Fatigue Life Assessment and Experiment Design for EMU Corbel

Wenxue Qian[1], Qingjie Wang[1], Zijian Sun[1], Xiaowei Yin[2] and Liyang Xie[1]

[1]*School of Mechanical Engineering and Automation, Northeastern University, Shenyang 110819, P. R. China*
[2]*Department of Mechanical Engineering, Shenyang Institute of Engineering, Shenyang 110136, P. R. China*
qwx99@163.com

Keywords: EMU corbel, Fatigue evaluation, Local stress-strain method, Experiment design.

Abstract: In order to ensure the safe operation of EMU, the fatigue assessment for corbel which a key components of EMU has been done. To refine the mesh quality for the weak parts of corbel though building a substructure using workbench software. According to finite element analysis, the local stress-strain method is adopted to estimate the fatigue life of the corbel. An analysis fatigue condition for corbel to determine the location and size of loading. Compared the body with single corbel finite element analysis results, determine the beam fatigue test program.

1 INTRODUCTION

With the development of economy and technology, the speed of EMU is increasing and the light weight requirement of car body is improved continuously. The safety problem of EMU is becoming the key to the development of motor vehicle technology. The safety of motor vehicles is not only to meet the requirements of strength and stability, but also fatigue life is one of the important indicators. The corbel is an important component of EMU and the fatigue performance directly affects the safety of train operation. The fatigue analysis of corbel's traction seats were carried out by some researchers(Han 2012). But right now, the EMU sleeper fatigue research is less at home and abroad.

At present, the fatigue assessment of large components mainly include the nominal stress method, the local stress-strain method, the stress field intensity method and so on(Zhang 2011). With the development of the finite element software, the local stress and strain of the dangerous part of the large component can be obtained by software simulation. This has been widely used in the engineering(Tong 2011). In this paper, the fatigue life of the corbel is evaluated by using the local stress strain method combined with the finite element analysis results. And the fatigue test design

of corbels is carried out combined with the actual operation of the EMU.

2 FINITE ELEMENT ANALYSIS

2.1 Establishing model and meshing of corbel

According to the 2D drawing to establish three-dimensional model of corbel as shown in Figure 1 (a). In the analysis of complex parts, it is necessary to use rough mesh to determine the dangerous parts, then the weak parts are refined by using the sub structure method(Song 2013, Japan Industrial Standards 2016). The corbel dangerous parts of the mesh for unit length of 10mm hexahedral elements, transition region for unit length of 15mm free mesh, other parts for the unit length of 30mm tetrahedral elements, the total number of nodes is 1064732, number of units is 549074.The mesh of key weak part shows as Figure 1 (b).

2.2 Finite element analysis and determine working conditions

EMU is great sensitive to environmental changes because of its high speed. According to the(Wang 2014), it is known that the fatigue condition is mainly based on the vibration, such as the stability of the track, body vertical and lateral vibration

which is caused by the passengers get on or off car, acceleration and braking of the car to produce longitudinal vibration. The change of conditions: the loads of body change between the preparation conditions (AW0) and overload condition (AW3). Calculating loads through the AW3 conditions：Vertical vibration acceleration to take (1+0.15 g); lateral and longitudinal acceleration take 0.15g. The main loads of corbel include the vertical load of air spring seat and the load of the center pin(Liu 2012).The loads condition is shown as Table 1 and Figure 7.

Using the static structural module of the finite element software of Workbench to make an evaluation of the fatigue condition for the corbel. The material parameters are shown in Table 2

(Sankaran 2011). The constraint boundary conditions at both ends of the corbel is fixed constraint. The two load step is set in the program, and the loading condition is shown in Table 1.1. Enhanced Lagrange method is used to solve the model. The equivalent stress and strain calculation results as shown in Figure 2, the greatly weak point is the intersection of left the through tube 1 and left corbel.

