

Development of LCA Software for Automotive Parts

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ABSTRACT

Conventional life cycle assessment (LCA) software was modified for application to automotive parts by adding an algorithm to determine end-of-life recycling paths identified and to calculate the environmental load for each of these paths. The software was tested in terms of its ability to calculate the environmental load in a bumper recycling system and results were confirmed to be equivalent to those calculated using a process analysis method. The software was applied to the LCA of rubber parts to compare the environmental load of the disposal of waste rubber in the factory process with that of recycling the rubber. Results showed that recycling waste rubber is effective in reducing the environmental load, but that it is very important to improve the quality of the recycled material and reduce the environmental load of the recycling process itself.

1. Introduction

There are calls for improvement in recycling rates with respect to scrap automobiles⁽¹⁾, making it necessary to take into account the recyclability of parts from the design stage. There are also demands for the reduction of emissions of substances that generate an environmental load {carbon dioxide (CO₂), sulfur oxides (SO_x), nitrogen oxides (NO_x), etc.} over the life cycle of the automobile⁽²⁾. Therefore, efforts to improve the recycling rate must also simultaneously consider methods for optimizing the environmental load. This requires the repeated implementation of life cycle assessments (LCA), which are examinations of the materials specifications, manufacturing methods, and so on of the items in question in order to assess the environmental load generated during their life cycle. Software that makes it possible to reduce the man-hours required to examine, manage, and conduct calculations using the data involved is indispensable when conducting repeated LCAs. However, most of the conventional LCA calculation software that is widely available (hereafter referred to as conventional LCA software) is designed for use with household electrical appliances. The life cycle stages of disposal and recycling are simplified in this software, making it unsuitable for use with automotive parts. Therefore, this project modified such conventional LCA software to enable calculation of the environmental load for the various processing paths at the disposal and recycling stages that are specific to automotive parts. This article reports on the development of this LCA software for automotive parts (hereafter referred to as the Software).

2. Software Aims

2.1. Current Status and Problem Areas of Conventional LCA Software

The basic algorithm for conventional software allows for the entry of the kinds and quantities of the materials and energy that are input in the various stages of the product's life cycle (manufacture of raw materials and materials, manufacture of the product, use and maintenance of the product, transportation, disposal and recycling, etc.). Then, in order to determine the unit quantities (hereafter referred to as base unit data) for each of the related materials and energies, the quantities of substances producing an environmental load that are emitted in each stage are totaled using data for the amounts of environmental load-generating substances emitted. One type of software handles base unit data through proprietary means of survey data entry, while another type is equipped with a database. The latter approach is advantageous for easily obtaining results at a certain level of accuracy and for conducting comparisons of specifications focused on a design, a process, and so on.

The problem with conventional software when applied to LCA calculations for automotive parts is that it allows only for limited processing paths for the disposal and recycling stages. Therefore, it cannot be used to assess the diverse processing paths found with automotive parts. The conventional LCA software disposal and recycling stages allow for shredding of the product after disposal, followed by recycling of only a limited proportion of certain parts of the shredded material for application in new products. The remainder is to be processed as landfill or incinerated. In

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the case of automotive parts, however, materials may have distinctive, specific compositions or functions, so that compound materials require their own specific processes during disposal and recycling, and other items may be recovered as parts and refurbished for reuse. Thus assessment must account for a variety of processing paths.

2.2. Software Objectives

The development objectives for this Software were defined as follows:

- (1) To be capable of assessment that accounts for the characteristic processing paths in the disposal and recycling stages of automotive parts; and
- (2) To be capable of assessing the recyclability of all materials rather than limiting the assessment to specific metal materials.

3. Methods for Achieving Objectives

3.1. Selection of Base Software

The conventional software used as a base for modifications was equipped with a base unit database derived from input-output analysis. This was selected because it allowed easy compilation of data lists showing the amounts of environmental load-generating substances for each life cycle stage of the parts in question. Therefore, this suited an LCA-based comparison for selecting automotive parts specifications.

