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DEVELOPMENT OF SIMPLIFIED TOTAL PRODUCTIVE MAINTENANCE SYSTEM FOR TINY INDUSTRIES AND ITS IMPLEMENTATION

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Abstract

TPM is a Highly Productive Maintenance Technique in Medium & Large Enterprises, rarely in Small Enterprises, but not at all Practiced in the 'Tiny (Micro) Manufacturing Industry' (TIs).The study began with SWOT analysis to assess the Key Performance Indicators/Critical Success Factors. Which leads to the development of a Conceptual Model 'STPM' to facilitate its implementation. To prove the simplified version is productive, implementation study was also conducted in TIs and found to be successful. Based on the Data a Mathematical Model was developed for Overall Equipment Effectiveness .OEE of the TI Improved leads to Overall Factory Effectiveness improvement.

Keywords : TPM,STPM,TI,MLE, SME,KPI,CSF,OEE,OFE,SWOT

Introduction: The Flow of Work

The following flow chart explains the way in which the work flowed, as far as the observations show that the SWOT analysis reveals that the KPIs in the case of TPM implementation is concerned are the Availability, Performance and Quality rates. And the Critical Success Factor is the OEE

Figure 1: Work Flow Chart

As far as the Indian Manufacturing Industry is concerned, the Confederation of Indian Industry CII is an authorized body whose TPM Club has proposed a model shown below and followed by the above.[1,2,3]

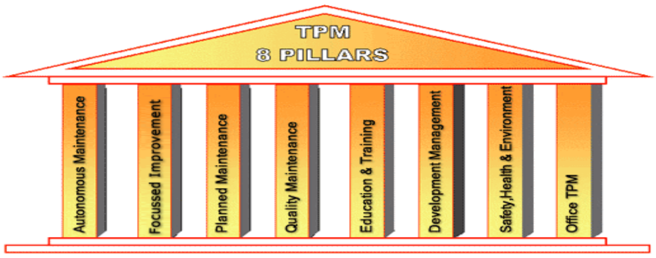

Figure 2: TPM Pillars of TPM Club of India

The research proposes a simplified version in order to suit the needs of Tiny (Micro) Manufacturing Industry, The first pillar comprises of whatever related to maintenance like autonomous maintenance, focused maintenance improvement, planned maintenance, quality maintenance and the second pillar comprises of whatever related to administrative activities like Office TPM, education and training as well as development management. The third pillar concentrates on safety, health and environment.[4,5]

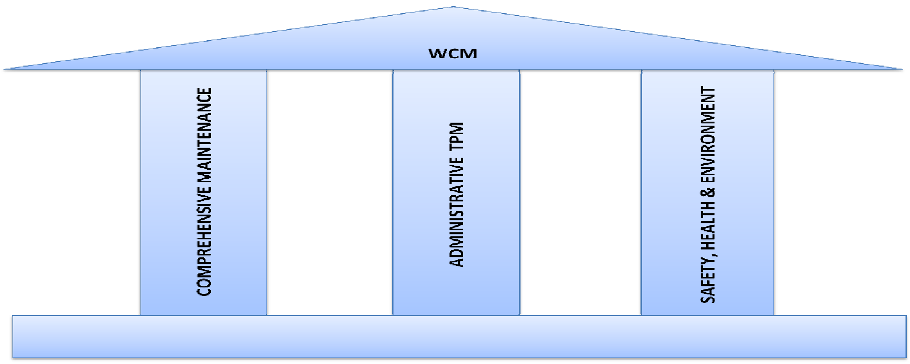

Figure 3: TPM Pillars of Simplified Version

The Approach: Action Research

The study is demanding the direct involvement of the researcher and as there is no TPM office or experts available, the researcher himself had to involve on the cyclic planning, acting, observing, reflecting and re-planning and the cycle continues on and on till desired result is attained.

