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Optimization for Disassemble Sequence Planning of Electromechanical Products during Recycling Process Based on Genetic Algorithms

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Abstract

Disassemble and re-manufacturing is an important way to save energy. Sequence planning is the core issue of disassemble. In this study, disassemble model has been established based on the analysis of disassemble route planning and disassemble sequence. The disassemble sequence optimization based on genetic algorithms has been carried out. In the gear pump disassemble sequence, for example, an illustrative example, proposed in this study to verify the disassemble sequence planning based on electromechanical product recovery process optimization genetic.

Keywords*: Disassemble sequence planning; Disassemble routine planning: Genetic algorithm: Optimization*

1. Introduction

Increased impact on the environment issues of waste industrial products have become increasingly prominent, resulting in excessive consumption of resources and energy. To save energy, and product can be remanufactured, recycled green design theory is proposed by many scholars. Disassemble and re-manufacturing is the product lifecycle management indispensable part of a recyclable resource key [1-2].

Sequence planning is the core issue of disassemble [3-5]. In addressing disassemble planning problem, according to most researchers T. L. deFazio and D. E. Whitney [6] proposed a network diagram, graph theory, and then combined with an exhaustive search method to deal with P. Veerakamolmal *et al* [7] proposed by the modular nature of the product in order to minimize the time and cost to arrive at a disassemble efficient disassemble sequence. They also propose a working knowledge of the laws of the different structure of the electronic device a set of modules, removable [8]. T. C. Kuo *et al*. [9-10] undirected graph constructed based on recycling demolition model mechanical and electrical products, try to cut through the set of the graph shows the disassemble sequence planning algorithm, and an example to the host computer recycling demolition application analysis. C. Chung *et al*. [11] In consideration of fastener disassemble tool on the basis of accessibility, disassemble least time and at the lowest cost as the goal, based on an undirected graph heuristic algorithm to construct the disassemble sequence planning method of mechanical products. G. Erdos [12] heuristic algorithm to obtain the components within the product structure to solve the problem disassemble. K. E. Moore *et al* [13] for recycling or disassemble simple mechanical products, building disassemble Petri net model, proposed demolition and conversion methods or diagrams and disassemble Petri nets, constructed on the basis of the priority matrix, disassemble sequence planning. J. R. Li *et al* [14-15] demolition priority by a predetermined relationship between product components to construct a directed graph model using genetic algorithm proposed method of disassemble sequence for maintenance and use of

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the method of the gear pump, bearing components and other products carried out the repairs disassemble sequence planning.

2. Basic Rule of Coupled Constraints and Disassemble Electromechanical Products

Electromechanical products are composed of many parts made of a combination of parts to form a connection between the relationship. Although a wide variety of mechanical products, but all of the coupling structures have certain similarities. Typically used coupling structure can be divided into non-fastener joints and fasteners connectivity options, according to engineering practice, commonly used disassemble the following rules:

(1) When using threaded connections or pin connections, connector demolition priority to non-connector disassemble.

(2) When using ordinary flat key connection, first disassemble having a hole features are connections, and then remove the connector, and finally dismantle a shaft features are connections.

(3) When using wedge bond or tangential linkage reasonable order of disassemble is to disassemble the connector, then remove with a hole features are connections, and finally dismantle characteristics are connected with a shaft member.

(4) When an interference fit connection bore axis and reasonable order of disassemble is to dismantle the hole feature has to be joined, and finally dismantle characteristics are connected with a shaft member.

(5) When using soldering or direct contact, no specific order of disassemble.

In addition, a part of the demolition process, the positional relationship between the parts will hinder the feasibility of the parts removed. Therefore, the need for product disassemble sequence generated in accordance with the positional relationship between the parts were screened derive reasonable and feasible disassemble sequence.

Filter the principle as follows:

(1) Basic items should finally be demolished. Base (such as base, *etc.*) due to the more complex relationship, and the assembly is generally used as a positioning reference member, it is generally final demolition;

(2) Located outside the internal parts should be disassembled components.

