checklists), and Standard Operating Processes (SOPs) of Quality Control & Quality Assurance related activities.

- *Preparation of Quality Defect matrix*

In order to achieve the zero defect status, it is essential to understand the present status of the defects wherein the occurrence data of the occurred and probable defects are obtained. The Quality Defect (QD) matrix of occurred and probable defects in the PU Lining process is prepared as shown in Table I. This table represents the statistics of the occurrence of defects for PU Lining Machine.

From this table, it can be noted that there are 13 types of sporadic defects or A-type defects (both occurred and probable type) in PU Lining Process. The total number of sporadic or A-type defects before implementing TPM on PU Lining process were 103 for the year 2010 and 53 for the year 2011. The analysis of this data leads to the actions concerned to the elimination of defects and thus this collection of data is very essential. While preparation of this data we also need to define the defects so that each and everyone acquainted with the process understands the defect in the same manner so that no confusion exist between the members of the circle. The images of the defects occurring in PU Lining are as shown Figure 3.

- *Preparation of Pareto analysis for occurred defects*

With reference to the number of occurrences of the defects as shown above, the analysis of these defects is carried out with the help of Pareto Chart. This has enabled us to understand which of the defects needs to be taken care on priority. The defects named 'bubbles in the pipe' and 'bubbles in the sealing face/countersink part/shark skin' has collectively contributed to about 80% of the total defects. The Pareto Chart for PU Lining Process is represented in Figure 1.

- *Preparation of list of processes involved in each operation (Preparation of Process Map / Quality Assurance Matrix / QA Matrix)*

In order to understand from which process the defects might have occurred, the Quality Assurance (QA) Matrix is prepared. QA Matrix is useful for investigating the processes from which the defect has occurred. This matrix enabled us to establish the relationship between defect and the process where the defect has occurred. The Quality Assurance Matrix for PU Lining process is shown in Figure 2.

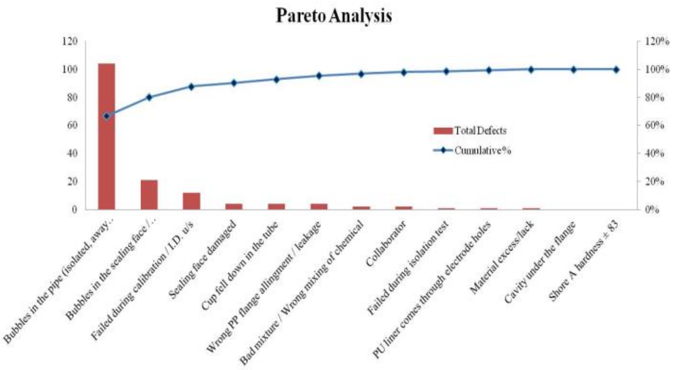

Fig.1. Image of Pareto Analysis Chart

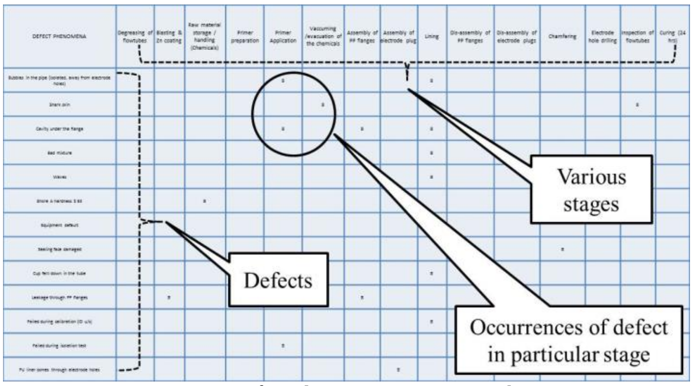

Fig. 2. Image of Quality Assurance Matrix Sheet

Table I. - Occurrences of defects

List of occurred & probable defects	Year 2010	Year 2011
Bubbles in the pipe (isolated, away from electrode hole)	68	36
Bad mixture / Wrong mixing of chemical	1	1
Collaborator	1	1
Material excess/lack	0	1
Cavity under the flange	0	0
Bubbles in the sealing face / Countersink part / Shark skin	10	11
Failed during calibration / Internal diameter undersize	12	0
Sealing face damaged	3	1
Cup fell down in the tube	3	1
Wrong PP flange alignment / Leakage	3	1
Failed during isolation test	1	0
PU liner comes through electrode holes	1	0
Shore A hardness ± 83	0	0
Total Number of Defects (A Type)	**103**	**53**

