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Research Article

Quality Hindering Factors In Tpm And Importance Of Skill Application In Injection Molding Process

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Abstract

The concept of quality industry is a journey initiated in the industry of Quality Circles (QC). A small group of members reviews their product shortcomings and endeavors to solve the issue. This as a whole, has a minimum impact on quality. Hence, the quality is moved from QC to the following category of Quality Assurance (QA) which is also a vision. Both QC and QA are such that, the efforts are made post quality defects in the process which implies that the quality factors are hindering in nature and not known to the operator. In this circumstance, the commodities are produced and good pieces are delivered to the customer despite the loss to the organization. This shortcoming are improved when the TPM practicing level are enhanced, further shifting the quality concept from QA level to Quality Maintenance (QM). This just reinsures that "a stitch in time, saves nine", that is precautions are taken before quality damage making this a 'cause oriented approach'. It is vital to maintain an optimum skill level to question the concept of "precautionary damage control". In this paper it is analyzed as the Quality hindering factors in TPM and importance of skill application in injection molding process. Input, in-process managements are with the prime TPM pillar which is quality although it is not practical to achieve zero quality defects. Hence, it is essential to understand that, besides the quality maintenance pillar, the autonomous maintenance, planned maintenance, Education and training and Focused Improvement pillar has to support the QM pillars.

Kywords- FI; AM; PM; QM; E&T; TPM; hindering factors; skill; OEE; availability; performance; quality; Kaizen and involvement.

1. INTORUDCTION

The word "quality" has multiple connotations as in a degree of excellence, a requirement of conformance, an ability to satisfy the entity of all characteristics, it serves as an implied need as fitness for use, free from defects, abnormalities, imperfections, and contaminations. **David Hoyle Quality**, in ISO 9000:2000 mentions that, quality is defined as 'the degree to which a set of

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inherent characteristics fulfills requirements. While, **Juozas Ruzevicius**[1] narrates the development stages of Quality management development in 1910, where the producers are given attention to a product-focused quality inspection started from 1924, from which time process quality control concept was observed. The quality improvement shifted the focus from producers to customers. The organization has given attention from 1930 onwards to quality assurance / ensures the customers that they can receive a qualified output. In this stage, the organizations produce the product and supply promising chunks to the customer. To overcome the haphazard management, the organization rewrote its knowledge during 1950 from quality assurance to quality management. At this phase, the focus was on clients leaving stakeholders. From 1979 - 1980 the Total Quality Management (TQM) series was introduced to insulate the customers and other stakeholders through organization and organizational performance improvement. In 1971 **Japan Institute of Planned Maintenance (JIPM)**[2]) introduced Total Productive Maintenance (TPM) with the QM being one among the eight pillars. From 2000 till date, the existence in sustainability, excellence, and Global Quality Management (GQM) is taken as a new quality dimension to the buyer's needs which are the ultimate purpose along with other stakeholders covering organization, organizational performance, and society.

II. OBJECTIVE OF THE STUDY

To survey the quality hindering factors in the TPM pillars of Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Education and Training, and Focused Improvement practice to find the skill impact in the injection molding process. This study was conducted in a large-scale plastic part manufacturing company through injection molding equipment of different model tonnage.

III. METHODOLOGY

Sayuti, M. (2019)[3]) the effectiveness of OEE is a **tool** to measure the equipment efficiency, performance efficacy, and quality impact. This concept was first experimented by the Japan Institute of Planned Maintenance (JIPM), Japan. Today every company in the world attempts to appreciate the tool and enforce the same in their workplace. The components in OEE are defined clearly with a state of the art description. The measurement of OEE methodology by using the formula **OEE** = Availability **(A)** x Performance **(P)** x Quality **(Q)** is used in the study. Here, an injection molding equipment and process operated in a large scale plastic manufacturing industry was borrowed to find the hindering factors of quality in TPM and to analyze the implication of skill application. The overall equipment's main elements are availability, performance quality. In this paper, special attention has been given to measuring the quality and its sub-components to calculate pre-and post-skill difference in product output, through a five-point scale. Quality training modules were equipped, a questionnaire was devised to measure the skill gap and compared with the respective hidden quality factors in the injection molding process as shown in **Fig.1.**

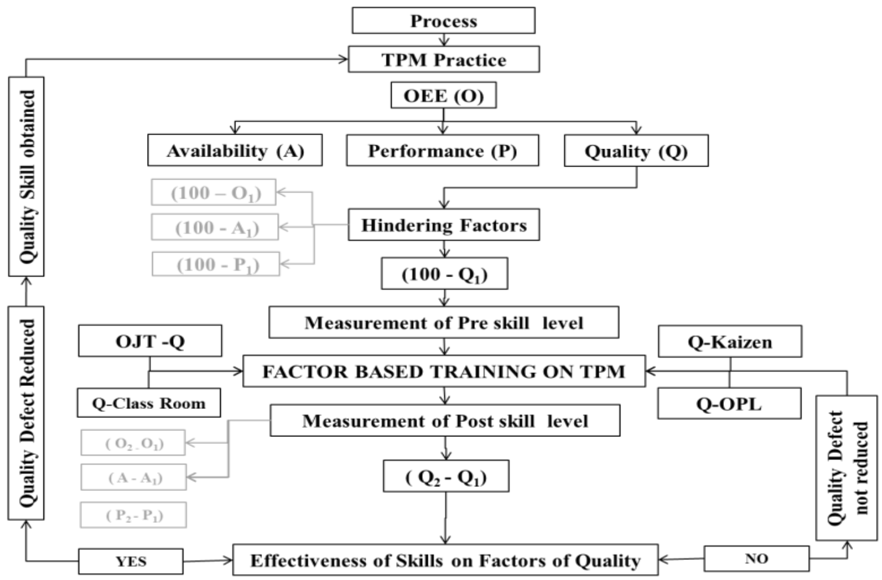


Fig1. Hindering Quality factors and improvement of skills

IV. TPM PILLARS

According to **Jain, V K et al (2013)[4]** TPM consists of eight pillars, OEE measuring the effectiveness of these pillars. The Preventive maintenance assists the procedure to generate a quality product. By practicing the given schedule like Time Based Maintenance (TBM), Condition Based Maintenance (CBM), Corrective Maintenance (CM), Autonomous Maintenance(AM), and Maintenance Prevention (MP) to maintain the parts in their original condition to get the quality product. In this way, TPM helps to eliminate the hindering quality defects in parts and tools of the equipment. Similarly, **Gupta P et al (2015)[5]** describes the seven steps of the autonomous maintenance concept that assists to eliminate quality defects from its inception. Before the process, initial cleaning, proper lubrication, tightening, inspection of the equipment, and the process gives the quality output of the product. **Wanjiru,M.W[6]** referred that, quality conditions settings that precludes the quality defects can obtain a defect-free product. The conditions have to be examined as per the quality check sheet that assists to ensure the quality of the product. If the given standard values are to be arrived at and obtain good product quality, the above check sheet and monitoring systems can help to take counter measures before the defect. To sustain the quality of the product, the process poka-Yoke (fool – Proof system) helps which achieves zero quality defects.

