PRESENTATION OF A NOVEL APPROACH TO RECYCLE METAL COATED PRODUCTS

Dipl.-Ing. Prumbohm M. F., Prof. Dr.-Ing. Lohrengel A., Dr.-Ing. Schaefer G.
Institute of Mechanical Engineering – Clausthal University of Technology, Germany

prumbohm@imw.tu-clausthal.de

Abstract: *By recycling old products mainly the elements, which are contained in large amounts in the product, are regained. Taking metal coated Waste Electrical and Electronic Equipment (WEEE) as an example, this is the plate of the component cover, which is made of steel or aluminum, the included plastic, the printed circuit board's material and copper. Those materials, which are contained on the printed circuit board belonging to the area of specialty metals such as tantalum, indium, palladium etc., cannot economically be extracted from a shredder plant's output mass flow. To solve this problem, a new approach for an automatic decomposition of metal coated components is introduced based on the process principle of the roll crusher. For finding a solution the systematic design approach and a first pilot plant's results are presented. Based on these results, conclusions for future developments are derived.*

Keywords: RECYCLING, DISASSEMBLING, WEEE, METAL COATED PRODUCTS, PRODUCT DEVELOPMENT

1. Introduction

With the increasing development of recycling technology the decomposition of metal coated products with valuable internal components is getting into the research focus. These products especially include WEEE. Those are for example hard drives, server and disk drives from desktop computers. In this context the automotive sector with its control units, entertainment units in high quantities and inverters from hybrid vehicles is quite important. The common WEEE recycling is structured into the detection of type and contaminants followed by sorting and extraction of the hazardous components. After this the shredding of the remaining products takes place in a machine (1). In this context it has to be pointed out that only for large parts or special units a manual disassembly is profitable.

As a result of the shredding process the outgoing mass flow, which contains small amounts of recyclable materials such as tantalum, indium, palladium etc., is highly mixed with all other materials. Large material fractions as plastic, ferrous metals and non-ferrous metals can be profitably separated from this mass flow and are reusable. This is not possible for small amounts of the previously named materials. They are getting lost for the recycling economy. Due to this effect the current recovery quota for these materials and some other important specialty metals from post-consumer-wastes is less than 1 % (2). Manual disassembly is the alternative to shredding as it is easier for the recycling of all the materials. However, as it enables on the one hand the separation of the circuit boards with only a few impurities and their use for another process, this procedure is on the other hand also very time-consuming and mostly not economically efficient. A third option for the preservation of all contained component materials, is the reuse of the whole component after some testing and repair work. This is done for instance by the Bosch company with components from the automobile sector (3).

2. Estimation of economics

Before a new approach is being developed, the needed time for the separation of components and the expected revenues are estimated by literature information. For this purpose a study on the content of recyclable materials such as circuit boards is used (4). Those circuit boards are taken from different car types. Within this study the revenue for the manual disassembly of the most profitable components is identified. In the following the revenue for the circuit boards is averaged over the different car types. For the manual disassembly the averaged revenue is 1.65 €/component. The gearbox control is with 7 €/component highly above this price (without considering the gearbox control price the averaged revenue amounts 0.96 €/component only). Comparing those values to german repair shop costs of 35 €/hour or approximately 0,58 €/minute, a maximum disassembly time of less than 3 minutes for a commercially profitable disassembly is required. Based on this assumption a revenue of 0.49 €/component is reachable, with a disassembly time of 2 minutes. This time target is difficult to reach even if impurities are neglected. A process, which separates at least 3 components/minute, increases the revenue by nine times up to 4.37 €/minute. Not considered in this calculation are the inverters in hybrid vehicles. Those reach a revenue up to 12.20 €/component, which improves the attraction of the manual disassembly as well as the attraction of an automatic separation process significantly. This rough analysis shows that an automatic component separation can be economically profitable.

3. current state of shredding processes

Components at the end of their life cycle are treated either by manual disassembly or more often by machines. The outgoing shredded fractions are sorted by type, decomposed and purified. Several well working first stage shredding processes exist for the shredding of components belonging to the WEEE-field. However, the recycling of elements, which are integrated only in small amounts in the component, cannot be regained afterwards, see chapter 1. It is looked upon the following existing shredding processes for metal coated components in more detail. They are the basis for the solution development, which is followed by an evaluation. In the brackets the main types of loads are listed (1); (5):

- profiled roll crusher (depending on the profile: pressure, shearing, impact),
- ripping machine (tension),
- rotary shear (combination of bending, tension, shearing and torsion lead to a complex stress state),
- Querstromzerspaner (impingement) (6) and
- pre-crushing machine SB² (impingement, shearing, bending) (6).