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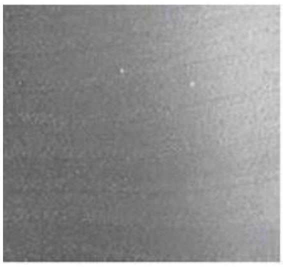
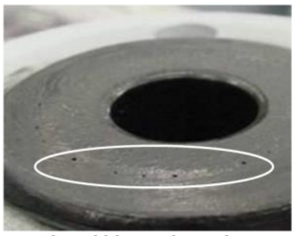
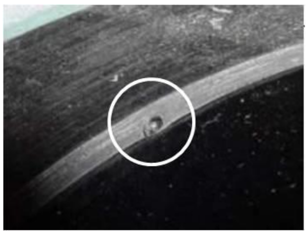
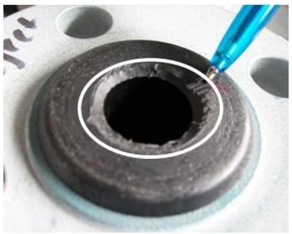
(a) Bubbles in the pipe

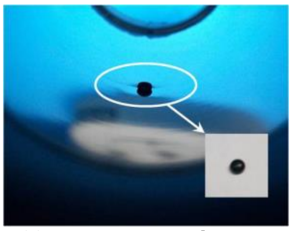

(b) Shark Skin

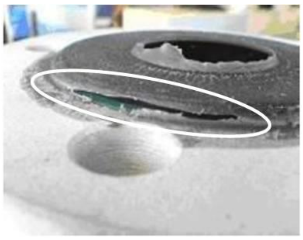

(c) Bubble near electrode hole


(d) Bubbles in the sealing face


(e) Bubbles in the countersink part


(f) Damaged sealing face


(g) Lumps on internal diameter surface


(h) Cavity under the flange


(i) Leakage through PP Flange


(j) PU liner comes through electrode hole

Fig. 3. Images of Defects in Polyurethane Lining process

D. Step 2: Understanding of Equipment Mechanism and Sequence of Operation

In this step, we have prepared the Process – Mechanism Mapping and Function Diagram. This has enabled us to understand the mechanism of the equipment with respect to the processes that are involved in the operation. This has also enabled the circle members to understand the relation between the control point of the processes and their respective associated mechanism. The sample of Process Mechanism Mapping for ‘shark skin’ defect is shown in Table II & the Function Diagram in the form of flowchart for PU Lining is shown in Figure 4.

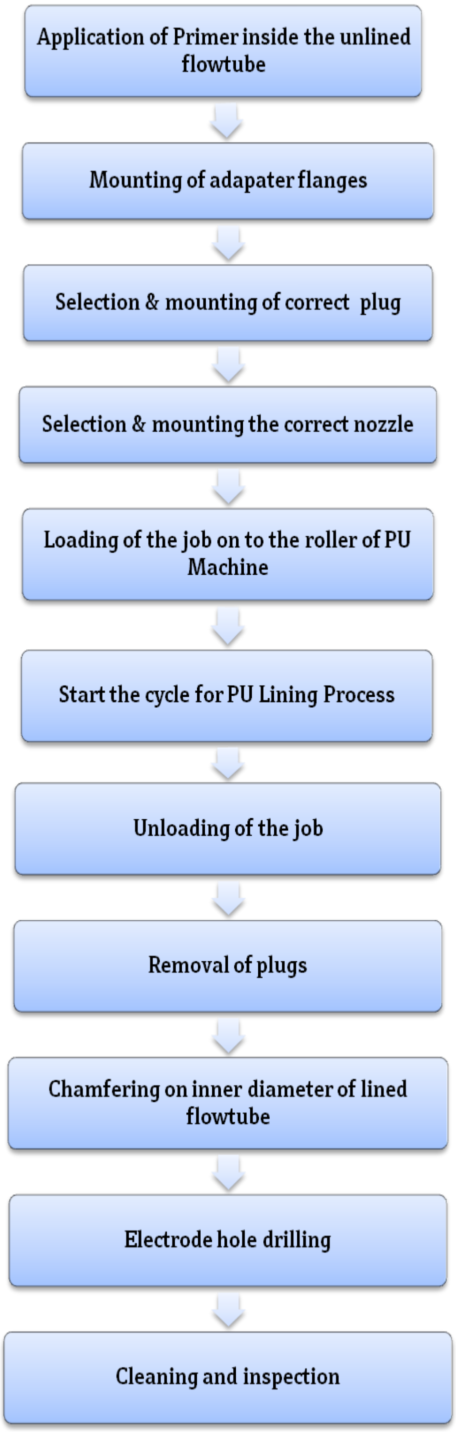


Fig. 4. Flowchart of Function Diagram for PU lining process

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E. Step 3: Survey and Analysis of 4M+T Conditions

In this step, the Quality Maintenance (QM) Matrix is prepared. In QM Matrix, the defects are correlated with 4M+T conditions by using either fish bone diagram or why-why analysis. This step serves as the survey so as to understand which of the 4M+T (Man, Machine, Material, Method and Tooling) conditions are responsible for the occurrence of defect at each process as in the QA Matrix. The details can be arrived at by examining drawings, standards and product designs. These conditions are verified and defective points are extracted and are worked upon in order to obtain the actions and implement the same for defect free process.