At the load step 1, the maximum stress value is 126.13Mpa and the maximum strain value is 1.7781E(-3). At the load step 2, the maximum stress value is 103.59Mpa, the maximum strain value is 1.46031.4603E(-3), and the other dangerous parts of the stress cloud is shown in Figure 3.
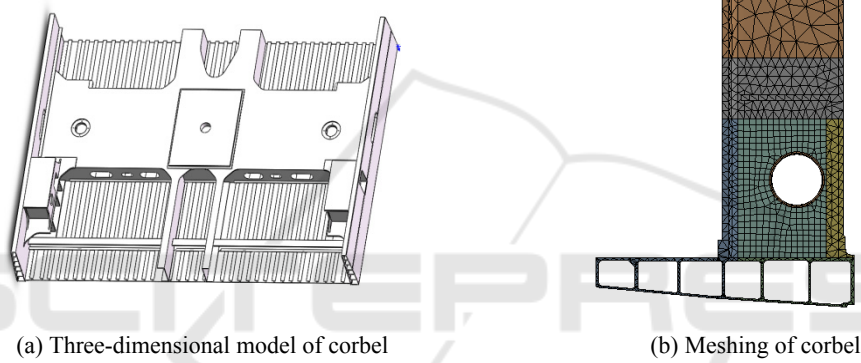

(a) Three-dimensional model of corbel   (b) Meshing of corbel

Figure 1: Model and mesh of corbel

Table 1: Loads condition

| Project	Number	Loads（KN）	The direction
Load of the center pin	1	15.5±15.5	With a transverse angle of 45 degrees
Load of air spring seat	2	120±18	Vertical

Table 2: The main corbel Aluminum Alloy material characteristics

Material	Position	Elastic modulus（GPa）	Poisson ratio	Density（Kg/m3）	Elastic limit（MPa）		Fatigue strength（MPa）	
					Base metal	Welding	Base metal	Welding
A7N01P-T4 (JISH4000)	Corbel reinforcing plate	69	0.3	2710	195	176	135	39
A7N01S-T5 (JISH4100)	Corbel left（right）				245	205	119	
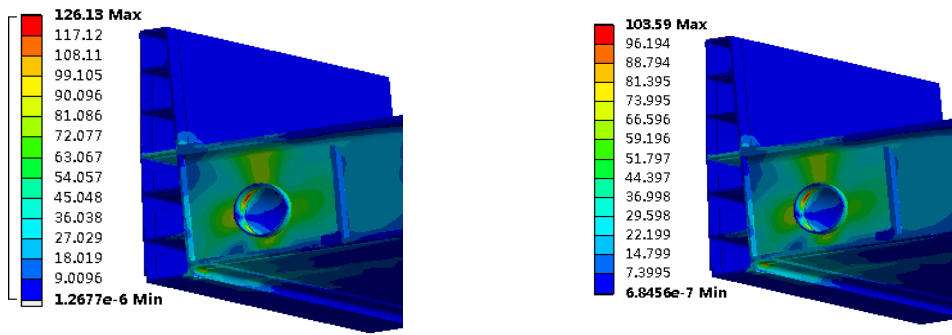
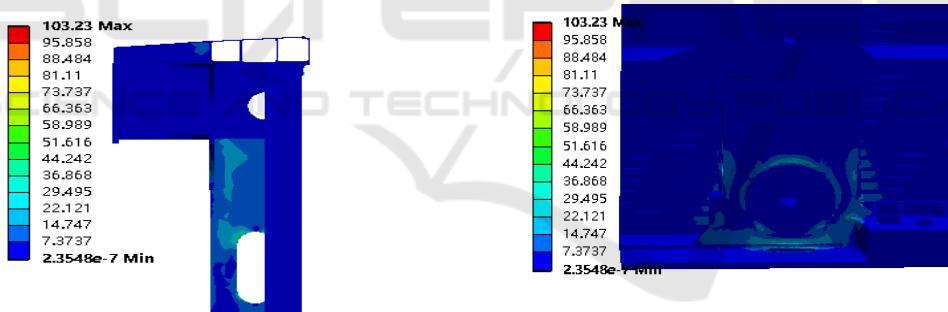(a) Stress cloud at the load step 1   (b) Strain cloud at the load step 1
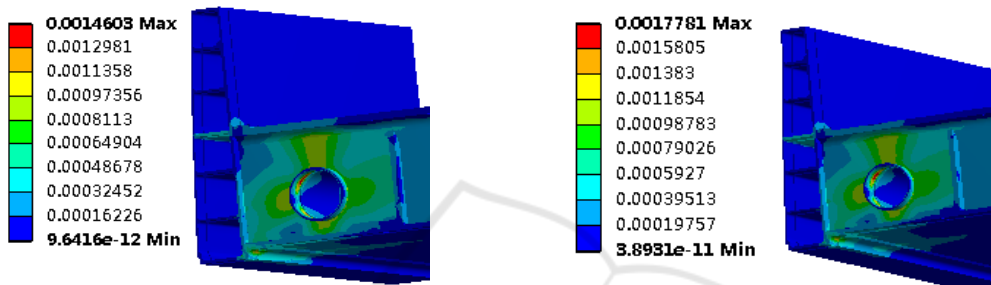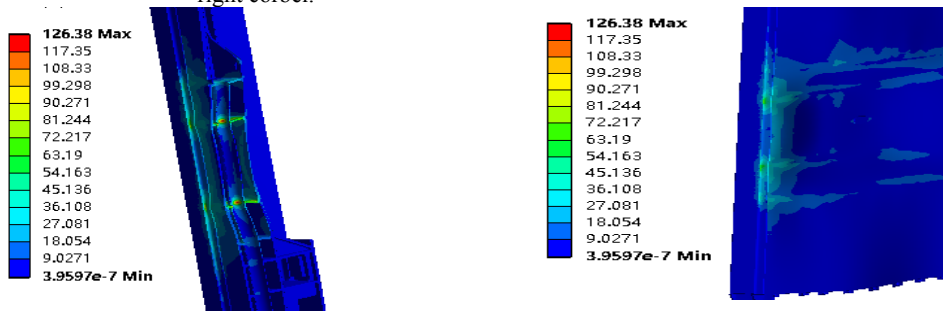
(c) Stress cloud at the load step 2   (d) Strain cloud at the load step 2