V. SELECTION OF INJECTION MOLDING PROCESS AND FACTORS

Ashwain Kapoor[7] et al (2018) documents that, out of the total plastic production, thirty percent of the products are from the injection molding processes. The manufacturers are depending on well-experienced employees with higher working knowledge. Human dependency is always with the trial-and-error method of production which is an expensive process. Different technologies are used in plastic manufacturing that directs to additional costs and higher spare parts inventory. The injection molding equipment consists of two main functions (a) injection function and (b) clamping. The three stages in the injection molding process are the filling phase, cooling phase, and the ejection phase which are the factors influencing the productivity and quality of the output. Many process parameters control the plastic injection molding process. (a) Part and function failures, (b) speed loss (less than standard or targeted production), and (c) quality factors such as shrinkages, warpage, weld lines, mold lines, flow marks, flash marks, sink marks, and void which depends on the process point of melt and mold temperature, pressure, cooling, screw speed, holding pressure, packing duration, cycle time and injection speed.

VI. IMPORTANCE OF SKILL AND ITS IMPACT ON FACTORS OF TPM

Tokutaro Suzuki[8] explains about the " ZERO-ORIENTED" Total Productive Maintenance which is an element to reduce all losses at zero levels by bringing the parts to optimal conditions by practicing autonomous maintenance. It is successful with the following method to enhance the skill of the operator.

1. Continuously identify, expose and remove all abnormalities.
2. Maintain the equipment at original condition by CLIT (Cleaning, Lubrication, Inspection, and Tightening)
3. Rectify all types of defects even though it is small.

Farhana Afreem Proma et al (2010, Jan)[9]) observed that quality defect is develops over time due to skill differences. Skill differences expand operation motion loss in each operation in three ways in equipment handling such as the setup and adjustment skill, loading and unloading skill, and the equipment cleaning skill. Five losses out of 16 in TPM related to human activities are known as; Management loss, Operation motion loss, Line organization loss, logistic loss, and Measurement and adjustment loss. These losses are hindering factors in TPM implementation and overcome imparting skill to the operators.

VII. MEASUREMENT TECHNIQUE OF TPM EFFECTIVENESS

Vijayakumar S.R t al (2014)[10] observed the hindering factors and the importance of working the reliability parameters. It works to obtain a quality production in the injection molding process. Joint working of operation and maintenance employees enables to understand others' situations and therefore operate accordingly to maintain the quality output by team cooperation.

VIII. PERFORMANCE MEASUREMENT MTRICS

Jha, K. N., & Iyer, K. C. (2006)[11] explained the performance measurement metrics to find the Overall Equipment Effectiveness (OEE) consisting of the health of equipment, strength of performance, and level of quality in output of a given product. OEE expresses the deviation of standard in each category in terms of loss and, categorized into sixteen types of losses, eight losses about impending equipment effectiveness, five losses related to the performance, and three losses to yield energy and others.

a. Availability Factor (A)

The equipment was used (operating time) against the working time TPM encyclopedia keyword book by JIPM (apr2002) "The average repair time"

$$\text{Availability (A)} = \frac{\text{Operating time}}{\text{Calendar time}} \qquad \text{.....1}$$

Where Operating time = Calendar time – Total downtime

b. Performance Factor (P)

Gautam Kocher et al (2012)[12] express that performance factors direct towards reducing the losses due to slowdowns or reduced speed.

$$\text{Performance (P)} = \frac{\text{Actual production}}{\text{Targeted production}} \qquad \ldots..2$$

Where, Actual production =Targeted Production – Loss in production numbers due to reduced cycle time loss. Targeted production = number of pieces planned x cycle time

Quality factor (Q)

The quality factor explains that how many customers accepted the product from the total produced unit.

$$\text{Quality (Q)} = \frac{\text{Good product}}{\text{Actual production}} \qquad \ldots..3$$

Where Good Product = Actual production – Defective Production

f. Overall Equipment Effectiveness(**OEE**) = **(A) x (P) x (Q **4

X. PRE AND POST EXPLORATORY DESIGN

Improper design of the parts is asses to be hindering factors of quality. Improper Mould design, poor condition of equipment, and wrong process parameters generate wastages and utilities, with all the rejection creating a situation of rework, and recycling can produce defects in the product. These are some of the familiar manifestations. Skill is influencing the major portions of quality defects arisen from unsatisfied buyers. In this paper a pre and, post-test analyses is made by an exploratory design method which is used by comparing OEE and its corresponding skill before and after training.

Step-1. Selection of the injection molding process
Step-2. Performance measurement matrices, Factors, Skill, and Defect Ranking.
Step-3. Pre and post exploratory study.
Step-4. Concluding remark

Step-1 Selection of the injection molding process

The large-scale plastic injection molding companies have identified the TPM hindering factors in the 450 tonnage injection molding process and the skill requirements. The following are the injection molding function and processes.

1. **Functions** including: mold closing, Injection, Cooling, Plasticizing the resin, Ejection, Removing the runner, and packing functions.

2. **The process:** Material receiving, Input quality inspection, Mixing, Preheating, Injection molding, Part ejection, Inspection, and Testing, De-flashing, and post-mold operation.

