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Disassembly Process Planning of End-of-Life Car

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ABSTRACT

In order to increase competitiveness and to gain economic benefit, companies ask more and more how to recycle their products in an efficient way. So far, to answer this question, companies are not sufficiently supported by suitable methods specially in the area of disassembly process planning. For this reason, we develop in collaboration with an industrial partner a new method for generating an optimal disassembly sequence. In this paper' this method will be described in detail by considering the exiting assembly information, disassembly method and disassembly depth. PLM(Profit-Loss Margin) curve that is used to determine disassembly depth consists of profit value, disassembly cost and disassembly effect. Using assessment parameters, generated alternative disassembly sequences are evaluated and an optimal disassembly sequence is proposed. This method is applied to generate the optimal disassembly sequence of Door Trim as an example.

Key Words : Disassembly depth, PLM(Profit-loss margin), MRFD(Modified reverse fishbone diagram), Evaluation criteria of disassembly sequence.

1. Introduction

Until the end of 20th century, problems about resources and environments have risen gradually all over the world. So the regulations of every country have been strengthened according to this situation[1]. For the last several decades, regulations about cars have focused mainly on air pollution. However, due to the increase of cars, disposal of end-of-life cars has become an important social problem. To solve this problem, the reuse and reutilization of car parts have been considered to be a unique resolution.

An end-of-life car is a large-sized waste that is composed of 20,000 parts. It also consists of various types of materials, such as iron, nonferrous metal, rubber, glass and so on. Also the disassembly and withdrawal of its parts are difficult due to the complex connections between parts.

In fact, most end-of-life car recycling companies don't have information about economical disassembly methods and ability to systematically analyze the recycleability of the parts after disassembly. Therefore, they cannot forecast the volume of reclamation, incineration and recycling of an end-of-life car. Also it is difficult for recycling companies to invest money, time and effort in this research field, because they are usually small scale business companies. From this reason, a disassembly planning system which generates an optimal disassembly sequence and decides an optimal disassembly method and an economical disassembly depth is needed to cope with regulation to be strengthened even more, to enhance competitiveness and to perform disassembly more effectively.

Research on disassembly has been mostly carried out in Europe and U.S.A. who have been interested in the environment and resource problems. The main research fields are a disassembly process planning, design for

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recycling and a development of disassembly system[2,3,4,5,6,7].

Related to process plan, Ishii proposed the Reverse Fishbone Diagram(RFD) as a model to generate disassembly sequences[8]. They took notice of contrary concept between assembly and disassembly in terms of sequence and they expressed the disassembly sequence by using Fishbone Diagram(FD) model for the assembly sequence in reverse order. The RFD having a tree structure is convenient to grasp progress situation and has merits in describing the disassembly process. However, the RFD makes it difficult to express the information about the relationship of the connection and interference between parts. Also the RFD itself can express only one disassembly sequence. It is a fatal demerit that the RFD doesn't generate various alternative disassembly sequences.

As a disassembly model to emphasize the relationship of parts, the Disassembly Structure Diagram was proposed by Bopp[3]. The Disassembly Structure Diagram uses disassembly levels and steps to represent the relationship of connection and interference. Using this model, workers can generate a sequence to get the target parts and also to describe the part's information minutely. However, the Disassembly Structure Diagram also has a demerit that it is not useful for generating an alternative disassembly sequence and that it is difficult to describe the connection or geometrical relationship between parts in the case of complex scrapped product. Thus the Disassembly Structure Diagram is not suitable for an end-of-life car having many parts.

Another model which was proposed for generating various alternative disassembly sequences is the Petri-net model[9,10]. The Petri-net model which has the basic concept of an AND/OR graph is useful for alternative disassembly sequences. However, the Petri-net model makes it difficult for workers to understand procedures of disassembly and the information of the disassembly process. Furthermore, the model becomes complex exponentially as the number of parts increases. So the Petri-net model is also not suitable for end-of-life cars which have many parts.

Considering all of these aspects, a new model is needed to find an optimal disassembly sequence, which can describe the exact disassembly information and can generate various alternative disassembly sequences.

In this paper, we propose such a new model, adding the AND/OR graph concept for a generation of alternative disassembly processes to the Reverse Fishbone Diagram. This model is useful for a description of the disassembly process as well as for understanding the disassembly process sequence. We named this the Modified Reverse Fishbone Diagram(MRFD).

All of the alternative disassembly sequences generated by the MRFD were evaluated to determine an optimal disassembly sequence using evaluation criteria such as setup change, tool change and so on. Also planner may use them to perform a disassembly process plan based on the knowledge and view of experts, stored in a database. We tried to meet the requirements of economics and to reduce the range of solutions as much as possible by suggesting an economical disassembly depth. Fig. 1 shows systematical procedure of disassembly process plan.

