Design and analysis of sustainable computer mouse using design for disassembly methodology

Taufik Roni Sahroni, Ahmad Fitri Sukarman and Karunia Agung Mahardini

1Industrial Engineering Department, BINUS Graduate Program – Master of Industrial Engineering, Bina Nusantara University, Jakarta, Indonesia 11480
2Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
3Industrial Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

Email: taufik@binus.edu

Abstract. This paper presents the design and analysis of computer mouse using Design for Disassembly methodology. Basically, the existing computer mouse model consist a number of unnecessary part that cause the assembly and disassembly time in production. The objective of this project is to design a new computer mouse based on Design for Disassembly (DFD) methodology. The main methodology of this paper was proposed from sketch generation, concept selection, and concept scoring. Based on the design screening, design concept B was selected for further analysis. New design of computer mouse is proposed using fastening system. Furthermore, three materials of ABS, Polycarbonate, and PE high density were prepared to determine the environmental impact category. Sustainable analysis was conducted using software SolidWorks. As a result, PE High Density gives the lowers amount in the environmental category with great maximum stress value.

Keywords: Design analysis, sustainable, manufacturing, computer mouse, disassembly

1. Introduction

At the moment, most of manufacturing industries are observing in reducing the production cost. The overall production cost is mainly came from materials, manufacturing process, and number of parts. There is one approach can be considered in developing new product using Design for Disassembly (DFD) methodology. This method has been interested in manufacturing industries due to reducing the production cost significantly. Numbers of part using in product development were lead the impact to environment. In other hand, the use of material and parts could difficult to manage during assembly and processing. Therefore, the use of less material or parts are still looking for the pattern, especially for design engineers. The main purpose this practice is to develop a new product with simple, ease of manufacture, and low cost in production.

Design for disassembly has received substantial academic and industrial attention over the past decades as a potential earnings to contribute to the sustainability of industrial production through a closed cycle economy. The systematic product disassembly was initiated in observing end –of-life (EoL) paradigm to achieve a closed loop economy [1]. This study mentioned the using of raw material lead
residues and emission during manufacturing processes. Furthermore, the production increases pollution and resource reduction. It is supported by another study in considering life cycle aspect in product development [2]. This study also recommend to optimize the product value and benefits. Another study stated the necessity of using emerging extraction technology in developing added-value product [3]. The necessity of recovery and recycling processes were discussed in developing lithium [4]; metal and nonmetal from electronic waste [5]. However, there is a research gap in developing a new product using easy comparative design concepts. The most relevant approaches were studied in 2016, a new model to select of fasters as a part of design for disassembly methodology using Analytical Network process (ANP) during the design stage [6] and new methodology is proposed to apply design for disassembly and environmental impacts. However, this methodology were completely complex and difficult to be applied in small medium manufacturing industries.

In developing a computer, the definition of a mouse is an aiming device that purposes by sensing two-dimensional motion relative to its supporting surface. In practice, a mouse entails of a body held under one of the user's hands, with one or more buttons. In addition, a mouse features other elements, such as roll that allows the user to complete various operations. Based on this reasons, this paper motivate the authors to develop a new computer mouse from difference perspective of economical and ease of manufacture.

Basically, the existing computer mouse model consist a number of unnecessary part that cause the assembly and disassembly time in production. Some of material used in computer mouse gives environmental impact such as ABS. The current computer mouse design is still use fastener like screw to assemble parts. Time of assemble and disassemble the computer mouse still can be reduce by reducing parts. Therefore, the objective of this paper is to design a new computer mouse based on Design for Disassembly (DFD) methodology. The research motivation is to study the design parameter of computer mouse in order to manufacture with economical price.

2. Materials and Methods

In this project, ABS (Acrylonitrile-butadiene-styrene) material is used due to better property such as tough, resilient, and easily molded. It is typically dense, although some grades transparent, and has vivid colors. In addition, ABS-PVC alloys has good property in toughness and usually used for the casings of power tools.

The composition of material (CH2-CH-C6H4)n, General properties, density and price, 1.01x10^3-1.21x10^3 kg/m^3 and Price 7.54-9.12 MYR/kg, respectively Figure 1 shows the sketch generation and was generated in 3 design concepts. Figure 1 shows the three design concepts and generated in order to be selected for further analysis.

![Figure 1. Sketch generation](image)

Material selection is important to ensure the product development can be manufactures with a good quality. In many applications, the material is chosen due to achieve the demand from customer such as a high tensile strength. In manufacturing industries, the material selection in developing a new product is based on economical purposes. Design economy has become trend issue today due to make a
significant impact to the production cost. Therefore, decision to select the best material is based on suitable and economic. However, there is another factor to be considered in developing a new product that is well environment issue. Most of people today has been considering the green or environmental friendly for selecting the product.

