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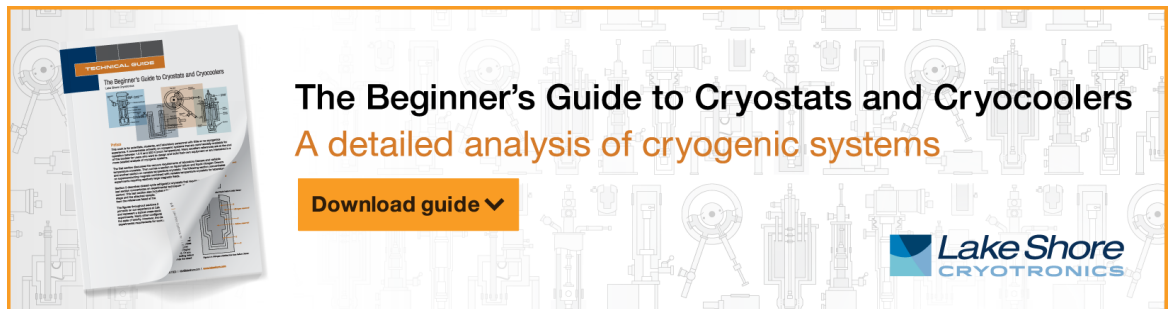


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A Preliminary Study of Remanufacturing on FDM Machine

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Abstract. The development of 3D printer machines is fast and extensive. Now 3D printer machines can be owned easily and at an affordable price. Because of this rapid development, many companies are making 3D printers. Therefore, to reduce e-wastes and other wastes, it is better to upgrade the 3D printer with new parts than to throw away the old one and buy a new one. Like the BFB 3D Touch which is no longer produced, it is a pity to throw it away. Therefore, this BFB 3D Touch is remanufactured and upgraded to be like the 3D printer that is currently circulating in general. The results obtained are remanufacturing steps for the BFB 3D Touch 3D printer machine, entrance diagnosis, complete disassembly, cleaning, inspection and sorting, recondition or replenishment by new parts, reassembly and testing. In the implementation, it was found that many electronic parts did not have spare parts because this 3D printer is discontinued. Therefore, the electronic components are replaced and upgraded. For example, motherboard, hot end, and LCD. Previously the maximum resolution was 0.125 mm, now it can reach 0.06 mm. Previously 3 mm filament measuring is used, now 1.75mm is used.

INTRODUCTION

Remanufacturing is the process of returning the condition and performance of used products to be like new, and the product is guaranteed to be like a new product (Ijomah *et al.* [1]). What is meant by “like a new product” is that the goods can function properly like before, and their physical appearance is like new goods. Remanufacturing can reduce CO₂ use and waste from items that should be reusable but disposed of, which can damage the environment. In addition, it can also extend the life of a product.

Prototype making is one of the keys to success or failure of a product to be launched. One way to make prototypes is by using rapid prototyping (RP) technology. Fused Deposition Modelling (FDM) is the most used RP technology of various types of existing RP technology. It is called FDM because its parts are formed by deposition of layers of fused materials in the product making process [2]. 3D printing is a type of additive manufacturing technology where a 3D object is created by laying down subsequent layers of material at the mm scale. 3D printers print objects by reading a CAD design file or by scanning an object [3]

3D printing is a technology that was first created in the 1980s. It was first created by Chuck Hull of 3D System Corp. Since then, 3D printers have continued to grow and are widely used. Technological developments make 3D printers change rapidly as well. If there is a new upgrade, the 3D printing machine will be more sophisticated than before. The old one will be outdated, and 3D printer users will buy a new one and the old one will be abandoned. Therefore, to reduce wastes from 3D printer machines and components that have been damaged, it is better to implement remanufacturing. Components from old 3D printing machines can be remanufactured and used for new machines.

Remanufacturing aims to reduce the waste of energy to make new goods and to reduce waste. In addition to reducing waste, remanufacturing is carried out so that the old 3D printer machine can be updated following the new machine because there are still opportunities for upgrades.

