SINGLE MINUTE EXCHANGE OF DIES WITH FUZZY-ANALYTIC HIERARCHY PROCESS METHOD FOR SETUP TIME REDUCTION: AN APPLICATION IN ADVANCED COMPOSITE MANUFACTURING INDUSTRY

by

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LIST OF ABBREVIATIONS

AROT	Angle of Rotation
CA	Clustering Analysis
CEA	Cause and Effect Analysis
CSA	Current Setup Analysis
DRJ	Drilling Router Jig
Fuzzy-AHP	Fuzzy-Analytic Hierarchy Process
JIT	Just In Time
LOB	Line of Balance
MA	Mapping Analysis
PC	Personal Computer
SMED	Single Minute Exchange of Dies

LIST OF SYMBOLS

$\tilde{A}^k$	Pair-wise contribution matric
$\tilde{d}_{ij}$	Average for decision maker's preference
$\widetilde{d_{ij}^k}$	Decision maker's preference
i^{th}	First criterion
j^{th}	Second criterion
k^{th}	Number of decision maker
M_i	Non-fuzzy weight
N_i	Normalized weight
$\tilde{r}_i$	Geometric mean values

Single Minute Exchange of Dies (SMED) dengan Kaedah Fuzzy-Analytic Hierarchy Process (F-AHP) untuk Pengurangan Masa Persediaan: Sebuah Applikasi di dalam industri pembuatan komposit canggih

ABSTRAK

Selama beberapa dekad, perhatian yang meluas telah diberikan kepada tindakan untuk mengurangkan masa persediaan dan sebahagian besar daripada mereka mengamalkan Single Minute Exchange of Dies (SMED), yang dibangunkan oleh Shigeo Shingo sekitar tahun 1960-an. Walau bagaimanapun, empat fasa yang disyorkan oleh Shingo dalam SMED beliau ialah bukan penyelesaian yang optimum untuk mengurangkan masa persediaan dalam semua keadaan. Pemilihan keputusan yang paling sesuai semasa pelaksanaan SMED memerlukan pemikiran yang mendalam dan pertimbangan yang teliti. Oleh itu, kajian penyelidikan ini bertujuan untuk membangunkan satu kaedah yang lebih baik untuk menyelesaikan masalah pengurangan masa persedian dengan mengintegrasikan Single Minute Exchange of Dies (SMED) dengan Fuzzy-Analytical Hierarchy Process (Fuzzy-AHP). Dalam kajian penyelidikan ini, pengesahan kaedah fasa jujukan telah dilakukan dalam persekitaran kerja industri yang sebenar. Kajian kes industri telah dibahagikan kepada tiga kajian kes individu. Kaedah Fuzzy-AHP menyumbang dalam pemilihan cara penyelesaian peningkatan yang terbaik bagi setiap kajian kes. Sebagai hasil dari pelaksanaan SMED-FAHP, masa persediaan untuk mesin pemangkasan 5-paksi bersama dengan pengurusan Drilling Router Jig (DRJ) dan panel komposit bagi Produk X telah dikurangkan. Dalam Kajian Kes 1, semua masa persediaan dalaman telah ditukarkan kepada masa persedian luaran yang mana boleh dilakukan tanpa memberhentikan operasi mesin. Sementara itu, dalam Kajian Kes 2, 91.2% daripada masa persediaan dalaman telah dikurangkan. Dalam Kajian Kes 3, 64.1% daripada masa persediaan dalaman telah berjaya dikurangkan selepas pelaksanaan penyelesaian peningkatan. Hasilnya membuktikan keberkesanan kaedah SMED-FAHP dalam mengurangkan masa persediaan untuk mesin pemangkasan 5-paksi dalam industri pembuatan komposit.

Single Minute Exchange of Dies with Fuzzy-Analytic Hierarchy Process Method for Setup Time Reduction: An Application in The Advanced Composite Manufacturing Industry

