Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 04, April-2022

Automated Selective Dismantling System for Waste Electrical And Electronic Equipment Recycling

Mr. Hemswaroop Raorane[1], Mr. Ashutosh Ambetkar[1], Mr. Shrikant Salaskar[1], Mr. Parth Chaphekar[1], Dr. Sunil Bobade[1], Mr. Shrikant Baste[1].
New Horizon Institute of Technology and Management, Thane.
University of Mumbai, India.
Department of Mechatronics Engineering.

***Abstract* - With ever-increasing technological advancements, there has been an increase in Waste from Electrical and Electronic Equipment (WEEE). The WEEE keeps on piling every day in tons and won't stop in the future unless specific measures are taken for recycling them. Considering the methods used for recycling in the current recycling organizations the chances of making profits due to high investment cost and leading it to set up a complete network of commerce around the recycling sector are low. This project addresses the current issue by proposing a system that will utilize minimum investment and work to bring out better results than currently observed in the industry. The paper also documents the methods and techniques for integrating the proposed systems into the current industries to boost profits and reduce WEEE as much as possible, ensuring a better future for the world.**

Keywords - Business adaptation, commercialization, cost-benefit analysis, desoldering, dismantling, e-waste, machine vision, machine learning, neural network, printed circuit boards, recycling, reuse, robotics, WEEE.

I. INTRODUCTION

The project's major goal is to - 'Propose an efficient, simple, general system for automated dismantling which will increase profit from e-waste PCB thus, increasing awareness for commercialization of recycling and reusing technology'. The system proposed here targets the reusable components of the PCB to extract more value from WEEE and reduce the hazardous waste being created. The project is a generalized system that can be adapted to the industrial needs as required. The fundamental blocks have been specified and alternatives have been mentioned in order to make the system a fit for a wide variety of industries. This proposed system is supposedly an ever-evolving system that can be iterated as the electronic industry standards regarding the PCB boards evolve further. The models proposed in this system make use of the already existing technologies which make it cheaper to build the system. The paper also makes suggestions on the cost-benefit analysis and industry adaptation for the system. The project functions by identifying the right components and taking data from repeated operations to create a trained software to provide faster dismantling of reusable components with as little human intervention as possible. These identified components are desoldered from the board and can be reused if tested completely okay.

II. LITERATURE SURVEY

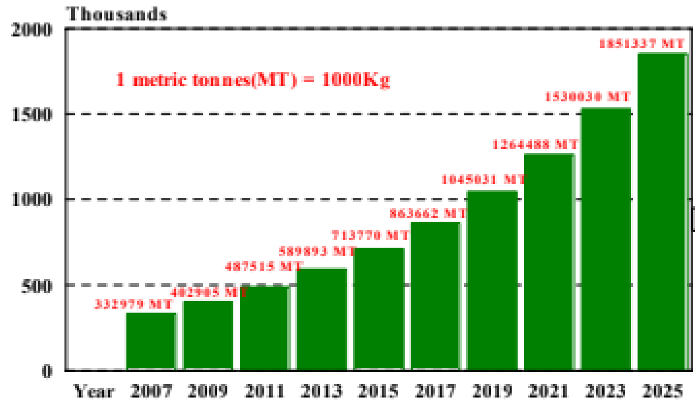

Fig. 2 growth of e-waste in india[8]

PCBs are copper-laminated non-conductive boards that allow electronic and electrical components to be connected without the need for wires . These boards are composed of epoxy, fiberglass, and other composite materials which reduce the complexity of the overall circuit design. E-waste is expanding at a 30 percent compound annual growth rate (CAGR) [4]. And the current recycling methodology can't cope with the increasing requirement.

The current methodology for desoldering these PCBs is majorly based on manual selection and desoldering/dismantling techniques. The Printed Circuit Boards (PCBs) which are in WEEE are first dismantled by manual methods and then sent directly to shredding and the components are harvested at the end of the process. In this process, some electronic components can't even be dismantled due to certain complexities. According to a paper on Printed Circuit Board Recycling [1], a new system can be implemented for automatic selection and dismantling of the components from the board. If effectively made, this system can not only save time but resources and make a way for profitable & commercial systems that can extract as much value out of WEEE as possible.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 04, April-2022

III. PROPOSED SYSTEM

The system proposed in the project has several stages that the PCB has to undergo for an effective dismantling. These stages ensure locating the electric components on the PCB board and training the systems for tailored dismantling as per the application and required industry.

