CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

Total Productive Maintenance (TPM) is a manufacturing program designed primarily to maximize the Overall Equipment Effectiveness (OEE) throughout its entire life by the participation and motivation of the entire workforce. Many companies have begun to understand the power of OEE and widened the application of OEE to improve their operational performance (Philip Godfrey 2002).

The work done by the earlier researchers in this area are classified in the following aspects.

(i) Total Productive Maintenance (TPM)
(ii) Maintenance management systems
(iii) Performance measurement of production equipment
(iv) Assessment of plant effectiveness
(v) Measurement of production losses

3.2 TOTAL PRODUCTIVE MAINTENANCE

Total Productive Maintenance is a new direction in production. The dual goal of TPM is Zero breakdown and Zero defects. TPM strives to
maximize output by maintaining ideal operating conditions and running
equipment effectively. More recently, both predictive maintenance and
equipment diagnostic techniques have attracted considerable attention
(Devadasan et al 2007). In factories, TPM is achieved in stages
(Ireland and Dale 2006).

The term TPM was first introduced by Seiichi Nakajima during
the year 1988. Seiichi Nakajima (1988) defined TPM as “Production
maintenance involving total participation.” TPM must be implemented on
a companywide basis. He described the principal features of TPM are,
Total effectiveness, Total maintenance system and Total participation of all
employee.

Benjamin S. Blanchard (1997) pointed out that the concept of
TPM is an excellent one, and the complete implementation of such should
lead to increased efficiency and greater productivity for any given
manufacturing system. He argued that, there is an educational barrier that
needs to be overcome. Orjan Ljungberg (1998) criticized that the
implementation of TPM is a difficult process of corporate change. Among
all the success stories reported, there also exist causes of failures that are
never reported. The information machinery losses will provide the
appropriate base for planning activities in the TPM frame work.

Bamber et al (1999) developed a generic model to indicate
factors affecting the successful implementation of TPM. Also, they
validated the model in small and medium size enterprise, and proposed a
stepwise program which can be used as a generic road map for SMEs,
which are committed to implementing their TPM strategy.
Ireland and Dale (2001) developed practical guidance on the type of TPM process which is suitable for different circumstances and in relation to specific strategic company objectives. Also, a comparative analysis of the different approaches is presented.

Emilio Ferrari et al (2002) insisted that, maintenance is a competitive instrument for factories. They analyzed this in Italian situation. For this the evolution from productive maintenance to TPM is introduced. A soft introduction methodology, first on a theoretical basis and a real application shows a great potential for the TPM approach. Barve et al (2004) developed a conceptual frame work of TPM applicable to a reputed Engineering company in India. The results proved that TPM is an excellent tool to provide business houses the competitive advantage.

Brar and Goal (2005) warned the Indian Industries that, there is a serious need for India to cope with increasing change and intense competition. They discussed many benefits of the implementation of TPM and insisted upon the Indian Industries about the ability to change and do it quickly enough. Rajiv Kumar Sharma et al (2006) indicated that TPM not only leads to increase the effectiveness of manufacturing systems, measured in terms of OEE index, by reducing the wastages, but also, prepares the plant to meet the challenges put forward by globally competing economies to achieve World Class Manufacturing (WCM) status.

Andrew Thomas and Gareth Lewis (2007) developed and applied a combined TPM and Six Sigma strategy in a sample SME. They
highlighted the approach employed, the tools and techniques used and showed the savings that were made through the structured application of a combined TPM/DMAIC procedure.

3.3 MAINTENANCE MANAGEMENT SYSTEM

Nowadays, organizations are under great pressure to continuously enhance their capability to create value to customers and improve the cost effectiveness of their operations. Maintenance, as a support function in business, plays an important role in backing up any emerging business and operation strategies. The effectiveness of maintenance management depends significantly on proper deployment of resources, in the form of spare parts and other maintenance materials, necessary tools and instruments and manpower, and ultimately life-cycle profit for an organization. In order to safeguard their performance, organizations need to formulate viable maintenance strategies and develop a fair measure of overall effectiveness aligning with industry’s best practices.

De Groote (1995) proposed a methodology for maintenance quality audit together with maintenance performance indicators and their evaluation. A much more professional approach to maintenance at all levels is the trend. Assessing maintenance performance gains a new and important dimension in this frame work. Basim Al-Najjar (1996) advocated that the quality and reliability of products and process may be improved through detecting and eliminating common and special cases of problems at early stages. The need for overhaul can be decided on the basis of the conditions of the machines and the pattern of stoppages. Total quality
maintenance provides a basis to find true optima or best approximations in more realistic situations for continuous reduction in the cost per unit of quality product.

