CO_2 Emission and Cost Estimation under Business Model of Aluminium Car

(model in which a car renders mobility and car materials are recycled)

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ABSTRACT

To investigate the economics of aluminium utilization for passenger cars, cost calculation parts were added to the CO2 emission estimation tool made previously. It was assumed that the aluminium passenger cars are produced and driven 100,000km over 10 years and aluminium and steel used in the cars are then recycled at a high rate. Giving reasonable value to each unit cost of materials and gasoline, variation over time of CO2 emission and cost due to production and recycling of material and driving were estimated. The results showed that shapes of the graphs “CO2 emission over time” and ‘cost over time” were similar. This means that the business model in which CO2 emission reduction and cost reduction are realized at the same time is feasible. The results also showed that rise in cost due to the aluminium utilization can be absorbed by reduction of driving cost which is 4 times larger than that. Accordingly the lifecycle cost of aluminium car can be reduced to 86% of that of standard car. External cost was also estimated by this tool.

INTRODUCTION

At the 6th International Conference on Ecobalance we reported that the use of aluminium cars can greatly reduce CO2 emission due to the effects of reducing car weight and recycling of materiasl[1)]. In order to realize this CO2 emission reduction, a business model needs to be developed which is economically feasible for the aluminium industry, automotive industry and users of cars. Drawing upon the process in which disposable camera system developed into lens-equipped film system, a trial LCA/LCC calculation was undertaken for the aluminium car system using the CO2 emission estimation tool extended by adding the cost calculation.

THE FLOW AND FEATURES OF THE MODEL

This model describes material and process in car

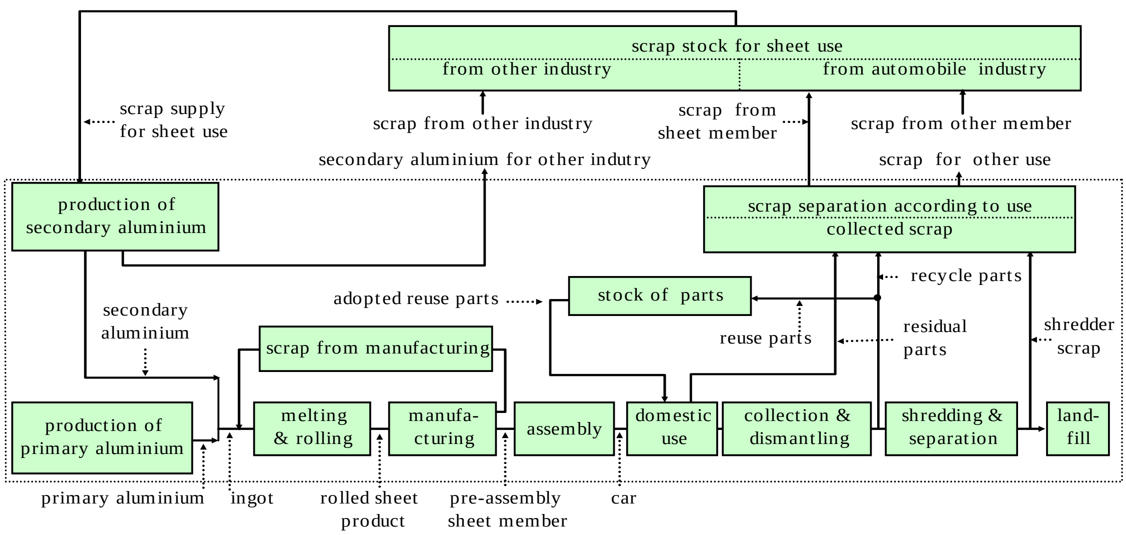

Fig. 1 The material flow of car lifecycle (for case of aluminium sheet product)

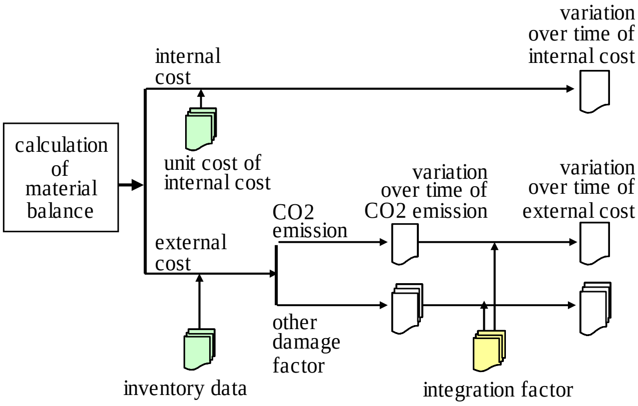

Fig. 2 Configuration of calculation

production rather minutely and has the following features.

