The strength analysis of no power bogie in rail-defect detector car

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Abstract. Rail-defect detector car compared with the artificial detection device has many advantage. This paper presents a certain type of rail-defect detector vehicle bogie’s Strength analysis. The finite element analysis software ABAQUS is used to setup the finite element model of bogie frame and analyze frame strength. Calculation results show that the structure can satisfy the strength requirements of the frame and fatigue assessment results show that the structure satisfied the infinite life design criteria.

1. Introduction

The software ABAQUS is used to conduct the FEM analysis of the bogie frame. It can make errors between the FEM model and the designed structure smaller and the results closer to the reality. The solution scale of the abaqus is larger, have cases to build up the entire unit finite element model which has the smaller grid unit. The model is built in 3 d model, through modeling and local simplified by the computer automatic discrete, then loading load in finite element calculation. The load case for bogie frame are determined according to UIC515-4 "*Tractive units-Bogies and running gear-Bogie frame structure strength tests*".

2. The calculation of the frame allowable stress and the cases of use

The allowable stress of material is equal to the quotient of the yield limit σ_s and safety factor S. Q345C welded-steel plate construction is mainly applied to the frame in designing， the yield limit of the material is 345MPa.

According to UIC515-4，for complex mechanical components，need to calculate the equivalent stress（Von Mises stress），this stress shall not exceed the allowable stress. This calculation stress results are all using equivalent stress. The formula of the equivalent stress is

$$\sigma_e = \sqrt{0.5\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]}$$

In this calculation，the allowable stress of Q345C welded-steel plate construction is 216MPa in operation, it's 314MPa while in extraordinary cases.

3. The frame finite element model

Based on the structure characteristics of the frame, it divided into solid element. Using ABAQUS finite element mesh tetrahedral partition technology, the frame is divided into 270640 units.

Considering the frame is supported on the axle-box spring-bearing, establish spring boundary element on the surface of each support, vertical, horizontal and vertical stiffness of the spring boundary element correspond with three direction stiffness of primary suspension; Spring boundary units are totally 24.In the model, X coordinate for the direction of the vehicle, Y coordinate for vertical upward direction and Z coordinate for transverse direction.

After the discrete, finite element calculate and load model is shown in figure, local finite element model is shown in figure 2.

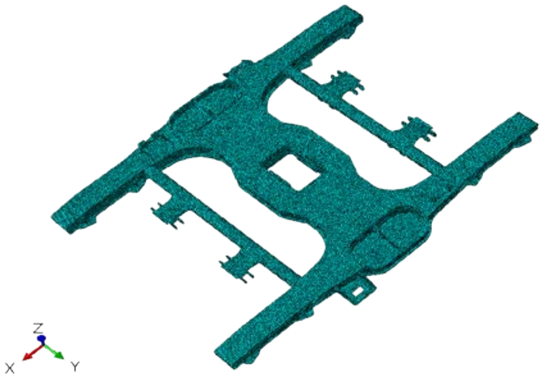

Fig.1 The frame finite element model

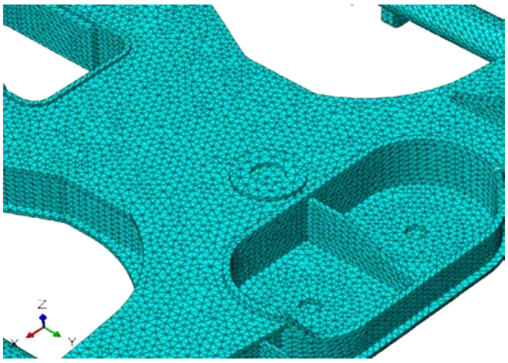
Fig.2 The frame local finite element model

4. The main computation load and calculation case of the frame finite element model

4.1 The main computation load of the frame finite element model

As space is limited, the detailed derivation process is not given. According to the request of UIC515-4, we can get them easily.

The vertical load of the frame is 66.87kN .

