The reliability research for heavy vehicles based on Grey system

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Abstract: The test of the heavy vehicles is depended on the experience, and is lack of quantitative citation index. This paper introduces the research of the oil spectroscopic analyzer for power transmission systems on different roads. The wear of impact factors of different road to power transmission systems are calculated, A new method is given to the power transmission systems reliability prediction based on road impact factors. The wear life of vehicle power transmission systems are predicted, A new plan of test reliability for the heavy vehicles is set.

Introduction

A heavy vehicle needs the entire life test before mass production. The test cycle is short and test road is harsh. In order to achieve the purpose of reliability assessment in the short term, it needs to develop a good test plan. The traditional experimental method is based on the accumulated some experience,lack of vehicle wear and tear index data basis. Because the road conditions heavy is complex and changeable, not only paved road, and the fluctuation of soil and sand road. So in the reliability assessment of heavy vehicles, the test mileage is in different proportion of several roads. After the dismantling, the power transmission system is analyzed.

The oil monitoring technology provides theory basis and the technical means for determining the wear condition of the power transmission system. In this paper, the relation is found out between the different roads and the oil spectral element concentration based on the oil wear spectral concentration analysis on different roads. The wear reliability factors of the roads pavement are determined for power transmission system. The factor of oil of Grey theory forecast method of reliability based on predicted pavement is put forward, and the heavy vehicle reasonable test scheme is formulated.

Research of the spectral concentration of weighted coefficient based on roads factors

Analysis of the roads affecting factors

The road and mileage distribution heavy vehicle driving are shown in table 1, from this scheme,The road mileage and the proportion have significant differences in different roads. The friction frequency and extent of power components are different. Metal elements of vehicle dynamic lubrication to the transmission system is also different, the wear degree is not the same.

Table .1 the mileage of vehicle driving on different road

road / speed	pavement road	fluctuation road	sand road	total
mileage km	1000	4000	5000	10000
km/h	45～50	30～35	25～35	--

The contrast of metal element concentration ratio for different roads

Because the type of vehicle and roads are diffident, the wear factor of vehicle power transmission system is not given accurate state. The road correction coefficient is difficult to test in the state of dynamic and timely. It needs to test and analyze a lot of oil spectral metal element for different types of vehicles, the heavy vehicles oil spectrum data database must be built to store different road oil spectral element concentration data. By analyzing these data, the relationships between the different road and the oil spectral element concentration are found out, and the effect of correction factor of pavement is determined.

In this paper, two typical vehicles are chosen, the oil spectrum metal element concentration is analyzed, the pavement correction factors are determined. Part of the data as shown in the following table 2:

Table .2 the first vehicle oil spectral element data on different road

time(h) / road	10	23	35	43	55	65	72	81	93	106
pavement road	7.68	10.8	16.9	15.2	18.6	21.2	26.5	30.8	35.6	40.7
fluctuation road	12.9	16.2	25.9	33.3	34.5	38.2	40	43.2	49.5	53.8
sand road	15.2	20.1	28.3	32.7	35.9	43.6	49.4	54.2	57.1	61.2

In practical work, the road factor value is difficult to determine. the characteristic parameters of spectral analysis include the elemental concentrations of C, relation elemental concentration of BC, concentration gradient of the elements G, element concentration gradient than BG. The wear degree and wear parts can be judged by these features. The most direct features that can show the wear degree of parts are oil concentration and gradient. .The gradient is wear identification concentration increased every 10 hours.

That is:

$$T = \frac{(M_1 - M_2)*10}{t} \quad (1)$$

T- Gradient value;

M_1, M_2 - Oil sample value and previous oil sample value.;

t - Actual sampling interval.

Through the analysis contrast values of oil spectral element concentrations and oil spectrometric concentration gradient value that several types' vehicles driving on different roads;

the relatively stable near constant values is taken as the scaling factor. So the road influence coefficient K is determined.

That is:

$$K_M = \frac{M_p}{M_t} \tag{2}$$

$$K_T = \frac{T_p}{T_m} \tag{3}$$

Table 3 the contrast of iron concentration for the first vehicles on different roads

time（h） / contrast	10	23	35	43	55	65	72	81	93	106
fluctuation/pavement	1.35	1.5	1.53	2.17	1.85	1.80	1.50	1.40	1.39	1.32
sand/ pavement	1.44	1.64	1.68	2.15	1.93	2.06	1.86	1.75	1.60	1.50

The contrast values of oil metal element concentration and gradient are analyzed from other vehicles and roads, from these data know the contrast values of element concentration is closer to the stable weight, so the contrast values of element concentration is regard as the scale factor between different roads.

The effect factor of road mileage distribution

The vehicle's reliability test first run on paved roads, so the element concentration data taken form pave road is used to predict change trend of oil metal element concentration for heavy vehicles on others roads, and so the entire power wear trend is predict.

