The B Life Assessment of Auto Chassis Components and Application Based on Weibull Distribution

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Abstract. The reliability life of auto chassis components is the important part of auto safety, and B life is theuniversal evaluation index. The essay established a method of fatigue reliability B life based on weibull theory. The method have been used in the actual test and got the B life, which give the reference to the reliability life of auto chassis components.

1. Introduction

Recently,the automotive industry grownrapidly,The requirements of the market for vehicle comfort and safety are getting higher and higher.Car chassis system as an important part of the overall structure of the car,Its safety,especially reliability aspects is the important evaluation basis of vehicle safety performance[1].

At present,fatigue life verification for chassis components,Most of theauto companies andparts suppliers only do experimental verification for a few parts,Test through the design life on it. But in the actual use of the process,the force situation of car chassis parts is complicated,environmental conditions is bad,A single design life or laboratory test life is not sufficient to fully demonstrate its reliability life.The cost of vehicle reliability testingis too high,which is maximum short point.Part of the automotive industry standards regulate thatthe fatigue life of the car chassis is to meet the life expectancy.Bx is that the sample of x% reaches the specified failure or overhaul indicator within the specified time zone or mileage[2]. The evaluation of the B-life is based on the reliability of the Weibull distribution, and this method is widely used in the automotive industry.But the calculation of B value life is complex,which is the difficulty of hindering its normal application.

In this paper, the steering knuckle in the car as the object of study,relying on the measured data ofreliability laboratory hydraulic servo system,based on Weibull theory, to estimate the Weibull distribution parameter in terms of the fatigue life,and to establish a reasonable B value life calculation method,so as to provide reference for the reliability life prediction and test judgment of automobile chassis parts.

2. Introduction ofweibulltheory

Weibull distribution is one of the random variable distributions,using the probability value to derive its distribution parameters,which isone of the most widely used distributions in failure data analysis and be widelyused in various life test data processing[3].

Weibull distribution can be defined mathematicallyasfollows:

$$F(t) = 1 - e^{-((t-t_0)/\eta)^\beta} \tag{1}$$

$F(t)$ —Faultdensity distribution function; t —Time of failure; t_0 —Distribution starting point or origin; η —Characteristic life or scale parameters; β —Slope or shape parameters; e —Natural constants.

$F(t)$ defines the cumulative probability of a set of components that will fail at time t, and $1-F(t)$ is the probability of no failure,expressed by reliability $R(t)$.

