Life Cycle Inventory of Aluminium Hoods and Bumper Reinforcements for Automobiles

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ABSTRACT
Reduction of CO₂ emission from the transport sector, especially from automobiles, is an important theme for overall reduction of CO₂ emission in Japan. As the weight reduction of automobiles is an effective way to reduce CO₂ emission, utilization of aluminium is being examined for this purpose. As part of the investigation of LCI data, which are needed for a quantitative estimation of aluminium's effect on CO₂ emission reduction at each stage of automobile's life cycle, LCI data for hoods and bumper reinforcements of steel and aluminium were calculated by using sum-up method.

1. INTRODUCTION
Reduction of CO₂ emission from the transport sector, especially from automobiles, is an important subject for total CO₂ reduction in Japan. Weight reduction of an automobile is an effective way for the reduction of CO₂ emission and aluminium utilization is now being examined for this purpose. Thus, in order to obtain CO₂ emission reduction, inventory data for the processing/assembling of hoods and bumper reinforcements, in which aluminium is currently used in some automobiles for the weight reduction were calculated by using summing up method on various kinds of data. Inventory analysis of hood and bumper reinforcement production was confirmed by the LCA sectional committee of JAMA.

2. INVENTORY ANALYSIS
2.1 Inventory analysis of hood production
2.1.1 Function and functional unit
LCI analysis was carried out for the process of processing and assembling aluminium hood and conventional steel hoods. Transportation within the facility was not taken into account. The functional unit is a hood of compact passenger car. The shapes and dimensions of the hood outer and inner panels (aluminium and steel), shown in Fig.1, were assumed based on pictures shown in a literature[1].

The weight of hood outer and hood inner, shown in Table 1, was calculated on the assumption that the thickness of hood panels (both outer and inner) of aluminium is 1 mm [1] while the thickness of hood panels (both outer and inner) of steel is 0.75 mm [1] in the models shown in Fig.1. The weight saving ratio amounts to 52%. While the total weight of steel hood (outer and inner) is 12.368 kg for this model, the weight of steel hood reported for Fairlady Z and Skyline are 14.9 kg and 16.8 kg, respectively [2]. Thus, the figure shown in Table 1 is relatively low, corresponding to relatively small vehicles.

| Table 1 Weight of hood outer and hood inner of aluminium and steel (kg) |
|------------------------|-----------------|-----------------|-----------|---------------|--------------|
|                        | Hood outer      | Hood inner      | Joint parts| Paint        | Total        |
| Aluminium              | 3.172           | 2.085           | 0.300      | 0.418        | 5.975        |
| Steel                  | 7.030           | 4.620           | 0.300      | 0.418        | 12.368       |
| Weight saving ratio(%) |                 |                 |            |               | 52           |
2.1.2 System boundary

As shown in Fig. 2, the system boundary (scope of data collection) for both aluminium hood and steel hood covers from the carrying in of the aluminium coil or steel coil to the completion of hood. The processes for producing hood include cutting of aluminium or steel sheets coil (for both outer and inner panels), pressing, spot welding, attaching the joint parts for fitting into the body and baking finish of the surface.

2.1.3 Calculation of the inventory

The inventory of the production of hood was calculated based on the processes shown in Fig. 2 and the data in the literatures/sources[3],[4],[5]. The consumption of electricity was converted to energy consumption at the rate of 2,250 kcal/kWh.

Fig. 3 shows the calculated inventory of processing and assembling of an aluminium hood and a steel hood based on the assumptions.
2.1.4 LCI of hood

The LCI of the material was calculated from the data on 6000 series aluminium [7] and cold-rolled steel [8]. As regards the coating materials, the use of a mixture of xylene (50%) and polyurethane (50%) was assumed and the background data [9] was used for calculation.

The inventory of joint parts was ignored because its effect seems to be negligible. For the LCI of electricity and fuel, the data from the database [9] was used. Based on the breakdown of the fuel sources obtained from the material-process (MP) inventories provided by JAMA [3], the LCI of the each component of fuel sources was calculated.

The leftmost bar in the chart of Fig. 4 shows the LCCO2 obtained from the calculation. For the calculation, it is assumed that the aluminium sheet is composed of virgin (primary) aluminium. Scrap from processing is deducted at the rate of 95%, considering the market price of aluminium scrap. For the purpose of reference, other bars on the left of pairs of bars in the chart show the LCCO2 for the aluminium sheet with a scrap content of 2.8 %, which is the same level as the steel scrap content of cold-rolled steel sheets, 50% and 100%. The bar on the right of each pair of bars shows the LCCO2 for the aluminium sheet with a scrap content of 0 %, 2.8 %, 50% and 100% when both the scrap from processing and the scrap from discarded hood are treated as equivalent of primary aluminium and deducted at the rate of 95%, considering the market price of scrap aluminium. Although the energy consumption during the discard and recovery processes of hood is not considered, it seems to be negligible if hood is to be discarded manually.

2.2 Inventory analysis of bumper reinforcement production

2.2.1 Function and functional unit

LCI analysis was carried out for the processing and assembling of aluminium bumper reinforcement. The conventional processing and assembling of steel bumper reinforcement was taken for comparison. Transportation within the facility was not taken into account.

The functional unit is a bumper reinforcement of compact passenger car. As the shape and dimension of bumper reinforcements varies with the type of automobile to which it is attached, the aluminium and the steel bumper reinforcement, shown in Fig. 5, were assumed as models.

2.2.2 System boundary

As shown in Fig. 6, the system boundary for aluminium bumper reinforcement is from the extruded aluminium alloy shape to the completion of bumper reinforcement. For steel bumper reinforcement, the system boundary is from the high tensile strength steel coil to the completion of bumper reinforcement as shown in Fig. 7.

2.2.3 Calculation of the inventory

The inventory of the production of aluminium bumper reinforcement and steel bumper reinforcement was calculated based on the processes shown in Fig. 6 and 7 and the data in the literatures [3],[4],[5]. Fig. 8 shows the inventory of processing and assembling of an aluminium and a steel bumper reinforcement based on the assumptions above.

2.2.4 LCI of bumper reinforcement

The LCI of the material was calculated from the data on 6000 series extruded aluminium alloy shape [5] and cold-rolled steel [6]. The LCI of bumper reinforcement using aluminium with a scrap content of 14%, which actually corresponds to the average for extruded aluminium alloy shape, was also calculated. For the LCI of electricity and fuel, same data base and inventories were applied as in the case of hood.
The leftmost bar in the chart of Fig.9 shows the LCCO$_2$ obtained from the calculation in which scrap from processing is deducted at the rate of 95%, considering the market price of scrap aluminium. Other bars on the left of pairs of bars in the chart show the LCI for the aluminium sheet with a scrap content of 14%, which is the actual scrap content, 50% and 100%. The figure decreases by 10% when aluminium with a scrap content of 14%, and further decreases to a half when the scrap content is 50%.

The bar on the right of each pair of bars shows the LCCO$_2$ when both the scrap from processing and the scrap from discarded bumper reinforcement are treated as equivalent of pure aluminium and deducted at the rate of 95%, considering the market price of scrap aluminium. If both the scrap from processing and from discarded bumper reinforcement are deducted, LCCO$_2$ is smaller than that of steel bumper reinforcement regardless of the scrap content.

**REFERENCES**


[9] Database supplied with JEMAI-LCA by JEMAI