The 1st International Conference on Automotive, Manufacturing, and Mechanical Engineering

SEPTEMBER 26 - 28, 2018
BALI, INDONESIA

IC-AMME
INTERNATIONAL CONFERENCE
ON AUTOMOTIVE, MANUFACTURING,
AND MECHANICAL ENGINEERING

UNIVERSITAS KRISTEN PETRA

Preface IC-AMME

The 1st International Conference on Automotive, Manufacturing, and Mechanical Engineering (IC-AMME 2018) has been organized by Mechanical Engineering Department and Continuing Education Center, Petra Christian University, Surabaya, Indonesia. This event was held on September 26–28, 2018 in Bali, Indonesia. As an effort to contribute in distributing research outcomes especially to search for alternative energy and more efficient equipment and machines.

IC-AMME 2018 presented three international honorable keynote speakers from representative countries: 1) Prof. Béla Pukánszky, Budapest University of Technology and Economics, Budapest, Hungary; 2) Prof. Sunaryo, University of Indonesia, Jakarta, Indonesia; and 3) Prof. Walter L. Bradley, Distinguished Professor Emiritus of Mechanical Engineering, Baylor University, Texas, USA (2012), Professor Emeritus of Mechanical Engineering, Texas A&M University, Texas, USA (2000). To reach a broader network of researchers, this event selected local researchers and overseas fellows to share their best research works in this conference. Over 100 representatives from 51 institutions participated in this event, involving more than 80 abstracts submitted. After a rigorous selection process, the Scientific & Editorial Board decided to publish 42 papers in E3S Web of Conferences, an open-access proceedings in environment, energy and earth sciences, managed by EDP Sciences, Paris, and indexed on Scopus, Scimago, Conference Proceedings Citation Index-Science (CPCI-S) of Clarivate Analytics's Web of Science, DOAJ (Directory of Open Access Journals) and the like.

Of 42 selected papers, 27 papers were the result of joint researches between Indonesia and various countries such as Australia, England, Germany, Japan, Lithuania, Malaysia, Nigeria, Republic of China, the Republic of Korea, Republic of Singapore, Sweden, and United States of America. Each of the 42 papers in E3S Web of Conferences was reviewed by at least two experts using the double-blind system. The published papers have passed all necessary improvement requirements in accordance to the Web of Conferences standard, reviewer's comments, SI (*Système International d'Unités*), similarity tests by Turnitin program (with the highest threshold of 20 %), 90 % of references must be at least dated from 15 years, and reflected on Google, as well as editing procedure by professional editors from seven countries (Georgia, India, Indonesia, Latvia, Lithuania, Malaysia, and Sweden).

We would like to express our gratitude to the official committee, scientific & editorial boards, and organizing partners. Special thanks as well to our co-host partners: University of Indonesia, Binus University, Binus ASO School of Engineering, Sebelas Maret University, Tarumanegara University, and *Badan Kerja Sama Teknik Mesin Indonesia* (Indonesian Mechanical Engineering Cooperation Agency) for trusting and supporting this conference.

Finally, we would like to briefly thank all presenters and attendees for their participations to share the wonderful ideas and take creative decision to inspire further research and exchange scientific reason. We hope this time, all papers can be compiled into scientific works as first publication of the 2018 IC-AMME. Lastly, we hope that this conference encourage further research collaboration. Also, everyone should be proud of this result.

Assoc. Prof. Dr. Didik Wahjudi
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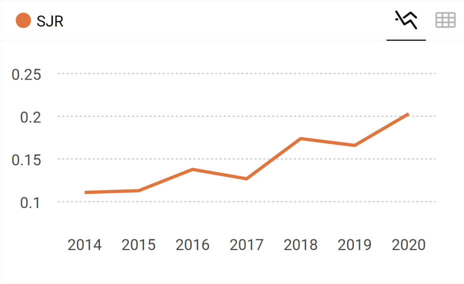