$$R(t) = e^{-((t-t_0)/\eta)^\beta} \tag{2}$$

The Weibullian analysis studiestherelationship between the life time of a component and its reliability by plotting thelife data of a single failure mode on a Weibullprobabilitygraph.
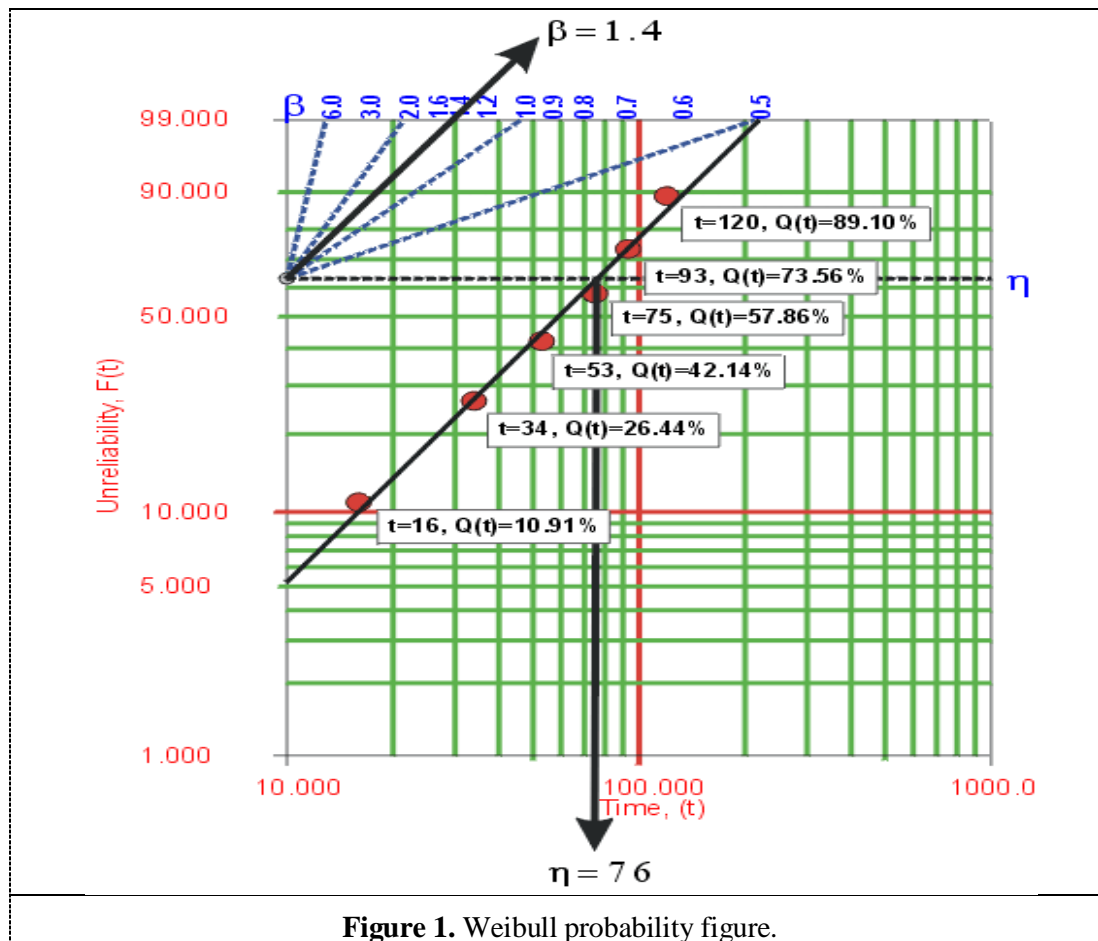

Figure 1. Weibull probability figure.

That is the Weibull probability figure[3] in Figure 1, where the abscissa is the time t, and the ordinate is the corresponding cumulative probability. The slope of the straight lineis β, its value is different, representing differentfailure categories, and corresponding to different failure reasons.

3. Reliability B value life algorithm

The B life is obtained by the Weibull cumulativeprobability density distribution function[4]. Weibull fault density distribution function expression is formula (1).

then,the reliability function is

$$R(t) = 1 - F(t) = e^{-((t-t_0)/\eta)^\beta} \tag{3}$$

t_0 isthe distribution of origin, when $t_0 = 0$,get

$$1 - F(t) = e^{-(t/\eta)^\beta} \tag{4}$$

take the logarithm , get

$$\ln\ln((1 - F(t))^{-1}) = \beta \ln t - \beta \ln \eta \tag{5}$$

The above equation is represented by a straight line equation,

$$Y = BX + A \tag{6}$$

$$Y = \ln\ln((1 - F(t)^{-1}) \tag{7}$$

$$X = \ln(t) \tag{8}$$

$$B = \beta \tag{9}$$

$$A = -\beta \ln \eta \tag{10}$$

For the linear equation, the least squares method is used to obtain the estimated value $\hat{B}$, $\hat{A}$

$$\hat{B} = \sum_{i=1}^{n} X_i Y_i - \frac{(\sum_{i=1}^{n} X_i)(\sum_{i=1}^{n} Y_i)}{n} (\sum_{i=1}^{n} X_i^2 - \frac{(\sum_{i=1}^{n} X_i)^2}{n})^{-1} \tag{11}$$

$$\hat{A} = \frac{1}{N} \sum_{i=1}^{n} Y_i - \hat{B} \frac{1}{N} \sum_{i=1}^{n} X_i \tag{12}$$

To bring it into the above formula and to find the value β and η, the expression of the Weibull fault density distribution function is obtained.For B life(take B_x for example),make

$$x\% = F(t) = 1 - e^{-(t/\eta)^\beta} \tag{13}$$

Find it,that is life of B_x , which means that the time or lifetime is t when the sampleof x% reaches the specified failure criteria.

