Fatigue Lifetime Design Method and Program Development of Pantograph V500 Based on Reliability

Dongli Song
State Key Laboratory of Traction Power,Southwest Jiaotong University,Chengdu, China
sdl.cds@163.com

Weihua Zhang
State Key Laboratory of Traction Power,Southwest Jiaotong University,Chengdu, China
tpl@swjtu.edu.cn

Ning Zhou
State Key Laboratory of Traction Power,Southwest Jiaotong University,Chengdu, China
zhou_ningbb@sina.com

Guiming Mei
State Key Laboratory of Traction Power,Southwest Jiaotong University,Chengdu, China
tpl@swjtu.edu.cn

***Abstract*—Reliability analysis of fatigue lifetime design has two assignments: a. To forecast fatigue lifetime of the structure on given reliability level, b. To evaluate reliability level of the structure on given service conditions, material features and designing dimensions. It aims at evaluating the structure's designing quality and providing a basis for designing improvement or manufacturing. At mean time, it provides instruction to updating management by parameter of failure rate under given fatigue lifetime.Lastly, this paper presents rain-flow program, lifetime-forcast program and reliability-forcast program, predicting the results of fatigue lifetime of pantograph V500 based on different reliability levels at 500km/h and the results of reliability level of Pantograph V500 under lifetime of 1,200,000km which provide direction of design, manufacturing and general management for Pantograph V500.**

***Index Terms*—Fatigue lifetime, Reliability, Pantograph V500**

I. INTRODUCTION

The pantograph of high-speed train is subjected to a complicated dynamic loading process. The contact force in pantograph-catenary system oscillates inspired by the non-smooth catenary and track[1,3], and it is a random variable.

The material characters of pantograph V500 is effected by many factors such as size,enviroment and temperature[4,5] and they are random variables.

Therefore, fatigue lifetime of pantograph V500 are determined by reliability method. this paper presents the predicting results of fatigue lifetime of pantograph V500 , and the predicting results of reliability level of Pantograph V500 under lifetime of 1,200,000km.

II. PROBABLISTIC FATIGUE FEATURE OF PANTOGRAPH

P-S-N Curve of probablistic fatigue is important basis for analysis of fatigue reliability design. Alloy steel 410 and Aluminum alloy 6061 are materials for key parts of Pantograph and their P-S-N Curves.

A. *P-S-N Curve at short or middle lifetime stage*

Referring to Regulation TB/T1335-199 and based on Equation Basquin[6]. The two materials' mean will be got by looking up the material manual. Set 0.08 of the mean as variance when there is lack of distributed data. The material's P-S-N Curve is indicated as:

$$(\lg N)_p = A_p + B_p \lg S \tag{1}$$

In which,

$$A \sim N(u_A, \sigma_A) \sim N(36.1736, 2.893888)$$

$$B \sim N(u_B, \sigma_B) \sim N(-11.349, 0.90792)$$

$$A_p = u_A - z_p \cdot \sigma_A, B_p = u_B - z_p \cdot \sigma_B .$$

Table 1 presents P-S-N Curve parameters of alloy steel at preliminary stage, table2 presents P-S-N Curve parameters of aluminum alloy at preliminary stage; S4 stands for stress of lifetime 10000 times circulation, S5-6 stands for stress of lifetime 5000000 times circulation.

Manuscript received March 1, 2011; revised April 1, 2011; accepted May 15, 2011.
The present research is supported by China 973 Program (2007CB714703), Key Projects in the National Science & Technology Pillar Program during the Eleventh Five-Year Plan Period(2009BAG12A05) and National Natural Science Fund for Creative Research Groups(50821063).

doi:10.4304/jcp.7.5.1252-1260

TABLE I.
TABLE 1 P-S-N CURVE PARAMETERS OF ALLOY STEEL AT PRELIMINARY STAGE

P	A	B	S_4	S_{5-6}
0.5	36.1736	-11.349	683.7592	395.4482
0.9	34.12312	-10.644	676.0683	377.0762
0.99	32.45144	-10.07	669.0777	360.9486
0.999	31.22923	-9.6495	663.4925	348.4454
0.9999	30.22317	-9.3036	658.5559	337.6715

TABLE II. P-S-N CURVE PARAMETERS OF ALUMINUM ALLOY AT PRELIMINARY STAGE

P	A	B	S_4	S_{5-6}
0.5	27.52429	-10.8323	105.4723	148.4841
0.9	25.6371	-10.1018	74.94202	138.6443
0.99	24.09855	-9.50628	67.65886	130.0885
0.999	22.97367	-9.07087	62.25472	123.5137
0.9999	22.04773	-8.71246	57.77001	117.8922

B. long-lifetime P-S-N Curve

Because, under normal operating conditions,the structure functions under random stress amplitude generally, it still will have fatigue crack initiation and growth to make fatigue damage even the stress amplitude is under “fatigue limitation”. So S-N Curve of probablistic fatigue at range of long lifetime is needed for analysis of fatigue reliability. According to criterion of European ECCS and Sweden BSK, extrapolate S-N Curve by index method 2m-1 after $N \geq 5*10^6$cycles.

Index method 2m-1 refers to, beginning with $N=5*10^6$cycles, turning index m 2m-1 of S-N Curve at preliminary stage into smoothed extrapolation for long-lifetime S-N Curve[6].