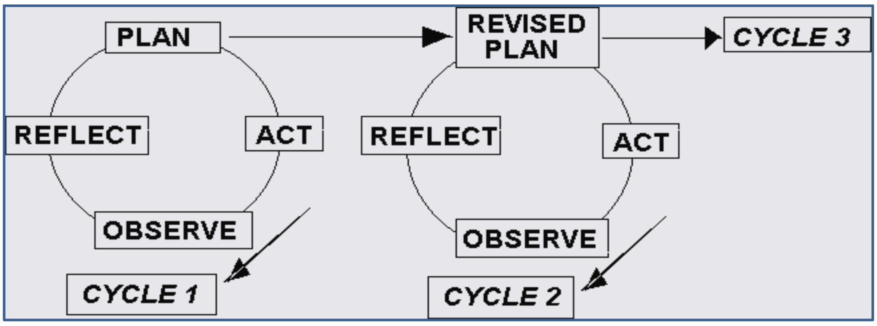

Figure 4: The Action Research Cycle

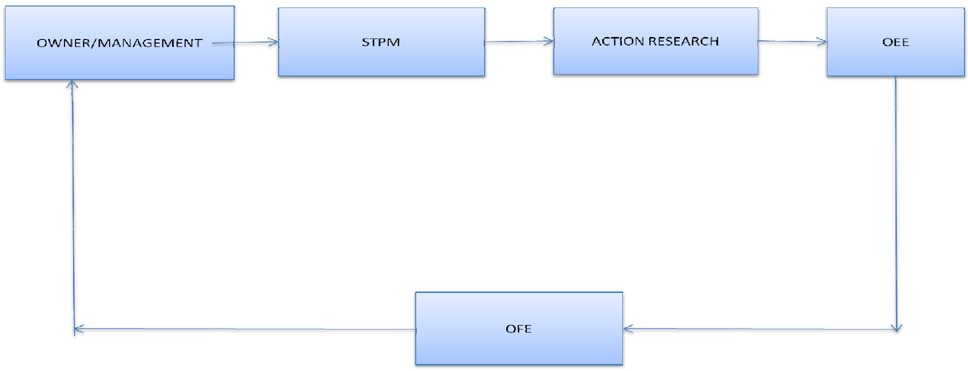

Figure 5: The Frame Work of Action Research

Study I: SWOT Analysis-Exploring KPI/CSF

SWOT analysis carried out for assessing TPM for STEs by visiting a variety of Small and Tiny Enterprises. Exploring the STRENGTH of the organizations to support TPM. The supportive OPPORTUNITIES that can further the strength identified. Unearthing inherent WEAKNESS of the organizations. The THREATS that may weaken the organizations listed. Considered as the primary work to be done before the implementation of TPM to know the KPIs/CSFs. Outcome: SWOT of TPM implementation in STEs.[6,7,8,9]

KPIs/CSFs (Industry Dependent)

- Management Support,
- Employee Participation,
- Knowledge and Skill,
- Maintenance Strategy,
- Supplier/Customer Support
- Maintenance Data

- Kaizens (Focused Improvements -Pushing Up)
- Fuguais (Abnormalities -Pulling Down)
- As far as this study, factors affecting availability, performance and quality are the KPIs
- OEE is the CSF

Study II: The Model Suitable For TI

Data collected from a tiny (micro) mfg. unit used. It's a comparative work on various optimization algorithms like GA. To predict the availability of a critical machine. The availability calculated using GA was compared with the experimental values. The GA prediction is closer to the actual values. Outcome: Synthetically Availability Data may be generated by GA for further enhancement in TEs.[10,11,12]

$$F(A_i) = a(optimz)\frac{1}{1+\exp[1-\sum_{i=0}^{N} y_i b(optimz)]}$$

(1)

Where,

a,b - optimum weights

y_i- input parameters

Why Genetic Algorithm - GA

Genetic algorithm can solve every optimization problem which can be described with the chromosome encoding. It solves problems with multiple solutions. Genetic algorithm is a method which is very easy to understand and it practically does not demand the knowledge of mathematics. Genetic algorithms are easily transferred to existing simulations and system.

StudyIII : The Better Model for TI

Data collected from another tiny (micro) mfg. unit . It's again a comparative work on various optimization algorithms like GA & PSO. To predict the OEE (A*P*Q) of critical machines. The availability calculated using GA and PSO were compared with the Experimental values. The PSO prediction was closer to the actual values than GA route. Outcome: Synthetic 'OEE' Data may be generated by PSO for further enhancement in SEs.

