Milan OPALIĆ, Krešimir VUČKOVIĆ, Nenad PANIĆ
Sveučilište u Zagrebu
Fakultet strojarstva i brodogradnje

Consumer electronics disassembly line layout

ISSN 0351-1871
UDK 621.3:628.477
Stručni članak / Technical Paper
Primljeno / Received: 15. 12. 2003.
Prihvaćeno / Accepted: 14. 6. 2004.

Summary

Reuse and recycling have become crucial owing to the rapid advance in technology, which leads to the accelerated obsolescence of electronic equipment. Disassembly is the first stage in the recycling process. Manual disassembly has proven to be the most efficient although cost-effective method. Automated systems are justified only when relatively uniform-type equipment or assemblies are disassembled. Layout changes can enhance the disassembly speeds by efficient material movement. New disassembly line layout concept introduces solutions for known problems in existing layouts

KEYWORDS:
disassembly
reuse
recycling
hazardous materials
layout

KLJUČNE RIJEČI:
rastavljanje
ponovna uporaba
oporaba
opasni materijali
postav

Postav linije za rastavljanje potrošačkih elektroničkih uređaja

Sažetak

Ponovna su uporaba i oporaba postali iznimno važni zbog brzoga napretka tehnike koja vodi do ubrzane zastare elektroničkih uređaja. Rastavljanje je prvi korak u procesu oporabe. Iako skuplje, ručno se rastavljanje pokazalo kao najučinkovitije. Automatizirani sustavi nalaze gospodarnu primjenu samo pri rastavljanju istovrsnih uređaja ili sklopova. Promjene u postavu mogu povećati brzinu rastavljanja učinkovitijim kretanjem materijala. Zamisao novoga razmještaja radnih mjesta za rastavljanje elektroničkih uređaja predstavlja rješenje za poznate probleme s postojećim postrojenjima.

Introduction

Electronic equipment, in the broadest sense, refers to any product that relies on batteries and/or electricity for operation. In this paper the focus is on electronic equipment typically found in residential waste stream, commonly referred to as consumer electronics. This includes brown goods, small household appliances, home and office, data processing and telecommunication equipment. This paper doesn't deal with other equipment, such as white goods and commercial equipment, because the infrastructure for the disassembly and recycling of such equipment is already well established. Consumer electronics contains some hazardous materials such as lead, cadmium, mercury, antimony, arsenic, barium, beryllium and selenium, which is why the disposal of obsolete or broken consumer electronics is a serious and costly problem. Reuse and recycling have become crucial owing to the rapid advance in technology which leads to accelerated obsolescence, resulting in increased volume of consumer electronics for disposal. Landfill constraints require that new and better reuse and recycle methods should be found. The legislation on recycling and the drafts on electronic scrap regulations have the objective to recycle a maximum of material groups from scrap materials and to dispose waste from recycling processes by using environmentally sound methods. Disassembly as the first stage in the recycling process provides means to efficiently remove components and assemblies containing hazardous materials, extract valuable components or metals, selectively destroy or recover proprietary parts, and avoid or reduce contamination in downstream volume reduction (shredding) and separation operations[1]. This paper introduces solutions for known problems in existing layouts that occur during disassembly process such as disassembly speed, lifting, contamination risk, cluttering of tools and overloading of the sorting operator.

Disassembly process

Most demanufacturers receive a large variety of electronic equipment, including personal computers, printers, small household appliances, brown goods, white goods, telecommunication equipment, cellular phones, large electric motors and electronic systems. This equipment ranges in weight from 0.1 to 2000 kg [2]. Large and heavy units are usually cut to smaller parts. Disassembly begins with an operator manually lifting and carrying the unit or part to be disassembled to a workbench from the sorting/staging area. For heavy parts a forklift is used. Disassembly work is manual and, if possible, at least mechanized. Mainly used are conventional tools driven pneumatically or electrically such as chisel, tongs, screwdrivers, etc. Selectively disassembled parts are placed on a conveyor belt or in bins. Full bins are hand-carried to a sorting area by the operator. If the operator at the disassembly workstation does not sort items, specially trained operators in the sorting area perform sorting and separation of disassembled parts into sorting bins by visual inspection. Primarily valuable parts and hazardous components are removed intact and visually inspected for possible reuse (chips, memory, hard drives, etc.). The secondary output stream, for example, contains intact plastic and steel cases, printed circuit boards and hazardous waste, such as batteries and capacitors.

Manual disassembly has proved to be the most efficient although cost-effective method. Automated systems are justified only when relatively uniform-type equipment or assemblies are disassembled[3].

