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Lightweight Design on Auxiliary Frame of Mixer Truck

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Abstract

In response to call for energy conservation and emissions reduction, and the lightweight design on auxiliary frame of mixer truck is put forward. The FEA model is built by HyperMesh software to mesh, then the solver Radioss is used to calculate respectively the maximum stresses and the positions at the different full load conditions, including the static, left front wheel up 210mm, the right rear wheels up 210mm and the left front and right rear wheels simultaneously up 210mm. Then the real vehicle test is done, and the test results and simulation results have the good consistency, and the accuracy of the finite element model is validated. On the basis of these, the optimization design scheme of the thin material, oblique support and else local optimizations are put forward, analyzing again, the results are obtained that the total quality of the frame decreases to 10%, at the same time the strength also increases a little. Which provide an effective method for developing the optimization of vehicles, and make an important contribution for "energy saving emission reduction".

Keywords: *Mixer Truck, auxiliary frame, lightweight design*

1. Introduction

Vehicle lightweight design has important meaning for energy conservation and emission reduction. If the total quality of the vehicle is lightened 10%, the fuel consumption can reduce about 8%, the emission can reduce about 6% [1-13]. Due to the auxiliary frame of mixer truck affording a variety of complex loads from road and loading, the frame often appears the cracks and the repair rate is higher. In order to reduce the cost of repair, the auxiliary frame should be changed, which can increase the stiffness and strength and reduce the frame damage, but increases the weight and the production cost. Under this background, the lightweight design of the frame is proposed to cut the weight of auxiliary frame.

There are two kinds of ways to realize lightweight design, one is using new material, that is low density materials such as light metal or modern composite materials to reduce the structure weight; the other way is the optimization design, for the existing steel structure frame, under the premise of carrying capacity and reliability to reduce its quality. The first way has obvious effect for weight reduction, but has the higher development costs, and complicated processes; the later has low cost and easy to realize, if the plan is proper, also can get good effect of lightweight.

Someone completes lightweight design for the front longeron of automotive by robust optimization method and welding plate method [1-2]. Someone realizes lightweight design for mechanism structure by bionic technology, energy absorption mechanism and the response surface method [3-5]. Some papers realize lightweight design for automotive, transplanter stents and dump truck frame by fractional optimization,

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sensitivity analysis method and ANSYS method, which have achieved a certain effect [6-12].

Therefore, the method of combining the finite element and experiment will be used to optimize the auxiliary frame of mixing truck to realize the lightweight design on the basis of improving strength.

2. Building FEM and Analyzing the Strength

The auxiliary frame of the concrete mixer truck is shown in Figure 1, which is mainly made up two main girder and four beams, beams and girders are welding connecting, the front support, rear support, reinforcement are welding connecting with longitudinal beams of auxiliary frame, and the auxiliary frame is connected with main frame by a U-shaped bolt. It plays a very important role in connecting the chassis with concrete special equipment. It bears a variety of forces in the working process of concrete mixing truck, including supporting the stirring drum, bearing all transmission parts vibration, supporting the random dynamic load. So, it has key effect on the structure and properties of the mixer truck.