1) Fatigue intensity of turning point: According to basic datas $u_A,\sigma_A,u_B,\sigma_B$ of S-N Curve at preliminary stage to get fatigue intensity of turning point

$$S_t = 10^{[\lg(5\times 10^6)-u_A]/u_B} \quad (2)$$

*2) Parameter of probablistic curve:*Confirm basic parameter of probablistic curve at range of long-lifetime based on equations (3) as follows

$$u_F = 2\cdot u_B - 1\,,\ \ u_E = u_A - (u_B - 1)\cdot \lg S_t$$

$$\sigma_E = [\sigma_A{}^2 + \sigma_B{}^2 \cdot (\lg S_t)^2]^{1/2}\,,$$

$$\sigma_F{}^2 = 4\cdot \sigma_B{}^2 \quad (3)$$

*3) Extrapolated P-S-N equation:*It is defined in equation (4):

$$(\lg N)_p = E_p + F_p \lg S$$

(4)

in which

$$E_p = u_E - z_p \cdot \sigma_E\,, F_p = u_F - z_p \cdot \sigma_F\,.$$

Table 3 presents extrapolated P-S-N Curve parameters of alloy steel, table 4 presents extrapolated P-S-N Curve parameters of aluminum alloy. S_8 stands for stress of lifetime 100000000 times circulation, S_{5-6} stands for stress of lifetime 5000000 times circulation.

TABLE III. EXTRAPOLATED P-S-N CURVE PARAMETERS OF ALLOY STEEL (INDEX METHOD 2M-1)

P	E	F	S_{5-6}	S_8
0.5	68.24532	-23.698	395.4482	348.4895
0.9	64.1237	-22.288	377.0765	329.6531
0.99	60.7614	-21.139	360.9518	313.2588
0.999	58.3016	-20.299	348.449	300.6392
0.9999	56.2759	-19.607	337.6708	289.8272

TABLE IV. EXTRAPOLATED P-S-N CURVE PARAMETERS OF ALUMINUM ALLOY (INDEX METHOD 2M-1)

P	E	F	S_{5-6}	S_8
0.5	52.55199	-22.665	105.4658	92.40771
0.9	48.89063	-21.204	97.68591	84.81508
0.99	45.90243	-20.013	90.97929	78.33068
0.999	43.7151	-19.142	85.86013	73.42151
0.9999	41.91272	-18.425	81.50841	69.27713

III. EQUIVALENT STRESS FEATURE OF PANTOGRAPH V500

A. Finite element analysis

Loads on pantograph V500 is shown in Figure.1, which are Fc,Fair, Fc is contact force, it is shown is Figure.2, Fair is air resistance, it is shown in Figure.3. And the boundary condition is that baseframe is fixed.

