SEMIAUTOMATIZED DISASSEMBLY - SOME EXAMPLES

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Abstract: The semi- or fully automatised disassembly especially of selected electr(on)ic devices is not only because of the standardization by the European Commission (Directive on waste from electrical and electronical equipment – WEEE) today a hot topic. One of the consequences is the increasing inefficiency of manual disassembly in the next years. Manual disassembly of such devices is today the state of the art. Usually only the toxic components are removed and the rest of the materials are shredered and deposed. The paper deals with some examples of semi-automatised, flexible disassembly cells. The main idea beyond is to develop a "tool kit" for such cells. Furthermore a hierarchical control structure consisting of PLCs as well as control computers is described and special control problems shortly outlined.

Keywords: Disassembly, disassembly cells, hierarchical control, distributed parameter system

1 INTRODUCTION

In Austria the first partly implementation of the European WEEE concept was to build a prototype of an **"**Economical Disassembly Plant for Sustainable Reuse of Parts, Components and Materials from Electr(on)ic Products" in the last years. The main innovative features of the system will be:

- ability to disassemble different boards with only few software modifications of the system
- low investment costs
- step-by-step investments because of the modularity
- the predominant working conditions (toxic vapours, hard work) could be changed efficiently by the system
- the work security and job quality will be increased
- because of the modularity it is easily possible to build up disassembly cells for different product groups
- the possibility of extracting some components without damage in an economical way for reusing and
- it fulfils all criteria proposed by the draft directive for waste from electrical and electronic equipment.
- Existing concepts are very inflexible and only developed for a special task or product. „Stiff" automated disassembly in single purpose cells – only for one product (e.g. one type of PC`s) – cannot be economically feasible today. The number of devices or parts to be collected and concentrated on the place of the disassembly cell is usually to low for a two shift operation of the cell. For example in the case of computer-keyboards of a distinct type all keyboards from whole Europe per year could be disassembled in three month by one fully automated cell.

2 SEMIAUTOMATIZED DISASSEMBLY CELLS - EXAMPLES

Compared with assembly disassembly is much more complex because of used parts which could be affected by corrosion or other influences during their life cycle.

2.1 Disassembling of minidisks

Sony DADC Austria was one of the largest producers of optical storage units – Mini Discs as their main product. As it is typical for every industrial production, some of the produced Mini Discs do not satisfy the desired high quality standard. Due to the rising waste disposal costs and the high costs of human work, an automatic recycling of Mini Discs was the key aspect of this project. There are two different types of Mini Discs in production: a playback-only and a recordable.

An assembled playback-only Mini Disc consists of the following parts- Upper Cartridge, Label, Disk, Clamping Plate, Shutter Lock, Shutter, and Lower Cartridge. The recordable one has a Shutter on both sides.

The clamping plate is made of a special type of magnetic steel - the label is made of paper. The Upper and Lower Cartridge as well as the Disc consist of Polycarbonat, the Shutter Lock and the Shutter of Ployoxymethylen.

The disassembly cell consists of two main components: a feeding system and the disassembly system itself. Furthermore there is the cell control unit, a transportation unit between the two components, and sensors to control the operation.

The feeding system takes the Mini Discs from a container. A recognition or inspection of the particular Mini Disc is not necessary, because every disk is the same and there is no wear, pollution or damage. The transportation system is equipped with sensors to orientate and align the Mini Discs.

Afterwards the Mini Disc is taken to the disassembly system. It will be fixed and cracked with wedges from the side separating the Upper and the Lower Cartridge. A vacuum gripper picks the Upper Cartridge and puts it into the special container. An optical sensor controls that the Upper Cartridge reaches its destination. At the next stations of the system the Clamping Plate, the Shutter Lock, and finally the Shutter are removed with special tools. The proper courses of these operations are also controlled by sensors. Every part is given into a specific container, where they are stored for further processes.