Step-2. Performance measurement matrices, Factors, Skill, and Defect ranking.
Injection molding, process performance measurement matrices help to find quality hindering factors in TPM, and importance of skill application, factors, skill, and defect classification is prepared and shown in **Ref: Fig.2**

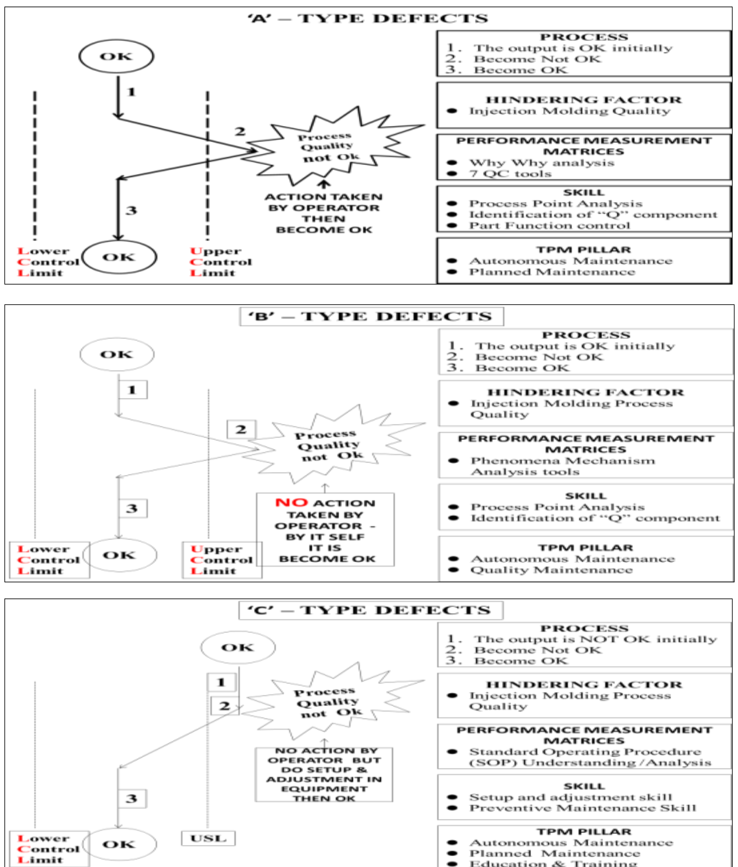


Fig 2 Performance Measurement matrices, Factors, Skill and Defect Ranking

The quality defects were ranked under three types 'A', 'B', and 'C'. 'A' type defects are sporadic which means that, the causes are known to the operator and using 'why why' analysis to solve the problem. In the case of 'B' Type defects, the causes are unknown to the operator, and to find the root cause, 'phenomena mechanism' analysis has to be used and take counter measures are taken. For instance, let us say that a black spot seemed to appear in the product during the process. Here, in the experiment, 'B' type defect in the process sequence serial numbers of 33,34,35,36 and 37 are the black spots evident in the products but the serial number 38 and above, no black spot exists and the quality defect disappears. In this case, there is no involvement of the operator. Till the end piece, there is no black spot defect in the production.

This, using the Phenomena Mechanism (PM) aanalysis is required for type B defects and corrections are made whenever applicable. In the case of 'C' type defects, the defect commences right at the starting point, hence it is right to say that, the process is not up to the standard which is a defective production. Utilizing a right layout and revision by the operator can bring the process into the control limit. No tool is required for this type of defect. Follow standard operating procedure (SOP), updated Check sheet, and operation manual have to be followed.

1. Collection of production data.
2. Segregation of good and bad quantity of product produced from the process
3. Classify the defects as A, B and C type
4. From the defect generation find the operator skill level
5. Select the performance indicators to find the cause related to each defect
6. Find the root cause of every defect.
7. Measure the defect – In this study, OEE, C-chart, Factor analysis is used, OEE gap analysis is taken to measure the deviation of standards from the actual production norm.
8. As mentioned in Step-2 quantity defects and in Step-3 the type of defects select the operator for skill training.
9. Measure the pre-training skill in 5 point scale and plot in a radar chart.
10. Prepare equipment training curriculum and train the operator
11. Prepare process and quality training curriculum and train the operator
12. Measure the post-training OEE percentage
13. Measure the Post-training skill in 5 point scale
14. Compare the skill level between pre and post results
15. Compare the OEE percentage improvement pre and post measurements. The result is the quality hindering factors in TPM and importance of skill application in the injection molding process

The effectiveness of skills on the factors of Total Productive Maintenance has to be established. In the next step calculation of OEE, Quality factor, C-Chart, Factor analysis is discussed in detail

Step-3.Pre and post exploratory analysis.

a. Pre Training Analysis of OEE and Skill
b. Quality Factor and Skill Training
c. Post Training Analysis of OEE and Skill

3.a. Pre Training Analysis of OEE and Skill

3.a.1 Pre-Training OEE Analysis

SP 450 INJECTION MOULDING OEE				
Month	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
	ηa	ηp	ηq	(ηaxηpxηq)
APR'19	92%	84%	96%	74%
MAY'19	98%	37%	95%	34%
JUN'19	90%	84%	96%	73%
Total	93%	71%	96%	**63%**

3.a.2 Pre-Training OEE Gap Analysis

SP 450 INJECTION MOULDING OEE GAP				
Month	AVAILABILITY GAP (%)	PERFORMANCE GAP (%)	QUALITY GAP (%)	OEE GAP (%)
	(1-ηa%)	(1-ηp%)	(1-ηq%)	(1- OEE%)
APR'19	8%	16%	4%	26%
MAY'19	2%	63%	5%	66%
JUN'19	10%	16%	4%	27%
Total	7%	29%	4%	37%

The effectiveness of SP450 equipment by calculating OEE arrived at 63% in the study against the standard OEE of 85% as mentioned by **Amit Kumar Gupta et al[13],** In the study, 93% equipment was available for production and downtime gap was 7% overall. The performance efficiency was 71% and, the production gap was 29%, and finally, the quality efficiency is 96%, and the quality defect of 4% was observed as shown in the OEE-Gap table.

3.b Quality Factor and Skill Training

To provide quality factor training, three months data that was retrieved was analyzed and the quantum of defects generated by the operators were interpreted.

3.b.1 Pre-Training Quality Analysis

INJECTION MOULDING QUALITY					QUALITY	
Month	Net Operating Time (min)	Actual Production (Nos)	Quality Defects (Nos)	Good Production	$\eta q = Gp/Ap$	
	Ot	(Ap)	(Qd)	(Gp)	ηq (%)	Gap (%)
APR'19	25694	29874	1128	28746	96%	-4%
MAY'19	9259	9864	520	9344	95%	-5%
JUN'19	38337	27778	1041	26737	96%	-4%
Total	**73291**	**67516**	**2689**	**64827**	96%	-4%

The quality defect generated in three months was observed to be 2689. This number assisted us to learn the hidden quality factors. The following were the training planned to be performed at the floor level with the purpose of eliminating the hindering factors in quality.