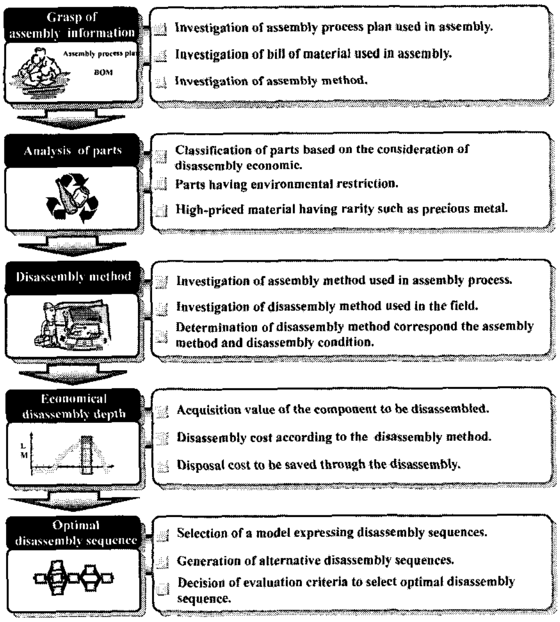


Fig. 1 Procedure for disassembly process plan

2. Basic Factors for Disassembly Planning

2.1 Influential Factors of Disassembly

To recycle or reuse end-of-life products, they should be disassembled. For executing the disassembly process effectively, a disassembly process plan should be established after thoroughly examining the influential factors of disassembly. Influential factors of disassembly, which have been acquired through a lot of disassembly experiments and existing data, are shown in fig. 2.

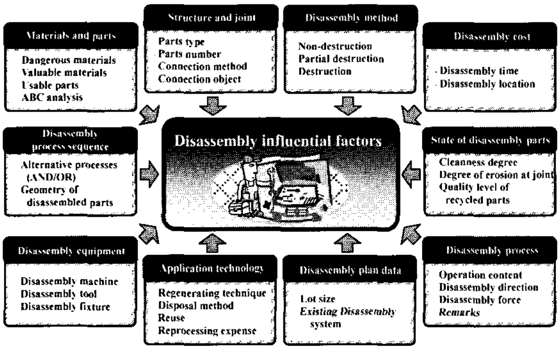


Fig. 2 Disassembly influential factors

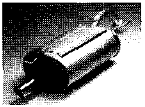
According to how deeply they influence the disassembly plan, we classified these factors in terms of the disassembly method, disassembly cost and disassembly sequence. Then we applied them to each plan step. They were used as qualitative and/or quantitative evaluation criteria with different weights according to their importance in influencing decisions in each step.

2.2 Classification of Disassembled Parts

One of the most important data is the information with respect to disassembled parts. This is not only the primary goal of disassembly but also one of the basic influential disassembly factors. For this reason, the classification of parts must be done before disassembly. The sorting criteria for parts are differentiated into two kinds. One is LWR classification which represents the duty of disassembly, i.e., parts should be disassembled from the product due to their characteristic related to danger, harm or value. The other is ABCD classification according to recycling methods.

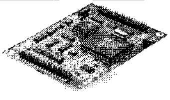
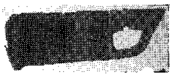
LWR classification shown in table 1 is the sorting of classified parts which should be necessarily disassembled to solve resource exhaustion and environmental problems. Dangerous and harmful materials to humans such as oil in an end-of-life car, lead in batteries or condensers having PCBs are regulated by the government or environment federation. Such materials should be disposed by specifically required methods. They are L type. Precious metals such as platinum used as a catalyst in car exhausts are not only a shortage of undevelopment resources but also have a high acquisition value because of the development of recycling methods. They are classified W type. The other parts are classified as R type.

Table 1 LWR analysis

Type	Example	Content
L		- Legal regulation - Harmful, dangerous etc. - Must necessarily disassemble
W		- Worthy component - Reutilization (material) - Fast disassembly - A development of recycling
R		- Reasonable component

The other sorting method is ABCD classification, which classifies according to recycling methods. Generally, disassembled parts may be reused as parts or subassembly just by a post-treatment process such as cleaning. In this case, we classify this as A type. B type parts such as computer boards having condensers and semiconductors consist of many materials. These are recycled as material through regenerating process after post-treatment such as sorting and crushing. C type parts consist of one material, thus the parts are recycled as material without disassembling and post-treatment. The parts which can't be recycled are classified as D type.