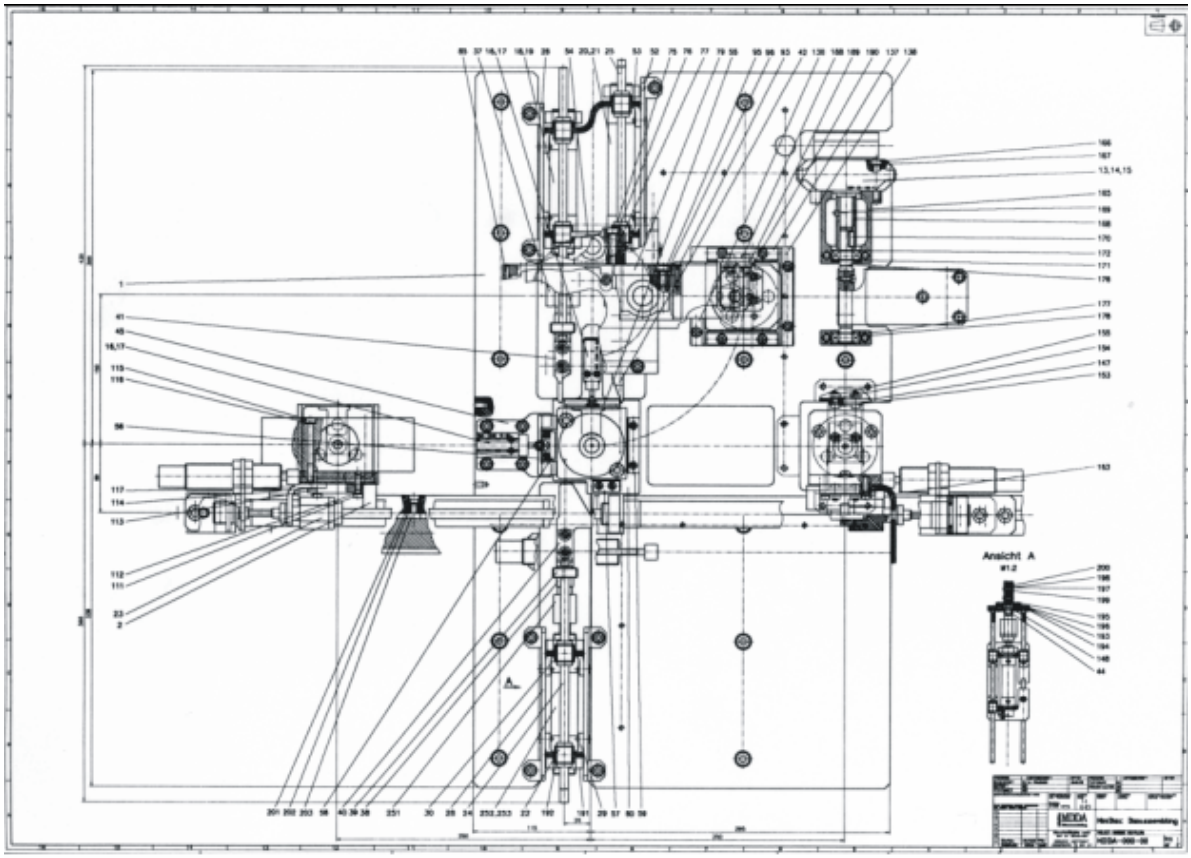

Fig. 1. Disassembly Cell for Minidisks

2.2 *Disassembly cell for printed circuit boards (Kopacek, 2001; Drinek et al. 2001)*

On old or new PCBs there are several re-useable parts. These chips can be soldered in old or new technique or socketed. The task was to develop a semi automatized disassembly cell for both kinds of chips.

The layout of the cell is shown in Fig. 2. The basis of a disassembly cell is a very stiff frame construction developed from commercially available profiles. In a manual feeding station the PCBs with a maximum size of 300 x 220 mm are attached on special work holding device. The disassembly cell consists of 4 stations:

- Vision system
- Laser desoldering system
- Removal station
- Heating removal station

The vision system has several tasks. It has to recognize the re-useable parts by means of a data base containing the data (kind, production company, assigned, dimensions). The vision system has to detect the re-useable parts and to determine the position, the size and the centre of inertia. Furthermore it has to classify the parts to be desoldered or removed from sockets.

The desoldering station consists of a cross table – two linear axes – controlled to reach every point (centre of inertia) on the PCB. The desoldering process is carried out by laser technology. The desoldered parts are put on a distinct area outside the laser from which they are removed by the industrial robot and to put into the appropriate magazines.

The third station is the removal station for socketed parts. An industrial robot equipped with special grippers as well as external sensors carries out the removing process. The robot removes these parts and puts them also in the right magazines. A prototype of this disassembly cell is now in the test phase.

2.3 *A semiautomatized Disassembly Cell for Mobile Phones (Kopacek, Kopacek, 2003)*

After a detailed analysis of used mobile phones concerning the parts as well as the assembly technology and tests for disassembly with the most frequent mobile phones the following concept for the disassembly cell was created (Fig. 3.). It consists on five automated stations plus a manual feeding and removal station:

- Feeding and removal station
- Drilling and milling station
- Removal station for the covers
- Drilling station
- Circuit board removal station
- Drilling station

For disassembly,the mobile phones were fixed on a pallet in a distinct position. These pallets are moving around on a transportation system. According to the necessary disassembly operations the pallets with the mobile phones to be disassembled are stopped, lifted and fitted in a distinct station.

