Research Article

Establishment and Evaluation of Energy Consumption, Carbon Emission, and Economic Models of Retreaded Tires Based on Life Cycle Theory

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This paper identifies the system composition of the life cycle of retreaded tires and constructs the energy consumption model, carbon emission model, and economic model of retreaded tires based on the life cycle theory. Moreover, the theoretical calculation model and method for the energy consumption, carbon emission, and economy at the production phase, transportation phase, usage phase, and reuse phase of retreaded tires are proposed. After that, this paper puts forward the energy substitution model, carbon reduction model, and cost profit model of five reuse methods of retreaded tires, namely, secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation. Finally, this paper proposes the evaluation index for the energy consumption, carbon emission, and economy in the life cycle of retreaded tires and quantitatively analyzes the energy consumption, carbon emission, and cost profit list in each phase of the life cycle of retreaded tires, obtaining the energy recovery rate, carbon reduction rate, and profit-to-cost ratio of the five reuse methods of retreaded tires. The main conclusions of this paper are as follows: the energy consumption and carbon emission of retreaded tires are the largest at the production phase, while the energy consumption and carbon emission are the lowest at the transportation phase. Among the five reuse methods, the energy recovery effect, carbon reduction rate, and economy of secondary retreading are the optimal ones, and the quantitative results show that retreading is the most effective way for the reuse of waste tires.

1. Introduction

There are mainly five different reuse methods of automobile waste tires, namely, retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation, among which retreading has developed rapidly in the automotive tire industry due to its low-carbon and environmentally friendly advantages. Tire retreading is an effective way to recycle waste tires, and it is an extension and development of tire industry, which is of great significance for promoting the comprehensive utilization of resources such as rubber, transformation of economic growth mode, and sustainable development [1, 2]. The degree of wear of a normal waste tire is less than 30%, while the remaining 70% of the carcass can be reused. It is suggested that each retreaded truck tire can save 4 kg of rubber, 1.7 kg of nylon cord fabric, 2 kg of carbon black, 18 kg of petroleum, and 1 kg of steel. Generally, the service life of retreaded tires with conventional methods is 50% to 70% of brand new tires while and the service life of retreaded tires with presulfurization method can approach or even exceed that of brand new tires. The material required for the retreading of old tires is 30% of that of new tires, and the service life of retreaded tires is 80% of that of new tires. If the quality of retreaded tires can satisfy the national standards and the security, wear resistance and comfort are as good as those of new tires, and the value for the recycling of waste tires is immeasurable considering the production of hundreds of millions of waste tires every year [1–3]. Andrea Corti studied the final disposal process of waste tires by LCA.
Huang et al., based on the theory of life cycle inventory analysis, analyzed the factors influencing energy consumption in tire's life cycle. Yang Lei analyzed the economy, energy, and carbon emissions of tire life cycle. Wu analyzed and studied the tire carbon footprint. At present, there is no report about the life cycle of retreaded tire at home and abroad. Therefore, increasing the retreading rate of waste tires will greatly save rubber resources and promote environmental protection. However, there is no systematic, targeted, and quantitative analysis and evaluation on the impact of tire retreading on society, enterprises, and environment. For this purpose, this paper establishes an evaluation benchmark based on the life cycle theory. By constructing the energy consumption model, carbon emission model, and economic model of retreaded tires, this paper qualitatively and quantitatively evaluates the energy recovery effect, carbon reduction rate, and economic benefits of retreaded tires in the production phase, transportation phase (twice), usage phase, and reuse phase (including secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation), which provides the theoretical guidance for the promotion and application of retreaded tires and the policy formulation of tire retreading industry.

2. Life Cycle System Composition of Retreaded Tires

Retreaded tire is a kind of tire that can be reused after grinding and repairing the outer layer of worn waste tire and pasting a layer of buffer rubber and tread compound and through vulcanizing. The structure of the retreaded tire is the same as that of the new tire; the main difference is that a layer of buffer compound is added to the worn tread, and then the tread compound is applied. The life cycle system composition of retreaded tires is shown in Figure 1, which mainly includes 4 phases: production, transportation (twice), usage, and reuse of retreaded tires. In the production phase, resources and energy such as tread rubber, buffer rubber, old carcass, and adhesive will be consumed while there are five reuse methods in the reuse phase, namely, secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation. In each phase, certain resources and energy will be consumed and certain amount of carbon emissions will also be generated. Particularly, in the reuse phase, new resources and energy will also be regenerated and new carbon emissions will be generated, consuming economic costs and generating new economic profits as well [4, 5].

