Maintenance Dynamics, Tools for Machines Functionality in a Competitive Environment

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Abstract

Maintenance dynamics as tools for machines functionality in a competitive environment is being discussed. The discussion centers on models formulated that assist in carrying out comprehensive maintenance activities plan as at when due even at the point when machines are being stressed to meet up with customers' demand. The formulated models were tested using a polyethene bag production machines for a period of three months. Data of records before the introduction of the developed models and when the models were introduced were collected and analyzed using the SPSS16.0 package. The analysis carried out shown that machines' functionality increased despite the ageing factor encountered as the developed models were used as compared to the past machines' functionality.

Keywords: Machines functionality, Maintenance dynamics, Models, Competitive environment

1. Introduction

Today's production environment is considerably complex and being influenced by the organization's ability to compete effectively on the basis of production time, price, technology involvement, innovation, reliability, quality and information management. Equipment maintenance and reliability management are vital to the effective running of business enterprises. With the growing dependence on technologies for most business operations, it is important to model appropriate maintainability and reliability strategies to ensure that production industries are able to deliver best quality and reliable services to their customers even at moderate and affordable prices (Christian, 2000).

Breakdowns in industrial manufacturing systems can have significant impact on the profitability of a business. Expensive production equipment is idled, labour is no longer optimized, and the ratio of fixed costs to product output is negatively affected. Rapid repair of down equipment is critical to business success. With the intense competitive pressure triggering many companies to look for every possible source of competitive advantage, therefore lies the ingenuity of each company in understanding the potential of manufacturing and maintenance. Once understood, it requires a proper strategy to exploit such potential. Strategy at any level – say at a business or functional level – will provide the company with a sense of direction, integrity and purpose. It guides in making a series of unified and integrated decisions in achieving the objective. Also, strategy with respect to each function needs to be evaluated for its effectiveness on a regular basis. This will allow knowledge of the competitive position of any production industry unit against its competitors, with respect to the given function (Liliane *et al* 2006).

2. Literature Review

A detailed analysis of optimization and models has been reviewed in Ben-Daya et al (2000). Ben-Daya (1999) presented a model for integrated production maintenance and quality for an imperfect process. Lee and Rosenblatt (1987) presented an optimization model for the case of simultaneous production cycle and inspection schedule determination. Marquez and Herguedas (2002) and Marquez et al (2003) provided various maintenance optimization models for repairable systems.

Stochastic simulation is one of the most commonly used approaches. Numerous works have been cited in this area. Zineb and Chadi (2001) established an effective way of modeling complex manufacturing systems through hierarchical and modular analysis by using stochastic Petri nets and Markov chains. In the proposed approach, the integration of maintenance policies in a manufacturing system is facilitated by the development of a generic model. Andijani and Duffuaa (2002) presented a critical evaluation of a number of simulation studies of maintenance systems. They reviewed various areas such as evaluation of maintenance polices, organization and staffing, materials management and shutdown polices. They also analyzed different types of simulation packages and failure patterns such as exponential and normal distributions etc. Duffuaa et al (2001) provided a framework or a conceptual model that can be used to develop a realistic simulation model. Yuan and Chaing (2000) formulated an optimal maintenance policy for a production system subject to aging and shocks.

Use of system dynamics in the study of production or supply chain systems is not new and a variety of literature is available in this area (Sterman 2000; CaulField and Maj 2001; Chen and Jan 2005, Marques 2005; Souza et al 2000; Greasly 2005) showed that the discrete-event simulation study could be done through system dynamics. He used the case of a gas cylinder production system. Earlier, Systems thinking models are also available in the literature (Holmberg 2000 and Jamber 2000).

Lu et al (2007) address a predictive condition-based maintenance approach based on monitoring, modeling, and predicting a system's deterioration. The system's deterioration is considered as a stochastic dynamic process with continuous degrading. Structural time series, coupled with state-space modeling and Kalman filtering methods, is adopted for recursively modeling and forecasting the deterioration state at a future time. The probability of a failure is then predicted based on the forecasted deterioration state and a threshold of a failure. Finally, maintenance decisions are made according to the predicted failure probabilities associated preventive and corrective maintenance cost, and the profit loss due to system performance deterioration. The approach can be applied on-line to provide economic and preventive maintenance solutions in order to maximize the profit of the ownership of a system.