① Kinds of material dealt with in the model are aluminium, steel and plastics.

② Kinds of product dealt with in the model are sheet product, extruded product, forged product and cast product for aluminium and plate product (hot rolled, cold rolled and plated), special steel, common steel and cast iron for steel.

③ Processes included are production of raw materials, production of products, manufacturing of products,
car assembly, scrapping (dismantling and shredding) and recycling.

④ 8 car parts are prepared, material composition and weight of which can be assigned

Figure 1 shows the material flow of aluminium in the car life cycle. The material flows of steel and plastic are similar to this flow except that the incineration process is included in the plastic material flow. Figure 2 shows the image of calculation flow. Added portions from the previous report are parts of internal unit cost, calculation of cost variation over time, integration factors and calculation of external costs variation over time. External costs are calculated using Life cycle Impact assessment Method based on Endpoint modeling (LIME).

ESTIMATION OF SYSTEM COST

ASSUMED SCENARIO AND CONSTANTS

Figure 3 shows the assumed scenario in this calculation. The process from standard car to aluminium car A starts in 2003 and finishes in 2012 after 4 steps of weight reduction of car parts each of which continues for 3 years. As the results of these processes engine displacement can

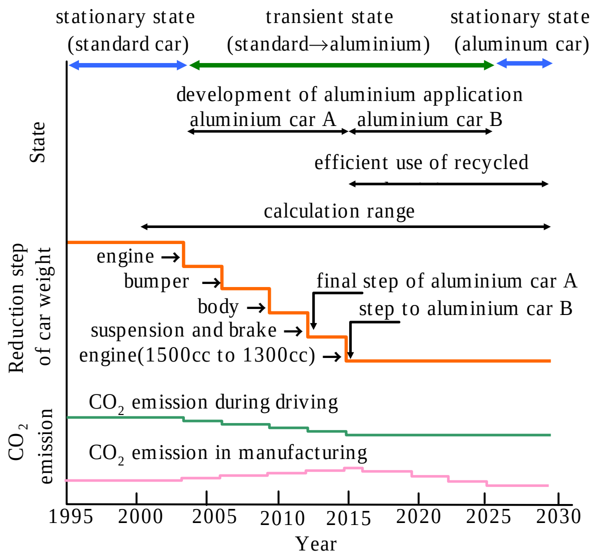

Fig. 3 Transition scenario from standard car to aluminium car

Table 1 Main specifications assumed in scenario

item		standard car	aluminium car A	aluminium car B
weight of car		1037 kg	845 kg	825 kg
weight ratio of Al to car		0.06	0.45	0.44
engine displacement		1500 cc		1300cc
lifetime milage , life span		100000 km , 10 years		
number of cars produced for domestic use		$3*10^6$ cars/year constant		
content of secondary aluminum	sheet	0	value determined by car to car recycle	
	extruded	0		
	cast	0.95		
CO2 emission calculation during driving		using measured data		using catalog data
time period of aluminization		12 year (5 steps, 3 years interval)		

*aluminium used in heat exchanger is reproduced as cast products

Table 2 Unit cost of material (yen/kg)

(←) material	(↓) product	state of process (↓)	production: primary aluminium / converter steel	production: secondary aluminium / electric steel	production: product (dissolved, rolled)	production: product processing	production: car assembly	driving fuel cost: catalog data	driving fuel cost: measured data	disposing·recycling
aluminium	sheet		200	0	200	0	0	(6.111＊car weight−208.15) /10*100 (yen/10^4km)	(2.967＊car weight+3052) /10*100 (yen/10^4km)	40
	extruded				200	0				
	forged				300					
	cast				80					
steel	hot rolled sheet		30		40	0				15
	cold rolled sheet		30		50					
	galvanized sheet		30		60					
	common or bar		30		40	0				
	alloyed		30		50	0				
	cast		20		10	0				

further be reduced from 1500cc to 1300cc and this results in 5th step to aluminium car B. Table 1 shows values used in calculation for standard car and aluminium car. The number of production was assumed to be 3million corresponding to the domestic use. Weight ratio of aluminium to car weight increases from 6% to 44% and the final weight reduction rate is 20.5%. Recyclable aluminium and steel are assumed to be recycled to the same kind of product (except heat exchanger) at a high rate. Content of secondary aluminium was taken to be present value for standard car and calculated value for aluminium car which is determined by (amount of recycled / amount of needed). Table 2 shows the unit costs of aluminium and steel products and gasoline which are thought to be typical. As the aim of this paper is to estimate the influence of costs due to production and recycle of material and consumption of gasoline to the system cost, Cost of assembly and disposal is not involved in Table 2.

