APPLICATION OF AHP METHOD IN THE DESIGN OF REMANUFACTURING IMPROVEMENT PROCESSES FOR CRANKSHAFT

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

by

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This project describes an approach, based on the Analytical Hierarchy Process (AHP) that assists decision makers or manufacturing engineers to determine the most appropriate remanufacturing process to be applied in the remanufacturing of crankshaft at the early stage of product remanufactured process. Remanufacturing can be defined as a process of restoring a non-functional, discarded, or traded in product to look and function like new condition, however the process of remanufacturing of crankshaft does not have a specific procedure and is inappropriate. It will make the manufacturing industry to incur more cost and increase time of remanufacturing the crankshaft. The best way to solve this problem is by developing a new process for remanufacturing of the crankshaft. As a result, the new process will give benefits to the manufacturers themselves in terms of income, but it has major benefits to the society as a whole. The selection of critical defects before remanufacturing a crankshaft was determined in this project. The factors influenced in the process selection of manufacturing process have been identified in order to fulfill the requirement of the remanufacturing. By using AHP as a decision making tool at an early stage of the product redevelopment process, the critical defect has been identified. AHP concept can assist remanufacturing engineers to evaluate and select the best remanufacturing process based on the various factors and sub-factors of a decision. The analysis has revealed that the most critical defect before remanufacturing a crankshaft is cracked with the highest percentage is 20.14%.
ABSTRAK

DEDICATION

I would like to dedicate this whole PSM report to my beloved family.
ACKNOWLEDGEMENT

First of all, I would like to express my grateful to ALLAH s.w.t. for the blessing given to me to complete my PSM 1. In order to complete my work, I have engaged with many people in helping me especially my supervisor Tuan Hj. Baharudin Bin Abu Bakar. I wish to express my sincere appreciation to him for his encouragement, guidance, advices and motivation. Without his support and interest, this thesis would not have been the same as presented here. I also want to thank to all my friends that involve direct or indirect to complete my task. Not forgotten, I would like to express my gratitude to all university staff from Manufacturing Engineering Faculty for being so cooperative and not forgetting all my friends for the support, advice and information sharing. Finally, I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Without endless love and relentless support from my family, I would not have been here.
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6.1 Hierarchical for common defect
# LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>EOL</td>
<td>End of life</td>
</tr>
<tr>
<td>CLSC</td>
<td>Closed loop supply chain</td>
</tr>
<tr>
<td>PDCA</td>
<td>Plan do check act</td>
</tr>
<tr>
<td>AHP</td>
<td>Analytic Hierarchical Process</td>
</tr>
<tr>
<td>CR</td>
<td>Consistency Ratio</td>
</tr>
<tr>
<td>MTI</td>
<td>Motor Teknologi &amp; Industri</td>
</tr>
<tr>
<td>MRO</td>
<td>Maintenance, Repair and Overhaul</td>
</tr>
<tr>
<td>APMM</td>
<td>Agensi Penguatkuasa Maritim Malaysia</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operation Procedure</td>
</tr>
<tr>
<td>SLM</td>
<td>Service Lifecycle Management</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer Numerical Control</td>
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</table>
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the literature review on remanufacturing. It started with an introduction about remanufacturing and its function. The element in remanufacturing and major environmental impact for remanufacturing will be reviewed in this chapter. This chapter also presents the advantages of remanufacturing, a policy framework for remanufacturing, barriers in remanufacturing and difference between design environments, design for reused and design for remanufacturing.

2.2 History of Remanufacturing

Remanufacturing has proliferated and is now a well-established, but an almost unnoticed activity. Remanufacturing began in 1930, where Henry Ford has applied manufacturing activity when car’s price decreases. In 1940 the remanufacturing activity was first developed in the United States and the United Kingdom, but in 1945 the manufacturing activities in the United States have been closed due to the Second World War. In 1947, the manufacturing activity has started operate in Germany. In the period 1930 to 1940 many countries have begun remanufacturing activities because of these activities have much effect on the generation of an economy. After seeing some of the effects resulting from the activities of remanufacturing, European countries began remanufacturing
activities in 1970. In 1990 a company called Fuji Xerox started its remanufacturing activities. After seeing the profits generated by the Fuji Xerox Company, other companies began to see the remanufacturing activity as an activity that will give advantage to tie up. In year 2000, Ricoh and Canon started applying the remanufacturing activities in their company.

2.3 Major Environmental Problem

According Amezquita et al. (1995), every year the United States produced 700 million tons of hazardous waste and 11 billion tons of hazardous waste caused by the extraction, processing and manufacturing of materials. In 1990, more than 190 million tons of solid waste were generated in the United States where nearly 87% is generated waste material by the extraction, processing and manufacturing required in producing a product. For maintaining a safe and secure ecosystem, Amezquita et al. (1995) and Ijomah (2009) suggested that the remanufacturing activities should be carried out in each country, because remanufacturing can reduce pollution and the cost of the landfill. Besides that, remanufacturing also can reduce the use of raw materials, waste disposal and water.