Input-output analysis uses input-output tables⁽³⁾ to derive the production ripple effect coefficients by which the existence of demand in a particular industry in Japan for production of a particular product causes an impact with regard to the supply of other products or materials, and then successively causes impacts on other industries. The base software determines the base unit data. It does so by first determining the per unit demand value for each type of material (materials, energy, etc.) and part based on the production ripple effect coefficient. Next, this is combined with, for example, various statistical data from the industry⁽⁴⁾⁻⁽⁷⁾ to estimate the fossil fuel supply value corresponding to the demand and, further, estimates the amount of substances generating an environmental load emitted in the production and consumption of that fossil fuel, etc.

3.2. Identifying Processing Paths at the Disposal and Recycling Stages

The processing paths and conditions at the automotive parts disposal and recycling stages were identified as follows:

- (1) After shredding, only specified materials are recovered and recycled as low-grade materials (steel being used to make shaped-beams, etc.). The remainder is transported to a disposal center and separated for processing as landfill and for incineration in set proportions.
- (2) Portions that have been disassembled and dismantled are recycled according to the paths below and the remainder is processed by the path in (1) above:
 - a. Compound materials and other items requiring distinctive recycling processes are processed for recycling accordingly (recycled material manufacture: bumper material recycling, etc.).

- b. Items are reused as parts after the application of simple processing (reuse: aluminum wheels, etc.).
 - c. Items are reused as parts after refurbishing by replacing small parts, etc. (rebuilt: air conditioner compressors, etc.).
 - d. Items are sold with functional compensation after refurbishing of functional parts, including the replacement of small parts (remanufactured: drive shafts, etc.).
 - e. Items are recovered and kept in storage (stocked).
- (3) The recycled materials in item "a" above are used as raw materials in the same kinds of parts as those they were recovered from.
 - (4) The recycled materials in item "a" above are used as raw materials for other parts.
 - (5) Further recycling takes place after shredding, with the recovery and reuse of steel, copper, and aluminum, as well as magnesium, plastic, glass, rubber, and so on.

3.3. Improvement of Calculation Flow Algorithm and Conditions

The calculation flow algorithms that work with the identified automobile parts processing paths and conditions were improved and the calculation conditions were set. Fig. 1 shows the basic algorithm used in the software. The points that were improved are explained below. The right-hand portion of Fig. 1 shows the portions that were added in order to perform assessment of the disposal and recycling stages

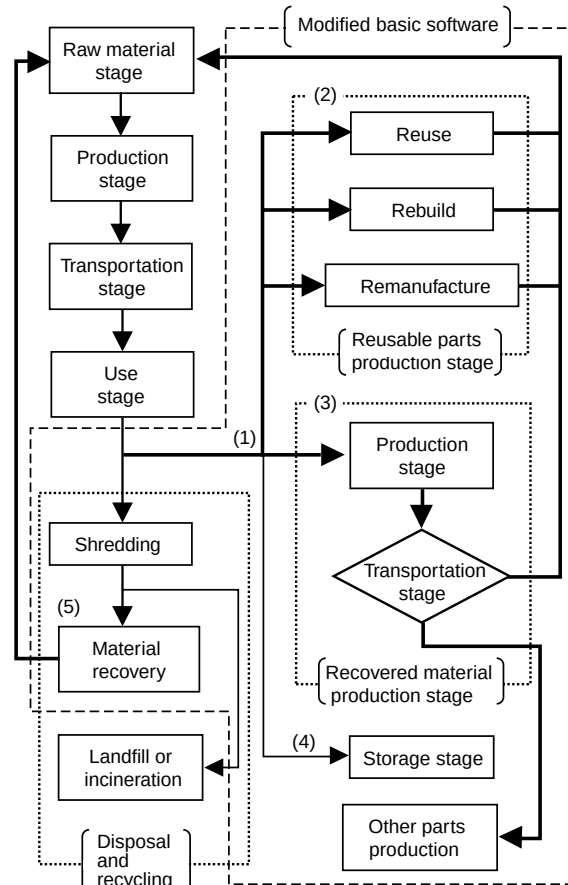


Fig.1 Main algorithm of the developed software

for automotive parts. Arrow symbols indicate the flow of the calculation procedures, and branching lines indicate where the percentage of a material that is to be moved on to the next stage is set. The numbers in the figure correspond to the numbers of the following items:

- (1) A path was established for the recycling of items that are collected from the market and not shredded before recycling. A routine was established to take that percentage and use it as the recovery rate.
- (2) A routine was established for parts that are reused in the same form as they were previously.
- (3) A routine was established for the recycling of compound materials and other such items that undergo distinctive recycling processes and then are recycled as raw materials for use in the same parts as before or in different parts.
- (4) A path was established for items that are held in storage after being recovered.
- (5) Steel, copper, aluminum, and additionally magnesium, thermosetting resin, thermoplastic resin, glass, rubber, paper, and polyvinyl chloride were classified as materials that are recycled as raw materials after shredding.

4. Software Features and Operating Environment

4.1. Features

- (1) The Software is capable of assessing environmental loads (CO_2 , NO_x , SO_x) for all automotive parts recycling paths.
- (2) The Software is capable of assessing the recycling effect for environmental loads (CO_2 , NO_x , SO_x) of all materials including compound materials. (Shredding recycling is excluded.)
- (3) The software is capable of assessing the recycling effect for environmental loads (CO_2 , NO_x , SO_x) in cases when raw materials recycled from parts are reused for different parts.

4.2 Software Operating Environment

- Hardware: Pentium (75 MHz) or better CPU, 50 MB or larger hard drive, 16 MB or more RAM
- Software: Microsoft Windows 95, Excel 97, Access 97

5. Software Verification

A report has been published regarding an automotive parts LCA of a bumper recycling system using the process analysis method, which is said to have superior data accuracy⁽⁸⁾. This report compared the environmental loads in two cases. In one, 30% of the recovered and recycled bumper material was used as raw material for bumpers (hereafter referred to as part-to-part recycling). In the other case, 100% of the recycled bumper material was used as raw material for splash shields (hereafter referred to as cascade recycling, meaning recycling into lower-grade materials or into parts with lower-order functions). Here, the Software was used to perform LCA calculations for similar systems, and the CO_2 emission quantities for the two were compared. Fig. 2 shows the processes and quantities of input materials used in calculations by the Software for the part-to-part system, and Fig. 3 shows the same for the