Table 2 ABCD analysis

Type	Example	Content
A		- Reuse (part) - Fast disassembly - Non-destruction
B		- Reutilization (material) - Fast disassembly - Destruction - A development of sorting
C		- Reutilization (material) - (Near-) Not disassembly - Destruction
D		- Disposal - Not disassembly - Destruction

These classifications of parts have a strong influence on the decision of disassembly method, depth and sequence in the disassembly process plan.

2.3 Determination of Disassembly Method

Disassembly is usually recognized as a reverse concept to assembly. However, the disassembly method is not just the inverse method of assembly. In fact, disassembly can be performed in a completely different way from the mechanism used in assembly, because the environment and conditions of carrying out disassembly is greatly different from the situation of assembly. The assembly process focuses on correct assembly without damage, but the disassembly process focuses on rapid disassembly because of economic value.

To find the disassembly method corresponding to each assembly method, the disassembly method used in practice was examined according to the state of the parts as well as the experience and data acquired from the disassembly experiment. Based on this analysis, rules for the selection of a disassembly method were generated by using a decision tree.

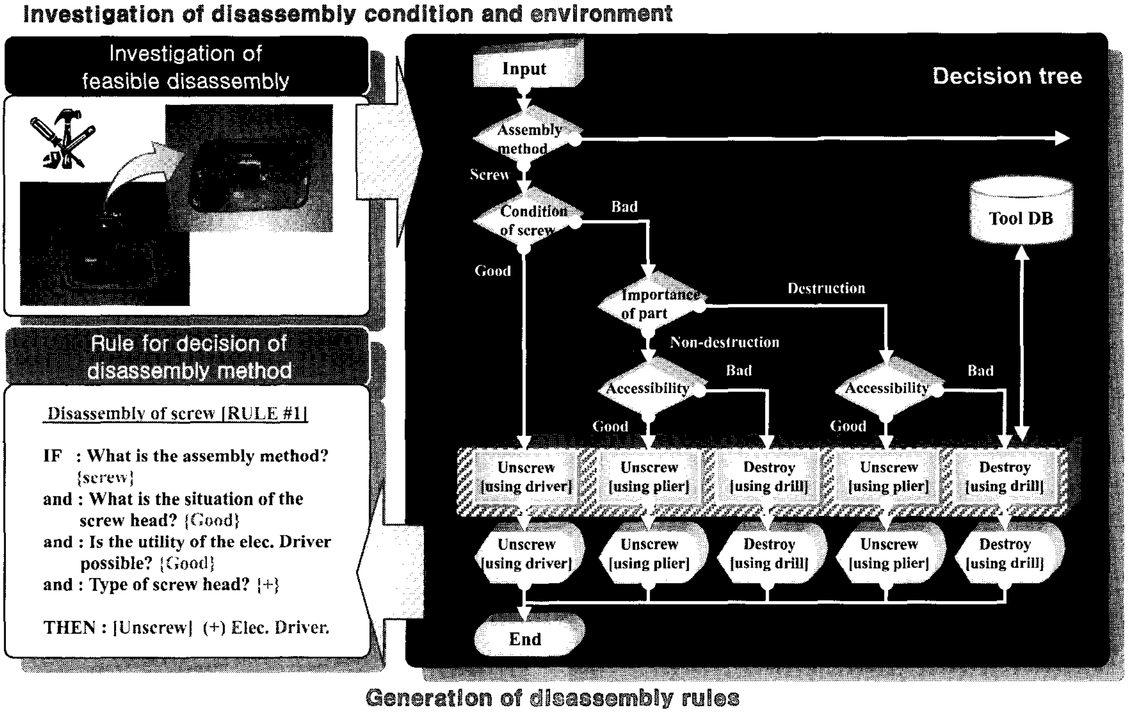
Fig. 3 shows the possible disassembly methods for screw joints mostly occurring at the disassembly of door trim. In the screw joint case, there are two methods for disassembly, i.e. unscrewing and destruction of screw. To determine detailed disassembly method, we used information of joint elements e.g. importance of parts, state and accessibility of screw and so on. Tools which were used in the disassembly process were stored in a database and are used for the new disassembly process.

With the help of this decision tree, rules for an optimal disassembly method were generated. An expert system was realized with the generated rules. The optimal disassembly method was fast and easily determined by it.

