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Characterization of Mobile Phone Cases for Remanufacturing Purpose Shu-San Gan 1,*, Juliana Anggono2 , Didik Wahjudi3, Yopi Tanoto4, and Randy5 1,2,3,4,5Mechanical Engineering Department, Petra Christian University Abstract. Remanufacturing is a process when used product or core is brought to 'like-new' condition, might be with an upgrade in performance. This process complies with technical specifications, including engineering, quality and testing standards. It yields a fully warranted product. The purpose of this study is to conduct an initial study on the feasibility of remanufacturing specifically on the mobile phone cases to provide information and consideration for a firm that would conduct remanufacturing of mobile phones. A material characterization on the mobile phone cases is performed to analyze the material structure for remanufacturing consideration. The results show that mobile phone cases are not suitable for remanufacturing, based on the material analysis, process difficulty, as well as cost projection. Key words: remanufacturing; mobile phone cases; case study; material characterization. 1 Introduction Rapid development in mobile phone technology during 2007 to 2017 has resulted in so many brands and types of mobile phones in the market, which further has shorten the usage phase of mobile phones. Furthermore, the number of discarded mobile phones increases significantly, either from damaged mobile phones or merely outdated models, which will become electronic wastes or e-waste. According to Baldé et al. [1], e-waste reaches 41.8 million tons in the world consisting of 1 million tons of waste lamps, 3 million tons of small electronic goods waste, 6.3 million tons of electronic display, 7 million tons of temperature control waste, 11.8 million tons

of large electronic **equipment** waste **and 12.8** million tons **of small** electronic **equipment.** 2

Mobile phone is categorized as small electronic goods. Therefore, one way to overcome the waste problem

is by performing remanufacturing. According to Franke et al. [2],Tong [3], and Rathore et al. [4], remanufacturing is a promising recovery process for electronic products and mobile phones. Other studies by Guide et al. [5], Xing et al. [6], and Kwak & Kim [7] show that it is profitable. Remanufacturing is a process when used product or core is brought to 'like-new' condition, might be with an upgrade in performance ([8], [9], [10]). This process complies with technical specifications, including engineering, quality and testing standards. It produces a product that provides similar guarantee to the new one. Remanufacturing is one * Corresponding author: gshusan@petra.ac.id among many recovery processes that is able to reduce the amount of waste by recovering products or components back to their usage stage, which consequently extends the products' life. Recently, remanufacturing activities are intended for products that have a very expensive price and have a reasonable component size to be remanufactured [10]. In this research, remanufacturing is focused on mobile phone cases, where a feasibility study is conducted to identify the possibility of remanufacturing mobile phone cases. Mobile phone case refers to the phone's frame and back case. The physical damage of a mobile phone is mostly found in the outer case due to the effects of abrasion, impact and other deformation acts, which are affected by the strength of mobile phone cases materials used. There are 3 types of materials that are commonly used for mobile phone cases in Indonesia, which are aluminum, plastic, and glass. The study is conducted in two phases: (1) a case study where we interview a mobile phone manufacturer and several mobile phone users, (2) material characterization where aluminum and plastic are tested in laboratory, and glass material is analyzed based on literature study. The results show that mobile phone cases are not suitable for remanufacturing, based on the material analysis, process difficulty, as well as cost projection 2 Methodology The material characterization consists of a) Selection of mobile phones with 3 types of materials for evaluation, which are aluminum, plastic, and glass as seen in table 1. Table 1. Mobile phone selection for material characterization Brand Model Case material Apple iPhone 5 Aluminum Xiaomi Redmi 3 Aluminum Samsung Galaxy S5 Plastic Samsung Galaxy S6 Glass b) Study the material structures and composition of phone cases made of aluminum and plastic using

