Research on the influence of different calculation methods of deterioration factors on light-duty vehicle emissions

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Abstract. The calculation method of deterioration factor of durability test in China 6 emission regulation of light-duty vehicle is studied. The difference between multiplication and addition in the implementation of the regulations is obtained. The results show that the additive DF can keep the actual deterioration level of the car, while the multiplication DF will change the deterioration level of the car and enlarge the error; With the decrease of emission limit, multiplication DF makes it more difficult for vehicles to pass through emission limit value than add DF; For emission consistency inspection, the two degradation factors have advantages in different regions.

1 Introduction

In light-duty vehicle emission regulations, emission durability test has always been an important automobile test item. By driving a certain mileage on the test track or chassis dynamometer according to the specific regulations (national emission regulations: 160000 km or 200000 km), and measuring the pollutant emission value every 10000 km, the deterioration factor of various pollutants is calculated [1,2], It is used to show the trend of emission deterioration during the future operation. After that, the degradation factor is applied to the type I test and production consistency inspection of the vehicle. The degradation factor is used to calculate the measured value of the type I test pollutants of the new vehicle with the initial mileage less than 3000 km in a certain way, and the test statistics are calculated, so as to determine whether the vehicle passes the type I test and production consistency inspection..

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In recent years, with the continuous improvement of environmental awareness and automotive technology level, countries have introduced more stringent automotive emission regulations, including China 6 national emission regulations. In these regulations, corresponding changes have been made to the emission durability test [3,4], not only the mileage of durability test has been increased and a variety of new test methods have been added, but also the calculation method of deterioration factor, an important parameter, has been changed, and a new calculation method of deterioration factor has been added, This degradation factor is called additive DF (ADF), and another degradation factor is called multiplicative DF (MDF)). Obviously, due to the different calculation methods of the two deterioration factors, the vehicle emission results after the two treatments will have different effects on the final judgment of the test. For the characteristics of the two, the impact on the test results, which degradation factor should be selected in the test and which degradation factor can better reflect the actual degradation trend of automobile emissions, are the issues that automobile manufacturers and testing units pay more attention to, and there are disputes. Aiming at the above problems, this paper analyzes the emission data of some endurance test vehicles, so as to determine the various effects of the two.

2 Two calculation methods of deterioration factors

The emission durability test starts from 0 km, measures the emission $M_i^0$of various pollutants at 0 km, and then every 10000 km(±400km) The vehicle emission M_i^j (China 6: J = 1, 2,..., 16, and the test can use AMA or SRC (standard road cycle) test cycle) [5-8]. The test should be carried out according to the type I test specification in the regulations, and the results of each test should meet the emission limits of various pollutants in the regulations.

After all the emission data are measured, the emission results need to be preprocessed to calculate the deterioration factor. First of all, it is necessary to fit all the emission data except 0km into a linear function of driving range to get the best straight line that can represent the deterioration process of automotive catalyst. The least square method is a simple and accurate method for linear fitting [7], and the calculation process is as follows.

The fitting linear equation is as follows:

$$M_{i*}^{j} = ax^{j} + b \tag{1}$$

In the above formula, M_{i*}^{j} is the fitting value of pollutant I emission at the driving mileage of J 10000 km; x^{j} is the mileage of the j-th emission test.

The optimization objective of the least square method is as follows:

$$\min \sum (M_{i*}^{j} - M_{i}^{j})^{2} \tag{2}$$

Let formula (2) calculate the partial derivatives of a and b respectively, which are equal to zero, and solve the equations with a and B as unknowns:

$$\begin{cases} b = (\sum M_i^j)/m - a(\sum x^j)/m \\ a = \left[m\sum M_i^j x^j - (\sum M_i^j \sum x^j)\right] \\ \quad /\left[m\sum (x^j)^2 - (\sum x^j)^2\right] \end{cases} \tag{3}$$

In the above formula, m is the number of tests, and m = 16 or 20.

Then, the linear equation is used to calculate the sum of various pollutant emission values M_{i1} or M_{i2} at 6400km and 160000km or 200000km.

In China 6, the deterioration factor can be calculated with the following formula [1]:

$$MDF = M_{i2}/M_{i1} \tag{4}$$

However, with the reduction of emission limits in emission regulations, the calculation method of deterioration factor shown in formula (4) enlarges the fluctuation of test results and has more and more adverse effects on the mass production management of enterprises. Therefore, another method for calculating degradation factor is added in European and American emission regulations [3,4,9].

$$ADF = M_{i2} - M_{i1} \tag{5}$$

After calculating the deterioration factor of the vehicle, the type I test results of the new vehicle can be calculated (for the calculation method given in formula (4), multiply the type I test results by DF, that is, MDF; For the calculation method given in formula (5), add DF to the results of type I test (i.e. ADF) and compare it with the specific value specified in the regulations to judge whether the vehicle emission meets the requirements of the regulations.