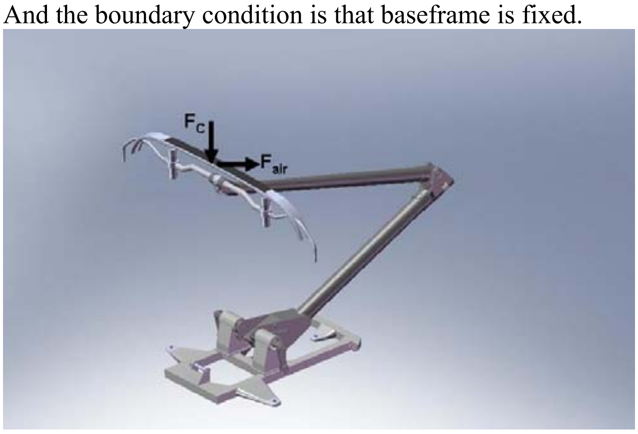


Figure.1 Loads on Pantograph V500

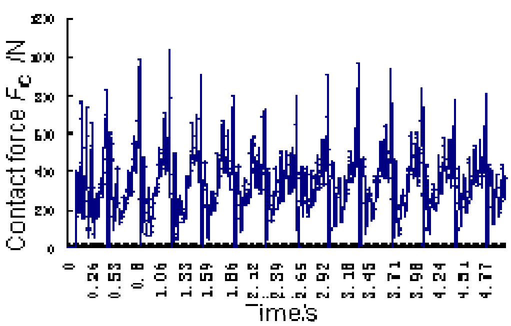


Figure.2 Time History of Contact force FC

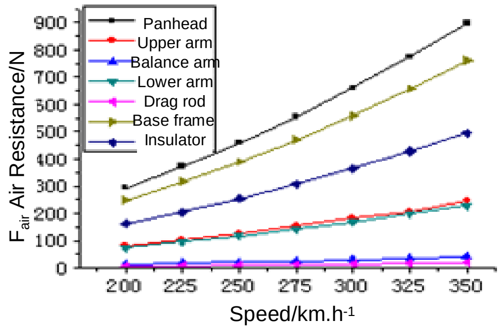
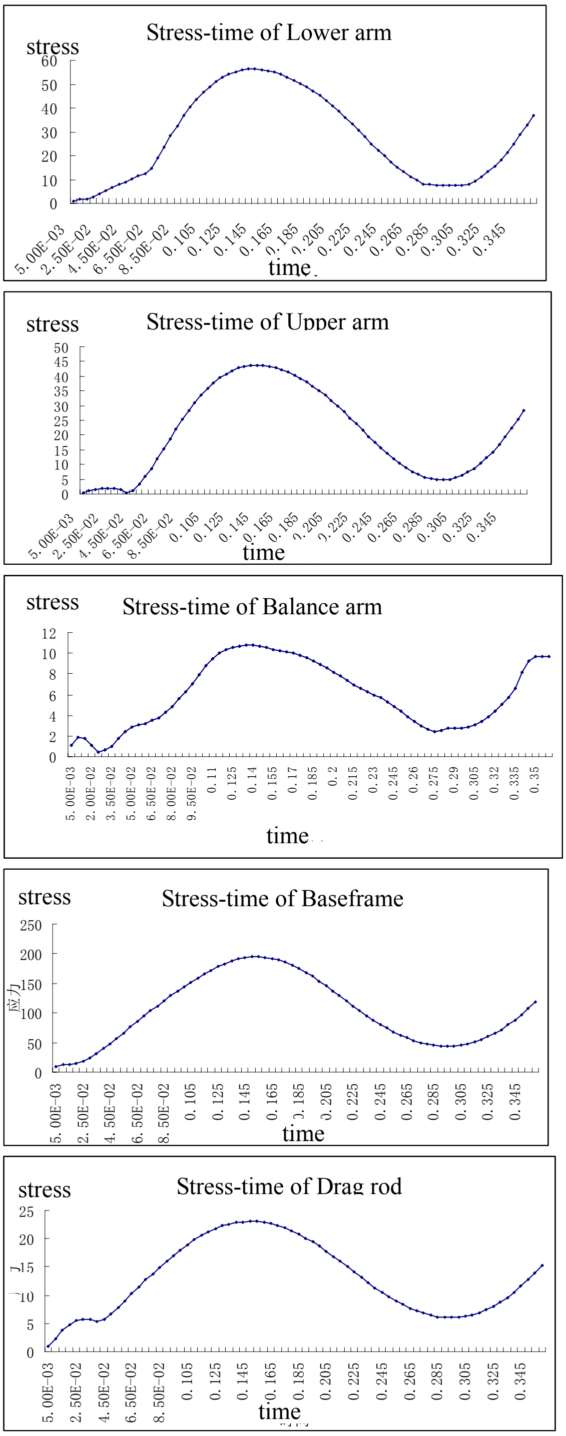


Figure.3 Air Resistance on Pantograph

By finite element analysis, stress-time of pantograph V500 is shown in Figure 4.



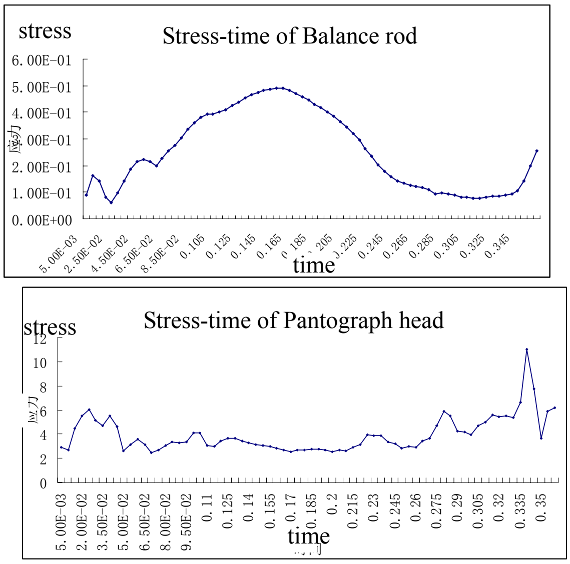


Figure.4 Stress-time of Pantograph V500 Running One Span

B. Rain flow method

The flowchart of rain-flow and Goodman correction programs is shown in figure 5.

The operating windows of rain-flow program is shown in figure 6.

Discrete stresss-time into a series peak values, and then gather statistic of the peak value, amplitude and mean value or the frequency through a certain load level to get the dissymmetrical fatigue stress table on condition of running 1,200,000km ,as Table5.

