CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Quality management programs have been extensively applied around the world, as companies seek to attain and sustain a competitive advantage. Six Sigma is the newest quality management program which helps for the companies to increase both customer satisfaction and financial benefits (Pande et al 2000). Six Sigma quality program seeks to find and eliminate causes of defects or mistakes in business processes by focusing on outputs that are important to customers (Antony and Fergusson 2004). The widespread process improvement methodology of Six Sigma was introduced by Bill Smith at Motorola in the 1980s (Pande et al 2000) and made famous when implemented by John F. ‘Jack’ Welch at General Electric (GE) in the 1990s (Eckes 2001). Since then, Six Sigma has spread far and wide and is now used by many companies around the world. Magnusson et al (2003) have stated that Six Sigma is in essence a structured way of solving problems in an existing process based on analysis of real process data, i.e. facts. Motorola called the procedure MAIC, which at GE became DMAIC of the Six Sigma process. One could argue that DMAIC is nothing new but a set of long well known tools used within quality management but, on the other hand, without Six Sigma these tools would probably still be in the possession of a limited number of people. What makes DMAIC into something new is rather the structuring of the individual tools to the process itself, which is basically the Shewhart cycle (Shewhart 1931), also known as the PDSA cycle for Plan, Do,
Study, Act. Six Sigma is often referred to as a ‘statistical method’, because decisions are made on the basis of statistical analysis of quantitative data. The work of Six Sigma is commonly performed by people who are trained to perform at different levels, as summarized by Jose et al (1999). Despite the massive amount of literature on Six Sigma, its impact on employees is an almost completely neglected. Six Sigma consists of both process and people aspects reported by Mcadam and Evans (2004), but, until today, only few studies focused on understanding the human factor satisfaction is affected by a number of different aspects and a few studies show successful methodologies for creating a healthy work environment and satisfied employees (Schon 2007, Schon 2005 and Schon 2006) and they explained that Six Sigma is action oriented and focuses on processes used in customer service and defect reduction through variation, reduction and improvement goals, but it requires the employee satisfaction. Chakravorty (2009) has described a model to effectively guide the implementation of Six Sigma programs to reduce variation or waste from the operations and concluded that the human side of Six Sigma implementation is an important area and it emphasizes an intelligent blending of the wisdom of an organization, with proven statistical tools, to improve both the efficiency and effectiveness of the organization for the whole-hearted satisfaction of the customer. The success of Six Sigma program hinges on the sequence of many Six Sigma elements of a model for implementation (Chakravorty 2009). Similarly, the application of Six Sigma played a vital role in the casting industry, which has gone through significant changes and a large number of experimental investigations linking green sand casting parameters with casting quality have been carried out by researchers and foundry engineers over the past few decades (ASM International Committee 1990). Until now, the gradient search method, the finite element method based neural network method and the Taguchi method are the optimization methods applying to the green sand casting process parameters design.
Green sand casting process, in general, involves a large number of parameters affecting the various casting quality features of the product in turn affecting customer satisfaction. The purpose of the process improvement is to improve the performance of the process related to customer needs and expectations. The process improvement can be achieved through experimentation and the aim is to reduce and control variation of a process. Subsequently, decisions must be made concerning which parameter negatively affects the performance of the process. Several new statistical tools and concepts of quality improvement depend on the statistical theory of experimental design introduced by Masters et al (1999). Sahoo et al (2008) have proposed a analysis of various critical process parameters and the interaction among them were carried out with the help of Taguchi’s method of experimental design and to optimize the results obtained and to make the analysis more precise and cost effective, response surface methodology are also used.