2.4 Definition of Remanufacturing

Remanufacturing can be defined in various ways but most of it has a similar purpose which is changing the end of a product's life for the better. Besides that, according to Robert et al. (1996) remanufacturing restoring non-functioning, discarded, or traded-in products to a new performance. In addition, remanufacturing can be defined as the process of rebuilding a product where the product cleaned, inspected and disassembled. In addition Ramstetter, (2011) reported that the remanufacturing of strategic importance as a concept that allows a large part of the value added to the product during the initial production should be retained. Moreover Steve Statham, (2006) claims that
remanufacturing is a process that uses the product and the installation of a new state back to them with minimum waste and spending on materials and energy that ensures the repair can be carried out on time and the item is returned to the function in an efficient manner.

2.5 Economic Impacts of Remanufacturing

Normally a company or a country must be conscious of their profit for a long term before starting an activity or a project. One of the activities that can guarantee good returns and profits are remanufacturing activities. According to Ron Giuntini, (1993) the product has been manufactured mostly just need cost 40 percent to 65 percent less than the production of new products, while the energy consumption of manufacturing also takes 15 percent of the energy needed in manufacturing; due to the activities remanufacturing process requires only a small part in the production of new products. One example of an activity that has been applied remanufacturing is an automotive activity, which Holzwasser, (1997) estimates that the manufacturing process can save 8.2 million of crude oil in the manufacture of steel, 51 500 tons of iron ore and 6000 tons of copper. This was supported by Hauser and Lund (2003) who claimed remanufacturing activities could benefit 1 million to 2 million per year.

2.6 Elements of Remanufacturing

According to Robert, (1978) a product is considered to be remanufactured based on characteristics as shown in Table 2.1.
Table 2.1: Remanufactured guideline

<table>
<thead>
<tr>
<th>Its main components come from a used product.</th>
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<tr>
<td>The used product is disassemble to the extent necessary to determine the condition of its components</td>
</tr>
<tr>
<td>The used product's parts are thoroughly cleaned and made free from rust and corrosion.</td>
</tr>
<tr>
<td>All missing, defective, broken or substantially worn parts are either recovered to sound, functionally good state, or they are change with new, remanufactured, or sound, functionally good used parts</td>
</tr>
<tr>
<td>To put the product in sound working state, such machining, rewinding, refinishing or other operations are conducted as necessary.</td>
</tr>
<tr>
<td>The product is reinstallation and a determination is made that it will work like a similar new product.</td>
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</table>

For remanufacturing industries, a closed loop supply chain management (CLSC) of EOL product is the main challenge. Closed loop supply chain management is important and an integral part of remanufacturing process. Success of perfect launching of a remanufactured product mainly depends upon CLSC. Vasudevan et al. (2012) identified some important key elements in the remanufacturing sector to support CLSC. The first element in remanufacturing is product acquisition management, which is it stated that reverse flow of used product with the right quantity and good quality at the right price and right time is the most important aspect in remanufacturing industries.
Figure 2.1: A framework for reverse supply chain activities

Figure 2.1 shows the framework for reverse logistics, describes about the remanufacturing process and the sequence of the process which disassembled the parts were in some are fitted into remanufacturing and some are fitted for recycling (Sasikumar, 2008).

Vasudevan et al. (2012) stated that the reverse logistics collection models are also one of the important elements in remanufacturing. This has been supported by Ravi et al. (2005) observed that “reverse logistics programs in addition to the various environmental benefits and the cost benefits can proactively minimize the threat of government regulation and can improve the cooperate image of the companies”. As a result, reverse logistics are now realized by organizations as an “investment recovery” as opposed to simply minimizing the cost of waste management. There are basically three methods for collection of end of life products for the purpose of remanufacturing. Usually it involves remanufacturer, retailer, third party and consumers. Figure 2.2 show that the consumer directly returns the used product to manufacturer. However, the
retailer is not involved in the reverse logistic collections. Many remanufacturing companies like Xerox, Canon and Hewlett Packard are collecting products directly from customers.

![Figure 2.2: Manufacturer collects from consumer.](image1)

Figure 2.3 shows about the sequence involving of retailers in the collection of end of life product from the consumer, which is retailers supply the end of life product to the manufacturer. Usually Consumer always feels comfortable to return end of life product to retailers, for example camera, television, refrigerators are returned from consumer to the retailer. Usually most of the remanufacturers adopted this method.

![Figure 2.3: Retailers collect from consumers.](image2)