The vertical load considering drifting and side-rolling.We can easily figure out

$$F_{Z1} = F_Z(1-\alpha-\beta) = 46.81kN \qquad F_{Z2} = F_Z(1+\alpha-\beta) = 60.18kN$$

$$F_{Z3} = F_Z(1-\alpha+\beta) = 73.56kN \qquad F_{Z4} = F_Z(1+\alpha+\beta) = 86.93kN$$

The extraordinary vertical load on each side of frame: $F_{Z1\max}(N) = F_{Z2\max}(N) =$ =137.21kN.The calculated operation lateral load of each frame is 48.24kN. The calculated extraordinary lateral load of each frame is 86.19kN.The calculated traction load is 16.77kN. The braking load is 14.29kN. The simulation operation skew symmetrical load is 6.25mm.The extraordinary skew symmetrical load is 12.50mm. The second vertical damper load is 10.8kN. The second lateral damper load is 3.6kN.The simulation operation rhombus load is 9.64kN.

4.2 The calculation case of the frame finite element model

4.2.1 The frame simulation operation cases

The finite element calculation cases have been given in table 1. Due to the limited space, calculated value is not given.

Table 1 Selected simulation operation finite element model calculation cases

cases	Simulation operation combination description
1st case	Vertical
2nd case	Vertical + traction
3rd case	Vertical+ longitudinal traction + brake
4th case	Vertical + three-direction stop (positive)+ traction +vertical, lateral damper
5th case	Vertical + the three-direction stop (positive)+ traction+ track distortion + vertical, lateral damper + longitudinal rhombus load
6th case	Vertical + three-direction stop (negative)+ traction + vertical, lateral damper
7th case	Vertical + three-direction stop (negative)+ traction + track distortion + vertical, lateral damper + longitudinal rhombus load
8th case	all loads combination as positive operation
9th case	all loads combination as negative operation

4.2.2 The frame extraordinary load cases

The finite element calculation cases have been given in table 2. Due to the limited space, calculated value is not given.

Table 2 Selected the frame extraordinary load finite element calculation cases

Load	case	Combination description
Extraordinary load	1st case	Extraordinary vertical，k=2.0
	2nd case	Extraordinary vertical，k=1.4+ extraordinary lateral
	3rd case	Extraordinary vertical，k=1.4+ extraordinary lateral （negative）
	4th case	Extraordinary vertical，k=1.4+ extraordinary lateral + extraordinary distortion
	5th case	Extraordinary vertical，k=1.4+ extraordinary lateral （negative）+ extraordinary distortion
Special extraordinary	1st case	Three-point support,low-speed derailment

4.3 Static strength calculation of the frame

4.3.1 Simulation operation load cases

From table 3,we can easily get the maximum von Mises stress under simulation operation load cases. The charts show that the maximum von Mises stress of the frame under simulation operation cases is 105.70MPa，appearing on the second spring seat plate edge.

Table 3 The maximum von Mises stress of simulation operation cases

cases	The maximum von Mises stress（MPa）	The maximum von Mises stress locations
1st case	77.84	the second spring seat plate edge
2nd case	78.16	the second spring seat plate edge
3rd case	96.31	beams and side frame connections
4th case	91.99	the second spring seat plate edge
5th case	91.35	the second spring seat plate edge
6th case	104.80	the second spring seat plate edge
7th case	105.70	the second spring seat plate edge
8th case	104.80	the second spring seat plate edge
9th case	105.70	the second spring seat plate edge

4.3.2 The frame extraordinary and special extraordinary load cases

The table 4 show the maximum von Mises stress under extraordinary and special extraordinary load cases. The charts show that the maximum von Mises stress of the frame under extraordinary and special extraordinary load cases is 159.9MPa,appearing in extraordinary vertical, on the second spring seat plate edge.