ABSTRACT

For many decades, extensive attention has been given to the action of reducing the setup time and most of them are practicing the Single Minute Exchange of Dies (SMED), developed by Shigeo Shingo in 1960s. However, the four phases recommended by Shingo in his SMED is not the optimal solution for setup time reduction in all circumstances. Selecting the most suitable decisions during SMED implementation require deep thought and thorough consideration of all possible solutions. Hence, this research study endeavored to develop an improved methodology to solve setup time reduction problem by integrating Single Minute Exchange of Dies (SMED) with Fuzzy-Analytical Hierarchy Process (Fuzzy-AHP). In this research study, the validation of the proposed sequential phases methodology was done in actual industrial working environment. The industrial case study was divided into three individual case studies. The Fuzzy-AHP method benefited in the selection of the best improvement solution for each case study. As the outcome from the SMED-FAHP implementation, the setup time for 5-axis trimming machine along with the Drilling Router Jig (DRJ) and composite panel management for Product X has been reduced. In Case Study 1, all of the internal setup activities are transferred into external activities which can be performed without the stoppage of the trimming machine. Meanwhile, in Case Study 2, 91.2% of internal setup time has been reduced. In Case study 3, 64.1% of internal setup time has been successfully reduced after the implementation of chosen improvement solution. The result proved the effectiveness of the SMED-FAHP method in reducing setup time for 5-axis trimming machine in composite manufacturing industry.

CHAPTER 1

INTRODUCTION

1.1 Research background

Since three past decades, trade liberalization and the unification of the worldwide economy have carried with them an expansion in aggressiveness towards assorted economic sectors, particularly for the industrial sector which should keep up pace with the day by day intensity's changes in the worldwide market (Méndez & Rodríguez, 2015). Due to the advancement of technology, the needs for production of higher productivity, enhanced quality and greater flexibility in a cost effective way has gained even more attention from manufacturing firms and organization in order to compete adequately in today's dog-eat-dog competitive world (Gibbons & Burgess, 2010).

The developing of the market demands brought with them high demands on quality and flexibility with low costs products from a manufacturing organization to a customer's market. This evolution and new transformation of market demands not only occurred in certain type of industries, but it involved in all type of production and manufacturing firms. Fast delivery with high reliability and quality products are often requested by customers and the key to it is to enable a production with the shortest lead times as possible (Spann et al., 1999; Goubergen, 2000; Cakmakci, 2009;).

Due to the fact that today's end-customers are more vivid in their selections of products, the needs for better changeover or setup time reduction has become very demanding as it may facilitate better response and can allow the production in smaller batches (Gest et al., 1995). Rapid changes in today's world economic traits such as the need for manufacturing parts in small batches causes by the increasing demand product varieties by customer and the use of JIT concept have raised the value and the necessity of fast changeover and setups. These days, the initiatives for reduction of setup time and quality improvement strategies have become more customary and has increased across all types of industries (Braglia et al., 2016)

To stay competitive, lean approach with numerous methods that focuses on eradicating waste, and enhancing the quality while lessening the cost make uses of various proven tools (Cudney & Elrod, 2011) such as 5S visual practice, SMED and Kaizen that are being applied by companies and manufacturing firms (Singh et al., 2010). The idea of manufacturing parts and products in a 'lean' manner was initially presented by a modest bunch of researchers in MIT's research group after they analysed the Japanese production traits, the Toyota Production Systems (TPS) in the 1980s (Womack et al.1991). Lean's sole aim is to minimize the waste from all production's aspects including waste in worker's and product's transportation, idle time and inventory to become highly responsive to customer demand and at the same time being able to deliver quality products in the most efficient and economical production system (Singh et al., 2010).

As been described by Schonberger (1982) and Monden (1983), the methods and concepts of the lean paradigm have been variously applied in western manufacturing firm in attempt to imitate the Japanese production systems (Mileham et al., 1999). The vital component of this concept has been the step concerning a more process-oriented thinking way and the participation of all workforces in an on-going drive for a "total improvement" production system (Imai, 1986). This is when the terms of "continuous process improvement" and "lean" takes place. The ability to achieve a responsive and small manufacturing batch is crucial for lean manufacturing systems to satisfy the rapid changing market demands (Cakmakci, 2009). As a matter of fact, lean is also an element of corporate culture, such as the tools and approaches (Womack & Jones, 1997; Asano, 2002; Garcia et al.,2006).

Planning and strategies for the application of lean manufacturing concept is important but it is not the real challenge. The most difficult phase to achieve a lean manufacturing culture in manufacturing organizations and firms is the implementation of it. Eiji Toyoda stated that one of the elements of lean's philosophy is the trust, respect and collaboration of all personnel and if there is no such philosophy, no employee would be willing to do the improvement (Cakmakci & Karasu, 2007).