BFB 3D Touch Printer is a 3D printer engine produced by Bits from Bytes [4]. The printer made by this company is one of the best of its time. This company was founded on December 12, 2008 and on January 9, 2018 it was purchased by another 3D printer company, 3D System. Because of this, the BFB Touch 3D printer machine is no longer produced. As production stops, components are becoming scarcer. Therefore, this machine is suitable for remanufacturing so that it can keep up with the time and can be reused.

METHODS

As the global demand for consumer goods continues to rise, the problem of electrical and electronic equipment wastes (or e-waste) increases. E-waste is of particular concern to the world governments and environmentalists alike, not just because of the sheer quantity that is being produced annually, but also because e-waste often contains both hazardous materials and scarce or valuable materials [5]. Because of this problem, remanufacturing is needed so it can reduce e-waste and save energy.

The simple definition of remanufacturing is turning used goods into new goods that are in accordance with their previous use without reducing the quality of the goods by using a combination of reuse, repaired, and new components. This process disassembles the used product as a whole and all its parts are inspected extensively. The worn part is replaced with a new one, after that it is tested. The remanufacturing process normally consists of 5 main steps, disassembly, cleaning, inspection, reconditioning and reassembly/testing. The number of sequences and steps depends on the product type and function. According to Steinhilper [6], there are 5 steps that must be passed. Meanwhile, according to Freiburger [7] in the book Map of Remanufacturing Process, for mechatronic and electronic products, it is better to add a sixth step, namely entrance diagnosis of the product so that non-mechanical damage can be identified and separated as shown in Fig. 1.

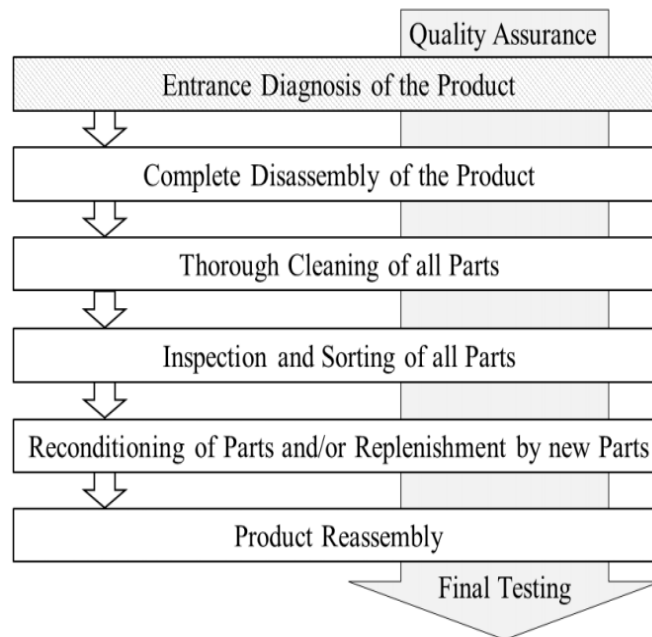


FIGURE 1. Remanufacturing steps

In the stage of entrance diagnosis of the product, the product's electronic components are checked to find out damage other than mechanical so that they can be identified and separated. Furthermore, in the stage of disassembly, the product is disassembled into components. The next process is a thorough cleaning of all parts. In this stage, the components are cleaned of oil, dust, rust, etc. The cleaning process depends on the needs of each component. The next stage is inspection and sorting of all parts. In this stage, the components are inspected and then separated based on their feasibility, which has 3 conditions, namely: 1. Reusable without reconditioning, in which components can still be

used without needing to be repaired and only cleaned. 2. Reusable after conditioning, in which components can still be used but must be repaired first. 3. Not reusable or to be exchanged, in which components cannot be reused or repaired. The next stage is reconditioning of parts and/or replenishment by new parts. Here the components are reconditioned or replaced with new ones to match the conditions they should be in. The next stage is reassembly and testing, in which components are reassembled and then tested.

First, identify the problem in remanufacturing of 3D printer. This will lead the research process. Then, conduct a literature review from books, journal articles, and other media for the research purposes. Next is analyzing the product for remanufacturing and doing the remanufacture. First, the product is diagnosed, disassembled, cleaned, then inspected and sorted. Some parts will be reconditioned and used, while some others will be used without reconditioned, and some will be replaced with new parts. The final step is to reassemble the core and test it. Then, make a remanufacturing guide for 3D printer machine, a summary, and conclusion.

