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A literature review on Total Productive Maintenance

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Abstract : Over the past five decades, the world has been experiencing intensified competition in any manufacturing. As a result, organizational leaders have been striving to adopt strategies that would aid in facing the intensified competition. This paper reports the literature review which was conducted with the primary objective of identifying the contributions of researchers towards Total Productive Maintenance. This paper presents, origin of researches on Total Productive Maintenance, early contributions of researches on Total Productive Maintenance and Case studies on Total Productive Maintenance. The literature review indicates that, Total Productive Maintenance is being adopted across many organizations in the world for enhancing the productivity and presently Total Productive Maintenance is regarded as a world class strategy.
Keywords : Total Productive Maintenance, World class strategy, Overall Equipment Effectiveness, literature review.

1. Introduction

In today's highly competitive and dynamic global business environment, organizations are required to deliver world class products and services (Ahuja and Kumar, 2009;Devadasan et al, 2005;Psomas and Fotopoulos, 2009;Magd, 2008;Thun, 2008).In pursuit of attaining this goal, organizations have been acquiring competitive strengths through the adoption of world class strategies like Total Quality Management (TQM), Total Productive Maintenance (TPM), Lean Manufacturing, Agile Manufacturing, Six Sigma and ISO 9001 Certification (Bamber et al, 1999; Leonard, 2010;Thomas et al, 2008;Vinodh et al, 2008). All these world class strategies originated during the last five decades and have conquered today's organizational arena (Ahuja and Khamba, 2008a;Ahuja and Khamba, 2008b;Devadasan et al, 2003;Fotopoulos and Psomas, 2009;Gotzamani et al, 2007;Hansonn et al, 2003; Hernandez, 2010; Magd and Curry, 2003; Sharma and Kodali, 2008). The benefits achieved through the implementation of these world class strategies have been widely reported in literature arena (Ahuja and Khamba, 2008c;Fotopoulos et al, 2010a; Hernandez, 2010;Koc, 2007).

The world has been adopting quality as a competitive strategy, a major portion of organizational arena has started to adopt maintenance as strategy through the implementation of TPM. Many leading organizations have been using TPM as a competitive strategy. For example, leading American organizations namely Proctor and Gamble, DuPont, Eastman Chemical, Ford, AT & T and Texas Instruments have adopted TPM as a tool for enriching competitiveness (Ahuja and Khamba, 2008a; Blanchard, 1997; McKone et al, 1999).In literature arena, several researchers have reported the power of TPM. For example, a few researchers stated that, the TPM program aids an organization to strive continuously for producing non-defective products (Ahmed et al, 2005; Ahuja and Kumar, 2009; Al-Hassan et al, 2000;Chan et al, 2005;Ireland and Dale, 2001;Ollila and Malmipura, 1999). Today TPM is adopted by the organizations to attain world class manufacturing goals (Ahuja and Kumar,

2009; Bamber et al, 1999; Sharma et al, 2006).The details of this literature review are briefly presented in this paper.

2. Origin, growth and importance of TPM

When the literature was searched, 15 papers describing the origin, growth and importance of TPM could be identified. The information and knowledge derived from these papers in this regard are briefly described in this section.

Traditionally, maintenance was looked as a strategy requiring high investments but delivering poorer rate of return (Ahuja and Khamba, 2008a). Maintenance was also viewed as a 'necessary evil' in many organizations situated across the world (Eti et al, 2007). Till early 1950s, maintenance activities were carried out as a 'fire fighting approach' through breakdownmaintenance (Ahuja and Khamba, 2008a; Kodali and Chandra, 2001). However, from 1950s, business leaders began to realize that, the poorly maintained facilities led to increased running cost. Besides it would reduce the effective utilization time of the facilities (Eti et al, 2006a; Wang and Lee, 2001). This led to the appearance and adoption of various maintenance practices like predictive maintenance, corrective maintenance, maintenance prevention, reliability-centered maintenance and computerized maintenance management system (Ahuja andKhamba, 2008a; Eti et al, 2006b; Kodali and Chandra, 2001; Thun, 2008). These maintenance strategies were not completely effective as they do not facilitate total employee involvement (Cooke, 2000)According to these strategies, only maintenance personnel carry out maintenance activities which on one hand increased the work load on them (Cooke, 2000;Rodrigues and Hatakeyama, 2006). On another hand, the work of maintenance personnel is not fully appreciated by other people in the organization. This leads to the demotivation of the maintenance personnel (Cooke, 2000). In this context, TPMemerged in the world to overcome the drawbacks of earlier maintenance strategies.