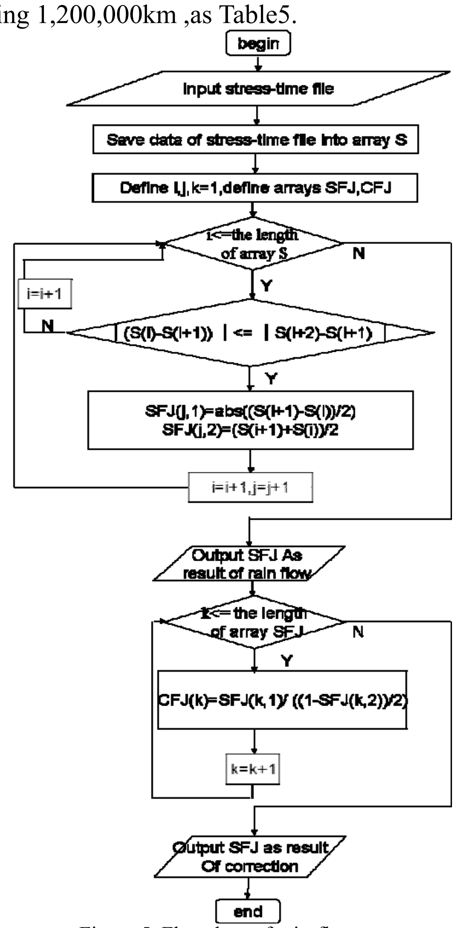


Figure 5. Flowchart of rain-flow program

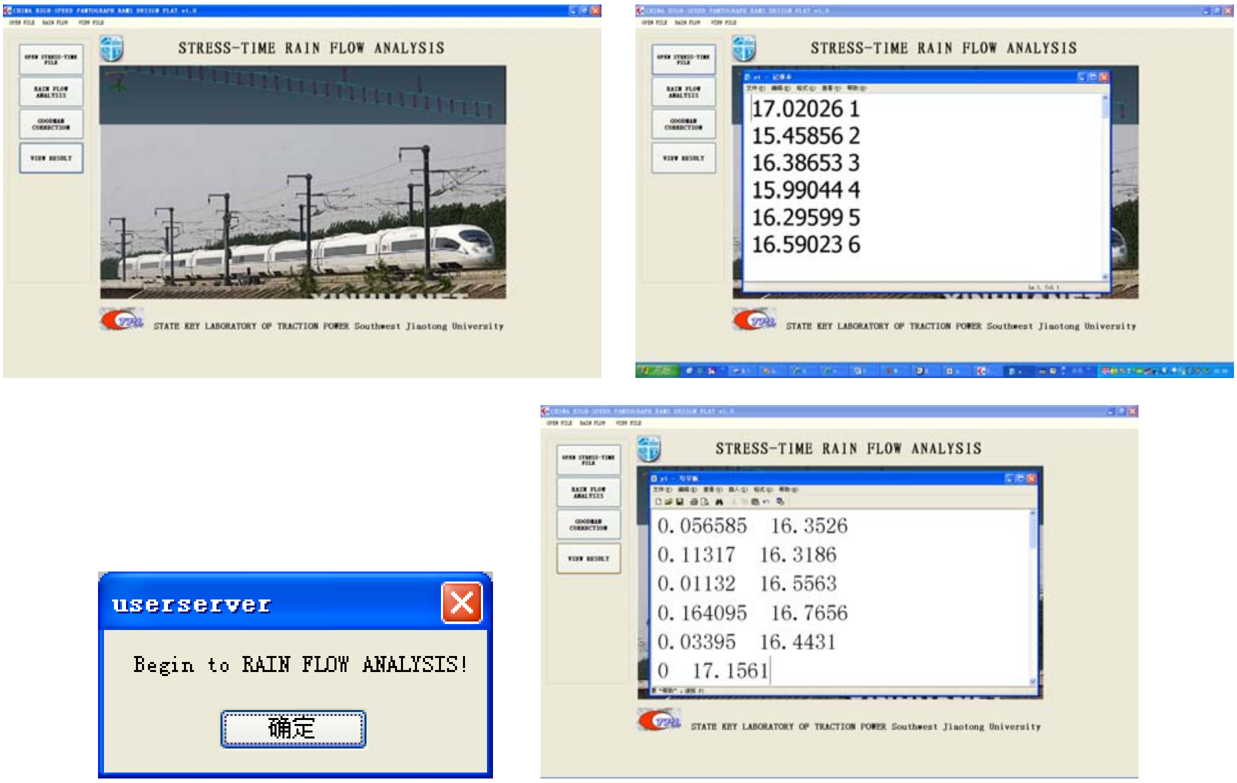


Figure 6. Windows of rain-flow program

TABLE V. DISSYMMETRICAL FATIGUE STRESS SPECTRUM FOR PANTOGRAPH V500 RUNNING 1,200,000KM

Stress Mean σ_{ami}	**Dissymmetrical stress ampletude σ_{ai}**	**Recurring count n_i**	**Stress Mean σ_{ami}**	**Dissymmetrical stress ampletude σ_{ai}**	**Recurring count n_i**	**Stress Mean σ_{ami}**	**Dissymmetrical stress ampletude σ_{ai}**	**Recurring count n_i**
Base Frame			Balance Rod			Pantograph Head		
102.415	184.89	1.2e8	0.210105	0.02515	2.4e8	5.07735	0.8057	2.4e8
119.174	151.372	1.2e8	0.09545	0.0017	2.4e8	3.11365	0.9889	2.4e8
80.889	74.802	1.2e8	0.12633	0.07066	1.2e8	3.3209	0.0316	2.4e8
下臂杆			0.11158	0.10016	1.2e8	3.32065	0.6847	2.4e8
28.603	55.456	1.2e8	0.275375	0.42775	1.2e8	2.655	0.0114	2.4e8
31.8703	48.9213	1.2e8	0.282675	0.41315	1.2e8	2.6446	0.0774	2.4e8
22.1523	29.4853	1.2e8	0.16546	0.17872	1.2e8	3.88375	0.0397	2.4e8
Drag Bar			Balance Arm			2.94875	0.0611	2.4e8
5.51495	0.3811	2.4e8	1.5183	0.7698	1.2e8	5.46885	0.0872998	2.4e8
12.0234	22.0592	1.2e8	1.19517	1.41607	1.2e8	2.66555	0.2027	2.4e8
14.5327	17.0405	1.2e8	5.62607	10.2779	1.2e8	3.37485	1.1465	2.4e8
10.6377	9.2505	1.2e8	6.6073	8.3154	1.2e8	5.49185	0.1917	2.4e8
Upper Arm			6.09225	7.2853	1.2e8	3.32215	1.6043	2.4e8
1.20772	1.38437	1.2e8	9.69775	0.0743008	1.2e8	4.9282	1.8884	2.4e8
1.19333	1.41315	1.2e8				2.7836	0.2578	1.2e8
22.1274	43.2813	1.2e8				4.33305	3.3567	1.2e8
24.2757	38.9846	1.2e8				4.21735	3.5881	1.2e8
16.5947	23.6226	1.2e8				6.71165	8.5767	1.2e8
						7.3337	7.3326	1.2e8
						4.91035	2.4859	1.2e8