But in the experiment, except for paving road driving, the heavy vehicles must be test on other roads, so the data analysis can not consider only one weighted pavement impact factor, two other pavement impact factors must be take into account. In reliability test, the heavy vehicles must driver 4000km on sand road and driver 5000km on fluctuation road. So i the proportionate relationship must to be take into account in the weighted factor. I.e.

$$K = W_1K_s + W_2K_T + W_3K_P \tag{4}$$

$$W_1 + W_2 + W_3 = 1 \tag{5}$$

$$W_1 = 0.4, W_2 = 0.5, W_3 = 0.1, K_s = 1.67, K_p = 1, K_T = 1.47.$$

$$K = 1.25 \tag{6}$$

Table 4 the oil spectral element concentration of the first vehicle on pavement road

time(h) / data	10	23	35	43	55	65	72	81	93
raw data	7.68	10.8	16.9	15.2	18.6	21.2	26.5	30.8	35.6
weighted data	9.6	12.6	21.1	19	23	26.5	33.1	38.5	44.5

In this paper, the model is built by the modified element concentration data, the wear state of power transmission system is predicted in the subsequent test.

The prediction of oil spectrum element development trend

The oil spectrum element prediction based on Grey system

Grey theory is used for fault prediction; the prediction system is regarded as a Grey system.. In Grey theory, all the random variables are Grey value changing within a certain range; it needs not to find probability distribution and statistical law, but to find the data of the law, so the prediction can be handled on only short data.

The prediction model is established by using weighting factor of roads and without weighted factor of roads in the gray system theory. The vehicle of lubricating oil iron element concentration is predicted in the whole operation. According to the $GM(1,1)$, the iron concentration data modified by weighted is taken into the equations (7):

$$x^{(o)} = [x^{(o)}(1), x^{(o)}(2), \ldots, x^{(o)}(n)] \qquad (7)$$

get: $x^{(0)} = [9.6,12.6,21.1,19,23,26.5,33.1,38.5,44.5]$

$x^{(1)} = [16.6,34.2,55.3,74.3,100.8,133.9,172.4,216.9]$

Take each time data $x^{(0)}, x^{(1)}$ into the differential equations, solute matrix B, get$[a,u]$

$$a = 0.013, u = 13.06.$$

The original data sequence can be obtained by taking a,u into the differential equation.

The original data sequence without road factor corrected can also get, so the predicted results are compared. The iron concentration trend forecast data are shown in Figure 1 to figure 3.

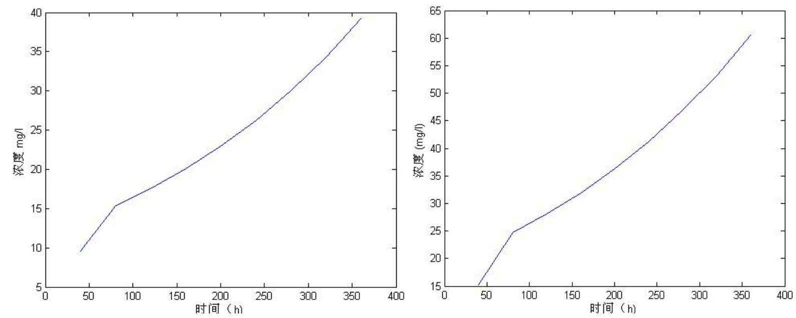

Figure 1 iron concentration forecast without weighted on paved road and gravel road

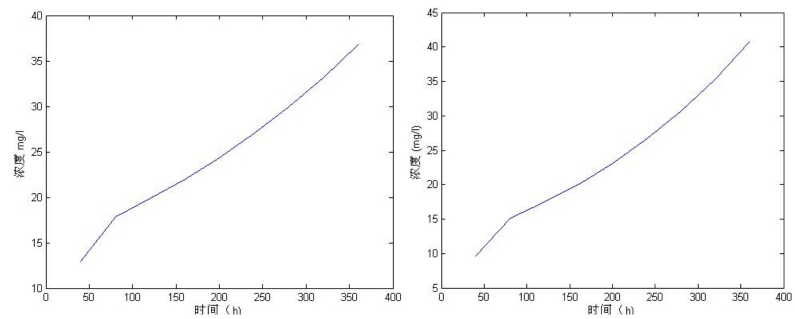

Figure2 iron concentration forecast without weighted data on fluctuation road

Figure3 iron concentration forecast data with weighted data

From figure 1-3 it can be seen that the gearbox's wear rate is higher when vehicle running on different roads before the 70 hours, because of gearbox is running in period of cutting wear stage. The iron concentration is higher on sand road than on fluctuation dirt roads, the iron concentration is lowest on paved road. The iron concentration weighted factor is between fluctuation roads and paved road. The gearbox's wear is in low and stable stage after 70 hours, because the antiwear layer is made in the wear surface due to load, oxidation and other reasons. The wear surface runs into a smooth stage in the macro, thus the wear is in low and stable stage. With the running time increased, the wear particles increases, the wear enter the stage of rapidly wear.