These listed existing shredding processes are compared with the following criteria of an ideal automatic separation process:

- complex stress states support separation with little deformation
- high stress speed supports separation with little deformation
- deformation of the component cover through pressure, impingement and impact by the process are rare or do not occur
- embedding of ductile elements of the component cover are avoided (double weighted)

An ideal solution fulfills the criteria entirely and is weighted with 100 %. It is used as a benchmark for the existing processes. The evaluation result shows that no existing process fulfills the majority

of the criteria. The profiled roll crusher achieves the best result with 54 % of an ideal solution. The main disadvantages of this process are the compaction of the components during the separation process and the cutting component due to the profiles.

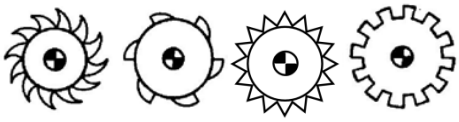

Fig. 1: *Considered roll crusher's profiles: toothed-, cam-, sting- und ripple-rolled crusher (5)*

The second-best result is achieved by the rotary shear with 42 %. Rotary shears have well suiting preconditions for the separation of metal coated components because of their complex stress states. However, the strong cutting component causes a good crushing of the electric and electronic components as well as a deformation of the component cover. The special application of the Querstromzerspaner and of the pre-crushing machine SB² from the manufacturer Andritz-MEWA are very well suited for electrical components with brittle component covers or components with metal elements and with high wall thickness such as die-cast cassis (6). Yet they are only limited suitable for the presented problem, see Fig. 2.

Fig. 2: *Querstromzerspaner's results. There are inclusions and compactions of the metal component cover.* ***(6)***

The evaluation results reveals that there is a high developing potential for a new process in comparison to the existing processes. The demand for the development of such a process is confirmed by the environmental authorities in Germany and Switzerland (3); (7); (8).

4. Solutions

Following the construction systematics by (9), the development of a new process for the automatic separation of metal coated components starts by developing a functional structure, which covers the main elements of the still unknown process. Root of this structure is the main function, which has to be fulfilled. The main function is described as follows:

Metal coated components, for instance from the WEEE-field, shell be opened due to energy input in a way that the inner components can be easily sorted and processed. Impurities of the inner elements in deformed cover components are avoided.

The main function shell be fulfilled by the part functions "component supply", "energy transfer" and "exit of the components". By using the constructing systematic tools "brainstorming", "synetics" and "morphological box" possible process principles are differentiated. As a result the tests for the principle of splitting, stripping and opening by sawing are carried out. Also the existing principle of the profiled roll crusher is tested. Desktop PC's CD-ROM-drives are used as testing components for all tests. For those a metal component cover with inner drive elements is typical. Due to their operating conditions they have a similar size and shape, which are independent of the manufacturer and the year of construction. Besides this CD-ROM-drives are easily available and have no data-protection related requirements like hard disks.

Splitting toll

In a first testing series the splitting of metal coated components is examined. The experimental setup allows examining different splitting tools as well as different heights respectively different velocities and energies of the fall. Considering a continuous process possible advantages of a drawing cut are tested. Furthermore the quality of component separation is regarded depending on the height of the fall, on the used energy input and on the component cover's deformation, which is depending on the tool's shape.

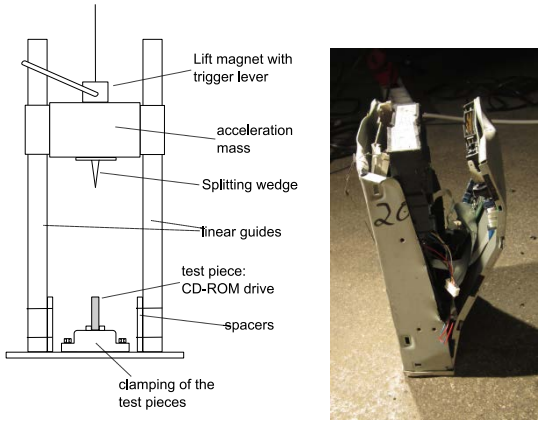

Fig. 3: *Left side: Schematic picture of the test series 1 to open the components. Right side: good result with little deformation but without a complete opening.*

No advantages of a drawing cut are discovered. Narrow and sharp tools penetrate the component's cover well at a minimum work of 880 J and a minimum velocity of 3 m/s, see Fig. 3. A reliable and complete component's opening has to be ensured trough a higher energy input per component. However, this endangers the process' economical implementation. With a high energy input per component the revenue decreases and by that the main advantage compared to a manual disassembly. Furthermore the cutting process turns out to be highly depending on the component's shape. With growing bending stiffness of the construction parallel to the cutting tool's direction of the fall, the deformation on the component's cover decreases, see Fig. 3. To use this circumstance effectively, an automatic component detection and orientation has to take place. Again this means a higher technical and economical effort. Due to the dependency of functionality on the component's shape the process of splitting is not persuade upon in more detail.