The proposed system is a generalized system that makes use of already available techniques to keep the setup investment low. There are various ways to approach the design while the fundamental objective remains the same.

The system is divided mainly into 4 stages:

1. Accommodation.
2. Scanning and recognizing.
3. Desoldering.
4. Dismantling and Sorting.

After Dismantling the board can be sent to shredding and further operations to harvest metals and non-metals from the waste. Every stage's mechanisms and equipment can be replaced with feasible alternatives according to the industry's specific needs.

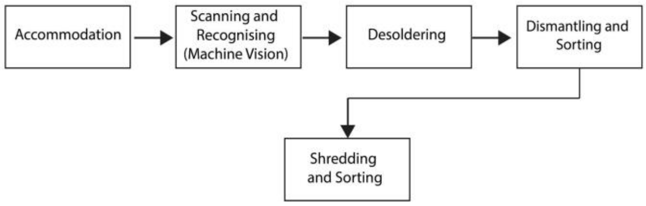

Fig. 3 Proposed system

3.1. Accommodation stage

This stage's main focus is accommodating the board within the operational area. Several methods can be used for accommodating boards with or without human intervention.

3.1.1. Manual Accommodation

Manual methods will require some parts where humans have to intervene from point to point. This may prove to be economical at times but when the amount of boards increases by a huge number, manual methods can prove to be time-consuming. Here, automatic accommodation can speed up the process. Here, such a pseudocode can be used for manual accommodation-

1. Set Initial clamping bracket to lock position[leftBracket = lock].
2. Hold the PCB in the initial clamping bracket (Human interaction) [initiate leftBracketClamp, develop⇒function clampFeedback(motor_n), while (motor_n current !> standard threshold){ run motor_n;} when condition is met : return "clamps attached";].
3. Check if PCB is clamped, develop ⇒ function to checkDifference (difference){if (difference == 100){return "no PCB"; } else{store the difference; return "leftBracketClamp fixed";}.
4. If clamped, initiate the second clamp bracket. If the leftBracketClamp is fixed then initiate the rightBracket.
5. Check for bracket contact & use function clampFeedback for checking attachment.
6. initiate the clamps, use the function clampFeedback.
7. check stability by the movement of wheels, perform an X, Y-axis movement for stability (Human Interaction) Start the process again if not connected properly or any fault.
8. initiate the scanning stage, initiate the camera.

3.1.2. Automatic Accommodation

A single conveyor will carry the PCB throughout the process of recycling. After feeding the PCB at the initial point the conveyor will carry it to the operational area and after completing the desoldering process it will take the board for shredding.

The conveyor needs to have multiple clamps on which the PCB can be accommodated.

Various designs can be sought for the selecting the accommodation method by considering the parameters :

Size, Shape of the board = Area of the board,
Quantity of boards = n,
Process time required for scanning, desoldering = t,
The number of reusable components on the board = m.

3.2. Scanning and recognizing stage

The scanning stage should capture the PCB as an image and process the data using machine vision.Machine vision can be implemented to locate, identify and mark the components needed to be extracted.[10]. The computing device can process the image based on -

- Size, Shape (Area of the board).
- Color.
- Location (coordinates on x, y-axis).
- Edges.
- Size and Shape of components (Area).

The color will help distinguish components, boards, and connection points. Size and shape will help map the board better and with precision. Combining these two data of colors and area will create a nearly accurate positional data for desoldering with distinct identification. The software will process the image and provide observational data by mapping the board in matrix format. This will help create a convolutional neural network that can be trained to identify and mark the locations of the connection spots to be desoldered. Components can then be identified with template matching using the color, area, and location data. This can be read to the axis control unit as a requirement for positioning and desoldering.

3.3. Desoldering stage

Desoldering process has a vital role in the proposed system. The desoldering has three processes involved including : the movement of the robotic arm along with the heat gun, desoldering the component, and dismantling the component completely off the board with a blower.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 04, April-2022

3.3.1. Movement of the robotic arm

The work envelope of the robotic arm will be a linear 2-dimensional space consisting of the X and Y-axis. If required, the robot can be designed to fully utilize the 3-dimensional space, in which the Z-axis can be used to provide an angle to the arm for precision and reach in complicated corners or to control the intensity of the heat gun. Selecting the correct robotic mechanism for the purpose can be done by taking into account the shape and dimensions of the PCB boards in question and the speed required (based on the requirement and capacity of the unit). The arm speed also needs to be decided early as per the requirement of the industry. Speedy operations can introduce movement errors due to no damping mechanisms involved. While slow operations will increase process time they will provide more precision. Selecting the optimal mechanism for movement can be done considering the following parameters:

Weight of the probe holding unit (m),
Motor torque (τ),
Area of the board (A),
Average height of the component on the board (h).