F. Step 4: Problem Countermeasure Study and Restoration of Sporadic defects (A type)

In this step, the results of the actions obtained and implemented through QM Matrix are monitored to see if the respective results are effective and up to the mark so as to enable a defect free process.

G. Step 5: Problem Countermeasure Study and Restoration of Chronic Defects (B type), Probable Defects

In this research, we have only focused and considered the Sporadic defects (A-type), thus the actions on Chronic (B-type) defects are not mentioned.

H. Step 6: Setting Ideal Conditions for Zero Defects

In this step, the following activities were carried out:

i. Educated the circle members to follow the standards
ii. Improved inspection reliability, simplification of inspections, etc.
iii. Checking the sustenance of zero defect for 2 months.

I. Step 7: Sustenance of Quality Maintenance towards Zero Defects

In order to maintain the sustenance and to achieve the zero defects the following actions are carried out:

i. Generation of Continual Improvement Process (CIPs) in inspection standards
ii. Establishment of formal standards
iii. Listing Q (Quality) - Components
iv. Horizontal deployment for the rest of the processes

III. CONCLUSION

By implementing the Quality Maintenance methodology in PU Lining Process through TPM, the defects are brought into limelight. The various defects are studied and analyzed with the help of AM and PM members which has enabled thorough understanding of the defects. Each and every processes pertaining to the defects are taken into consideration and then appropriate actions are carried out in order to nullify these defects. The total number of defects from the year 2010 to 2016 (till March) has been shown in Table III. From this table, it is very clear that the defects have been minimized and ultimately eliminated to a greater extent. In the year 2010, the total numbers of sporadic defects were '103' and these defects have come down extensively to '1' by the year 2015 followed by '0' for the first three months of the year 2016. It can be also noted that, the percentage of acceptance has increased from 92.99% to 100%.

Moreover, the intangible benefit by implementation of QM Methodology is setting up the Team Spirit wherein the personnel from different departments come together for a single cause. This even leads to sharing of knowledge between the AM, PM and QM members. Thus the process and the cause of the defects are better understood among all the TPM circle members that would enable them to work effectively and efficiently so as to set a defect free process throughout the organization.

Table II. Process Mechanism Mapping for Shark Skin defect

Defect Phenomena	Specification	History of Defect		Process Control Points	Mechanism involved	Function	Required condition of mechanism	Responsibility
		Occurred	Probable					
Shark Skin	There should be no traces of Shark Skin in lined flow-tube	Yes		PU Lining Process	Vacuum Pump	Vacuuming of Chemical	The required pressure is - 1 Bar	AM
					Vacuum Hose	Medium from which vacuuming is carried out	There should be no any kind of leakage	AM
					Tank Valve	To restrict the flow of surrounding air	The Tank Valve should be closed and not loose	AM

Table III. Yearly Occurrences of Defects

List of occurred & probable defects	**Year 2010**	**Year 2011**	**Year 2012**	**Year 2013**	**Year 2014**	**Year 2015**	**Year 2016 till March**
Bubbles in the pipe (isolated, away from electrode hole)	68	36	4	0	1	0	0
Bad mixture / Wrong mixing of chemical	1	1	0	0	0	0	0
Collaborator	1	1	0	0	0	0	0
Material excess/lack	0	1	0	0	0	0	0
Cavity under the flange	0	0	1	0	0	0	0
Bubbles in the sealing face / Countersink part / Shark skin	10	11	1	2	0	1	0
Failed during calibration / Internal diameter undersize	12	0	0	0	0	0	0
Sealing face damaged	3	1	0	0	0	0	0
Cup fell down in the tube	3	1	0	0	0	0	0
Wrong PP flange alignment / Leakage	3	1	0	0	0	0	0
Failed during isolation test	1	0	0	0	0	0	0
PU liner comes through electrode holes	1	0	0	0	0	0	0
Shore A hardness ± 83	0	0	0	0	0	0	0
Total Number of Defects (A Type)	**103**	**53**	**6**	**2**	**1**	**1**	**0**
Total Number of Units Produced	**1469**	**1541**	**1706**	**1668**	**1529**	**1512**	**612**
Percentage of Acceptance	**92.99%**	**96.56%**	**99.65%**	**99.88%**	**99.93%**	**99.93%**	**100%**

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