Table 4 The maximum von Mises stress of extraordinary and special extraordinary load cases

Load	case	The maximum von Mises stress（MPa）	The maximum von Mises stress locations
Extraordinary load	1st case	159.70	the second spring seat plate edge
	2nd case	114.80	the second spring seat plate edge
	3rd case	114.70	the second spring seat plate edge
	4th case	128.80	the second spring seat plate edge
	5th case	128.80	the second spring seat plate edge
Special extraordinary	The case	137.80	the second spring seat plate edge

5.The fatigue strength evaluation of frame simulation operation cases

Vehicle bearings usually work under three stress states. The research report OREB13.5/RP17 from UIC experiment research center and the paper about the structure fatigue show that, the direction of the structure to produce fatigue crack and the maximum principal stress direction perpendicular to each other. According to the significant structure fatigue characteristics, three stress state is converted into unidirectional stress state, calculate the average stress cycle stress and stress amplitude, then judge the structural fatigue strength by the manufacturing material modified Goodman curve.

Modified Goodman fatigue limit diagram is actually a kind of fatigue damage stress envelope. The using method is: If any stress points in the polygon above or beyond, it means that after the specified circulation N fatigue or fatigue after a N time, material will break. If stress points in the polygon, then after a specified cycle N fatigue or fatigue after a N time, material is safe. So, a stress point in the polygon is safe. So, the points located in the polygon are safe.

5.1 Load conditions established

This article load conditions established according to the rule about working condition of frame structure in UIC515-4*"Tractive units-Bogies and running gear-Bogie frame structure strength tests"*, set its fatigue loading conditions.

5.2 Load Material Smith-Goodman fatigue curve and bogie frame fatigue strength evaluation

According to the information about bogie frame structure material provided by the manufacturer, frame adopts Q345 weathering steel, so we draw two material Smith-Goodman fatigue curve considering the safety factor k=1.5 and k=1.65 .The main parameter is showing here: σb =480 Mpa, σs =345 Mpa, $\sigma 1$=222.75 Mpa. Tensile strength and yield strength are given in the standard, fatigue characteristics obtained by empirical formula calculation. Each respectively consider parent metal and weld in the process of drawing curves of two kinds of Goodman, see Figure 5.。

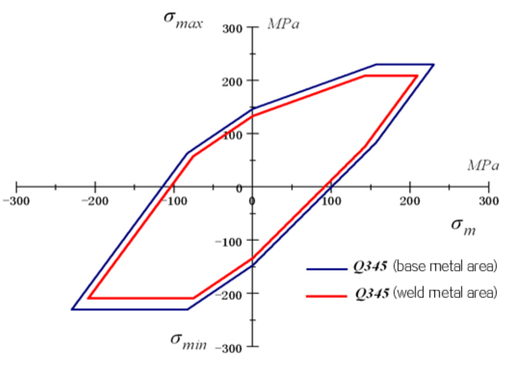

Fig.3 Goodman curve of bogie frame materials

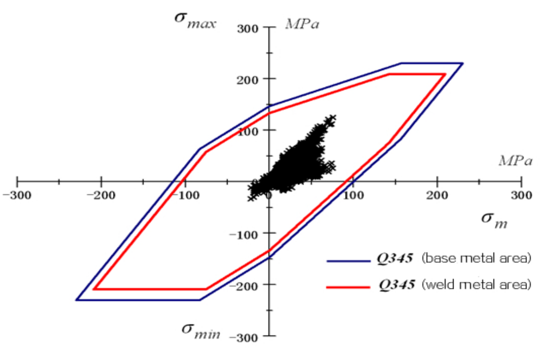

Fig.4 No power bogie frame fatigue evaluation

Rreferences to the condition of table 7,we evaluate the fatigue of the no power bogie frame. Seen from the figure 4,all nodes in the power bogie frame, finite element model of mean stress and maximum and minimum principal stress value are included in the smallest envelope, it shows that the power bogie frame design meet the requirements of infinite life design criteria.

6. Summary

Through the static strength test and the fatigue strength test of the bogie frame, we can easily obtain the following conclusions:

Among the calculation cases required by UIC515-4，the maximum von Mises stress of the frame is 105.70MPa，in simulation operation cases, not exceeded the material allowable stress 216MPa under operation conditions standard. And in the extraordinary cases, the maximum von Mises stress is 159.70MPa，not exceeded the material allowable stress 314MPa under extraordinary cases standard.

According to the figure Goodman for the frame fatigue strength assessment from UIC515-4, the power bogie frame design meet the requirements of infinite life design criteria.

Acknowledgements

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