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A comprehensive study on Lean Manufacturing Implementation and its Applications

Tasvir Singh[1], Mr. Yogesh Sharma[2]
[1]Dept. of Mechanical Engineering, C B S Group of Institutions Fatehpuri, Jhajjar, Haryana
[2]Assistant Professor, Mechanical Engineering Dept., C B S Group of Institutions Fatehpuri, Jhajjar, Haryana

Abstract: The paper is based on a systematic literature review that examines how the implementation of Lean could bring value to the organization processes and contribute for achieving an operational excellence. Different organizational factors which have importance in the implementation process, are thoroughly examined. Key success factors that enhance the implementation process are identified - human resource practices, management style, organizational strategic vision, organizational culture, external partnerships. The research outlines the challenges that companies experience when they change their business model towards implementing a new to the company management system – Lean concept. For better understanding of the term the paper suggests definitions from the authors acknowledged in the field. Part of the research considers some critical points that impede the implementation of Lean.

The conclusions are drawn upon considering lean as a complete business system, which change the way organization thinks in striving for a competitive advantage.

I. Introduction

Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to Unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, Red Mud is one of the most inexpensive reinforcement available in large quantities as solid waste by-product during bayer process, the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminium by the Hall–Héroult process. Hence, composites with Red Mud as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of Red Mud particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products. Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components.

The present investigation has been focused on the utilization of abundantly available industrial waste Red Mud in useful manner by dispersing it into aluminium to produce composites by stir casting method. Tribological behavior of the metal matrix composites was studied by performing dry sliding wear test using a pin-on-disc wear tester. Experiments were conducted based on the plan of experiments generated through Taguchi‟s technique. L9 Orthogonal array was selected for analysis of the data. Investigation to find the influence of sliding speed, applied load and sliding distance on wear rate, as well as the coefficient of friction during wearing process was carried out using ANOVA and regression equation for each response were developed for both 5% and 10% Red Mud reinforced Al-6063MMCs. Objective of the model was chosen as "smaller the better‟ characteristics to analyze th e dry sliding wear resistance. Results show that sliding distance has the highest influence followed by load and sliding speed. Finally Scanning Electron Microscope were done on wear surfaces. Top Japanese manufacturing industries have achieved excellent international competitiveness in a number of industries such as auto, electronics, and machinery in the past two decades. So due to intensive competition from the world, increasing manufacturing cost, and increasing operational problems, many manufacturing firms around the world, have made tremendous efforts to understand Japanese manufacturing practices. According to Hall (1983) and Schonberger (1982), Japanese had developed a new approach to increase the production rate and decrease overall cost in manufacturing firms.

Japanese developed Lean manufacturing which was previously known as the Toyota Production System (TPS) or the Just-in-Time (JIT) system (Toyota, 1988; Womack et al., 1990). Lean manufacturing attracted a lot of attention in the United

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States from both academia and industry. In recent time many automobiles and other manufacturers are actively adopting the lean manufacturing concepts. Most auto manufacturers have now adopted at least some aspects of this system. Maccoby's (1997) did a study and according to his study one-fourth of United States plants have tried to adopt the lean manufacturing system in their industries. However, to transfer the lean production system in a foreign country is a very long journey and a very challenging work because so many different aspects of plant operation are involved to manufacture a component. The transfer of Just in time approach to Toyota Production System, need a large amount of efforts.

Lean manufacturing, developed by Toyota, involves quality and inventory control, industrial relations, labor management, and supplier-manufacturer practices. Some researchers (Cusumano and Takeishi, 1991; Liker, 1997; Womack and Jones, 1996b) suggest that transfer of traditional manufacturing system to lean manufacturing had a significant positive impact on the performance of manufacturing firms.

