Design for Using Purpose of Assembly-Group

Hak-Soo Mok[1], Chang-Hyo Han[1], Chan-Hyoung Lim[2], John-Hee Hong[3], and·Jong-Rae Cho[3]

[1] Dept. of Industrial Engineering, Pusan National University, 30 Changjeon-Dong, Kumjeong-Ku, Busan, 609-735, Korea
Tel.: (051)510-1435; Fax: (051)512-7603
hsmok@pusan.ac.kr

[2] Nemo Solutions Consulting, 7th floor, Korea Electric Power Corporation Building, 21, Yeoido-dong, Yeongdeungpo-gu, Seoul, 150-875, Korea
Tel.: (02)3454-0340; Fax: (02)786-0349
chan0070@hotmail.com

[3] Hyundai Kia Motors co, Corporate Research & Development Division 104, Mabuk-Ri, Guseong-Eup, Yongin-Si, Gyenonggi-Do, 449-912, Korea
Tel.: (031) 899-3056; Fax: (031)368-6786
muyoung@hyundai-motor.com

Abstract. In this paper, the disassemblability is determined by the detail weighting factors according to the using purpose of assembly-group. Based on the disassembly mechanism and the characteristics of parts and assembly-groups, the disassembly functions are classified into three categories; accessibility, transmission of disassembly power and disassembly structure. To determine the influencing parameters, some assembly-groups of an automobile are disassembled. The weighting values for the influencing factors are calculated by using of AHP (Analytic Hierarchy Process). Using these weighting values, the point tables for the using purpose are determined. Finally, an optimal design guideline for the using purpose of an assembly-group can be decided.

1 Introduction

The shortage of landfill and waste burning facilities constantly reminds us that our products do not simply disappear after disposal. It is currently acknowledged that the most ecologically sound way to treat a worn out product is recycling. Because disassembly is related to recycling and is a necessary and critical process for the end-of life (EOL) of a product, the design methodology should be developed in terms of environmentally conscious designs (Eco-design). Disassembly can be defined as a process of systematic removal of desirable parts from an assembly while ensuring that parts are not impaired during the process.[1] The goal of disassembly for recycling is to separate different materials with less effort. There should be a countermeasure for companies to reduce the recycling expenses. There is also increased demand for products that can be easily maintained. In other words, by the reducing the disassembly time we can decrease the man-hours. Now the environmental problems are seriously discussed among many companies. Fig. 1 shows the life cycle of a worn

M. Gavrilova et al. (Eds.): ICCSA 2006, LNCS 3982, pp. 832 – 840, 2006.

out product. In order to design a product, which is environmentally benign, the life cycle of the product should be well understood. The disassembly technology should be systematized to reduce the recycling cost and time, because the worn out products transported from the logistics center can be reused or recycled after disassembly processes.[2],[3].

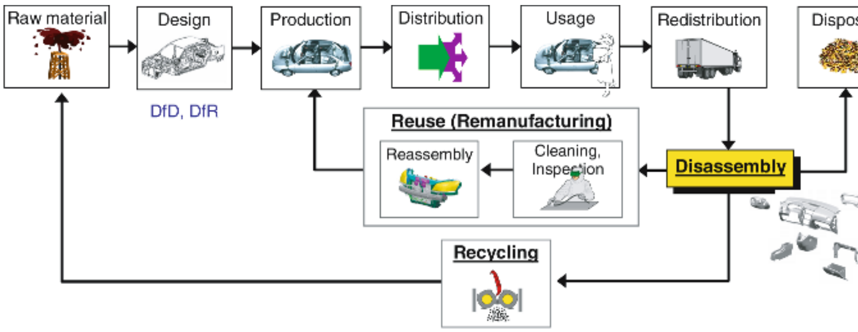

Fig. 1. Location of disassembly in life cycle of a product

The EU policy is calling for mandatory environmental policies for EU-member countries to regulate scrapped vehicles recycling. From early 2006, 85% of the weight of a scrapped vehicle should be recycled and 95% including 10% energy of a vehicle should be recycled after 9 years. [4],[5]

In order to recycle an assembled good, there must be disassembly and sorting processes. To conduct these processes easily, the structure of a product and assembly-groups should be oriented to disassembly. Furthermore, the product and assembly-groups have to be designed with consideration of their using purposes.

