Technical Review

Environmental Impacts of Steel Products —LCA of Steel Products—

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Abstract

It is very important to evaluate the environmental impact of a product in its life cycle (life cycle assessment, LCA). Steel products have a low environmental impact in the production and use phases, and have a high recovery rate and recyclability compared to other materials. Thus, their life cycle environmental impact including the recycling potential is very low. The calculation methodology including the recycling potential of steel products has been standardized by ISO and JIS. Global and regional life cycle inventory data of steel products including the recycling potentials are available.

1. Environmental Impacts of Products

The manufacturing of products including steel has environmental impacts. Environmental impacts here refer to the consumption of natural resources and energy and emissions of greenhouse gases (typically, CO_2), acidifying materials (e.g., SO_x and NO_x), ozone-depleting substances (e.g., chlorofluorocarbons), and other various types of substances that affect environments. This paper describes environmental impacts mainly focusing on CO_2 emissions.

2. Environmental Impacts and Life-cycle Assessment

The environmental impacts of a product occur at each stage of the product life cycle. Specifically, the phases include mining of natural resources, raw material production, material production, component production, final product production, use of the product, waste disposal, transportation, and recycling potential.

The smaller the environmental impacts in each step, the better, but what is more important is the total of the impacts in all the phases, i.e., the environmental impacts in the entire life cycle of the product. This evaluation is called life cycle assessment (LCA).

In the assessment of environmental impact of a product, LCA is very important. For example, for automotive products, environmental impact at its use phase, i.e., tail-pipe emissions closely related with fuel consumption, is often the focus of attention. However, other impacts such as production and recycling phases are often overlooked (**Fig. 1**)[1].

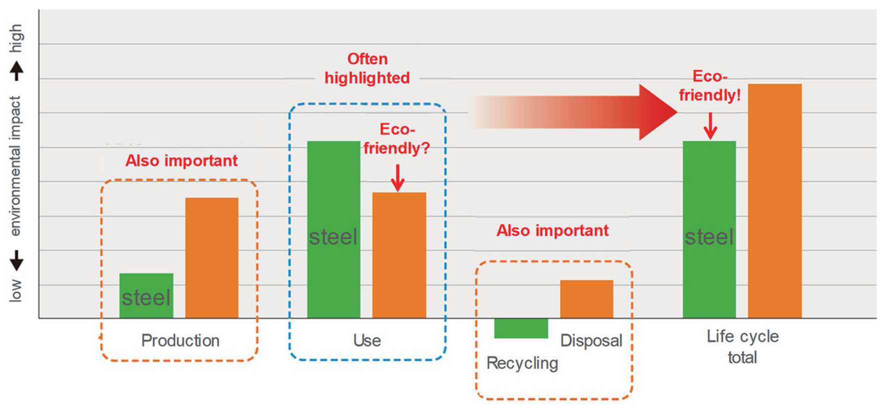

Fig. 1 Importance of life cycle assessment[1]

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3. LCA of Steel Products—Production and Use Phases

Figure 2[2)] shows the CO_2 emissions in the production, including mining of the raw material, of the materials used for automobiles per the same functional unit of auto part. This figure clearly shows that the CO_2 emissions from the steel product production are very small compared to the light-weight materials such as aluminium and carbon fiber reinforced plastics.

Because primary aluminium production consumes a large amount of electrical power, the CO_2 emissions greatly depend on the power mix in the production countries. Currently, a greater part of the world's aluminium is produced in China where the ratio of coal thermal power is high and thereby CO_2 emissions in the production phase are very large. Carbon fiber production also emits a large quantity of CO_2 due to the use of electric heating furnaces.

Although there are several aspects in the environmental impact assessment of the use phase of the steel products, weight reduction is directly related to CO_2 emissions in the use phase of automobiles. **Figure 3**[3)] shows the specific density per specific strength as an index for weight reduction. Because the strength of the steel sheets for automobiles has become very high as shown in the figure, the weight of the steel sheets for automobiles is now comparable with that of other light-weight materials. Although there are some other requirements (e.g., stiffness) for auto parts, the environmental impact in the use phase of steel products is also very low in automobiles.

4. Recyclability

The recyclability and recycling potential of a product, i.e. reduction potential of environmental impacts by recycling, is also important in LCA, in addition to the environmental impacts in the production and use phases. Because steel scrap can be easily recovered and sorted magnetically, almost all the end-of-life steel products are recovered as scrap. In addition, because most of the impurities in the steel can be removed from iron by oxidization as shown in **Fig. 4**[4)], it can be recycled again and again in any steel products. Therefore, steel products achieve closed-loop recycling.

Meanwhile, the recovery rates of other materials are generally low, because they are difficult to sort, and removing impurities is difficult. As a result, the number of materials that achieve closed-loop recycling like steel is small.