From the literature, it is observed that the researchers have contributed significantly, but in general, they have not validated their work on the casting process optimization and no attempt has been made in the area of on-time delivery and OEE measure in the Six Sigma implementation to improve the customer satisfaction in the sand casting process foundry. This work also focuses on the Six Sigma implementation with the PWA based on TRIZ concept in order to validate and optimize the casting process variables. More and more customers are demanding that manufacturers quickly respond to their wants and needs and deliver perfect quality products on time. Ahmad et al (2005) and Su et al (2006) have expressed that the trend and advises companies to focus on their order-to-delivery cycle time and Six Sigma techniques were used extensively to understand the relationship between process inputs and process output, reducing the unwanted movements of resources for each set up and maintaining optimal inventory to enhance higher
customer satisfaction. Ramanarayan et al (1988) have developed a formula for calculating base stock level for patient customers when inter arrival times of demands are independent, which reduces the shortage and holding cost was considered and it was further extended to some level for higher accuracies. Breyfogle (1999) suggested that Six Sigma can be considered both a business strategy and a science that has the aim of reducing manufacturing and service costs, and creating significant improvements in customer satisfaction and bottom-line savings through combining statistical and business process methodologies into an integrated model of process, product and service improvement support problems encountered in Six Sigma environment were identified and quantitatively the equipment losses are measured in terms of OEE.

The focus on the implementation model of the literature is referred and studied for the successful completion of the present investigation. In sand casting industries the performance measurement indicators are quality of products, wastage of materials, equipment effectiveness, plant efficiency or productivity, minimum inventory, sigma level as well as employee aspects to evaluate existing process in the Six Sigma environment. These performance indicators are selected because they indicate important manufacturing performance areas and they are critically linked to Six Sigma business strategy, internal organizational and technological basis and they are fairly easy to measure or estimate.

2.2 OVERVIEW ON SIX SIGMA AND ITS MEASUREMENTS

Before 1980’s, many industries could detect defects in production and find out reasons for defects by using defect detection concepts, but they could not prevent the defects. But today it is necessary to achieve the global
quality and hence many companies follow the defect prevention concepts. Six Sigma is a way for Motorola to express its quality goal of 3.4 Defects per Million Opportunity (DPMO) where a defect opportunity is a process failure that is critical to the customer. Motorola set this goal so that process variability is ± 6 S.D. from the Mean (Pete Pande et al 2002) and they further assumed that the process was subject to disturbances that could cause the process mean to shift by as much as 1.5. Standard Deviation (S.D) and the sigma characteristic are given in Figure 2.1. This goal was far beyond normal quality levels and required very aggressive improvement efforts. For example, 3 Sigma results in a 66,810 DPMO or 93.3% process yield, while only Six Sigma is 3.4 DPMO or 99.99966% process yield as given in Table 2.1 (Montgomery 2001). The relationship between DPMO and process sigma assumes the normal distribution. Currently the concept of the Six Sigma is proposed as a management tool for achieving process improvement, reduced cost, reduced wastage, increased customer satisfaction and above all, increased profitability. All processes need not operate at the Six Sigma level. The appropriate level will depend on the strategic importance of the process and the cost of the improvement relative to the benefit. If a process is at the two or three sigma level, it will be relatively easy and cost effective to reach the four sigma level. However, to reach five or Six Sigma will require much more effort from employees and more sophisticated statistical tools. The effort and difficulty increases exponentially as the process sigma increases. Ultimately, the return on investment for the improvement effort and the strategic importance of the process will determine whether the process should be improved and the appropriate sigma level should be targeted (Montgomery 2001).
By adopting this Six Sigma approach, an ever increasing number of companies, of all sizes, are now establishing a far better understanding, and gaining much tighter control, of their processes and as a result are generating significant cost savings, along with increased customer satisfaction and improved profitability.
2.3 OVERVIEW ON SIX SIGMA IMPLEMENTATION MODEL