1. Training on quality defect mode
2. Causes of quality defects
3. Process condition and control
4. Training on quality circle, quality assurance and quality maintenance.
5. Phenomena Mechanism analysis (PM)
6. Failure Mode Effective analysis (FMEA)
7. Cost of poor quality
8. Cost to quality
9. Quality pillar and circle management training.

3.b.2 TPM hindering Quality Factors

The following are the TPM hindering quality factors identified in SP450 equipment

S.No	Quality hindering Factors	S.No	Quality hindering Factors
1	Color Change START-UP Rejection	17	Lumps Issue
2	Mold Change START-UP Rejection	18	Oil Mark
3	Other Start-up Rejection	19	Part Weight Variation
4	Black Lines	20	Patch Mark
5	Black Spot	21	Pin Mark
6	Blow Holes	22	Raw Material Problem
7	Bubbles	23	Rib Damage / Catching
8	Burn Mark	24	Scratches
9	Color Variation / Line	25	Short Fill
10	Crack	26	Shrinkage
11	Cut Mark	27	Silver Mark
12	Damage	28	Spray Mark
13	Drooling	29	Strain Mark
14	Filling Mark	30	Warpage
15	Flow Line	31	Water Mark
16	Glossiness Variation		

3.b.3 Pre-Training Quality Defect Data Collection

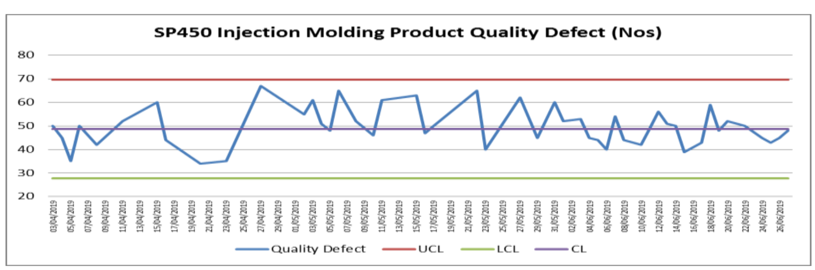
These quality defects are further studied and categorized into different types of defects, and each type is well defined to train the operator. For which three months data were collected (Fig3) and prepared. The readers are recommended to view the C – Chart.

C-Chart - Pre-Training SP 450 Injection Molding Quality Defect (Nos)					
Sample Size	Date	Quality Defect	UCL	LCL	CL
1	03/04/2019	50	70	28	49
2	04/04/2019	45	70	28	49
3	05/04/2019	35	70	28	49
4	06/04/2019	50	70	28	49
5	08/04/2019	42	70	28	49
6	11/04/2019	52	70	28	49
7	15/04/2019	60	70	28	49
8	16/04/2019	44	70	28	49
10	20/04/2019	34	70	28	49
11	23/04/2019	35	70	28	49
12	27/04/2019	67	70	28	49
13	02/05/2019	55	70	28	49
14	03/05/2019	61	70	28	49
15	04/05/2019	51	70	28	49
16	05/05/2019	48	70	28	49
17	06/05/2019	65	70	28	49
18	08/05/2019	52	70	28	49
19	10/05/2019	46	70	28	49
20	11/05/2019	61	70	28	49
21	15/05/2019	63	70	28	49
22	16/05/2019	47	70	28	49
23	17/05/2019	50	70	28	49
24	22/05/2019	65	70	28	49
25	23/05/2019	40	70	28	49
26	27/05/2019	62	70	28	49
27	29/05/2019	45	70	28	49
28	31/05/2019	60	70	28	49
29	01/06/2019	52	70	28	49
30	03/06/2019	53	70	28	49
31	04/06/2019	45	70	28	49
32	05/06/2019	44	70	28	49
33	06/06/2019	40	70	28	49
34	07/06/2019	54	70	28	49
35	08/06/2019	44	70	28	49
36	10/06/2019	42	70	28	49
37	11/06/2019	49	70	28	49
38	12/06/2019	56	70	28	49
39	13/06/2019	51	70	28	49
40	14/06/2019	50	70	28	49
41	15/06/2019	39	70	28	49
42	17/06/2019	43	70	28	49
43	18/06/2019	59	70	28	49
44	19/06/2019	48	70	28	49
45	20/06/2019	52	70	28	49
46	22/06/2019	50	70	28	49
47	24/06/2019	45	70	28	49
48	25/06/2019	43	70	28	49
49	26/06/2019	45	70	28	49
50	27/06/2019	48	70	28	49
	Total	2437			

Fig.3 Pre-Training SP450 equipment Quality defects (Nos)

3.b.4. Quality Factor C- Chart.

C- Chart			
CL =	Total Defect / No of Samples		
UCL=	CL + 3 sqrt of CL		
LCL =	CL - 3 sqrt of CL		
CL =	2437	50	49
UCL=	49	21	70
LCL =	49	-21	28



The range if defects we're interpreted to be more considering the higher quality hindering factors of UCL = 70, LCL =28, and the mid-point 49.

3.b.5 Quality Factor Analysis.

It is confirmed from the C- Chart that the data are within the limits, from where the individual defects were analyzed by preparing the quality defect factor estimation. It encouraged to comprehend the defect divergence of increasing/decreasing trend for which the collection of data for three months was essential on which the factor analysis table was tabulated and the same is given in the following **Fig.4.**