1.1 Practices of lean manufacturing-

JIT works on the principle of small-lot production and JIT delivery (Purchasing, 1992). According to Nakamura et al. (1998), just in time has improved the performance of manufacturing firms. The results of a study of 200 US manufacturers by Germain and Droge (1997) states that improved inventory, financial, and market performance correlates with increased adoption of Just in time purchasing methods. Zayko et al. (1997) states that, with the help of lean manufacturing we can reduced 50 percent of human effort, manufacturing space, tool investment, and product development time, and also 200-500 percent improvement in product quality. However, Toyota recently makes a dramatic policy change for its lean support service. A decade after providing free instruction in lean manufacturing to all suppliers, Toyota is curtailing the service. Parts suppliers need to pay the tuition if they want to learn the lean manufacturing system (Chappell, 2002). Logistics or supply chain management learns the art to manage the flow of materials and products from source to consumer (Copacino, 1997). Levy (1997) states that, JIT delivery and low inventory are the main part of logistics or supply chain management.

According to Bowersox et al., (2002) Lean logistics refers to the superior ability to design and administer systems to control movement and geographical positioning of raw materials, work-in-process, and finished inventories at the minimum cost. Jones et al. (1997) states that the "value stream" is a new and more useful term to analysis the supply chain or the individual firm. They reinforce the importance of the value stream concept that extends both upstream from the product assembler into the "supply chain" and downstream into the "distribution chain". However, large manufacturers have a better chance in achieving such "lean logistics" than their suppliers do, because large firms to have more resources and bargaining powers than their suppliers. For suppliers, though it may not be possible for them to optimize their supply chain effectively, it is still critical for suppliers to have a responsive logistics system in place to meet the customer's demand.

According to Suzaki (1987), automobile manufacturers are striving toward the lean manufacturing and demand JIT logistics from suppliers, suppliers with lean systems in place are more likely to be incorporated into the total system. As Heim and Compton (1992) put it, "A world-class manufacturer encourages and motivates its suppliers to become coequals with the other elements of the manufacturing system." An analysis conducted by Swenseth and Buffa (1990) shows that the implementation of lean strategy results in an increase in the total logistics cost of a manufacturer and his vendors. These cost increases are in the form of increased transportation, inventory carrying, and expected stock out costs.

A supplier may take different strategies to satisfy the requirements set by a particular customer (Wu, 2002). A comparative analysis of lean manufacturing performance by Liker and Wu (2000) reveals that a buyer's lean logistics practices and internal policies can have a profound impact on its suppliers' ability to optimize operations. This exploratory study compares many different independent variables in more of a descriptive mode. The literature on lean manufacturing methods as compared to traditional production methods suggests some possible propositions for directions of differences.

Zipkin (1991) states that inventory reduction are a result of the adoption of lean manufacturing. Lean manufacturing achieves inventory turnovers of 20 in comparison with three to five for the traditional production setting (Nakamura et al., 1998; Schonberger, 1986; Wurz, 1995). A survey by Germain and Droge (1997) shows that lean manufacturing have less inbound inventory in industries.

1.2 Benefits from Lean Manufacturing-

To fully benefit from lean manufacturing, lean suppliers understand that they can meet customer demands for an ever increasing variety of products with frequent, quick changeovers in combination with other JIT techniques (Suzaki, 1987). In addition, high machine mobility and multi-skilled workers can help lean manufacturing adjust production to changes in customer demand quickly (Hirano, 1989; Suzaki, 1987).

According to Shingo (1989), Lean manufacturing focuses on preventing defects, not merely finding them. As a result, lean manufacturing are expected to be responsive to quality problems on the shop floor so defects can be prevented. Zayko et al. (1997) states that with the help of lean manufacturing, we improved the quality of product to 250-550 percent from traditional manufactured product. According to Levery (1998), preventive maintenance in industries put a significant impact on quality, quantity, and cost of a product.

