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A Study on Disassemblability and Feasibility of Component Reuse of Mobile Phones

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Abstract

Reuse is a good way to prolong product life and reduce environmental impact due to production. When the whole product cannot be reused, reuse of components might be the option. Mobile phone is a product in which technological progresses are made every year. Components of mobile phones often have high qualities. Such components may have good functionalities after the lives of the phones themselves. This paper focuses on mobile phone components and tries to find the feasibility of reuse. Because of the functionality of the component, the paper selects liquid crystal display (LCD) as the target of reuse. Firstly, disassemble experiments are carried out to clarify disassemble time and bottlenecks of dismantling. Secondly, design improvements to enhance disassemblability are discussed. Then, by comparing LCDs of mobile phones with target products, technological feasibility is examined. Finally, the paper concludes component reuse of LCD can be feasible by implementing design for disassembly.

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Keywords: used mobile phones, component reuse, LCD, disassemblability, functionality

1. Introduction

Japan depends most of the natural resources necessary for industries on import from overseas. As the “rare earths crisis [1]” occurred in 2009 showed that strategic 3R (reduce, recycle, reuse) policies are very necessary to maintain competitiveness of Japanese industries and establish a sustainable society. Many researchers and organizations have analyzed the demands of elements after now and evaluated the criticalities of materials, recycling potentials, and so on. [2-4]. On the other hand, as a practical effort to promote circular use of materials, a new recycling legislation [5] which covers small-sized EEE (electric and electronic equipment) such as mobile phones, digital cameras, audio players, etc has been enforced from April 2013. However, the legislation mainly focuses on material recycling of such products and does not consider reuse of products or component. After Ricoh Co. Ltd. showed the concept of “Comet Circle [6]”, it has been widely recognized that “reuse” should be primarily considered than “recycling.” In addition, proper combinations of “reuse,” “recycling” and “reduce” based on strategic lifecycle planning [7] is the key for sustainable manufacturing. This paper focuses on component reuse of small-sized e-waste especially considering used mobile phones as targets and examines the technological and economic feasibility of component reuse. For the purpose, disassembly experiments of used mobile phones are carried out to clarify the bottlenecks of manual disassembly which is inevitable to reuse components.

2. Statistics of used mobile phone collection

Mobile phone is one of the most widespread products among small-sized EEE. As shown in Table 1 [8] the amount of mobile phones reaches more than 200 units per 100 families. Although other products are spreading, mobile phones have been already spread and it is estimated that many used products are hibernated at personal homes. Another important point is that average product life of a mobile phone is less than 3years and shorter than other small-sized EEE. This fact also suggests that the collection of used mobile phones and efficient treatment strategy is an emerging problem in establishing circular economy.

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Table 1. Commodity of small-sized EEE (original data from [8])

Products	Spread ratio (%)		Number of units per 100 families	
	As of 2005	As of 2008	As of 2005	As of 2008
Mobile phone	82	88	178	209
DVD player	49	72	70	109
Digital camera	46	66	56	86

Plus, the collection rate of used mobile phones is gradually decreasing in long-term view. Fig.1 shows the number of collected phones via private recycling network (Mobile phone Recycling Network [9]) established by carrier companies. The collected number was nearly 12 million units in 2003, but decreased to about 6.6 million units in 2012, while the number of emitted phones per year is increasing. Based on the existing survey [9], the number of mobile phones that reach to the end-of-life in 2011 was about 36 million units. This means that the collection rate is less than 20%.

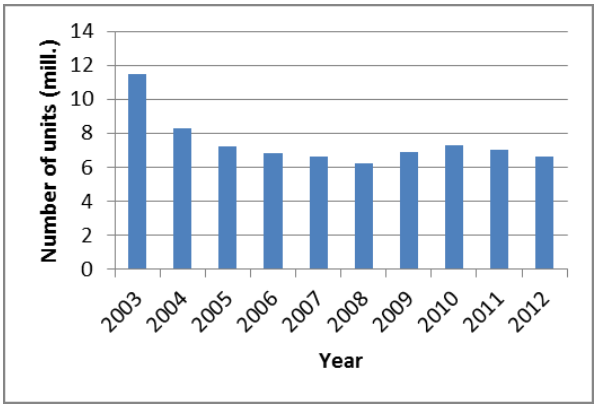

Fig.1. Number of collected used mobile phones (original data from [9])