3. Energy Consumption, Carbon Flow, and Economic Model in the Life Cycle of Retreaded Tires

3.1. Energy Consumption Model in the Life Cycle of Retreaded Tires. The total energy consumption TE of retreaded tires is mainly composed of energy consumption TE1 during the production phase, energy consumption TE2 during the transportation phase (twice), energy consumption TE3 during the usage phase, and energy consumption TE4 during the reuse phase. The energy consumption model in the life cycle of retreaded tires is shown in the following equation:

\[ TE = TE_1 + TE_2 + TE_3 + TE_4. \]

New products or new energy will be produced in the secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation of treaded tires, which are regarded as alternative energy (AE) in this research, equivalent to the energy consumption required for the production of this new product or new energy. It is mainly composed of 5 parts, namely, the energy consumption AE1 of secondary retreading, energy consumption AE2 of mechanical pulverization, energy consumption AE3 of low-temperature pulverization, energy consumption AE4 of combustion decomposition, and energy consumption AE5 of combustion power generation. The energy alternative model in the reuse phase of retreaded tires is shown in the following equation:

\[ AE = AE_1 + AE_2 + AE_3 + AE_4 + AE_5. \]

3.2. Life Cycle Carbon Flow Model of Retreaded Tires. Based on the life cycle energy consumption composition of retreaded tires, the total carbon emission TC of retreaded tires is mainly composed of the carbon emission TC1 during the production phase, carbon emission TC2 during the transportation phase (twice), carbon emission TC3 during the usage phase, and carbon emission TC4 during the reuse phase. The life cycle carbon emission model of treaded tires is shown in the following equation [6, 7]:

\[ TC = TC_1 + TC_2 + TC_3 + TC_4. \]

Similarly, new products or new energy will be produced in the secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation of treaded tires, which are regarded as carbon reduction AC in this research and are composed of 5 parts, namely, the carbon reduction AC1 of secondary retreading, carbon reduction AC2 of mechanical pulverization, carbon reduction AC3 of low-temperature pulverization, carbon reduction AC4 of combustion decomposition, and carbon reduction AC5 of combustion power generation. Based on the life cycle energy consumption composition of retreaded tires, the total carbon emission TC of retreaded tires is mainly composed of the carbon emission TC1 during the production phase, carbon emission TC2 during the transportation phase (twice), carbon emission TC3 during the usage phase, and carbon emission TC4 during the reuse phase. The life cycle carbon reduction model of treaded tires is shown in the following equation:
3.3. Economic Model in the Life Cycle of Retreaded Tires. The economic model in the life cycle of retreaded tires mainly includes economic-cost analysis model, economic-profit analysis model, environment-cost analysis model, and environment-profit analysis model [8, 9].

3.3.1. Economic-Cost Analysis Model. The economic cost in the life cycle of retreaded tires mainly includes the sum of costs of various raw materials and various resources at each phase of the retreaded tires, where the cost of various raw materials is equivalent to the product of unit consumption of various raw materials and the corresponding unit price, and the cost of various resources is equivalent to the product of unit consumption of various resources and the corresponding unit price (water, electricity, coal, natural gas, etc.) and the corresponding unit price.

The economic cost in the life cycle of retreaded tires is shown in the following equation:

$$AC = AC_1 + AC_2 + AC_3 + AC_4 + AC_5.$$  \hfill (4)

3.3.2. Economic-Profit Analysis Model. Unlike the economic-cost model, the profit in the life cycle of retreaded tires only occurs in the production phase and reuse phase of retreaded tires. The profit only occurs in these two phases. The profit in the production phase and reuse phase only occurs in the production phase and reuse phase; and the profit in the production phase and reuse phase only occurs in the production phase and reuse phase.