SEM (Scanning Electron Microscopy) and EDX (Energy Dispersive X-Ray Analysis) 1

evaluation. For phone cases made from glass, we use literature study from Corning gorilla glass's reference. c) Analyze the results and provide a recommendation for remanufacturing. 3 RESULTS AND DISCUSSION Material characterization is performed on mobile phone cases using SEM and EDX. Evaluation was performed on three back cover sections of the top surface, cross section and bottom surface of the evaluated mobile phone case pieces. The material evaluated was carried out on aluminum and plastics. Plastic material comes from Samsung Galaxy S5 while for metal materials using iPhone 5 and Xiaomi Redmi 3. 3.1 Plastic: Samsung Galaxy S5 Figure 1 shows the SEM results from 3 different cross sections, i.e. top, bottom, and cross section. It can be seen from Figure 1(c) that this case has a thickness of 636.4 μm and uses plastic material completely and no coating is found that protects the plastic. Chemical composition tests with EDAX confirm the plastic material in which the main constituent elements are carbon and oxygen as shown in Table 2. (a) (b) (c) Figure 1. SEM photographs of material case Samsung Galaxy S5 from (a) top, (b) bottom dan (c) cross section Table 2. Chemical composition of plastic material in Samsung Galaxy S6 Case section % Weight Carbon Oxygen Magnesium Top 58.02 29.67 - Bottom 63.96 28.84 - Horizontal 55.55 34.65 2.11 3.2 Aluminum: Apple iPhone 5 and Xiaomi Redmi 3 The process of preparing and testing is similar to the plastic one. Figure 2 shows the cross sections of the iPhone 5 and Redmi 3 from a SEM test. (a) iPhone 5 (b) Xiaomi Redmi 3 Figure 2. SEM evaluation cross-section for

aluminum material Figure 2 shows that this Xiaomi Redmi 3 has a layer on its case surface but with a size of 8.975 μm or nearly twice as thick as the layer of iPhone 5. Table 3 explains that the amount of oxygen in iPhone 5 is significantly higher due to the anodizing process for coloring, while in Redmi 3 it uses spraying for coloring. Table 3. Chemical composition of plastic material in iPhone 5 and Redmi 3 Case Horizontal % Weight

C O Mg Al Si S K Ca iPhone **5**	**3**

31.66 1.07 1.37 35.02 24.76 1.46 1.78 2.87 Redmi 3 8.55 -- 2.35 68.73 1.22 1.51 -- -- 3.2.2 Glass: Samsung Galaxy S6 Samsung Galaxy S6 uses gorilla glass 4 which was introduced in November 2014. Until now Corning has marketed gorilla glass until the 5th series which was introduced in July 2016. Most of the mobile phone companies that uses glass material for the case, use Corning gorilla glass. We focus on mobile phone age within 2 to 5 years, therefore the gorilla glass discussed in this section is of series 4 and 5. From the reference provided by Corning ([11], [12]), it appears that Gorilla Glass 5 has the highest durable level compared to the previous series as described in Figure 3. (a) drop test (b) scratch test Figure 3. Glass material characterization ([11], [12]) In Figure 3(a) a drop test is performed using a pendulum and an emery paper of 180. The glass attached to the pendulum will be dropped to a certain degree and hit the emery paper 180. The damage resistance of Gorilla Glass 5 increases by 1.5 up to 1.8 times. The glass thickness parameter is set from 0.4 to 0.8 because there are differences in thickness produced by Corning for Gorilla Glass 4 and Gorilla Glass 5. As for Figure 3(b) it can be seen that Gorilla Glass 5 is able to withstand 10% more scratches for 25psi pressure and 65% more for 45psi pressure compared to Gorilla Glass 4. 4 Analysis The analysis are performed by considering the material structures and composition, as well as the process needed to remanufacture the phone case. The results in section 3 show that not all phone cases provide coating as a protection layer, as seen in table 4. Table 4. Mobile phone case coating Brand Model Case material Coating Thickness Apple iPhone 5 Aluminum yes 4.628 Xiaomi Redmi 3 Aluminum yes 8.975 Samsung Galaxy S5 Plastic no -- Samsung Galaxy S6 Gorilla glass 4 no -- In the case of physical damage where the coating is tempered, the process of recovering it would be removing the coating and applying new one. However, it is not a simple task because the remanufacturer should provide labor and materials, furthermore, the thickness of the coating should be consistent with certain tolerance to ensure the compatibility with external accessories casing which increase the complexity of the process. Cost projection for this process of cleaning and reconditioning is quite high. As for the plastic material, it is not feasible to recover the phone case since replacing the damaged phone case with the new case would be much cheaper and manageable. Therefore, recovering or reconditioning plastic phone case is not an option. For glass case, the literature study shows that it is not possible to recover a damaged glass phone class, since the process of manufacturing the case cannot be made partially. However, considering the improvement in the latest series of gorilla glass, it seems that the probability to reuse the glass phone case series 5 is high. It is most likely that the gorilla glass is still in a good condition when the product is collected for remanufacturing. Therefore, a remanufacturing is only possible when the glass phone case is still in a good condition, with no scratch or cracks. The analysis shows that remanufacturing of mobile phone case is very limited. However, it does not mean that remanufacturing a mobile phone is not possible. It can be conducted when the other parts of mobile phone is recoverable, as follows: a) plastic phone case: the phone case can be replaced by a new one with low cost b) aluminum phone case: the phone case can be remanufactured when the physical damage is minimal and can be recovered by thin coating c) glass phone case: the phone case can be remanufactured when it is still at a good condition. 5 Conclusion In carrying out remanufacturing for mobile phone case it is necessary to study its characterization in terms of material