One of the reasons of low collection rate is that recycling of used mobile phones is not profitable. Since there are huge number of units become to the end-of-life per year, the total amount of critical metals, rare earths, etc. which can be potentially recovered from used mobile phones are considerable. However, since the products are very small, amount of materials in a unit is still small. An existing survey [10] says that the total labor cost of manual disassembly reaches about 145JPY per unit, while the total material price included in the used products will be around 100JPY at most. This unbalanced cost can be a barrier to promote circular use of used mobile phones. Everyone knows that recycling is good for environment and preserving natural resources. But, no one wants to cover the cost. One way is to decrease the cost of recycling drastically. In another study [11], we are discussing the new idea on the recycling process. Contrarily in this paper, our focus is “how to recover more value from the used products.” Component reuse can be one of the solutions.

3. Disassembly experiment of used mobile phones

3.1. Work Flow Analysis

At first, according to the guidelines of "design for disassemble [12]," disassembly experiments of used mobile phones were carried out. In the experiment, Work Flow Analysis (WFA) was used to quantify the standard disassembly time. Every disassembly motion was divided to 8 specific motions. Those are "Grasp," "Release joints," "Pull-out," "Adjust direction," "Move," "Re-grasp," "Put" and "Change attitude." WFA thinks any disassembly motions can be written by repetition of these 8 specific motions. Each specific motion has a several variations depending on the part sizes, conditions, type of joints, and so on. Table 2 shows the variations of 7 specific motions except “Release joints,” and modified standard time of operations. Table 3 shows variations of joints, and standard work time to release the corresponding joints.

Table 2. Variations of disassembly motions and standard work time.

Disassembly motion	Variations	Code	Standard work time [min]
Grasp	-	Fd100	0.01
Pull-out	Not necessary	Fd300	0
	Fitting is loose	Fd301	0.01
	Fitting is tight	Fd302	0.02
Adjust direction	Upper surface	Fd401	0
	Inclined upper surface	Fd402	0.005
	Side surface	Fd403	0.01
	Inclined lower surface	Fd404	0.015
	Lower surface	Fd405	0.02
Move	Light and small	Fd501	0.01
	Heavy and small	Fd502	0.015
	Light but large	Fd503	0.015
	Heavy and large	Fd504	0.02
Re-grasp	Easy recognizable shape	Fd601	0
	Not easy recognizable shape	Fd602	0.02
Put	-	Fd700	0.01
Change attitude	Same surface	Fd801	0
	Other surface	Fd802	0.02

Table 3. Variations of "Joints" and corresponding standard work time.

Mark	Type	Explanation	Standard work time [min.]
	Snap fit	By making a hook-like shape in a plastic part, it is possible to joint 2 parts by snapping.	0.02 -0.08
	Screw	Normal screw. But, if the screw is a special one, extra work time is necessary for the first one.	0.04/unit (0.1 min for the first one)
	Ring joint	Custom made joint to attach parts to an axis.	0.08
	Press fit	The diameter of the joint part is slightly larger than the hole. To assemble, it is necessary to push-in the part very strongly.	0.12
	Calking	Joints are tightened by bending or crushing the top of the joint parts	0.12
	Solder	Easily disassemble by heating. However, heating is not always possible.	0.08
	Glue	Widely used for assembly. However, it is not easy-to-disassemble.	0.12
	Welding	Usually, this type of joint cannot be disassembled.	0.12

If the operation is to detach "front cover" attached by "snap-fit," the disassembly tree will be written as Fig.2. And then, when there are 4 snap-fits to detach the "front cover" for example, the operation can be precisely written as Table 4. The description means that "top cover" can be approached from the normal side," "it was attached by 4 snap-fits," "fitting was tight," "it could be detached from upper surface," "the part was light and small," "the part wasn't an easily recognizable shape," "the detached part was put" and "the next operation can be carried out from the same side." Finally, the standard time was estimated to be 0.16 minute.