Many organizations worldwide have implemented Six Sigma and achieved remarkable improvements in their market share, customer satisfaction, reliability and performance of products and services with impressive financial savings as a result of Six Sigma implementation. Robinson (2005) dealt the benefits of implementing Six Sigma programs have been extensively reported in the literature and range from the simple reduction in the number of manufacturing defects to the improvement of the market share and the competitive advantage of a company. Six Sigma programs involve a host of critical decisions and many researchers have contributed to the existing literature. For example, Schroeder et al (2008) have identified many critical decisions or elements of Six Sigma programs such as management involvement, improvement specialists, performance metrics, a systematic procedure, and project selection and prioritization. Six Sigma programs improve operational performance in order to enhance customer satisfaction with a company’s products and services (Tarek Sadraoui and Ahmed Ghorbel 2011). Despite the immense popularity and the wide-spread adoption of Six Sigma, there is an increasing concern across industries regarding the failure of Six Sigma programs because an implementation model detailing the sequence of Six Sigma elements/activities is not available. The existing literature identifies many elements of Six Sigma which does enhance our understanding of Six Sigma programs. However, the success of Six Sigma programs hinges on the sequence of many Six Sigma elements/activities or a model for implementation. In a literature review Schon (2006) found success factors in a study on how Six Sigma had been implemented in three major Swedish companies compared with very successful and less successful case studies of Six Sigma implementations and identified the attributes as characteristics of the successful companies. Antony (2004), Antony and Fergusson (2004) have defined the Six Sigma, has the
flexibility to be used as an operational strategy to reduce the number of defects or as a business strategy to improve business processes and evolve new business models. Taguchi (1986) has described any improvement in Sigma level is likely to reduce the Cost of Poor Quality (CoPQ) and it is a result of manufacturing defects, a function of rework cost, excessive use of material, warranty related costs and unnecessary use of resources.

Current applications of the Six Sigma methodology emphasize the phases that are integrated in conducting a project, which include DMAIC cycle comes into play to meet the customer needs consistently and perfectly. Schroeder et al (2008) and Lindeman et al (2006) have summarized the unique features of the Six Sigma approach includes: (1) sequences and links improvement tools into an overall approach (known as DMAIC); (2) integration of the human and process elements for improvement using a belt based organization (Champion, Master Black Belt, Black Belt and Green Belt), and (3) attention to bottom-line results and the sustaining of gains over time. More related applications about Six Sigma methodology has been adopted in Raisinghani (2005). Tarek Sadraoui and Ahmed Ghorbel (2011) have proposed a new practice of Six Sigma for reduction of the number of non-conformities and minimization of the number of customers' complaints. Based on the investigations for the implementation of successful Six Sigma program, the purpose of this research work is to develop a model consists of technical and human factors to effectively guide the implementation of these programs in the casting company.

2.4 STUDY OF JOB SATISFACTION UPON IMPLEMENTING SIX SIGMA PROGRAM

Zimmerman and Weiss (2005) have reported a survey of aerospace companies concluded that less than 50% of the respondents were satisfied with their Six Sigma programs. Another survey of healthcare companies
revealed that 54% of personnel did not intend to embrace Six Sigma programs (Feng and Manuel 2007). Schon (2007) and Emin kahya (2009) have defined work satisfaction as one’s sense of satisfaction not only with the work but also with the larger organizational context within which work exists is closely related to job satisfaction, which is more commonly used in the implementation process.

Work satisfaction is affected by a number of different aspects and a few studies show successful methodologies for creating a healthy work environment and satisfied employees (Schon 2007) and Schon (2006). Zu et al. (2008) studied the evolving theory of quality management and the role of Six Sigma, focus of any organization should be effective and efficient utilization of human resources and retaining talents in the organization. The importance of management commitment in the context of Six Sigma, as identified in the present study, is in accordance with several previous studies (Evans and Lindsay 2008, Antony and Banuelas 2002, R, Pande et al 2000, Pete Pande et al 2002 and Basu et al 2006) and they have reported that the prime reason for product defects is due to human errors caused by unsatisfied workers. When the employees are satisfied, then the performance of the employee will also increase and it will result in increase in productivity and also profit of the company.