Why Particle Swarm Optimization – PSO

The main difference between the PSO approach compared to GA is that PSO does not have genetic operators such as crossover and mutation, otherwise very similar to GA. Particles update themselves with the internal velocity; they also have a memory important to the algorithm. Also, in PSO only the 'best' particle gives out the information to others. It is a one-way information sharing mechanism, the evolution only looks for the best solution. Compared to GAs, the advantages of PSO are that PSO is easy to implement and there are few parameters to adjust. PSO is more computationally efficient (uses less number of function evaluations) than the GA.

$$Y_{A_{opt}} = \sum_{i=0}^{N} \omega_i \frac{1}{1-\exp(\sum_{j=0}^{n}((T+B+D+R+N+F+G+P_t+T_t)\mu_{ij}))} \quad (2)$$

$$Y_{Q_{opt}} = \sum_{i=0}^{N} \omega_i \frac{1}{1-\exp(\sum_{j=0}^{n}((T+B+D+R+N+F+G+P_t+T_t)\mu_{ij}))} \quad (3)$$

$$Y_{P_{opt}} = \sum_{i=0}^{N} \omega_i \frac{1}{1-\exp(\sum_{j=0}^{n}((T+B+D+R+N+F+G+P_t+T_t)\mu_{ij}))} \quad (4)$$

$$E_{opt} = Y_A * Y_Q * Y_P \quad (5)$$

Where

$Y_{A_{opt}}$ - optimized value of availability

$Y_{Q_{opt}}$ - optimized value of Quality

$Y_{P_{opt}}$ - optimized value of performance

E_{opt} - optimized value of OEE

T, B, D, R, N, F, G, Pt, Tt- parameters(+/_)

μ, ω, - random functions

Study IV: Implementation in STEs

Study carried out at STEs, Nov'14 – Feb'15.Considering the status of STEs, 'S-TPM' was implemented. Tailor made for STEs, easier and quicker implementation. Modification without much compromise. Barrier and 5S Analyses done. Concentration only on Plastic Injection Molding industry. Objective: Actual Productivity Improvement using S-TPM-KAIZEN.

The 'OEE Frame Work

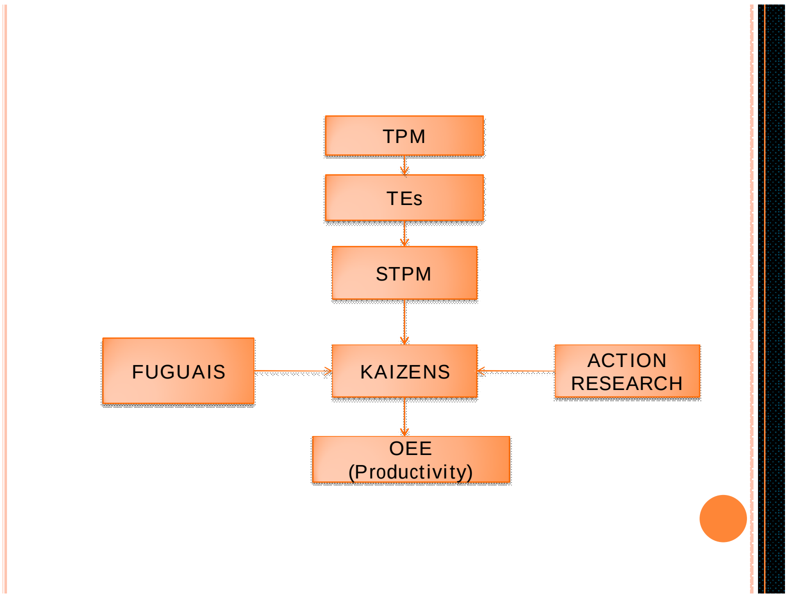

Figure 6: The Frame Work of OEE

The Case Industries

The industry1: SR Plastics. Run by : Individual Owner. Investment : > Rs.25 lakhs. Work Force : 10 Nos. Machinery: Plastic Injection Molding Machine,Scrap Grinder, Gantry Crane, Water Cooling Tower. Capacity: 160T clamping force. Customers: Automobile and Electrical & Electronics Indy. in and around Chennai The industry2: Anbu Plastics. Run by : Manager Respectively. Investment : < Rs. 25 lakhs. Workforce : 7 Nos. Machinery: Plastic Injection Molding Machine, Gantry Crane, Water Cooling Tower. Capacity: 150T clamping force. Customers: Automobile and Electrical & Electronics Indy. in and around Chennai

