Efficiency Enhancement of Modern Manufacturing Industries through the Integration of Lean Manufacturing Principles and Software based Mechatronics System

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Abstract

Industries are struggling in their business during economy crisis. In order to recover from that, they are announcing volunteer retirement schemes and lay-off their employees, some medium and small scale industries are even closed too. In this situation, they are forced to either increase the selling price of their product or reduce their internal costs and improve the quality of their product these things to survive in their field. At present situation, it is not possible to increase the selling price of their products. So, the only way is to reduce their internal costs and improve the quality of the product to fulfill the customer requirement. In order to overcome the above mentioned difficulties, this paper suggest them to integrate the lean manufacturing principles and the software based mechatronics systems in their factory premises for taking necessary steps to reduce the internal cost. In this paper, a pump manufacturing industry would be taken for case study. The solution given in this paper could be applied to various industrial segments, which would enable to cater the current customer demanding needs.

Keywords

Economic crisis; Lean techniques; Software based mechatronics system; Internal cost reduction.

1. Introduction

As global competition continues to intensify across industries, companies are actively pursuing strategies that will enable them to compete more effectively and improve profitability. Over the past decade the application of the lean principles has emerged as the primary improvement strategy in companies around the world. The Lean principles that stem from the Toyota Production System have over the past decade expanded to incorporate other concepts resulting in variants. Together the different variations of the Lean approach have emerged as the predominant strategy for achieving operational excellence [1]. In high Precision manufacturing, software based systems are widely used to automate various processes. The advances in microchip and computer technology have bridged the gap between traditional electronic control and process control engineering. The increasing demand on quality and productivity of products and services changed the industrial dynamics on several fronts including economics, research, technical knowledge, software, latest electronics and communication technologies and so on. To match these demands of increased quality at lower cost, more and more industries are moving towards automation. [2].

2. Problem Statement

The integration of lean manufacturing principles and the software based mechatronics system requires high degree of expertise to achieve it. This limits the application of lean within managerial executives possessing the high degree of literacy. The practical knowledge is given inadequate representation in lean analysis. The lean techniques provide a formal procedure to meet out the practical requirements. The software based mechatronics systems provide a simple procedure to predict and analyze the relevant data pertaining to the selected problem. The practical compatibility of lean techniques and the software based mechatronics systems have been considered as the research problem and solution methodologies are proposed.

3. Literature Review

The literature review assesses the past, current and future statuses of research work in the area of Lean techniques and software based mechatronics system. According to Karlsson & Ahlstrom (1996) [3] and C.R. Kothari 2004 [4], The ultimate goal of implementing lean production in an organization is to have the Customer in focus when improving productivity, enhancing quality, shortening lead times, reducing costs etc. Flinchbaugh (2003) [5] stated that the success of lean implementations highly depends on seeing lean as a philosophy and a culture. According to McCarter et. el. (2005) [6], the Multi-skilled workers and managers are a key component of Lean manufacturing organizations. Bicheno (2004) [7] stated that the Lean Manufacturing is "a philosophy, not a system or a technique. It is about simplicity, flow, visibility, partnership and value".

According to Mahalik (2003) [8], an automatic control system could perform a repetitive job; but could not take any decision in the event of variable circumstances. So, the introduction of software based system monitors the status of the process continuously and takes corrective action dynamically to stabilize the process. Robert H Bishop (2008) [9] stated that mechatronics is the synergistic combination of precision mechanical engineering, electronic control, and systems thinking in design of products and manufacturing processes.

4. Lean Manufacturing System

Lean manufacturing system (LMS) having the main concept of using less of everything compared with mass production. The LMS insisting the manufacturing industries can use minimum human effort, minimum manufacturing space, minimum investment, and minimum engineering hours to develop a new product. [10]