3. Economical Disassembly Depth

3.1 Consisting of PLM(profit-loss margin) curve

M. R. Johnson used PLM(Profit-Loss Margin) as a term indicating disassembly economics[11]. The PLM is defined as the difference between the profit and expense produced by executing a disassembly process. To get the

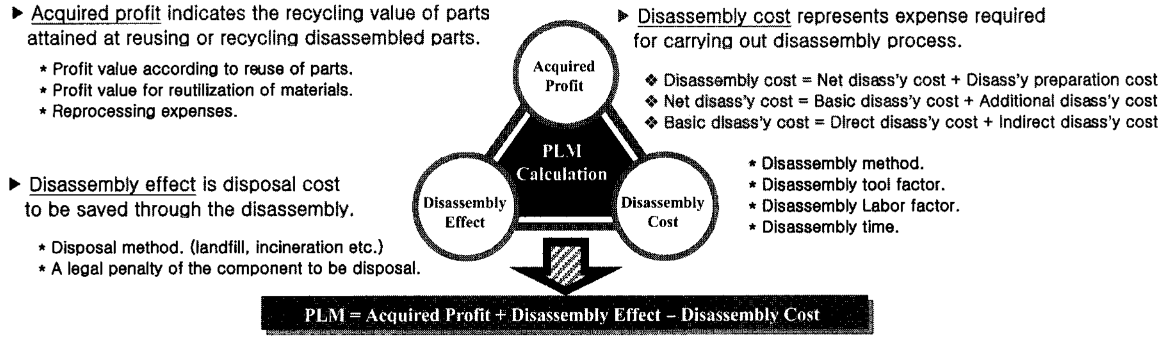


Disassembly of screw [RULE #1]

IF : What is the assembly method? {screw}
and : What is the situation of the screw head? {Good}
and : Is the utility of the elec. Driver possible? {Good}
and : Type of screw head? {+}

THEN : [Unscrew] (+) Elec. Driver.

Fig. 3 Determination of optimal disassembly method



▶ Acquired profit indicates the recycling value of parts attained at reusing or recycling disassembled parts.

- Profit value according to reuse of parts.
- Profit value for reutilization of materials.
- Reprocessing expenses.

▶ Disassembly cost represents expense required for carrying out disassembly process.

- ❖ Disassembly cost = Net disass'y cost + Disass'y preparation cost
- ❖ Net disass'y cost = Basic disass'y cost + Additional disass'y cost
- ❖ Basic disass'y cost = Direct disass'y cost + Indirect disass'y cost

- Disassembly method.
- Disassembly tool factor.
- Disassembly Labor factor.
- Disassembly time.

▶ Disassembly effect is disposal cost to be saved through the disassembly.

- Disposal method. (landfill, incineration etc.)
- A legal penalty of the component to be disposal.

PLM = Acquired Profit + Disassembly Effect – Disassembly Cost

Fig. 4 Composition of PLM value

PLM which represents the economic value of disassembled parts, we embody the term of loss representing the disassembly cost and the term of profit such as acquired profit and the disassembly effect(Fig. 4).

The acquired profit may be considered as main purpose of disassembly and it indicates the recycling value of parts attained at reusing or recycling the disassembled parts. Moreover, to determine the recycling value, we need to consider expenses for reprocessing after disassembly. Reprocessing expenses consist of the cost of executing a post process and the cost of measuring and examining disassembly parts for reuse.

Another merit resulting from disassembly is the disassembly effect. End-of-life products are disposed by scrap merchants in ways as the reclamation and incineration and so on. The disposal amount is reduced by recycling them as the parts or material. This is another benefit of disassembly, so called disassembly effect. To use the disassembly effect in a PLM equation, it must be quantified. As the disassembly effect is defined as saving the disposal cost, we can calculate the disassembly effect.

The disposal expense is the sum of net disposal expense and additional disposal expense. Net disposal expense is the cost to accomplish the disposal process and the additional disposal expense is the collection, storage and transfer cost for disposal parts. Generally, the disposal expense at scrap merchants was calculated as a collective value of the end-of-life product's collector.

The last one consisting of the PLM is the disassembly cost which is the required expense for the disassembly process. Each term and its content is shown in Fig. 4.

The direct disassembly cost which was calculated exactly represents the required expense to disassemble parts actually using disassembly tools. The indirect disassembly cost was computed by the exchange of disassembly tools, disassembly attitude correction and time to access the disassembly place. This cost was estimated by a methodology introduced in reference books based on experimental data and the MTM method[12]. The additional disassembly cost is the expense for technical research about uncertainty, re-analysis of drawing and so on. Because they occur irregularly, it makes it difficult to estimate an exact computational value. Thus, the additional disassembly cost is determined by the rate of the basic disassembly cost. This cost can differ greatly according to the accumulated know-how and organizing ability of a recycling company. In the case of the investigated car junkyard, to solve the problems occurring during the disassembly operation, an extemporary decision was more dominant than systematic methodology. Based on the obtained data through conversation with the car junkyard, the additional disassembly cost was estimated at 5% of the disassembly basic cost. The disassembly preparation cost usually consists of expenses to prepare disassembly tools or to set up the jig/fixture. For an estimation of this cost, a graph or table based on several years of experimental data and accumulated know-how of the recycling company was used.

