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Present situation and problems on recycling of aluminum wrought alloy scrap materials recovered from end of life vehicle

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Aluminum products for the automobile use in Japan are mainly the pressure die-casting and/or casting products as engine block, transmission case, and wheel et al., though aluminum wrought alloy products for the automobile use as front hood, heat exchanger increase gradually. Aluminum material recovered by dismantling and shredding from end of life vehicle (ELV) was recycled mainly to the secondary aluminum alloy ingot for the die-casting and/or casting use. In future, aluminum wrought alloy scrap will be desired to recycle for the aluminum wrought alloy ingot. Several dismantling and shredding methods were studied to separate the aluminum wrought alloy materials from the mixed aluminum scrap products and/or shredded chips recovered from ELV. Experimental results show that technical problems are prevention of metallic impurity element from the steel, copper and zinc parts in ELV and optimization of the removal method of paint. It is important to adapt the secondary dismantling process to separate the steel part from the aluminum alloy products. Shredding and heating process is recommended to remove efficiently the paint at the front food in order to keep the safety of working environment at melting process. The large aluminum wrought alloy products over 1kg as front food, radiator and condenser were easy to dismantle and possible to recycle by only the technology now on use.

Keywords: *aluminum alloy scrap, end life of vehicle, recycling, dismantling, shredding*

1. Introduction

Aluminum products for the automobile use in Japan are mainly the pressure die-casting and/or casting products as engine block, transmission case, and wheel et al., though aluminum wrought alloy products for the automobile use as front hood, heat exchanger increase gradually. Aluminum material recovered by dismantling, shredding and separating from end of life vehicle (ELV) was recycled mainly to the secondary aluminum alloy ingot for the die-casting and/or casting use. In future, aluminum wrought alloy scrap will be desired to recycle for the aluminum wrought alloy ingot. Several dismantling and shredding methods were studied to separate the aluminum wrought alloy materials from the mixed aluminum scrap products and/or shredded chips recovered from ELV.

2. Present situation

2.1 Recovery of aluminum alloy parts from ELV

Experimental result of the dismantling test by use of ELV produced at 1994 years was shown in Fig.1. The total weight of the car was 1,040kg and the aluminum material weight was 60.9kg. Aluminum material ratio was 5.9%. After dismantling, the weight of aluminum casting parts, as the engine and transmission component was 50kg (82%) , the weight of brake parts was 3kg(5%) and the weight of heat exchanger parts was 5kg(8%). Recovered ratio of the aluminum material by the dismantling process was 97%. Only the 2kg（3%）of aluminum alloy was recovered by the shredding process.

Engine, transmission components and wheel, the main parts of aluminum material in the vehicle has the large shape and those parts are easy to remove in the dismantle process. The steel parts as the bolt usually attached in those aluminum alloy parts are one of the origin of impurities in the melting process and it is necessary to remove those steel parts in the dismantling process or shredding process.

Aluminum casting alloy specification has usually the high allowance of Fe content. In addition, composition of those aluminum alloy parts is Al-7 to 12 wt%Si base alloys. So, in Japan, aluminum alloy scrap is mainly recycled to the aluminum ingot for the casting and/or die-casting use, as ADC12, ADC10 or AC4B et al. Now in Japan, there is no problem to recycle the aluminum alloy materials from ELV to the aluminum casting and/or die-casting ingot use.