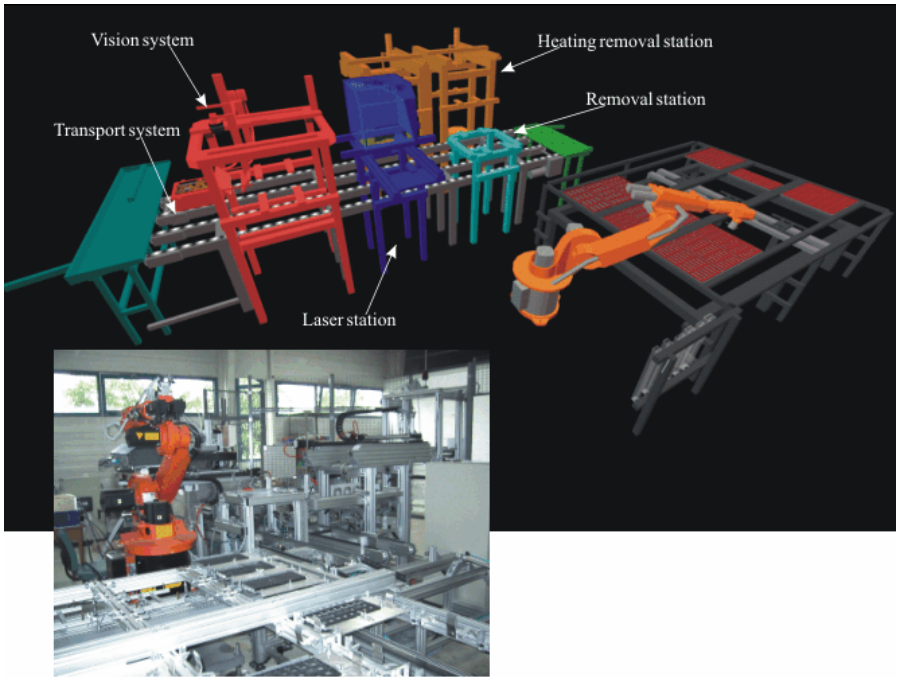

Fig. 2. Disassembly Cell for PCB's

Before the mobile phone is fixed on a pallet the power supply will be removed and the type of the handy will be recognized by a barcode reader manually. Now the control computer knows exactly the type of the handy. The main dimensions of the handy are stored in a database of the host computer.

In the drilling and milling station the upper part of the handy will be cut off from the lower part and the screws – usually between 4 and 17 – are removed by a simple drilling mechanism. The dust content is removed by air from the pallet.

In the cover removal station the cover as well as the keyboard of the handy will be removed by pneumatic sucks. These two parts are separated in a storage device. In the drilling station, e screws which connect the printed circuit board on the lower part of the housing are removed. In the printed circuit removal station various other parts will be removed from the handy and separated in special storage devices. Because some mobile phones have additional parts connected with the power part of the housing of the handy the remaining screws will be removed in the last drilling station. Finally the lower part of the handy will be removed in the fixing and removal station.

As a development of this semi-automated disassembly cell for used mobile phones some previous tests were necessary. For the milling in the drilling and milling station it was necessary to make tests with grinding wheels, with different saws and with milling devices. Finally a milling device was chosen as the right tool for this task.

Further extensive tests were carried out for the removal of the screws. From the literature there are very high sophisticated, complicated and therefore very expensive and heavy devices known. We found a very simple and very cheap method for the removal of the screws.

3 CONTROL

For these modular, flexible, semi-automated, intelligent, “low cost” disassembly cells a hierarchical control concept is necessary. It have to be a modular system for the hard- as well as the software - modular control software.

In such cells binary as well as digital information (data) have to be submitted and handled. Therefore the control hardware consists of a control computer