Table 1: Fuguais & Kaizens at both SRP and AP

Sl No.	Abnormality (Fuguai)	What will happen if it is left	Why did it become so	Kaizen performed	Benefits

1	Leakage from tapped portion	Feed wastage	Gasket loose	Tight it properly	Reduced feed wastage
2	Leakage from gear box	Oil wastage	Nut loose	Tight loose	Reduce oil wastage
3	Driver belt loose	Less agitation	Negligence	Tight it properly	Proper speed, time saving
4	Electric wires not covered	Cause drip down	Negligence	Cover all wires	More safe and Unexpected drip will not occur
5	Machine base found unclean	Look bad	Negligence	Clean	Better look, safe work
6	Gear shaft tight	Gear shift tight	Negligence	Proper lubrication	Easy gear shift
7	Standing platform filthy	Look bad, unsafe	Negligence	Clean	Easy, safe Work
8	Cooling system not working	Heat emission from motor	Dirt in fan or fins	Clean it	Reduce temperature of motor
9	Improper lighting	Less vision on machine	Negligence	Provide bulb	Indication achieved

Table 2: Inspection Employed at both SRP And AP

Location	Method of inspection	Standard	Time	Frequency	Action taken if not OK
Cooling fan, cooling fins	Visual	Kept free from dirt	30-40 sec	Daily	Remove the dirt

Diver belt	Visual	Tension, wear, seating of belt	20-30 sec	Daily	Corrected
Electrical insulation	Visual	Full insulated	20- 30sec	Weekly	Give proper insulation
Gear box	Noise	Free engagement	20sec	Daily	Call maintenance
Bearing	Noise	No noise	20sec	Daily	Call maintenance

Table 3: Lubrication Employed at both SRP And AP

Sl no	Location	Methods of lubrication	Type of lubricant	Quantity	Frequency
1	Bearings	Manual	Grease	As required	Monthly
2	Gearbox	Manual	Oil	As required	Quarterly
3	Gear shaft	Manual	Grease	As required	Weekly
4	Driver pulley	Manual	Oil	As required	Daily

Table 4: Kaizen Analysis Sheet for Injection Molding Machine

BEFORE S-TPM at SRP				
S.No.	PROBLEM/MONTH	Freq.	Freq.%	Cumulative %

1	Hydraulic oil leakage	100	31.8%	31.8%
2	Lubrication problem	91	28.9%	60.7%
3	Electrical fault	91	28.9%	89.6%
4	Cooling water problem	18	5.7%	95.5%
5	Untrained operator	09	2.8%	98.5%
6	Sudden power failure	05	1.5%	100%

