Evaluation of the life cycle greenhouse gas (GHG) emissions of lightweight steel body and part

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The authors' group has been proposed vehicle weight reduction technologies consist of new advanced high-strength steels (AHSSs) as well as solutions for high-strength part manufacturing and for crashworthy body structural design. An application of them is a concept of high-strength lightweight steel body of which mass is comparable to a typical lightweight body made mainly of aluminum alloys. Since the greenhouse gas (GHG) emission per unit mass for steel is generally smaller than those for other materials, it is expected that our technologies can provide one of the best solutions for the reduction of GHG emissions both in body manufacturing and in use. In this paper, therefore, the life cycle GHG emissions were quantified for three types of body or part, i.e., a conventional steel type, a lightweight AHSS type, and a lightweight aluminum-alloy type. We clarify the degree of influence on GHG emissions of the composition of materials, the manufacturing process, and the manufacturing method utilized for vehicle body and part. Furthermore, we analyzed the influence of material composition and of manufacturing process on GHG emissions. Finally, effective factors to reduce GHG emissions throughout the life cycle of a vehicle were discussed.

The life cycle impact assessment (LCIA) in the area of global warming evaluation of lightweight steel body and part was carried out using WorldAutoSteel UCSB GHG Comparison Model Version 5 (UCSB model 5) and LCA database. The LCIA study was conducted according ISO14040/44 standard for LCA.

A key point of evalution is the definition of the scope of investigation, especially to rule out inappropriate comparisons of data, and the evaluation in the same scope. The target of this study is for vehicles and parts that can be manufactured from steel sheets, or from aluminium, using public data from literature and standard LCA databases (IDEA v3.1., LCA database). A vehicle with a body or part of 0 kg and composed of other parts was introduced as an alternative system. Using the system boundary of the entire vehicle of UCSB model 5 and the alternative system, the contribution of the target vehicle body / parts was extracted by subtraction evaluation as shown in Fig. 1. Then, GHG emissions of vehicle life cycle was evaluated.

It has been reported that the weight reduction rate of a vehicle body including a chassis to which an aluminum alloy material is applied is 20% to 30% for a steel conventional body. This is equivalent to the weight reduction rate of developed lightweight steel body. Therefore, the weight of the aluminum alloy vehicle/parts was set to be the same as that of the lightweight steel vehicle/parts. As a automotive parts, bumper reinforcement (R/F) model was employed. Based on the technical level currently in practical use and the author's investigation, the base case and the lightweight steel case were made of 1470 MPa class and 2.0 GPa class AHSS, respectively. For additional case, the lightweight aluminum extrude bumper R/F model was defined. The average mileage of the vehicle was set to 100,000 km. The material recycling models other than steel are controversial, then a cut-off evaluation was conducted at the vehicle end of life.

Fig. 2 shows the result of life cycle GHG emissions of bumper R/F including parts production process. The lightweight 2.0 GPa bumper R/F has the excellent performance in terms of GHG emissions during both manufacturing and running phase. The GHG emissions during vehicle production tends to be smaller than that during material production&finishing and use.

It is considered to be an effective measure to reduce GHG emissions that AHSS materials, which are highly functional in resource recycling, are utilized for vehicle or parts considering sufficient weight reduction design.

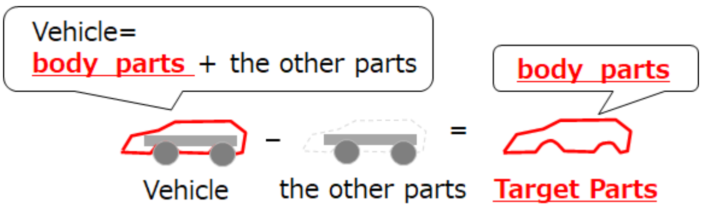

Fig.1 Extraction method for LCA GHG emissions of body/parts.

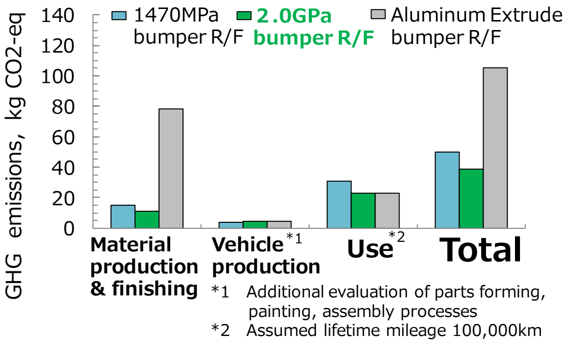

Fig.2 LCIA result of life cycle GHG emission of bumper R/F