ASSESSMENT OF RECYCLABILITY FOR ELECTRICAL EQUIPMENT

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The proposed model of EOL (End-Of-Life) products recyclability evaluating is based on product disassembling and analyzing of its structure: time required for disassembling, quantity of components, materials, recyclability of components. The model has been applied on the sample of twenty-five electro-equipment items (small household appliances, computer equipments). The recyclability of products is expressed as a ratio between established and maximal possible recycling applicability. Calculated value is potential reciclability for EOL products. The paper also describes short procedure for recyclability determination, named “recyclability indicator”, based on material structure of product.

1. INTRODUCTION

The End-Of-Life (EOL) products caring becomes more and more expensive obligation. Recycling is a method of EOL products processing that can earn benefit covering costs and even achieving profit. The study deals with assessment solution of recyclability EOL products. The recyclability is a characteristic marking suitability of a product or material to be separated from scrap and re-used as functionally sound part or raw material source [1, 2, 3]. Investigations up to now haven't offered generally accepted method for the evaluation of products' recyclability.

2. THE MODEL OF RECYCLABILITY EVALUATION

The model determining recyclability of product, which met the end of its life, has been established [4]. In the first phase of the model's application experimentally are determined the basic indicators relevant for the recyclability evaluation. Six indicators determined during dismantling are used. These are respectively the name of element, number of repetitions (b_i), sort of material/component, time required for separation, the mass of element (m_i), and the most important indicator – the recyclability of particular element (r_i). To determine the recyclability table is used (Table 1) comprising the scale of marks from 0 to 5, where the higher mark is attributed to parts being recycled the most successfully. Such evaluation manner is based on the scale used by Vehicle Recycling Development Center (VRDC) [5]. The table has been adapted to broad application (electro technical appliances and electronic equipment, telecommunication devices and so on). The class of hazardous waste has been introduced, bearing the lowest mark 0. The application of the table assumes knowing of available wastes treatment processes.

Table 1. Material recyclability evaluation

Mark	Definition
0	Materials or part contains hazardous substances – special treatment is necessary.
1	Material is inorganic with no known technology for recycling.
2	Material is organic - can be used for energy recovery but cannot be recycled.
3	Material is technically feasible to recycle with further process or material development require.
4	Material is technically feasible to recycle - infrastructure to support recycling is not available.
5	Material in part is recyclable - with a clearly defined technology and infrastructure.

In the second phase, complex indicators on the product level are calculated according to the basic indicators. These are:

B the total number of product elements (lower, more desirable)

M the total mass of product

B_{vm} the number of sorts of materials/components (desired is as low number of different material sorts as possible). Undeveloped recycling processes require more detailed sorting (more expensive)

VR the total time needed to dismantle product (sum of particular dismantling operations, separation and storing)

R the recyclability of a product is the ratio between parts recyclability sum, weighting by the mass and maximal recyclability of product. This is dimensionless index amounting from 0 to 1. It is calculated according to the expression (1)

$$R = \frac{\sum_{i=1}^{n} b_i \cdot m_i \cdot r_i}{M \cdot r_{max}} \qquad (1)$$

where:

R..... the recyclability of product
b_i .... the number of repetitions of *i* part in the product
m_i .... the mass of *i* part
r_i..... the evaluation mark of *i* part recyclability
r_{max}.. the highest recyclability evaluation mark, here it is 5
M .... the total mass of product, kg

The good side of such recyclability evaluation is the consideration of technological level of recycling in given surrounding. It means that the same product has higher degree of recyclability (processing and utilization) in developed surrounding than undeveloped one. The level of recyclability increases by discovering of new processes, i. e. by the development of recycling technology.

3. THE APPLICATION OF MODEL ON ELECTRICAL PRODUCTS

The model has been applied on the sample of 25 electrical products (aged electrical household appliances and computer equipment). The calculation of indicators has been facilitated by the application of table calculator in MS Excel.