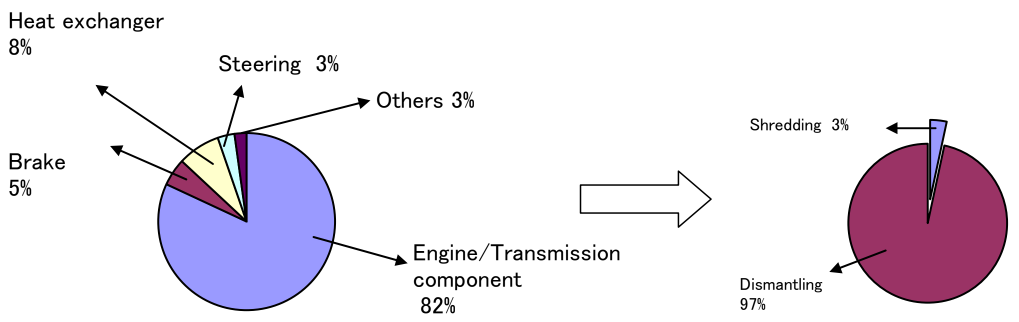

Fig.1 Experimental result of the dismantling test

2.2 Future prediction

A life of the car is usually over 10 years. Amount of the aluminum alloy scrap in Japan is affected mainly by the amount of the car (new car, imported car, exported car and ELV), the weight of aluminum alloy parts and the adapted rate of the aluminum parts. So, it is difficult to predict the future trend of the amount of aluminum scrap from ELV.

Simulated result for the amount of aluminum scrap from ELV in Japan is reported as shown in Fig.2 [1]. A shortage amount of the aluminum scrap gradually decreases and the start of aluminum scrap surplus is predicted at 2018 year. So, in future, it is difficult to absorb the aluminum scrap from ELV by only the aluminum casting and /or die-casting ingot and it is necessary to confirm the recycle system based on the concept of product to product recycling.

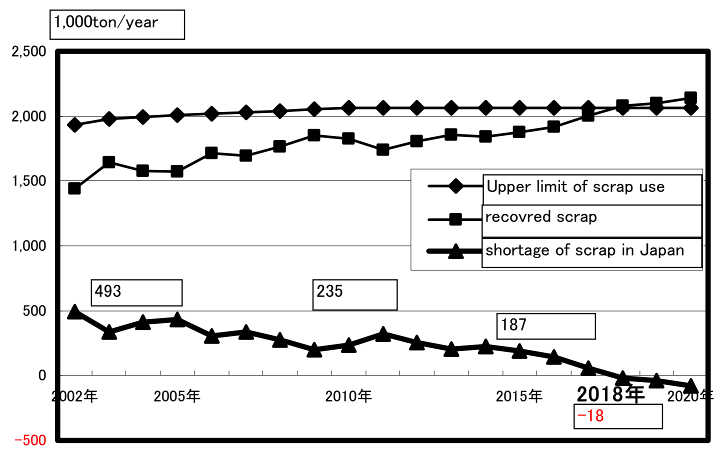

Fig.2 Simulated result for the amount of aluminum scrap in Japan [1]

3. Problem of the recycling of aluminum wrought alloy scrap

One of the major problems on the aluminum scrap recycling is the contamination of the impurities as Fe from the steel parts mixed with the aluminum scrap. Usually, the upper limit of Fe content is severely restricted for the aluminum wrought alloys and it is not easy to recycle the aluminum scrap from ELV for use of aluminum wrought alloy ingot. Increase of the amount of aluminum wrought alloy now in use will result in the increase of the different kind of aluminum wrought alloy scrap in future. On the other hand, it is important to remove the hard and thick paints used as the body sheet in order to improve the working environment.

In this paper, dismantling and shredding tests by use of the actual ELV were carried out. The effect of the kind and the amount of aluminum wrought alloy on the recovered yield or the melted yield was experimented from those tests.

3.1 Dismantling time for the recovery of aluminum wrought alloy parts [2]

The dismantled aluminum food has usually the steel parts as the bolts or the reinforcement parts. In this test, the weight ratio of the steel parts in the usual dismantling process was 2 to 48wt%.

The special dismantling test to remove those steel parts was carried out and the dismantling time was measured. In this test, the same kind of ELV (Mazda roadster) produced at the 1995 year and the 2000 year was prepared and the effect of the product year on the dismantling time of aluminum parts was also measured. Experimental result is shown in Table1. It was easy to dismantle the large aluminum parts as food, condenser and radiator. Evaporator and heater core was difficult to dismantle because of the deep mounting position. The large part over 1kg weight was easy to dismantle and estimated as the economical aluminum wrought alloy parts in ELV.