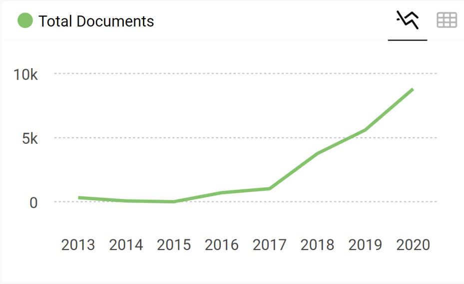

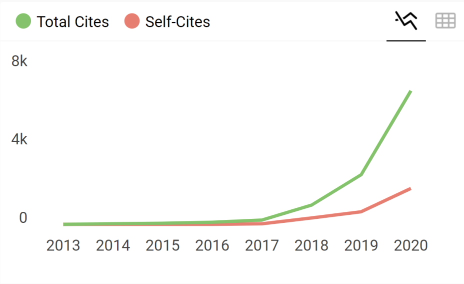

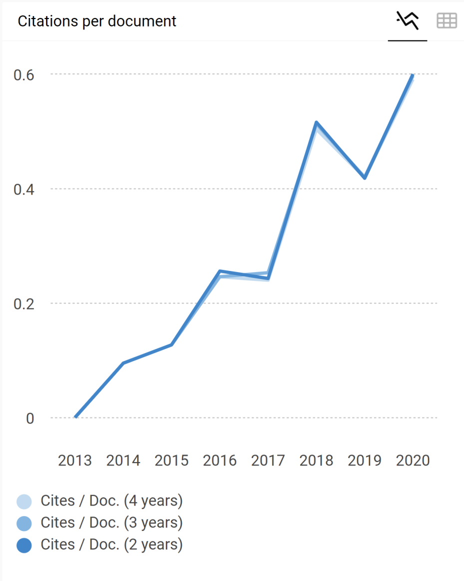

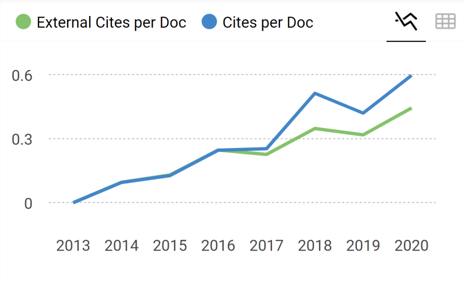

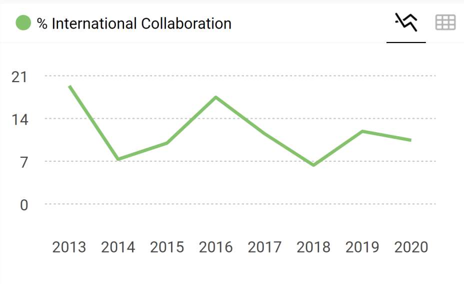

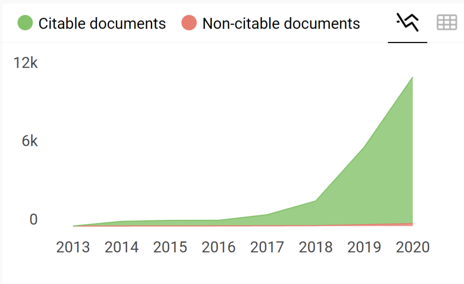

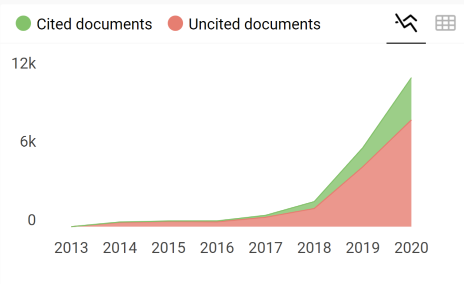

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A Feasibility Study of Mobile Phone Casings Remanufacturing

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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 was to conduct initial research on the feasibility of remanufacturing primarily on the mobile phone casings to provide information and consideration for a firm that would do remanufacturing of mobile phones. A series of material characterization on several mobile phone casings manufactured by major international brands revealed that remanufacturing is not a viable route to attempt. The evaluation shows that remanufacturing used casing mobile phone require several stages of repair, which cause an increase in the cost that can, in turn, affect the prices.

Keywords: Casing material, electronic goods, material characterization, recovery process.

1 Introduction

Rapid development in mobile phone technology during the last decade has resulted in the availability of various brands and specifications of mobile phones in the market. The growing dependence on smartphones as well as the availability of brands offering higher specification devices at an affordable price has triggered a faster upgrade cycle or in other words, reducing the smartphone replacement cycle. 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, e-waste reaches 41.8 × 10^9 kg in the world consisting of 1 × 10^9 kg of waste lamps, 3 × 10^9 kg of small electronic goods waste, 6.3 × 10^9 kg of electronic display, 7 × 10^9 kg of temperature control waste, 11.8 × 10^9 kg of large electronic equipment waste and 12.8 × 10^9 kg of small electronic equipment [1]. The mobile phone categorized as small electronic goods. Therefore, one way to overcome that waste problem is by performing remanufacturing.