5. Calculation Methodology of Recycling Potentials

Because almost all the steel products are recycled as described above, the recycling potentials need to be included in the calculation of the life cycle inventory of the steel products.

ISO 20915 standard and JIS Q 20915 show the calculation meth-

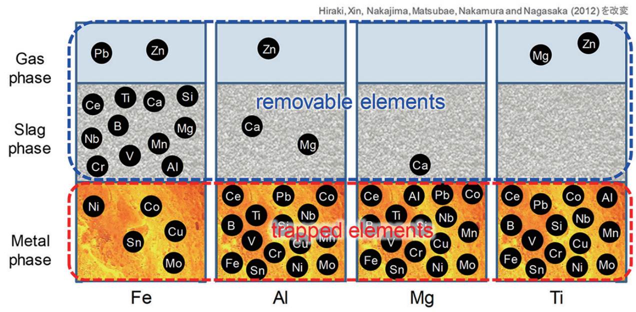

Fig. 4 Removal of impurities by oxidation, adapted from Hiraki et al. (2012)[4)]

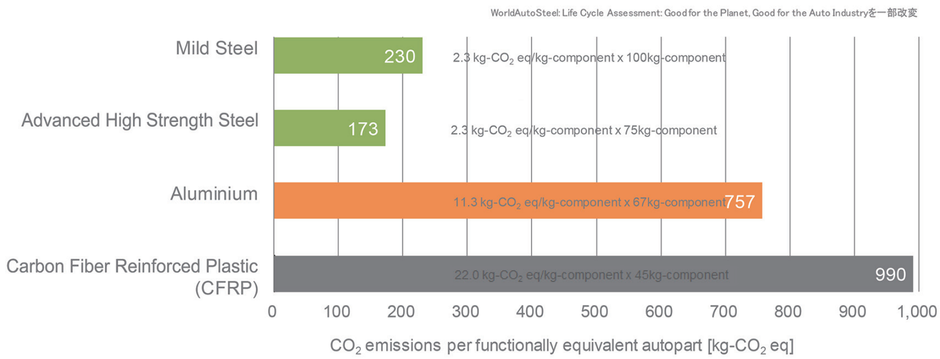

Fig. 2 Greenhouse gas emissions from primary production per functional unit, adapted from published literature[2)]

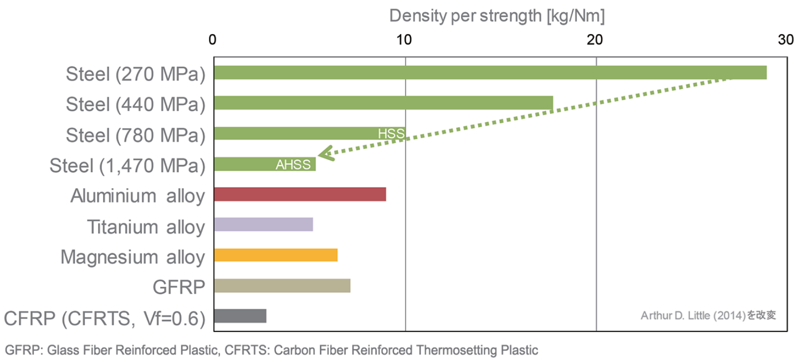

Fig. 3 Specific density per specific strength of materials, adapted from Arthur D Little (2014)[3)]

odology of recycling potentials (environmental impact reduction effects)[5]. They are shown as the green bars in **Fig. 5**. When materials are recycled, emissions in the production from natural resources ('A') can be avoided. Therefore, scrap produced after the use of the steel product has the potential to reduce the CO_2 quantity equivalent to the CO_2 emissions in the production using natural resources (negative environmental impact). However, the potential needs to be subtracted by the CO_2 emissions in the recycling process, and multiplied by the yield in the recycling, and also by the scrap recovery rate. The actual recycling potential is then calculated as 'B' in the figure.

If scrap is used in the production of the steel product, the calculation methodology is as shown in **Fig. 6**. The quantity of the scrap to be produced in the future is substantially reduced by the quantity of the scrap used in the production (B1). Therefore, the scrap recycling potential is deducted from recycling potential 'B' in Fig. 5 (B2 in Fig. 6).

In this case, the CO_2 emissions (A) in the production decrease depending on the quantity of the scrap used (recycled content). Actually, the reduction is equal to B1. This means that the environmental impact on the life cycle considering the recycling potentials is constant regardless of the quantity of scrap used in the product production. In other words, the environmental impacts of ore-based blast furnace steel with lower recycled content and scrap-based electric arc furnace steel with higher recycled content are the same regardless of the recycled content when recycling potentials are included. This is a good indication of the significance of the recycling potential for steel products.