FACTOR ANALYSIS - SP450 INJECTION MOLDING QUALITY DEFECTS -(PER-TRAINING)										
SUB FACTOR		Apr'19	May'19	Jun'19	Total	More % for each items	Failure Mode Factors	Failure Mode	Increase in Failur Mode	Decrease in Failire Mode
1	Color Change STAR	0	0	281	281		1st Month	514		
2	Mould Change STA	0	0	176	176	0%	1	514	0	0
3	Other Start-up Reje	0	0	159	159	0%	2	514	0	0
4	Black Lines	0	0	0	0	0%	3	514	0	0
5	Black Spot	0	0	0	0	0%	4	514	0	0
6	Blow Holes	0	0	0	0	0%	5	514	0	0
7	Bubbles	0	0	100	100	0%	6	514	0	0
8	Burn Mark	0	0	0	0	0%	7	514	0	0
9	Color Variation / Li	135	101	105	341	0%	8	514	0	0
10	Crack	0	40	35	75	-3%	9	480	0	34
11	Cut Mark	0	62	0	62	0%	10	520	40	0
12	Damage	0	0	0	0	0%	11	582	62	0
13	Drooling	0	0	25	25	0%	12	582	0	0
14	Filling Mark	0	0	20	20	0%	13	582	0	0
15	Flow Line	0	0	10	10	0%	14	582	0	0
16	Glossiness Variation	0	0	9	9	0%	15	582	0	0
17	Lumps Issue	0	0	20	20	0%	16	582	0	0
18	Oil Mark	0	20	0	20	0%	17	582	0	0
19	Part Weight Variatio	105	155	60	320	0%	18	602	20	0
20	Patch Mark	0	0	0	0	0%	19	652	50	0
21	Pin Mark	40	81	0	121	0%	20	652	0	0
22	Raw Material Proble	10	48	0	58	0%	21	693	41	0
23	Rib Damage / Catch	10	57	0	67	0%	22	731	38	0
24	Scratches	0	104	0	104	0%	23	778	47	0
25	Short Fill	67	174	52	293	0%	24	882	104	0
26	Shrinkage	77	77	0	154	0%	25	989	107	0
27	Silver Mark	0	29	0	29	0%	26	989	0	0
28	Spray Mark	30	30	0	60	0%	27	1018	29	0
29	Strain Mark	40	40	0	80	0%	28	1018	0	0
30	Warpage	0	0	0	0	0%	29	1018	0	0
31	Water Mark	0	0	0	0	0%	30	1018	0	0
		514	1018	1052	2584	0%	31	1018	0	0
							2nd Mont	1018		

Fig.4 Pre-Training SP450 Factor Analysis

From the above factor analysis, it is evident that the quality defects are in an increasing trend. This emphasizes that, it is crucial to furnish the employees with the right skill to improve the quality of the product. The questionnaire devised, was applied to collect the primary data on five point scale and the pre and post-test survey is explained with the result interpretation below.

3.b.6. Quality Skill Evaluation 5 Point Scale

Level-1: Don't know (not educated) lack of knowledge
Level-2: Know only in a theoretical sense- Shortage of training.
Level-3: Can partially do it – Shortage of training
Level-4: Can do it with self-confidence–State of having bodily learned it.
Level-5: Can teach others–State of completely mastered it.

3.b.7. Pre – Training Quality skill Assessment

The following are the skill measurement table and questionnaires used are also given.

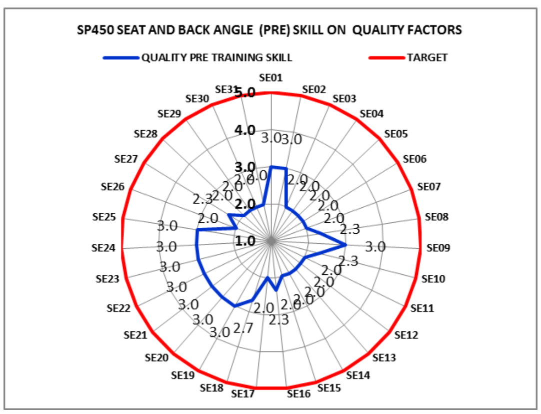
Pre Training SP450 Seat and Back Angle Process Operational / Maintenance skill attributes																																	
			GAP IN OPERATOR SKILLS (BEFORE TRAINING)																														
Factors	Skill Attributes	Target	SE01	SE02	SE03	SE04	SE05	SE06	SE07	SE08	SE09	SE10	SE11	SE12	SE13	SE14	SE15	SE16	SE17	SE18	SE19	SE20	SE21	SE22	SE23	SE24	SE25	SE26	SE27	SE28	SE29	SE30	SE31
A	[1]	5	2	3	2	3	2	2	2	3	3	2	2	2	2	2	2	3	2	3	3	2	3	3	3	3	3	2	2	2	2	2	2
A	[3]	5	3	3	2	2	2	2	2	3	3	2	2	2	2	3	2	3	2	3	3	3	3	3	3	3	3	2	2	2	2	2	2
A	[11]	5	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	3	2	2	3	3	3	2	3	3	3	2	3	2	2	2	2
A		**5.0**	**2.3**	**3.0**	**2.0**	**2.3**	**2.0**	**2.0**	**2.0**	**2.7**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.3**	**2.0**	**3.0**	**2.0**	**2.7**	**3.0**	**2.7**	**3.0**	**2.7**	**3.0**	**3.0**	**3.0**	**2.0**	**2.3**	**2.0**	**2.0**	**2.0**	**2.0**
P	[6]	5	3	3	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	2	2
P	[4]	5	3	3	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	3	3	3	3	3	3	3	3	2	2	2	2	2	2
P	[2]	5	3	3	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	3	3	2	3	3	3	3	2	3	2	2	2	2
P		**5.0**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.7**	**2.0**	**2.3**	**3.0**	**3.0**	**2.7**	**3.0**	**3.0**	**3.0**	**3.0**	**2.0**	**2.3**	**2.0**	**2.0**	**2.0**	**2.0**
Q	[9]	5	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	2	2	2	2	2	2
Q	[10]	5	3	3	2	2	2	2	2	3	3	2	2	2	2	2	2	3	2	2	3	3	3	3	3	3	3	2	3	2	2	2	2
Q	[8]	5	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	2	2	2	2	2	2
Q		**5.0**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.3**	**3.0**	**2.3**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.3**	**2.0**	**2.7**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**2.0**	**2.3**	**2.0**	**2.0**	**2.0**	**2.0**
I	[7]	5	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**2**	**2**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**
S	[5]	5	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**3**	**3**	**2**	**2**	**2**	**2**	**3**	**2**	**3**	**2**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**

3.b.8. Quality Skill Assessment Questionnaire

Factors	Operational / Maintenance skill attributes SP 450 Seat and Back Angle Process
A	1. I am able to support preventive maintenance.
S	2. I am able to eliminate unsafe act
A	3. I am able to make mold change adjustments and repairs
P	4. I am able to identify and eliminate abnormalities in equipment and process
P	5. I am able to prepare and update TPM activity board.
P	6. I am able to maintain input/output temperature in cooling
I	7. I am able to inspect moisture in input material
Q	8. I am able to control high melt or mold temperature (if gate freeze off slow)
Q	9 I am able to eliminate speed loss
Q	10.I am able to increase clamp force to eliminate flash
A	11.I am able to clean vents, increase size or number of vents to avoid burning mark
	A= Availability, P= Performance, Q= Quality, S=Safety and I=Involvement

From the above skill on quality factor analysis, the present skill level of the operator is between 2-3 skill points out of 5 point scale. There is a relationship between quality defects and skill availability and prepared a radar chart.