3 The influence of two deterioration factors on the determination of test results

3.1 M-DF changes the deterioration trend

After the vehicle emission durability test, the emission deterioration trend line is obtained by linear fitting, and the MDF and ADF can be calculated by different methods. When using the degradation factor to determine whether the vehicle emission meets the regulations, it is found that the two degradation factors have great differences in the determination of the test results when the test error (i.e. the difference between the measured value of a pollutant in the 0 km I-type test of a new vehicle and the pollutant value fitted by the degradation trend line) is the same. Figure 1 is the NOx test data diagram of a test vehicle, the multiplicative DF is equal to 2.89, and the additive DF is equal to 0.0268g/km.

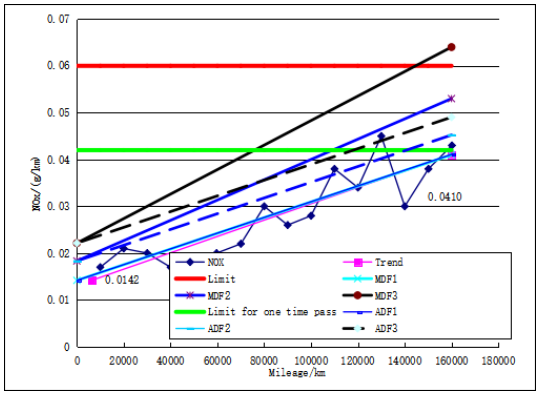

Fig. 1. NOx durability data diagram of test vehicle.

Three I-type tests were carried out under the condition of new vehicle. Due to the existence of test error, the measured values of NOx in the three tests are different. The measured values are treated with two kinds of deterioration factors respectively, and the NOx emission value equivalent to 160000km is obtained. As shown in Figure 1, as the measured value of NOx in the new car type I test increases, and both are greater than the fitting value, the slope of the straight line between the emission value and the measured value after the multiplicative DF treatment becomes larger, which is greater than the slope of the deterioration trend line of the durability test, that is, the deterioration trend after the calculation is more and more deviated from the actual deterioration trend of the car, and the test error is amplified. However, the slope of the straight line between the emission value and the measured value after using the additive DF treatment is parallel to the slope of the durability deterioration trend line, which maintains the deterioration effect of the vehicle, so that the difference between the emission value before and after using the deterioration factor treatment remains unchanged.

From the above analysis, it can be seen that the additive DF can keep the vehicle deterioration trend unchanged, while the multiplicative DF will change the vehicle deterioration trend and enlarge the test error due to the influence of the measured emission values. Detailed statistical data are shown in Table 1. The difference between the measured values of test 1 and test 3 is the largest, which is 0.008g/km. After the addition DF treatment, the difference remains unchanged, and the treated emission values have passed the regulatory requirements, while the multiplicative DF enlarges the difference between the two test results to 0.023g/km, which makes the number of tests passing the regulatory limit increase or exceed the regulatory limit.

Table 1. Statistical table of test results.

	Raw NOx (g/km)	MDF correction result(g/km)	MDF Judgment result	ADF correction result(g/km)	ADF Judgment result
Test 1	0.022	0.064	fail	0.049	2 times pass
Test 2	0.018	0.053	3 times pass	0.045	2 times pass
Test 3	0.014	0.041	1 time pass	0.041	1 time pass
Maximum difference	0.008	0.023	-----	0.008	-----

3.2 Impact of emission limits

With the release and implementation of the six emission standards of light vehicles, the emission regulations of vehicles are becoming more and more strict, and the pollutant limits are lower and lower. This change also has different effects on multiplication DF and additive DF using different calculation methods.

As shown in Figure 2, the lower the limit value of vehicle emission regulations is, the lower the vehicle emission level is, the greater the difference between the values equivalent to 160000km of pollutant emission after two degradation factors is treated. The difference between the emission value and 160000km fitting value after adding DF is equal to the difference between the measured value of 0km and the fitting value of the new vehicle, without amplification error level, which keeps the deterioration level of the vehicle; The difference between the emission value and 160000km fitting value after multiplicative DF treatment increases with the decrease of vehicle emission level. That is, with the increase of emission regulations, the change of multiplicative DF on the deterioration level of vehicles increases, and the pollutant emission value after treatment is becoming worse, which makes the vehicle emission fail. It can be seen that the addition DF can reflect the actual

deterioration factor of the vehicle, which is not affected by the change of the regulation limit value.