The economic-profit analysis model is shown in the following equation:

$$C_E(r_{m_i}, r_{e_i}, E_{T_{ij}}) = \sum_i r_{m_i} E_{L_{T_{ij}}} + \sum_j r_{e_i} E_{L_{e_{ij}}}.$$  \hfill (7)

3.3.4. Environmental-Profit Analysis Model. Environmental profit is the benefit brought to the environment, which is the CO2 emission reduction achieved by reusing the product of retreaded tires generated at the reuse phase in the industrial production. It mainly includes the sum of CO2 emission fee generated by producing the same product at the reuse phase; the output of various products at the reuse phase; the fee of CO2 emissions. The environmental-profit analysis model is shown in the following equation:

$$PE_i(T_{ij}, CEC_i, PC_i) = \sum_i T_{ij} CEC_i PC_i.$$  \hfill (8)

4. Energy Consumption Model and Carbon Emission Model of Retreaded Tires at Each Phase

4.1. Energy Consumption Model and Carbon Emission Model at the Production Phase. The energy consumption of retreaded tires at the production phase is mainly composed of the raw materials and energy consumed. The energy consumption during the production phase of retreaded tires is established based on the first law of thermodynamics and the law of conservation of mass. The total carbon emission during the production phase is shown in the following equation [10, 11]:

$$TE_i = \sum_i (PM_i \times PM_{p_i}) + \sum_j (PE_j \times PE_{p_j}).$$  \hfill (9)

The carbon emission during the production phase of retreaded tires is mainly included in the greenhouse effect caused by CO2 emissions. The carbon emission during the production phase of retreaded tires is established based on the first law of thermodynamics and the law of conservation of mass. The total carbon emission during the production phase of retreaded tires is shown in the following equation:

$$TC_i = \sum_i (PM_i \times PM_{CL}) + \sum_j (PC_{E_j} \times PC_{E_{CL}}).$$  \hfill (10)

4.2. Energy Consumption Model and Carbon Emission Model at the Transportation Phase. The transportation phase of retreaded tires mainly includes three parts, namely, the
transportation of raw materials to the production point, the production point to the point of sales, and the collecting point of waste tires to the reuse disposal point. The total energy consumption during the transportation phase is mainly subject to the impact of transportation method, transportation distance, and fuel used by transportation vehicles. \( \text{TE}_2 \) is total energy consumption during the transportation phase; \( \text{TD} \) is the average distance during the transportation phase; \( \text{TE}_j \) is the energy density of energy consumed during the transportation phase. The energy consumption model for the transportation phase is shown in the following equation:

\[
\text{TE}_2 = \text{TD} \times \text{TE} \times \text{TE}_j. \tag{11}
\]

The carbon emission coefficient during the transportation phase is related to the average transportation distance, energy consumption, and carbon emission coefficient. \( \text{TC}_2 \) is the total carbon emission during the transportation phase; \( \text{TD} \) is the average transportation distance during the transportation phase; \( \text{TCE}_j \) is the energy consumption during the transportation phase; and \( \text{TCEI}_j \) is the carbon emission coefficient of energy consumed at the transportation phase. The carbon emission model during the transportation phase is shown in the following equation:

\[
\text{TC}_2 = \text{TD} \times \text{TCE}_j \times \text{TCEI}_j. \tag{12}
\]

4.3. Energy Consumption Model and Carbon Emission Model at the Usage Phase. The energy consumption of retreaded tires during the usage phase is subject to the impact of average transportation distance and the fuel used. \( \text{TE}_3 \) is the total energy consumption at the usage phase; \( \text{UD} \) is the average transportation distance at the usage phase; \( \text{UE} \) is the energy consumption at the usage phase; and \( \text{UE}_j \) is the energy density of energy consumed at the usage phase. The energy consumption model at the usage phase is shown in the following equation:

\[
\text{TE}_3 = \text{UD} \times \text{UE} \times \text{UE}_j. \tag{13}
\]

The carbon emission during the usage phase is mainly related to the average transport distance, energy consumption, and carbon emission coefficient. \( \text{TC}_3 \) is the total carbon emission during the usage phase; \( \text{UD} \) is the average transportation distance at the usage phase; \( \text{UCE}_j \) is the energy consumption during the usage phase; and \( \text{UCEI}_j \) is the carbon emission coefficient of energy at the usage phase. The carbon emission model at the usage phase is shown in the following equation:

\[
\text{TC}_3 = \text{UD} \times \text{UCE}_j \times \text{UCEI}_j. \tag{14}
\]