In this paper, the using purposes are divided into (1) user aspect, (2) A/S aspect, (3) reuse aspect and (4) recycling aspect. According to these four categories, a new product and assembly-groups should be designed. Then, the main activities for this research are showed in the followings:

- Analysis of the mechanism of disassembly and understanding of the weak disassembly processes
- Determination of the influencing parameters on the disassembly
- Determination of the detail weighting factors for detail disassembly functions
- Determination of the weighting values for using purposes of assembly-groups
- Evaluation of the disassemblability points
- Establishment of the point tables of the disassemblability
- Selection of an optimal alternative among several design guidelines

2 Detail Functions of Disassembly Definition of Disassemblability

In this paper, we determined that five detail functions are normally needed for disassembly: fixing of the object, accessing the disassembly point, transmitting the disassembly power, grasping and handling of the object. Fig. 2 shows the definitions of these detail functions. In order to improve the disassemblability of a product, the previous five detail functions should be simplified and be conducted more easily.

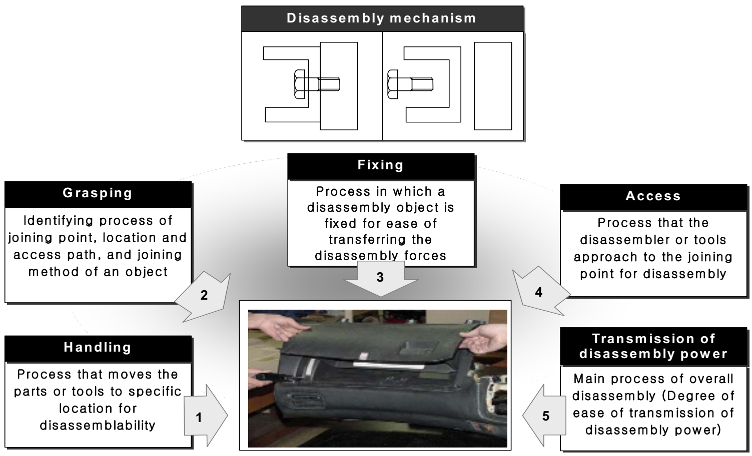

Fig. 2. Definition of detail functions of disassembly

In Fig. 3, the detail functions of disassembly are classified according to the required disassembly time and the object of the assembly-group [6].

Before modification

	Disassembly of subassemblies	Disassembly of parts
Main-process	• Grasping • Access process • Transmission of disassembly power	• Fixing • Access • Handling • Transmission of disassembly power

After modification

	Disassembly of subassemblies	Disassembly of parts
Main-process	• Access (including grasping) • Transmission of disassembly power	• Access (including handling, fixing) • Transmission of disassembly power (including fixing)
Structure feature	• Part structure (part number of pre-disassembled, arrangement of the parts) • Assembly structure (number of assembly factors, number of connecting parts, number of joining points)	

Fig. 3. Classification of the disassembly functions

The object of disassembly-groups is divided into the disassembly of product and the disassembly of part. In the disassembly of product, it is not needed the fixing processes, because the product is fixed and stable by the weight of the product. In this case, only three detail functions would be used: (1) access into the object, (2) transmission of the disassembly power and (3) structure of the product (Table. 1).[7]

Table 1. Definition of detait disassembly function

	Category	Definition
Process	accessibility	Degree of ease of access to joining point or specification position for disassembly.
	Transmission of disassembly power	Degree of ease of transmit the disassembly power at disassembly position
Structure	Disassembly Structure	Structural properties of objects that influence on diassemblability

For the analysis of these disassembly functions, the geometrical properties of parts, the applied fastening methods, the connecting parts and the number of parts are checked.

3 Determination of the Detail Weighting Factors

In order to determine the weighting factors of the detail disassembly function for the product and the assembly-group, several disassembly experiments were performed in the lab. Using these experimental data, the criteria for the evaluation of the disassemblability and the levels for each criterion should be determined. The difficulty of disassembly function, the needed personal motion, the average disassembly time, the frequency of disassembly process and the frequency of weak process are considered as the criteria.