3. Methodology

The functionality of machines lies on their effective usage and uncompromising maintenance activities plan. To keep the machine's functionality under a competitive situation requires better strategies and dynamics. Based on these consideration, the model equations stated in this section were formulated to ease maintenance plan as well improves on the machines availability and functionality.

Competitively, If demand population for product = D, and there are N companies producing this same product, then each company will have a market share of M_s. And

$$M_s = D\alpha \tag{1}$$

where α = share factor.

Then the balance in market will be

$$M_{SN-1} = D(1-\alpha) \tag{2}$$

Due to promotion drive or advertisement, some additional gain, with gain factor β is possible from the existing loss share with penalty cost C_β .

$$\begin{aligned} M_s &= D\alpha + \beta D(1-\alpha) \\ M_s &= D[\alpha + \beta(1-\alpha)] \end{aligned} \tag{3}$$

Additional demand gain or loss is likely when the unit price of P_c^r (current price) of similar products changes (decrease or increase) from initial price, P_O^r with or without advertisement. Then the market share will be

$$M_s = D\alpha + \lambda\beta D(1-\alpha) \tag{4}$$

where

$$\lambda = P^r_{initial} \Big/ P^r_{current} \tag{5}$$

The cause of action could be determined based on the output of the company.

For the capacity Q_c for a unit number of workforce, *m* and a unit quantity of raw material is *w*, then the total output, P_t is

$$P_t = \sum_{i=1}^{n} Q_{ci} w_i m_i \qquad (6)$$

Due to useful maintenance activities, this capacity in equation (6) may not be met.

Therefore, the output loss due to maintenance activities is expressed as,

$$P_i = \sum_{i=1}^{n} \frac{t_b}{t_e} Q_{ci} w_i m_i = \sum_{i=1}^{n} \mu_i Q_{ci} w_i m_i \qquad (7)$$

where $$\mu_i = \left(\frac{t_b}{t_e} \right) \qquad (8)$$

and t_b= mean time to maintain machine i

t_e = expected running time of machine i.

The range of severity μ_i will determine whether to carryout preventive, breakdown and predictive maintenance, or their combination in group or not.

High value of $\frac{t_b}{t_e} \approx \mu$ i.e. above 0.5 indicates high maintenance severity, and at this level opportunistic preventive and breakdown maintenance, back up with condition monitoring (predictive) maintenance based on static and opportunistic grouping will be worthwhile, depending on the level of demand.

If demand can be satisfied at this level, opportunistic breakdown maintenance could be good, if it is not, opportunistic preventive maintenance backup with condition monitoring could be better. In case of $0 \le \mu \le 0.2$, which shows that not more than 20% of time is available for predictive and preventive maintenance, opportunistic predictive maintenance based on dynamic grouping or opportunistic grouping is good.

If demand is satisfied at this level, dynamic grouping is adopted, if not, opportunistic grouping is carried out. In case of $0.2 \le \mu \le 0.5$, at this level, maintenance severity is moderate. Planned preventive and breakdown maintenance will be worthwhile based on static and opportunistic grouping.

If demand is satisfied, static grouping is good, else, opportunistic grouping is proposed.

Spare part inventory is necessary when $\mu \ge 0.5$.

Then the actual production, P_{actual} is expressed as

$$P_{actual} = P_t - P_i \qquad (9)$$

Where $P_t = total\ output / expected\ output$

P_i = total loss due to maintenance activities

The following conditions are being modeled for actual production as a function of demand, processing strategies (AUTO, CON, JIT) and the maintenance activities:

i. If $P_{actual} < demand$, and $\mu < 0.5$, AUTO, breakdown maintenance based on opportunistic and static grouping is preferred with little or no inventory and advertisement.

ii. If $P_{actual} < demand$, and $\mu > 0.5$, AUTO, preventive and dynamic maintenance based on opportunistic grouping is recommended with inventory and little or no advertisement.

iii. If $P_{actual} > demand$, and $\mu < 0.5$, CON, breakdown maintenance based on static opportunistic grouping is preferred with little or no inventory and advertisement required.

iv. If $P_{actual} > demand$, and $\mu > 0.5$, CON, preventive, predictive maintenance with opportunistic and dynamic grouping is recommended with inventory and advertisement

v. If $P_{actual} = demand$, and $\mu > 0.5$, JIT, dynamic maintenance strategy based on static and opportunistic grouping with reasonable inventory is employed with little or no advertisement.

vi. If $P_{actual} = demand$, and $\mu < 0.5$, JIT, opportunistic or static maintenance strategy is employed with little or no inventory and advertisement.