Current layout configurations

Existing layouts can be divided in three different configurations[2]. In the first one, after receiving units from the receiving dock, the operator disassembles them on a workstation and puts the disassembled parts into their respective bins around the table. These workstations normally follow a parallel batch operation method, so that each operator independently receives a batch, then disassembles the unit and finally delivers the full bins to the collection/shipment area. The problem is that the operator spends most of his time in material handling activities (receiving and delivering) rather than disassembly, and is lifting and placing units to be disassembled. In the second configuration, products arrive into the sorting and staging area on the conveyor. Products are then sorted and scheduled for disassembly, as opposed to the first configuration, where products are disassembled without any prior sorting. The disassembly operator receives products from a sorting area and delivers the disassembled parts to the sort bins area. This is also a parallel operation where only a single operator is involved. The material handling time is less than that of the first configuration, because products arrive closer to the workstation for disassembly. Problem is that this configuration requires more effort in delivering disassembled parts to sort bins area every time the disassembly process progress. Operator, also in this configuration, is lifting and placing all units to be disassembled. The third configuration is similar to the second one except for the addition of a conveyor for disassembled parts. An operator disassembles units at a workstation adjacent to the conveyor belt. As each piece is disassembled, it is placed on the belt. A skilled operator then sorts the disassembled parts into different bins at the end of the conveyor. This layout reduces lifting and lowers cost by increasing actual disassembly time by introducing a conveyor belt for disassembled parts. Problem is that conveyor carries mixed parts to sorting place. The operator, who places these disassembled parts into bins at the end of conveyor, may get overloaded.

For all configurations, a characteristic is that there is no arrangement such that all items of similar type could be disassembled on a separate group of dedicated workstations, eliminating cluttering of tools at a single workstation[2].

New disassembly line layout concept

New disassembly line layout configuration has been designed for disassembly of electronic equipment typically found in residential waste stream, commonly referred to as consumer electronics (Figure 1.). This includes brown goods, computers, small domestic appliances and small office and telecommunication equipment. Prior to disassembly, electronic equipment is sorted at collection sites. Units that are considered to have the least commodity value (clocks, house telephones, etc.) are sent to an auto shredder for mechanical separation. Units that have potential value are sent for testing to be reused or refurbished for sale. Units that are returned from testing, because they did not pass it are, with the rest of the equipment, sorted by type and sent to disassembly facilities.

The layout configuration is divided in two partially separated disassembly lines (they share an outgoing conveyor for disassembled parts and a sorting place). The first line is an improved and upgraded version of the previously mentioned third layout configuration and is designed for disassembly of electronic equipment, weighing from 0.1 to max. 25 kg (telephones, computers, vacuum cleaners, microwave ovens, etc). The second line is an improved and upgraded version of the previously mentioned first layout configuration and is designed for TV sets and computer monitors disassembling.