In the selection of materials, a systematic approach is necessary to select the best materials for a particular application. If a proper technique is followed, first it is required to carefully define the application requirements in terms of mechanical, thermal, environmental, electrical, and chemical properties. Then the choices are narrowed down by the method of elimination. Making all the right decisions so that the product is profitable and competitive as well as the performer technically is a virtual tight rope walk.

The systematic selection of the specific materials to meet required properties has been given considerable attention. Numerous textbooks and handbooks have been devoted to this material selection of this sustainable product. Table 1 list of selection criteria to be measured for design concept A, B, and C. Based on the result of Table 1, the design concept B is selected for further development due to highest ranking.

| Selection Criteria          | Concept |
|----------------------------|---------|
|                           | A | B | C |
| Manufacturing Process      | - | + | + |
| Easy to disassemble        | - | + | - |
| Material safety            | - | + | - |
| Non hazardous material     | + | + | + |
| Ergonomic design           | + | + | + |
| Comfortable to use         | + | + | + |
| Size                       | + | + | - |
| Easy to storage            | + | + | + |
| Others                     | - | - | + |
| Cheap                      | - | - | - |
| Sum (+)                    | 3 | 5 | 3 |
| Sum (-)                    | 2 | 0 | 2 |
| Net Score                  | 1 | 1 | 1 |
| Ranking                    | 3 | 1 | 2 |
| Further Development        | NO | YES | NO |

Table 2 list of the concept scoring for three concept of design. The result shows that design concept B is selected due to highest ranking.

| Characteristics                | Weight (%) | Concept |
|--------------------------------|------------|---------|
|                                | Rating     | WS      | Rating | WS | Rating | WS |
| Manufacturing Process          | 30         | 3 | 0.9 | 8 | 2.4 | 6 | 1.8 |
| Easy to disassemble            |            |     |     |    |     |    |
| Material safety                | 20         | 4 | 0.8 | 7 | 1.4 | 5 | 1 |
| Non hazardous material         |            |     |     |    |     |    |
| Ergonomic design               | 15         | 7 | 1.05 | 7 | 1.05 | 8 | 1.2 |
| Comfortable to use             |            |     |     |    |     |    |
| Size                           | 20         | 6 | 1.2 | 9 | 1.8 | 5 | 1 |
| Easy to storage                |            |     |     |    |     |    |
| Others                         | 15         | 7 | 1.05 | 5 | 0.75 | 5 | 0.75 |
| Cheap                          |            |     |     |    |     |    |
| Total score                    | 100        | 5 | 7.4 | 5.75 |
| Ranking                        |            | 3 | 1 | 2 |
| Continue                       | No         | Yes | No |

Table 1. Concept selection

Table 2. Concept scoring
3. Results and Discussion

Based on the design concept B, a new shell for mouse’s cover that by considering the factor of Design for Disassembly (DfD) was redesigned. The common mouse design still use fasteners like screw to assemble the mouse’s cover. After discussion and some research have been made, the new mouse’s cover is proposed to ease the assembly process yet decrease the parts of mouse’s cover itself. By implementing the easy and cheaper fastening method, like slotting and snap fit, the new design of DfD mouse’s cover shown in Figure 2.

![Figure 2. New mouse’s cover design](image)

The old design of mouse’s cover was using fasteners screws as fastening the top and base cover. Fastening using screw is meant to secure more on assembly. By considering the Design for Disassembly concept, the better way to create a fastener is to have less part to disassemble and easy method of unlocking the fastener. Figure 2 shows fastening system is designed for new mouse’s cover.

![Figure 3. Fastening System (Slotting and Snap Fit)](image)

The part of the mouse’s cover has been reduced to two parts only, the top shell and the base shell. At the top shell, we have combined the middle shell (commonly consist scroll wheel) underneath the top shell to reduce the disassemble part. In addition, the fastening method was used slotting and snap fit concepts. Figure 3 also shows, the slotting method was created at the front of the mouse, where the male slot was placed inside the base shell and the female slot was on the middle shell beneath the top shell. In order to ensure the design economy, the snap fit method was designed at the back (butt) of the mouse, where the snap fit hole was placed on the base shell and the snap fit hook placed beneath the top shell. In general, the assembly concept is simple, place the top shell by leaning the front into the slotting area on the base shell, when slot was placed, push the top shell back downward until the snap fit insert the slot.
In this project, three materials (ABS, Polycarbonate, and PE high density) were prepared to determine the environmental impact category. Sustainable analysis was conducted using software SolidWorks. The design parameter for sustainability analysis and environmental impact category for was listed in Table 3.

