



## A STUDY ON THE PSO MODEL BASED QUICK TOTAL PRODUCTIVE MAINTENANCE FOR SMALL AND TINY ENTERPRISES

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### ABSTRACT

The Significance of Total Productive Maintenance (TPM), its applicability in small and tiny enterprises (STEs), the condition of the STEs, their survival problems, lack of any modern management/maintenance methodology that helps improve the productivity are what the driving forces of this work. A fast track version is designed, considering Critical Success Factors (CSF) and it can be called as Quick Total Productive Maintenance (Q-TPM), without diluting the essence of original TPM, in this study. The study is also an attempt to develop a mathematical model called Particle Swarm Optimization (PSO) specifically for the STEs. Thus, the model developed can be handled/extrapolated /interpolated in various manners, so that selective parameters may be altered to improve productivity and Synthetic Data Generation (SDG) may be done for further enhancement.

**Keywords:** *TPM, Q-TPM, CSF, STEs, SDG, PSO, Mathematical Model, Productivity*

### 1. INTRODUCTION TO 'TPM' AND MODIFIED 'Q-TPM'

Total Productive Maintenance (TPM) [1],[2],[3] is a management methodology adopted worldwide by major industries to maximize productivity. It is something that is measured by the overall equipment effectiveness (OEE) and is applicable throughout the life of the equipment/machinery/plant considered. It is of Japanese origin but has been proved successful in major industries everywhere. It is a comprehensive maintenance program and it involves everyone in the enterprise. It has been observed to be complicated to implement, but if implemented perfectly it is evident to be highly productive. Though there is a well defined procedure for implementation, available in the form of pillars of TPM, following it is tricky. It has been observed that, if it is partially or for namesake implemented, the result would be uninteresting. The industries usually show much enthusiasm initially and as the years go by, they start losing interest in it, as the result of it, would be experienced only after a

considerable period with a steady implementation. The version that is adopted by the medium and large enterprises (MLEs) cannot be adopted for the Small and Tiny Enterprises (STEs) and a modified version is needed. For adaptability, ease of implementation as well as for quicker tangible results, a fast track version is designed and it can be called as Quick Total Productive Maintenance (Q-TPM), without diluting the essence of original TPM. Q-TPM helps the STEs to try an easily implementable set of modified pillars (Figure1). The Q-TPM has only 3 pillars in order to avoid cumbersomeness in understanding it in an STE, where, the First Pillar 'Comprehensive Maintenance' includes, Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Kaizen and Early equipment Maintenance. The Second Pillar 'Administrative QTPM' includes Education and Training as well as all administrative aspects of TPM including Office-TPM. The Third Pillar concentrates on Safety, Health and Environmental aspects of TPM. The modifications done to help us to quicken the process of implementation.