4. The test of life assessment and analysis

The car steering knuckle is an important part of the chassis system. An automobile company is required to carry out fatigue and durability tests for the knuckle components to verify its fatigue and reliability performance. The number of samples is 10, In the chassis reliability test system using hydraulic servo for single load fatigue life test, The loading conditions (Figure 2) and test photo (Figure 3) are as follows.

The test bench is hydraulic servo system. It was made by IST. The biggest load is 6.3t and the biggest frequency is 50Hz at special load.
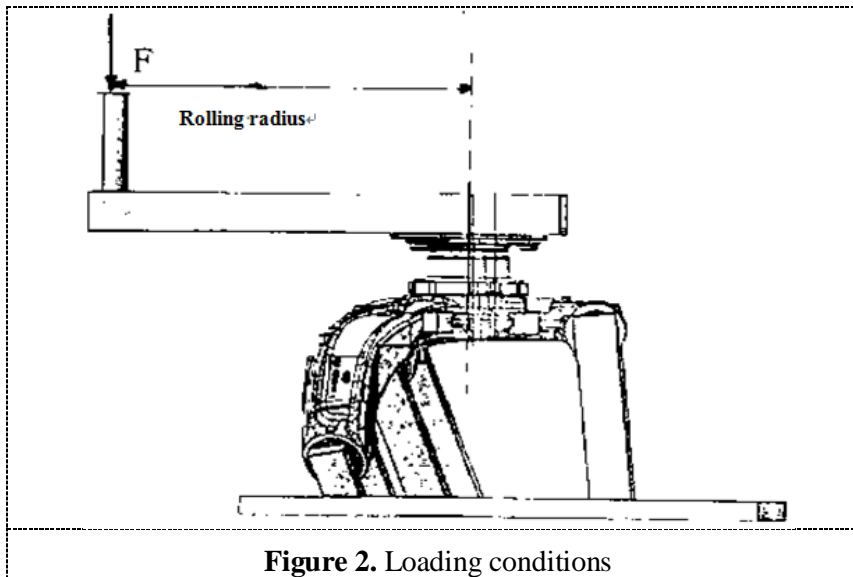
Figure 2. Loading conditions
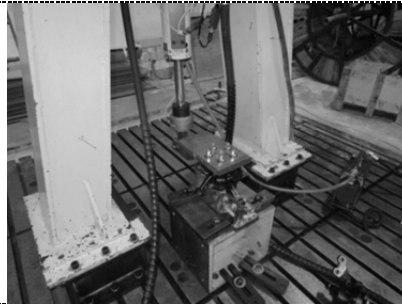
Figure 3. Test photo

Test conditions: According to the standard requirements (to meet the torque requirements) fixed samples, test load±3900N,load frequency 5Hz。 After 1 million timestest, check the knuckle for cracks, cracks and other failure forms. The test load increased to 1.1 times to continue the test 700,000 times, the steering knuckle does not appear cracks, cracks and other failure forms. And then the test load increased to 1.6 times to continue the test 500,000 times, the steering section of local cracks, cracks and other failure forms. During the test, any sample appeared in the crack and the length was greater than 10mm, or the sample appeared to break, then, the sample failed and the test stopped. According to the test requirements, 10 samples were tested in succession. The sample number and the corresponding test life were shown in Table 1.

Table 1. Test sample life

Sample No	Sample life / million times
1	200．0
2	125.7
3	159.4
4	168.9
5	165.0
6	152.4
7	202.1
8	152.6
9	108.8
10	100.0

The sample size of the test sample is small, and the fatigue life of the chassis parts is evaluated for B_{10} life. According toformula (5) —formula (12), The Weibull probability density function $F(t)$ is obtained, and then put $x = 10$ into the formula (13), you can find the B_{10} life of the knuckle sample.

First of all, the test data in accordance with the life cycle from small to large rearrangement, and serial number. According to the literature [3, 5], the median rank value is obtained by using the median rank of Benard's formuls.

$$P = \frac{i - 0.3}{N + 0.4} \tag{14}$$

Where N is the total number of samples and i is the adjustment rank (the number after the test life is adjusted).

Using the formula (1) - formula (10), the data are shown in Table 2.

