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Disassembly sequence and cost analysis for electromechanical products

Tsai C. Kuo

Department of Industrial Engineering and Management, Shu-Teh Institute Technology and Commerce, Taichung, Taiwan

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Abstract

For companies, the improvement of the recyclability performance of their newly designed products is becoming an integral part of product development process. The concept of environmental conscious design (ECD) has been adopted to assist the environmental performance of the products at the early stage of designing. This new trend requires that the design strategies need to be modified by integrating the environmental constraints. This paper provides the disassembly sequence and cost analysis for the electromechanical products during the design stage. The disassembly planning is divided into four stages: geometric assembly representation, cut-vertex search analysis, disassembly precedence matrix analysis, and disassembly sequences and plan generation. The disassembly cost is categorized into three types: target disassembly, full disassembly, and optimal disassembly. The result of this approach shows that the electromechanical products can be disassembled systematically and economically.

Keywords: Disassembly sequences; Graph theory; Design for disassembly

1. Introduction

Resource optimization (energy and material) and environmental issues in product life-cycle context are taken very seriously by companies as well as government agencies. For example, the governments of Germany and the US require that original equipment manufacturers (OEM) need to take responsibility for the disposal of their products [1]. The Green Plan of Canada was produced in 1990 to reduce the stabilization of CO_2 and other greenhouse emissions by the year 2000 (MSS 1990). Some governments have also set up official Eco-labeling schemes, which are intended to inform customers of environmentally friendly products. All of these regulations are intended to minimize the environmental impact of products.

These activities urge designers to design new products that are more environmental friendly and economical. Alting [2] proposed life-cycle engineering (LCE) approach, which emphasizes that products affect the environment at many points in their lifecycles (Fig. 1). These environmental impacts could be minimized only if the products can be disassembled and recycled easily. Disassembly is defined by Brennan et al. [3] as "the process of systematic removal of desirable constitute parts from an assembly while ensuring that there is no impairment of the parts due to the process". Two methods are used to remove components or materials: destructive and non-destructive disassembly. For destructive disassembly process, the most common ways are shredding processes. In shredders, scrap is compressed and fed into a drum, where it is ripped apart by a set of rotating hammers until it is sufficiently small to drop out of an output grid. Then, light materials (e.g., textile or some plastics) are separated from heavy weight materials (e.g., steel or other ferrous metals). It results in fractions containing more than one material (e.g., a mixture of plastics and metals) and more separation and identification are required.

For the non-destructive disassembly process, the products allow complete material recycling of products, along with possible part and subassembly reuse [4]. From the perspective of recycling, the non-destructive disassembly can have higher recycle value for the electromechanical products. However, it needs to have a systematic method to analyze the disassembly sequences and processes. This paper provides the disassembly

E-mail address: tckuo1@tcts.seed.net.tw (T.C. Kuo)

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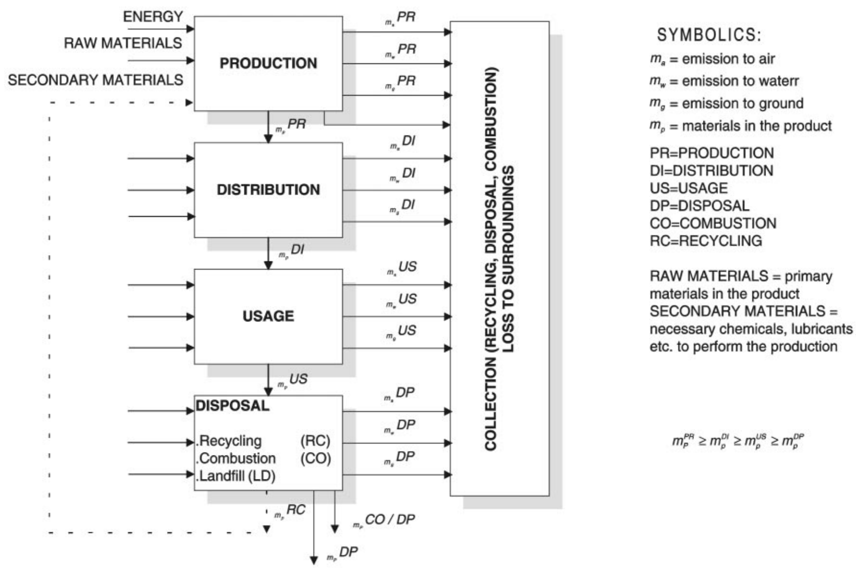

Fig. 1. Material flow for product life cycle [2].

sequence and cost analysis for the electromechanical products during the design stage. The disassembly planning is divided into four stages, geometric assembly representation, cut-vertex search analysis, disassembly precedence matrix analysis, and disassembly sequences and plan generation. The disassembly cost is categorized into three types: target disassembly, full disassembly, and optimal disassembly.

2. Literature review

A possible disassembly sequence is defined as "to remove one part without interference from other parts [5]". A lot of research work and effort on the analysis of disassembly sequences can be found in the literature [5–7]. These approaches include user/planner interaction, heuristics, expert systems, and geometrical modeling and reasoning. Bourjault [8] presented an approach for the generation of all possible and valid assembly sequences for a set of parts that form an assembly. The information contained in the part list and assembly drawings was used to characterize the assembly by a network in which nodes represent parts and the lines between the nodes represent any of the user-defined relations between parts, called "Liasons". A liason diagram shows the assembly connections between parts and is created by the user.

Ko and Lee [9] also used the mating graph to describe the assembly. Ko and Lee's system chose the part that has the most virtual links (or connections) with other parts as the base part. Then, parts that have a connection with the chosen base are grouped, and a part hierarchy is built from it. The next step is enforcing ordering among siblings, assuming that the base part will be assembled after its descendants. This is done by checking the interference exhaustively between siblings by pairs. Lee [10] developed sweeping tables by using the concept of degree of freedom of the part and the degree of interference between parts. A sweeping table is a matrix that represents the disassembly direction. Theoretically, once the sweeping tables are obtained, all the possible sequences can be generated. However, this system is not designed to be fully autonomous. For complex cases, it will be very difficult to build a sweeping table.

3. Graph-based approach with a case study

In this paper, we propose the disassembly sequence generation based on a disassembly tree analysis. A disassembly tree is a group of possible disassembly sequences. The disassembly relationships among the components of an end of life product are represented by using the language of graph. To determine the disassembly sequence, the first step is to analyze the structure of a product. Product structure refers to the geometric components and assembly relationship among these components. In this paper, the product model is represented as a graph in which all the relevant components, physical relationships, non-physical relationships between them are displayed. These relationships include component-fastener assembly relationships and disassembly precedence relationships. In order to represent the relationships among the components of an electromechanical product fully, the component-fastener relationship graph and disassembly precedence matrices are developed. The second step is to obtain the disassembly modules from the whole