Profiled-roll crusher

After some further tests the best common process, the profiled roll crusher process principle, is modified and tested. The test bench is realized as shown in Fig. 4. As a special feature the adjustability of the roller gaps is emphasized. It should reduce or rather completely avoid a component's compaction. Only during deactivated test bench state the adjustment of the roller gabs is manually done. It is driven by two motors, each having 0.75 kW. The torque is transferred with rigid couplings to the roller axis. The tested roller speed varies from 6 – 36 rpm.

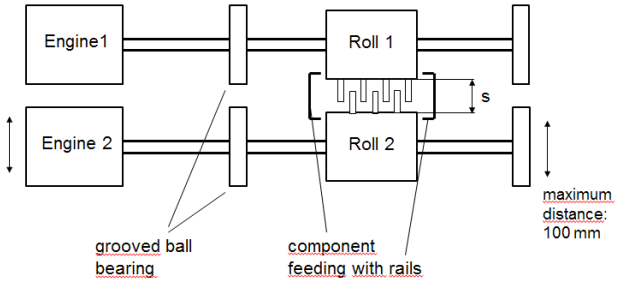

Fig. 4: *Schematic view from above the test bench, which is based on crushing with profiled rolls*

After the test run the evaluation of the test's is done depending on the component's opening degree. It is differentiated in

- 0 %: no opening, no main deformation of the component‘s cover, only perforation and grinding marks
- 25 %: no opening, only one cover side is highly deformed
- 50 %: partly component opening, one cover side open, other sides have only little deformation (this evaluation stage is declared as the minimum for an aceptable result)
- 75 %: partly component opening, one cover side is open, a second cover side is strongly deformed and almost open
- 100 %: complete opening, component is completely separated or at least two sides are completely open and on the inner component's elements are only a few cover rests.

5. Results and Discussion

As shown in Fig. 5, the results are promising. The component's cover is separated tidy and completely from the inner component's elements. This is done in one process step. At the moment components having a width of $s \leq 42$ mm can be fed to the system and are opened. For hard drives as well disk drives satisfying results are gained too.

Fig. 5: *Result with a 100 % - rating*

The best results are achieved with a roller gab, which is at a maximum the component's width. By that the component's compaction does not occur. The opening of only 21 % of the components does not satisfy the expectations. More than half of the used components with this parameter setting are completely opened, see Fig 6. This value meets the previously done theoretical evaluation.

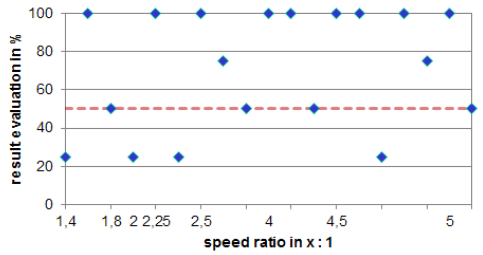

Fig. 6: *Result chart with distance between the rolls ≈ component width*

With the existing testing bench metal coated components are opened in an automatic and continuous process. Besides the automatically running main process, the accompanied processes such as supply, stripping of component rests and size setting are manually done in a deactivated state only. After the first step of process verification the further goal is to expand the process scope of performance in a second plant. For reaching market maturity the occurring stresses have to be documented and considered for the follow-up plant's construction which fulfills the stress requirements. The prospective goal is the separation of all kinds, shapes and sizes of metal coated components, which mainly come from the automotive sector.

Further steps will be

- more powerful motors
- flexible component guidance system
- flexible distance between the tool plate
- new tool design
- new solution for stripping of component rests
- maintenance suitable tool design

Including those changes, the process reliability of good and very good results should be increased up to over 80 %. Along with that the process evaluation improves compared to an ideal solution. Due to the changes a new concept for component separation is developed.

6. Conclusion

Within this article the need for developing a new concept for a continuous opening of metal coated components has been described. The carried out studies for possible solutions led to the redesign of the process principle of the profiled roll crusher. By changing the speed, the roll gab and the tools the first tests have shown remarkable results. Also some further possible improvements have been displayed. Those will be the basis for future research work at the Clausthal University of Technology.

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