1.3 Requirements of lean manufacturing-

Levy (1997) states that lean manufacturing needs frequent and rapid flows of information and goods along the value chain in industry. In addition to the famous kanban system extensively used by Toyota, lean manufacturers are also increasingly exchanging computerized information with suppliers who can help them reduce the lead time from product design to market (Kasarda and Rondinelli, 1998). It is important for lean manufactures to have good communication networks with their customers to get information on communication, order, production schedule, track and management material flow and inventory.

According to Udoka (1993), in lean manufacturing, due to a large number of parts in small quantities coming into the assembly plant, efficient, effective containerization is important. According to Nicholas (1998), use of containers of a standardized size can help reduce inventories and facilitate the distribution process in plant. According to Schniederjans (1993), use of bar-coding can result in reduction in wasteful activities of inspection, classification, and storage of inventory and use of reusable containers can lead to improvement in materials handling methods.

According to Florida (1996), he examines the relationship between advanced production practices and innovative approaches to environmentally conscious lean manufacturing. He states that industries that are innovative in terms of their manufacturing process are likely to be more active in addressing environmental costs. According to Maxwell et al. (1993), we maintain a good relationship between lean manufacturing and innovative environmental manufacturing practices in industries.

1.4 Concluding Remarks –

Above analysis shows that lean manufacturing is very important for all kind of organizations to improve sustainable competitiveness. In these chapter different issues of lean manufacturing such as main practices, benefits and requirements have been discussed. Next chapter will discuss about literature review of lean manufacturing.

2. Literature review

The term "lean manufacturing" or "lean production" was first used by Womack et al. (1990) in their historical book "The Machine That Changed the World". The lean manufacturing describes the profound revolution that was initiated by the Toyota Production System against mass production system. Womack and Jones continued their research in lean production and studied the transfer of other companies into lean crusade in their second book, "Lean Thinking" (Womack and Jones, 1996). They explained that lean manufacturing is much more than a technique, it is a way of thinking, and the whole system approach that creates a culture in which everyone in the organization continuously improve operations. Liker (1997) wrote the third book in this series with the title of "Becoming Lean – Inside Stories of U.S. Manufacturers". The most recent book about the Toyota system is also by Liker (2004) where he describes the management principles of Toyota that he claims to be the world's greatest manufacturer.

Al-Sudairi (2007) built a simulation model to study the impact of certain lean manufacturing principles for enhancing the flow of construction material and found that lesser the time spend in the value stream, leaner is a process. Lian and Van Landeghem (2007) discussed on the application of VSM-based simulation generator in a manufacturer of poultry and pig-raising equipments for feeding, drinking, feed storage and feed transportation systems. Singh et al. (2009) suggested industries to apply lean manufacturing techniques to find money drain points in their balance sheets and also apply these techniques to cut down operational cost to save business during recessionary times. Singh and Sharma (2009) showed that value stream mapping is a versatile tool for lean implementation by a case study of an Indian manufacturing industry and witnessed 92.58 percent reduction in lead time, 2.17 percent reduction in processing time, 97.1 percent reduction in work in process and 26.08 percent reduction in manpower requirement. Singh et al. (2010a), developed an index for measuring leanness of any manufacturing firm based on the scores awarded by leanness measurement team members. Various types of manufacturing wastes addressed by lean manufacturing are taken as one parameter for measuring leanness index. This assessment tool helps to investigate, evaluate, and measure key areas of manufacturing. The tool is very user-friendly and the result is a deeper understanding of key issues, problem areas, and potential solutions.

Sanchez and Perez (2001) focused on six Lean Manufacturing indicators:

i) Elimination of zero-value adding activities
ii) Continuous improvement
iii) Multifunctional teams
iv) Just-in-time production and delivery
v) Integration of suppliers
vi) Flexible information system

i) Elimination of zero-value adding activities

Eliminating waste and zero-value added activity is one of the main goals of Lean production. If the task does not add value from the customer's point of view it should be eliminated. It is believed that by minimizing waste and zero-value added activities, companies can reduce production costs and the overall production system will be more efficient and thus achieve the Lean ideal.