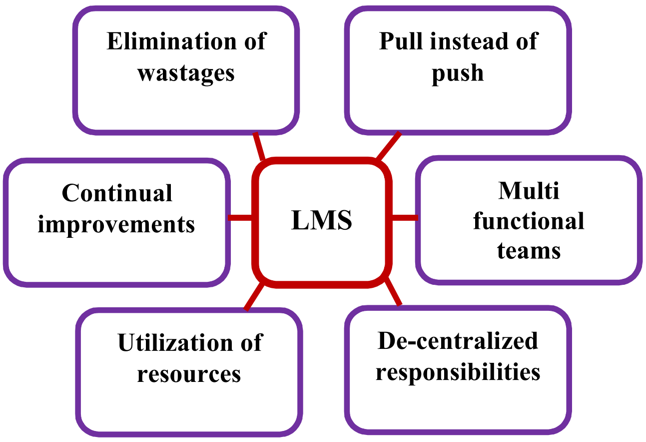

Fig.4.1. Components of LMS

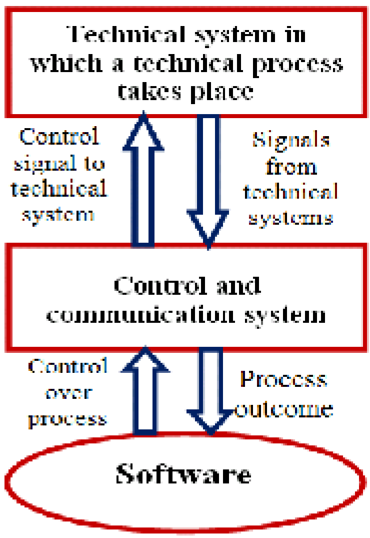

Fig.5.1. Mechatronics system

The main components / elements of LMS are shown in figure.4.1. The main elements include elimination of wastages; pull instead of push, continual improvements, multi-functional teams, effective utilization of resources etc.

The main objectives of Lean manufacturing it to minimize and or eliminate the identified wastages like over production, waiting time wastages, transportation wastages, excess inventory, motion wastages, over processing and defective parts / products / services. [11]

5. Software Based Mechatronics System

The genesis of mechatronics is the interdisciplinary area relating to mechanical engineering, electrical and electronic engineering, and computer science. This technology has produced many new products and provided powerful ways of improving the efficiency of the products we use in our daily life. [12]

Multiple object identification is a benefit in several automation and mechatronics application cases. Accurate item identification, high operation efficiency, reliable control and real time monitoring or tracking are achievable. [13]. The main components of software based mechatronics system are shown in figure 5.1.

6. Case Study

This paper presents detailed case study for the integration of Lean techniques and software based mechatronics system. The Lean techniques are used to identify the product wastages in the pump manufacturing industry and the software based mechatronics system is used to predict and analysis the relevant data pertaining to this research.

Figure.6.1. Shallowel jet pump

Fig.6.2. Data acquisition card

6.1. Selection of manufacturing environment

Based on the concept formulation, the manufacturing environment has been selected like manufacturing industry or service provider. The regular formalities like submission of permission letter, getting the permission for perusing the research etc. have been completed simultaneously to minimize the lead time to get the permission for the research [14]. M/s. Mayur motor Industries, Coimbatore – 641 015 has been chosen for the case study. They are one of the leading pump manufacturers and suppliers throughout India. They produces Centrifugal Regenerative Self-priming pumps, Centrifugal mono block pumps, Jet pumps and centrifugal self priming Jet mono block pumps, and Shallowel jet pumps with a wide variety from 0.5 HP to 10 HP.

6.2. Product chosen for the case study

The lean team has gone through the customer care records, customer complaints book, service engineers' log book and all. Based on the observations, it has been decided that the Shallowel jet model pumps have more problems when compared to other models. Based on the discussion had with top level management, it has been decided that the Shallowel jet pump, TUR1025 model, single phase, 1 HP has been chosen for the case study. The shallowel jet pump is shown in figure. 6.1.

6.3. Software chosen for the case study

The LabVIEW software has been chosen for the prediction of existing temperature level of the shallowel jet pump. LabVIEW is a highly productive graphical programming language for building data acquisition and instrumentation systems. With LabVIEW, we quickly create user interfaces that give you interactive control of your software system. To specify your system functionality, you simply assemble block diagrams – a natural design notation for scientists and engineers. Its tight integration with measurement hardware facilitates rapid development of data acquisition, analysis, and presentation solutions.