C. Goodman Correction

S-N Curve is to express the regular pattern of symmetrical circulation stress. As for dissymmetrical circulation stress, the impact of failure by dissymmetrical coefficient r to fatigue should be considered. To get different fatigue limitation value under value r, dissymmetrical stress ampletude should be corrected into symmetrical stress ampletude by Goodman Correction. Equation below can convert dissymmetrical stress ampletude into symmetrical stress ampletude[6]:

Goodman Average Stress Correction Equation(5)

$$\sigma_{-1ai} = \frac{\sigma_{ai}}{1 - \sigma_{ami} / \sigma_S}$$

$$(\sigma_{ai}, n_i, i = 1, 2, \cdots, n_L)。 \quad (5)$$

In the equation, σai is dissymmetrical recurring stress ampletude, σm is stress mean value; σb is tensile strength, σs yield limit, σ-1ai is relevant symmetrical stress amplitude converted into symmetrical circulation.

The symmetrical circulating fatigue stress table for Pantograph V500 running 1,200,000km is got by usage of the equation, as Table 6

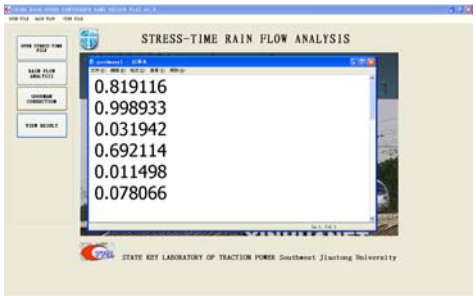


Figure 7. Window of Goodman correction

TABLE VI.
THE SYMMETRICAL CIRCULATING FATIGUE STRESS TABLE FOR PANTOGRAPH V500 RUNNING 1,200,000KM

Stress Ampletude σ_{-1ai}	Recurring No. n_i	Stress Ampletude σ_{-1ai}	RecurringNo n_i	tress Ampletude σ_{-1ai}	RecurringNo n_i
Base Frame		Balance rod		Pantograph Head	
215.50101	1.2e8	0.0251584	2.4e8	0.819116	2.4e8
181.34679	1.2e8	0.0017003	2.4e8	0.998933	2.4e8
84.254515	1.2e8	0.0706742	1.2e8	0.031942	2.4e8
Lower Arm		0.1001777	1.2e8	0.692114	2.4e8
58.050399	1.2e8	0.4279371	1.2e8	0.011498	2.4e8
51.485122	1.2e8	0.4133355	1.2e8	0.078066	2.4e8
30.542465	1.2e8	0.178767	1.2e8	0.040204	2.4e8
Drag rod		Balance Arm		0.061687	2.4e8
0.3844125	2.4e8	0.7716597	1.2e8	0.088868	2.4e8
22.481551	1.2e8	1.4187615	1.2e8	0.204458	2.4e8
17.436435	1.2e8	10.370511	1.2e8	1.159119	2.4e8
9.4068552	1.2e8	8.4035344	1.2e8	0.195157	2.4e8
Upper Arm		7.3564385	1.2e8	1.621679	2.4e8
1.3897844	1.2e8	0.0754624	1.2e8	1.918906	2.4e8
1.4186109	1.2e8			0.260136	1.2e8
46.608128	1.2e8			3.404284	1.2e8
42.296808	1.2e8			3.637587	1.2e8
24.95867	1.2e8			8.766499	1.2e8
				7.510271	1.2e8
				2.52591	1.2e8

IV. A LIFETIME FORECAST OF PANTOGRAPH V500 UNDER GIVEN RELIABILITY

When Pantograph V500 is under non-stable stress, Miner Linearing Accumulated Damage Theory should be adopted to estimate the fatigue lifetime of V500. This theory is to deem: when the testing sample is on the process of load, every load circulation will lose certain valid lifetime component of the testing sample; And fatigue damage is directly proportional to the work absorbed during the test, this work is proportional to the ratio of action circulating number of stress and damaged circulation times under this stress value; In addition, the total damage (total work) of the testing sample being damaged is a constant; The damage is doing nothing with the action sequence of the load; Finally,when the total number added by all the damage yeilded by every circulating stress is 1, the testing sample will have fatigue damage. To sum them up to the basic relation below[6]:

$$d_1 + d_2 + \cdots + d_k = \sum_{i=1}^{k} d_i = D$$

$$\frac{d_i}{D} = \frac{n_i}{N_i}$$

$$d_i = \frac{n_i}{N_i} D$$

$$\frac{n_1}{N_1} D + \frac{n_2}{N_2} D + \cdots + \frac{n_k}{N_k} D = D$$

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_k}{N_k} = \sum_{i=1}^{k} \frac{n_i}{N_i} = 1$$