ii) Continuous improvement

Continuous improvement is a process that requires involvement of employees at different levels and support of management. This process relates to the Jidoka concept, which states that since people are not working for the machines, they have the ability to use their best judgment to improve the process. In addition, they will assume more than minimum responsibilities making sure the machines function correctly. All members in the company should strive for continuous improvement in products and processes. This would require the creation of improvement teams to lead the organization to move toward zero defects.

iii) Multifunctional teams

Multifunctional teams are also related to the Jidoka concept in that floor workers are not tied to one machine and do not work in "isolated is lands." Workers should be trained to work on multiple tasks and thus al low the company to flexibly "accommodate changes in production levels."

iv) Just-in-time production and delivery

Just-in-time is also related to the first indicator of eliminating waste because it reduces excess inventories and work-in-progress.

v) Integration of suppliers

Suppliers can play an important role in achieving the just-in-time production concept. By reducing the amount of time required to wait for parts and arrival of materials, manufacturing companies can place an order after they are certain of the quantity and products desired by their customers. This can greatly reduce "just-in-case" inventories in the system and production lead time.

vi) Flexible information system

Excessive paper work is considered to be one of the traditional areas of waste. Lean production requires the diffusion of useful and relevant information to the production line. By decentralizing responsibilities to the first line workers, the amount of time wasted in processing documents can be reduced. Rather than embracing one or two isolated tools it is suggested that it is important that companies practice most, if not all, of the following: Continuous improvement/kaizen: The continual pursuit of improvements in quality, cost, delivery and design. Cellular manufacturing: It is vital to group closely all the facilities required to make a product (or related group of products), in order to reduce transport, waiting and process time.

3. Justification of Lean Manufacturing Using Analytic Hierarchy Process (AHP)

In this chapter, lean manufacturing has been compared with traditional manufacturing. To justify use of lean manufacturing in place of traditional manufacturing different benefits have been analyzed. With the help of literature review, different benefits of lean manufacturing are shown in table 3.1. According to Sohal and Eggleston (1994), lean manufacturing increases the net profit because it reduced the wastages in the production system. Lean manufacturing increases productivity of the plant so that production rate increases (Philips, 2002). Shingo (1989) states that lean manufacturing decrease waste in the plant. Lean manufacturing eliminates the non value adding process so that wastage decreased. Gilson et al. (2005) have observed that Lean manufacturing improves the quality of product because it uses the standard process to make a product. According to Monden (1983), lean manufacturing improves the flexibility in production system. According to Suzuki (1995), the amount of inventory gets reduced in industry by using lean manufacturing. With the help of Lean manufacturing, lead time gets reduced because it decreases the set up time of machine (Al-Najjar and Alsyouf, 2000). For justifying use of lean manufacturing based on these benefits, Analytic Hierarchy Process (AHP) approach has been applied.

4. Research Methodology

Saaty (1980) had suggested analytic hierarchy process (AHP) which is used to solve complex problems. Basically, decision makers have to decompose the goal of the decision process into its constituent parts, progressing, from the general to the specific perspective. It organises the basic rationality by breaking down a problem into its smaller and smaller constituent parts and then guides decision makers through a series of pair wise comparison judgements to express relative strength or intensity of impact of the elements in the hierarchy. Once the hierarchy has been structured, decision makers judge the importance of each criterion in pair-wise comparisons, structured in matrices. According to Satty (1980) the final scoring has been on relative basis after that compare the importance of one decision alternative to another. In analytic hierarchy process takes both objective and subjective evaluations. In subjective evaluation, we directly question the decision makers after that we get the priority weight of element. Kodali and Chandra (2001) used AHP for justification of total productive maintenance. In this research, justify the lean manufacturing vs. traditional manufacturing with the help of Analytic hierarchy process (AHP). In this methodology, we follow four phases to reach the final result.

This study has gone through four phases, as follows:

1. structuring the problem and building the AHP model
2. collecting data from expert interviews
3. determining the normalized priority weights of individual factors and sub factors
4. synthesis-finding solution to problem.