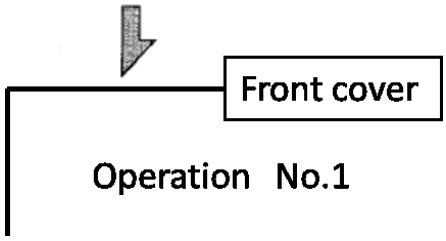

Fig.2. Part "Front cover" attached by snap-fit was disassembled

Table 4. An example of description of a disassembly operation

Number of the operation	Description	Work time [min]
No.1	Fd100Fd201*4Fd3024Fd401Fd501Fd602Fd7Fd801	0.16

3.2. Measurement of disassembly time

As well as the WFA, actual time of each disassembly motion was measured. If the actual time is not very different from the standard work time obtained by WFA calculations, actual time is used. But, if there is too much difference (approximately more than double), standard work time is used, since we think the extremely long disassembly time is because of operators skill. Sometimes, the operator cannot find the right way to disassemble. Fig.3 shows an example of the detached parts. Table 5 is the estimated time to dismantle some major components of 2 types of mobile phones. The time was estimated by using both actual measurement data and WFA data.

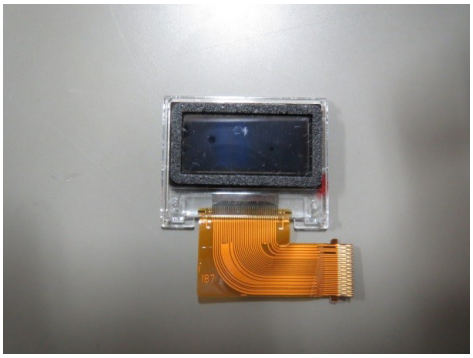

Fig.3. Detached part (sub display)

Table 5. Disassembly time of major components

Components	Type A	Type B
Liquid crystal display	1'54"	3'27"
Screw	1'13"	33"
Loud speaker	1'34"	1'55"
Camera	2'14"	3'23"
Sub-display	1'34"	-
Printed circuit board	2'18"	3'23"

3.3. Ideas to enhance disassemblability

As it was mentioned above, manual disassembly of LCD unit is usually possible and does not take too much time. However, still the time for disassembly operation can be a cost driver for component reuse. So, decreasing disassembly time will be helpful in promoting efficient component reuse. As the result of the disassembly experiments, these problems have been found.

- Special screws are used.
- Screw holes are often broken.
- In some cases, locations of screws are unrecognizable.
- Some joints are glued or soldered and not detachable.

In response to the above-mentioned problems, some design improvements can be listed. Although screws are the driver of disassembly time, they are helpful in making the disassembly process consistent and understandable. So, as the general guidelines to design easy-to-disassemble mobile phones, these general guidelines can be suggested.

- Replace glued joints by screws.
- Reduce number of joints.
- Replace 4 screws by 2 screws plus a flap like Fig.4

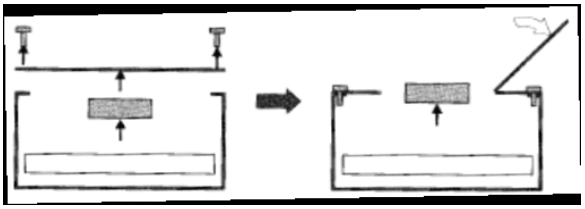

Fig.4. An idea to improve disassemblability [11]

4. Feasibility assessment of component reuse

4.1. Target component

As it was mentioned in the beginning, component reuse can be a way to extract higher value from used products. In Japan, there is a company that takes out LCDs from used mobile phones, and develops products using the recovered LCDs. Or, the company directly sells recovered LCD itself (Fig.5) as a component. Thus, among major components of mobile phones, LCD can be a good candidate to reuse.

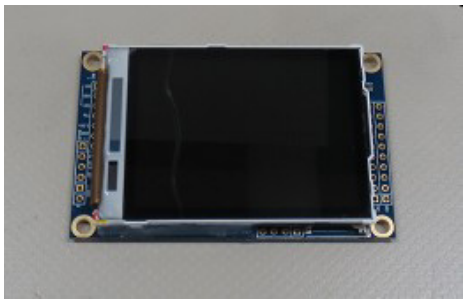

Fig.5. Reused component (LCD)

4.2. Technological feasibility

One of the barriers of component reuse is the technological adjustment of old recovered components and requirement from current products. If the recovered components cannot be used to new products because of the low functionality or old design, it won't be meaningful to disassemble used products and recover components. In this section, specifications of LCD units of used mobile phones are compared to specifications of display monitors of digital cameras. Digital camera can be a good candidate of utilizing recovered LCD for cost reduction. And the reuse of LCD is one of successful examples [13] in business utilizing e-waste. Table 6 to 8 show the specifications of monitor displays of top 5 sales cameras in each category, compact type, mirror-less single lens reflex type and single lens reflex type. On the other hand, Table 9 shows the specifications of LCD units used for mobile phones.