Set NL as the fatigue lifetime of parts under non-stable stress action, to make

$$\alpha_i = \frac{n_i}{\sum_{i=1}^{k} n_i} = \frac{n_i}{n_L}$$

Then $n_1=\alpha_1 N_L$, $n_2=\alpha_2 N_L$,···, $n_k=\alpha_k N_L$

$$N_L \sum_{i=1}^{k} \frac{\alpha_i}{N_i} = 1$$

$$\frac{N_1}{N_i} = \left(\frac{S_i}{S_1}\right)^m$$

$$N_L = \frac{1}{\sum_{i=1}^{k} \frac{\alpha_i}{N_i}} = \frac{N_1}{\sum_{i=1}^{k} \alpha_i \left(\frac{S_i}{S_1}\right)^m} \qquad (6)$$

Hai Bahe Fatigue Curve is another kind of deformed fatigue curve adopted by correction theory. In double logarithmic coordinate system, it is composed by normal

S-N fatigue curve of slope m and fatigue curve below the diagonal of slope 2m-1,beginning from 5*106. Apparently, these two curves are presented as straight in double logarithmic coordinate system, and their curvilinear equations (7) seperately is: Sim·Ni=const; Si2m-1·Ni=const.

$$N_L = \frac{1}{\sum_{i=1}^{k} \frac{\alpha_i}{N_i}} = \frac{N_1}{\sum_{i=1}^{k_1} \alpha_i \left(\frac{S_i}{S_1}\right)^m + \sum_{i=1}^{k_2} \alpha_i \left(\frac{S_i}{S_0}\right)^{2m-1}}$$

$$N_L = \frac{1}{\sum_{i=1}^{k} \frac{\alpha_i}{N_i}} = \frac{N_1}{\sum_{i=1}^{k} \alpha_i \left(\frac{S_i}{S_1}\right)^d} \quad (7)$$

In which d=(0.8～0.9)*m

This correction way is adopted when there are many circulations under fatigue limilation.

Adopting Hai Bahe Fatigue Curve is correction theory.

$$N_{L[R]} = \frac{1}{\sum_{i=1}^{k} \frac{\alpha_i}{N_{i[R]}}} = \frac{N_1}{\sum_{i=1}^{k} \alpha_i (\frac{S_i}{S_1})^{m_{[R]}}} \quad (8)$$

In equation (8), NL[R] is lifetime of parts under reliability of R, Ni[R] is lifetime under reliability of R and relevant stress level of Si, in P-S-N Curve.αl,m[R] are the curve's material constant under reliability of R, in P-S-N Curve.

The flowchart of a lifetime-forcast programs is shown in figure 8.

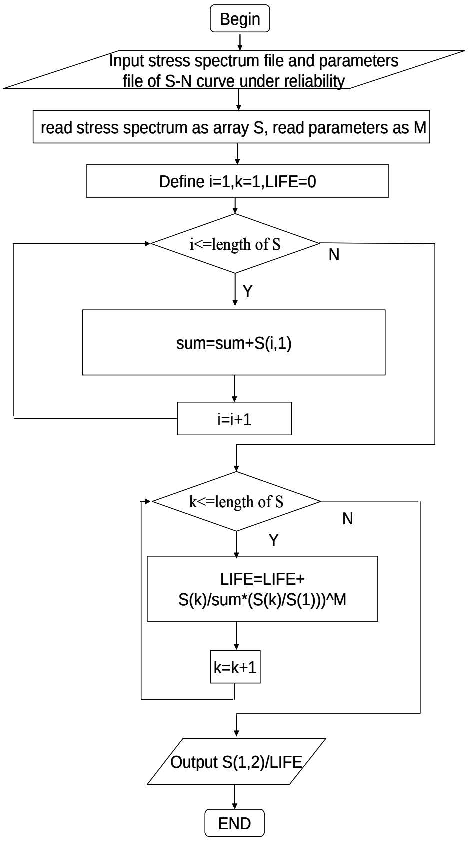


Figure 8. Flowchart of a lifetime-forecast program

The operating windows of a lifetime-forecast program is shown in figure 9.

Figure 9. Window of a lifetime-forecast program

TableVII shows a fatigue lifetime forecast of every part of Pantograph V500 at speed of 500km/h.

