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The advantages of remanufacturing from the perspective of eco-efficiency analysis: A case study

Feri Afrinaldi[a,]*, Zhichao Liu[b,c], Taufik[a], Hong-Chao Zhang[c], Alizar Hasan[a]

[a]*Department of Industrial Engineering, Andalas University, Limau Manis, Padang, 25163, Indonesia*
[b]*School of Mechanical Engineering,Dalian University of Technology, Liaoning, China*
[c]*Department of Industrial Engineering, Texas Tech University, Lubbock, TX, 79409, USA*

* Corresponding author. Tel.: +62-812-87291352; fax: +62-751-72566. *E-mail address:* feri_afrinaldi@ft.unand.ac.id

Abstract

This paper presents a comparison of the eco-efficiency of a newly manufactured cylinder block and the eco-efficiency of a remanufactured cylinder block. For the environmental dimension, global warming potentials (GWP) of the cylinder blocks are considered and measured using life cycle assessment (LCA) methodology. For the economic perspective, the prices of the cylinder blocks are taken into account. The eco-efficiency portfolio of the cylinder blocks is constructed through a series of normalization processes. It is found that the remanufactured cylinder block results in a 90% reduction in GWP and a 39% reduction in cost. The value of the GWP to cost relation (*R*-value) of the cylinder blocks is 0.44 and indicates that cost is more important than GWP by about a factor of 2. Furthermore, the eco-efficiency portfolio shows that the remanufactured cylinder block has a better eco-efficiency by about 62%, if compared to the eco-efficiency of the newly manufactured cylinder block. This study supports the claim stating that remanufacturing is a better end-of-life option in reducing the environmental and economic impacts of products.

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Keywords: cost; eco-efficiency; global warming; manufacturing; remanufacturing

1. Introduction

Human activities have a major contribution to greenhouse gases emission. US EPA [1] reported that industrial sector has contributed around 19% to the global level of greenhouse gases emission. According to Afrinaldi et al. [2], among the sector of industry, automotive industry has received more attention.

Using life cycle assessment (LCA) methodology, Li et al. [3] showed that diesel engine manufacturing has a contribution of 51% to the global warming potential (GWP) of the pre-consumer stages (mining, raw materials production, and engine manufacturing) of the life cycle of the engine. Jiang et al. [4] used input-output life cycle assessment (I/O LCA) to measure the environmental impact of diesel engine manufacturing process. Similar to [3], Jiang et al. found that, among the pre-consumer stages, the manufacturing process accounts for around 44% of total CO_2 emission.

To reduce and ease the environmental impact of the manufacturing process of automotive products, remanufacturing is regarded as one of the best solutions. Remanufacturing is a series of processes, involving disassembly, cleaning, inspection, and repair, aiming to restore the functionality of products that have reached their end-of-life [5]. The environmental benefits of remanufacturing in the automotive sector have been reported by many researchers.

Sutherland et al. [6] found that by remanufacturing a diesel engine, a 90% reduction in energy consumption can be obtained. Dias et al. [7] also reported that 74% and 40% reductions in CO_2 emission and energy consumption, respectively, are resulted from remanufacturing a diesel engine. According to Liu et al. [8], diesel engine

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remanufacturing results in a 67% savings in global warming potential (GWP).

Research has also indicated that remanufacturing has a significant benefit from the economic standpoint. Smith and Keoleian [9] reported that the price of remanufactured engine parts is about 30% - 53% lower than the price of the newly manufactured engine parts. Similarly, Deng et al. [10] also found that that remanufacturing process results in an up to 50% cost savings.

From the above literature, it can be seen that most research compared the economic and environmental benefits of remanufacturing as a separate dimension. This paper aims to integrate and simultaneously compare the economic and environmental benefits of the remanufacturing process of automotive products in an eco-efficiency portfolio. The products being compared are a newly manufactured and a remanufactured diesel engine cylinder block.