3.3.2. Desoldering

The solder used commonly for electronic circuits and PCB is a Sn63Pb37 (tin 63% /lead 37%) alloy with a melting point around 180-190°C [5]. This solder is also widely known as soft solder. To melt this solder a two stage heating process can be followed which is preheating and then desoldering during the reflow stage[2]. The paper proposes a hot air blowing method for desoldering. The temperature should be optimal so as not to excessively damage any pin or component on the board. During the preheating, temperature will ramp up at a rate of 2.5°C per second and the desoldering will be in the reflow zone where temperature should be around 225°C for 90s [9].

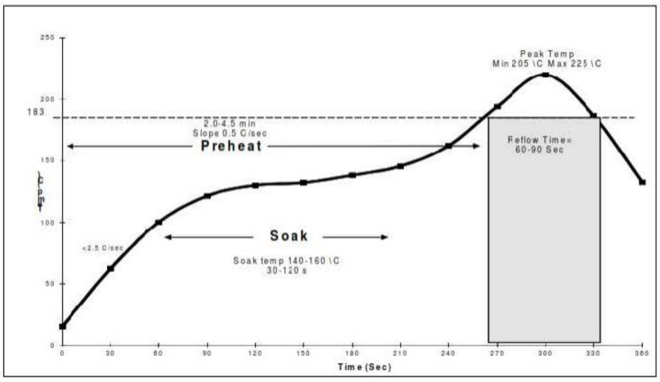

Fig. 3.3.2 Desoldering[10]

3.3.3. Dismantling

The Dismantling process also can be complicated as the fitting of the components may be stiff enough to hold the component even after solder is dropped off. This will create a need for extra mechanisms in order to force the component out of the connection holes. If possible the component can be dismantled due to falling out naturally but in order to assist the process, a blower is proposed which should be at a set angle to the pinholes of the component to get the solder away, so the components may drop off from the PCB onto the bay.

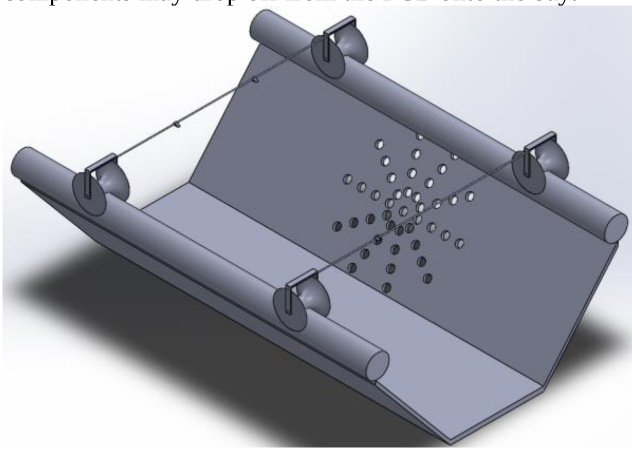

Fig. 3.3 CAD model of desoldering bay

3.4. Sorting stage

The components can be sorted according to shape or weight by creating an inclined floor where the dismantled components will accumulate and slide off onto the conveyor. These components can then be taken to the collection area using the conveyor belt, for OK testing and further processing.

IV. SYSTEM WORKING

The delivered PCB board will first be clamped and held in place by mechanisms such as clamping or conveyor setup. All probes and arms will be reset to the origin position. The camera will capture the PCB board with the components. This image will be processed using machine vision software. Software must be trained on the required PCB boards in advance for identifying the components and marking the coordinates for the connection spots. The software will collect data such as the area and shape of the PCB and components, location, color, etc. This data will be compared with the template's data (trained data) to provide locations and component identity. This will be verified manually in earlier stages of the deployment and operation until the software provides accuracy over 85%. This data of locations and components will be given to the desoldering units namely axis control and probe control. These units will move accordingly and the probe will start preheating the area of connection spots and then desolder the pins with hot air. As the solder melts the components are expected to fall out naturally as the PCB will be upside down (alternatives can be considered). The blower will be used to blow air on the board to force the components out of the pinholes (alternatives can be considered). The components will fall off the board onto the inclined bed region which then can be led onto a conveyor, where the components can be sent for OK testing and sorted according to the categories required. The PCB board after dismantling can be taken to the next process which is shredding and separating the materials by weight, metallic and non-metallic properties. Further the materials are harvested as granulated substances for manufacturing processes.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 04, April-2022