Hence the company has to develop the human resources by identifying the problems of employees which prevent them from carrying out their job effectively and efficiently. Schon (2006) describes job satisfaction, Six Sigma improvement work and the interconnection between the two and attributes this exercise to be an initiative from the senior management. In order to make employees satisfied and committed to their jobs in companies, there is need for strong and effective motivation at the various levels, departments, and sections of the company. Buch and Tolentino (2006) have
conducted empirical study to focus on the human perspective and rewards of Six Sigma. Buch and Tolentino (2006) have found that job satisfaction is correlated with Six Sigma but not to the extent that a predictive model can be created. Rajeshkumar et al (2011) have explored the status and imminent factors for evaluating the feasibility of implementing Six Sigma in medium scale Indian automotive industry. Their research finding shows diversified practices of traditional quality initiatives, e.g. ISO 9000, total quality management, Kaizen, etc. over Six Sigma as well as various rationale of poor implementation of Six Sigma in manufacturing sectors of Indian automotive industry. Schon (2007) explained the dimensions being used in the evaluation of job satisfaction and the relationship between Six Sigma and job satisfaction is essential to make human aspect of Six Sigma efficient in his tentative model to gain good results. Based on the above discussions, there are no empirical studies of job satisfaction upon implementing Six Sigma. This study developed a structured methodology incorporating job satisfaction to achieve Six Sigma in the existing environment.

2.5 OVERVIEW ON SAND CASTING PROCESS PARAMETER OPTIMIZATIONS, DEVELOPMENT AND VALIDATION

A large number of experimental investigations linking green sand casting parameters with casting quality have been carried out by the researchers and foundry engineers over the past few decades (ASM International Committee, 1990) and it has been recognized that green sand casting parameters design plays one of the key elements in casting quality. The casting process has a large number of parameters that may affect the quality of castings. Some of these parameters affecting quality are controllable, while others are noise factors (Noorul haq et al 2009, Guharaja and Noorul Haq 2006, Sushil kumar et al 2011a). There are several guidelines for the design of green sand casting parameters. The variations in casting parameters chosen by different researchers have led to significant variations
in these empirical guidelines. Some applications of Taguchi’s methods in the foundry industry have shown that the variation in casting quality caused by uncontrollable process variables can be minimized (Ghani et al 2002). Taguchi (Ross 1988) approach is suitable in using experimental design for (a) designing and developing products/processes so as to be robust to component variation; (b) designing products/processes so as to be robust to environmental conditions; and (c) minimizing variation around a target value.

During the 1990s, a lot of developments had been done for the foundry process (ASM International Committee 1990). Some of these programs were able to simulate the behavior of the molten metal close to reality, as the researchers studied the behavior of the molten grey cast iron during the filling of different gating systems by optical means, and correlated the measurements to obtain the behavior by some simulators. By the end of the 1990s, the trial and error approach practices moved away from the real mould to the virtual one. According to Taguchi, the parameters, which exert a great deal of influence on the die casting process can be adjusted to varying levels of intensity so that some settings can result in robustness of the manufacturing process. Barua et al (1997) used the Taguchi’s method to optimize the mechanical properties of the Vacuum V-casting process. In their paper, they considered the effects of the selected process parameters on the mechanical properties of alloy casting and subsequent optimal settings of the parameters, which were accomplished using Taguchi’s parameter design approach. Changyu et al (2007) have proposed a combining artificial neural network and genetic algorithm method to optimize the injection molding process. Juran et al (1951) have stated that control factors are the selected independent variables of the experiment, which have different effects on the response variables when adjusted to different levels. They can be subdivided into quantitative control factors and qualitative control factors. Noise factors are the variables, which influence the response variables. They may or may not be known. Special care should be taken to prevent the noise factors from interfering in the experimental results. Masters et al (1999) have described a
robust design method for reducing cost and improving quality in an aluminum re-melting process. An experimental investigation into the process parameter effect was presented to determine the optimum configuration of design parameters for performance, quality and cost.

Muzammil et al (2003) have made a study for the optimization of a gear blank casting process by using Taguchi’s robust design technique. In this study, they demonstrated that the casting process involves a large number of parameters affecting the various casting quality features of the product. The reduction in the weight of casting compared to the target weight was taken to be proportional to the casting defects. Bikram Jit Singh and Dinesh Khanduja (2011) have explained with various problems of industries which act as bottlenecks in the path of successful optimization of processes, specifically for foundry units and further it chalks out an integrated approach of Design of Experiments (DOEs) for its implementation in product or process type industrial environments. Syrcos (2002) has analyzed various significant process parameters of the die casting method of aluminum alloy. He made an attempt to obtain optimal settings of the die casting parameters in order to yield the optimum casting density of the aluminum alloy castings.