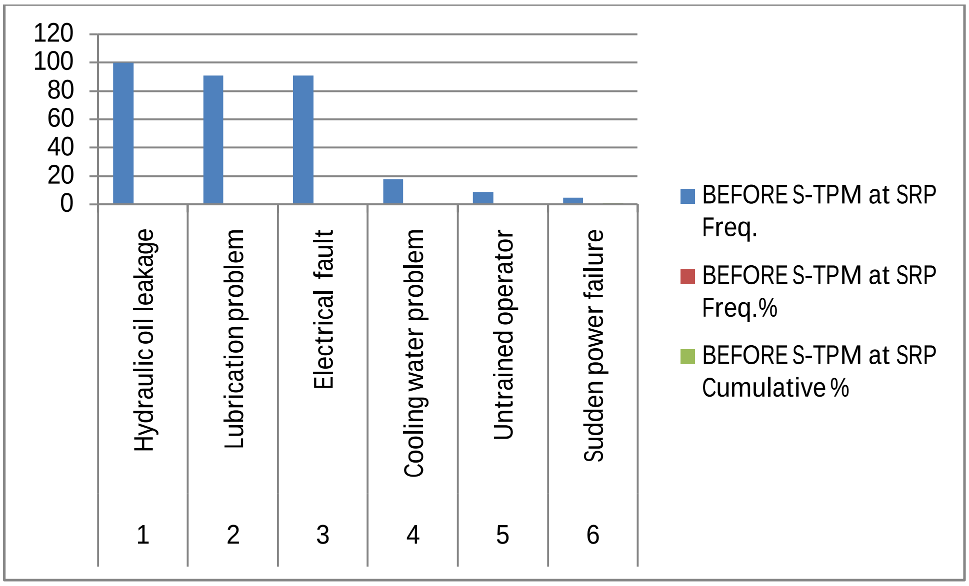

Figure 6: Kaizen Analysis Graph for Injection Molding Machine

Table 5: Kaizen Analysis Sheet for Injection Molding Machine

AFTER S-TPM at SRP				
S.NO	PROBLEM/ MONTH	Freq	Freq. %	Cumulative %

1.	Hydraulic oil leakage	35	61.4%	61.4%
2.	Lubrication problem	20	35%	96.4%
3.	Electrical fault	01	1.8%	98.2%
4.	Cooling water problem	01	1.8%	100%
5.	Untrained operator	00	00	00
6.	Sudden power failure	00	00	00

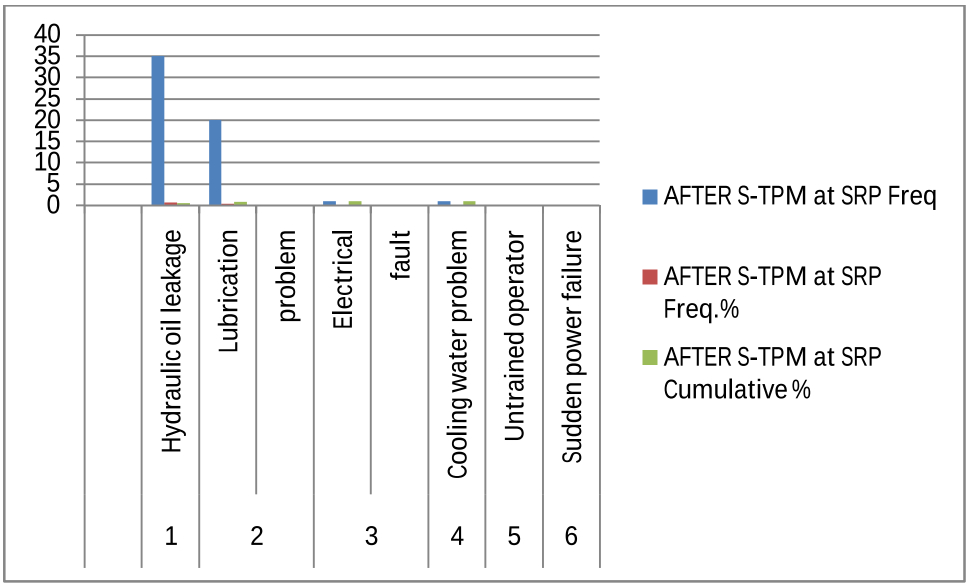

Figure7: Kaizen Analysis Graph for Injection Molding Machine

Table 6: Kaizen Analysis Sheet for Scrap Grinder

BEFORE S-TPM at AP				
S. NO	PROBLEM/ MONTH	Freq.	Freq. %	Cumulative %
1	Equipment failure	92	46.9%	46.9%
2	Cutter Problem	72	36.9%	84.6%
3	Vibration problem	14	7.1%	91.7%
4	Tool change	07	3.5%	95.2%
5	Sudden power failure	06	3.0%	98.3%
6	Untrained operator	05	2.7%	100%

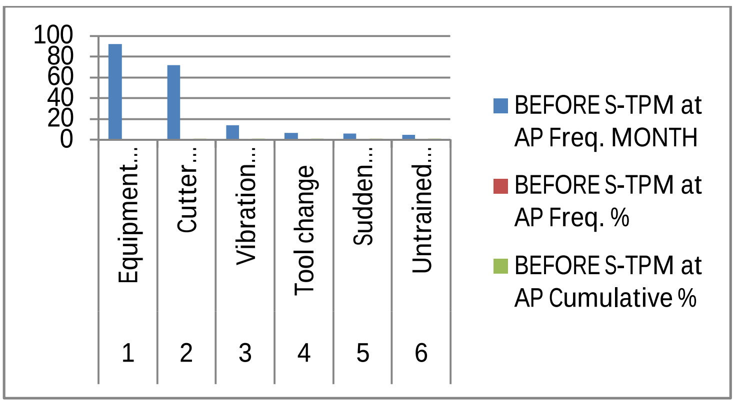

Figure 8: Kaizen Analysis Graph for Scrap Grinder

Table 7: Kaizen Analysis Sheet for Scrap Grinder

AFTER S-TPM at AP				
S.NO	PROBLEM/ MONTH	Freq.	Freq. %	Cumulative %
1	Equipment failure	40	48.80%	48.80%
2	Cutter Problem	40	24.40%	73.20%
3	Vibration problem	2	24.40%	97.60%
4	Tool change	1	1.20%	98.80%
5	Sudden power failure	1	1.20%	100%
6	Untrained operator	0	0	0