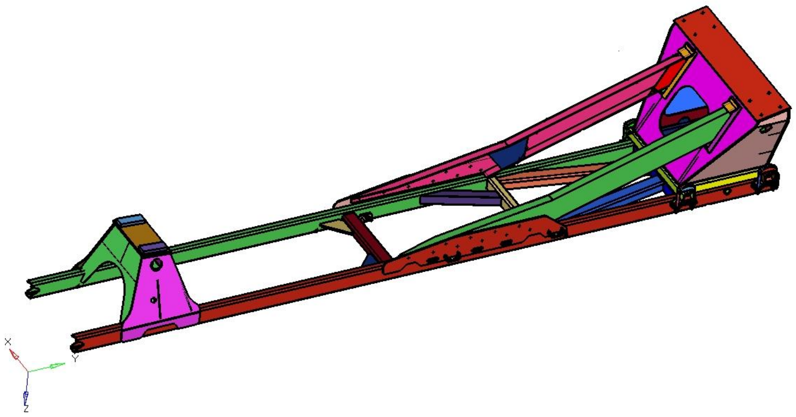


Figure 1. Auxiliary Frame Structure

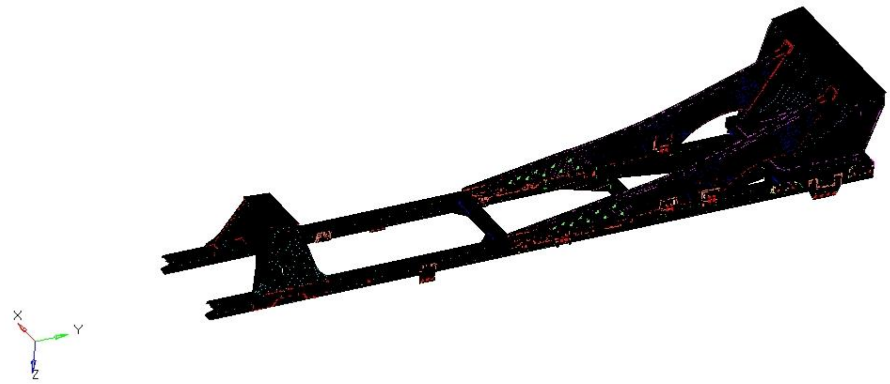


Figure 2. FEM of Auxiliary Frame

It is generally known that the lightweight design has become a new hotpot in vehicle design, especially in heavy vehicle, which is important for environment protection and energy conservation. Many users find that the total mass is too large of this kind of mixer truck. In order to solve the lightweight design problem, we will use the method combining the simulation and real vehicle experiment to analyse. Firstly, we apply the finite element analysis software to analyse the strength and find the location of the stress concentration. Then, we do the real vehicle test to verify the simulation analysis results. The specific test process and results have been described in the paper named "Optimization Design on Triangle Plate of Auxiliary Frame of Mixer Truck" from the same author, published by The Open Mechanical Engineering Journal, 2014 (Sun, Liu, Fu, 2014) [13].

3. Lightweight Design and Stress Analysis

Lightweight design of auxiliary frame by optimization design scheme is done, and the concrete scheme is to thin the thickness.

3.1. Auxiliary Frame Thickness Thinning

By analyzing of auxiliary frame, it is fully considered the safety design, which can satisfy completely the requirements of strength and stiffness, thus the material thickness thinning of auxiliary frame is proposed, which is shown in Table 1.

Table 1. Structure Thickness Thinning Parameters

Part name	Original thicknes s/mm	Thinning thickness /mm	Part name	Original thickness /mm	Thinning thickness /mm
Vice beam	8	7.5	First beam	8	8
Second beam-1	16	16	Second beam -2	8	7
Third beam-1	6	6	Third beam -2	8	7
Fourth beam-1	8	6	Fourth beam -2	8	7
Fourth beam -3	4	4	Fifth beam	8	7
Stiffening beam-1	8	6	Stiffening beam -2	6	5
Stiffening beam -3	6	5	Stiffening beam -3	6	5
Upper plate of front support	20	18	Front plate of front support	10	12
Rear left and right plate of front support	10	8	else of front support	8	6
Upper plate of rear support	16	16	front plate of rear support	8	8
Left and right plate of rear support	8	6	rear plate of rear support	8	8
Ladder plate of rear support	6	4	Two large riser plate of rear support	8	6

Four single foot of rear support	6	4	Four baseplate of rear support	7	7
Slab reinforcement plate of rear support	6	4	Two large riser plate of rear support	8	6
Shrouding plate of vice main beam	10	8			

Due to decrease of the structure thickness, the volume decreases relatively, corresponding quality lessen, which original mass (excluding connections) is 1116 kg, reducing mass is about 114 kg, and the lightweight ratio near to 10%, which can satisfy the requirements of lightweight.

3.2. Strength Analysis

The thickness of the auxiliary frame structure is reduced, on the one hand, the mass of the frame is reduced, and on the other hand the stress of the key area of the frame is increased. When the frame is under the bending condition, the stress increases little, which is shown in Figure 3. But, when the frame is under the torsion condition, the stress increases greatly, which is shown in Figure 4.