4.4. Energy Consumption Model and Carbon Emission Model at the Reuse Phase. Energy is consumed and recovered at the reuse phase of retreaded tires. \( \text{TE}_4 \) is the total energy consumption at the reuse phase; \( \text{RM}_i \) is the consumption of raw material \( i \) at the reuse phase; \( \text{RM}_j \) is the energy density of raw material \( i \) at the reuse phase; \( \text{RE}_j \) is the consumption of energy \( j \) at the reuse phase; and \( \text{RE}_j \) is the energy density of energy \( j \) at the reuse phase. The carbon consumption model at the reuse phase is shown in the following equation:

\[
\text{TC}_4 = \sum_i (\text{RM}_i \times \text{RM}_j) + \sum_j (\text{RE}_j \times \text{RE}_j). \tag{15}
\]

Both raw materials and energy are consumed at the reuse phase of retreaded tires. \( \text{TC}_4 \) is the total carbon emission at the reuse phase; \( \text{RCM}_i \) is the consumption of raw material \( i \) at the reuse phase; \( \text{RCM}_j \) is the carbon emission coefficient of raw material \( i \) at the reuse phase; \( \text{RCE}_j \) is the consumption of energy \( j \) at the reuse phase; and \( \text{RCEI}_j \) is the carbon emission coefficient of energy \( j \) at the reuse phase. The carbon emission model at the reuse phase is shown in the following equation:

\[
\text{TC}_4 = \sum_i (\text{RCM}_i \times \text{RCM}_j) + \sum_j (\text{RCE}_j \times \text{RCEI}_j). \tag{16}
\]

4.5. Evaluation Indexes of the Energy Consumption, Carbon Emission, and Economy of Retreaded Tires

4.5.1. Evaluation Indexes of Energy Consumption. New products or new energy will be produced in five reuse methods of retreaded tires, namely, the secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation. \( \text{AE} \) is the alternative energy at the reuse phase; \( \text{RPP}_j \) is the output of new product \( i \) at the reuse phase; \( \text{RPE}_j \) is the energy density of new product \( i \) at the reuse phase; \( \text{RPE}_j \) is the output of new energy \( j \) at the reuse phase; and \( \text{RPE}_j \) is the energy density of new energy \( j \) at the reuse phase. The alternative energy model is shown in the following equation [12, 13]:

\[
\text{AE} = \sum_i (\text{RPP}_i \times \text{RPE}_i) + \sum_j (\text{RPE}_j \times \text{RPE}_j). \tag{17}
\]

The net energy surplus (NES) at the reuse phase of retreaded tires can be expressed by the difference between the alternative energy and the total energy consumption at the reuse phase, as shown in the following equation:

\[
\text{NES} = \text{AE} - \text{TE}_4. \tag{18}
\]

The recovery degree of the input energy of the five reuse methods of retreaded tires, namely, secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation, at the reuse phase can be expressed by ERR, which is the proportion of output energy at the reuse phase to the input energy (mainly including the energy consumption at the production phase and reuse phase), as shown in the following equation:
4.5.2. Evaluation Indexes of Carbon Emission. The net carbon surplus (NCS) of retreaded tires is the difference between the carbon reduction (AC) and the total carbon emission (TC) during the reuse phase, as shown in the following equation:

\[
NCS = AC - TC_4.
\]  

(20)

New products or new energy will be produced from the five reuse methods of retreaded tires, namely, secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation. Every type of new product or new energy can be regarded as a type of carbon reduction, whose value is the carbon emission from the direct production of the new product or new energy. RPP, is the output of new product j at the reuse phase; RPCI, is the carbon emission coefficient of new product i at the reuse phase; RPE, is the output of new energy j at the reuse phase; and RPCE, is the carbon emission coefficient of new energy j at the reuse phase. The carbon reduction model at the reuse phase is shown in the following equation:

\[
AC = \sum_i (RPP_i \times RPCI_i) + \sum_j (RPE_j \times RPCE_j).
\]  