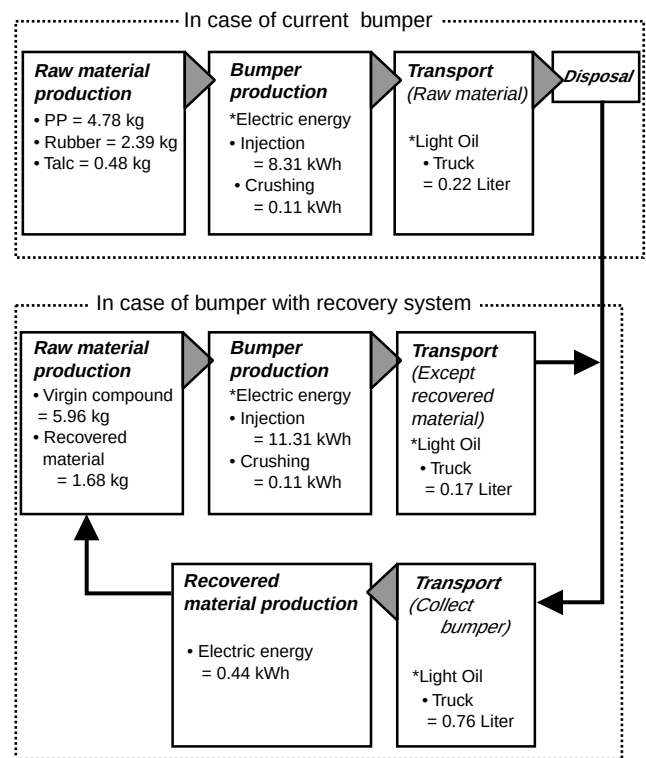


Fig.2 Process and material data for bumper part-to-part recycling

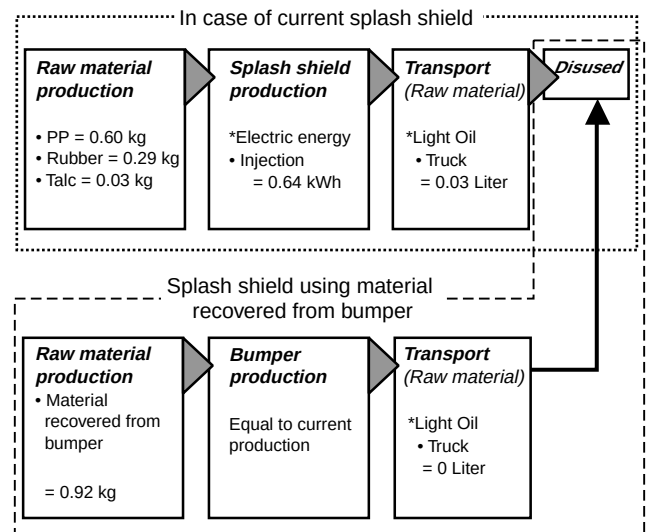


Fig.3 Process and material data for bumper cascade recycling for use in splash shields

cascade system.

The results of LCA calculation by the Software came out nearly equal to the results from the process analysis method. Table 1 shows a comparison of CO_2 emission quantities for both methods. Fig. 4 shows details of the Software calculation results for the part-to-part and cascade cases.

Part-to-part recycling shows a reduction of the environmental load generated by raw materials. However, the environmental load from the manufacturing stage was large, so the overall effect was slight. The reason for this is

that the reduced physical properties of the raw materials from recycled materials resulted in the recycled materials having a low rate of application as raw materials and further greater energy was required in the forming process, as two materials must be sandwiched together. On the other hand, cascade recycling imposes a larger load in the transportation and manufacturing stages for both the bumper recovery and the recycled material manufacturing portions of the process. It was demonstrated, however, that the overall recycling effect was greater because the raw material input portion is zero. This is because the physical properties of the raw material for splash shields are of a lower order than that for bumpers,

Table 1 Life cycle environmental load (CO₂) of bumper and splash shields according to LCA method

		Software	Process analysis method
Bumper using	Current production	19.13 kg	19.21 kg
	Recovered material from bumper 30 %	17.58 kg	18.74 kg
Splash shield	Current production	1.95 kg	2.09 kg
	Using recovered material from bumper 100 %	0.59 kg	0.67 kg