Remanufacturing is a process when an old product or core is made like a new condition, even upgrade in better performance [2–4]. This process complies with technical specifications, including engineering, quality, and testing standards. It produces a product

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that provides a similar guarantee to the new one. Remanufacturing is one among many recovery processes that are 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 high price and have a reasonable component size to be remanufactured [4]. Remanufacturing is a promising recovery process for electronic products and mobile phones [5–7]. Other studies showed that it was profitable [8–10]. In this research, remanufacturing was focused on mobile phone casings, where a feasibility study was conducted to identify the possibility of remanufacturing mobile phone casings. Mobile phone casing refers to the phone's frame and back casing. The physical damage of a mobile phone is mostly found in the outer casing due to the effects of abrasion, impact and other deformation acts, which are affected by the strength of mobile phone casings materials used.

2 Methodology

There are three types of materials that commonly used for mobile phone casings in Indonesia, which are an aluminum alloy, plastic, and glass. This study was conducted in two phases: (i) an interview process with a mobile phone manufacturer and several mobile phone users to understand their view on the possibility of doing mobile phone remanufacturing, (ii) material characterization using Scanning Electron Microscopy (SEM) and Energy Dispersive X−Ray Analysis (EDAX) to analyze the structure of casing materials casings including their manufacturing process. The results show that the mobile phone is not suitable for remanufacturing, based on material analysis, process difficulty, as well as cost projection.

The mobile phones which used for materials characterization were selected from three different brands representing brands from Unites States (Apple), South Korea (Samsung), and China (Redmi). Those three brands had their casings made from aluminum alloy, plastics, and glass (Table 1).

Table 1. Mobile phone selection for material characterization.

Brand	Model	Casing material
Apple	iPhone 5	Aluminum
Xiaomi	Redmi 3	Aluminum
Samsung	Galaxy S5	Plastic
Samsung	Galaxy S6	Glass

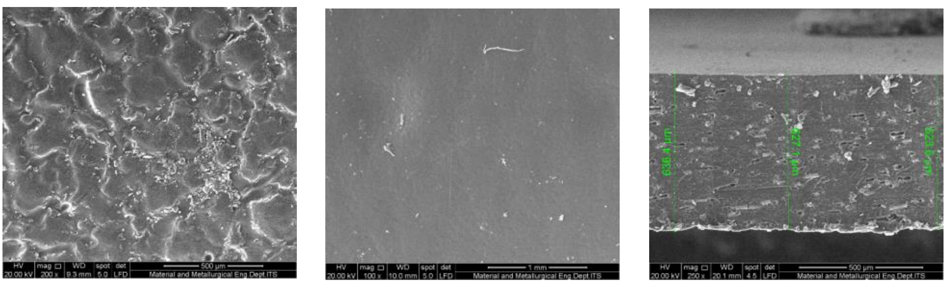
Study of the material structure and composition of the phone casings was conducted using SEM and EDAX analysis for iPhone, Redmi, and Samsung S5. Meanwhile, for phone casings made from glass (Galaxy S6), a literature study from Corning's Gorilla glass was used as a reference. Upon completing the characterization and obtaining information from interviews with national smartphone manufacturer and users, those results were analyzed to provide some recommendations for remanufacturing.

3 Results and discussion

Evaluation with SEM and EDAX was performed on the back cover section at three different locations, i.e., at the top surface, cross-sectional area, and the bottom surface of each evaluated casing piece. The materials evaluated were aluminum alloy (iPhone 5 and Xiaomi Redmi 3) and plastic (Samsung Galaxy S5).