Table1 Experimental results for several parts recovered from ELV

Parts	Weight of aluminum material (kg)			Dismantling time(minuts)	Economical estimation
	1995 year car	2000 year car	Average		
Food	7.8	8.3	8.1	1	○
Evaporator	1.8	1.3	1.6	−37	×
Condensor	2.0	1.9	2.0	1	○
Radiator	2.3	2.1	2.2	1	○
Heater core	0.9	0.5	0.7	−37	×
Beam	3.6	3.7	3.7	8	△
Rear bumper reinforcement	−	2.1	2.1	2	△

3.2 Shredding test with the mixed aluminum wrought alloy parts [2,3]

In future, the increase of the amounts of aluminum wrought alloy plate, extruded materials and low-impurity cast alloys for the use of food, door, fender and flame is expected. In this case, not only the dismantling process, optimization of the shredding process is also necessary to separate the aluminum wrought alloys and the cast/die-cast alloys from mixed scrap.

Shredding test with the mixed aluminum wrought alloy parts was carried out as shown in Fig.3 and Fig.4. The aluminum materials used in this test were 6000alloy plate, 6063alloy extruded sash and AC4CH wheel as shown in Table2 and Table3. The 10 cars were prepared in each shredding test. After shredding, air classifier, magnetic separation and hand-sorted separation was carried out to estimate the recovered ratio of the aluminum materials from the mix scrap to the plate material, extruded material and casting/die-casting material as shown in Fig.5. It was easy to separate the aluminum scrap to those three kinds of material by hand-sorting. Typical result of the weight of recovered materials is shown in Table4. Almost of all aluminum alloy scrap was recovered.

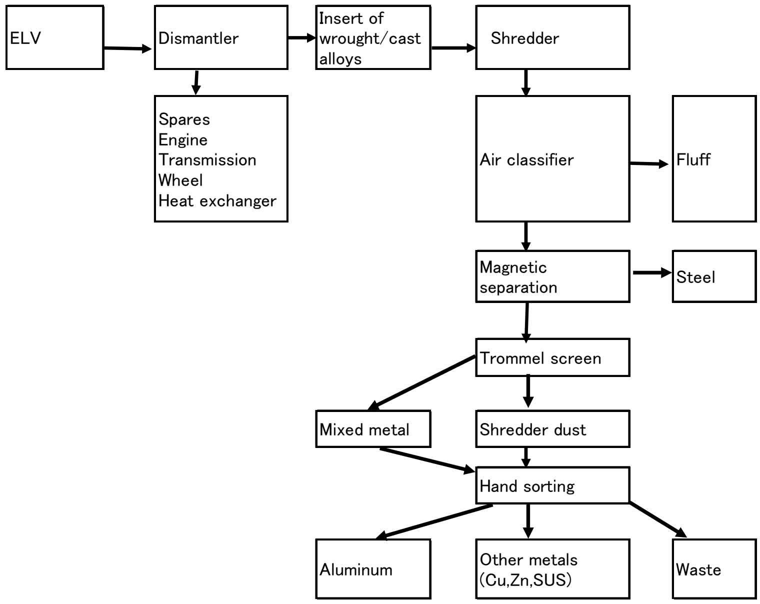

Fig.3 Flow of the shredding test

Table2 Kinds of the used material for experiment

	Alloy	Dimensions(mm)		Total Weight(kg)
Plate	6000 alloy	Thickness	1	1,230
		Width	500	
		Length	500	
Extruded	JIS6063	Sshape	Hollow square	700
		Thickness	1.3 to 2.0	
		Outer size	70	
		Length	500	
Cast	AC4CH	Used cast wheel		220