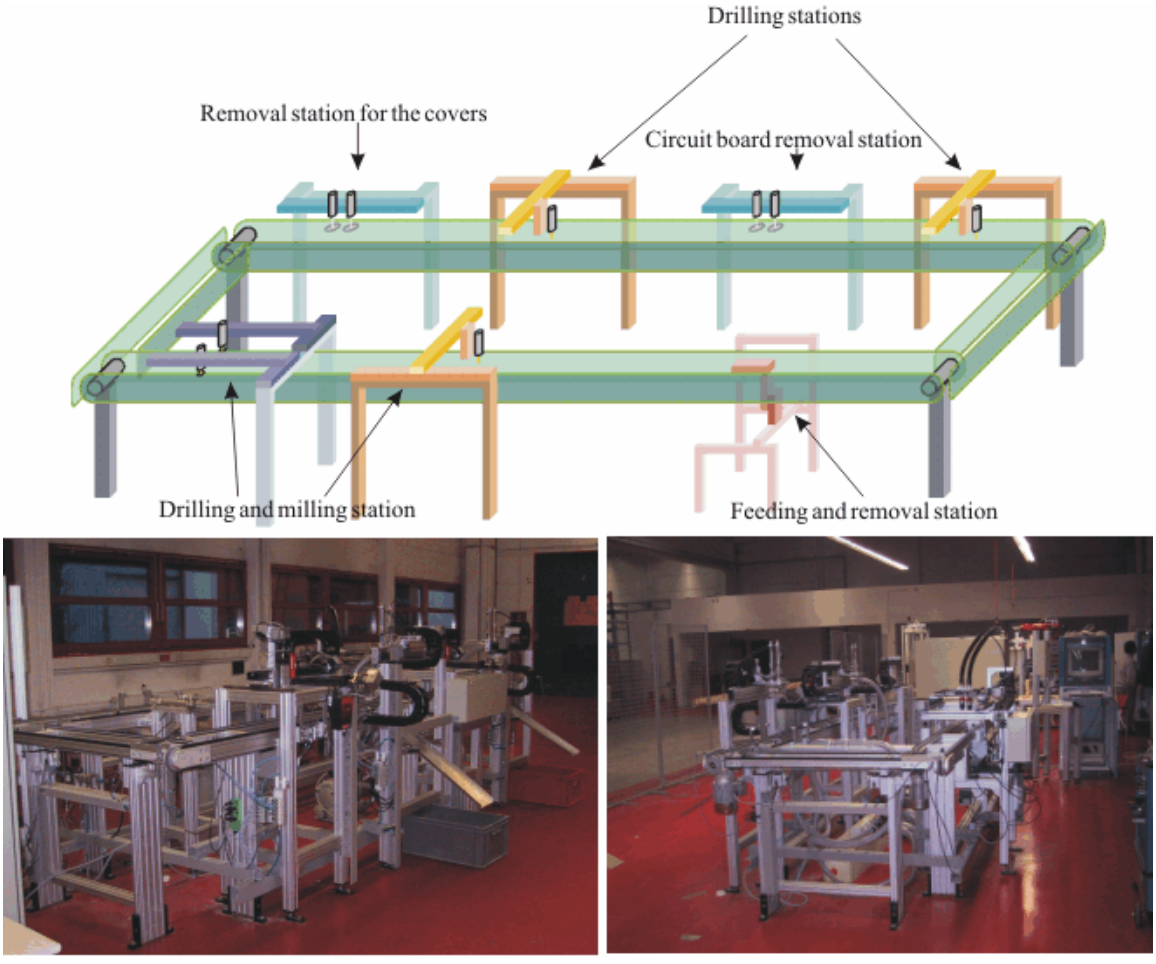

Fig. 3. Disassembly cell for moile phones

(CC) for data processing and a PLC (programmable logic controllers) for handling of binary information.

It consist of one CC connected to a database (DB), several PLCs and local control units with an appropriate user interface. In the DB information on the re-usable and therefore parts to be disassembled are stored. This connection is bi-directional: the CC can ask the DB for more or less detailed information about these parts. On then other hand the DB can give additional information probably necessary for recognizing reusable parts. Based on the requests of the CC the DB is able to "learn" – collect and store – additional information (intelligent or self learning DB). The CC supervises the PLC`s and is responsible for logistics in the cell. CC submits binary information like data transmitted to station x; the PLC have to quit this information. Because of the education of the operators of such a cell a user friendly interface is absolutely necessary. Usually a panel with three push bottoms (START, STOP, SECURITY STOP) and several warning devices (lights, sound, …) might be appropriate. For the system supervisor a computer keyboard, a screen, a printer are necessary. For very simple applications the CC can be replaced by an "advanced" PLC.

The PLCs are responsible for the supervision of the cell stations or components. They have to process binary sensor information from the system components and to actuate vice versa components or parts of them. They are connected to distinct components of the cell directly or to their local control units. In the latter case PLCs give only the start commands and are waiting for their execution.

Local control units are commercially available control devices which are necessary and attached to commercially available components of such a cell (e.g. robots, laser de-soldering, …). They are connected to the PLCs as well as to the CC. One of the main problems of local control units are the different data interfaces. Fig.4 shows a part of the HMI.