Figure 2: Stress or strain cloud of the weak point

(a) The intersection of right the through tube 2 and right corbel.   (b) The intersection of lower cover plate and side member.

(c)The intersection of right the through tube 1 and corbel inside.   (c)The intersection of left the floor and side member

Figure 3: Stress cloud at different risk positions

3 FATIGUE LIFE PREDICTION OF CORBEL

Corbel as large structures whose nominal stress is difficult to gain, but the local stress and strain can be obtained by finite element method. So using local stress-strain method to evaluate the fatigue life of the corbel. The strain life curve is usually described by Manson-Coffin formula, which is based on the low cycle fatigue strain life relationship (Manson-Coffin formula) and the high cycle fatigue stress life relationship (Basquin equation).As type (1)

$$\Delta\varepsilon_0 = \frac{\sigma_f^{'}}{E}(2N)^b + \varepsilon_f^{'}(2N)^c \qquad (1)$$

In formula (1), $\Delta\varepsilon_0$ represent the total strain when the average stress is 0; $\sigma_f^{'}$ represent the fatigue strength coefficient; $\varepsilon_f^{'}$ represent the fatigue ductility coefficient; b represent the fatigue strength index; c represent the fatigue ductility index; N represent the fatigue life(Yin 2010, Qian 2012).

In equation (1) for the Manson-coffin formula under fluctuating load, the non fluctuating load need to be modified to the average stress, and the average stress is modified by the total strain of Morrow, follow the formula (2):

$$\Delta\varepsilon = \frac{\sigma_f^{'}}{\sigma_f^{'} - S_m}\Delta\varepsilon_0 \qquad (2)$$

In formula(2)： $\Delta\varepsilon$ represent total strain whose average stress is corrected; S_m represent the average stress value.
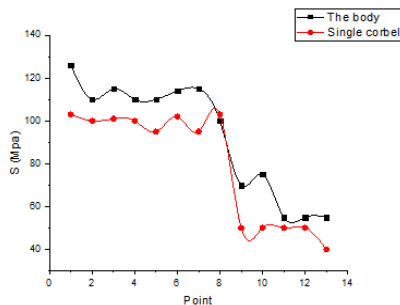
Through finite element analysis to ensure the critical points of corbel is in through pipe. The maximum stress is 126.13Mpa，and the minimum stress is 103.56mpa，whose material is A7N01S-T5. Material's tensile strength is 245Mpa、reduction of area is $\psi = 11.5\%$. Calculating that：

$$S_m = 114.86 \qquad , \qquad \varepsilon_f^{'} = 0.16252 \qquad ,$$

$\varepsilon_f^{'} = 0.16087$, $\sigma_f^{'} = 618.8$, applying the parameter to (1)、(2)：

$$\Delta\varepsilon = 1.228 \times \left[\frac{618.8}{69 \times 10^{-3}}(2N)^{-0.12} + 0.1681(2N)^{-0.6} \right]$$

The finite element calculation results show that the dangerous point strain is $\Delta\varepsilon_0 = 3.178E(-4)$. The fatigue life of corbel is $N > 10^7$.