6.4. Data Acquisition Card

Nanosecond-scale relative timing on a single board allows rough determination of temperature and vibration via time-of-flight. Inter-site timing on the order of a few tens of nanoseconds, achieved by time stamping triggers with GPS data. The NI PCI-6034E data acquisition card, included discriminator and logic functions, 16 single ended channels, 16 bit resolutions, 200kS/s sampling rate, input signal range from 50mV 10V, has been chosen for the case study [15]. A diagram of the DAQ card is shown in Figure.6.2.

6.5. Software development using LabVIEW

The software has been developed using VI LabVIEW software through the construction of block diagram without worrying about the syntactical details of text-based programming languages. By selecting objects (icons) from the Functions palette and connecting them together with wires to transfer data among block diagram objects. These objects include simple arithmetic functions, advanced acquisition and analysis routines, network and file I/O operations, and more [15]. The program construction using LabVIEW software is shown in figure.6.3.

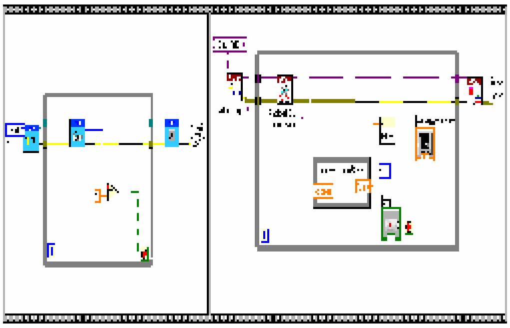

Fig.6.3. LabVIEW Program

Fig.7.1. Experimental setup

7. Prediction of heat generation in Shallowel jet pump using LabVIEW software

Temperature generation analysis, properly done, allows the user to evaluate the condition of equipment and avoid failures. Modeling and computer simulation technology have been widely used in designing and analyzing temperature prediction and temperature distribution analysis. [16]

7.1. Experimental setup

The Shallowel jet pump was placed on the work bench properly. The sink (probably the PVC tank is used) was placed nearer to the work bench. The suction and delivery hoses were connected as per the requirements. The experimental setup for the vibration analysis is shown in figure. 7.1. Whenever accurate measurements or continuous monitoring is required, the vibration sensor should be mounted such that the axis of the sensor is perpendicular to the direction of vibration surface. The vibration sensor was mounted on the motor perpendicular to the shaft rotation. The LabVIEW front panel was noted with the predetermined interval of time.

7.2. Prediction of heat generation in shallowel jet pump

This experiment deals with 10 numbers of pumps of the same model namely TUR1025 model, single phase, 1 HP, Shallowel jet pump. The outcomes of the same are shown in table. 7.1.

Table.7.1. Heat generation test report

Sl. No.	**Details**	**Time**					
		2.00 pm	**2.30 pm**	**3.00 pm**	**3.30 pm**	**4.00 pm**	**4.30 pm**
1	Core temperature	31	37	45	46	46	46
2	Room temperature	31	30	30	30	29	29
3	Temperature difference	0	7	15	16	17	17
4	I_L (Amps)	5.38	5.35	5.28	5.29	5.22	5.23
5	I/P (Watts)	1340	1335	1325	1322	1318	1318
6	Speed	2464	2454	2445	2438	2420	2408
7	Frequency (Hz)	49.5	49.6	49.6	49.7	49.5	49.7
8	Suction Head (mm. Hg)	210	210	210	210	210	210
9	Delivery Head (Q)	20	20	20	20	20	20
10	Discharge (Q)	45.73	45.8	45.9	45.9	45.92	45.96

R_{MC}	3.12	R_{AC}	6.89	T_C	29

Heat generation details:

R_{MH}	4.09	R_{AH}	8.98	T_E	29	TR_{MW}	82.07	TR_{AW}	**80.08**

The experiment was carried out the constraints like Time, Voltage, Current, Main windings, Auxiliary windings, pump speed, Current frequency, Delivery head, Suction head, Discharges etc. The above table shows the various parameters changes pertaining to different time intervals.