RESULTS AND DISCUSSION

Disassembly

The guide of remanufacturing 3D printer in this paper is the simplified form. First the 3D printer machine will be disassembled into smaller parts as shown in Fig. 2. Then, there will be LCD, motherboard, stepper motor, power supply, end stop, hot end, extruder, bearings, belt, rod, cylinder, acrylic, and bed. From the disassembly process, the parts can be divided into 3 groups; electronics, mechanics, and frames.

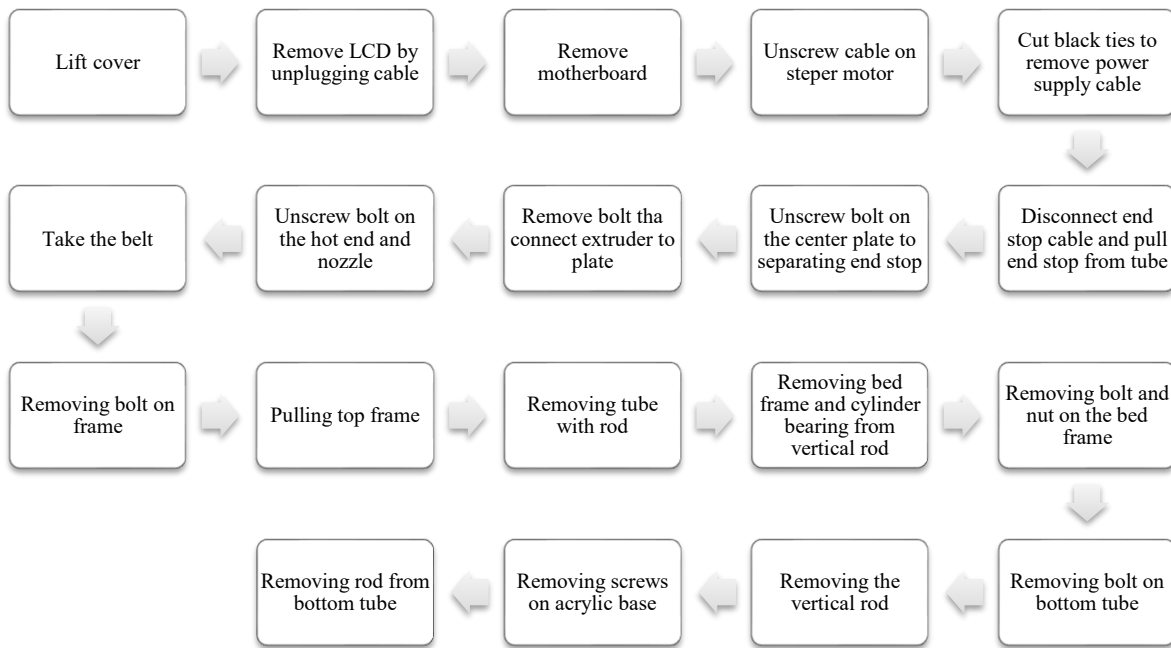


FIGURE 2. Disassembly steps

Electronic Parts

The LCD is not cleaned or washed because the LCD will be replaced with a new one to match the motherboard. For reassembly and testing, try the LCD by connecting the LCD to the motherboard and connect it to a power source. If it lights up and can be operated, then it can be used. Motherboard is not cleaned or washed because the motherboard will be replaced to make it applicable with the marlin software. The motherboard is replaced with Ramp1.4 and Arduino Atmega 2560 and uses the A4988 driver. For testing, the motherboard works when it can receive commands and execute them such as moving the stepper motor and extruder. To do this, enter the program marlin into the

motherboard. For stepper motor, clean only the outside part using a wet tissue to clean it from dust and other dirt. For inspection, first select “beeping mode” on the multimeter then test pins 1 and 3 as well as pins 4 and 6. If the sound is issued, the stepper motor can still be used. For testing, the stepper motor needs to be connected to the motherboard, and then instruct the stepper motor to move on the LCD. If it spins and there is no abnormal sound, then it is still good.