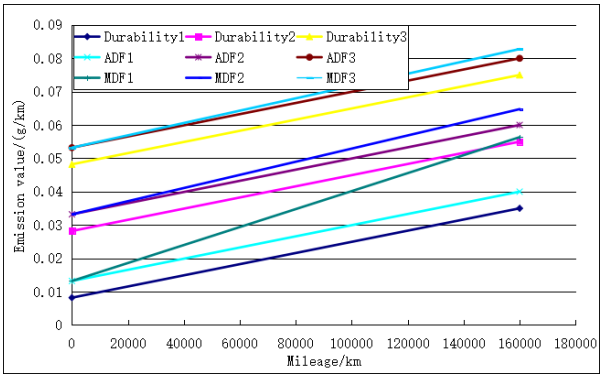

Fig. 2. Treatment results of two deterioration factors on three tests.

3.3 Influence of two deterioration factors on automobile production consistency

Automobile production conformity inspection is an important part of automobile emission regulations, and the type I test production conformity inspection is applied to the emission deterioration factor [10]. Different calculation methods for the emission deterioration factor will inevitably have an impact on the determination result of conformity, Table 2 shows the difference between the two deterioration factors when a test vehicle passes the type I test at one time.

Table 2. Difference of two deterioration factors in type I test.

		THC (g/km)	CO (g/km)	NOx (g/km)	NMHC (g/km)
0.7 Limit		0.07	0.7	0.042	0.048
M_{i2}		0.0813	0.5762	0.0246	0.0347
M-DF	DF	3.177	2.144	2.724	1.904
	Max value for one time pass	0.0220 (22%L)	0.228 (30.4%L)	0.0154 (25.7%L)	0.0252 (37.1%L)
A-DF	DF	0.0557	0.3074	0.0156	0.0165
	for one time pass	0.0143 (14.3%L)	0.1825 (19.7%L)	0.0264 (44%L)	0.0315 (46.3%L)
Difference		-7.7%L	-10.7%L	18.3%L	9.2%L

It can be seen from table 2 that when two deterioration factors are used respectively, the maximum measured value of pollutants allowed for the same vehicle to pass the test at one time in type I test is quite different, and both have their own advantages and disadvantages. When the emission value mi2 of 160000km on the fitting line of vehicle durability test data is greater than 0.7 times of the emission limit, the probability of passing the test at one time by using multiplicative DF is higher than that by using additive DF; When the former is less than the latter, it is easier to pass the test with additive DF at one time. The larger the difference between the former and the latter, the greater the difference between the multiplicative DF and the additive DF. The reason for the above phenomenon is that the multiplicative DF algorithm will change the deterioration trend of the vehicle when the pollutant test value deviates from the pollutant durability data fitting line. When the measured value is greater than the fitting value, the slope of the line between the measured

value and the emission value after the multiplicative degradation factor treatment becomes larger. On the contrary, the slope becomes smaller, and the larger the deviation is, the larger the slope changes, while the added DF will not change the slope, as shown in Fig. 3 and Fig. 4.

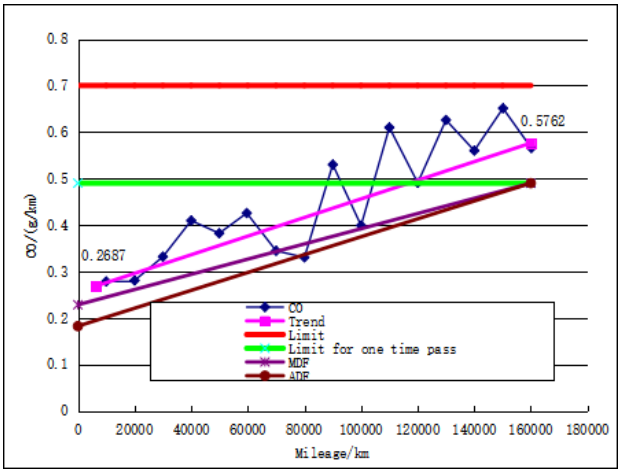

Fig. 3. 160000km fitting value is greater than 0.7 times limit value.