Jens. O. Riis (1997) presented a situational approach for designing maintenance systems that very much depends on the specifics of an individual industrial enterprise. A model describing the various elements of a maintenance system is proposed. The situational model embraces concepts from TPM, for linking corporate goals with specific target for maintenance activities, in order to eliminate losses that occur during production. Daivd Sherwin (2000) proposed a better way of managing maintenance by optimizing schedules and integrating the maintenance function with rest of the company’s activities through advanced IT.

Wang and Lee (2001) suggested a random effect non linear progression model called the time constant model, to formulate a prediction model for the learning rate in terms of company size, sales, TPM award year etc. A two stage analysis was employed to estimate the parameters. Using the approach of study one can determine the appropriate time for checking the performance of implementing TPM. By comparing the expected OEE, one can improve the maintenance policy and monitor the progress of OEE. Fu-Kwun Wang (2005) pointed out that, TPM has been recognized as an important methodology to improve the equipment effectiveness and OEE is an important metric for TPM adoption. The forecast of OEE can be used to indicate the success or failure of the TPM adoption during a given period.
Kit Fai pun et al (2002) discussed the increasing needs of Effectiveness Centered Maintenance (ECM). Two ECM performance indices namely, Individual System Effectiveness (ISE) and Overall System Effectiveness (OSE) were introduced to monitor the ECM process in the company. Aditya Paride and Udaykumar (2006) analyzed the need for Maintenance Performance Measurements (MPM). The issues and challenges involved in developing and implementing an effective MPM system are discussed.

Imad Alsyouf (2006) introduced a Balanced Score Card (BSC) frame work to assess the contribution of support function such as maintenance to strategic business objectives. Ahuja, and Khamba (2007) described the contributions of maintenance function to ensure enhanced equipment reliability, thereby affecting improvements in the manufacturing system performance.

Devadasan et al (2008) developed a model called Maintenance Quality Function Deployment (MQFD) on foreseeing the synergic impact of infusing QFD in TPM projects that has witnessed wider application in Total Productive Maintenance (TPM).

3.4 PERFORMANCE MEASUREMENT OF PRODUCTION EQUIPMENT

In order to ensure the companies, the achievement of their goals and objectives, performance measures are used to evaluate, review, control
and improve production processes. The selection of appropriate measurement parameters and procedures is very important to obtain a good method of monitoring, control and evaluation of variations and improvements. In a Kaizen or TPM or TQM or JIT organization, measurement of equipment effectiveness is an important performance indicator. This excellent performance indicator should be maintained as a bench mark for increasing the manufacturing capability.

John Konopka and Walt Trybula (1996) addressed the significant advantages for improving throughput in a semiconductor manufacturing line over traditional utilization reports. Robert C. Leachman (1997) suggested a strategy to measure and monitor equipment efficiency. They classify the data collection techniques for OEE measurement and monitoring as Level - 0, Level 1, Level 2 and Level 3. They also explain the features of these levels.

Bulent Dal et al (2000) explore the use of OEE, not only as an operational measure, but also as an indicator of process improvement activities within a manufacturing environment. Munir Ahmad and Nasreddin Dhafr (2002) sets out the basis to establish Key Performance Indicators (KPI) in manufacturing companies. Most of the papers the KPIs are indicated as, quality, delivery, reliability, cost, delivery, lead time etc. These KPIs are taken into consideration because they indicated important aspects of manufacturing performance areas and are usually fairly easy to measure or estimate.
Philip Godfrey (2002) developed the way in which the OEE measure can be used to enhance the capital investment process. The author argues that, the use of OEE as key diagnostic for informing investment decisions should be high on the agenda of manufacturing managers and business leaders alike. In recent years, many companies have recognized the power of OEE measure, to help inform the effective management of assets throughout their life cycle. The OEE measure is a simple tool that can be used to inform decision making at all stages of the investment life cycle. Ohwoon Kwon and Hongchul Lee (2004) presented a new calculating methodology to calculate the total saving monitoring amount composed of contribution profit and saving cost that are obtained by improving the Overall Equipment Effectiveness (OEE) of processing type equipments.

Arne Ingemansson et al (2005 b) presented a methodology for working with bottleneck reduction by using a combination of automatic data collection and discrete – event simulation for a manufacturing system. Jabiri et al (2005) addressed the features of “OEE” and TLCC (Total Life Cycle Cost) per unit product, as conventional technical and financial measures.