Now for the power supply, it is not cleaned or inspected because it will be replaced with a new one that has a 12V 30A specification. To test the power supply, use a multimeter on the input and output cables. The input receives 220V and the output produces 12V. Make sure the fan is on. The end stop is not cleaned or inspected because the connector from the old end stop cannot be used with the new motherboard. This is because the old end stop uses 2 pins while Ramp 1.4 requires 3 pins. To test the end-stop, just make sure it can stop the stepper motor when it is touched. The hot end will be replaced so it is not cleaned or inspected. It will be replaced with V6 hot end because the old one has a different hole size and the build is outdated and the nozzle cannot be replaced. For testing, the hot end works when it can reach the desired temperature and melt the existing filament. Comparison between new and old hot end can be seen in Fig. 3. Table 1 is a summary of the cleaning process to the reconditioning process on electronic parts.

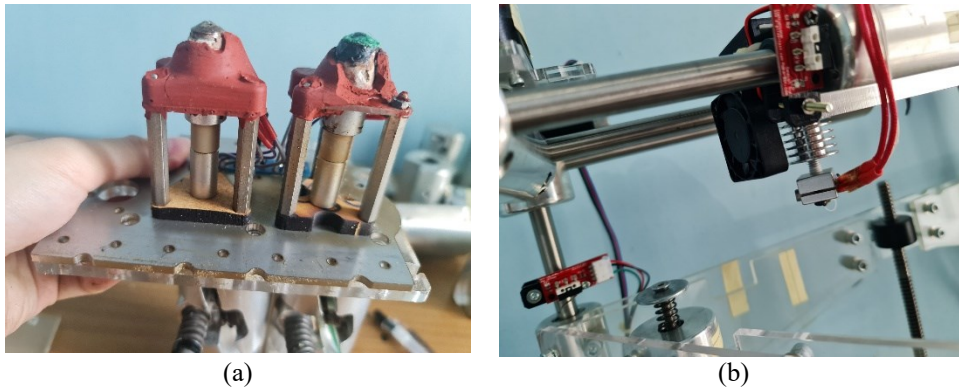


FIGURE 3. Hot end (a) old, (b) new

TABLE 1. Electronics

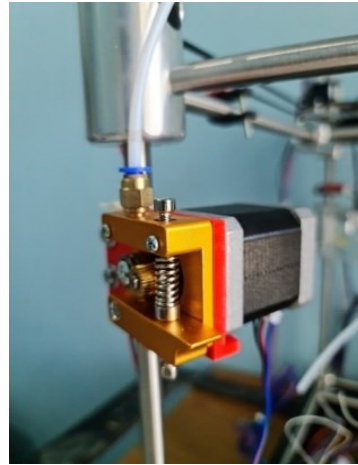
Part	Cleaning	Inspection	Recondition
LCD	-	-	Replaced with LCD RepRap
Motherboard	-	-	Replaced with Arduino Mega 2560 and Ramp 1.4
Stepper motor	Use tissue with water	Use multimeter to check	Use again
Power supply	-	-	Replaced with power supply 12V 30A
End stop	-	-	Replaced with limit switch
Hot end	-	-	Replaced with E3D V6 Hot end

Mechanical Parts

Now for the mechanical parts, there are extruder, bearing, and belt. The extruder is not cleaned or inspected. It will be replaced because with the new one it is easier to install the filament, and to adjust the gear pressure against the filament is also easier. The bearing will be cleaned using the guide from NSK [9]. Clean the bearings using kerosene and brush. After quite clean, rinse them again using kerosene. For inspection, use the guide from NSK [10]. Try to see if the bearing can still move easily by inserting the rod into the bearing and tilting it, and the bearing should move without a hitch. There are 3 things that need to be checked: check for rust on bearings and rods; check the bearing for cracks; and check for non-smooth scratches on the rod if there is a possibility that the bearing is damaged. Then, it can be concluded that it will be used again because there are no rust and cracks, and visually the rod is still good. It means there is no damage on the bearing. For the belt, it just needs a simple cleaning using a damp cloth to clean it from dust and dirt. The inspection will be done visually. If there are no damages, it can be used again. The belt does not need to be reconditioned. However, if there is damage, it is better to replace it. For installation, make sure the belt is pulled tight, so it does not slip when it moves in testing the belt. Comparison between new and old extruder can be seen in Fig. 4. Table 2 is a summary of the cleaning process to the reconditioning process on mechanical components.