The eco-efficiency portfolio of the cylinder bocks is constructed through a series of normalization processes. For the environmental perspective, GWP of the cylinder blocks are considered and measured using LCA methodology. For the economic dimension, the prices of the cylinder blocks are taken into account. Finally, a single value representing a combined economic-environmental benefit achieved from remanufacturing a cylinder block is presented.

2. Materials and Methods

2.1. Goal and scope definition

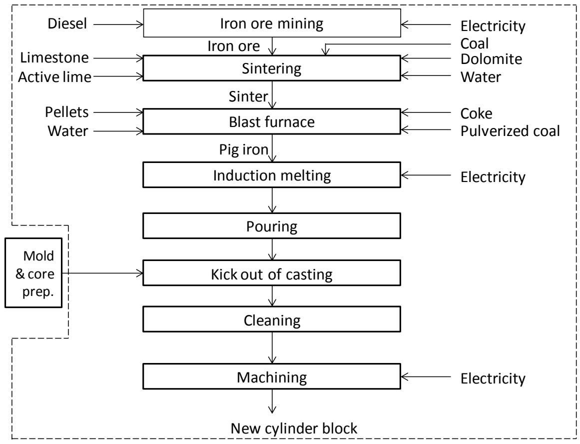
The goal of this study is to compare the eco-efficiency performance of a newly manufactured and a remanufactured cylinder block. The weight of the cylinder block is 260 kg and made of cast iron. The engine using the cylinder block is a WD615 diesel engine produced in China.

The manufacturing and remanufacturing processes being considered in this study are presented in Fig. 1 and 2, respectively. All processes depicted in the figures occur in China. Producing a new cylinder block and remanufacturing an old cylinder block are the functional units of this study.

Fig. 1 presents that the processes of making a new cylinder block starts with iron ore as raw material and proceeds through sintering, blast furnace, induction molding, casting, and ends with machining. The processes of preparing mold and core are not considered in this study. Furthermore, the transportation activities between processes included in Fig. 1 are also excluded from the analysis. From Fig. 2, it can be seen that the remanufacturing process is preceded by pyrolysis, shot blasting, and cleaning and followed by another cleaning and ended with inspection. Similar to the manufacturing process, transportation activities between processes involved in Fig. 2 are excluded from this study.

2.2. Life cycle inventory analysis

The inventory data of producing a new cylinder block are presented in Table 1. The inventory data related to iron ore production, sintering, blast furnace, and induction melting are calculated based on [11,12,13,14]. However, the emission data for the machining processes are generated using GaBi® software based on the information on electricity consumption provided by the manufacturer. According to the manufacturer, the price of a newly manufactured cylinder block is US$1,346.



Legend: ----- boundary of the study

Fig. 1. Cylinder block manufacturing process

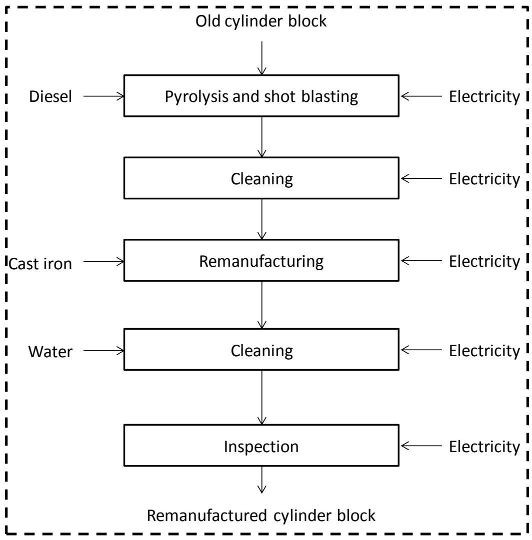


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Fig. 2. Cylinder block remanufacturing process

In Table 2, the inventory data for cylinder block remanufacturing are presented. Based on the energy consumption information provided by the remanufacturer, the emission data of the remanufacturing process are generated using GaBi® software. According to the remanufacturer, the price of a remanufactured cylinder block is US$825.