Table 3. Environmental impact category

| Material          | Environmental Impact Category |
|-------------------|------------------------------|
|                   | Carbon Footprint, kg CO₂ | Water Eutrophication, kg PO₄ | Air Acidification, kg SO₂ | Total Energy Consumed, MJ |
| ABS               | 0.2                        | 0.000108                      | 0.00202                      | 2.58                        |
| Polycarbonate (PC) | 0.25                       | 0.000114                      | 0.00209                      | 3.35                        |
| PE High Density   | 0.02                       | 0.0000144                     | 0.000104                     | 0.16                        |

In Table 3 gives some results in carbon footprint, carbon-dioxide and other gasses. It is found that there were significant contributed from selected material to environment. The results were caused by the boiling of fossil fuels gather in the atmosphere which in turn rises the earth’s average temperature. In addition, it is found that most of contribution due to material processing to produce the final product. However, there is a lack of temperature rises in the affecting the total energy losses. The study is compared the carbon footprint acts as a proxy for the larger impact factor referred to as Global Warming Potential (GWP). In addition, water eutrophication is an overabundance of nutrients and added to a water ecosystem, eutrophication occurs. In different conditions, this result could lead a significant error due to involving the measurements tools. Although for air acidification, sulphur dioxide, nitrous oxides other acidic discharges to air leads an increase in the acidity of rainwater, which in turn make become acid to lakes and soil. Moreover, these acids lead the toxic to the land, water, plants and aquatic life. Finally is total energy consumed, where the impact embraces not only the electricity or fuels used during the product’s lifecycle, but also contributed the upstream energy required to obtain and process these fuels, and the embodied energy of materials which would be released due to burning process. From the results, PE High Density gives the lowers amount in the environmental category. The result gives the best material that should be used in designing the computer mouse product. It is shown that the impact of material selection to environment greatly increased.

Simulation Xpress Analysis also was conducted using SolidWorks, and found that that the maximum stress for the product is 3.21 kN/m². While the maximum displacement is 4.16x10⁻⁵ mm. The pressure used in this analysis is 5N/m² on the top surface of the shell. Based on the result, it is feasible to use PE High Density in designing of mouse cover.

Figure 4. Maximum stress simulation
4. Conclusion

This paper presents the design and analysis of computer mouse using Design for Disassembly methodology. Basically, the existing computer mouse model consist a number of unnecessary part that cause the assembly and disassembly time in production. The objective of this project is to design a new computer mouse based on Design for Disassembly (DFD) methodology. The main methodology of this paper was proposed from sketch generation, concept selection, and concept scoring. Based on the design screening, design concept B was selected for further analysis. New design of computer mouse is proposed using fastening system. Furthermore, three materials of ABS, Polycarbonate, and PE high density were prepared to determine the environmental impact category. Sustainable analysis was conducted using software SolidWorks. As a result, PE High Density gives the lowers amount in the environmental category with great maximum stress value.

The benefit of this project is to propose a new design of computer mouse using fastening system, less environmental impact and economic manufacturing cost.

References

[1] Jovane F, Alting L, Armillotta A, Eversheim W, Feldmann K, Seliger G, Roth N. (1993). Keynote Paper: A Key Issue in Product Life Cycle: Disassembly. Annals of the CIRP, 42(2), 651–658.
[2] Westka¨mper E. (2003). Assembly and Disassembly Processes in Product LifeCycle Perspectives. Annals of the CIRP, 52(2), 579–588.
[3] Richard G. Maroun, Hiba N. Rajha, Eugene Vorobiev, Nicolas Louka. (2017). Emerging Technologies for the Recovery of Valuable Compounds from Grape Processing By-Products, Editor(s): Charis M. Galanakis, In Handbook of Grape Processing By-Products, Academic Press, 155-181.
[4] Godlewksa,, J. (2017). Recovery and Recycling of Waste Tires in Poland. Procedia Engineering, 182, 229-234, https://doi.org/10.1016/j.proeng.2017.03.173.
[5] Kaya, M. (2016). Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes. Waste Management, 57, 64-90.
[6] Jeandin, T and Mascle C. (2016). A New Model to Select Fasteners in Design for Disassembly. Procedia CIRP, 40, 425-430.
[7] Peeters, J. R., Paul Vanegas, P., Dewulf, W., Duflou, Joost R. (2017). Economic and environmental evaluation of design for active disassembly. Journal of Cleaner Production, 140(3), 1182-1193.