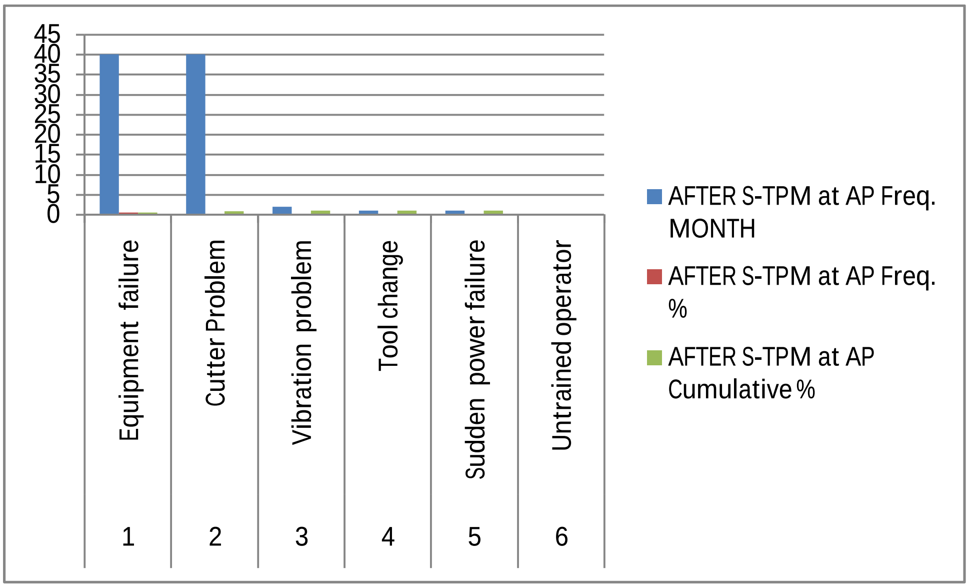

Figure 9: Kaizen Analysis Graph for Scrap Grinder

Table 8: Resultant OEE For At SRP

At SRP	During S-TPM		After S-TPM	
	Nov'14	Dec'14	Jan'15	Feb'15
Operating time (min)	26176	28736	38058	39755
Loading time (min)	28804	30412	40105	40540
Down time (min)	320	330	101	98
Output/month (no's)	121000	119000	128000	129000
Availability (%)	90.87	94.48	94.89	98.06
Performance efficiency(%)	95.12	96.22	98.21	98.33
Quality performance (%)	97.49	98.07	99.29	99.36
OEE (%)	84.26	89.15	92.52	95.47

Hypothesis: 'T' Test

H0: S-TPM has not improved OEE = 85%

H1: STPM has improved OEE > 85%

Where, n=4, x = 90.35, μ= 85, s = 4.1,ν=3,α=0.05

t = [x - μ] / [s / sqrt(n)] = 2.61

t3,0.05 = 2.353 (from t table)

Since table value (2.353) < claculated value (2.61)

H0 is rejected and H1 is accepted shows that STPM has significance in OEE improvement