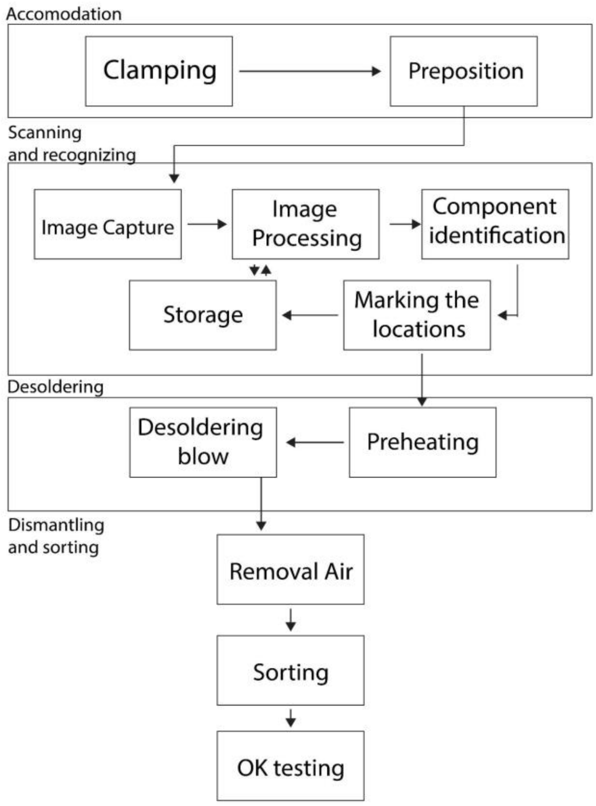

Fig. 4 Block diagram of the system

VI. COST-BENEFIT ANALYSIS

The proposed system utilizes resources that are readily available in the market for use, with the exception of some equipment that will have to be specially configured or fabricated. Even these devices are designed with keeping the generalization of the system in mind. The costs to be considered can be classified as tangible (hardware and software) and intangible (maintenance, training) costs. The cost calculated is a one-time investment cost that doesn't include up-gradation and future developments in design. The cost can vary depending on design choice, industry specific requirements, and availability of machines. For accommodation, if the system is built around manual accommodation the cost incurred will be approximately Rs.3,000 (includes motor, clamping, rods for movement). If automatic accommodation is chosen, the cost will be Rs.9,000 for conveyor setup. The PCB scanning is the most costly to set up in the proposed system that includes the camera and its setup. As the camera has to be high speed with good resolution and must be compact. The camera setup will cost Rs.5,000 and above. The software and computing device cost is the highest, as machine vision requires high performance computation. So, the price will reach Rs. 1.5 lakhs approximately with other input and output peripherals like keyboard, display screen, storage. The desoldering bay needs to be fabricated, which can cost around Rs.9,000. Here, the robotic setup for using the heat probe will cost Rs.50,000. While dismantling and sorting set up can cost around Rs.10,000, that includes the conveyor and sorting mechanism. The intangible costs include the software testing phase and maintenance cost for the desoldering probe. Complete cost of equipment and software will be approximately Rs.2.5 Lakhs. Even adding the regular maintenance and professional charges setting up the entire system wouldn't cross Rs.4 Lakh. Reusing the dismantled equipment wherever possible, would save up manufacturing cost and if the system is designed well it can even be used for harvesting very small components cleanly. The received data about the PCB will also help the company to design a better product and overcome the flaws of the manufacturing.

VII. MARKET ANALYSIS

The Indian PCB market exhibited high growth from 2015 to 2020. Looking forward, the IMARC group expects the market to grow at a CAGR of around 18% from 2021 to 2026. In the Asia-Pacific area, India is one of the largest and fastest-growing consumer electronics markets. PCBs are used in a variety of industries, including electrical devices, vehicles, power systems, computers, and aerospace. The Indian government has also supported manufacturing through initiatives such as 'Make in India' and 'Digital India.' The government hopes to stimulate local manufacturing plants through these programs [7]. This is likely to result in considerable progress in a variety of end-use industries, positively impacting overall PCB demand [3]. Since 2011, India has laws in place to manage e-waste, requiring only authorized dismantlers and recyclers to collect e-waste. India accounted for 178 registered e-waste recyclers, accredited by the government in 2019 [4]. Majority of the companies dealing with recycling in the country use manual dismantling techniques which take a lot of processing time. Yet these techniques prove to be economical as there is very little technology involved. Dismantling units are available in the market but these systems dismantle components as trash. The market still sees the recycling sector as a small non-profit, no-loss sector. Hence, there are less companies involved in these technologies. As new systems like the one proposed in the paper become more common, the recycling sector will also be seen as a profitable market and more companies will join in.