TPM was introduced by Nippondenso Co in Japan in the year 1971 (Ahuja and Khamba, 2008a;Rodrigues and Hatakeyama, 2006). From the same year, Seiichi Nakajima, a Japanese expert popularized TPM concept through the then Japanese Institute of plant Engineers (JIPE) [now, this institute is known as Japanese Institute of Maintenance (JIPM)] (Bamber et al, 1999;Cooke, 2000;Etiet al, 2004;Huang et al, 2002;Kodali and Chandra, 2001;McKone et al, 1999;McKone et al, 2001;Wang and Lee, 2001). Seiichi Nakajima is regarded as father of TPM (Ahmed et al, 2004; Bamber et al, 1999). TPM involves an organization's entire human force towards carrying out the maintenance activities to enhance the availability, performance, quality, reliability and safety of equipment (Ahuja and Khamba, 2008a; Ahuja and Khamba, 2008d; Eti et al, 2006a). This facilitates the employees of the organization to coordinate with maintenance personnel. This coordination between the operator and the maintenance personnel is the core theme of TPM (McKone et al, 1999) which in turn makes it a comprehensive maintenance strategy(Eti et al, 2006c;McKone et al, 2001;van der Wal and Lynn, 2002;Yamashina, 1995).

TPM, with total employee involvement, over the years emerged as a successful and sustainable maintenance strategy of organizations of all types (Blanchard, 1997;van der Wal and Lynn, 2002). TPM is a team working philosophy (Ahmed et al, 2004). TPM is regarded as one of the world class manufacturing (WCM) strategies (Chand and Shirvani, 2000;McKone et al, 1999;McKone et al, 2001). Though originated in Japan, TPM is widely accepted and successfully implemented throughout the world. Some of the countries in which TPM implementation is widely reported are, the USA (Tsang and Chan, 2000), the UK (Ireland and Dale, 2001), China (Tsang and Chan, 2000), India (Sharma et al, 2006), Malaysia (Ahmed et al, 2005), South Africa (van der Wal and Lynn, 2002), Nigeria (Etiet al, 2004) and Puerto Rico (Perez-Lafont, 1997). Thus the world community has realized the importance of TPM implementation.

3. Case Studies on TPM

As TPM has been widespread, numerous case studies reporting its implementation have appeared in literature. During the literature review being reported here, 12 papers reporting case studies on TPM were studied. An outlook of these papers can be had by referring to the contents of Table 1. The details of these case studies are described in this section.

Table 1. Outlook of the case studies on TPM reported in the literature

Serial Number	Paper	Country in which the case study was conducted	Mode of implementing TPM
1	Tsang and Chan, 2000	China	Three phases involving 15 steps of TPM implementation. (Nakajima's 12 steps of TPM implementation is included)
2	Chan et al, 2005	Hong Kong	Four stages including 12 steps of TPM implementation
3	Ireland and Dale, 2001	UK	Actions to overcome six big losses as stated by Nakajima and Nakajima's autonomous maintenance
		Packaging company with global network in Europe, Asia, Africa and America	Seven TPM pillars, Nakajima's seven steps of autonomous maintenance
		Japanese owned automobile company	Sevenautonomous maintenance steps of Nakajima
4	Bohoris et al, 1995	UK	TPM implementation took place in 20 steps which were built on Nakajima's 12 steps
5	Ahmed et al, 2005	Malaysia	TPM was implemented through the eight pillars
6	Bamber et al, 1999	UK	TPM was implemented through a five pillar model
7	Ahuja and Kumar, 2009	India	TPM was implemented through the eight pillar approach built on 5S (JIPM approach)
8	Ahuja and Khamba, 2007	India	TPM was implemented through the eight pillar approach contributed by JIPM
9	Sharma et al, 2006	Supplier to South East Asian Countries	Four stages of TPM implementation. Nakajima's sevenautonomous maintenance steps followed
10	Tsarouhas2007	Greece	TPM implemented in four steps
11	Perez-Lafont, 1997	Puerto-Rico (Caribbean)	Two phase TPM implementation
12	Ferrari et al, 2002	Italy	TPM implementation in seven steps

A case study involving the implementation of TPM in a high precision machining factory located in China has been reported by Tsang and Chan (2000). In this factory, significant investments have been made on high-precision machine tools like CNC and NC machines.In this factory, a workforce of about 2000 employees isemployed. In the year 1995, this factory started implementing TPM by a three phase methodology which comprised 15 implementation steps which included the 12 steps enumerated by Nakajima (Bohoris et al, 1995). In order to implement TPM, changes in the organizations and maintenance department's hierarchy were made in this factory. TPM implementation effects were measured after a period of 14 months and the factory experienced reduction in the number of machine breakdowns from 175 to around 60.

A case study involving the implementation of TPM in a semiconductor manufacturing company located in Hong Kong has been reported by Chan et al (2005). This company made heavy investments on maintaining the facilities and decided to implement TPM in consultation with JIPM. The implementation of TPM was carried out in 12 steps. After TPM implementation, the firm experienced 83% increase in equipment's productivity and reduction in stoppage rate of machines from 517 to 89 times. TPM implementation also resulted in intangible benefits like empowerment of the employees.