Apart from the casting process, the Taguchi method can be used for other manufacturing processes, like milling, grinding and the machining of composites etc. Ghani et al (2002) used the Taguchi method in the optimization of end milling process parameters. They applied it to optimize cutting parameters in end milling when machining hardened steel with a tin-coated carbide insert tool under the semi-finishing and finishing conditions of high-speed cutting. Shaji and Radhakrishnan (2002) have performed an analysis of the process parameters in surface grinding with graphite as the lubricant based on the Taguchi method. They analyzed the process parameters such as speed, feed, and mode of dressing as influential factors on the force components and surface finish developed based on Taguchi’s experimental design methods. Sushil Kumar et al (2011) have explained and analyzed an
orthogonal array; the signal-to-noise ratio and analysis of variance criterion are used to analyze the effect of selected process parameters and their levels on the casting defects of the cast iron (grade-25) differential housing cover castings.

Surekha et al (2011) have developed multi-objective optimization of green sand mould system using evolutionary algorithms Genetic Algorithm and Particle Swarm Optimization developed between the control factors (process parameters) and responses like green compression strength, permeability, hardness and bulk density have been considered for optimization. Lakshmanan (2010) have analyzed the casting parameters at different levels on casting quality and optimal setting of the parameters are accomplished with neural network model to map the casting defects. Sachin et al (2011) have analyzed the rotational sand moulding process using DOE with significant parameters. Based on the above discussions, researchers attempted to optimize the sand casting process parameters by conducting ANOVA experiments on Taguchi’s concept to minimize the defects in the casting process.

RSM is the collection of statistical and mathematical techniques employed for developing, improving, and optimizing a process. The objective of quality improvement, including reduction of variability and improved process and product performance, often are accomplished by directly using RSM (Montgomery (2001)). Sahoo et al (2008) have focused on minimizing the residual stress developed in components manufactured by the radial forging process. Analysis of various critical process parameters and the interaction among them was carried out with the help of Taguchi’s method of experimental design and made the process more precise with RSM model. Sudhir kumar et al (2007) have dealt the effect of selected process parameters, RSM was used to formulate a mathematical model which correlates the independent Process Parameters with the desired solidification time of Al–7% Si alloy castings. Taha Ali El-Taweel and Gouda (2010) have analyzed
further about the feasibility of using a wire as a tool in electrochemical turning process to measure the performance criteria of the process through investigating the effect of working parameters using RSM. Palanikumar (2008) has evaluated the effect of selected process parameters, the response surface methodology is used to formulate a mathematical model which correlates the independent process parameters with the desired surface roughness of Al–7% Si alloy castings in machining Glass Fiber Reinforced Plastics parameters. El-Taweel (2009) presents a systematic methodology for modeling and analysis of the rapidly resolidified layer of spheroidal graphite cast iron in the electrical discharge machining process using the RSM.

Sivssakthivel (2011) has focused on prediction of vibration amplitude from machining parameters by response surface methodology in end milling process reduces tool wear and improves surface finish. Kurtaran and Erzurumlu (2006) have explained the response surface method to optimize the process parameters for reducing the warpage of plastic parts. Kundu and Lahiri (2008) have explained a systematic design of experiment study based on central composite rotatable design method on green sand mould sand with calcium bentonite clay were analyzed with statistical models and response surfaces correlate bulk density, compactability, permeability and compression strength to the set of inputs of percentage of bentonite and water, curing time, and the immediate environment of the specimen preparation. Based on the literature discussions, there are no literatures analyzing the sand casting parameters with Taguchi and RSM for selected significant parameters to obtain single objective phenomena. This work, Taguchi analysis is used for critical to quality casting parameters and made the optimization process more precisely by analyzing the significant parameter using RSM.