Measuring and collecting data

After building the AHP hierarchy, then our next step is to measurement and data collection. It was done by a team of experts and assigning pair-wise comparison to the main factors used in the AHP hierarchy. We use nine-point scale to assign relative scores to pair wise comparisons amongst the main factors. With the help of scale, experts assign a score to each comparison. Experts continue this process until all levels of the hierarchy and eventually a series of judgment matrices for the major factors were obtained. Team consisted of twelve experts, Out of these twelve experts; six were from industry, mainly from manufacturing sector such as automobile and electronics equipment sectors and six from academic sector. Each one of them has more than eleven year of experience in lean manufacturing area.

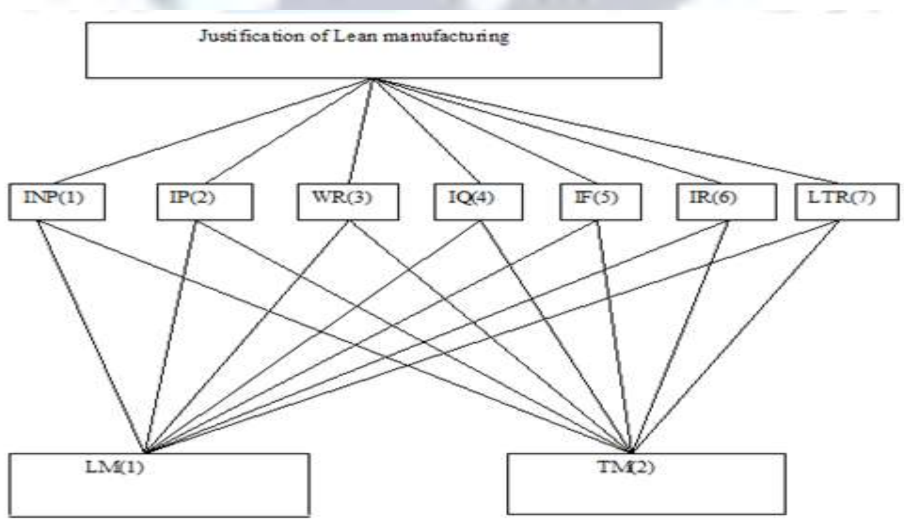

Fig. 1: Schematic of AHP model

A questionnaire consisting of all main factors of the two levels of AHP model is designed and is used to assemble the pair wise comparison judgment from all the experts. We do this process continue until consensus made otherwise decision of majority gives more importance. In past, some researchers adopted a team of decision makers which have less than ten experts. Bayazit (2005) used AHP approach in decision making for flexible manufacturing system by having a team of six experts from various departments. Zaim et al. (2012) also used a team of five decision experts while selecting maintenance strategy.

5. Results and discussion

When we make AHP hierarchy model, table 3.1 shows seven main factors which are considered for analysis. AHP model developed as shown in Figure 3.1 is used for justification of Lean manufacturing in SMEs. Then we make pair-wise comparison judgment matrices to find out the normalized weight. Pair wise criteria comparison matrix shown in table 3.4, this table shows all the seven major benefits of lean manufacturing. After that we calculate the CR value to check the degree of consistency of the pair wise comparison matrix and CR for level 1 are shown in table 3.5. Then we follow same procedure to find the PV and CR for other levels. Then table 3.6 shows the results. We observed from table 3.6 that all seven factors of lean manufacturing have more PV in comparison to traditional manufacturing. We also examined that CR value is less than 0.1 for all decision factors. Local weight of attributes for alternatives shows in table 3.7. Global weight of major benefits for lean manufacturing shown in table 3.8. Global weights have been calculated by following method:

Individual weight of the main factor = P.V. value from the respective normalized table
Individual weight of the sub factor = P.V. value from the respective normalized table
Global weight of main factor = individual weight of that main factor
Similarly, global weights for other strategic factors and sub factors can be calculated:
Global Wt. of lean manufacturing (LM) = Level 2 Wt. × LM Wt.
Global Wt. of traditional manufacturing (TM) = Level 2 Wt. × TM Wt.
Total global Wt. = sum of the global wt. of respective column.