VIII. BUSINESS ADAPTATION

The system proposed in the project is a generalized approach and can be used in any industrial setting. But to make the system more efficient it is advised for every manufacturing industry to have such a department that will ensure its own components and reusability to profit for the company itself. The company will have more accurate data on the product's important components and flaws. Having an in-house dismantling and recycling unit helps to collect data on damaged as well as well-working components. This can help the company in improving the product and also provide profits from the harvested components. Government can also make it a compulsion to have an in-house recycling system for every manufacturing company. And as the system presented in the paper makes use of the existing technologies, the cost of building such a system accounts for a cheaper and a one-time expense. The system will also be improving continuously after every operation as it has elements of machine vision and machine learning. Considering the employment lost due to automating the process, the same manpower can be utilized in verifying the accuracy of the system. Many new positions and roles for collecting the WEEE, Recycling awareness, and management can open up. This type of business model in the consumer electronics sector has the potential to have a significant impact on the commercialization of recycling businesses. It can prove to be profitable to the company and give greater returns as the company gains data, profits, and its own components even as waste. Such a type of ecosystem in the consumer electronics industry can reduce the hazardous waste to be let out into the environment and flourish the companies by getting data on their own flaws and strengths.

IX. DRAWBACKS IN THE SYSTEM

The system being general, there are drawbacks in the system which can be eliminated by certain steps. The clamp will have to be redesigned if the board is broken. The PCBs need to have allowances for accommodating into the clamp setup. As the camera doesn't have a designated area it will have to be kept in the desoldering operation bay. This might introduce thermal noise while capturing the PCB image. Accounting for damping should be done for the robot arm moment if speedy operation is chosen for the process. While desoldering, the heating air should be blown precisely onto the solder as there are components that obstruct the air. After desoldering, there may be cases where the component doesn't fall off the board naturally. Here, the external air force will be applied yet such issues can arise at times.

X. CONCLUSION

WEEE is growing at a faster rate globally. With the digitalization of many sectors and new advancements in various areas, the quantity of electronic waste generated will increase substantially. A simpler way to reduce the accumulation of this waste and elimination is by recycling and reusing whatever is possible. But if the technology and methods used for recycling and reusing are commercialized, it can give a huge boost to the economy and also bring in a lot of big projects and companies in this business. This paper presents a setup that makes use of the technologies and mechanisms already available in the current industrial setting for dismantling WEEE PCBs. Re-configuring these technologies would create a system that will be simple and cheap to install while helping extract more value from the WEEE. The paper also suggests for every electronic manufacturing company to have in-house recycling and dismantling set up to provide better results for innovation and put a step forward toward a better future. As the system advances further in design and more precise mechanisms can be used, it will be easier even to desolder and dismantle SMD components and smaller integrated chips from small sized PCBs.

REFERENCES

[1] Jianzhi Li, P. Shrivastava, Zong Gao and Hong-Chao Zhang, "Printed circuit board recycling: a state-of-the-art survey," in *IEEE Transactions on Electronics Packaging Manufacturing*, vol. 27, no. 1, pp. 33-42, Jan. 2004, doi: 10.1109/TEPM.2004.830501.

[2] S. Janusz, K. Marek, A. Aneta, S. Wojciech and J. Kamil, "Challenges of reuse and remanufacturing of modern chips in smart mobile devices," 2016 Electronics Goes Green 2016+ (EGG), 2016, pp. 1-7, doi: 10.1109/EGG.2016.7829846.

[3] Indian PCB (Printed Circuit Board) Market Size, Share, Analysis and Forecast 2021-2026

[4] Recycling of e-waste in India and its potential

[5] Modeling solder melting of Tin/Lead — Ansys Learning Forum

[6] Make In India Programme, All About The Manufacture in India Initiative

[7] Selecting the Correct Camera | Selecting Machine Vision | Machine Vision Basics | KEYENCE America

[8] Dr.S.Chatterjee, "*Electronic Waste and India"*

[9] Sn63/Pb37 No Clean Solder Paste 4860P Technical **uh8 9 Data Sheet

[10] Machine Learning and Computer Vision for PCB Verification