The analysis of prediction results

According to the above forecasting, the iron concentration change up close to the line after 350 hours on paved road, it shows that gearbox wear goes to the severe wear stage after 350 hours, namely the wear fault stage; This stage generally occurs in 300 after hours on the fluctuation roads ; This phenomenon generally occurs after 280 hours on the sand roads; This occurs after 330 hours on the weighted factor roads model.

Above forecast shows that the vehicle wear reliability life is shorter on the sand and fluctuation roads than on the paved roads because the vehicles often transform speed and gear friction, the wear is more intense due to the complex road, Because the vehicle's test is run on different roads according to different proportion in different road mileage, the prediction on only one road can not predict the vehicle's reliability life, so it is need to solute the road weighted factor, the reliability life of power transmission system can be accurately predict in this model.

Heavy vehicle test and wear analysis

Components wear decomposition analysis

After a type of vehicle derived 10000 kilometers, the power transmission system is decomposed. Analysis of the wear condition of gearbox is shown as the following parts.

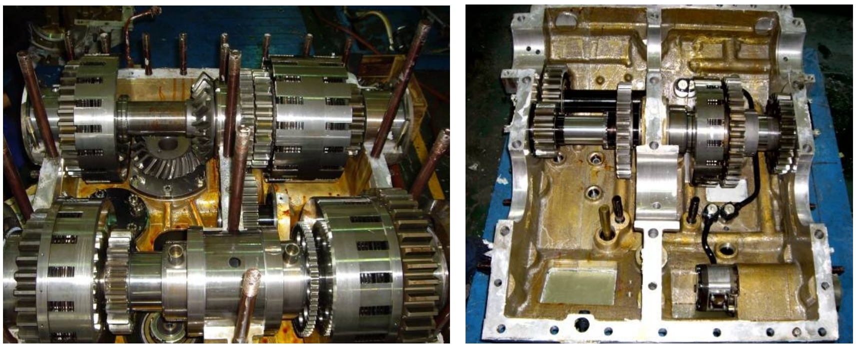

Fig. 4 clutches decomposition

After the transmission device opened, It is found that a right axis bearing seat is more serious wear,other parts are in good condition. The meshing clearance is examined, it is found that the main and passive spiral bevel gear is more serious wear, the gap is too large, and the rest of the gears have slight wear. Test data of each gear pair meshing clearance is shown in table 5.

Table 5 the decomposition of gear mesh clearance

list	gear	design value	measured value
1	main, driven bevel gear	0.15～0.35	0.65～0.95
2	steering driving gear pump idler wheel / steering	0.17～0.55	0.36～0.60
3	cr// reverse idler gear		0.43～0.49
4	zero axis gear / motor idler		0.18～0.30
5	planetary gear / sun gear	0.2～0.35	0.25～0.38

Six clutches are detected, it is found that CH clutch is obvious wear, other clutches have slight wear, and separation gaps are in the allowable range.

Decomposition conclusion

Above decomposition and detection show that the synthetic transmission device mainly wears condition s are analyzed as following:

(1) The left sliding bearing wear is large;

(2) The main and passive spiral bevel gear are more serious wear, the gap is large;

(3) The CH clutch is obvious wear.

From the above analysis, in the process of moving a few parts have serious wear, other parts of the wear are in normal curve range. So after the heavy vehicle run 10000km, the synthetic transmission device wear begin to intensify, but it is still not to wear fault multiple stage, this vehicle can continue running for a period of time, after replace the serious wear parts.

The heavy vehicles reliability test scheme based on spectrometric oil wear

The heavy vehicles' speeds are 35-40 km/h when running on soil road and sand road, according to the prediction of road weighted factor, the transmission system wear is intensified after 350h running, and this also means that transmission system is into the multi fault stage. According to the vehicle speed and time, the vehicle is generally driven:

$$s = v.h = 35 \times 350 = 12250(km) \quad (8)$$

In the heavy vehicle test, the test mileage is the 10000km, through the analysis of decomposition and wear prediction, it is found that the transmission system still can run normally for a period of time, the transmission system wear life is at the end stage after 12000km running. According to above calculation and the actual situation, the vehicle has not reached the point of harsh assessment after 10000km test, it need to continue to test. So its evaluation mileage should be set at about 12000km.

Conclusion

In this paper, the prediction method based on road weight factor is proposed, the oil metal elements concentrations are predicted with road weight factor using grey system model. The vehicles wear reliability life is calculated. Combined with the heavy vehicle decomposition analysis of transmission system, the model's correctness is verified. Through above study, the heavy vehicles' new test scheme is made.

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