3.b.9. Pre -Training Skills Radar Chart



3.c. Post Training Analysis of OEE and Skill

3.c.1. Post-Skill Training Analysis.

Importing skills to the operator is mandatory to curtail the quality defects gaps. The following is the training summary provided to the SP450 injection molding operators on the training floor.

1. Quality pillar training with ten steps(QM)
2. Autonomous Maintenance Training(AM)/
1. Seven steps of AM
2. Special training on AM step-5

3. The quality Factor Analysis training
4. Phenomena Mechanism Analysis
5. ‘Q’ component training
6. Training on defect sources identification
7. Quality tool usage training

After training for two months with the module, every operator we’re assessed and allowed to exercise the learnt skill in TPM in SP450 injection molding equipment under the supervision of their managers. The secondary data thus collected to calculate OEE, were to identify the extent of impact of training, change in skill level and the range of widespread development in terms of product quality. These were in the form of interviews with the operator and plotting the data for pre and post-skill gaps for improvements.

3.c.2 Post – Training impact on OEE

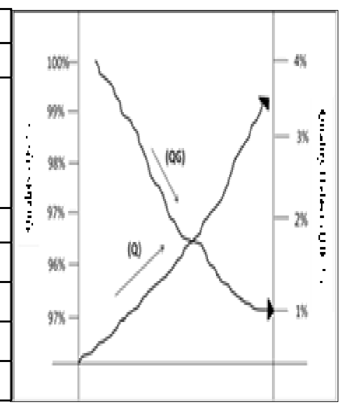
PROCESS	SP 450	Injection molding process OEE		
Month	ηa	ηp	ηq	(ηaxηpxηq)
DEC'19	97%	89%	99%	86%
JAN'20	96%	83%	99%	79%
FEB'20	96%	98%	99%	94%
Total	96%	92%	98%	86%

3.c.3 Post – Training impact on OEE Gap

PROCESS	Injection Molding Process SP450 OEE Gap			
Month	(1-ηa%)	(1-ηp%)	(1-ηq%)	(1- OEE%)
DEC'19	3%	11%	1%	14%
JAN'20	4%	17%	1%	21%
FEB'20	4%	2%	1%	6%
Total	4%	8%	2%	14%

3.c.4 Post – Training impact on Quality and Quality Gap

PROCESS NAME:		SP 450	INJECTION MOLDING PROCESS			
INJECTION MOULDING QUALITY						
Month	Net Operating Time (min)	Actual Production (Nos)	Quality Defects (Nos)	Good Production	ηq Quality	
	Ot	(Ap)	(Qd)	(Gp)	ηq (%)	Gap (%)
DEC'19	28988	28575	306	28269	99%	1%
JAN'20	24932	22865	321	22544	99%	1%
FEB'20	37721	38992	367	38625	99%	1%
Total	**91641**	**90432**	**994**	**89438**	**99%**	**1%**



There was advancement in OEE by 14% and particularly in quality by 2%. The OEE had heightened from 63% to 86%. It was found that the increment observed in the study is superior to the international norms of 85%. The OEE gap was reduced to 23% (Pre-Training OEE 37% - Post Training OEE 14%) and it is apparent that there is an importance on improving the skill to diminish the quality hindering factors. The study also observed that quality training was a major factor in the reduction of gap from 4% to 1%.

c.3.5. Preparation of Post- Training C-Chart analysis.

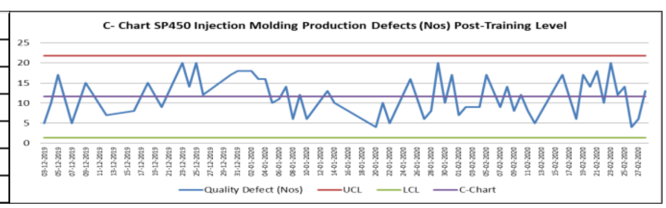
SP 450 INJETION MOLDING PRODUCT DEFECTS (POST TRAINING)					
Sample Size	FM 450	Quality Defect (Nos)	UCL	LCL	C-Chart
1	02-12-2019	13	22	1	12
2	03-12-2019	5	22	1	12
3	04-12-2019	10	22	1	12
4	05-12-2019	17	22	1	12
5	07-12-2019	5	22	1	12
6	09-12-2019	15	22	1	12
7	12-12-2019	7	22	1	12
8	16-12-2019	8	22	1	12
9	18-12-2019	15	22	1	12
10	20-12-2019	9	22	1	12
11	23-12-2019	20	22	1	12
12	24-12-2019	14	22	1	12
13	25-12-2019	20	22	1	12
14	26-12-2019	12	22	1	12
15	30-12-2019	17	22	1	12
16	31-12-2019	18	22	1	12
17	02-01-2020	18	22	1	12
18	03-01-2020	16	22	1	12
19	04-01-2020	16	22	1	12
20	05-01-2020	10	22	1	12
21	06-01-2020	11	22	1	12
22	07-01-2020	14	22	1	12
23	08-01-2020	6	22	1	12
24	09-01-2020	12	22	1	12
25	10-01-2020	6	22	1	12
26	13-01-2020	13	22	1	12
27	14-01-2020	10	22	1	12
28	20-01-2020	4	22	1	12
29	21-01-2020	10	22	1	12
30	22-01-2020	5	22	1	12
31	25-01-2020	16	22	1	12
32	27-01-2020	6	22	1	12
33	28-01-2020	8	22	1	12
34	29-01-2020	20	22	1	12
35	30-01-2020	10	22	1	12
36	31-01-2020	17	22	1	12
37	01-02-2020	7	22	1	12
38	02-02-2020	9	22	1	12
39	04-02-2020	9	22	1	12
40	05-02-2020	17	22	1	12
41	07-02-2020	9	22	1	12
42	08-02-2020	14	22	1	12
43	09-02-2020	8	22	1	12
44	10-02-2020	12	22	1	12
45	11-02-2020	8	22	1	12
46	12-02-2020	5	22	1	12
47	14-02-2020	11	22	1	12
48	15-02-2020	14	22	1	12
49	16-02-2020	17	22	1	12
50	18-02-2020	6	22	1	12
51	19-02-2020	17	22	1	12
52	20-02-2020	14	22	1	12
53	21-02-2020	18	22	1	12
54	22-02-2020	10	22	1	12
55	23-02-2020	7	22	1	12
56	24-02-2020	12	22	1	12
57	25-02-2020	14	22	1	12
58	26-02-2020	4	22	1	12
59	27-02-2020	6	22	1	12
60	28-02-2020	13	22	1	12
	Total	694			