The cost of each term is expressed in terms of time and added for the calculation of disassembly cost. By multiplying disassembly tool cost and disassembly labor cost, the disassembly cost is determined.

Disassembly tool cost is the total expense of operating disassembly tools and the disassembly labor cost is the expense for workers to accomplish disassembly tasks. The disassembly tool cost is described as follows.

$$\begin{aligned}\text{Disassembly tool cost} &= \text{depreciation cost} + \text{interest cost}\\ &+ \text{space cost} + \text{repairing cost} + \text{energy cost}\\ &+ \text{auxiliary operating cost}\end{aligned} \quad (1)$$

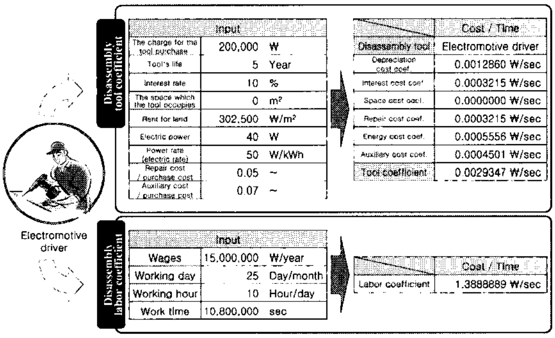
In eq. (1), the auxiliary operating cost is the auxiliary material expense used to operate disassembly tools, e.g. cost of lubricant and so on.

The disassembly tool cost and disassembly labor cost are made to coefficient as expense per a hour. The disassembly cost is calculated as a multiplication of their coefficients and disassembly time.

$$\text{Disassembly cost} = (DTF+DLF)\times T \quad (2)$$

DTF : disassembly tool coefficient
DLF : disassembly labor coefficient
T : total disassembly time

Fig. 5 shows the disassembly tool coefficient and the disassembly labor coefficient of the electromotive driver. Using these coefficients, the disassembly cost can be calculated by merely finding the disassembly time.



Input		
The charge for the tool purchase	200,000	₩
Tool's life	5	Year
Interest rate	10	%
The space which the tool occupies	0	m²
Rent for land	302,500	₩/m²
Electric power	40	W
Power rate (electric rate)	50	₩/kWh
Repair cost / purchase cost	0.05	~
Auxiliary cost / purchase cost	0.07	~

	Cost / Time
Disassembly tool	Electromotive driver
Depreciation cost coef.	0.0012860 ₩/sec
Interest cost coef	0.0003215 ₩/sec
Space cost coef.	0.0000000 ₩/sec
Repair cost coef.	0.0003215 ₩/sec
Energy cost coef.	0.0005556 ₩/sec
Auxiliary cost coef.	0.0004501 ₩/sec
Tool coefficient	0.0029347 ₩/sec

Input		
Wages	15,000,000	₩/year
Working day	25	Day/month
Working hour	10	Hour/day
Work time	10,800,000	sec

	Cost / Time
Labor coefficient	1.3888889 ₩/sec

Fig. 5 Disassembly tool and labor coefficient

3.2 Determination of Economical Disassembly Depth

In progressing disassembly in reverse sequence of the existing assembly sequence, acquired profit, disassembly effect and disassembly cost were calculated at each step of disassembly. We found an accumulated value per accumulated weight. Using these three values, the accumulated PLM value of each unit process was calculated. Due to the accumulated PLM representing the total profit acquired through disassembly, it is economically the most advantageous to disassemble only up to the maximum point of the PLM curve. This point is called the optimal disassembly depth and it is theoretically proposed to disassemble up to this point. But, in the case where parts or materials are restricted by environment regulations, disassembly must be carried out over the optimal disassembly depth.

Fig. 6 shows a PLM curve for the occasion of disassembling the door trim module of the door assembly. This curve has its maximum value at process No. 360 in reverse order of assembly sequence, and the PLM value at that point was 100.95 won. This implies that disassembly should be carried out at least by the No.360 process and the maximum profit through disassembly of the door trim is 100.95 won.

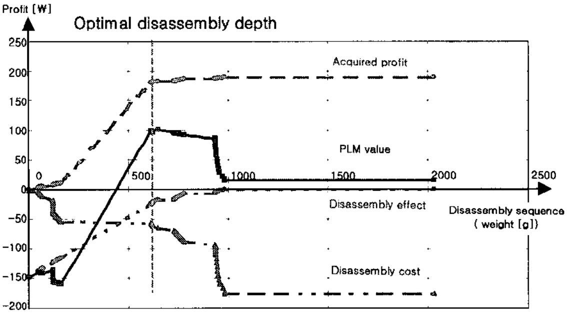


Fig. 6 PLM curve of door trim disassembly

4. Determination of Disassembly Sequence

4.1 Generation of Alternative Disassembly Sequences using MRFD

The disassembly sequence used to determine disassembly depth is only a reverse sequence of assembly to find disassembly depth more quickly. However, though the reverse sequence of assembly is one of many possible disassembly sequences, it can't be identified as the optimal disassembly sequence. To propose an optimal disassembly sequence up to the disassembly depth suggested by the PLM curve, a model generating various alternative disassembly sequences was generated by using a developed Modified reverse fishbone diagram(MFRD).