2.5.1 Study on PWA based on TRIZ

The theory of inventive problem solving, one of the most important innovation theories, is capable of pointing out directions and approaches for
solving technical problems. As TRIZ asserts that somebody, someplace, has already solved problem or one a lot like it (Altshuller et al 1999, Li et al 2007), they can find creative schemes or measures for solving problem by referring to analogous inventions, not only in related fields, but also in other technical areas explained by Liang et al (2008). Furthermore TRIZ has enjoyed some remarkable successes within a broad range of product design and optimization, and developed some problem oriented innovative design methods, as explained by Hung and Hsu (2007) and Marsh (2004). However it should be noted that less effort has been put in to applying TRIZ to process design and optimization, and particularly to the sand casting process operations. Though it still takes some creativity to determine the ultimate solution for a problem, the goal of TRIZ is to order how the problem is thought about to help arrive more quickly at the optimal solution. Like any other tool, the more often it is used, the better the user becomes at judging which solution path will be most effective.

Kynin (2006) used TRIZ method in materials change their sizes under the action of temperature. The purpose of the work is the generalization of available data on averting and using the thermal deformations in the technology, the analysis of the methods of compensating the thermal deformations with the use of tools TRIZ. Hassan (2004) used TRIZ method in taking into account of safety on both design and exploitation levels highlights management contradictions comprising technical, economic or human aspects. Wu (2006) has expressed TRIZ theory and Taguchi methods in automobile muffler design phase to fit the requirement of engineering optimization design. Yufang Chiu and Daniel Su (2010) have explained that the decision-makers frequently need to develop new strategic plans to correct weaknesses or build new strengths for a changing business condition through optimizing the production period, and initial investment in process improvement so as to minimize total cost. Process Window Index (PWI) has
been developed for more than 10 years to produce much related research and literature; they are only focused on improving quality in the electronics process industry using PWI, as given by Jim Hall and Phil Zarrow (2002). Based on the literature discussions, there are no referenced discussions or literature on implementing PWA using TRIZ application. Additionally, it is extremely difficult to find an experienced technical talent of PWA. As such, this article will introduce the TRIZ innovative design method to assist the implementation process of PWA. Through case analysis, this article wishes to establish a systematic PWA based on TRIZ application.

2.6 VIEW ON OPTIMAL BASE STOCK LEVEL FOR ON-TIME DELIVERY IN THE SIX SIGMA ENVIRONMENT

Sambhe and dalu (2011) have focused on the current empirical study of the Indian medium scale automotive industries along with the scope of implementing Six Sigma. They also noted the achievable Six Sigma results not only in cost reduction but also in improved customer satisfaction and increased sales. The application of Six Sigma techniques will also contribute to lowering the costs while lowering the lead-time and lead-time variation. Sadraoui and Ghorbel (2011) have proposed a new practice of Six Sigma for reduction of the number of non-conformities and minimization of the number of customers' complaints. Customer feedback reveals that a key to customer satisfaction is on-time delivery and any deviation from promised dates has a negative impact on customer satisfaction. With Six Sigma techniques, the ‘dial-in’ portion of each set-up could be shortened, reducing the required labor hours for each set up, reducing the unwanted movements of resources for each set up and maintaining optimal inventory to enhance higher customer satisfaction. Shil et al (2010) found that the customer satisfaction is of paramount importance in research due to rapidly increasing the customer demands. Chopra et al (2007) has explained a model both, analyzing the costs
involved in bundling the variance from these two distinct sources in a single-period setting and they stress the importance of correctly identifying and analyzing the types of stochastic in supply.