Fig:5 C- Chart Table –Post Training

c.3.6. Post- Training C-Chart Table

It is identified from the C-Chart that the displacement in defect spanned between 3 to 25 (Numbers) This is correlated to the Pre-training defect that varied between 30-70 (Numbers) This the TPM quality hindering factor-related training benefits to enhance the skill and ameliorate the defects as shown in C-Chart and, the table given in **Fig-4**

C- Chart			
CL =	efect / No of Samples		
UCL=	L + 3 sqrt of CL		
LCL =	L - 3 sqrt of CL		
CL =	694	60	12
UCL=	12	10	22
LCL =	12	-10	1



c.3.7. Post-Quality Hindering Factor Analysis

FACTOR ANALYSIS - SP450 INJECTION MOLDING QUALITY DEFECTS -(POST-TRAINING)										
SUB FACTOR		Dec'19	Jan'19	Feb'20	Total	More % for each items	Failure Mode Factors	Failure Mode	Increase in Failur Mode	Decrease in Failire Mode
1	Color Change START-UP Rejec	49	43	22	114		Total1st Month	237		
2	Mould Change START-UP Rejec	38	34	24	96	-3%	1	231	0	6
3	Other Start-up Rejection	108	92	177	377	-2%	2	227	0	4
4	Black Lines	5	0	0	5	-23%	3	242	0	16
5	Black Spot	0	0	0	0	0%	4	247	0	5
6	Blow Holes	0	0	0	0	0%	5	247	0	0
7	Bubbles	0	0	0	0	0%	6	247	0	0
8	Burn Mark	16	0	0	16	0%	7	247	0	0
9	Color Variation / Line	7	5	5	17	-7%	8	231	0	16
10	Crack	0	0	0	0	-1%	9	229	0	2
11	Cut Mark	0	0	0	0	0%	10	229	0	0
12	Damage	4	0	46	50	0%	11	229	0	0
13	Drooling	0	0	0	0	-2%	12	225	0	4
14	Filling Mark	0	0	0	0	0%	13	225	0	0
15	Flow Line	0	0	0	0	0%	14	225	0	0
16	Glossiness Variation	0	0	0	0	0%	15	225	0	0
17	Lumps Issue	0	0	0	0	0%	16	225	0	0
18	Oil Mark	0	0	0	0	0%	17	225	0	0
19	Part Weight Variation	0	0	0	0	0%	18	225	0	0
20	Patch Mark	0	0	0	0	0%	19	225	0	0
21	Pin Mark	0	0	0	0	0%	20	225	0	0
22	Raw Material Problem	0	0	0	0	0%	21	225	0	0
23	Rib Damage / Catching	0	0	0	0	0%	22	225	0	0
24	Scratches	0	0	0	0	0%	23	225	0	0
25	Short Fill	10	7	0	17	0%	24	225	0	0
26	Shrinkage	0	0	0	0	0%	25	228	0	3
27	Silver Mark	0	0	0	0	0%	26	228	0	0
28	Spray Mark	0	0	0	0	0%	27	228	0	0
29	Strain Mark	0	0	0	0	0%	28	228	0	0
30	Warpage	0	0	0	0	0%	29	228	0	0
31	Water Mark	0	0	0	0	0%	30	228	0	0
		237	181	274	692	0%	31	228	0	0
Fig. 6 Post Quality Hindering Factor Analysis							2nd Month	228		

From the above **Fig.6** post quality hindering factor analysis, it is evident that the quality defects were in decreasing trend as compared to **Fig.4** of pre-training factor analysis. The factor-related skill training is an impact not only on quality but also improve the OEE. Merely improving the OEE percentage will not give sustainable results, but eliminating the hindering factors in availability, performance, and quality through skill enhancement of employees leads to optimum utilization of capital. It is possible with the combined efforts of the TPM pillars of autonomous maintenance, planned maintenance, quality maintenance, Focused improvement, Safety Hygiene, and Environment led by the essential TPM pillar of education and training. The following are measures taken to enhance the skill.**c.3.8. Training on Quality Skill Assessment**

In the next stage post-skill assessment were conducted and plotted as follows.

Skill Level Post Training - SP450 Seat and Back Angle Process

Factors	Skill Attributes	Target	SE01	SE02	SE03	SE04	SE05	SE06	SE07	SE08	SE09	SE10	SE11	SE12	SE13	SE14	SE15
			GAP IN OPERATOR SKILLS (AFTER TRAINING)														
A	[1]	5	4	5	4	5	4	5	5	5	5	5	4	5	5	4	4
A	[3]	5	5	4	4	5	5	5	5	5	4	5	5	5	4	5	4
A	[11]	5	4	5	4	4	4	4	5	4	5	4	5	5	4	4	5
A		5.0	4.3	4.7	4.0	4.7	4.3	4.7	5.0	4.7	4.7	4.7	4.7	5.0	4.3	4.3	4.3
P	[6]	5	5	5	4	4	4	5	4	5	5	4	5	5	4	4	4
P	[4]	5	5	5	5	5	5	5	4	5	5	4	4	5	4	4	4
P	[2]	5	4	5	5	5	4	5	5	4	5	4	4	5	4	4	4
P		5.0	4.7	5.0	4.7	4.7	4.3	5.0	4.3	4.7	5.0	4.0	4.3	5.0	4.0	4.0	4.0
Q	[9]	5	5	5	5	5	5	4	4	4	5	4	5	4	4	4	5
Q	[10]	5	5	5	5	4	5	4	4	5	5	4	5	4	4	4	5
Q	[8]	5	4	5	5	4	5	5	5	4	4	5	5	4	4	4	5
.		5.0	4.7	5.0	5.0	4.3	5.0	4.3	4.3	4.3	4.7	4.3	5.0	4.0	4.0	4.0	5.0
I	[7]	5	5	5	5	4	4	4	4	4	5	4	4	4	4	4	4
S	[5]	5	5	5	5	4	5	4	4	5	5	4	4	4	4	5	4