As aluminium is assumed to be recycled to the same kind of product, the unit cost of secondary aluminium was taken as 0 (yen/kg), and unit costs of products instead were given reasonably. Unit cost for aluminium recycling was taken as 40 (yen/kg) and that for steel recycling was taken as 15(yen/kg). Fuel consumption due to driving was calculated by using measured data for aluminium car A and by using catalog data for aluminium car B. Both data correspond to 10・15 mode of driving. Unit fuel cost was taken as 100 (yen/L). Fuel cost in table 2 shows that for 10^4 km corresponding to 1 year driving.

CALCULATION RESULTS

System cost calculated using figure 1 and table 1 and 2 can be understood to represent the material and fuel cost needed to produce, drive and recycle passenger cars in Japan. Figure 4 shows the variation of this cost over time. Figure 5 shows the variation of CO2 emission over time under same conditions. As shown in figure 4 and 5, shapes of the graphs of system cost and CO2 emission resemble each other. This means that as far as the cost of producing and recycling material and the cost of driving are concerned, realization of cost and CO2 emission reduction at the same time seems to be feasible. Figure 4, also shows that though the system cost of aluminium car increases 9.8% to that of standard car in transient state, it decreases 14% in the final aluminium car B state.

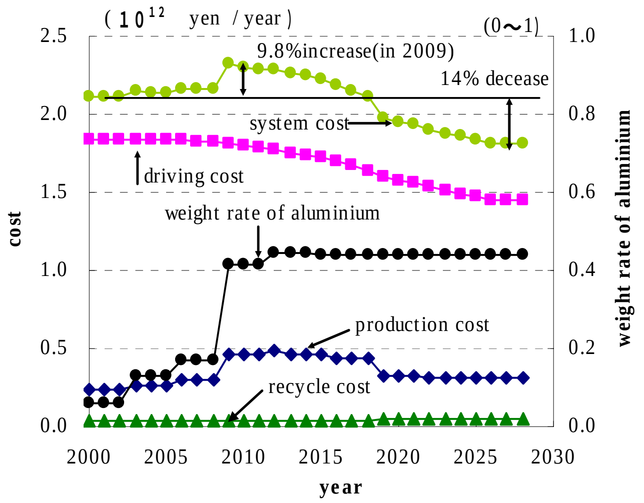

Fig. 4 Cost due to production, driving and recycling

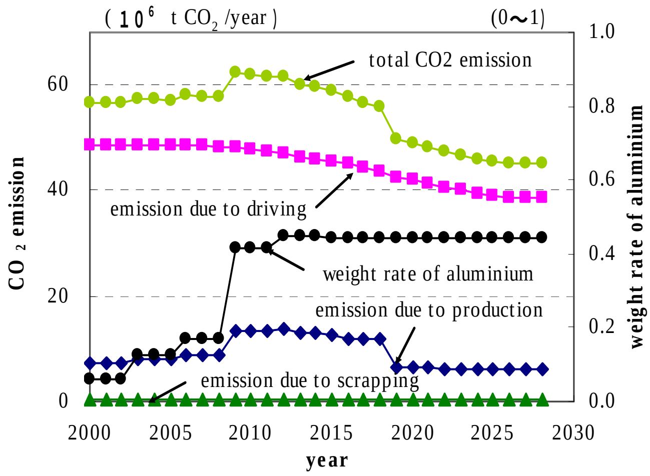

Fig. 5 CO2 emission due to production, driving and scrapping

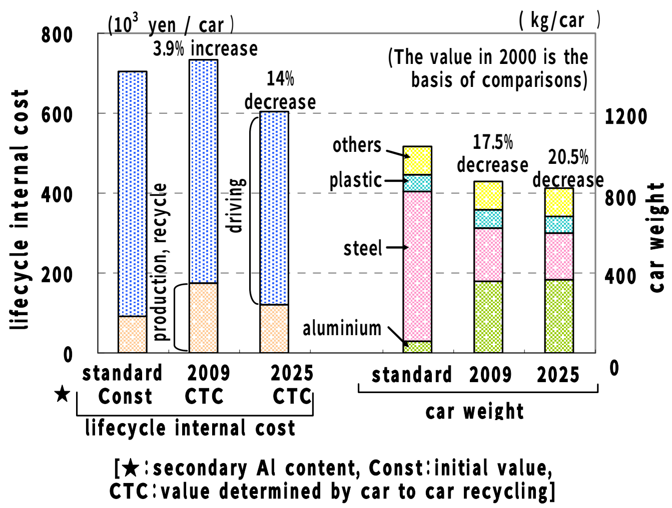

Fig. 6 Car weight and lifecycle internal cost of production, recycling and driving