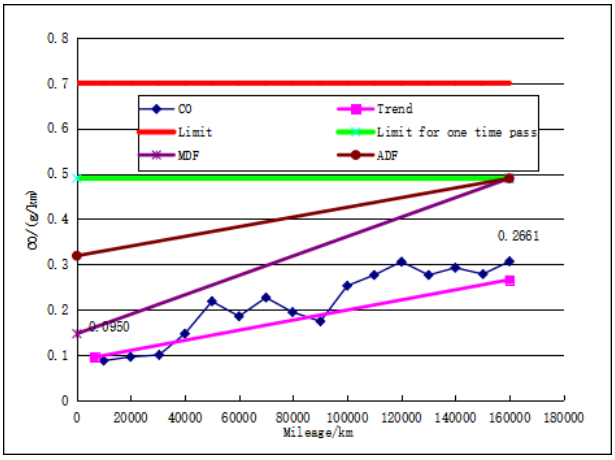

Fig. 4. The fitting value of 160000km is less than 0.7 times the limit value.

Another important parameter of production consistency check is the test statistic, which is formulated as follows:

$$\frac{1}{s}\sum_{i=1}^{n}(\ln L - \ln x_i) \tag{6}$$

where s is the natural logarithm of the production standard deviation estimate; L is the emission limit; xi is the emission value of pollutant i corrected by deterioration factor; n is the current number of vehicles.

As shown in Figure 5, the influence of deterioration factor on test statistics can be divided into two situations: when the measured value is larger than the fitting value of endurance fitting line, the emission value corrected by multiplicative DF is greater than that of additive DF correction, which makes the test statistics corrected by multiplicative DF

smaller and that of additive DF correction, making the former more difficult to pass the judgment than the latter; On the contrary, when the measured value is less than the fitting value on the durable fitting line, the former is easier to pass the judgment than the latter.

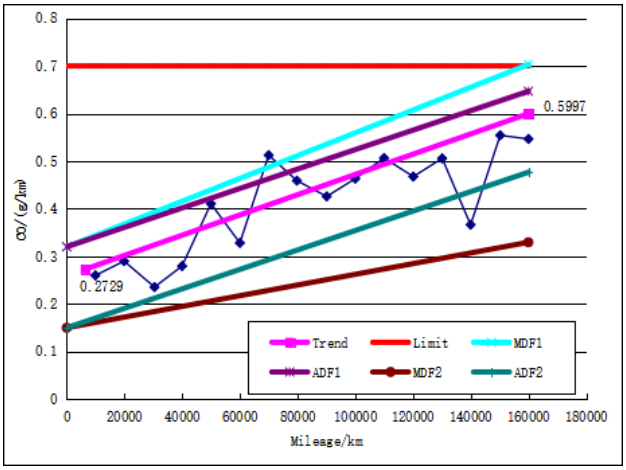

Fig. 5. Difference of two deterioration factors when measured values are different.

When DF is not obtained by real vehicle durability or bench durability, the standard recommended DF can also be directly used. The specific recommended values are shown in the table below.

Table 3. Recommended DF values.

		THC	CO	NOx	NMHC
M=DF		1.5	1.8	1.8	1.5
A-DF	6a	30	150	25	20
	6b	16	110	15	10

When the measured emission values are determined, different emission correction values will be obtained by choosing different deterioration factors. The specific deterioration factor can be determined by the following methods:

a) When (M-DF-1) * measured value ≥ A-DF, A-DF is used;
b) When (M-DF-1) * measured value ＜ A-DF, M-DF is used.

4 Conclusion

In this paper, two kinds of emission degradation factors, multiplication and addition, are studied

(1) When there is a deviation between the measured value of pollutants in type I test and the fitting value of pollutants on the deterioration fitting line, the multiplication DF will amplify the deviation, and the larger the deviation is, the more obvious the amplification effect is, while the addition DF will always maintain the deviation, that is, it can keep the deterioration trend of the vehicle unchanged.

(2) With the lower and lower limits of automobile emission regulations, additive DF can always maintain the deterioration level of automobile, while multiplicative DF will increase the change of automobile deterioration level, and the pollutant emission value after treatment will develop in the direction of deterioration, reducing the test passing rate. The

added DF can reflect the actual deterioration factor of the vehicle better and is not affected by the change of the limit value of the regulation.

(3) For the vehicle emission consistency inspection, when the limit value of test times required for type I test or the measured value of pollutants is greater than the corresponding mileage fitting value on the durability fitting line, compared with the additive DF, the multiplicative DF will reduce the probability of passing the test, increase the test times and reduce the test statistics; On the contrary, compared with the additive DF, the multiplicative DF will increase the probability of passing the test, reduce the number of tests and increase the amount of test statistics. It shows that the two deterioration factors have their own advantages in different cases.

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