To model disassembly sequences, the relationship of parts and the precedence of disassembly processes had to be considered in the first place. Since the Reverse Fishbone Diagram proposed by Ishii represents only AND function among parts, it is difficult to generate various alternative disassembly sequences. To get over the disadvantages, the MRFD describes the relationship of the parts and the precedence of disassembly processes through the addition of OR function.

While AND function represents the dependent relationship of parts in terms of sequence, OR function represents the independent relationship of parts. Generally, OR function causes lots of alternative disassembly sequences. Thus, reduction of the number of OR precedences means the reduction of alternative disassembly sequences.

In fig. 7, the disassembly sequence of Door Trim is expressed in the MRFD.

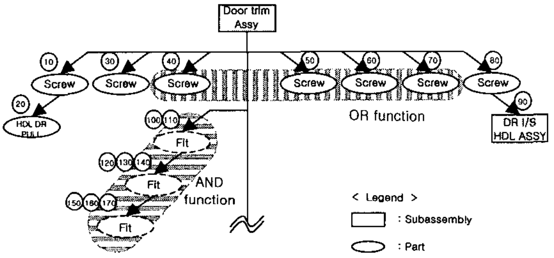


Fig. 7 Modified reverse fishbone diagram

The parts expressed as an ellipse in the MRFD represent, are disassembled parts after the disassembly process. Subassemblies expressed as rectangles show that another low level MRFD is needed for disassembly. As shown in fig. 7, the relationship between process No. 10 and No. 20 is AND function and No. 10, 30, 40, ... , 70, 80 in the same level for alternative disassembly sequences have the relationship of OR function among each part. In order to determine the optimal disassembly sequence, it is inevitable to derive all possible solutions with the processes or function. For the reduction of solution range, it is required to remove unnecessary solutions with the strategy. The optimal sequence is chosen through evaluation among the reduced solutions.

The MRFD has a graph structure, which makes it easy to understand the progress state of disassembly process and its tree structure is helpful to grasp the geometric relationship expressing the priority among parts. Using these merits, it is feasible to combine the processes with the same operation mechanism in terms of disassembly direction, tools and fixtures. This reduces the number of disassembly processes expressed in the MRFD. This reduces greatly the number of generated alternative disassembly sequences.

In fig. 8, the number of OR function is 7, which are placed at the first level. 7 kinds of OR function result in 7! of disassembly sequences and a total 5040 sequences were generated. Process No. 40, 50, 60 and 70 have the same conditions of tools, direction and operation methods. Thus, No. 40, 50, 60 and 70 are regarded as one process due to the same characteristics of disassembly. Then, the first level of the MRFD has 4 kinds of OR function and 4!(=24) alternative disassembly sequences shown in fig. 8 were generated.

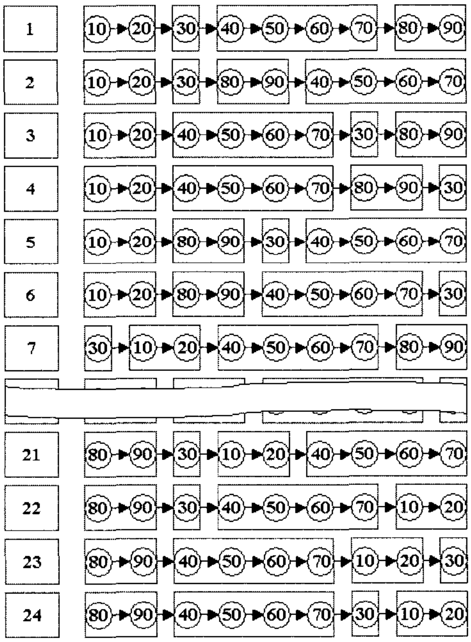


Fig. 8 Generation of alternative disassembly sequences

4.2 Determination of Optimal Disassembly Sequence

To determine the optimal disassembly sequence among the alternative disassembly sequences generated by the use of the introduced MRDF, criteria which can evaluate each sequence are needed[13,14]. Generally, the change of Setup, the exchange of tools and/or the number of disassembly direction is small, it becomes economical. Also it is reasonable to disassemble parts widening the accessibility of tools or the working area prior to others. It is recommended to disassemble the basepart as late as possible because it has a lot of connections with other parts. The method of quantification of each evaluation criterion and the relative weight between evaluation criteria are presented in fig. 9.