Three cases of implementing TPM have been reported by Ireland and Dale (2001). Company A is a rubber manufacturing plant located in the United Kingdom (UK). Thiscompany analyzed the six big losses stated by Nakajima and improved them by setting up of targets and including Overall Equipment Effectiveness (OEE) as a measure of performance. This company also adopted the sevenautonomous maintenance steps

proposed by Nakajima. Company B is a packaging company having a global network connecting 30 countries across Europe, Asia, Africa and America. TPM was implemented using seven TPM pillars and seven autonomous maintenance activities. Planned maintenance activities were also carried out. TPM implementation also included the setting up of World Class Performance (WCP) promotion organization. The improvements made through the implementation of TPM were reduction in number of customer complaints, increase in production volumes, reduction in overtime costs and absenteeism and increase in the percentage of output per employee. Company C is a manufacturer of motorized vehicles under the ownership of a Japanese company. In this company TPM was implemented through the sevenautonomous maintenance steps and appointment of TPM coordinators.TPM implementation in Land Rover Transmissions in UK is reported by Bohoris et al (1995). In this case, the TPM implementation took place through20 steps which were built on Nakajima's 12 steps along with the assistance of Computerized Maintenance Management System (CMMS).

In Malaysia, a semiconductor component manufacturer implemented TPM by identifying their problems under the eight pillars of TPM. TPM was implemented by this manufacturer by consulting JIPM.Autonomous maintenance and planned maintenance activities were carried out during the course of TPM implementation. Tools like why-why analysis, Preventive Maintenance (PM) analysis, Design of Experiments, Failure Mode and Effect Analysis, Poka-Yoke, Quality Maintenance Matrix were used while implementing TPM. The TPM implementation resulted in many tangible and intangible benefits in this manufacturing company. (Ahmed et al, 2005).

TPM implementation in Land Rover Transmissions in the UK through a five pillar TPM model is reported by Bamber et al (1999). This paper reveals various reasons for TPM failure in organizations. Some of them include, simultaneous introduction of TPM on too many machines, lack of involvement of production operators and applying TPM to a machine which is not considered important for carrying out that process. In the same paper, another case study on TPM implementation in Thorsman and Co situated in the UK is discussed. Some of the developments that occurred as a result of TPM implementation in this company were setting up of TPM steering committee, planned and coordinated efforts, developing implementation plan, imparting training and education and applying continuous improvement program for new machinery.

TPM implementation in Tata Steel Tubes Strategic Business Unit, India is reported by Ahuja and Kumar (2009). TPM was implemented in this organization through the eight pillar approach built on 5S (JIPM approach) along with the modification of organizational structure. TPM implementation in this organization resulted in 59% improvement in OEE, 63% reduction in equipment breakdowns and failures, 80-90% reduction in rejection, realization of zero major accidents, 80% reduction in minor accidents, 34% reduction in Work In Process (WIP) inventory and significant increase in employees' suggestions and contributions.

A case of TPM implementation in a steel manufacturing plant located in India has been reported by Ahuja and Khamba (2007). TPM was implemented through the JIPM model's eight pillar approach. TPM implementation in this manufacturing plant enhancedOEE from 30.6% to 71.6% and resulted in total savings of 80 million Indian Rupees.Implementation of TPM in a plant located in India (a supplier of assembly spares for diesel and electric locomotives) is reported by Sharma et al (2006). TPM was implemented in four stages through the adoption of seven autonomous maintenance steps of Nakajima. After implementing TPM in this plant, OEE increased from 39 to 69% percent.

TPM implementation in a pizza production line located in Greece using a four phase implementation method enhanced the equipment availability from 89% to 91.5% (Tsarouhas, 2007). TPM has also reached small economies like the Puerto Rico (Caribbean). A two phase (Introduction and Team building) TPM implementation is reported by Perez-Lafont (1997). TPM implementation enhanced OEEfrom 41% to 67%. Ferrari et al (2002) have reported the TPM implementation in a ceramic factory located in Italy. Teams were developed for TPM implementation. In this factory, TPM was implemented in five stages and as a result the OEE was expected to increase from 60-62% to 80%.

Altogether, the review of above papers has revealed that, TPM has been subjected to implementation in both Japanese and non-Japanese companies. Although the approaches followed to implement TPM in these two categories of companies differ broadly, all of them have rested their implementation on certain foundations. First, these implementations have adopted TPM pillars. Second, these implementation efforts have striven to eliminate losses. Third, these companies have adopted OEE as a measurement model of TPM.

4. Conclusion

The literature review which was conducted with the primary objective of identifying the contributions of researchers towards Total Productive Maintenance. This paper presented the origin of researches on Total Productive Maintenance, early contributions of researches on Total Productive Maintenance and Case studies on Total Productive Maintenance. All these findings from the literature review clearly strengthens the status of Total Productive Maintenance as a world-class manufacturing strategy. Presently, TPM is also regarded as Total Productive Manufacturing. This review indicates that, organizations expect to gain substantial benefits in terms of productivity, quality and safety in their organization through the effective and sustained implementation of Total Productive Maintenance.

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