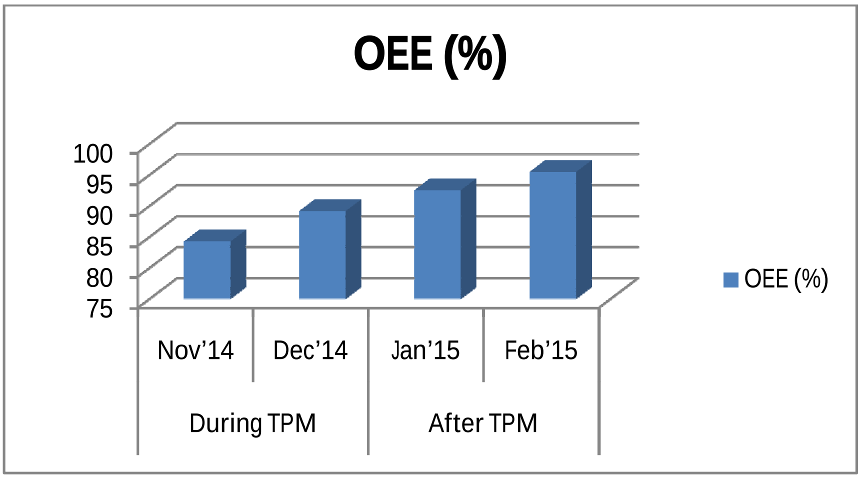

Figure 10: OEE at SRP

Table 10: Resultant OEE at AP

At AP	During TPM		After TPM	
	Nov'14	Dec'14	Jan'15	Feb'15
Operating time (min)	25132	27511	38532	39464
Loading time (min)	27765	29035	39734	40387
Down time (min)	190	244	80	68
Output/ month (min)	175000	170000	185000	188000
Availability (%)	90.51	94.75	96.97	97.71
Performance Efficiency (%)	94.54	96.12	97.84	97.73
Quality performance	98.30	98.44	99.26	99.32
OEE (%)	84.12	89.66	94.18	94.85

Hypothesis: 'T' Test

H0: STPM has not improved OEE = 85%

H1: STPM has improved OEE > 85%

Where, n=4, x = 90.70, μ= 85, s = 4.29,ν=3,α=0.05

t = [x - μ] / [s / sqrt(n)] = 2.68

t3,0.05 = 2.353 (from t table)

Since table value (2.353) < claculated value (2.68)

H0 is rejected and H1 is accepted shows that STPM has significance in OEE improvement

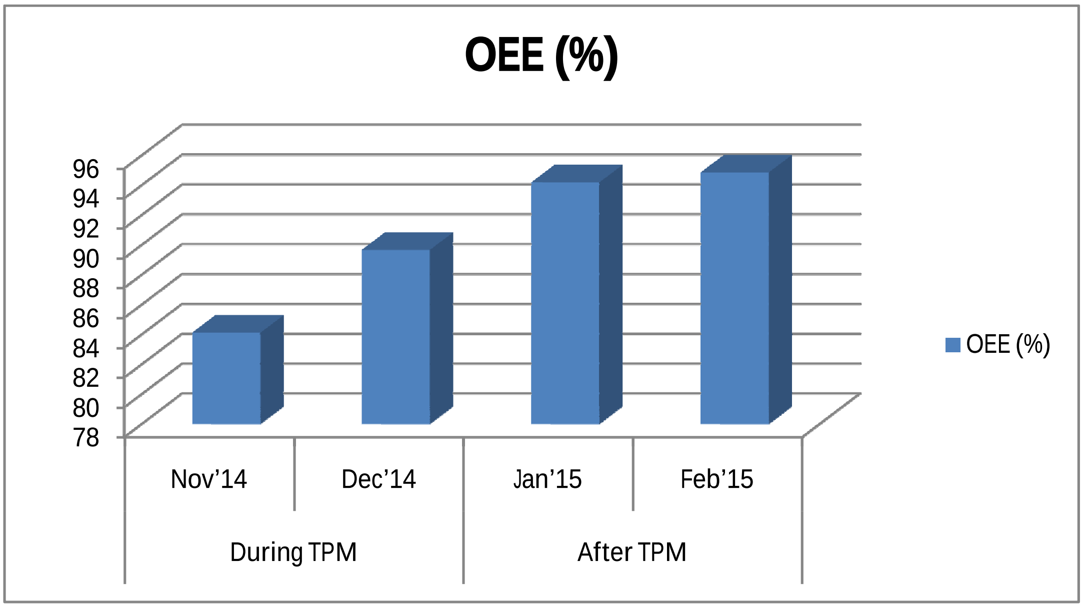

Figure 11: OEE at AP

Table 11: Observation of the Changes on a Day during the Study in SR Plastics

Sl.No.	Category	Implementation	
		Before Oct'14	After Feb'15
1	Shift time	720 min.	720 min.
2	Total production in a	720 Nos.	1600 Nos.