Table 2. Complex indicators of recyclability on the sample of electrical product

Product name	Total mass of product, M, kg	Total number of product elements, B	Number of sorts of materials/ components, B_{vm}	Total time needed to dismantle product, VR, s	Recyclability, R
Coffee maker	1.59	64	6	269	0.7
Iron A	1.37	46	4	174	0.75
Iron B	1.16	57	3	185	0.82
Food mixer	0.92	38	3	96	0.58
Coffee mill A	0.7	40	5	125	0.6
Coffee mill B	0.6	17	3	72	0.55
Coffee mill C	0.61	31	3	86	0.62
Personal computers AT 286	16.12	51	3	125	0.74
Printer	3.31	30	5	170	0.76
Hair dreyer	0.45	22	3	50	0.59
Telephon A	0.86	25	3	48	0.63
Telephon B	0.85	59	4	78	0.28
Keyboards A	1.34	247	4	393	0.63
Keyboards B	1.23	218	4	350	0.39

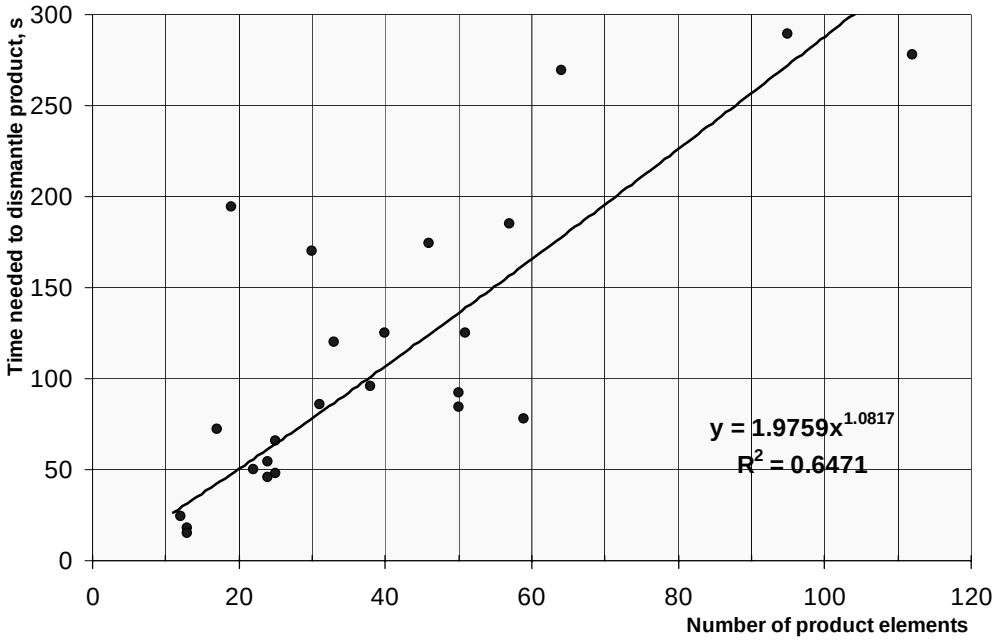

Figure 1. The dependence between number of product elements and time needed to dismantle product

Table 2 indicates recyclability (R) of other products, mostly ranging from 0.40 to 0.70, which may be mainly attributed to the older generation of products when recyclability had not been demanded. The lowest recyclability, 0.28, has aged telephone set (because of high contribution of unmarked polymers and printed circuits having low

recyclability evaluation marks). The high recyclability of 0.82 indicates electric iron (because of high iron content).

Viewing numerical recyclability amounts, values from 0.75 to 1.00 are considered to be the favorable result. The values ranging from 0.50 to 0.74 indicate the necessity for product reconstruction (redesigning) or selective dismantling (separation of poorly or highly recyclable components). Values bellow 0.50 indicate to down-cycling processes (the lower quality of recycled materials) or disposal. In the interpretation of of numerical values of recyclability caution is needed because the model does not consider other important aspects of processing (costs, dismantling time, environment load and others). Obtained recyclability values in this sense should be accepted as special potential of product reprocessing.

The model, under minor adjustments, may be used for shortened calculation of recyclability (so called recyclability indicator, pR). The calculation is based on multiplication of proportion of mass material or component in the structure of product with recyclability evaluation mark (table 1) as of a measure of recycling suitability of particular component of run out product (metals, the best; hazardous wastes, the poorest). The idea is to apply such recyclability calculation to cases when only proportions of materials in product are known. The coincidence of results of shortened (pR) and complete recyclability calculation (R) has been checked on the results obtained on the sample of run down, aged products [4]. The correlation coefficient of 0.92 is established between the recyclability and «recyclability indicator».

4. CONCLUSION

Conclusively, the model provides numeric expression of EOL products to recycling. In that sense, the model is beneficial to compare products on the basis of recyclability and to estimate recycling profitability. The model of product recyclability analysis is easy to use and it provides basic data for the evaluation of recyclability of products or units. Limitation is the result of fact that obtained recyclability values depend on the level of technological development of given surrounding, i. e. they are not comparable for different countries, or, more precisely, for different economic development.

5. REFERENCES

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