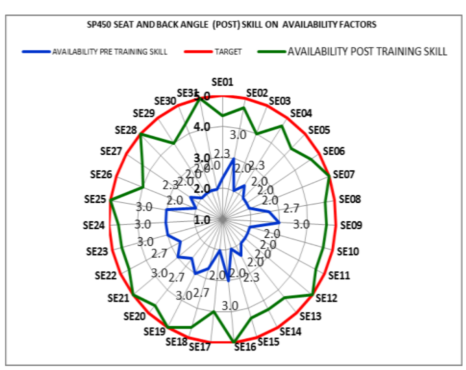
Factors	Skill Attributes	SE16	SE17	SE18	SE19	SE20	SE21	SE22	SE23	SE24	SE25	SE26	SE27	SE28	SE29	SE30	SE31
A	[1]	5	4	5	5	4	5	5	5	4	5	4	4	5	4	4	5
A	[3]	5	4	5	5	5	5	5	4	5	5	4	4	5	4	5	5
A	[11]	5	4	4	5	5	5	4	5	5	5	4	5	5	4	4	5
A		5.0	4.0	4.7	5.0	4.7	5.0	4.7	4.7	4.7	5.0	4.0	4.3	5.0	4.0	4.3	5.0
P	[6]	5	4	4	5	5	5	5	5	5	5	4	4	5	4	5	4
P	[4]	5	4	5	5	4	5	5	4	5	5	4	4	5	4	5	4
P	[2]	4	4	4	4	5	5	5	4	5	5	4	5	5	4	4	5
P		4.7	4.0	4.3	4.7	4.7	5.0	5.0	4.3	5.0	5.0	4.0	4.3	5.0	4.0	4.7	4.3
Q	[9]	4	4	5	5	5	5	5	4	5	5	4	4	5	4	5	4
Q	[10]	5	4	4	5	5	5	5	5	5	5	4	5	5	4	5	4
Q	[8]	4	4	5	5	4	5	5	4	5	5	4	4	5	4	5	5
.		4.3	4.0	4.7	5.0	4.7	5.0	5.0	4.3	5.0	5.0	4.0	4.3	5.0	4.0	5.0	4.3
I	[7]	4	4	4	5	5	4	4	5	5	5	4	4	4	4	5	4
S	[5]	5	4	5	5	5	4	5	5	5	5	4	4	4	4	4	5

c.3.9. Post- Quality Skill Assessment Questionnaire

Factor	Operational / Maintenance skill attributes SP 450 Seat and Back Angle Process
A	1. I am able to support preventive maintenance.
S	2. I am able to eliminate unsafe act
A	3. I am able to make mold change adjustments and repairs
P	4. I am able to identify and eliminate abnormalities in equipment and process
P	5. I am able to prepare and update TPM activity board.
P	6. I am able to maintain input/output temperature in cooling
I	7. I am able to inspect moisture in input material
Q	8. I am able to control high melt or mold temperature (if gate freeze off slow)
Q	9 I am able to eliminate speed loss
Q	10.I am able to increase clamp force to eliminate flash
A	11.I am able to clean vents, increase size or number of vents to avoid burning mark
	A= Availability, P= Performance, Q= Quality, S=Safety and I=Involvement

From the above tables, it is obvious that the effect post-effect training on Quality control is a major determining factor of quality factor analysis, since the skill level had augmented 3-5 points as against the pre-skill level of 2-3 skill points out of the five point scale. It is noticeable that the training impact is strikingly high using the quality defect-based curriculum as a training module. The refinement of skill post training was compared to the pre-OEE data and the expanse of new skill level post test-was by 3-5 points, against the pre-skill result of 2.3 points out of the target of five points. Training impact is pronounced for quality defect-based curriculum is thus proved. It pertained the connection between skill improvement and OEE obtained. It is thus discerned that, there was a restoration of OEE post-skill OEE to 86% from 63% (pre-skill). To relate the pre-skill and post-skill training impact the radar chart is prepared

c.3.9. Pre and Post-Skills Radar Chart



Step-4. Concluding remark

This is a study conducted to evaluate the quality hindering factors in TPM and to assess the significance of skill application in a large-scale injection molding manufacturing industry of plastic products. Based on the test strategy, inclusion and exclusion criteria were identified and 31 employees were chosen. The study compared the influence of skill on the Overall Equipment Effectiveness using a training module for skill learning and application. This was provided to the employees with the pre-training OEE from the study observed as 63%, and a gap of 37% was retrieved before pre-skill training. The 37% gap was further taken and assessed with the hindering sub-factor analyses to expand the pre-skill OEE which was 63%. TPM quality factors-based training was delivered to 31 employees using on-the-job training, cut model training, autonomous maintenance step-5 training, and the deficit definition to comprehend the rationale for counter measures. The usage of visual control and visual management was to find the quality deviation before the process. Quality kaizen and the quality one point lesson (QOPL) helped the employees march towards zero quality defect concepts. The impact in OEE reflected in the post-skill training is as follows.

1. The post-skill OEE had improved at 86% as compared with the pre-skill at 63%.
2. Post-skill training improved to 3-5 points against 5 point scale compared with the pre-skill to2-3 points.
3. There was a removal in the skill gap of 14% against the pre-skill training level of 37%.
4. After post-skill training, the employees developed nine quality one-point lessons.
5. After post-skill training, fourteen kaizens were prepared to eliminate the quality defect. The same was two in the pre-skill level.
6. It was observed that the employees had to acquire reasonable safety knowledge and so is to practice on the shop floor.
7. Thirty-one respondents had practiced TPM in their daily work management with the support of supervisors.
8. The post-training evaluation was carried out in the same way as pre-training to find the impact of skill on the quality factor with the help of the unit head.
9. Quality skill improvement had an improvement part of productivity.
10. Development of existing operator quality skills commences from the comprehension of hindering quality factors affecting TPM
11. Quality skill training modules should be formulated on a tailored basis depending on the existing scenario.
12. Guided training under supervision is a mission that can shift the existing hardships in quality assurance on a positive side.

Nevertheless, the effect of quality skill as a hindering factor is camouflaged with other confounding factors, hence an integrated knowledge of the pillars of TPM is inevitable.

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