The evaluation level is determined by the analysis of the disassembly experiment of assembly-groups. Using these criteria and the levels, we can find the weighting factors for the detail disassembly process. Table 2 shows the procedure to find the detail weighting factors. The detail weighting factor for the accessing process is the value in 0.342 and for the transmission of disassembly power is 0.658. If the weighting factor for the structural property will be 0.5, the weighting factor for accessibility will be 0.171 and the weighting factor for the transmission of disassembly power is 0.329. Because the characteristics of product structure play an important role in the disassembly process.

Table 2. Detail weighting factors of detail disassemblability

	Evaluation criteria					Total
	Difficulty of process	Grade of necessary in Body part	Average work time	Frequency of process	Frequency of bottleneck process	
Accessibility	3	3	1	3	3	13/38 =0.342
Transmission of disassembly power	5	5	5	5	5	25/38 =0.658

- The weight of accessibility: 0.342 * 0.5 = 0.171
- The weight of transmission of disassembly power : 0.658 * 0.5 = 0.329
- The weight of disassembly structure : 0.500

4 Determination of an Optimal Alternative of Design Guideline Using the Point Table for Disassembly

The following steps are used to determine the point of disassemblability:

- Determination of the detail weighting factors ; (in 3chapter)
- Determination of the weighting values(wi) for the influencing parameters
- Multiplication of the detail weighting factor(wj) for the disassemblability by the weighting value for the influencing parameter ; (This equals total weighting factor)
- Multiplication of the score for the level of the detail influencing parameter for the detail influencing parameter by the total weighting factor

The disassembly experiments are performed to determine the detail weighting factors, which are used to identify the weak disassembly process and more complex parts that cannot be disassembled easily. Then using these results, the detail weighting factors for the detail influencing parameters can be calculated by the AHP (Analytic Hierarchy Process).

The total weighting factor is a main contribution of the higher quantitative evaluation of the disassemblability. The score for the level of the detail influencing parameter can be decided by the given disassembly conditions and the level number.

The following step is the procedure to estimate the disassemblability points for the disassembly purpose according to the user of a product.

Step 1. Definition the weighting factors(wi) for the detail disassemblability
(ex. the weighting for accessibility : 0.171)

Step 2. Definition the weighting value(wj) for each influencing parameter
- Size of access space : 0.281
- Visuality of access route : 0.260
- Self-location : 0.299
- Number of access direction : 0.160

Step 3. Multiplication < wi * wj *100>
(The weight of access space: 0.171 * 0.281 *100)

Step 4. Multiplication the detail disassemblability for each influencing parameter and the score value of Step 3.
(here, the detail disaaaemblability with 3 grade : 1 , 3, 5 point and 2 grade : 1, 5 point)

Step 5. As the disassemblability point is determined the sum of Step 4 for each influencing parameter

Using the point of the disassemblability, the point table of the disassemblability for each using purpose of the product can be established. In the point table of the disassemblability we can find the position according to the given disassembly condition: the property of access, the visual ability, the existence of self-location and the number of access directions. From this position we can have four possible alternatives to improve the disassemblability of a product. Here we assume that it is possible that an alternative can be obtained by the changing only one parameter at a time. This assumption could give us the simple solution.

This suggests that the possible direction of the improvement can not be found in a diagonal line. Now in this step, an optimal alternative can be determined by choosing the alternative that has the highest score of the disassemblability.

Fig. 4 shows the step used to determine the possible alternative of the design guideline. In the first step, the disassemblability point is determined according to the disassembly condition. Then, we can find the position in the point table. For example, the disassemblability point is 41 in the given disassembly condition: when the access is direction-restricted, a visuality is medium, the selflocation is zero, and the change of disassembly direction is one. In the second step, the alternative is determined using our algorithm to get a design guideline. In this paper, there are four alternatives.