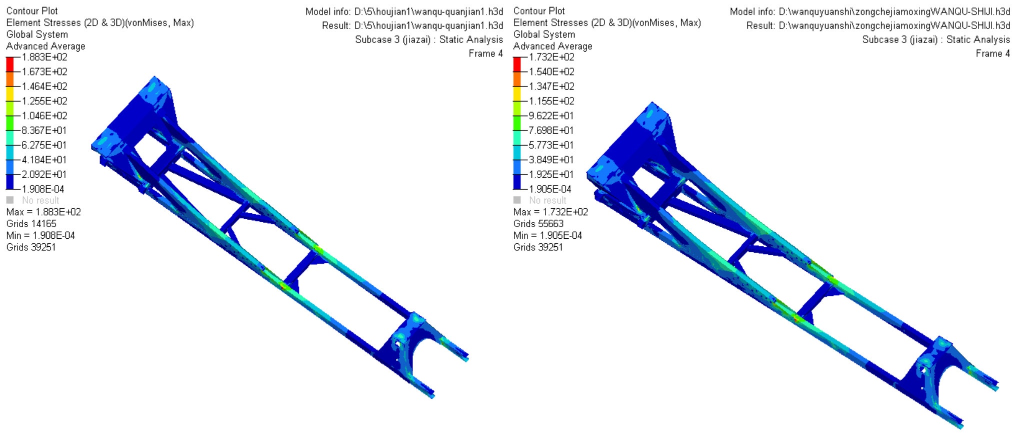


Figure 3. Stress Analysis of Bending Condition

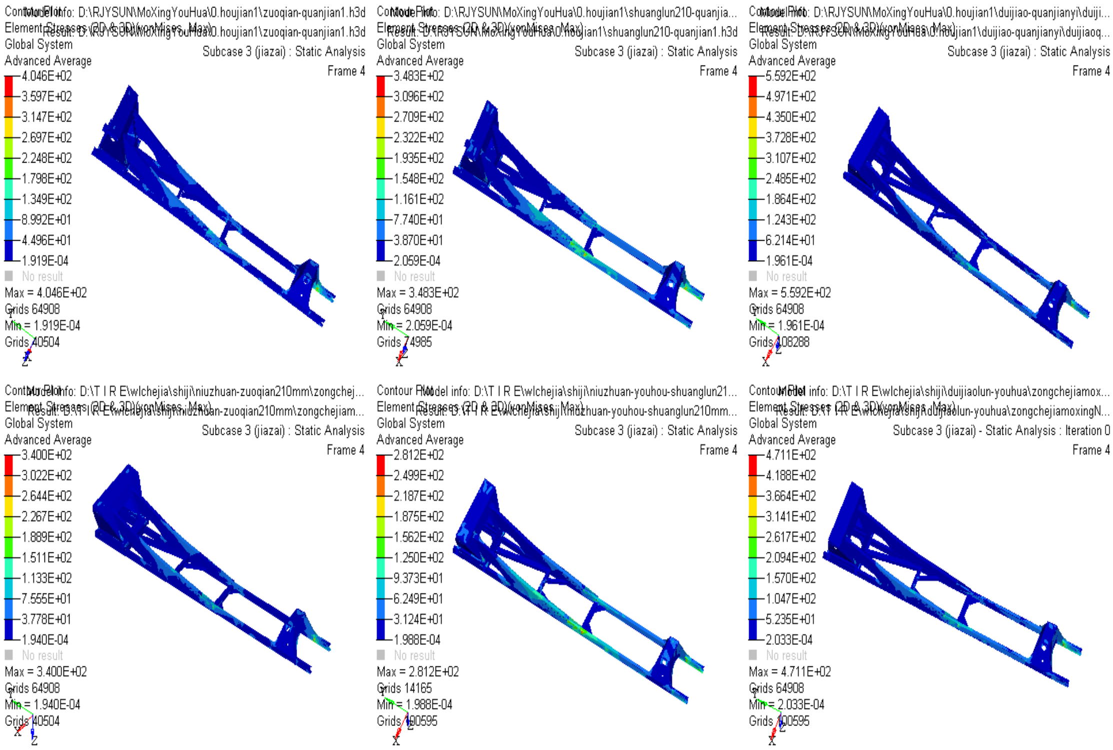


Figure 4. Stress Analysis of Torsion Condition

Thinning the thickness of the structure makes the local stresses increase, so optimization design of the key position structure is necessary.