(a)



(b)

FIGURE 4. Extruder (a) old, (b) new**TABLE 2.** Mechanical

Part	Cleaning	Inspection	Recondition
Extruder	-	-	Replaced with a new mechanical extruder that matches the Hot end V6.
Silinder Bearing	Clean it using kerosene and brush. Brush until quite clean then rinse it with kerosene again.	Check if the bearing can still move easily by inserting the rod into the bearing.	Use again
Belt	Clean from dust using cloth and water	See if the serrations on the belt are still good	Use again

TABLE 3. Frames

Part	Cleaning	Inspection	Recondition
Rod	Clean with water and soap.	See if it is bent and there is damage on the surface that makes it not smooth	Use again
Tube	Clean with soap and water then dry it	See if there are cracks. The physical condition of the tube has little effect on the performance of the 3D printer	Use again
Mica	Clean with water and soap	See if there are any broken parts	Use again

Frames

The frame consists of rod, acrylic, cylinder, and bed. To clean the rod, use water and soap, and to remove thin scratches, it needs to be polished. For inspection, test the straightness using a coordinate measuring machine, such as a height gauge or a straightness measuring instrument. If there is no deformation, and it is still straight, it is still good. If there is damage, it should be replaced immediately, especially those used for cylindrical bearings. Otherwise, it can be used again. Installation is done like the beginning, and for testing make sure the cylinder bearing can move smoothly on the rod used by the cylinder bearing. For the bed, it is not cleaned or inspected. It should be replaced using glass because it is flat, durable and easy to clean. The test is carried out during printing and make sure the print results can stick well with the help of glue on the glass and flat bed. For cylinder and acrylic, they just need to be cleaned. Table 3 is a summary of the cleaning process to the reconditioning process on Frames.

Reassembly

After recondition process, next step is reassembly. The reassembly step can be seen in Fig. 5.