Table 6. Specifications of compact digital camera monitor displays

Model	A	B	C	D	E
Inches	3	3	3	3	3
Dots	460,000	922,000	920,000	1,229,000	1,040,000

Table 7. Specifications of mirror-less single lens reflex digital camera monitor displays

Model	A	B	C	D	E
Inches	3	3	3	3	3
Dots	1,040,000	1,040,000	920,000	921,600	921,600

Table 8. Specifications of single lens reflex digital camera monitor displays

Model	A	B	C	D	E
Inches	3	3	3.2	3	3.2
Dots	920,000	1,040,000	1,229,000	1,040,000	920,000

Table 9. Specifications of LCD of mobile phones

Model	A	B	C	D	E
Inches	2.2	1.9	4	4	4
Dots	76,800	76,800	727,040	727,040	727,040
Date	2006,10,7	2006,3,21	2013,9,20	2013,9,20	2012,9,21

Table 6-8 and Table 9 suggest LCD units of the present type of mobile phones, so–called smart phones, can be used for latest models for digital camera, since the specifications are enough. However, for relatively old type of mobile phones, other targets should be considered. The survey suggests that providing some products to reuse recovered components and some business models to enable such products to be widely used are necessary.

4.3. Economical feasibility

Based on the disassembly experiment in the former section, a rough calculation to confirm the economical feasibility is possible. Since the experiment says, 2 to 3.5 minutes are necessary to detach LCD from the phone body. (say 3 minutes in average). Suppose the hourly labor cost is 1,000JPY, the cost to detach LCD is about 50JPY per unit. Of course, not every LCD unit from a used mobile phone is reusable. Assuming the reusable rate is 0.1, the value extracted from the used LCD is higher enough than the labor cost of manual disassembly, since the recovered LCD units are sold about 800JPY at the cheapest [14]. So, if there is an efficient system to collect used mobile phones, to transport to reuse companies, to disassemble manually and to sell recovered units or products utilizing recovered units, component reuse of LCD units will be profitable enough.

4.4. Proposal of a product utilizing used components

It was calculated in the former section that component reuse of LCD units from used mobile phones can be profitable. But, few people can purchase LCD units and make products by themselves. On the other hand, companies can purchase reuse LCD units for their products. However, the problem is stable supply of LCD units is difficult, since the supply of the units depends on how many used phones can be collected. Thus, the one of the best solutions is to provide products utilizing reused components, and business models along with the products. According to the survey in section 4.2, combination of 2 products can be efficient.

1) High resolution type LCD units are used for monitor displays of digital camera.
2) Low resolution type LCD units are used for portable information device in museums or outdoor events.

In EXPO2006 held in Aichi, Japan, such portable information devices (Fig.6.[15]) were used to provide information for participants or pavilion staffs. The LCD unit used for this device was 2.1 inches TFT type and the resolution was 320*240. It means that relatively old type LCD units shown in Table 9 will be enough for the purpose. If this kind of device is used in big outdoor events or public facilities such as museums, it will be helpful in providing information, guiding people for a secure flow, etc. In addition, a big advantage is that such devices can be provided in inexpensive prices by utilizing reuse LCD.

Fig.6. An example of portable information device

5. Conclusions

This paper explained that even for small-sized electronic equipment such as mobile phones which have high speed of technological progress, still component reuse will be one of the keys to reduce environmental burden and to establish better circular economy.

To reinforce this view point, the paper surveys some successful examples of component reuse and confirmed that LCD will be a good candidate of component reuse.

Then, the time and procedure for manual disassembly process to detach the LCD was precisely analyzed based on WFA which is a powerful tool in “design-for-disassembly.”

The paper also compared specifications of monitors of digital camera versus those of LCD units of used mobile phones. It was concluded that LCD units recovered from latest mobile phones can be used for the digital cameras and LCD units from relatively old phones require some alterative product ideas such as inexpensive portable information devices.

In future, more precise examination of disassemblability of used mobile phones along with the feasibility assessment based on practical proposal of a product in which the recovered LCD is used, will be necessary. Plus, design and prototyping of such products will be useful too.

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