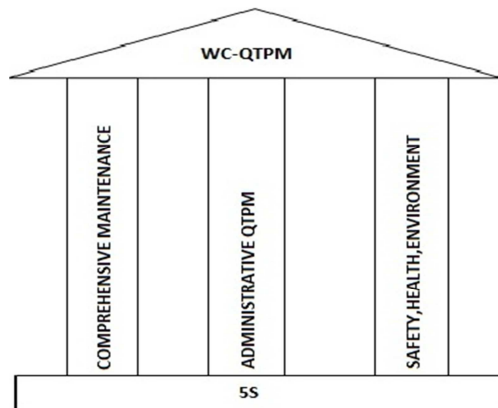


Figure1: QTPM Pillar

**2. MOTIVATION: STATUS OF THE SMALL AND TINY ENTERPRISES (STEs)**

Most of the small, medium, and large enterprises (SMLEs) rely on many tiny industries for most of their smaller and sub-components, which may be functioning as individual units or may be ancillary units of the main units. Whatever may be the case, tiny enterprises have a noticeable impact on the whole. Our consideration is the tiny units run individually, where the annual transaction is limited and varies with the country. There are many tiny units functioning in a conventional manner without the knowledge of or not considering the modern trends. On the other hand they struggle a lot for a survival and to withstand the competition. Of course, to be competitive they need to update themselves. But they are afraid of the increase in the expenses as well as lack of personnel to guide them. Moreover the complications in the understanding of the core concept of any modern tools, aids, techniques etc., impair such implementation of them, even in small, medium and large industries themselves, it is difficult, due to non involvement of the top management as well as the personnel up to the lowest rung. Cynicism is always there considering TPM also as one of the 3 or 4 letter acronym of the month. Since the outcome as well as the benefits of TPM could be perceived only after a long term proper implementation [5],[6],[7] without any lacuna. But there is a clear evidence of positive outcomes and noticeable benefits as found by Mishra RP [12], Gadjick [14], work force is of small strength it should be properly paid, educated, and trained so that understanding

Then comes the critical success factors (CSF), for a successful implementation and productivity

Considering the tiny enterprises, to taste the benefits they are not ready to spend time, money, personnel etc., and they still prefer short-term benefits. This makes the introduction of TPM in such industries become more and more difficult. Finding an apt industry and convincing the management remains a Himalayan task. Despite all the obstacles, TPM remains a relevant and important technique to be competitive in all respects. This aspect motivated and made this research possible and fruitful [8],[9] [10],[11].

**3. THE ‘SWOT’ AND ‘CSF’ ANALYSES**

As discussed by Mishra RP et.al [12] there exists a number of frame works designed by or adopted by a variety of industries/organizations, selecting a suitable frame work for a tiny/small manufacturing facility is a difficult job. So conducting a SWOT (strength, weakness, opportunities and threat) analysis is a right choice. Initially a model may be designed which concentrates on the economic efficiency, which plans and controls the maintenance expenses, to gain confidence of the top management, of course a tiny enterprise is mostly run by an individual. Convincing the management using economic efficiency of the model may be attractive; of course, zero accident, zero defect and zero failure are underlying agenda of the model. Coming to the workers participation, the tiny/small units normally have only temporary workers or workers’ turnover would be more, this should be changed. Though the and involvement would be there from their part, which in turn results in staff retention. enhancement there are certain criteria responsible and they may be termed as Critical Success Factors (CSF) like, Management Support,

Employee Participation, Knowledge and Skill, Training and Education, Maintenance Strategy,

Supplier /customer Support Maintenance Data etc.; These were analyzed from the context of STEs [29].

**4. DOWN TIME DETAILS OF A LAMINATION MACHINE IN A PRINTING INDUSTRY**

A data was collected on a Lamiantion Machine of a Printinting Industry falling under STE category and Fig.1 details the alteration of one of the procedures of down time procedure in Lamination machine. In fact, the downtime procedure is the synthesis of many methods. However, we are concerned only with the chronological career deficiency procedure in the entire downtime procedure. It is the mix of No. of job and job

variation procedures. With a view to decreasing these procedures, we carry out the QTPM doctrines in the company and the downtime process gets decreased without any complication. We also execute suitable design and decision making procedures in the company, and hence the chronological career deficiency procedure gets dwindled by about 56%.