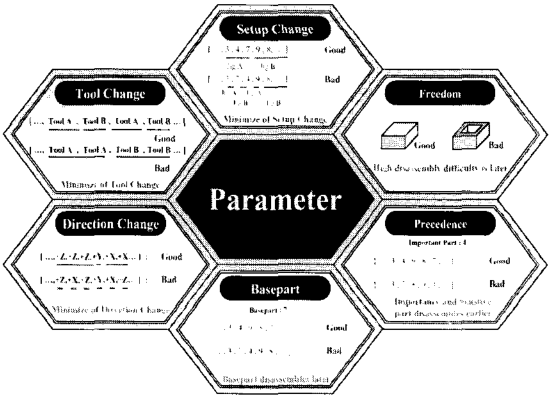
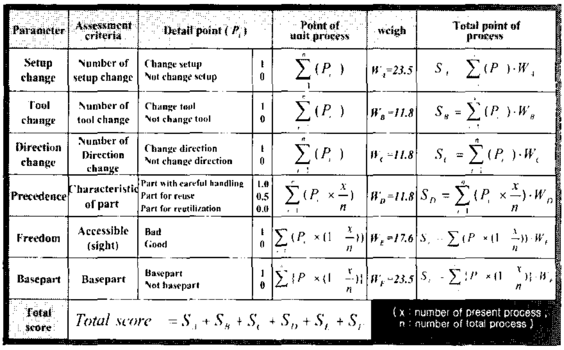


Fig. 9 Criteria for selection of disassembly sequence

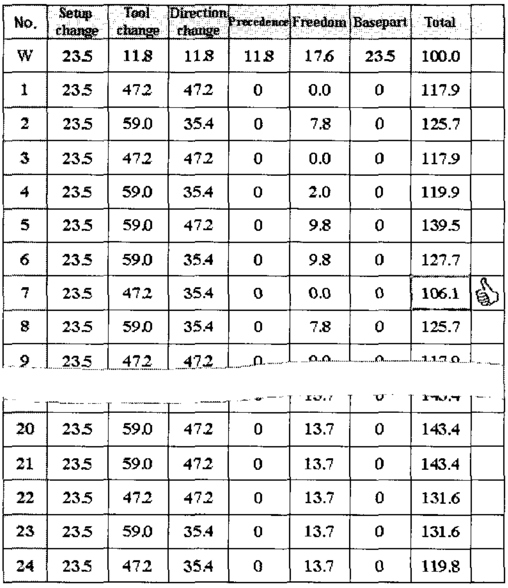
To evaluate alternative disassembly sequences using the evaluation criteria, weight of each criteria and method for quantification are required. They are introduced in fig. 10.



Parameter	Assessment criteria	Detail point (P_i)		Point of unit process	weigh	Total point of process
Setup change	Number of setup change	Change setup Not change setup	1 0	$\sum_{i=1}^{n}(P_i)$	W_A=23.5	$S_A = \sum_{i=1}^{n}(P_i)\cdot W_A$
Tool change	Number of tool change	Change tool Not change tool	1 0	$\sum_{i=1}^{n}(P_i)$	W_B=11.8	$S_B = \sum_{i=1}^{n}(P_i)\cdot W_B$
Direction change	Number of Direction change	Change direction Not change direction	1 0	$\sum_{i=1}^{n}(P_i)$	W_C=11.8	$S_C = \sum_{i=1}^{n}(P_i)\cdot W_C$
Precedence	Characteristic of part	Part with careful handling Part for reuse Part for reutilization	1.0 0.5 0.0	$\sum_{i=1}^{n}(P_i \times \frac{x}{n})$	W_D=11.8	$S_D = \sum_{i=1}^{n}(P_i \times \frac{x}{n})\cdot W_D$
Freedom	Accessible (sight)	Bad Good	1 0	$\sum_{i=1}^{n}(P_i \times (1-\frac{x}{n}))$	W_E=17.6	$S_E = \sum_{i=1}^{n}(P_i \times (1-\frac{x}{n}))\cdot W_E$
Basepart	Basepart	Basepart Not basepart	1 0	$\sum_{i=1}^{n}\{P_i \times (1-\frac{x}{n})\}$	W_F=23.5	$S_F = \sum_{i=1}^{n}\{P_i \times (1-\frac{x}{n})\}\cdot W_F$
Total score	Total score $= S_A + S_B + S_C + S_D + S_E + S_F$				(x : number of present process , n : number of total process)	

Fig. 10 Evaluation form of criteria

Using the method introduced in fig. 10, 24 alternative disassembly sequences generated by MRFD were evaluated. As a result of this evaluation, sequence No. 7 which had the lowest score was determined as the optimal disassembly sequence(fig. 11).