3. Disassemble Sequence and Disassemble Route Planning

3.1. Disassemble Sequence Planning

Figure 1 shows a block diagram of disassemble sequence planning process, the principle is

(1) Find all candidates parts from the assembly;

(2) If more than one candidate for the part, then must first determine the best one;

(3) To determine the best candidate for the part, the part to be demolished route planning;

(4) If find disassemble route, remove from the assembly of the parts of the assembly to adjust, repeat step 1) until the assembly all parts are disassembled; otherwise, go to step 5);

(5) Removing the parts from the candidate centralized parts, repeat step 2);

(6) If the candidate part is empty, then the algorithm is ended.

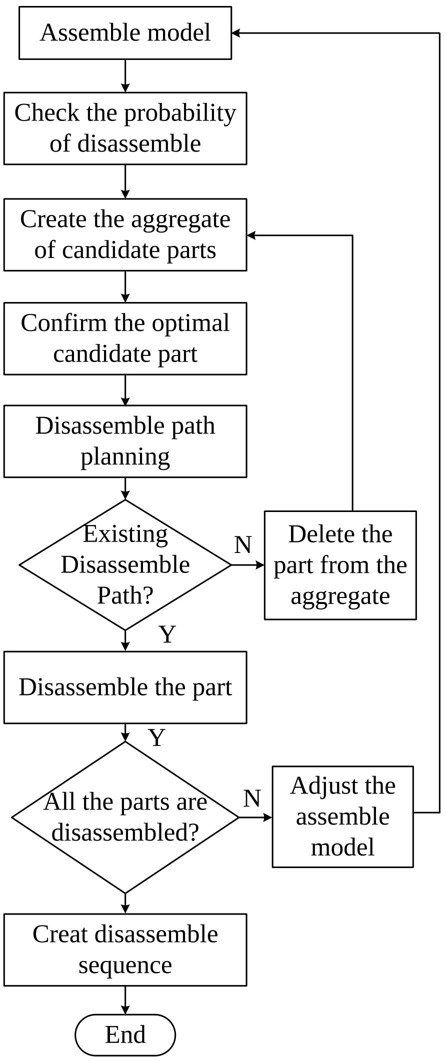

Figure 1. Algorithm of Disassemble Sequence Planning

In the course of the algorithm needs to determine the best candidates for the part, the most important criteria is to determine the best candidate for the demolition of parts to compare the candidates parts, usually good demolition dismantling other parts priority criterion include: the outermost parts , assembly constraints least parts and small parts priority demolition. Under normal circumstances, the assembly on the basis of the final demolition of parts, because the underlying parts are mounting reference other parts, according to the designer's experience, the first assembly base part , it is usually the final demolition.

3.2. Disassemble Route Planning

The disassemble planning algorithm is a very important step is carried out parts disassemble route planning, route planning algorithm can automatically or interactively find the parts disassembled disassemble feasible route, and interference checking globally. Figure 2 is a block diagram dismounting route planning algorithm.

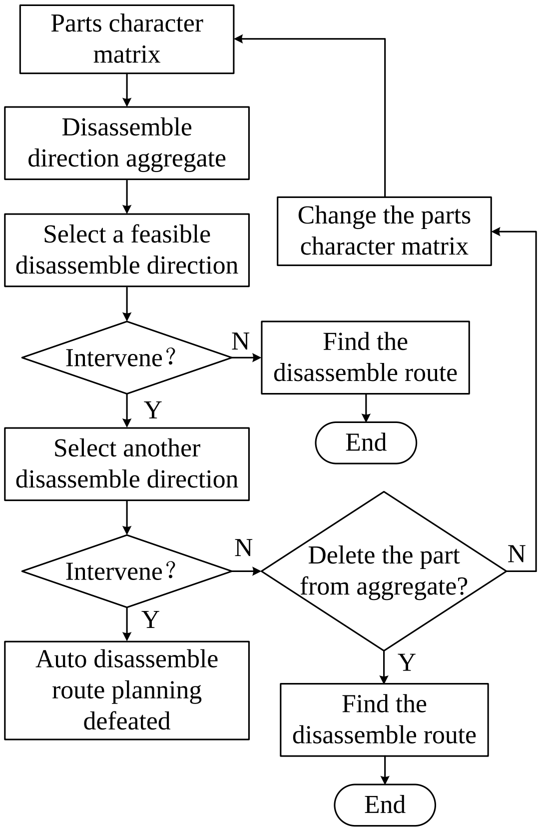

Figure 2. Algorithm of Disassemble Route Planning

4. Disassemble Model Building

4.1. Inter-Parts Assembly Constraints Description

Product disassemble demand model considered here includes: disassemble part information, process information, and demolition constraint information. Specifically described as follows:

Removing parts connection between the main consideration product information in between parts.