Li et al (2010) have examined the effects of organizational variables on conformance quality, design quality and customer satisfaction in quality management system. Six Sigma is centered on variation reduction and this will improve stability, repeatability, control, and allow for permanent inventory reduction. Not all inventories are bad since every process has some amount of variation (hopefully common cause only). As long as there is uncontrolled variation, an organization must carry inventory to cover the "just-in-cases" or risk jeopardizing a customer, shutting down, or negatively impacting their scorecard. Gaver (1959) explains Inventory as a lagging metric and it is not a variable switch that can be controlled without serious risks to customer. Metrics include a lower DIOH (Days Inventory On Hand) or increased Inventory Turns. This is a great idea and good thing to target to improve satisfaction but the focus should be on fixing the key inputs that are causing the need to carry the inventory. Lead Time must be reduced (the mean) and the variation within the value stream must be first controlled, and then reduce the common cause must be reduced. This will automatically lead to better inventory control and cash flow allows an organization to meet customer expectation that promotes higher value to the Six Sigma implementation, improve sigma ratings, and many more. Ahmed et al (2005) expressed this trend and advised companies to focus on their order-to-delivery cycle time for streamlining internal and external supply operations to reduce overall order-to-cash cycle Time. Neves and Nakhai (2011) have proposed a Six Sigma methodology that is based on a broad understanding of customer satisfaction and on the five gaps of the service quality model. Sharma (2011) has attempted to link voice of customer to product development process through quality function deployment for complete customer satisfaction through the implementation of Six Sigma and its performance calculation. Zu
et al (2010) have explained how organizational culture influences the implementation of different practices incorporated in the recent Six Sigma approach as well as those associated with traditional total quality management and also they have remarked that how the customers are increasingly emphasizing flawless delivery, that is, very short-cycle, on-time delivery, and responsiveness to the customers’ changing needs. Six Sigma will aid this process by removing variation from the process, again aiding in the synchronization of supply and demand. Silver and Bischak (2010) have proposed a periodic review order-up-to-level (or base stock) inventory control system under normally distributed demand without backordering. Johansen and Thorstenson (2008) have extended well-known formulae for the optimal base stock of the inventory system with continuous review and constant lead time to the case with periodic review and stochastic, sequential lead times. Based on the literatures discussions, there are no literatures dealing base stock system implementation for on-time delivery in the Six Sigma environment. This work determined and implemented optimal base stock inventory system easily due to their structured way in all aspects to improve the effectiveness of the Six Sigma system towards customer satisfaction.

2.7 THE PERFORMANCE MEASUREMENT OF SIX SIGMA MANUFACTURING SYSTEM THROUGH OEE

Performance measures are defined as a tool for assessing how well the activities within a process or the process outputs, achieve a specified goal. The performance areas must be made measurable through performance indicators that allow the company to monitor the performance and assess the goal realization (Shamsuddin Ahmed et al 2005). Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm’s resources are utilized in providing the given level of customer satisfaction. A business can achieve success only by understanding and fulfilling the needs of its customers. Most studies ignored
the quality factors at different stages in the Six Sigma process and the consequential cost resulting in a huge potential loss (Sousa 2003) and dealt the context of quality management, customer-focus practices involve the establishment of links between customer requirements, satisfaction, and internal processes. However, many companies use performance measures that are based on traditional management cost systems that are now outdated and incompatible with their new operating philosophies which regard the entire organizational activities as a “process” such as Total Quality Control/Management (TQC/M) system, Just-in-Time (JIT), TPM, 5S housekeeping techniques and Theory-Z, present a more comprehensive picture of a system (Ahmad and Benson 1999). The elements of measures under the ISO 9000, ISO 14000 and Malcolm Baldrige Quality Awards are different from those of conventional measures. Kaplan (1990) states that “traditional summary measures of local performance-purchase price variances, direct labor and machine efficiencies, ratios of indirect to direct labor, absorption and volume variances are harmful and should be eliminated, since they conflict with attempts to improve quality, reduce inventories and increase flexibility. Direct measurement is needed for quality, process time, delivery performance and any other operating performance criterion that needs to be improved”.

Consequently, many researchers are suggesting new performance measurement approaches that support day-to-day operations and provide managers, supervisors, and operators with information that is both timely and relevant (Shah and Ward 2003). To provide an overall view of company performance and prevent local optimization, researchers have tried to combine more than one performance aspect through integrated performance measurement systems. Therefore, Mahesh Pophaley and Ram Krishna Vyas (2010) have stated that a performance measurement system of an organization should include a set of well-defined procedures to compare actual performance to standards and procedures for dealing with discrepancies
between actual and desired performance. The manufacturing performance assessment and analysis (Ahmad and Benson 1999) covers the areas of quality, delivery reliability, cost (price minus profit margin) and delivery lead time.