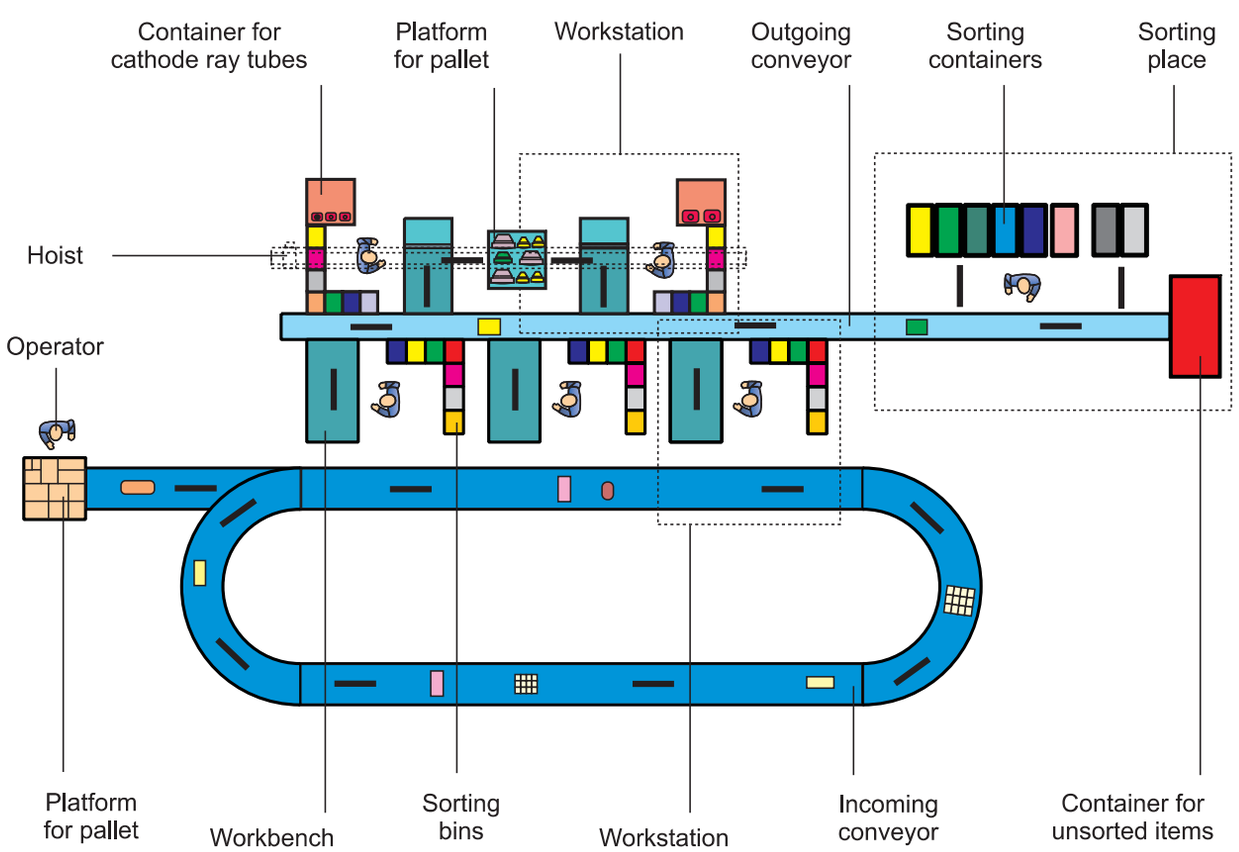

FIGURE 1. Disassembly line layout

The disassembly process at the first disassembly line starts with a forklift carrying sorted items on a pallet from the receiving dock to a closed loop roller conveyer. The pallet is placed on the unloading platform that is in level with the conveyer. Items are, then, manually unloaded from the pallet onto an 80 cm wide closed loop conveyor by an operator, and transported to disassembly workstations adjacent to the conveyor. All disassembly operations are performed manually. After disassembling, easily identified larger parts such as plastic and steel cases are placed directly on the outgoing 60 cm wide belt conveyor. Smaller parts are sorted at disassembly working station into appropriate sorting bins. Sorting bins are in different colors and each color corresponds with a disassembled component type. Full sorting bins are placed onto the outgoing belt conveyor and together with larger parts transported to the sorting place. The operator at the sorting place near the end of the outgoing conveyor sorts the disassembled parts in the appropriate containers.

At the second disassembly line, the disassembly process starts also with a forklift carrying TVs and monitors from the receiving dock to the unloading platform. Smaller items are manually lifted and carried to the workbench by the operator, while the rail hoist placed above the pallet and the working stations carries heavier ones. The disassembling process is similar to the one described at the first disassembly line. Sorting is done at the already described sorting place. Because cathode ray tubes are easily broken and because they contain hazardous materials such as lead, phosphorus and beryllium[4] they are not placed onto the conveyor for disassembled parts but in a container adjacent to the workstation. Intact cathode ray tubes are sent to specialized facilities for further treatment. It's not recommended to break cathode ray tubes because when broken they are treated as hazardous waste and transportation costs are significantly increased. The gained volume reduction compared to intact cathode ray tubes is only 2-3 times[5].

Conclusion

Layout changes can enhance the disassembly process by efficient material movement. The new disassembly line layout concept introduces solutions for known problems in existing layouts. Focusing on the disassembly of electronic equipment found in residential waste stream and sorting it by type prior to disassembly enhances the disassembly speed because the operators disassemble similar equipment per time unit. The closed loop conveyor is introduced so that the operator could pick certain type of unit which is the most similar with the last one disassembled. Because of all that, the cluttering of tools at each workstation is significantly lowered. Placing only easily identified disassembly parts directly onto the outgoing conveyor and sorting other ones at workstations into appropriate colored bins increases visual inspection and thus reduces the possibility of overloading the sorting operator. Lifting is reduced to a minimum by introducing hoists, platforms and conveyors while the workstations are placed adjacent to them. Introducing the partially separated disassembly line for this type of equipment reduces the contamination risk by hazardous materials found in the equipment containing cathode ray tubes.

The disassembly process can be further enhanced by implementing automatic operations for specific processes, such as punching out screws, or unscrewing screws. Manual sorting operations can be replaced with automatic vision recognition system but its effectiveness must be enhanced.

Acknowledgement

This paper is the result of research conducted as part of the TEST project number: TP-02/0120-14 supported by the Ministry of Science and Technology of the Republic of Croatia.

REFERENCES

1. Koch, P., Kasper, R.: *Dismantling and Process Technology for Electronic Scrap and Discarded Electrical Appliances*, Aufbereitungs-Technik, 37(1996), 211-220.
2. N. N.: *Demanufacturing of Electronic Equipment for Reuse and Recycling Technology and Demonstration Center: Mission Need Statement*, National Defense Center for Environmental Excellence (NDCEE), DEER2, 2000, www.deer2.com, 10. 7. 2003.
3. Kopacek, B., Kopacek, P.: *Intelligent Disassembly of Electronic Equipment*, Annual Reviews in Control, 23(1999), 165-170
4. Menad, N.: *Cathode Ray Tube Recycling, Resources*, Conservation and Recycling, 26(1999), 143-154.
5. N. N.: *CRT Recycling Project*, Cascade, 2002, /www.cascade-assets.com, 2. 7. 2003.

DOPISIVANJE / CORRESPONDENCE

Prof. dr. sc. Milan Opalić
Sveučilište u Zagrebu
Fakultet strojarstva i brodogradnje
Ivana Lučića 5
HR-10000 Zagreb
Hrvatska / Croatia
Tel.: +385-1-61-68-109
Fax: +385-1-61-56-940
E-mail: milan.opalic@fsb.hr