TABLE VII. FATIGUE LIFETIME FORECAST OF EVERY PARTS OF PANTOGRAPH V500 AT SPEED OF 500KM/H

	R=0.5lifetime (km)	R=0.9lifetime(km)	R=0.95lifetime (km)	R=0.99lifetime (km)	R=0.999lifetime (km)	R=0.9999lifetime (km)
Base Frame	8.70E+11	1.27E+11	2.65E+10	2.65E+10	8.36E+09	3226757758
Lower arm	2.64E+25	6.06E+23	2.77E+22	2.77E+22	2.90E+21	4.50E+20
Drag rod	2.63E+11	3.86E+10	8.05E+09	8.05E+09	2.55E+09	984178006
Upper arm	4.37E+13	2.61E+12	1.17E+12	2.60E+11	4.80E+10	1.19E+10
Balance Arm	1.48E+43	3.01E+40	1.92E+38	1.92E+38	4.74E+36	2.28E+35
Pan- Head	1.80E+12	2.51E+11	1.44E+11	5.05E+10	1.56E+10	5.96E+09

V. PREDICTING RELIABILITY OF PANTOGRAPH V500 UNDER GIVEN LIFETIME N

According to Miner Accumulated Damage Theory, limited lifetime design is proceeded.

$n_1, n_2, \ldots, n_L$ is the circulating times under stress level of $\sigma_{-1a1}\sigma_{-1a2,\ldots,}\sigma_{-1aL}$; $u_{N1}, u_{N2}, \ldots, u_{NL}$ is mean value of relevant logarithmic lifetime; $\sigma_{N1}, \sigma_{N2,\ldots,}\sigma_{NL}$ is standard deviation of relevant logarithmic lifetime normally distribution; n_{ie} under σ_{i+1} is equal to n_i under σ_i. The rest may be deduced by analogy till the last stress level. The calculation steps are as follows[6]:

For z_1

$$z_1 = \frac{\ln n_1 - u_{N_1}}{\sigma_{N_1}}$$

For n_{1e}

$$n_{1e} = \ln^{-1}(u_{N_2} + z_1 \cdot \sigma_{N_2})$$

For z_2

$$z_2 = \frac{\ln(n_{1e} + n_2) - u_{N_2}}{\sigma_{N_2}}$$

The rest may be deduced by analogy till the last stress level zL

$$z_L = \frac{\ln(n_{(L-1)e} + n_L) - u_{N_L}}{\sigma_{N_L}} \quad (9)$$

Looking up normal distribution form by zL, and making zRL=-zL, to get the reliability R of this part

The flowchart of a lifetime-forcast programs is shown in figure 10.

The operating windows of a reliability-forecast program is shown in figure 11.

When R≤[R], the part's fatigue lifetime is not reliable in given lifetime; when, R>[R],the part's fatigue lifetime is reliable in given lifetime. Now, based on The Weakest Theory, set [R]=0.95, table8 is the reliability of PantographV500 running1,200,000km at speed of 500km/h