4. Local Structure Optimization Design and Stress Analysis

According to the stress distribution of Figure 3, and Figure 4, it can be seen that the overall stress distribution of the auxiliary frame is not very large, but the local weld is larger, so the local structure can be optimized.

4.1. Auxiliary Frame Local Structure Optimization

The local structure of being more large stress will be optimized to reduce stress concentration and prolong its service life.

a) The support bracket foot extends obliquely downward 50 mm;

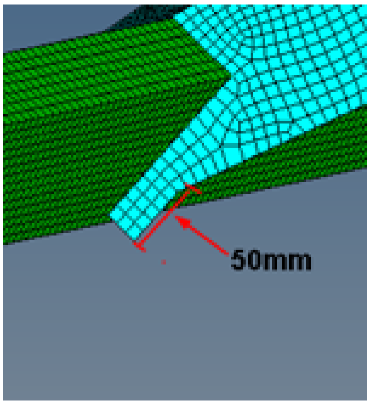
b) A beam extends downward 30 mm;

c) The front of oblique support extends 100 mm;

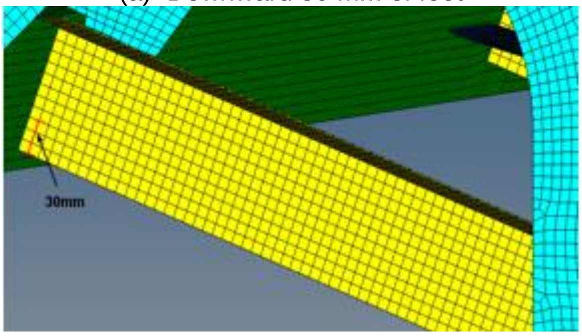
d) The rear support steel plate is reinforced;

e) Adding the reinforcing plate into the inside of the support plate.

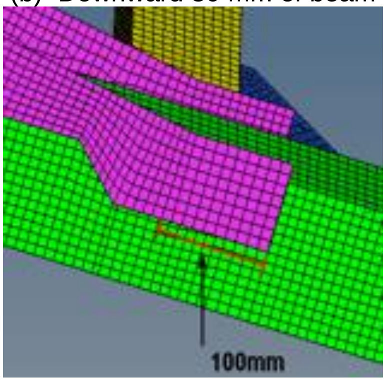
Above schemes are shown in Figure 5.