8. Validation

The validation plays a vital role The above shallowel jet pump was given to M/s. Hi-Tech Industrial mountings limited, Vedappatty, Coimbatore for validating the heat generation analysis before the implementation of LMS. As per their report (Ref. HIML/QC/ET/2009-10/033 dated 24th March 2010, the heat generation of the shallowel jet pump is 80°C. So it was clearly understood that the results obtained from the LabVIEW software are co-insides with the conventional type vibration analysis.

9. Results and Discussions

The integration of lean technique and software based mechatronics systems very much successful for the prediction of product wastages. The identified problem is best suitable for the lean principles to arrive an optimal solution. The outcomes of the experimental analysis are given below:

9.1. Cost and time saving applications

The cost and lead time of the conventional vibration test systems are extremely high in a pump manufacturing environment. The experiment discussed in this paper provides the plug-and-play simplicity of USB to sensor and vibration measurements on the bench top, in the field, and on the production line. By combining the ease of use and low cost of data logger with the performance and flexibility of modular instrumentation, LabVIEW software delivers fast and accurate measurements in a small, simple, and affordable system.

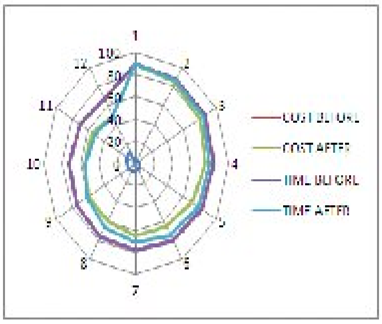

Figure.10.2. Cost and time savings

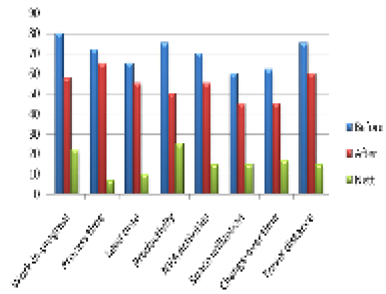

Fig.10.3. Process improvement

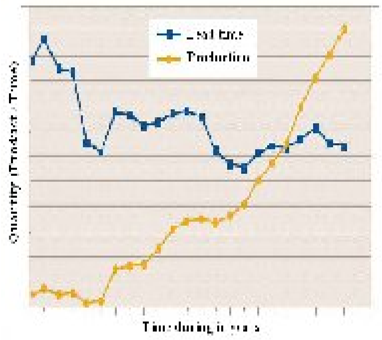

Figure.10.4. Performance

This research has developed a new cost and time effective approach to minimize the cost for vibration analysis. The cost savings using software based mechatronics software is shown in figure.10.2.

9.2. Reliability of software based mechatronics system

The reliability of LabVIEW software was checked with a conventional vibration analysis system. The data predicted by the LabVIEW software were fully satisfied with the conventional analysis. It has been very much proven during the third party validations.

9.3. Limitations of software based mechatronics system

The data predicted during the fluctuations in electrical power supply, computer hardware malfunctions, improper computer operating system, improper development of software, installation errors, software and hardware incompatibility are not reliable.

9.4. Benefits in industrial sectors

When the Lean techniques and software based mechatronics system is successfully integrated and implemented, the performance of parts, products, services and organization should be improved significantly as shown in figure.10.3. At this point, the lean manufacturing characteristics like work-in-process, processing time, lead time, productivity, Non-value added activities, space utilization, change-over time, travel distance etc. have been demonstrated a considerable improvement in production rate and performance. Based on the significant improvements in the process characteristics, the lead time will be reduced gradually and production rate and performance will be improved significantly as shown in figure.10.4.

10. Conclusion

This paper has described the successful integration of lean techniques and software based mechatronics system with realization of success factors like concept generation, field selection, prediction of existing data and the implementation of proposed approach in a pump manufacturing environment.

The identification of product wastages will play vital role in the area of decision making, product forecasting, new innovations, and the arrival of new problem solving techniques. The integration of lean techniques and software based mechatronics system has given highly reliable data during the prediction and analysis of existing vibration condition of the shallowel jet pump. This paper brings in a number of indirect benefits like employee involvement, employee motivation, employee enthusiasm, Employee work culture, improved employee communication skills, Positive employee attitude and employee awareness.

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