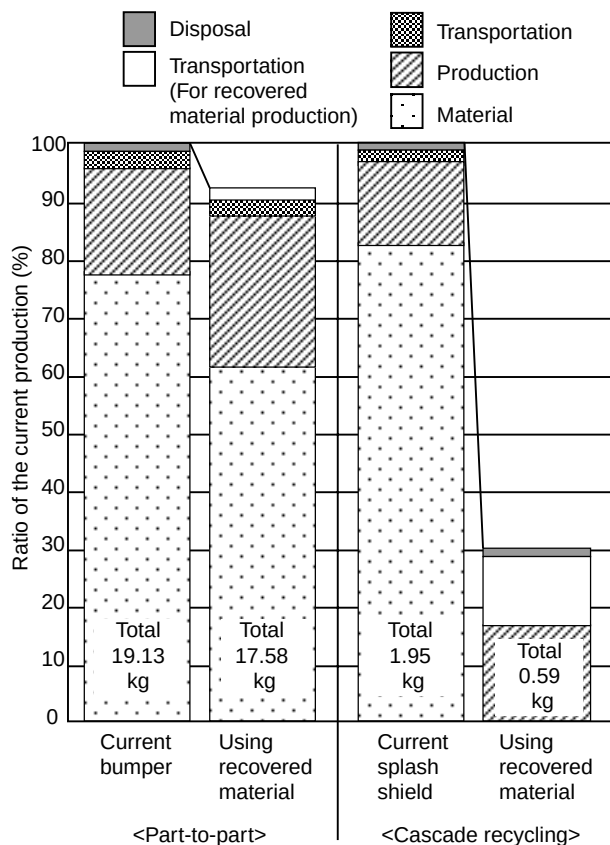


Fig.4 Environmental load (CO₂) of bumper recycling system calculated by the Software

so the recycled material from bumpers can be applied as raw material for splash shields. As a result, this approach leads to the same conclusion as the process analysis method, which is that the cascade method of bumper recycling has a greater effect on environmental load.

6. Software Application Example

The software was used to conduct an LCA on rubber parts, and simulations of CO₂ emission quantities were performed for the recycling of manufacturing process waste materials. The rubber part selected for study was the water hose. Working from the assumption that the shearing method would be used for recycling, the energy required for manufacturing recycled material was set at 1 kWh per 1 kg of waste material. Product weight was set at 1 kg per vehicle. Fig. 5 shows the processes and the quantities of input resources used for the calculations.

The calculation results show that, compared to the 2.02 kg of CO₂ emitted with the ordinary product, the amount emitted when 30% recycled raw materials were used was 1.68 kg, and when 60% recycled raw materials were used it was 1.33 kg. This demonstrated the environmental load reduction effect. Fig. 6 shows the breakdown of these three cases. The use of recycled material as raw material increases CO₂ emissions at the stage of recycled material manufacturing. However, the reduction in CO₂ emissions at the stage of raw material manufacturing is even greater than this increase. Therefore, the overall environmental load