An Internet connection between several cells allows the transfer of data for statistics as well as new programs, program upgrades, program parameters. This could be a first step in the direction of so called "e-cells".

But there are also some "classical" control problems to solve. One example is the temperature control in the infrared heating station of the PCB disassembly cell. Fig 4 shows the temperature profile for an one layer PCB after 100sec heating.

Theoretically the system is nonlinear with

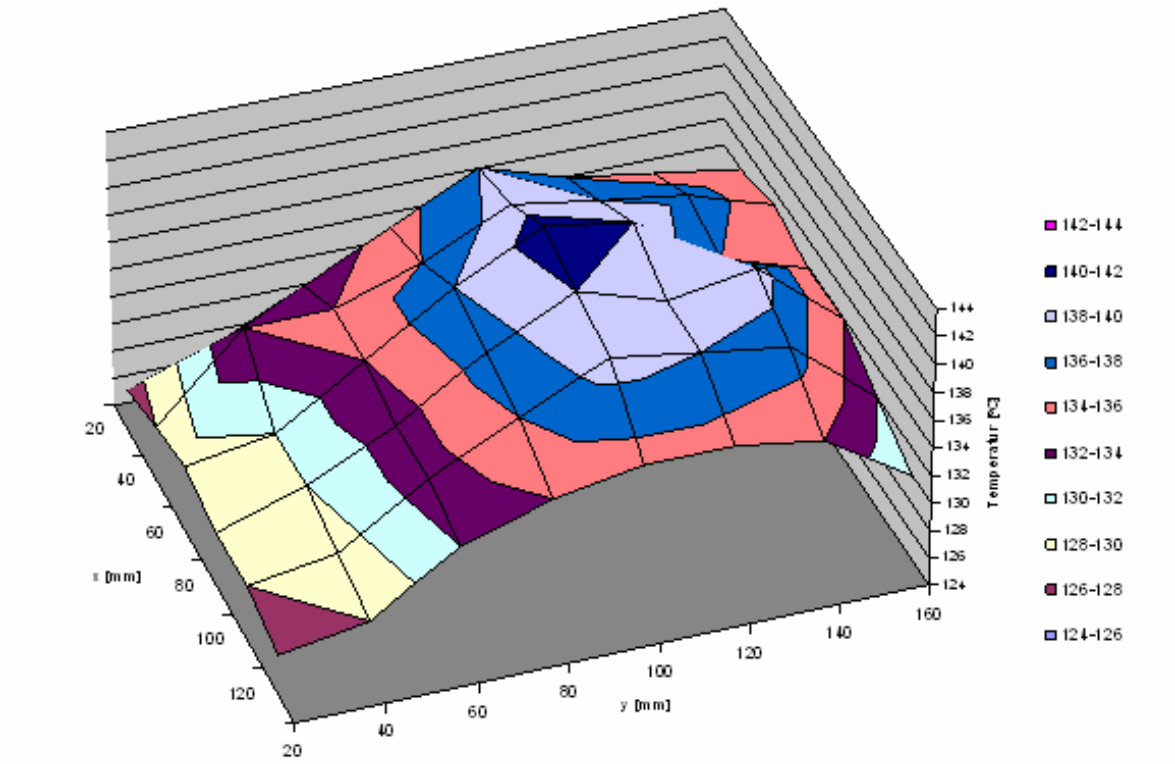

Fig.4 Temperatureprofile for a one layer PCB after 100sec heating, Decker (2005)

distributed parameters. But from the viewpoint of control engineering the dynamic behaviour of this system can be approximated by a first order lag element – gain K and time constant T_1 - with a small dead time (T_t). The time constant T_1 as well as the dead time T_t varies for heating and cooling until a factor of 3 and all the parameters depends from the coordinates on the PCB. Therefore we have to control a direction depended distributed parameter system.

The control is realised by a 3 group PWM algorithm. Furthermore the different melting temperatures of the solds and the maximum possible temperatures for the various chips are used for a "disassembly logistics" automatically generated by the CC.

4 SUMMARY AND OUTLOOK

Semiautomatized disassembly especially for electr(on)ic equipment becames more and more important today und in the nearest future. Starting 10 years ago semiautomatised disassembly cells were developed. In this paper 3 examples are described and shortly discussed. One of the mayor features is the modularity of hard- and software of these cells.

For the control a hierarchical system was realised. The PLC-program is according to IEC 1131 / DIN 61131 using as HMI a display, lamps and pushbottoms. Robot-Programs are written in a special „robot" language. The program of the Host are realised in Visual C++ with the HMI Windows and the Control program of the laser in Visual Basic.

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