Table 2. Date sheet

Serial number	The original serial number	Test life	Adjust the rank value	Median rank value	Xi	Yi
1	10	100.0	1	6.73%	4.6052	-2.6638
2	9	108.8	2	16.35%	4.6895	-1.7233
3	2	125.7	3	25.96%	4.8339	-1.2020
4	6	152.4	4	35.58%	5.0265	-0.8217
5	8	152.6	5	45.19%	5.0278	-0.5086
6	3	159.4	6	54.81%	5.0714	-0.2304
7	5	165.0	7	64.42%	5.1059	0.0329
8	4	168.9	8	74.04%	5.1293	0.2990
9	1	200.0	9	83.65%	5.2983	0.5940
10	7	202.1	10	93.27%	5.3088	0.9927

Then, using the least squares method, the data is taken into the formula (11), the formula (12),get the minimum estimate $\hat{B} = \hat{\beta} = 4.64$, $\hat{\eta} = e^{-\hat{A}/\hat{\beta}}$ =167.73,the Weibull probability density function is obtained,

$$F(t) = 1 - e^{-(t/167.73)^{4.64}} \tag{15}$$

In the function,Slope or shape parameters $\beta = 4.64$,It can be seen from the literature [3], [6], the steering section failure is a rapid loss, the reasons of may cause the loss: the aging parts; material properties have changed or defect; manufacturing process problems.

Thus, the relationship between the available life and the Weibull distribution probability is shown in Figure 4.
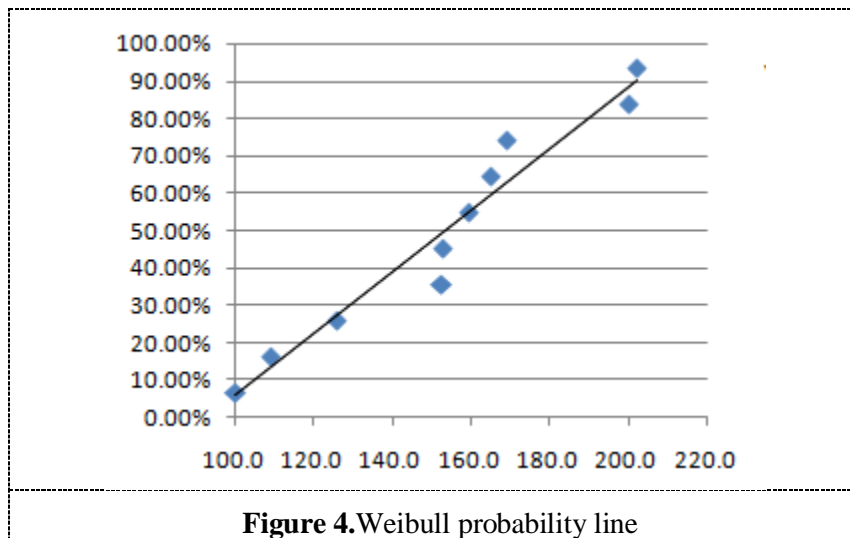
Figure 4. Weibull probability line

Among them, the abscissa is the experimental life, the ordinate is the corresponding Weibull distribution cumulative probability, the distribution data correlation coefficient r = 0.98.

put $x = 10, \beta = 4.64, \eta = 167.73$ into formula (13), get the relable life span $B_{10} = 103.29$ million times.

From the distribution data correlation coefficient r and B_{10} we can see that Weibull can be reasonably applied to the reliability of data processing, more in line with the actual situation, and can be applied to thelife assessment of automotive chassis fatigue reliability B value.

5.   Conclusions

Based on the Weibull distribution theory, this paper deduces the reliability B value life evaluation algorithm of the automobile chassis. Weibull distribution is widely used for its powerful failure analysis processing and forecasting capabilities. The application of Weibull distribution and B value life is summarized as follows.

1)   The B-life assessment can be used to evaluate the reliability of the chassis parts, providing a great deal of usefulness for product design life and verification of life assessment.

2)   Weibull distribution is suitable for engineering life assessment and analysis, its β value can be a good analysis of fault data and the reasons and can be widely applied to engineering practice.

3)   The B life assessment method is very necessary for the chassis parts, this method could give the components accurate quality status.

4)   Weibull distribution is powerful, parameter estimation methods are more, the accuracy is also different, we can seek high precision and easy to implement the method to improve the calculation accuracy.

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