Recycling Mode and Remanufacturing Cost Analysis of Used Automobile Engine Based on System Dynamics

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Abstract: From the three processes of recycling, remanufacturing and remanufacturing product sales, this paper analyses the characteristics of the automobile engine cost. By using the theory of system dynamics method, it establishes system flow diagram of automobile engine recycling and remanufacturing cost under the methods of network recovery and 4S shop recovery, and constructs engine remanufacturing cost model. Taking Shandong heavy-duty automobile diesel engine remanufacturing as an example, the model is simulated and analyzed with Vensim PLE software, and the change trend of engine recovery cost and profit from 2015 to 2035 is analyzed and predicted. The sales revenue, cost and profit of remanufacturing under the two recovery methods are compared and analyzed. Furthermore, the simulation results show that the different selections of engine recovery strategies have significant differences on the economic impact of engine remanufacturing, and the economic analysis can provide a reference for the development decision of engine remanufacturing.

1. Introduction

With the rapid development of economy, people's demand for cars is also increasing, and people face with the problem of recycling and dismantling caused by increasing number of scrapped cars[1]. Recycling and remanufacturing of scrapped automobile engines can fully explore and utilize the value contained in it, effectively extend the service life of the products, and have the advantages of saving resources and reducing environmental pollution[2].

At present, the analysis of recycling mode and remanufacturing cost of waste automobile engines is seldom involved, which has become a gap in the remanufacturing industry chain[3,4]. From the point of view of system dynamics, this paper studies the economic benefits of recovery and remanufacturing of heavy-duty automobile engine under different recovery modes.

2. System dynamics model of automobile engine recovery and remanufacturing under different recovery modes

The research object of this paper is the heavy-duty automobile diesel engine. At present, there are two recycling modes for the waste diesel engine in remanufacturing enterprises, which are network recycling and 4S shop recycling, respectively. In the long term, the two modes vary in terms of investment cost, recovery cost, recovery quantity, and sales price, makes the sales profit is also different. Taking the diesel engine remanufacturing of Shandong Province as an example, this research analyzes the cost,
revenue and profit of engine recycling and remanufacturing under two recycling strategies of network recycling and 4S shop recycling. Vensim PLE software is used for simulation and the results are analyzed.

The time of the simulation model is set as 2015–2035, and the time step is selected for one year. Since the initial data from 2015 to 2019 is relatively complete, the accuracy of the data can be guaranteed, so that the differences in costs, revenues and profits under different recovery methods within 15 years can be reliably predicted based on the data of the five years.

2.1. System flow diagram
Fig.1 shows the system flow diagram of scrapped automobile engine recovery and remanufacturing under the network recovery mode. And Fig.2 shows the system flow diagram of scrapped automobile engine recovery and remanufacturing under the 4S shop recovery mode.

Fig.1 System flow diagram of network recovery engine

2.2. Main parameter
According to the statistical data of China Statistical Yearbook[5], the table function of birth rate, death rate and GDP growth rate of Shandong Province is obtained. Some variables that do not change much over time are approximated as constants. The scrap rate, recovery rate and replacement rate of automobile engine are approximately 0.06, 0.12 and 0.06, respectively. The abbreviations and meanings of each variable and constant are shown in Tab.1. Parameter values under different recovery modes are shown in Tab.2.
Fig. 2 System flow diagram of the recovery engine in 4S shop