The reason of the system cost reduction is that not only the rise of material cost is held down by the effect of recycling but also driving cost is reduced by the effect of car weight reduction. Numerically, the increase of material cost is compensated by the decrease of driving cost which is 4 times as much as that. The life cycle cost of a car has more impact than system cost on car users, because it directly influences the price when users buy or drive cars.

Figure 6 shows lifecycle cost of a car calculated by using the results of figure 4. Table 3 shows the breakdown of weight and cost of this case. In Figure 6 it is shown that the life cycle cost of aluminium car B decreases 14% to that of standard car like system cost when the weight of it decreases 20.5%. On the other hand in the transient state of 2009 life cycle cost of aluminium car increases only 3.9% when the weight of it decreases 17.5%. This value of 3.9% in the transient state is smaller than system cost increase of 9.8%. Driving cost of the system cost is composed of that of cars which are made during past ten years, so the average weight of these cars is heavier than that of the car made in 2009. Consequently the system cost becomes higher than the life cycle cost in the transient state. And that the life cycle cost increase of 3.9% is small as an absolute value. This means that from the stand point of material and fuel cost the barrier to the transition from standard car to aluminium car is supposed to be rather low. As shown in Table 3 the aluminium cost of 2025 car is 10 times as large as that of standard car while the weight increase is only 6 times. This is because not only the total aluminium weight but also the weight ratio of sheet product to that increase due to mainly body aluminization in a 2025 car, where the unit cost of production and processing of sheet product is 2.5 times that of cast product.

To understand the approximate effect of the external cost, external costs due to CO_2 emission, crude oil and aluminium depletion were calculated, using LIME. Figure 7 shows total cost in which the external cost was added to the internal cost .The external cost corresponds to the sum of above-mentioned 3 items. The value of this external cost is about 6.6～7.1% of the internal cost and 87% of this external cost is caused by CO_2 emission.

CONCLUSION

The cost and CO_2 emission in introducing aluminium car are calculated for the production and recycling processes of material and the driving process. Results obtained are summed up as follows

1）From the fact that time variation patterns of CO_2 emission and cost in introducing aluminium car are similar, realization of cost and CO_2 emission reduction at the same time seems to be feasible.

2）For stationary state of aluminium car B, the system cost is 14% less then that of a standard car.

3）In the transient state from standard car to aluminium car system cost increases 9.8%, while life cycle cost increases only 3.9% compared with that of a standard car, which means the barrier for transition seems rather low.

4）The sum of external cost of crude oil and aluminium depletion and CO_2 emission was 6.6～7.1% of the internal cost.

ACKNOWLEDGEMENTS

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REFERENCES

1) Yamaguchi, et al.: Effect of Weight Reduction by Aluminium Utilization for Passenger Cars Using CO_2 Emission Tool, The 6th International Conference on Ecobalance

Table 3 breakdown of weight and cost of material

	item	standard	2009	2025
weight (kg/car)	aluminium	61.6	356	364
	steel	748	272	233
	car	1037	856	825
cost (10^3yen/car)	aluminium	9.6	147	99.8
	steel	82.5	25.7	21.9
	sum	92.1	173	122

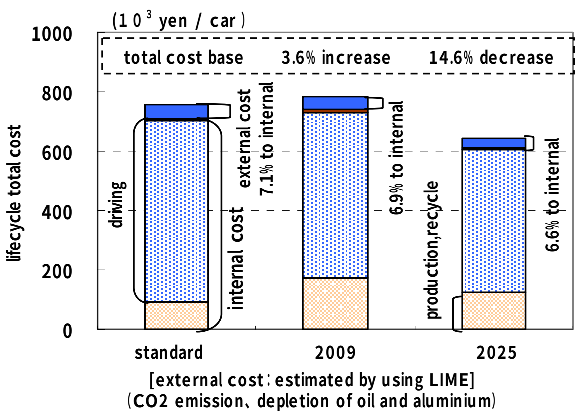

Fig. 7 Lifecycle total cost due to production, recycling and driving