Table3 Amounts of the used material for experiment

Experiment	Assumption	Total weight for one experiment by 10 cars (kg)			
		Plate	Extruded	Cast	Total
A	Increase of aluminum wrought alloys 110kg/car and half of that is dismantled	400	200	0	600
B	Increase of aluminum wrought alloys 110kg/car and 3/4 of that is dismantled	200	100	0	300
C	Increase of aluminum wrought alloys 140kg/car and half of that is dismantled	350	200	150	700
D	Increase of aluminum wrought alloys 140kg/car and 3/4 of that is dismantled	180	100	70	350

Table4 weight of recovered materials

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D	Increase of aluminum wrought alloys 140kg/car and 3/4 of that is dismantled	180	100	70	350

Typical compositions of each recovered aluminum materials were shown in Table5. Compared with the alloy specification, contamination of Fe, Cu and Zn was observed. Fe powders and /or particles were observed at the surface of recovered aluminum materials. Melted yields of each aluminum materials were over 95% and estimated to the good condition.

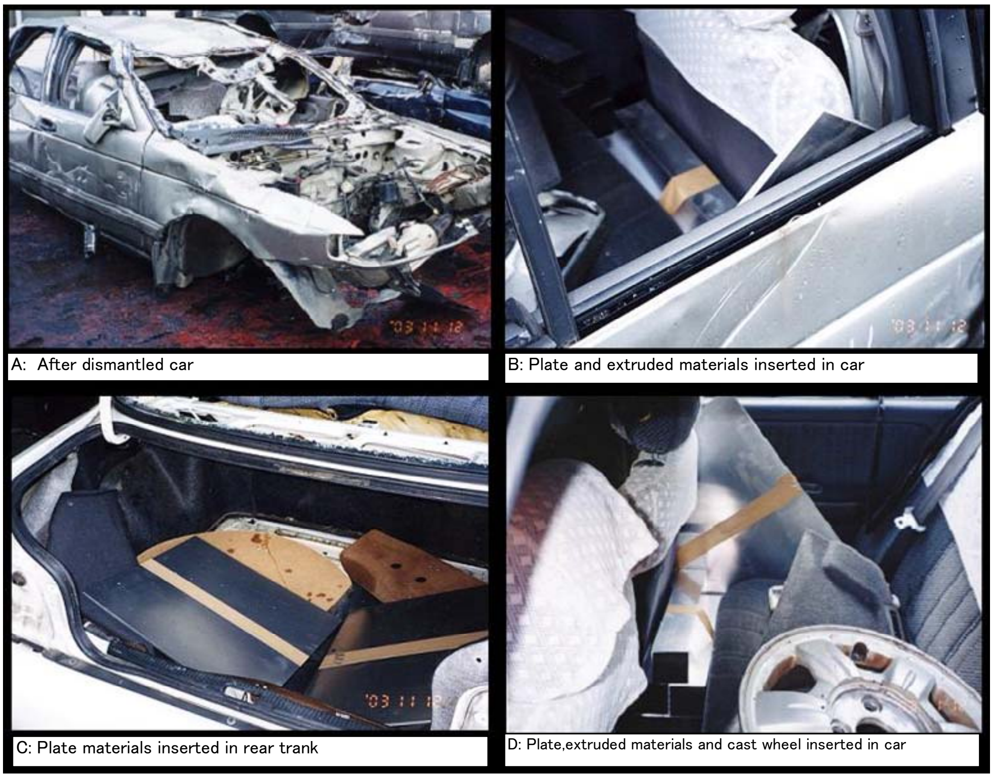

Fig.4 Appearance of the inserted materials at the shredding test

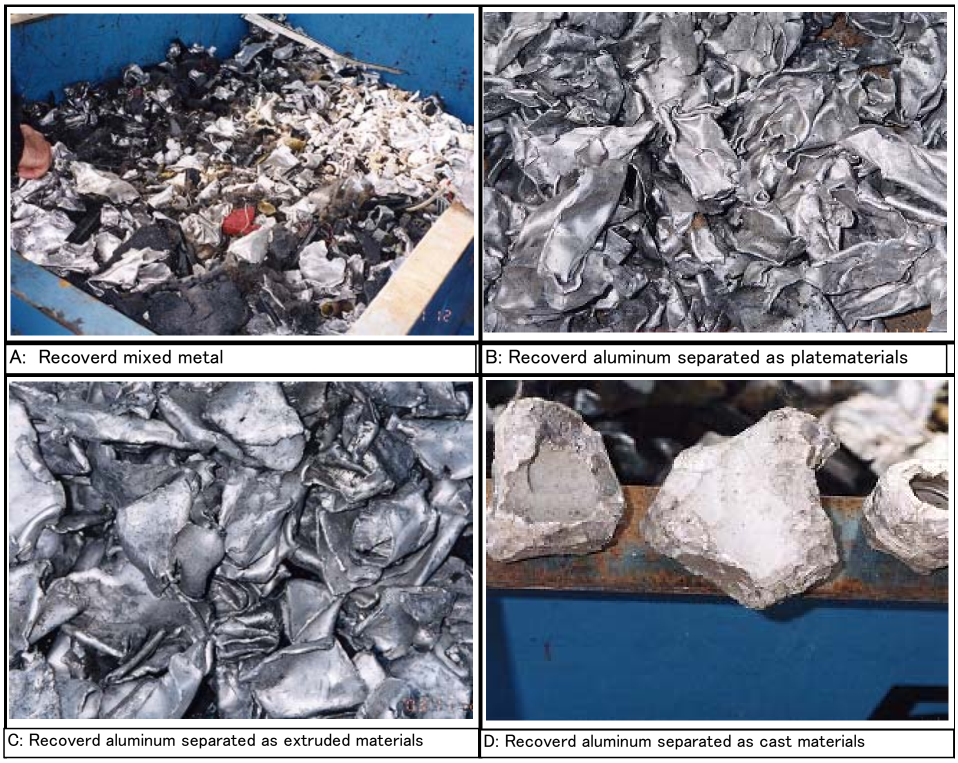

Fig.5 Appearance of the recovered aluminum alloy materials

Table5 Typical compositions of each recovered aluminium material

Recovered as plate materials		Composition (wt%)							
6000 base alloy		Fe	Si	Cu	Mn	Mg	Cr	Zn	Ti
	Spec.	<0.40	0.80–1.50	0.50–0.70	<0.15	0.40–0.70	<0.20	<0.10	<0.15