Tab. 1 Abbreviations for variables and constants

| Abbreviations | Variables or constants               | Abbreviations | Variables or constants               |
|---------------|-------------------------------------|---------------|-------------------------------------|
| TP            | total population                    | RC            | remanufacturing cost                |
| GDPV          | total GDP value                     | NOC           | network operating cost              |
| COQ           | car ownership quantity              | RRTC          | recovery and remanufacturing total cost |
| QES           | quantity of engines to be scrapped  | SR            | sales revenue                       |
| ERV           | engine recovery volume              | SP            | sales profit                        |
| ERQ           | engine replacement quantity         | NN            | network number                      |
| AADQ          | annual automobile demand quantity   | RRA           | recovery rate                       |
| AESQ          | annual engine scrap quantity        | RRB           | rejection rate                      |
| AERV          | annual engine recovery volume       | TR            | turnover rate                       |
| AERQ          | annual engine replacement quantity  | RRC           | remanufacturing rate                |
| BR            | birth rate                          | PIF           | population impact factor            |
| DR            | death rate                          | GDPIF         | GDP impact factor                   |
| GDPGR         | GDP growth rate                     | BP            | birth population                    |
| RQ            | remanufactured quantity             | DP            | death population.                  |
| ERC           | engine recovery cost                | GDPG          | GDP growth                          |
| RTC           | recovering transportation cost       | RUP           | recovery unit price                 |

Continued table

| Abbreviations | Variables or constants | Abbreviations | Variables or constants |
|---------------|------------------------|---------------|------------------------|
| MC            | marketing cost         | UTC           | unit transport cost    |
| USC           | unit sales cost        | NCC           | new component cost     |
| UPC           | unit production cost   | OCUN          | operating cost of the unit network |
| USP           | unit selling price     |               |                        |
3. Analysis and comparison of simulation results

3.1. Comparison of total cost of recovery and remanufacturing
The general trend of recycling network and 4S shop is shown in Fig. 3. It can be seen that the total cost of engine recycling network is higher than the total cost of 4S shop. In the first ten years, the cost gap is small and increases year by year, while the total cost gap gradually stabilizes in the latter ten years. Because the network recycling method involves network operating costs. By contrast, 4S shop recycling method can save the cost. And the recovery unit price and new component costs under 4S shop recycling mode is slightly less than that under network recycling mode. The two aspects lead that total cost of 4S Shop engine recovery is lower than that of network engine recovery.

3.2. Comparison of sales revenue
The comparison of sales revenue is shown in Fig. 4. It can be seen that the sales revenue of 4S shop as a whole is lower than sales revenue of network. This kind of situation is mainly because the recovery rate and replacement rate of the recycling network is higher than that of 4S shop and the unit price and sales quantity of the recycling network are higher than that of 4S shop. They cause that the sales revenue of network as a whole is always higher than that of 4S shop.

3.3. Comparison of sales profit
The comparison of sales profit is shown in Fig. 5. Generally, there is little difference between the sales profit of recycling network and 4S shop, and both of sales profit have an obvious growth trend. From this point of view, although the total cost of engine recovery in the network is higher than that of 4S shop, the predicted sales status of the network is better than that of 4S shop. Therefore, the economic benefits of engine recovery and remanufacturing through the recycling network are better than that of 4S shop.

![Fig. 3 Total cost comparison between engine recovery and remanufacturing](image-url)
Fig. 4 Comparison of sales revenue between engine recovery and remanufacturing

Fig. 5 Comparison of sales profit between engine recovery and remanufacturing

4. Conclusions
Based on the theory of system dynamics, this paper establishes diesel engine remanufacturing cost models under network and 4S shop recycling modes. This paper takes Shandong Province as an example to simulate and analyze the economy of engine recycling and remanufacturing under the two recycling methods, including the comparative analysis of the total cost, sales revenue and sales profit of remanufacturing. The research shows that with the increasing population of Shandong Province and the continuous improvement of people's living standard, the economy of engine recovery in network is better than that of engine recovery in 4S shop in terms of total cost, revenue and profit. Therefore, enterprises may take appropriate measures to increase the economic benefit brought by the engine remanufacturing. For one thing, they can establish more new engine recycling networks to increase the number of recycling network, and expand the size of the recycling network. For another, from the aspects of government efforts to control, they can effectively improve the recovery rate and turnover rate of scrapped automobile engine. Thus, it can make engine remanufacturing quantity of the recovery network and 4S shop increasing in order to improve the economic benefits generated by the engine remanufacturing.

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