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Enhancing effectiveness of Shell and Tube Heat Exchanger through Six Sigma DMAIC phases

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Abstract

This research portrays the pilot implementation of Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) phases to improve the effectiveness of shell and tube heat exchanger in a small sized furnace manufacturing company. Shell and tube heat exchanger is one of the critical components of the furnace. The imperative objective is to improve the quality of the furnace through DMAIC phases. In define phase, the critical to quality (CTQ) parameter was identified as effectiveness in shell and tube heat exchanger through the voice of the customer (VOC) and Pareto Chart. In measure phase, the present effectiveness was measured as 0.61. In analysis phase, the reason for the reduction of effectiveness was identified as less heat transfer area through cause and effect diagram. In improve phase, the existing design was modified through various alternative solutions by conducting brainstorming sessions. In this phase, the solution was identified with the introduction of circular fins over the bare tubes to improve the effectiveness in the shell and tube heat exchanger. Consequently, the effectiveness has been enhanced from 0.61 to 0.664. In control phase, the control strategies were recommended to sustain the improvements in shell and tube heat exchanger. In the end, the annual monetary savings of Rs.0.34 million were achieved through the implementation of DMAIC phases in the furnace manufacturing company.

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*Keywords:*Six Sigma; DMAIC; CTQ; quality; effectiveness; furnace; shell and tube heat exchanger.

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1. Introduction

In the modern era of business practice, furnace plays an imperative role in metal extraction, metal forming and heat treatment process. The furnace products manufacturers maintain global competitiveness through strategic energy management by using energy efficient technologies. The performance of the furnace strives to enhance the quality by considering efficiency and performance of the furnace together. Among the various methods available to improve the furnace performance, a systematic approach should be used for achieving impetus improvement at an affordable cost. In engineering arena, the complexity reduction of the functional unit can be achieved through either break down of the system or process. The furnace has some basic performance influential components namely heat exchanger, nozzle, burner and control valve. The performance of individual components can be evaluated and integrated to embark the total performance of the furnace. The strict investigation was taken over to identify and eliminate the vital parameters that affect the efficiency of the furnace through a systematic approach namely Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control)phases. Six Sigma is a quality management tool introduced by Bill Smith of Motorola in 1980 [1]. It is said to be fierce approach that directly hits imperative woes faced in customer end, by reducing the variation to achieve 3.4 defects per million opportunities (DPMO) that subsequently enhance the quality, market share of the manufacturing organization. The variations are controlled by using a hierarchical approach of Six Sigma DMAIC, which have been derived from Deming's improvement cycle namely PDCA (Plan-Do-Check-Act). This case study narrowly performs investigations on improving current performance of heat exchanger that improves the overall efficiency of the furnace by using the Six Sigma DMAIC approach. In this regard, the atmospheric air is preheated for complexity reduction through exhaust flue gas of a furnace. The preheating of combustion air illuminates to reduce energy loss in the furnace by improving overall efficiency. This preheating process provides 10–30 percentage monetary savings with the economical fuel usage [2].

2. Literature review

Furnace efficiency can be refined by concentrating on overload and heat transfer for diminishing the heat loss from flue gas [2]. In order to save the process industry economically, attention must be given to heat transfer improvement instead of reducing the size of equipment [3]. [4] Stated that, for improving performance and efficiency of the compact cross flow heat exchanger with affordable cost, the velocity of the air should not be higher. [5] Investigated the performance level of plain tube and finned tube that the heat transfer can be improved by using fins when comparing with plain tubes that produces high thermal performance and found the efficiency of the fin to be increased by43%.[6] Made a qualitative analysis of the heat transfer capacity on various fin configurations. Elliptical fins are suitable for lower pressure, and circular fins can withstand higher pressure after carry out various analysis and optimization process on their parameters and geometry. However, the staggered arrangement provides better performance improvement than inline arrangement for most cases. [7] Carried out an analysis and comparison of thermal performance of plate fin sinks and pin fin sinks, which is usually used in electronic equipment industry and explains that the increasing heat sink length reduces thermal resistance of the pin fin and the same increases in plate fin. [8] Illustrate about the advantages of circular fin in various fields and given the important aspect that should be concentrated when fins are getting contact with gas/fluid. The fin efficiency or performance is improved by the optimization of fin thickness and fin radii, also focused on one and two dimensional solutions of fin performance. By implementing Six Sigma DMAIC (a revolutionary approach) with its statistical tools and techniques in different process industries, fuel energy along with monetary savings can be achieved [9]. Six Sigma is the statistical breakthrough tool which improves the existing performance level of business strategy and controls the variations in the processing stage to less than 3.4 DPMO. The reputations of the Six Sigma are gained by identifying defects and insinuate their root cause [10]. [11] Clearly reckoned that, the primary objective of Six Sigma is the elimination of non-value added process activities along with continuous improvement. [12] Enumerated that Six Sigma is a data driven approach for reducing variation, by eliminating defects and errors such

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