Kumar et al (2006) proposed a frame work for lean tools with six sigma DMAIC methodology to enhance the bottom line results and win customer loyalty. Jeroen De Mast (2006) advocated that the first functionality of six sigma projects is to reduce cost of poor quality and increase to operational efficiency OEE. Chen Fu Chien et al (2007) constructed a frame work for monitoring equipment performances from critical tool groups to singles machines via longitudinal analysis.
3.5 ASSESSMENT OF PLANT EFFECTIVENESS

The metrics for Overall Equipment Effectiveness is widely used, but not sufficient to characterize a complex manufacturing system. Metrics for measuring and analysis, the productivity of manufacturing operation form the equipment level to the system level are of increasing importance to companies seeking to continuously optimize existing operations.

Tom Pomorski (1997) pointed out that the OEE measures the performance of the entire manufacturing process. The productivity metric standard proposal defines variations of OEE as production OEE, Demand OEE, simple OEE, and cluster tool OEE. OEE management also provides insight into the TPM losses, which identifies the improvement opportunities available. Scott and Pisa (1998) described that OEE of semiconductor industries are in the range of 30-40 %. There are great opportunities for improvement. While OEE is about achieving excellence in individual equipment, OFE is about the relationship among different machines and processes. They explain the meaning of OFE and practical steps that can be taken to achieve it.

Samuel H. Huang et al (2002) described that the productivity improvements achieved at the equipment level are significant but insufficient what a company really needs is a highly efficient system. An approach, based on OEE is developed to model the productivities of a manufacturing system in terms of Overall Throughput Effectiveness (OTE). Bamber et al (2003) discusses the purpose of OEE measurement and defines OEE as a total measure of performance. Also, they addressed
that, the concept of OEE is appropriate to all operations containing plant and machinery and showed that the most successful method of employing OEE to use cross functional teams aimed at improving the competitiveness of business.

Samuel H. Huang et al (2003) expressed that, quantitative OEE analysis is still in the early stage. So, development is limited to productivity behavior of individual equipment. It is necessary to focus one’s attention beyond the performance of individual tools towards the performance of the whole factory. Richard Oechsner et al (2003) have explained the samples of modeling methods, models and also the software tools for the calculation and monitoring of OEE. A wider approach has to focus also on the performance of the whole factory.

Sarkar (2007) and Paul Martin Gibbons (2006) introduced OEE as an indicator of plant effectiveness to be used in conjunction with the 6σ DMAIC improvement methodology. Nachiappan and Anantharaman (2006) presented an approach to measure the Overall Line Effectiveness (OLE) in continuous line manufacturing system. Kanthi M. N. Muthiah et al (2008) presented the algorithms developed to automate the factory level performance monitoring and diagnostics process using OTE.

Kanthi M.N. Muthiah and Samuel H. Huang (2006) stressed that productivity measurement and improvement goes hand in hand, because one can not improve what one cannot measure. They indicated that factory level productivity and for performing factory level diagnostics are lacking.
To address this gap, a factory level effectiveness metric based productivity measurement and diagnostic methodology is proposed by them.

Panagiotis Tsarouhas (2007) proposed a methodology based on analysing the reliability data of an automatic production line. It is divided into four steps, whose aims are to bring forth improved maintenance policies of the mechanical equipment. The continuous and thorough inspection of the production process is also achieved through measurements of the Overall Equipment Effectiveness (OEE).

3.6 MEASUREMENT OF PRODUCTION LOSSES

The OEE tool is designed to identify losses, that reduce the equipment effectiveness. These losses are activities that absorb resources but create no value. The industrial application of OEE, as it is today, varies from one industry to another. Though the basis of measuring effectiveness is derived from the original OEE concept, manufacturers have customized OEE to fit their particular industrial requirements.

Patrik Jonsson and Lesshammar (1999) explained that, the exact definition of OEE differs, between applications and authors. Nakajima was the original author of OEE and De Groote is one of the several later authors. The availability measures the total time that the system is not operating because of breakdown, set-up and adjustment, and other stoppages. It indicates the ratio of actual operating time to the planned time available. The authors discussed the effect of planned production time and planned down time in availability calculation.
Chand and Shirvani (2000) pointed out that the true performance of the equipment productivity is measured by Total Effective Equipment Productivity (TEEP), and is a combined measure of equipment utilization (which includes planned downtime) and OEE. The OEE is not an exact measure of equipment effectiveness as set-up, changeovers and adjustments are included. Therefore, to provide a more accurate analysis, the Net Equipment Effectiveness (NEE) can be measured that reflects the true quality and effectiveness of the equipment while running.

Ki-Young Jeong and Don T. Phillips (2001) The original definition of OEE suggested by Nakajima is not appropriate for capital intensive industry. Most authors adopted Nakajima’s loss classification without further discussion. The author believed, however, that loss classification schemes are ultimately tied to the industry type. Stefan Tangen (2003) reviewed the most frequently used performance measures to identify their strength and weakness. OEE is not suitable for manual manufacturing process, since it does not consider the number of workers working in a process and anticipates that there is a fixed ideal cycle time of each machine that controls the maximum processing rate OEE. Also, it does not consider the disturbances from incoming material.