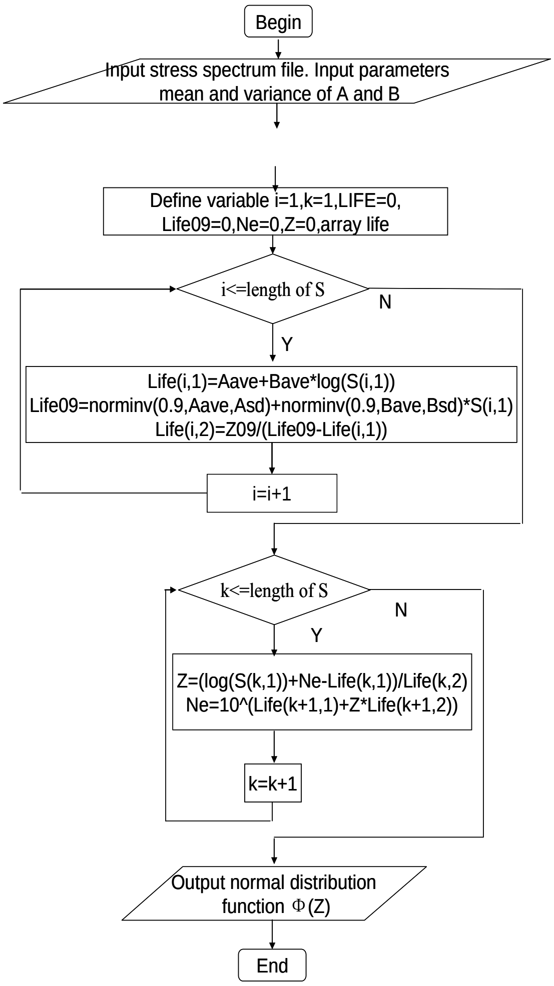


Figure 10. Flowchart of a reliability-forecast program

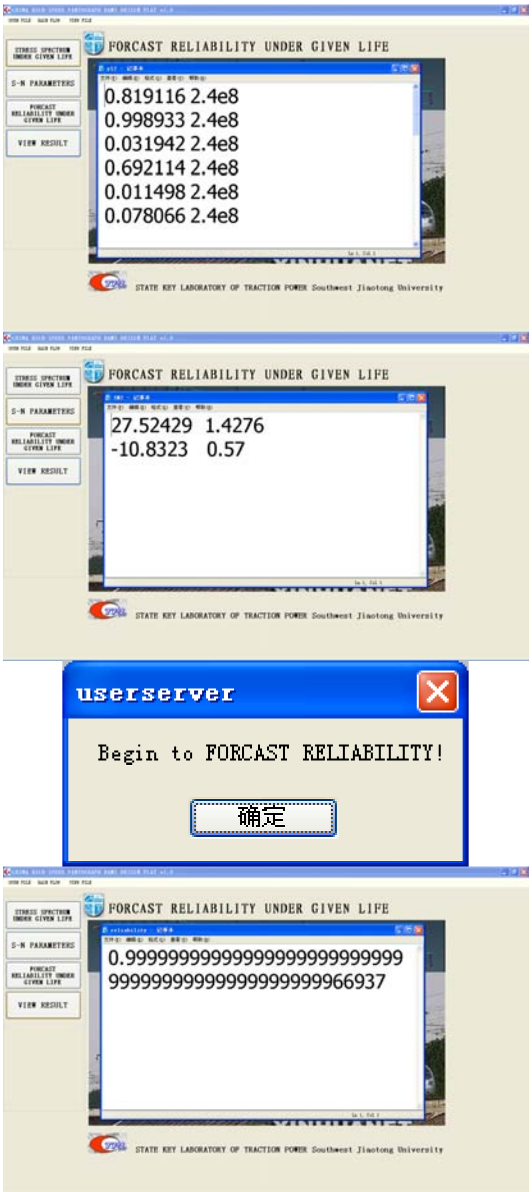


Figure 11. Flowchart of a reliability-forecast program

TABLE VIII. RELIABILITY FORECAST OF PANTOGRAPH V500 RUNNING 1,200,000KM AT SPEED OF 500KM/H

Parts Name	The Reliability of Pantograph V500 running12* 10^6 at 500km/h	Reliability judgement (R>[R])
Base Frame	$0.9^{38}53188$	Yes
Lower Arm	$0.9^{54}56666$	Yes
Drag Rod	$0.9^{65}41052$	Yes
Upper Arm	$0.9^{22}4154$	Yes
Balance Arm	$0.9^{82}6166$	Yes
Pantograph Head	$0.9^{47}66937$	Yes

VI. CONCLUSION

This paper developments rain-flow program, lifetime-forcast program and reliability-forcast program.

Spreaded material's basic probablistic S-N relationship to long lifetime probablistic S-N relationship; compounded Pantograph V500's operating stress spectrum in elastic-plastic model, an fatigue reliability analysis of Pantograph V500 at designed speed 500km/h has been completed.

Pantograph V500 has long- lifetime fatigue reliability, all the predicting results of key parts'lifetime under different reliability level excess the standard regulation of Pantograph design, 1,200,000km.

Pantograph V500 has high reliability level under condition of 1,200,000km lifetime and given crack length, it excesses the reliability distributed in the weakestness theory .

ACKNOWLEDGMENT

The present research is supported by China 973 Program (2007CB714703), Key Projects in the National Science & Technology Pillar Program during the Eleventh Five-Year Plan Period(2009BAG12A05) and National Natural Science Fund for Creative Research Groups(50821063).

References

[1] Weihua Zhang, Guiming Mei,Xuejie Wu and Zhiyun Shen. Hybrid simulation of dynamics for the pantograph-catenary system, Vehicle System Dynamics,2002,38:393-414.
[2] W. Zhang, G. Mei and J. Zeng. A study of Pantograph/Catenary System Dynamics with influence of presag and irregularity of contact wire. Vehicl System Dynamics Supplement,2002,37:593-604.
[3] W H Zhang, G M Mei, X J Wu and L Q Chen. A study on dynamic behaviour of pantographs by using hybrid simulation method. Rail and Rapid Transit,2005 219 Part F:
[4] Paradl wrter H J, PellissettiM F . Realistic and efficient reliability estimation for aerospace structures [J]. Computer Methods in Applied Mechanics and Engineering, 2005, 194: 1597～1617
[5] Jose E R M, DavidW C. A Monte2 Carl o simulation approach for approximating multi-terminal reliability [J]. Reli ab ility Engineer i ng and System Safety, 2005, 87: 253～264
[6] Liu WeiXin. Mechanical reliability design [M]. Beijing: Tsinghua University Press, 2006: : 188-220(In Chinese)

Dongli Song was born in 1971-11-10 at Yuanhe Gui Zhou province, is a PhD student in State Key Laboratory of Traction Power, Southwest Jiaotong University, Chengdu 610031, Cihina. The major research is mechanical reliability engineering and RAMS. From 1991-9-1 to 1994-7-1, to study in Aba Teachers College, the major research is Mathematics; From 2000-9-1 to 2003-7-1, to study in University of Electronic Science and Technology of China, the major research is Computer Science and Technology, degree is Bachelor; From 2005-9-1 to 2007-3-1, to study in College of Mathematics, Southwest Jiaotong University, the major research is Mathematics,degree is Master; From 2007-3-1 to now, to study in State Key Laboratory of Traction Power, Southwest Jiaotong University, Chengdu 610031, Cihina, the major research is Mechanical Reliability Engineering and RAMS.

Weihua Zhang was born in 1959, is a Changjiang Scholar, Doctor, Professor in State Key Laboratory of Traction Power, Southwest Jiaotong University. The major research is railway vehicle dynamics and pantograph dynamic behaviour study.

Ning Zhou was born in 1978, is a PHD in State Key Laboratory of Traction Power, Southwest Jiaotong University. The major research is pantograph dynamic behaviour study.

Guiming Mei was born in 1976, is a doctor in in State Key Laboratory of Traction Power, Southwest Jiaotong University. His major research is pantograph dynamic behaviour study.