Disassemble process information mainly consider the demolition process requires disassemble tool.

Removing the constraint information mainly consider parts detaching direction: + x, -x, + y, -y, + z and -z.

According to information of the product disassemble of parts, product parts into functional parts and connections between the parts assembly relationship can be expressed as [16]

$$G = \{V, E_f, E_{fc}, E_c\} \tag{1}$$

Where, $V = \{v_1, v_2, \cdots, v_n, \cdots v_N\}$ denotes the mini-disassemble unit. N denotes the number of the mini-disassemble unit;

$E_f = \{e_{f1}, e_{f2}, \cdots, e_{fk}\}$ is physical constrains, denotes the direct disassemble and with equal disassemble priority, k denotes the number of the physical constraints.

$E_{fc} = \{e_{fc1}, e_{fc2}, \cdots, e_{fcd}\}$ is importune physical constrains, denotes the direct disassemble and exist equal disassemble priority, d denotes the number of the importune physical constraints.

$E_c = \{e_{c1}, e_{c2}, \cdots, e_{cl}\}$ is space constrain, denotes un-direct disassemble and exist equal disassemble priority, l denotes the number of the space constrain.

4.2 Disassemble Priority Constraint Matrix

In the disassemble process, the priority constraints matrix is used to denote the relationship between priority constrain and connection, the built disassemble priority constrain matrix R expressed as

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \quad (2)$$

In the constraint matrix, the constraint relationship between the parts and disassemble precedence constraints mapping relationship between the matrix elements are defined as follows

$r_{ij} = 0$ denotes there is no disassemble priority constrain and reverse constrain between v_i and v_j.

$r_{ij} = 1$ denotes there is positive disassemble priority constrain between v_i and v_j.

5. Optimization for Disassemble Sequence Planning Based on Genetic Algorithms

In this paper, the genetic operation after the process of considering the feasibility of crossover and mutation disassemble geometric sequence, for geometric feasibility of disassemble sequence is not satisfied, it was abandoned until a sufficient number of offspring to meet the geometric feasibility.

5.1. Fitness Function

Disassemble time, to a certain extent, reflects the complexity of disassemble and disassemble efficiency. Therefore, the goal of shortening the time the disassemble, to optimize the sequence of disassemble. The main factors to consider are: redirect time, the disassemble tool change time and disassemble jig transition time.

(1) Redirect time $OT(i,w)$, denotes the sum of redirect time of i parts in the front of w.

$$OT(i,w) = \sum_{i=2}^{i} ot(i,w) \quad (3)$$

(2) Disassemble tool change time $tt(i,w)$ denotes the disassemble tool change time of the i-th part in the w. Suppose the disassemble tool change times are all equal t_2, then

$tt(i,w) = 0$ denotes no tool change;

$tt(i,w) = t_2$ denotes there is tool change.

$TT(i,w)$ denotes the sum of disassemble tool change time of the front i parts of w, and

$$TT(i,w) = \sum_{i=2}^{i} tt(i,w) \quad (4)$$

(3) Disassemble clamp change time $ct(i,w)$ denotes the disassemble clamp change time of the i-th part in the w. Suppose the disassemble clamp change times are all equal t_2, then

$CT(i,w)$ denotes the sum of disassemble clamp change time of the front i parts of w, and

$$CT(i,w)=\sum_{i=2}^{i} ct(i,w) \tag{5}$$

$DT(i,w)$, the total disassemble time of the i parts in the disassemble sequence w can be written as

$$DT(i,w)=\sum_{i=2}^{i} ot(i,w)+\sum_{i=2}^{i} tt(i,w)+\sum_{i=2}^{i} ct(i,w)(i \geq 2) \tag{6}$$

In order to make the fitness decrease with the time and the fitness function is positive, the fitness function is defined as

$$Fitness(W)=DT(i,w)(1 \leq i \leq N-1) \tag{7}$$

5.2. Flow Process of Genetic Algorithms

Combined with the actual situation of the general idea of genetic algorithm and disassemble sequence planning, disassemble sequence planning algorithm is proposed based on genetic algorithm process as follows.