The Japan Iron and Steel Federation launched its average life cycle inventory, LCI, in Japan[6] for steel products using the calculation methodology and the World Steel Association (worldsteel) launched the global or regional average LCI[7].

6. Importance of the Concept of LCA

Figure 7 shows the LCA results of various beverage packaging such as a 350 mL PET bottle, 350 mL aluminium can, and 350 mL steel can[8]. This figure shows that when comparing the PET bottle and aluminium can, the CO_2 emissions in the life cycle of the steel can are the smallest regardless of whether the recycling potentials are included or not. This figure also shows that the environmental impact of the lid (aluminium) is at the same level as that of the body (steel).

LCA makes it possible to clearly understand the importance of the choice of materials and targets that are effective for reducing environmental impacts. Contributions of the products to the reduction of CO_2 emissions and recycling potentials, in particular, can be understood only by LCA. To solve global warming, the reduction of CO_2 emissions in the value chain has also been demanded. LCA contribute to the basis of such challenges and thereby the LCA will become increasingly important.

References

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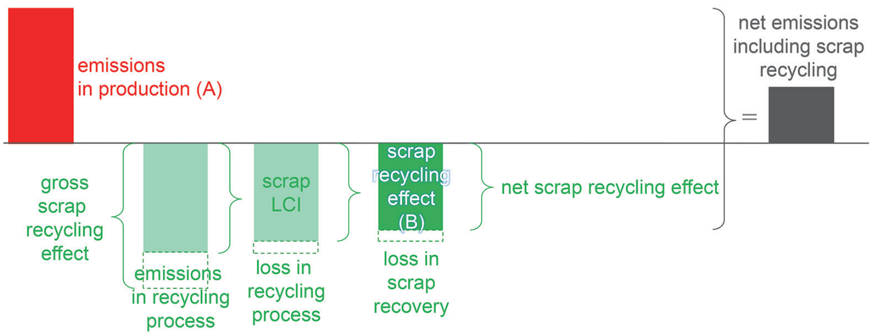

Fig. 5 Calculation methodology of the recycling potential in the ISO 20915 standard, without the use of steel scrap

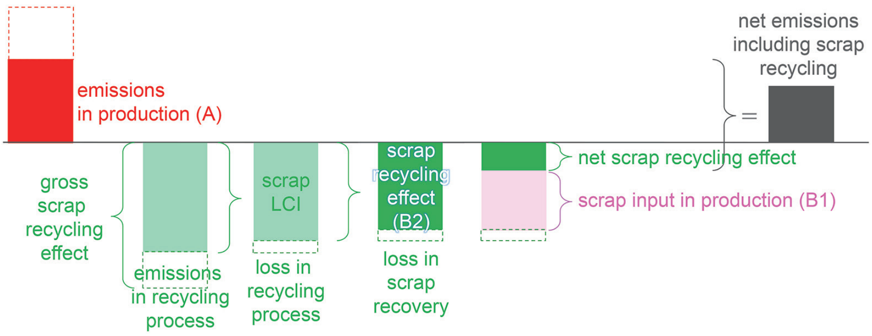

Fig. 6 Calculation methodology of the recycling potential in the ISO 20915 standard, with the use of steel scrap

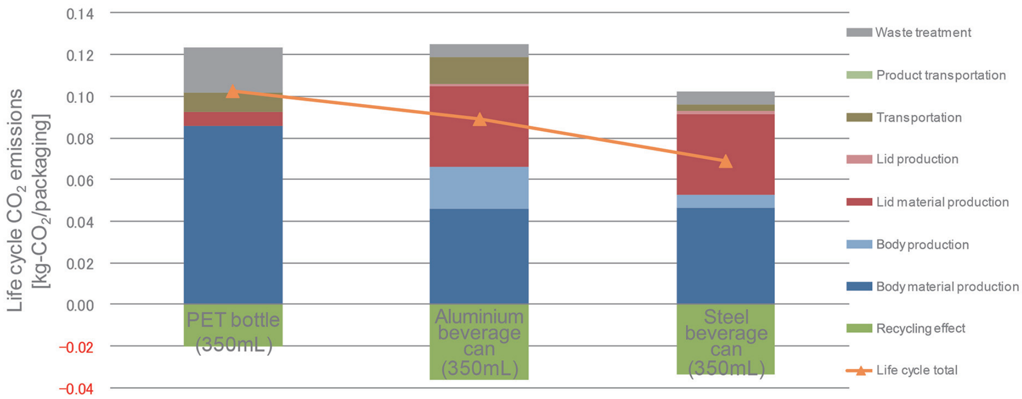

Fig. 7 LCA of beverage packaging

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