4 CORBEL FATIGUE TEST

test points. Using the finite element software to analyze the body of fatigue working condition and the same conditions corbel analyzed separately scheduled monitoring results as shown in Figure 4, the same detection should be a smaller force deviation, corbel constraint and load method is reliable. The constraint imposed on the side beam and corbel test loading clamp mode is shown in Figure 6, load size as shown in Table 1.1 shows, load location and direction as shown in Figure 7. Load test for hydraulic drive, the test frequency is 3Hz, corbel fatigue test site as shown in Figure 5.

Figure 4: Results of key point of vehicle and corbel alone
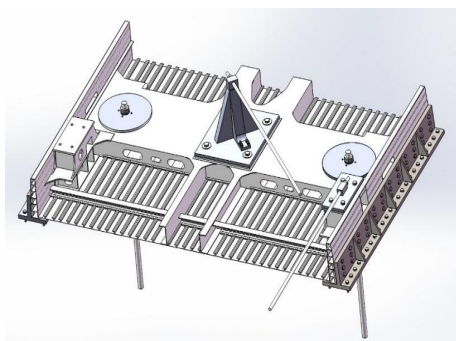

Figure 5: Fatigue experiment
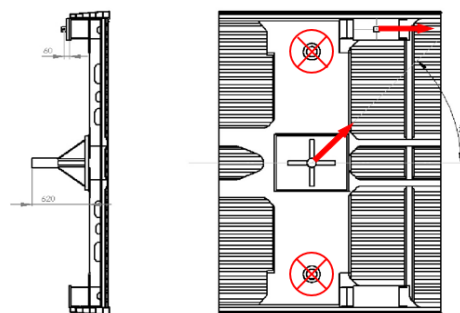
Figure 6: Fixture of corbel test

Figure 7: Loading position and direction

5 CONCLUSIONS

1) The evaluation of fatigue life by local stress strain method is conservative and accurate, and it is safe to be applied in engineering application;

2) Using the finite element software workbench to analyze corbel fatigue working condition, Applying the results of analysis to Manson coffin equation to obtain the dangerous position of the corbel fatigue life, which is $N > 10^7$. Satisfying fatigue life requirements;

3) Corbel fatigue test can be carried out independently. Do not need to analyze the whole body.

ACKNOWLEDGMENTS

REFERENCES

Han T, Liu Z, Li Q, et al, 2012. Evaluation of Fatigue Life and Reinforcing Scheme on 6K Electric Locomotive Traction Seats[J]. Procedia Engineering, 45(2): 930-935.

Japan Industrial Standards: General specification for design of railway vehicle body, 2006 (JISE7106-2006)

Liu X, Zhang L, Wang L, et al, 2012. Fatigue behavior and life prediction of A7N01 aluminium alloy welded joint. Transactions of Nonferrous Metals Society of China, 22(12): 2930-2936.

Qian Wenxue, Yin Xiaowei, Xie Liyang, 2012. System Reliability Allocation Based on Bayesian Network. Applied mathematics & information sciences, 6(3): 681-687.

Sankaran Mahadevan, Ruoxue Zhang, 2001, Natasha Smith. Bayesian networks for system reliability reassessment. Structural Safety, 23(3): 231-251.

Song Shaoyun, 2013. Mechanical design and manufacturing of parts in static simulation of assembly body. Mechanical design and manufacture, (9): 224-226.

Tong Dihua, Chen Zhiwei, 2011. Local should reform prediction hole part of the fatigue life. Aviation Materials Journal of aircraft structural belt, 31 (5): 86-90.

Wang Boming, 2014. General and bogie of high speed train car group. Chengdu: Southwest Jiao Tong University Press: 143-144.

Yin Xiaowei, 2010. Common Cause Failure Model of System Reliability Based on Bayesian Networks. International Journal of Performability Engineering, 6(3): 160-170.

Zhang Xiaoli, Chen Xuefeng, Li Bing, et al, 2011. A survey of the life prediction of machinery major equipment. Journal of Mechanical Engineering, 47(11): 100-116.