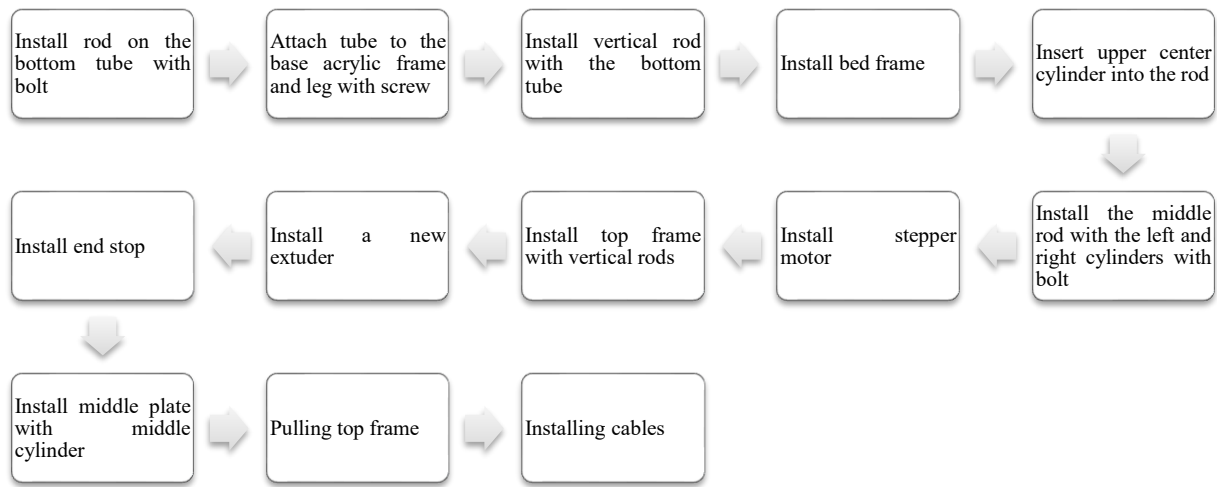


FIGURE 5. Reassembly

Final Inspection

Final inspection is a final step of remanufacturing process. Figure 6 is comparison of old and new look of 3D printer machine. Remanufactured 3D printer shows working properly after several printing tests. Replaced components are not as original. Change the specifications of this 3D printer machine. Previously, the maximum resolution was 0.125 mm, now it can reach 0.06 mm. Previously, 3 mm filament measuring is used, now it is 1.75mm. Previously, a nozzle with a size of 0.5 mm is used and it cannot be replaced. Now it uses a 0.4 mm nozzle and can be easily replaced with another size nozzle. The large number of replacement parts in the remanufacturing process for electronic parts, due to the cessation of production and the rapid development of electronic products, which opens up opportunities for upgrading. Table 4 is a summary of the upgrades carried out along with their considerations. During the remanufacturing process, especially for mechatronic goods, supporting and constraining factors were also encountered which can be seen in Table 5.

TABLE 4. Upgrades

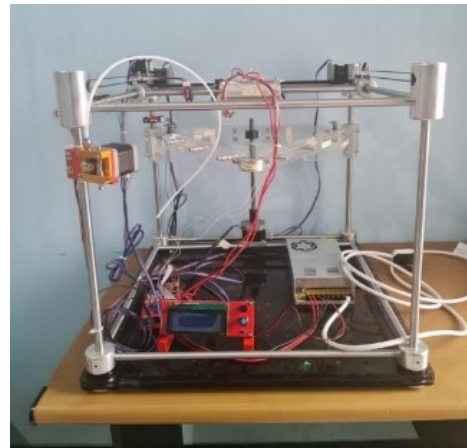
Part	Reason
Motherboard	Upgraded to Arduino Atmega 2560 with Ramp 1.4. Because this motherboard can be used with the marlin software
Software	Use this software because marlin is opensource and up to date. There is a community contributing to make marlin better. Also, marlin is easy to use
Hot end	Upgraded to E3D V6 J-Head. This hot end can be used with the 1.75 mm filament and the nozzle can be changed to another size.
Bed	The bed will be using glass because glass is easy to clean and flat. Also, for PLA use, heated bed is not required
Powe supply	The power supply will use 12V 30A because the electronics need 12V and 30A just in case there is another upgrade that requires more Ampere
Extruder	The extruder is upgraded because the new one is easier for inserting the filament
LCD	The LCD is changed because the old one can't be used with the new motherboard

TABLE 5. Constraint and supporting factor

Remanufacturing Stage	Cconstraint	Supporting factors
<i>Product Enterance</i>	-	Can search for item details on the internet because the product name is clear
<i>Dissassembly</i>	Placement of bolt and nuts in corners and hard to reach. Also a very large number of nuts and bolts	The circuit is quite easy to disassemble because the majority of the connectors are nuts and bolts. No glue or clip
<i>Cleaning</i>	-	Easy to clean because there is no rust or paint
<i>Inspection</i>	-	Checking visually, and for some parts, it is clear that there is no need for inspection because it must be replaced
<i>Reconditioning</i>	It is difficult to find replaced parts and upgraded - parts take delivery time because they are not available directly in Surabaya. There are parts that are not compatible for mounting, so it needs to be made	-
<i>Reassembly</i>	The same with disassembly, it takes time because the nuts and bolts are hard to reach and there are a lot of them	The circuit is quite easy to install
<i>Final Testing</i>	Slightly complicated bed settings	Because programs and electronic parts are like today's 3D printers, doing a test print is not complicated



(a)



(b)

FIGURE 6. 3D printer machine(a) before, (b) after

CONCLUSION

The remanufacturing process of BFB 3D Touch is quite different from remanufacturing other objects such as vehicle engines or heavy equipment. Due to the rapid development of 3D print and the discontinued BFB 3D Touch, the component of the BFB 3D Touch is not available. Although so many hardware can still be used, the software and electronics are being upgraded due to the fast development. After the 3D printer is assembled, it can't be used like before because many parts have been replaced and modified. However, the ability to print is better than before. For example, you can use a filament with a smaller diameter and a smaller diameter nozzle which will produce smoother print results.

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