These formulated models were used for a production firm producing polyethene bags which are highly competitive. The production capacity records were recorded before and during the introduction of the developed models for a period of three months consecutively. The approach was used since production capacity of the firm is an index to machines performance and functionality.

4. Results and Discussion

The outcomes of the plant production capacity, machines' running hours and down time recorded from the industry used are as stated in table 1. The records taken from October to December, 2011 were ascribed to the machines' production capacity when the model developed had not been adopted by the industry. While the production records taken from February to April, 2012 give the records of machines or plants activities when the model was fully adopted.

For Comparative view, the plant production capacities, downtime and running hours of the machines based on the three months covered are displayed in bar charts shown in figures1, 2 and 3 respectively. The plant production capacity improved as the model developed was adopted compare to what was obtainable when the industry had not adopted the model. Since production capacity and machine running hours are directly proportional to machine's functionality, it could be inferred that the plants functionality increases as the maintenance strategies developed were used.

Qualitatively, the records of table 1 were statistically analyzed using SPSS 16.0. The results got therein are shown in tables 2 and 3. Significance value of 0.106 was got for the plant machine running hours and 0.92 for plant production capacity output. This implies that 10.6 % and 9.2% were gained on improvement of machines functionality and plant production output respectively. The values ought to be more if the number of months used increases or if the number of data accessed is not limited. It is an indication that the model developed is perfectly good and significantly effective on machines functionality and maintenance practices.

5. Conclusion

The efficient and optimum performances of machines lie on the prompt actions of maintenance dynamics taken. The tool herein described would assist conventional equipment maintenance and personnel in decision making as they progress towards optimizing maintenance plans. With this approach, the industry under consideration has her machines' functionality/ availability increased from 85.4% to 94.3% and production products turnover to be 74.2% as compared with her past production activities.

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Table 1: Plant production records before and after the adoption of the developed model

Period	Designed Plant Production capacity per month from the manufacturer (tons)	Plant production capacity by the company with the adoption of the model (tons)	Past three months plant production capacity (ton) by the company before adoption of research model	Expected plant/ machines running hour	Plant /machines uptime hour (hrs) with the adoption of the model	Plant /machines uptime hour (hrs) before model adoption	Machine down time with the adoption of the model (hrs)	Past three months plant down time before adoption of research model
6/02/12 to 29/02/12 (1st Month)	12	9.5	**6.4** *(in October, 2011)*	200	195	174	5	26
1/03/12 to 31/03/12 ((2nd Month)	12	9.2	**6.2** *(in November, 2011)*	216	198	170	18	46
2/04/12 to 28/04/12 (3rd Month)	12	8	**7.2** *(in December., 2011)*	200	188	182	12	18
Total	**36**	**26.7**	**19.8**	**616**	**581**	**526**	**35**	**90**
Efficiency		**74.2%**	**55%**		**94.3%**	**85.4%**		

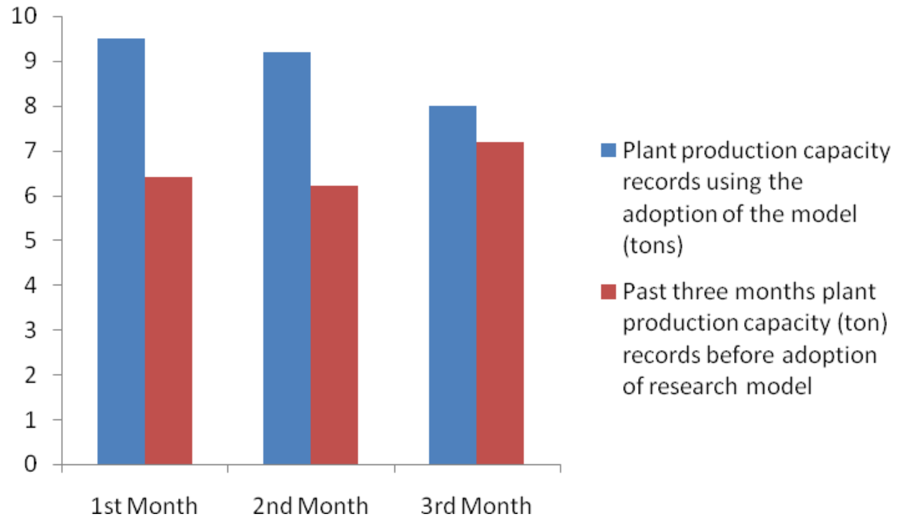

Figure 1: Three months comparative plant production capacity before and after the adoption of model