structure and composition. A study is conducted for mobile phone cases using three types of materials namely plastic, aluminum, and glass. Mobile phone case that uses aluminum or plastic material has different content of elements and dimensions, which varies for each brand depending on the design and price setting. As for mobile phones that use the majority of glass materials will have similarities in the constituent elements but differ in dimensions. Almost all existing mobile phone brands work with Corning glass. It is concluded that mobile phone cases are not suitable for remanufacturing in terms of materials, process difficulties and cost projection. However, considering the current practices by Apple and a refurbish company in Malaysia, it is possible to recover mobile phone under refurbishment. Therefore, it would be an opportunity for further research where a characterization for material or processes is studied for improving the refurbishment of mobile phone cases. References 1. C. Baldé, F. Wang, R. Kuehr, and J. Huisman (2015). The Global E-Waste Monitor 2014. Bonn, Germany: United Nations University. 2. 3. C. Franke, B. Basdere, M. Ciupek, and S. Seliger. Omega, 34, 6, 562 – 570 (2006). B. Tong. Research on the cell phone remanufacturing and reselling. [Dissertation] Erasmus University Rotterdam (2006). 4. 5. P. Rathore, S. Kota, and A. Chakrabarti. J. Clean. Prod. 19, 15, 1709–1722 (2011). V. D. R. J Guide, V. Jayaraman, and J. D. Linton. J. Oper. Manag., 21, 3, 259–279 (2003). 6. K. Xing, M. Belusko, L. Luong, and K. Abhary. Int. J. Adv. Manuf. Tech., 35,1, 1–14 (2007). 7. M. Kwak and H. Kim. J. Mech. Des., 135, January, 1–10 (2013). 8. R. T. Lund and W. M. Hauser. Remanufacturing – An American Perspective. Proceeding of 5th International Conference on Responsive Manufacturing - Green Manufacturing (ICRM 2010, Ningbo, China, 11-13 January 2010), 1–6 (2010). 9. C. Gray and M. Charter, Int. J. Prod. Dev., 6, 3, 375–392 (2008). 10. A. Ikeda. Remanufacturing of automotive parts in Japanese market. Procedia CIRP 61, 800-803 (2017). 11. Corning Inc. Corning Gorilla Glass 5. [Online] from https://www.corning.com/content/dam/corning/microsites/csm/gorillaglass/PI_Sheets/Corning Gorilla Glass 5_PI Sheet_Rev_C.pdf [Acessed on 21 May 2018]. 12. Corning Inc. Corning Gorilla Glass 4. [Online] from https://www.corning.com/content/dam/corning/microsites/csm/gorillaglass/PI_Sheets/CGG_PI_Sheet_Gorilla Glass 4.pdf [Acessed on 21 May 2018]