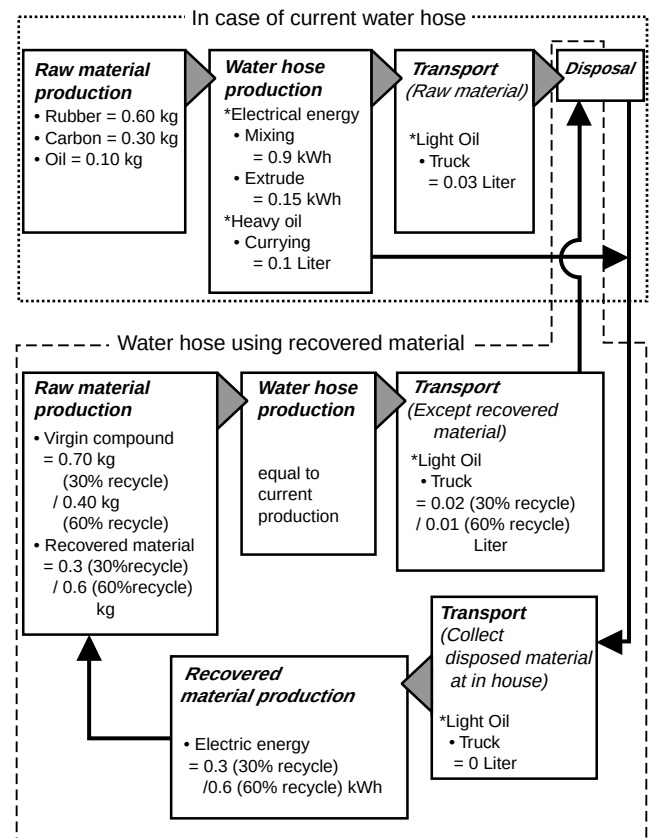


Fig.5 Process data for cascade recycling for water hoses

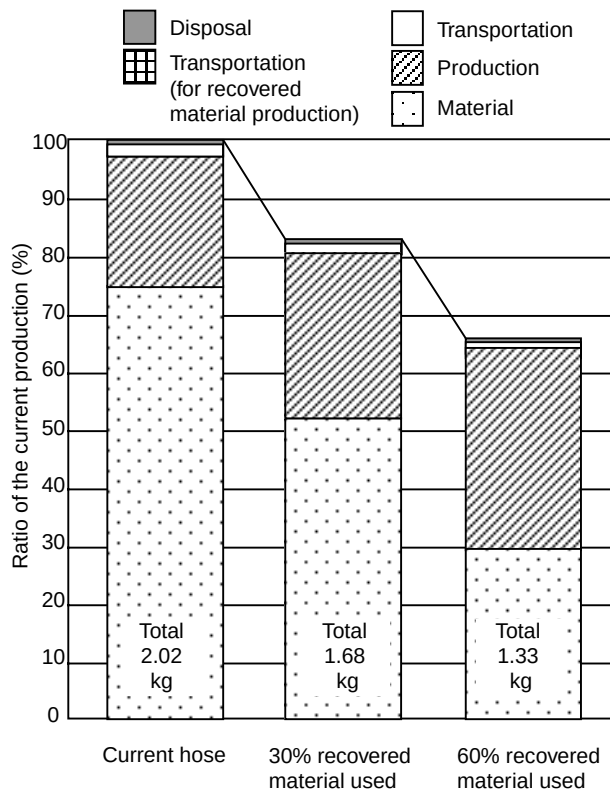


Fig.6 Environmental load (CO₂) of water hoses

decreases in proportion to the higher rate of utilization of recycled material as raw material for the product. This leads to the observation that improvements in the quality of recycled material that link to increased utilization of recycled material as product raw material, and the reduction of the environmental load of the manufacturing stage of the recycled material, are vital in the recycling of waste rubber. It is apparent from the above, therefore, that the Software is effective in the assessment of recycling by LCA.

7. Conclusions

The following results were obtained by improving conventional LCA software through the addition of algorithms thereby enabling it to assess the processing paths in the automotive parts disposal and recycling stages that are specific to such parts:

- (1) The development of Software that is capable of assessing environmental loads, including those from the recycling of parts made of compound materials that involve distinctive, specific processes for recycling, and that provides assessment accuracy nearly equal to the process analysis method.
- (2) Assessment of the effects of recycling process waste material for utilization in rubber parts yielded confirmation of the recycling effect and the issues involved.

In the future, the project will examine the application of this Software in LCAs of larger modules and of entire vehicles.

8. Acknowledgements

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References

- (1) Ministry of International Trade and Industry, Recycle initiative for end of life vehicle, May 1997 (Written in Japanese)
- (2) Japan Federation of Economic Organizations, Keidanren Voluntary Environmental Action Plan: Automobiles, June 1997 (Written in Japanese)
- (3) Bureau of Statistics, Management and Coordination Agency, Input-Output Tables for 1993, (1999) (Written in Japanese)
- (4) Minister of International Trade and Industry Cabinet Research and Statistics Department, Industrial Statistical Tables for 1993 (Commodity Volume), (1997) (Written in Japanese)
- (5) Minister of International Trade and Industry Cabinet Research and Statistics Department, Annual Report on Energy Production and Supply-Demand Statistics for 1993, (1997) (Written in Japanese)
- (6) Gas Industry Division, Agency of Natural Resources and Energy, Annual Statistical Report on the Gas Industry for 1993, (1997) (Written in Japanese)
- (7) Minister of International Trade and Industry Cabinet Research and Statistics Department, Oil and Other Consumption Statistics for 1993, (1997) (Written in Japanese)
- (8) Minoru Makuta, Yuichi Moriguchi, Yasoi Yasuda, Shigeo Sueno, "Evaluation for the Effect of Automotive Bumper Recycling by Life-Cycle Inventory Analysis," in 10th Collected Papers of the Japan Society of Waste Management Experts, p. 150-152, October 1999 (Written in Japanese)

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