(21)

The reduction degree of carbon emissions by the five reuse methods of retreaded tires, namely, secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation, at the reuse phase can be expressed by CRR, whose value is the proportion of the carbon reduction at the reuse phase to total carbon emissions (mainly including carbon emissions at the production phase and reuse phase), as shown in the following equation:

\[
CRR = \frac{AC}{TC_1 + TC_4} \times 100\%.
\]  

(22)

4.5.3. Economic Evaluation Indexes. When evaluating the economic benefits of the five reuse methods of retreaded tires, namely, secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation, the profit-to-cost ratio \(P_{CR}\) can be used as the evaluation index to show the impact of cost recovery rate at different reuse phases. The economic evaluation index is calculated based on the following equation [14–16]:

\[
P_{CR} = \frac{\sum_i E_{P_i} + P_{E_i}}{\sum_i E_{C_i} + C_{E_i}} \times 100\%.
\]  

(23)

5. List of Energy Consumption, Carbon Emission, and Economic Analysis of Retreaded Tires

5.1. Research Object. The 26.5R25 retreaded tire is selected as the research object. The calculation is based on the single tire weight of 0.5 t, service life of 1.5 years, and average transportation distance of 50,000 km. The weight of two retreaded tires, namely, 1 t, is taken as the functional unit.

5.2. Data Sources. The data of retreaded tires at the production phase refer to the Rubber Tire Industry Report in China and the actual data of two tire retreading companies (Harbin Huiliang Automobile Tire Retreading Co., Ltd. and Xinhongqi Tire Retreading Factory); the data of retreaded tires at the transportation and usage phase refer to the actual data of a transport company (Heilongjiang Longyun (Group) Co., Ltd.); the data of the mechanical pulverization, combustion decomposition, and combustion power generation of retreaded tires at the reuse phase refer to the research results in [10, 12]; and the data of low-temperature pulverization refer to the research results in [12]. The geographic boundary is Northeast China, and the time boundary is from 2018 to 2020.

6. Analysis and Evaluation of the Energy Consumption, Carbon Emission, and Economic Results of Retreaded Tires

6.1. Analysis and Evaluation of Energy Consumption Results. The energy input-output list in the life cycle of retreaded tires is shown in Table 1.

It can be seen from Table 1 that the total energy consumption in the life cycle of retreaded tires is about 144607 MJ, of which the energy consumption at the production phase is 132913 MJ, accounting for 91.91% of the total energy consumption in the life cycle; the energy consumption at the usage phase is 10591 MJ, accounting for approximately 7.32%; and the energy consumption at the transportation phase is 1103 MJ, accounting for about 0.76%. The ranking energy consumption is production phase > usage phase > transportation phase. It can be seen from the comparative analysis of the net energy surplus of the five reuse methods (secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation), shown in Figure 2, that the net energy surplus of the secondary retreading is 91062 MJ and the energy recovery rate is 74.88%, which is the highest among these five reuse methods. The ranking of the energy recovery effect of the five reuse methods of retreaded tires, shown in Figure 3, is secondary retreading > combustion decomposition > mechanical pulverization > low-temperature pulverization > combustion power generation.

6.2. Analysis and Evaluation of Carbon Emission Results. The input-output list of carbon emission and carbon re-duction in the life cycle of retreaded tires is shown in Table 2.

It can be seen from Table 2 that the total carbon emission in the life cycle of retreaded tires is about 3280 kgC, of which the carbon emission during the production phase is 3,046 kgC, accounting for about 92.87% of the total carbon emission; the carbon emission at the usage phase is 212 kgC, accounting for about 6.46% of the total
and the carbon emission at the transportation phase is 22 kgC, accounting for about 0.67% of the total. The ranking of carbon emission is production phase > usage phase > transportation phase. It can be seen from the comparative analysis of the net carbon surplus and carbon reduction rate of the five reuse methods (secondary retreading, mechanical pulverization, low-temperature pulverization, combustion decomposition, and combustion power generation), shown in Figures 4 and 5, that the net carbon surplus of secondary retreading is 2052 kgC and the carbon reduction rate is 74.77%, which is the highest among these five reuse methods. Therefore, the ranking of the carbon reduction effect of these five reuse methods is secondary retreading > combustion decomposition > mechanical pulverization > combustion power generation > low-temperature pulverization.
Table 2: Input-output list of carbon emission and reduction in retreaded tires life cycle.