	Mil sheet	0.15	1.06	0.67	0.06	0.47	0.04	0.01	0.01
Experiment A	Mixed metal	0.34	1.07	0.71	0.07	0.14	0.04	0.30	0.01
	Heavy dust	0.18	1.14	0.73	0.07	0.25	0.04	0.06	0.01
Experiment C	Mixed metal	0.45	1.16	0.65	0.07	0.26	0.04	0.11	0.01
	Heavy dust	0.19	1.11	0.72	0.06	0.24	0.04	0.03	0.01

Recovered as extruded materials		Composition (wt%)							
6063		Fe	Si	Cu	Mn	Mg	Cr	Zn	Ti
	Spec.	<0.35	0.20–0.60	<0.10	<0.10	0.45–0.90	<0.10	<0.10	<0.10
	Mil sheet	0.19	0.44	0.04	0.01	0.52	0.0.	0.01	0.01
Experiment A	Mixed metal	0.28	0.50	0.11	0.02	0.32	0.02	0.10	0.01
	Heavy dust	0.19	0.47	0.08	0.01	0.34	0.02	0.02	0.01
Experiment C	Mixed metal	0.30	0.47	0.06	0.02	0.41	0.02	0.12	0.01
	Heavy dust	0.19	0.47	0.07	0.02	0.33	0.02	0.02	0.01

Recovered as cast materials		Composition (wt%)							
AC4CH		Fe	Si	Cu	Mn	Mg	Cr	Zn	Ti
	AC4CH spec.	<0.20	6.5–7.5	<0.20	<0.10	0.25–0.45	<0.05	<0.10	<0.20
	ADC12Z spec.	<1.30	7.5–9.5	2.0–4.0	<0.5	<0.3	–	<3.0	–
Experiment C	Mixed metal	0.24	7.60	0.09	0.08	0.25	0.00	1.21	0.10

3.3 Removal treatment of the paint

In order to optimize the pre-treatment methods to remove the thick paints over the aluminum food, 61 numbers of aluminum food with paint were dismantled from ELV. Several pre-treatment methods in this test and experimental results were shown in Table6. When pre-treatment was not carried out, the working environment in the melting process was not good as shown in Fig.6. The combination process with shredding and heating in the rotary kirn was recommended.