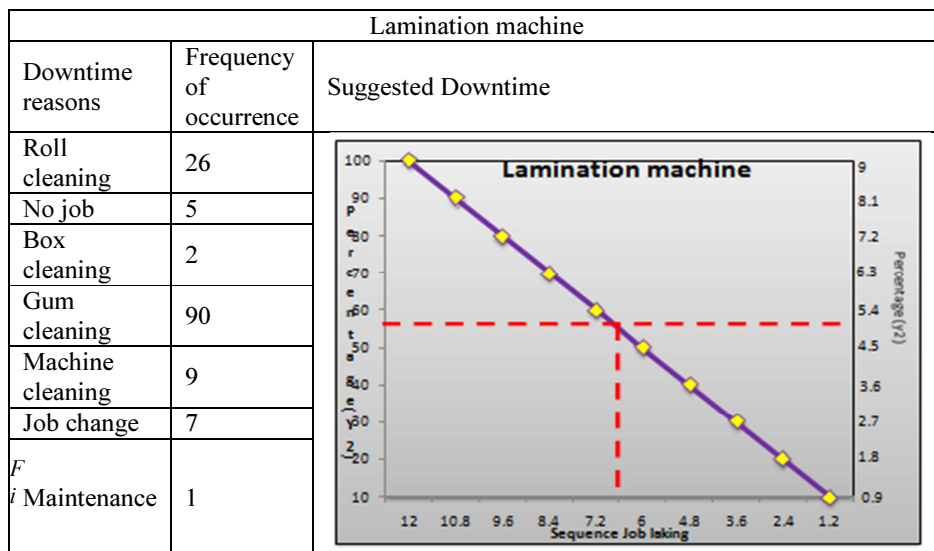


Figure 2: Downtime Variation of Lamination Machine

**5. MODEL BUILDING USING PARTICLE SWARM OPTIMIZATION (PSO)**

The next step would be to find an option for QTPM model building, as a part of the study, Particle Swarm Optimization model (PSO algorithm Figure 3) and the PSO codes were generated and employed for the purpose [4][13]. The test outcomes yield us the values of Availability (%), Performance (%), Quality (%) and

in turn OEE (%) by using input values of specific constraints and equivalent shift values. The planned methodology constitutes of a statistical pattern with PSO route which yields a much desired optimal results in several systems. Subsequently these values conformed to test outcomes, producing results of values closer to the test values. The most important advantage of the PSO method is that the results are more accurate and consistent.

PSO optimization method yields encouraging outcomes, as there is a significant reduction in the machine downtime and proportional productivity

improvement. As a general rule, competence of a product is based on several constraints, in accordance with corresponding changes in values and times. The proposed strategy is to find a way to

upgrade the OEE value, by making use of certain methods which will ultimately usher in further decrease in downtime. This method enables the downtime values to go down sufficiently enough to augment the efficiency of the systems. When considering the Lamination machines with downtime values decrease in the process to 56%. After measuring the down time and total operation time, it is computed the new values of all constraints and shift values to find out the efficiency values, which is then

mathematical model, which is applied on all the parameters and shift values for finding out the overall efficiency values, which are validated with the experimental results. It is then considered for all the output parameters such as availability, performance, quality and OEE for the up gradation later. The figures 3 and 4 below were plotted for mathematical model with PSO technique output performances and experimental results. From these graphs, we can show that PSO technique has performances closest to the experimental results. [15]

supplied to the proposed model. At last it is arrived at the better values to the experimental values [4],[13]. Using PSO route, introduced the

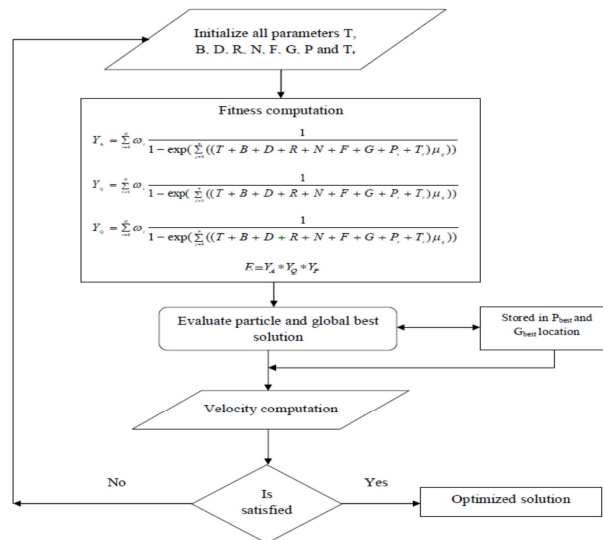


Figure 3: Flow Chart Of PSO Algorithm

$$Y_{P_{opt}} = \sum_{i=0}^N \omega_i \frac{1}{1 - \exp\left(\sum_{j=0}^n ((T + B + D + R + N + F + G + P_i + T_i) \mu_{ij})\right)}$$

$$Y_{A_{opt}} = \sum_{i=0}^N \omega_i \frac{1}{1 - \exp\left(\sum_{j=0}^n ((T + B + D + R + N + F + G + P_i + T_i) \mu_{ij})\right)}$$