3.1 Plastic: Samsung Galaxy S5

Figure 1 shows SEM images at three different regions in the observed sample of Samsung Galaxy S5 casing. The areas studied were the top surface, bottom surface, and cross-sectional area. Figure 1(c) shows that this casing made from plastic material with a minimum thickness of 623.6×10^{-6} m and maximum to 636.4×10^{-6} m. There was no coating applied to this plastic casing. Chemical composition tests with EDAX confirmed that, this plastic material in which their major constituent elements are mainly carbon and oxygen, as shown in Table 2. The type of plastic is polycarbonate, which manifests high strength and toughness; therefore, do not scratch, deform, and crack easily [11]. Plastic is also lighter, compared to the metal casing and does not conduct heat well. Therefore, there is no cold feeling when holding it. Polycarbonates much cheaper to form and mold than metal or glass.



(a) (b) (c)

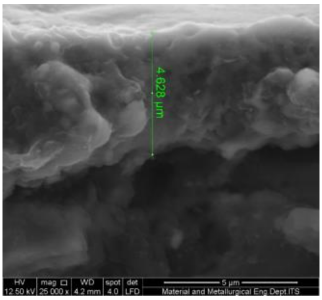
Fig. 1. SEM micrographs of material casing of Samsung Galaxy S5 (a) top surface, (b) bottom surface and (c) cross sectional area.

Table 2. Chemical composition of plastic material in Samsung Galaxy S6.

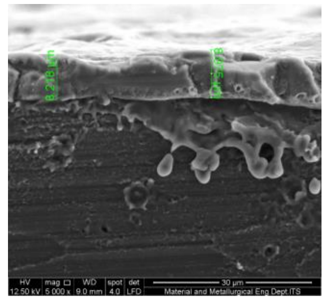
Casing section	% Weight		
	Carbon	**Oxygen**	**Magnesium**
Top	58.02	29.67	-
Bottom	63.96	28.84	-
Cross section	55.55	34.65	-

3.2 Aluminum: Apple iPhone 5 and Xiaomi Redmi 3

SEM studies observed that this Xiaomi Redmi 3 consisted of aluminum alloy casing with a coating layer adhered to it with a minimum thickness of 8.218×10^{-6} m to a maximum of 8.975×10^{-6} m (Fig. 2b) or nearly twice the coating layer thickness identified on iPhone 5 (Fig. 2a).



(a) iPhone 5



(b) Xiaomi Redmi 3

Fig. 2. SEM micrographs of cross-sectional of aluminum casings.

The Apple phone used aluminum alloy 7 000 series that was stated as its Apple's Patent Pending. This type of alloys has high yield strength such that the alloys do not dent easily [12]. Table 3 explains that the amount of oxygen in iPhone 5 is significantly high due to the anodizing process for its coating, while in Redmi 3, it uses spraying for coloring.

Table 3. Chemical composition of aluminium alloy in iPhone 5 and Redmi 3.

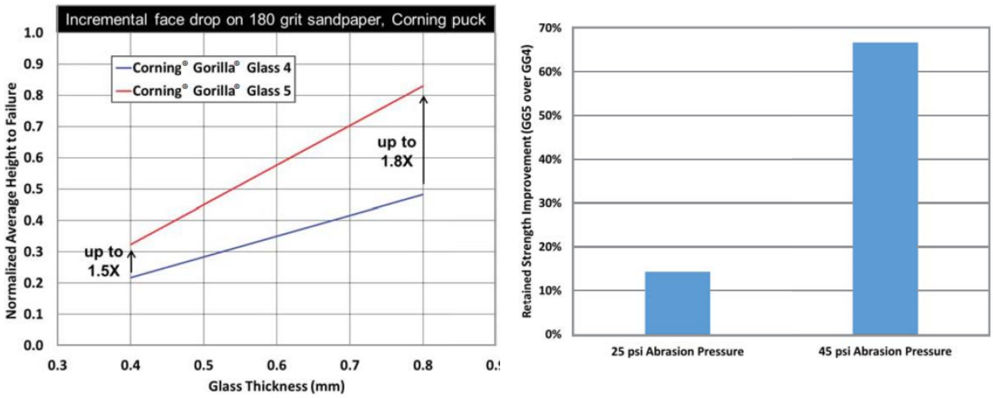
Casing Horizontal	% Weight							
	C	O	Mg	Al	Si	S	K	Ca
iPhone 5	31.66	1.07	1.37	35.02	24.76	1.46	1.78	2.87
Redmi 3	8.55	--	2.35	68.73	1.22	1.51	--	--

3.3 Glass: Samsung Galaxy S6

Samsung Galaxy S6 used Gorilla glass 4, which introduced in November 2014. Until the present time, Corning has marketed Gorilla Glass 6 (has a compressive strength due to the chemically strengthened surface produced through new glass composition compared with Gorilla Glass 5) which was introduced on 18 July 2018 and twice better than Gorilla Glass 5 [13, 14]. Most mobile phone companies that use glass material for the casing use Corning Gorilla Glass. In this research, the studied mobile phones were within the age of two to five years. Therefore the gorilla glasses that were discussed in this section were of serie 4 and serie 5.