In the third step, an optimal design alternative is determined from the comparison of the point difference among the occurred alternatives. In this case, the fourth alternative is selected as the best solution from among four alternatives, because the rising gap of the score of the disassemblability is the highest point (here, 21 point). In other words, the most valuable design guideline is: a self-location should be established in the product.

Point table of disassemblability for a user in aspect of accessibility

Step 1

Accessibility		free			restriction			difficult		
Score table		high	middle	low	high	middle	low	high	middle	low
Existence Self-location	0	86	77	68	76	67	58	66	57	49
	1	80	71	62	70	62	53	61	52	43
	2	75	66	57	65	56	47	55	46	38
Nonexistence self-location	0	65	56	47	55	47	38	46	37	28
	1	60	51	42	50	41	32	40	31	23
	2	54	45	36	45	36	27	35	26	17

- **Point 41 position :**
  - **access space : restriction**
  - **access visuality : middle**
  - **self-location : Nonexistence**
  - **access direction : 1**

Step 2

Accessibility		free			restriction			difficult		
Score table		high	middle	low	high	middle	low	high	middle	low
Existence Self-location	0	86	77	68	76	67	58	66	57	49
	1	80	71	62	70	62	53	61	52	43
	2	75	66	57	65	56	47	55	46	38
Nonexistence self-location	0	65	56	47	55	47	38	46	37	28
	1	60	51	42	50	41	32	40	31	23
	2	54	45	36	45	36	27	35	26	17

- **Point 41 position to detail design principle :**
  - **alternative 1 : Nonexistence self-location → Existence**
  - **alternative 2 : Number of access direction ; 1 → 0**
  - **alternative 3 : visuality low → high**
  - **alternative 4 : size of access space restriction → free**

Step 3

Accessibility		free			restriction			difficult		
Score table		high	middle	low	high	middle	low	high	middle	low
Existence Self-location	0	86	77	68	76	67	58	66	57	49
	1	80	71	62	70	62	53	61	52	43
	2	75	66	57	65	56	47	55	46	38
Nonexistence self-location	0	65	56	47	55	47	38	46	37	28
	1	60	51	42	50	41	32	40	31	23
	2	54	45	36	45	36	27	35	26	17

Alternative 1
Alternative 2
Alternative 3
Alternative 4

- **Alternative 1 : 41 point → 62 point**
  21 point improvement
- **Alternative 2 : 41 point → 47 point**
  6 point improvement
- **Alternative 3 : 41 point → 50 point**
  9 point improvement
- **Alternative 4 : 41 point → 51 point**
  10 point improvement

Fig. 4. The point table of disassemblability for the user according to the accessibility

5 Case Study

As a case study we considered the air cleaner of an automobile. By disassembling air cleaner, we found several weak disassembly processes. The condition of the disassembly process and the characteristics of three assembly-groups are analyzed according to their using purpose. Fig. 5 shows the disassembly condition and the position in the point table. And we can have four possible design guidelines in the aspects of a user of product.

Transmission of disassembly power point table		Visuality high						Visuality low					
		Free space			Restriction space			Free space			Restriction space		
		low	middle	high	low	middle	high	low	middle	high	low	middle	high
bolt	high	165	143	122	133	112	90	142	121	100	111	89	68
	middle	147	125	104	115	94	73	124	103	82	93	72	51
	low	129	108	87	97	76	55	107	85	64	75	54	33
insert	high	165	142	120	142	119	97	132	110	88	110	87	65
	middle	148	126	104	126	103	81	117	94	72	94	71	49
	low	132	110	88	110	87	65	101	78	56	78	55	33
Snap Fit	high	165	139	114	133	108	82	142	117	91	111	85	60
	middle	151	126	100	120	94	69	128	103	78	97	72	47
	low	137	112	87	106	81	55	115	90	64	84	58	33
Clamp	high	165	148	132	127	110	94	141	125	109	103	87	71
	middle	146	129	113	108	91	75	122	106	90	84	68	52
	low	127	110	94	89	72	56	103	87	71	65	49	33

Object of Research

Condition : Disassembly of a Air Body
- assembly point: visuality-bad
- disassembly time: high
- interference of interface: existed
- handling: difficult

Fig. 5. The current status of the transmission of disassembly power in the aspects of User and the design principle