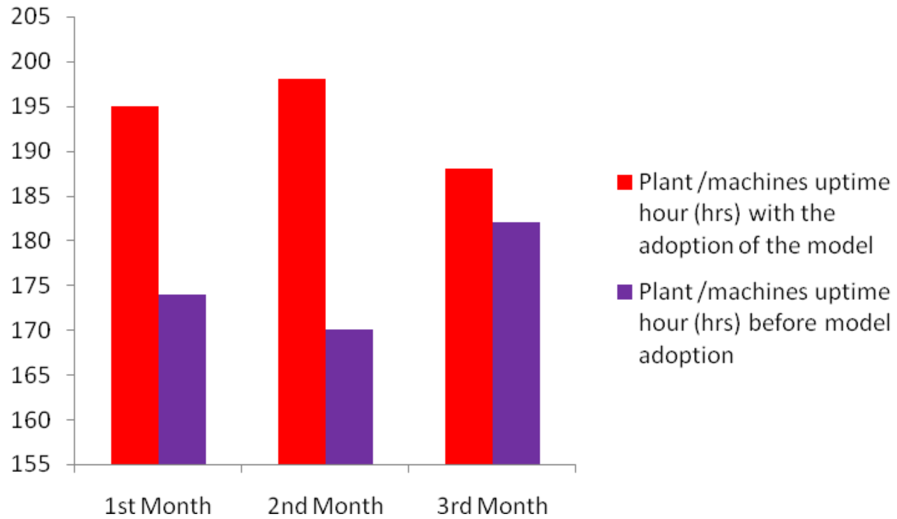

Figure 2: Three months comparative plant/machines running hours before and after the adoption of model

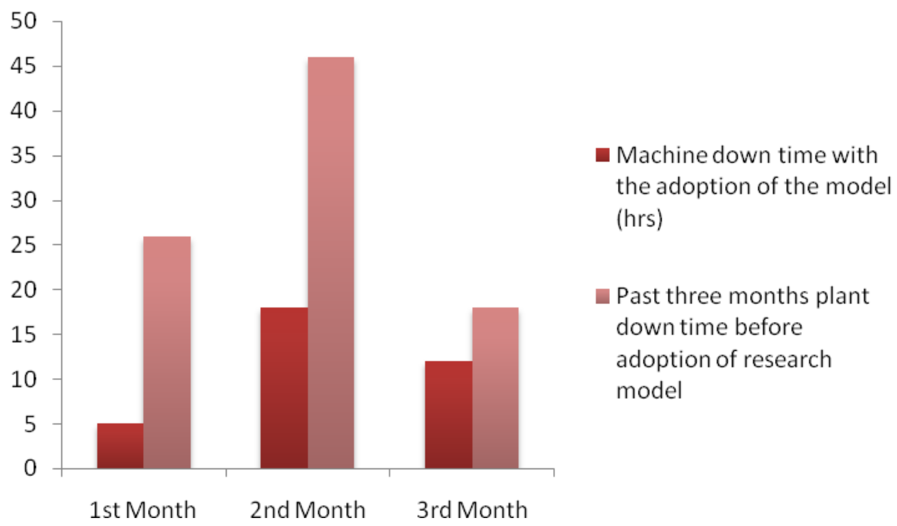

Figure 3: Three months comparative plant/machines down time before and after the adoption of model

Table 2: Paired samples test on plant machine uptime hour using model developed and without model

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	PlantMachineUptimeHour WithModel - PlantMachineUptimeHour WithoutModel	1.8333E1	11.23981	6.48931	-9.58790	46.25457	2.825	2	.106

Table 3: Paired samples test on plant production capacity using model developed and without model

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	PlantProductionCapacity ByCompany - PlantProductionCapacity ByTheCompanyBefore AdoptionModel	2.30000	1.30000	.75056	-.92938	5.52938	3.064	2	.092