Out of seven major benefits of lean manufacturing, lead time reduction has highest global weight (0.33832). minimum lead time is required to obtain maximum profit because lead time decrease production increase. Second highest global weight is to increase productivity (0.22258). If productivity increased then net profit increase. So we increase the productivity in such a manner that overall cost of operation decrease. Improve flexibility has third highest global weight whose global weight is (0.15218). If flexibility increases in production system then our profit increased. Fourth highest global weight is improves quality (0.07793). With the help of lean manufacturing, quality of product increased because we use standard process to make a product. Waste reduction is the fifth benefit of lean manufacturing whose global weight is 0.04861. With the help of lean manufacturing we eliminate non value added process so that our wastage is reduced. Six benefit of lean manufacturing is inventory reduction and its global weight is 0.03804. With the help of lean manufacturing, raw material and work in process inventory decreased because of standard process and JIT. Next benefit of lean manufacturing is increased net profit. When lean manufacturing used then production increased, inventory decreased, waste decrease, lead time decrease, increase flexibility and improve quality. So that effect of these factors our net profit increased. Global desirability index of lean manufacturing and traditional manufacturing shown in table 3.9.Global desirability index of lean manufacturing is 0.89568 and traditional manufacturing is 0.10431. So this analysis shows that application of lean manufacturing is better than traditional manufacturing.

Table1: Criteria pair wise comparison matrix P1 (level 2)

	INP	IP	WR	IQ	IF	IR	LTR	P.V
INP	1	1/9	1/5	1/5	1/8	¼	1/9	0.02025
IP	9	1	6	5	3	6	1/4	0.24732
WR	5	1/6	1	1/3	1/5	2	1/7	0.05556
IQ	5	1/5	3	1	¼	3	1/4	0.08907
IF	8	1/3	5	4	1	4	1/3	0.16908
IR	4	1/6	½	1/3	¼	1	1/8	0.04279
LTR	9	4	7	4	3	8	1	0.37591

Conclusions

In this research, it is observed that lean manufacturing is better than traditional manufacturing. Seven benefits of lean manufacturing have been discussed. Based on AHP comparative analysis for lean manufacturing and traditional manufacturing has been done. From this analysis it is observed that lead time reduction has highest global desirability index. Lead time reduction is followed by improvement in productivity, improvement in flexibility, improvement in quality, waste reduction, inventory reduction and net increased profit. Overall global score for lean manufacturing was In next chapter, twelve critical success factors of lean manufacturing are identified. Ranking of these factors were done by TOPSIS approach. Top management commitment got highest rank. It means top management commitment is critical factor to successfully implement the lean manufacturing in organizations. Top management commitment is followed by process management, organization culture, employee training and team building, Just in time and lean practices, application of advanced technology and tools, product design and development, value stream mapping, total productive maintenance, inventory management, supplier development, and customer involvement.

The success rate of lean manufacturing in organizations is low due to its barriers. So in next chapters, barriers of lean manufacturing are identified. After that, solutions to overcome the barriers of lean manufacturing were analysed. In this study, scientific framework to rank the solutions of lean manufacturing in organization to overcome its barriers by using a multi criteria technique combining fuzzy AHP and fuzzy TOPSIS is proposed. Fuzzy AHP is used to get weights of the barriers of lean manufacturing. Fuzzy TOPSIS is utilized to rank the solutions. Use of lean manufacturing process got highest rank. It implies that organisations should apply different lean manufacturing processes very carefully. These findings will motivate organizations to implement lean manufacturing successfully for sustainable performance improvement. This study can be further extended in form of different case studies as well as empirical study from manufacturing sectors.

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