$$Y_{Q_{opt}} = \sum_{i=0}^N \omega_i \frac{1}{1 - \exp\left(\sum_{j=0}^n ((T + B + D + R + N + F + G + P_i + T_i) \mu_{ij})\right)}$$

$$E = Y_A * Y_Q * Y_P$$

Eqns 1,2,3,4



Where,

$Y_A$  - Percentage value of availability;  $Y_Q$  - Percentage value of Quality;  $Y_P$  -Percentage value of Performance;  $E$  - Percentage value of OEE;  $\mu, \omega$  -Random function value,  
 $T$  - Total Time;  $B$ - Production Breaks;  $D$ -Machine Downtime;  $R$  -Production Rate;  $N$ -Total products Produced;  $F$  -Total Products Rejected;  $G$ -Total Good Products Produced ; $P_t$  .Total Planned Production time;  $T_t$  -Total Operating time;  $G_{best}$  - position of swarm;  $P_{best}$  - position of particle

**6. SUGGESTED MODELING**

After the actual statistical modeling is completed, we advance to assess the recommended output values using statistical modeling of PSO algorithm. The authentic experiments yield trial output values like Availability, Performance, Quality, and OEE. With a view to increasing the output values, we have suggested some proposals based on the down time alteration, considering the fact that downtime is the main trait which has a

sway over the entire process of the company. Our statistical model values have previously been compared with real experimental values. Clearly, the real experimentation has nine input parameters and four output values. We perform alteration in the downtime according to the deviation of each input parameter. The production breaks are programmed to default. Then we calculate some input parameters as per the following equation.

$$\boxed{T_t = T - D} \quad (5)$$

$$\boxed{P_t = T - B} \quad (6)$$

$T_t$ -Total Operating time ;  $T$ -Total Time ;  $D$ -Machine Downtime; $P_t$ .Total Planned Production time ;  $T$  - Total Time ;  $B$ -Production Breaks

The value of Total No. of cartons created is the product of Total intended production time and production rate according to the real performance values. The process is done again and again to estimate the input parameters of all machines. After they are estimated, these values are furnished to the mathematical model of PSO algorithm. We derive the optimum output value vis-à-vis that of the existing technique.

**7. SUGGESTED RESULT OF OEE**

At first, we devised a statistical modeling of genuine test outcome employing PSO algorithm. This model was demonstrated with genuine test outcomes. And it was found that the model values were identical to the actual test values. Subsequently this statistical model is employed for estimating the recommended table output values according to the downtime alteration. Then we proceeded to make the input data of recommended table using equations 5 and 6 for the machine. Thereafter all input values are furnished to the PSO algorithm and at last we derived the optimum output values superior to the current output values.

**8. LAMINATION MACHINE - SUGGESTED RESULT.**

*Table 1: Suggested Input Parameters Of Lamination Machine*

Production/shift	1	2	3	4	5	6	7	8	9	10
Total time (Minutes)	510	510	510	510	510	510	660	480	690	1020
Production Breaks (minutes)	30	30	30	30	30	30	30	30	30	60
Machine Downtime (minutes)	86	114	86	257	57	228	114	29	86	114
Production Rate (Unit/minute)	26	26	26	26	26	26	26	26	26	26
Total cartoons Produced	6986	7908	8728	4569	8732	5667	9713	9173	12088	15705
Total Cartoons Rejected	77	87	96	50	96	62	107	101	133	173
Total Good Cartoons Produced	6909	7821	8632	4519	8636	5605	9606	9072	11955	15532
Total planned production time	480	480	480	480	480	480	630	450	660	960
Total operating Time	394	366	394	223	423	252	516	421	574	846

Table 1 shows the recommended input data of Lamination machine of the cartons making Industry. These input values are arrived at according to the downtime alteration by using equations 5 and 6. In fact the Lamination machine employed for the cartons picture sheet is pasted on

the cardboard as required by the clients of the company. The company competence QTPM was established by OEE values. If the OEE[16] values achieved are about 85 %, the company is treated as a global company.