Table 3. The design principle in the purpose of usage from disassemblability

	Detail disassemblibility / Purpose of using	Accessibility	Transmission of disassembly power	Disassembly structure
Design of principle	User	● Existence self-location	● Valuality high	● Connect part add
	A/S	● Existence self-location	● Disassembly power down	● Connect part add
	Reuse	● Existence self-location	● Grasp-ability high	● Assembly point down
	Recycling	● Existence self-location	● Disassembly power down	● Assembly point down

In this case study, the disassembly conditions are: the assembly method is bolting, the gripping ability is low, the visual ability is low, and the working area is not enough (limited), the disassembly force is high needed. Based on these experimented data, we could determine the position in the point table of the disassemblability. The disassemblability point is 33 for the user-oriented purpose.

In this position, we could find four possible design guidelines. From among these four alternatives we choose one with the largest value (here, 75). It is the optimal design guideline in this case.

In order to prepare an alternative for a design guideline of subassembly (air cleaner), some design guidelines according to the purpose of usage are shown in Table 3. In this case, its visuality is low at the point of bolting to the body, transmission of disassembly power is in low condition, also the visuality of the parts of duct is low and assembly point is hard to confirm. Since it was difficult to access the disassembly point with tools, the transmission of disassembly power was low. Fig. 6 shows an alternative of the design guideline from the aspects of the user.

<table>
<tr><th>User</th><th colspan="3">Principle: Reduce the disassembly power</th></tr>
<tr><td colspan="2">Disassembly process : Air Body</td><td colspan="2">Alternative</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th>Assembly factor</th><th>Disassembly time</th><th>Assembly factor</th><th>Disassembly time</th></tr>
<tr><td>Re-bolt</td><td>19.68 sec</td><td>Re-bolt</td><td>12.27 sec</td></tr>
<tr><td colspan="4">Problem
• Assembly point: Not visible
• Disassembly time: Much
• Interference: Exist
• Handling: Bad</td></tr>
<tr><td colspan="4">Alternative
• Remove the interference
• Move the assembly point
• Reduce the number of assembly factors</td></tr>
</table>

Fig. 6. Design guidelines in the aspects of User for Duct and Air Body

6 Conclusion

In this paper, the using purpose of an assembly-group is divided into four categories: aspect of user, A/S, reuse and recycling. According to these categories, the detail disassembly function and the influencing parameters were considered. The total weighting factors were used to evaluate the disassemblability.

To choose an optimal alternative for a disassembly-oriented design we established the point table of disassemblability. Using the point table we found the position. This position shows the quantitative disassemblability for a given disassembly condition. The suggested algorithm was used to find an optimal design guideline systematically.

Acknowledgment

This work was supported by Cleaner Production Technology Development of Ministry of Commerce, Industry and Energy (20040521) and Pusan National Research Grant.

References

1. Mok, H. S, Moon, K. S, Kim, S. H, Moon, D, S.: The Complexity Evaluation System of Automobile Subassembly for Recycling, Journal of the Korean society of Precision Engineering 16(5), (1999) 132-144
2. Mok, H. S, Kim, S. H, Yang, T. I.: Evaluation of the Product Complexity Considering the Disassemblability, Journal of the Korean society of Precision Engineering 16(5), (1999) 14-24
3. Mok, H. S, Cho, J. R.: Development of Product Design Methodology for Assemblability and Disassemblability Considering Recycling, Journal of the Korean society of Precision Engineering 18(7), (2001) 72-84
4. Autorecycling Wohin fuehrt der Weg, RECYCLING magazin, 4, (2003)
5. European Union, Speeding up the vehicle recycling, EU Kommission, 3 (2003)
6. Moon, K. S.: Analysis and Evaluation System for Disassembly, Ph.D thesis, Pusan… National University, Busan, South Korea, (2003)
7. Mok H. S, Hwang Hoon, Yang Tae-Il.: Module design of a product considering disassemblability, Korean Institute of Industrial Engineers/The Korean Operations and Management Science Society collaborated art and science contest in, Spring. A collection of a treaties. (2000)