Step1: Set the initial population size pop, crossover probability Pc, mutation probability Pm;

Step2: Generating initial population Gn meet demolition priority relationship and technological requirements;

Step3: Calculate the fitness of the population of each disassemble sequence;

Step4: Determining an individual selection, crossover and mutation operators;

Step5: When optimizing result does not meet conditions

(1) Select the parent population from the initial disassemble sequence according to fitness;

(2) the parent disassemble sequence of genetic manipulation to produce pop progeny disassemble sequence M;

(3) For each note on behalf of the disassemble sequence, calculate the fitness value;

(4) carried out by individuals and pop pop progeny parent individuals intergenerational competition, get pop on new offspring fitness function, updating the original population with these new individuals;

(5) Set evolution generation n = n + 1;

Step6: Output individuals obtain optimal disassemble sequence.

5.3. Optimization of Genetic Algorithms

(1) Encoding. Using real-coded method expressing the assembly parts information in the genome.

(2) Select operation. Using roulette way to perform select operations, namely higher fitness disassemble sequence is selected to participate in a higher probability of crossover and mutation.

(3) Crossover and mutation.

(4) Determine geometric feasibility of disassemble sequence. The use of interference matrix, in order to detect the sequence of parts of its removable, if there is not removed some parts and components interfere, then abandon this entry disassemble sequence, re-crossing and genetic manipulation, until you produce the geometric feasibility of disassemble sequence.

6. Example Analysis

Figure 3 is a gear pump assembly drawing, the assembly is composed of 12 parts, select 10 as the base member. To optimize disassemble sequence of the assembly, given the following initial conditions: the right to re-take the fitness function is 0.5, the number of initial population pop=30, crossover probability pc=0.9, mutation probability pm=0.1, the number of genetic iteration C=50. Convergence characteristic is shown in Figure 4. The optimized disassemble sequence generated by the genetic algorithm is 12→11→1→2→3→4→6→5→7→9→8→10. After repeated testing, the rationality and feasibility of the disassemble sequence is verified.

7. Conclusion

In this study, disassemble model has been established based on the analysis of disassemble route planning and disassemble sequence. We have carried out the disassemble sequence optimization based on genetic algorithms. In the gear pump disassemble sequence, for example, an illustrative example, proposed in this study to verify the disassemble sequence planning based on electromechanical product recovery process optimization genetic algorithm is reasonable.

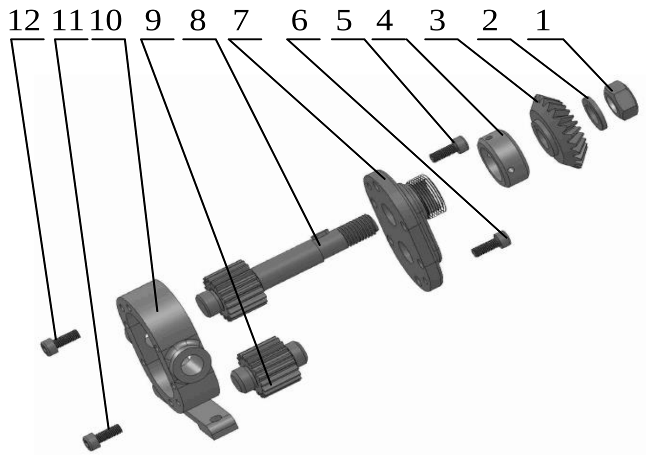

Figure 3. Gear Pump Assembly Drawing

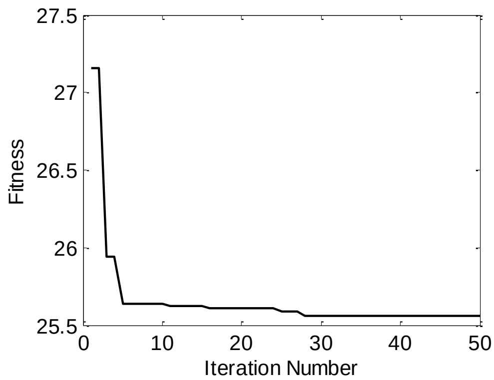

Figure 4. Convergence of the Optimized GA

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