| Category                  | Name                      | Value (kgC/t tire) |
|---------------------------|---------------------------|--------------------|
| Carbon emission production phase | TC₁                       | 3046               |
| Transportation phase      | TC₂                       | 22.065             |
| Usage phase TC₃           | Secondary retreading      | 894                |
|                           | Mechanical pulverization  | 144                |
|                           | Low-temperature pulverization | 812.2            |
|                           | Combustion decomposition  | 793                |
|                           | Combustion power generation | 26               |
| New product substation, AC|                           | -7396              |
|                           |                           | 173                |
|                           |                           | 352                |
| Carbon reduction           | Net carbon surplus, NCS   | 2946               |
| evaluation index          | Carbon reduction rate, CRR| 74.77%             |
|                           |                           | 22.70%             |
|                           |                           | 6.51%              |
|                           |                           | 25.94%             |
|                           |                           | 12.30%             |

Figure 3: Energy recovery rate of the five reuse methods.

Figure 4: Net carbon surplus of the five reuse methods of retreaded tires.
6.3. Analysis and Evaluation of Economic Results. The economic cost-profit in the life cycle system of retreaded tires is shown in Table 3 (the cost of plant, equipment, and labor is not considered in the research).

It can be seen from Table 3 that the profit-to-cost relationship in the life cycle of retreaded tires is secondary retreading (50.05%) > combustion decomposition (27.20%) > mechanical pulverization (22.44%) > low-temperature pulverization (8.21%) > combustion power generation (4.62%), of which the profit-to-cost ratio of secondary retreading is the largest, much higher than that of the remaining four reuse methods. Namely, it is about 2 times that of combustion decomposition and mechanical pulverization, about 6 times that of low-temperature pulverization, and about 11 times that of combustion power generation. Thus, it can be concluded that retreading is the most effective way to realize the economic benefits of waste tire recycling while the profit-to-cost ratio of low-temperature pulverization and combustion power generation is below 10% and 5%, respectively. From the economic point of view, these two reuse methods are not recommended in reality.

7. Conclusion

(1) Based on the life cycle evaluation theory, this paper establishes the energy consumption model, carbon emission model, and economic model of retreaded tires; determines the evaluation index and calculation method; and conducts the quantitative analysis and evaluation of the energy consumption, carbon emission, and economy.

(2) The energy consumption and carbon emission at the production phase of retreaded tires are the largest, followed by the usage phase, while the energy consumption and carbon emission at the transportation phase are the smallest, indicating that the impact on the total energy consumption and environment is the greatest at the production phase of retreaded tires.

(3) Among the 5 reuse methods of retreaded tires, the ranking of the energy recovery effect is secondary retreading > combustion decomposition > mechanical pulverization > low-temperature pulverization > combustion power generation; the ranking of the carbon reduction effect is secondary retreading > combustion decomposition > mechanical pulverization > combustion power generation > low-temperature pulverization; and the ranking of the profit-to-cost ratio is secondary retreading > combustion decomposition > mechanical pulverization > low-temperature pulverization > combustion power generation.
The results of energy recovery, carbon emission, and economic benefits all indicate that tire retreading is the most effective way in the reuse of waste tires. At the same time, the secondary retreading of retreaded tires will generate greater energy recovery effect and economic benefits, greatly reducing the carbon emission. The secondary and multiple retreading are also the development trend in future tire recycling. Life cycle assessment of retreaded tire is a complex process. This paper takes engineering tire as the main evaluation object, and its research conclusions have certain limitations. In the future, life cycle assessment of the various types of tires will be tried, so as to enrich related theories of retreaded tire about the life cycle energy consumption, carbon emission, and economy aspect, thus providing further theoretical guidance for industry policy making and retreaded tire manufacturing.

Data Availability
No data were used to support this study.

Conflicts of Interest
The authors declare that there are no conflicts of interest regarding the publication of this article.

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