One of the well-known lean tools that are regularly applied by industrial engineers and lean taskforce is the Single Minute Exchange of Dies (SMED) (Alves & Tenera, 2009) as it can plays very important role for changeover time reduction and therefore able to provide quick changeover for equipment and rapid die exchange (Shingo, 1985; Desai, 2012) .In a nutshell, SMED is a set of theory which also acts as a tool to make accomplished changeover process in below 10 minutes (in other words, “single digit minute”), which gives the name of this approach (Shingo, 1985).

1.2 Problem statements

In spite of the fact that many cases of successful SMED initiations are being reported in numerous articles, there are still a number of companies which failed on the implementation phase. The possible cause of this failure is the strictly usage of the SMED methodology. Four phases recommended by Shingo in his SMED are not the optimal solution for setup time reduction in all circumstances (McIntosh et al., 2000). This fact shows that the original SMED by itself cannot guarantee a positive outcome without considering some factors that affect changeovers (Ferradás & Salonitis, 2013).

The decision making process in SMED phases require deep thought and thorough consideration of all possible solutions. For the purpose of setup process improvement, the best improvement solution among several alternatives need to be chosen based on a number of criteria. Criteria can be described as a set of potential factors that can affect the flow of the setup process. Literature founds that the SMED methodology does not possess a systematic and scientific procedure in order to select the best improvement solution among all possible solutions (Almomani et al., 2013; Benjamin et al., 2013)

1.3 Objectives

This section explained the objectives of the research study. The purpose is to give the view of what this research is all about and to make it clear what is need to be achieved at the end of this research study. This research aims at the following objectives:

i) To develop SMED-FAHP methodology for solving setup time reduction problem

ii) To validate the developed methodology by using case studies from advanced composite manufacturing industry

iii) To implement the best improvement solutions suggested by the developed methodology

1.4 Scopes

The scopes of this research are stated as follows:

i) This research is focusing on reducing the setup time by incorporating Fuzzy-AHP into SMED for systematically advancing the decision making process for selecting the best improvement solution

ii) The validation of the SMED-FAHP methodology is focusing on a setup process of a 5-axis composite material's trimming machine for product X.

1.5 Significances of research

The significances of this research study can be divided into two perspectives; in knowledge contribution and industrial practice.

i) Knowledge contribution:

This research can provide a new platform for other researcher in this field of interest to focus on the decision making aspects in the SMED implementation in order to suit with the current industrial problem.

ii) Industrial practice:

The integration of the original SMED with Fuzzy-Analytical Hierarchy Process (F-AHP) provides a better way for lean practitioners in selecting the most practical improvement solutions throughout SMED implementation in order to achieve a production of higher productivity, enhanced quality and greater flexibility in the most cost effective way.

1.6 Thesis Outline

This thesis is divided into five chapters.

Chapter 1 presents the general introduction to this research study which includes the research background, problem statements, research objectives as well as scopes and limitations. This chapter ended with the description on the significance of this research study.

Chapter 2 reviews the concept lean approach as well as the definition and concept of changeover and setup process. The needs of setup time reduction in industry is also being reviewed in this chapter. This chapter continues with review on the concept and benefits of SMED. The next section reviews the application of original and improved SMED by other researcher in industries. This chapter ends with the discussion on the SMED literature findings and the Fuzzy-AHP.

Chapter 3 presents the three phases methodology of integrating SMED with Fuzzy-AHP to reduce setup time for 5-axis trimming machine of Product X. The first phase presents the four initial analysis methods applied in analysis the current setup process. The seconds phase discusses the detailed procedure for selecting the best improvement solution by applying Fuzzy-AHP technique. This chapter ends with the explanation on the third phase, which is the implementation and control phase.

Chapter 4 discusses on the results obtained through this research study. The first section presents the industrial case study and the current setup process overview. The next section presents the application of four initial analysis methods in analysis the current setup process. The third section presents the application of Fuzzy-AHP in selecting the best improvement solution for each case study. This chapter continues with the procedure on the implementation of the chosen improvement solutions. The next section discusses on the result of the setup time after the implementation of improvement solutions. This chapter ends with the explanation on the proposed control actions in order to sustain the improvements done.

Chapter 5 presents the research finding including the objectives achievements in order to solve the proposed problem statements. This section also presents the result after the implementation of SMED-FAHP method in solving setup time reduction problem in the case study company. Due to the fact that this research is completed within certain boundaries, this chapter ends with the future research and recommendations that are possible to be conducted for continuous improvement purpose.