Table6 Result of removal test of paint over the aluminium materials

Pre-treatment	Remaining paint after pre-treatment	Working environment in the melting process		Melting yield(%)	contents after melting (wt%)		
		smoke	smell		Fe	Si	Cu
None	bad	bad	bad	87.4	0.12	0.16	0.37
Shredding	bad	bad	bad	87.4	0.18	0.14	0.34
Rolling	bad	bad	bad	92.2	0.14	0.29	0.5
Heating in the rotary kirn	good	good	good	92.8	0.14	0.29	0.5
Shredding + heating in the rotary kirn	good	good	good	95	0.11	0.08	0.42
ADC12 ingot	good	good	good	94.8	0.13	0.14	0.34

Fig.6 Appearance of the melting furnace without any pre-treatment

4. Conclusions

In this paper, several dismantling and shredding methods were carried out to separate the aluminum wrought alloy materials from the mixed aluminum scrap and/or the shredded chips recovered from ELV. Technical problems from the experimental result are the prevention of the metallic impurity elements from the steel, copper and zinc parts in ELV and the optimization of the removing method of the thick paint over the aluminum parts. It is important to adapt the secondary dismantling process to separate the steel part from aluminum alloy products. The combination process of shredding and heating is recommended to remove efficiently the thick paint over the front aluminum food in order to keep the safety of working environment at the melting process. A large aluminum wrought alloy products over 1kg as front food, radiator and condenser were easy to dismantle and possible to recycle by only the technology now on use. Recommended aluminum material recycling flow by ELV is shown in Fig.7.

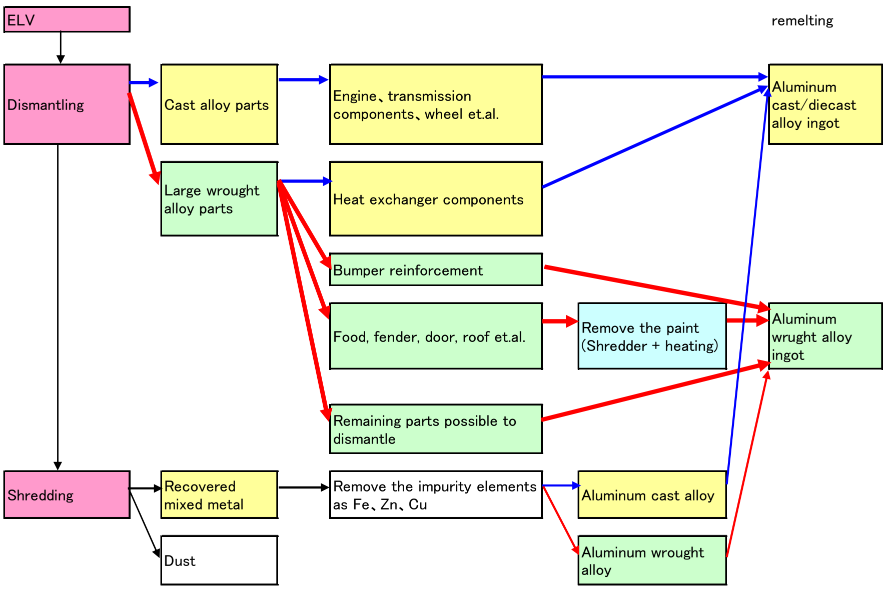

Fig.7 Recommended aluminum material recycling flow by ELV

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