	shift		
3	Scheduled break	50 min.	50 min.
4	Non-scheduled break	5 min	0 min
5	Breakdown	4 min.	0 min.
6	CLIT	0min.	15min.
7	Operator Non-Utilization	55 min	6.5min
8	Non-conforming product	5Nos	3Nos.
9	Theoretical cycle time	7.5 min.	3 min.
10	Availability Rate (*AR*)	0.84	0.90
11	Performance Rate (*PR*)	0.73	0.85
12	Quality Rate (*QR*)	0.95	0.96
13	OEE ($AR \times PR \times QR$)	0.58	0.73

Table 12: Observation of the Changes on a Day during the Study in Anbu Plastics

Sl.No.	Category	Implementation	
		Before	After
1	Shift time	600 min.	600 min.
2	Total production in a shift	1000 Nos.	1500 Nos.
3	Scheduled break	45 min.	45 min.
4	Non-scheduled break	10 min	0 min
5	Breakdown	5min.	0 min.

6	CLIT	0min.	15min.
7	Operator Non-Utilization	45 min	10 min
8	Non-conforming product	10 Nos.	5 Nos.
9	Theoretical cycle time	10 min.	7 min.
10	Availability Rate (*AR*)	0.82	0.88
11	Performance Rate (*PR*)	0.70	0.85
12	Quality Rate (*QR*)	0.90	0.95
13	OEE ($AR \times PR \times QR$)	0.51	0.71

Table 13: Reduction in Incidents

Sl. No.	Incidents	SR Plastics		Anbu Plastics	
		Before	After	Before	After
1.	Near miss	3	1	2	1
2.	Slips	2	0	2	1
3.	Minor	4	1	3	1
4.	Major	1	0	1	0

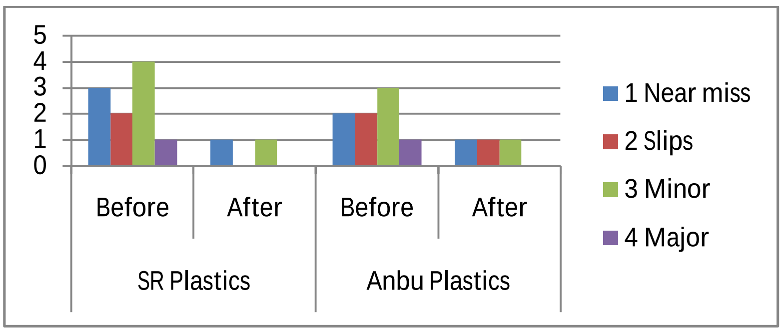

Figure 12: Incident Status

Administrative TPM

Introducing the Freeware CWMAIN a CMMS software. It was well received by SR plastics which is run by Owner. Not well received in Anbu plastics which is run by a Manager. Only in the long run its benefits could be ascertained. Usage of Laptops, Mobile Phones used for information communication modes being streamlined. Steps have been taken to use the above to 'Train and Educate' workers.

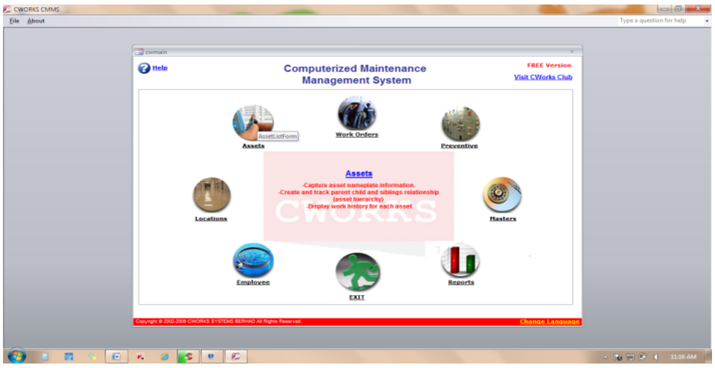

Figure 13: Free Maintenance Software Console

Safety Health & Environment

Introduction of simple First Aid Kit and Introduction of Fire Extinguisher

Figure14: The Safety Gadgets

As safer working is prerogative simple safety gadgets like gloves, helmets, shoes, fire extinguisher, etc were introduced. First Aid Kits were also installed. As the materials handled are plastic products their recycling is being tried. Several safety, health and environmental aspects are also being enforced but only a diluted form could be achieved. Financial implications in these aspects are hurdles.

Conclusion

The research has successfully developed an innovative methodology to the implementation of TPM in Tiny (Micro) Manufacturing Industry and has also been proved statistically that STPM is significant in the improvement of the OEE which in turn will improve OFE.

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