**9. RESULT AND DISCUSSION**

**9.1 Real Experimental Modeling**

The Table 2 shows the comparison of two results of Lamination machine which are Modeling suggested PSO result and Modeling Real PSO result, where we find the suggested output parameters using input parameters. The 9 input parameters are used to find the mathematical model, where the input parameters of Lamination machine are named as 1) Total time (Minutes), 2) Production Breaks (minutes), 3) Machine

Downtime (minutes), 4) Production Rate (Unit/minute), 5) Total Cartoons Produced, 6) Total Cartoons Rejected, 7) Total Good Cartoons Produced, 8) Total planned production time, and 9) Total operating Time. These values are taken from the real experimental tabular column 5, and then the suggested output parameters are obtained using those values and we utilize the equation 1 to 4 for using PSO algorithm. The 5<sup>th</sup> observation of Performance values for comparison purpose has values as 79.381 and 80.5, but the existing Lamination machine OEE value is 58.7%, where our suggested output parameters OEE value is 62%, which is 4% higher than Real PSO modeling result.

Table 2: Modeling Result Of Lamination Machine

Lamination Machine		1	2	3	4	5	6	7	8	9	10
Availability (%)	Real PSO	81.2822	74.9233	81.2016	43.846	87.5657	50.0338	81.0729	93.2826	86.413	87.5367
	Suggest PSO	82.0833	76.25	82.0833	46.45833	88.125	52.5	81.90476	93.55556	86.9697	88.125
Performance (%)	Real PSO	68.106	83.0338	85.1673	78.757	79.381	86.5371	72.4378	83.7024	81.0553	71.4507
	Suggest PSO	69.4	83.9	85.6	79.5	80.5	87.1	72.9	84.3	82.9	71.9
Quality (%)	Real PSO	98.9214	98.9138	98.9523	98.8694	98.8033	98.9107	98.8075	98.9735	98.8639	98.8666
	Suggest PSO	99.41	99.56	99.15	99.35	99.26	99.23	99.71	99.68	99.47	99.62
OEE (%)	Real PSO	54.8649	61.5996	68.4965	34.1714	68.7951	42.7436	57.9034	77.227	69.1255	61.8267
	Suggest PSO	56.62973	63.69227	69.6661	36.6943	70.41566	45.3754	59.53542	78.61496	71.71576	63.1211

The four diagrams below (Figure 4) are of the 4 output parameters of Lamination Machine, where the output parameters are Availability, Performance, Quality, and OEE. With each output parameter of the machine, the above diagrams exhibit the comparison of real PSO modeling result with the suggested PSO modeling result. The X axis represents the number of the observations taken during the working condition of the machine, and the Y axis represents the output parameters of the machine. The Red Color represents the output parameters of suggested result with the help of PSO algorithm and the Blue Color represents the output parameters or actual result of machines with the help of PSO algorithm. Overall, our suggested model result is always higher than the actual result of Machine Modeling result, which is as already discussed.