Shamsuddin Ahmed et al (2005) addressed that, the currently applied measurement technique of the rejection rate in the plant was based on number or percentage rejects, which is traditional measure. It is observed that in most of the plants, different products simultaneously produced were of different sizes and there is no unique standard. Therefore, this measure is inappropriate. The weight consideration, to find
the rejection rate in term of weight (Kilogram), is more meaningful and suitable to get better performance review for the plant. If the company’s intention is to know the consumption of material used, then the rejection rate should be in term of weight. However, if the company would like to find out the exact number of products rejected (for customer information) from each type of product produced, then it would apply the calculation in terms of unit.

De Ron and Rooda (2006) advocated that the literature indicates imperfections in applying OEE with regard to the time base and rate efficiency. As OEE lacks a proper framework, the equipment effectiveness (E) has been developed based on a systematic approach to the equipments. ‘E’ considers the effectiveness of the equipment with respect to availability, speed and quality losses. E is a performance measure for stand alone equipment isolated from the environment.

Muchiri and Pintelon (2008) pointed out that, in the literature, effectiveness is defined as a process characteristic that indicates the degree to which the process output conforms to the requirements. Efficiency, on the other hand, is defined as a process characteristic indicating the degree to which the process produces the required output at minimum resource cost. The three measures (availability rate, performance rate, and quality rate) captured by the OEE tool indicates the degree of conformation to output requirements. Therefore, indeed the OEE tool is a measure of effectiveness. The insufficiency of OEE tool has led to modification and enlargement of the original OEE tool to fit a broader perspective as deemed important in the manufacturing systems.
With the modification of OEE, different terminologies have also come up in the literature and in practice, coupled with their modified formulations. The literature review on OEE evolution reveals many differences in formulation of equipments’ effectiveness. The main difference lies in the types of production losses that are captured by the measurement tool. Though the original OEE tool identifies six major losses in a production set-up, other types of losses have been found to have a significant contribution to the overall production loss. Each type of loss requires special attention and corrective action.

It has been claimed that many manufacturing companies measure the efficiency of their lines in such a way as to ‘mask’ many of the causes of lost efficiency. To measure production losses using OEE, two units can be used: production output (tonnage) loss and production time loss. Quality and speed losses are calculated using production output while availability is calculated using downtime.

Recording of individual production time loss is the most practical measurement method in many production systems. The frequency of measurement varies from one industry to another. A current survey (2006) on manufacturing companies (Aberdeen Group) indicates that best performing companies are not only more vigilant and persistent in their measurement efforts but also monitor and measure their performance more frequently. The survey indicates that operational measures such as OEE, in such companies are monitored daily in order to indicate corrective or preventive action.
3.7 CONCLUSION

The literature review on OEE evolution reveals many differences in formulation of equipment effectiveness. The main difference lies in the types of production losses that are captured by the measurement tool. The basis of measuring effectiveness of the equipment is derived from the original OEE concepts, and manufacturers have customized OEE to fit their particular industrial requirements.

3.7.1 The Problem

In the literature, although OEE is accepted as an effective measure of manufacturing performance and as a driver of performance improvements, reported applications of this approach suggest that there are inconsistencies in how it is calculated. Different definitions and applications of OEE in different factors such as industry production system, process and machine type some inconsistencies in the calculation of OEE have been encountered.

In the calculation of OEE, the factor ‘quality’ is taken at the end of the process only. The quality in different stages of the manufacturing process is not at all accounted so far. Also, the quality parameters are not unique always. The products with multivariate quality characteristic are not addressed so far in the literature.

In a process, like casting, the factor ‘yield’ contributes a lot for the assessment of performance. The existing OEE model cannot reveal the performance properly for such processes.
3.7.2  Proposed Methodology

In this research new models are proposed to overcome the above deficiencies. The model proposed for a casting process, includes the parameter ‘yield’. Evolutionary Programming (EP) is used to optimize the parameters of Real Equipment Effectiveness (REE). The model proposed for a tyre manufacturing process, the factor yield is used that accommodates the parameter quality. The number of rejection in that process is negligible. Also, in the proposed models, the availability is calculated, using MTBF and MTTR of each machine in the manufacturing process. The output of the bottleneck machine is taken as the output of the line. The performance of the machine having smallest processing time is taken as the performance of the line or process. Another model is proposed to incorporate the multivariate quality characteristic using Principal Component Analysis (PCA).

Hence, the proposed models in this research focus on the accurate measurement of OEE factors. In the next chapter, the new model proposed is for a casting industry.