A six-item scale is used to measure the operational performance of a manufacturing plant after different levels of lean manufacturing practice. The items include 5-year changes in scrap and rework costs, manufacturing cycle time, first pass yield, labor productivity, unit manufacturing cost, and customer lead time (Abdul Talib Bin Bon and Noorazira Karim 2011). Global competition demands that manufacturing organizations improve quality, reduce delivery time, and minimize costs. In response to this, many manufacturing organizations have implemented different excellence programs to improve their performance by applying TPM, Six Sigma, Lean manufacturing techniques, performance measurement, and benchmarking, are included in many of those excellence programs (Shah and Ward 2003). In the Six Sigma environment, the customer satisfaction is determined by the quality, cost, delivery indicators for process evaluation (external customer performance indicators), availability, equipment effectiveness indicators for the machine utilization estimation (Shamsuddin Ahmed et al 2005) labor productivity, employee commitment indicators as internal customer performance indicators. Innovativeness, both in system management and performance measurement are highly important in today’s manufacturing. Few innovations can be generalized for a large number of firms. For example, a company, which introduces Six Sigma, has already advanced significantly to apply the concept of OEE. In practice, those existing manufacturing performance measurement systems are unable to quantify the customer orientation and objective orientation requirement levels in the past decade and those measurement systems could not highlight the quality of business concerns in a just-in-time manner that will promote the effectiveness of
improvements. OEE is the performance measurement indicator of the Six Sigma program and the advantages of establishing this new approach attempts to highlight suitable factors in industry performance measurement systems that could help transform these factors into measurable, quantitative, Just-in-Time parameters. These parameters could be utilized in planning and establishing a manufacturing performance rating system based on the work with a casting company. Nakajima (1988) have pointed out primarily the TPM approach is linked with the ‘Lean’ concept which aims at reducing waste due to poorly maintained machinery and provides for value added inputs by way of ensuring machinery in productive operation for longer period of time. The goal of TPM is to maximize equipment effectiveness, and the OEE is used as a measure (Almeanazel 2010). Chen and cheng (2007) have investigated the product line based company under study, the vital parameters were identified to measure the performance related to its productivity, quality, efficiency and equipment maintenance, in order to get the overall scenario of the success and weakness.

Based on the above survey, there is no literatures discussed on OEE with Six Sigma. This research work is to study the performance measurement of a factory by OEE in the Six Sigma environment towards achieving better performance. In this study, the system focuses on improving manufacturing competitiveness by overcoming the limitations of existing performance measurement systems and the object of this research (Shamsuddin Ahmed et al 2005) is to establish effectiveness and efficiency of the system.

2.8 SUMMARY

- The overview on six sigma measurements and implementation model literatures are discussed. Based on the discussions, the purpose
of this research work is identified. The studies of job satisfaction upon implementing six sigma program literatures are also discussed.

- The overview on green sand casting process parameter optimizations, process development and validation literatures are discussed and there are no literatures analyzing the sand casting parameters with Taguchi and RSM for selected significant parameters to obtain single objective phenomena. Study on PWA based on TRIZ implementation literatures are discussed. Based on the literature discussions, there are no referenced discussions or literature on implementing PWA using TRIZ application.

- Literatures on optimal base stock level for on-time delivery to improve customer satisfaction in the six sigma environment have been discussed and there are no literatures dealing base stock system implementation for on-time delivery in the Six Sigma environment.

- The performance measurements of six sigma manufacturing system through OEE literatures are discussed. Based on the above survey, there is no literature discussed on OEE with Six Sigma.

- From the literatures, it is observed that the researchers have contributed significantly, but in general, they have not validated their work on the casting process optimization and no attempt has been made in the area of PWA, on-time delivery and OEE measure in the Six Sigma implementation to improve the customer satisfaction in the sand casting process foundry.