9.2 Graphical Explanation of Real PSO Model and Suggested PSO Model

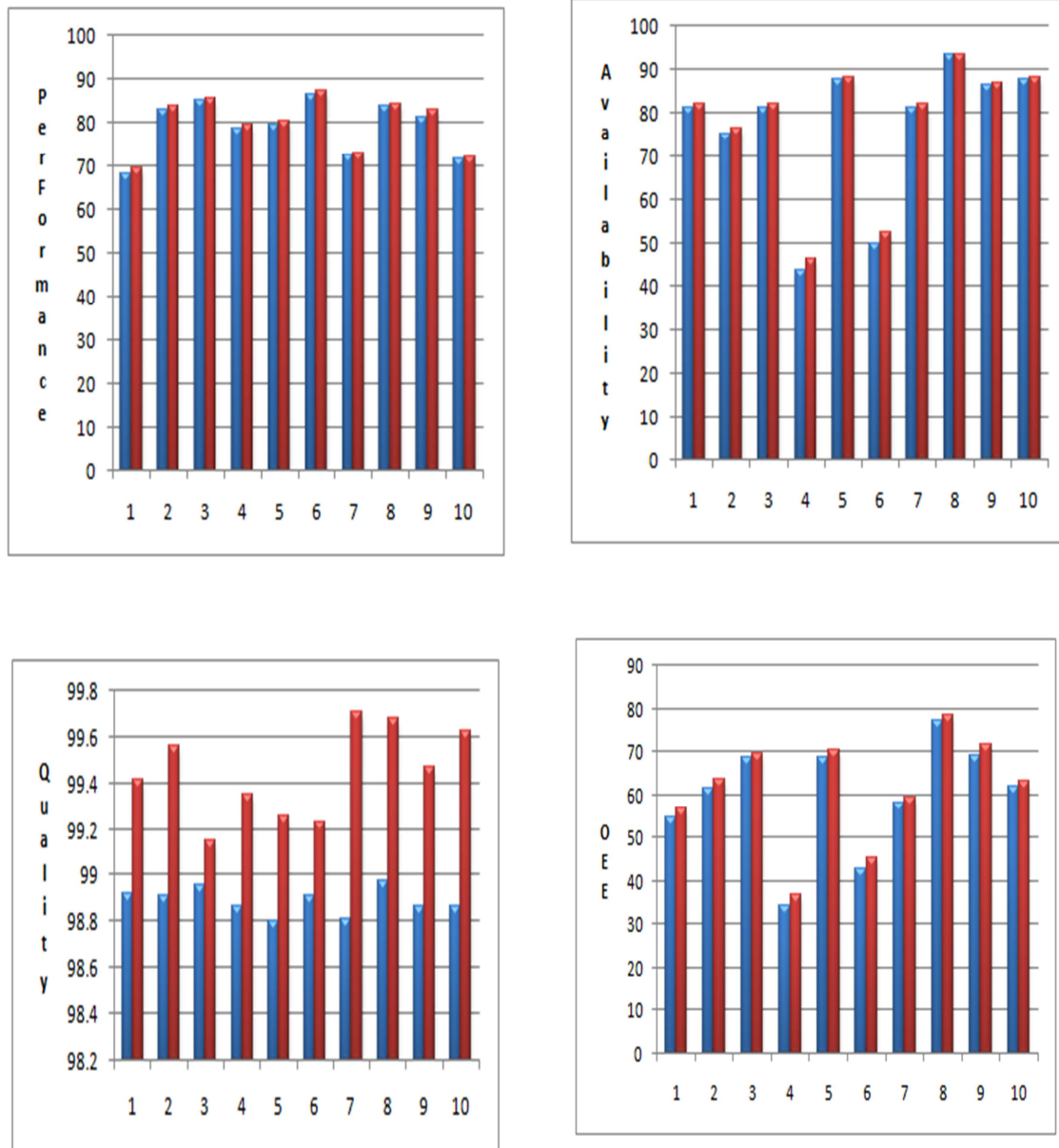


Figure 4: (A: Availability, B: Performance, C: Quality, D: OEE) Comparison Results Of Lamination Machine

10. CONCLUSION

In this paper, we have discussed about the analysis of QTPM principles with the CSFs and their implementation.[17]. The real experimental outputs of a cartons making industry were the bases initially [9], the machine used is Lamination Machine. Then was developed, the mathematical

model [18] for finding the real experimental outputs and this model was compared with real experimental values in an undisclosed small Indian industry too. Based on the suggestions of reducing downtime, the mathematical model was utilized to predict outputs for the suggested dataset. This was carried out with the aid of Particle Swarm Optimization for the purpose of predicting output





for suggested data. Finally, optimum values of the output parameters when compared to the existing results were obtained. The existing results of the machine is 58.77% and the final OEE value obtained for the suggested machine outputs is 62%, which is superior when compared to the existing results. Thus Mathematical modeling can be used to find any real experimental values without any complexity and it could be implemented easily as well as used to predict the future outcomes also, like SDG .[19]-[25].

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