No.	Setup change	Tool change	Direction change	Precedence	Freedom	Basepart	Total	
W	23.5	11.8	11.8	11.8	17.6	23.5	100.0	
1	23.5	47.2	47.2	0	0.0	0	117.9	
2	23.5	59.0	35.4	0	7.8	0	125.7	
3	23.5	47.2	47.2	0	0.0	0	117.9	
4	23.5	59.0	35.4	0	2.0	0	119.9	
5	23.5	59.0	47.2	0	9.8	0	139.5	
6	23.5	59.0	35.4	0	9.8	0	127.7	
7	23.5	47.2	35.4	0	0.0	0	106.1	👍
8	23.5	59.0	35.4	0	7.8	0	125.7	
9	23.5	47.2	47.2	0	0.0	0	117.9	
				0	13.7	0	143.4	
20	23.5	59.0	47.2	0	13.7	0	143.4	
21	23.5	59.0	47.2	0	13.7	0	143.4	
22	23.5	47.2	47.2	0	13.7	0	131.6	
23	23.5	59.0	35.4	0	13.7	0	131.6	
24	23.5	47.2	35.4	0	13.7	0	119.8	

Fig. 11 Determination of optimal disassembly sequence

5. Conclusions

To determine the optimal disassembly sequence, information about the parts and processes required for disassembly planning were acquired through an analysis of the BOM and assembly process plan existing in the company. Using these, economic disassembly depth was determined by generating a PLM curve with the acquired profit, disassembly effect and disassembly expense. Alternative disassembly sequences up to an economical disassembly depth were generated by MRFD and an optimal disassembly sequence was determined through an evaluation. Lots of rules concerning disassembly were derived from experiments as well as practical experiences were used for the solution.

Applying the developed method to the door trim of an end-of-life car, the validity was verified.

A system to be implemented by using the introduced method will contribute to carrying out the disassembly process planning more quickly, efficiently and effectively.

References

1. Park, H. S., "Environment agreeableness in design process," Jr. of the KSPE, Vol. 17, No. 8, pp. 15-18, 2000.
2. Franke, H. J., Firchau, N. L. and Schoppe, K. D.,

"Ablaufplan für Maβnahmen zur Erhöhung der Recyclingquote auf Grundlage eines systematischen Monitorings," Recyclingorientierte Entwicklung technischer Produkte 2000, VDI Berichte 1570, pp. 253-268, 2000.

3. Boop, R. and Bullinger, H. J., "Methoden und Hilfsmittel zur recyclinggerechten Produkt – entwicklung," VDI berichte 1171, ISBN:3-18-091171 -9, pp. 145-185, 1996.
4. Feldmann, K., "Effizienzsteigerung bei Demontage und Recycling durch flexible Demontage-technologien und optimierte Produckgestaltung," Meisenbach Verlag Bamberg, 2000.
5. Tritsch, C., "Flexible Demontage technischer Gebrauchsgüter," Institut für Werkzeugmaschinen und Betriebstechnik, 1996.
6. Kroll, E. and Carver, B. S., "Disassembly analysis through time estimation and other metrics," Robotics and Computer-integrated Manufacturing, pp. 191-200, 1999.
7. Das, S. K. and Naik, S., "Process planning for product disassembly," Int. Jr. Prod. Res., Vol. 40, No. 6, pp. 1335-1355, 2002.
8. Ishii, K. and Lee, B., "Reverse fishbone diagram: A tool in aid of design for product retirement," 1996 ASME Design Technical Conference, 1996.
9. Moor, K. E., "Disassembly petri net generation in the presence of XOR precedence relations," IEEE, 1998.
10. Yi, H. C., Joo, H. H. and Kyung, K. H., "A study on disassembly path generation using petri net," Jr. of the KSPE, Vol. 17, No. 2, pp. 176-184, 2000.
11. Johnson, M. R. and Wang, M. H., "Planning product disassembly for material recovery opportunity," Int. Jr. of Production Research, Vol. 33, No. 11, pp. 3119-3142, 1995.
12. Mok, H. S., Moon, K. S., Kim, S. H. and Moon, D. S., "The complexity evaluation system of automobile subassembly for recycling," Jr. of the KSPE, Vol. 16, No. 5, pp. 132-144, 1999.
13. Park, H. S. and Son, S. B., "A knowledge-based system for assembly process planning," Jr. of the KSPE, Vol. 16, No. 5, pp. 29-39, 1999.
14. Park, H. S., "A knowledge-based system for assembly sequence planning," Int. Jr. of the KSPE, Vol. 1, No. 5, pp. 35-42, 2000.