From the reference provided by Corning Inc [14-15], it appears that Gorilla Glass 6 has the highest durable level compared to the previous series as described in Figure 3 [13].

A pendulum and an emery paper of 180 use for drop test (Figure 3a). The glass attached to the pendulum will be dropped from a certain distance and hit the emery paper of 180. The damage resistance of Gorilla Glass 5 increases by 1.5 up to 1.8 times compared to glass 4. 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 in Figure 3(b) it can be seen that Gorilla Glass 5 is able to withstand 10 % more scratches in the pressure of 3 462.122 407 5 Pa and 65 % more in 6 231.820 333 5 Pa pressure compared to Gorilla Glass 4.



(a) drop test through incremental face drop on 180 grit sandpaper (b) scratch test

Fig. 3. Glass material characterization [14, 15].

4 Analysis

The analysis was performed to evaluate their material structures, including the presence of the coating layer as well as their composition. Their construction will dictate the required process to remanufacture the phone casings to 'like-new' condition. The SEM observations in section 3 show that not all phone casings provide coating as a protection layer, as summarized in Table 4.

Table 4. Coating identification on mobile phone casing.

Brand	**Model**	**Casing material**	**Coating**	**Thickness** (m)
Apple	iPhone 5	Aluminum alloy	yes	$4\,628 \times 10^{-6}$
Xiaomi	Redmi 3	Aluminum alloy	yes	$8\,218 \times 10^{-6}$ to $8\,975 \times 10^{-6}$
Samsung	Galaxy S5	Polycarbonate	no	--
Samsung	Galaxy S6	Gorilla glass 4	no	--

In the case of physical damage on the coating part, the process of recovering it would take two stages, i.e., first is removing the coating, and the next part is applying the new one. However, those stages are not simple tasks because the remanufacturer should provide labors and materials. Furthermore, the thickness of the coating should be consistent with a certain tolerance to ensure the compatibility with the external accessories casing, which increases the complexity of the process. Cost projection for those processes of cleaning and reconditioning is considerably high. As for the plastic casing, it is not feasible to recover the phone casing since replacing the damaged casing with the new casing would be much cheaper and manageable. Therefore, recovering or reconditioning plastic phone casing is not an option. As with glass casing, the literature study shows that it is not possible to recover a damaged glass phone class since the process of manufacturing the casing can not be made partially. However, considering the improvement in the latest series of gorilla glass, it seems that the probability of reusing the glass phone casing series 5 is high. It is most likely that the gorilla glass is still in good condition when the product collected for remanufacturing. Therefore, a remanufacturing is only possible when the glass casing even in good condition, with no deep scratch or cracks.

The analysis shows that the remanufacturing of mobile phone casing 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 the mobile phone are recoverable, as follows:

(i) Plastic casing: a new one can replace the casing with low cost

(ii) Aluminum casing: the phone casing can be remanufactured when the physical damage is minimal and can be recovered by a thin coating

(iii) Glass casing: the phone casing can be remanufactured when it is in good condition.

5 Conclusion

In carrying out remanufacturing casing for mobile phones, it is necessary to study its materials structure, composition, and damaged condition. Mobile phone casings from plastic, mainly made from polycarbonate and are varied in their texture, color, and thickness from one brand to another depending on the design and price setting. As with mobile phones using glass materials for their casings, their casings are mainly made of Corning Gorilla glass. It is concluded that mobile phone casings are not suitable for remanufacturing due to the required remanufacturing work will be needed several stages of repair. As a result, the cost of remanufacturing may surpass the price of new casings available in the market. Therefore, it makes remanufacturing become impractical to implement. However, considering the current practices by Apple and a refurbishing company in Malaysia, it is possible to recover the mobile phone under refurbishment. Therefore, it initiates research toward improving the feasibility of refurbished mobile phone casings through material characterization.

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