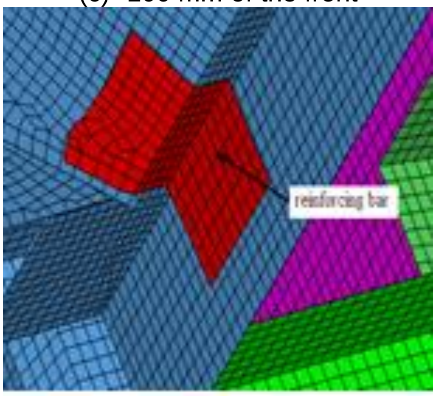
(a) Downward 50 mm of foot



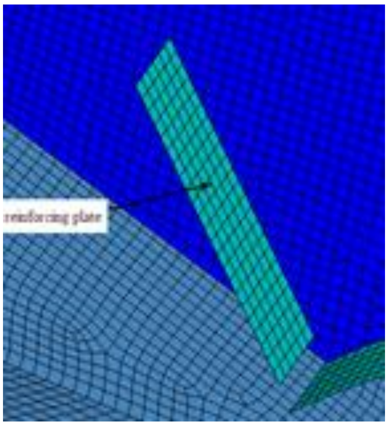
(b) Downward 30 mm of beam



(c) 100 mm of the front



(d) Reinforcing bar

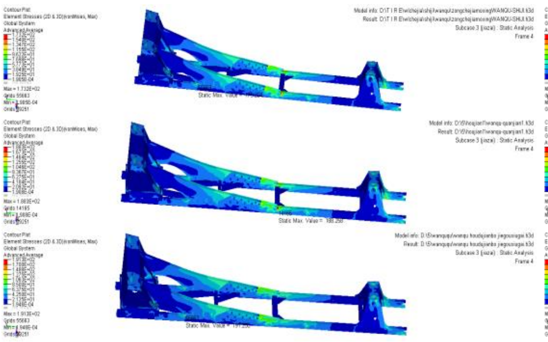


(e) Reinforcing plate

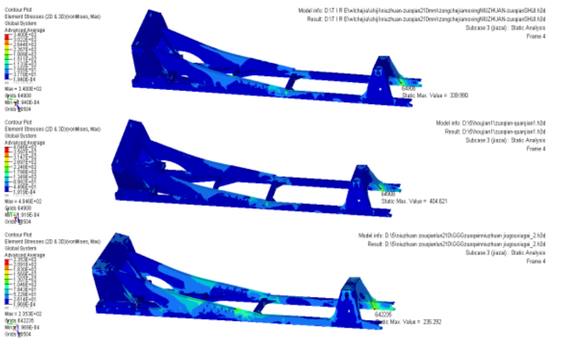
Figure 5. Local Structure Optimization

4.2. Stress Analysis after Optimizing of Auxiliary Frame

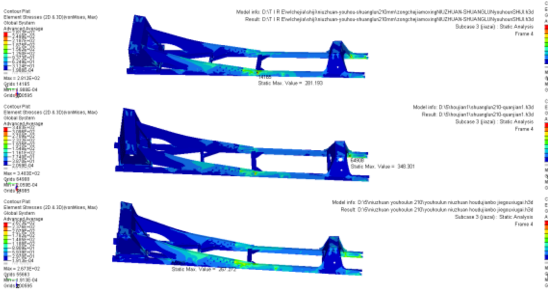
After optimizing, rebuild the finite element model of auxiliary frame, according to the loading boundary conditions, Radioss mode in HyperMesh software is used to calculate respectively the strength of bending condition, left front wheel lifted up 210mm, the strength of the right rear wheel lifted up 210mm, and the strength of left front wheel and right rear wheel lifted up 210mm at the same time under full load working condition. Aiming at the original, thinning thickness and the optimization, the stress nephogram under every working condition are shown contrast in Figure 6.



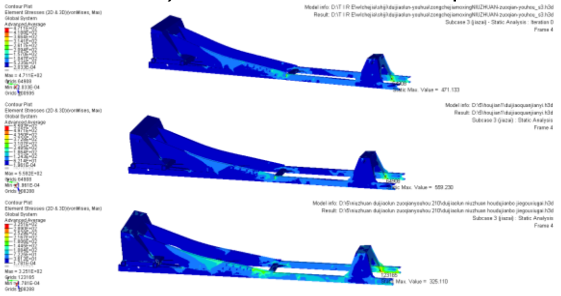
a) bending condition



b) Left front wheel lifted up 210mm



c)Right rear wheel lifted up 210mm



d) Lifted up 210mm at the same time

Figure 6. Auxiliary Frame Stress Nephogram under Full Load after Optimizing

After optimizing, maximum stresses of most local areas under each working condition are smaller than the thinning thickness and close to the values of the original auxiliary frame, which means the optimization structure of auxiliary frame is in accordance with the design requirements of strength and rigidity.

5. Conclusions

Finite element model of mixer truck main and auxiliary frames is built by Hyperworks finite element software, then it is analyzed under the working conditions of bending and twisting, and the corresponding tests are done to show that the model is valid and accurate. Then, the rectangle tube thickness of auxiliary frame is optimized. On the basis of this, the oblique support and local structure are optimized, the results are that the optimization design not only meet the requirements of strength and stiffness design, but also realize the lightweight design, the conclusions are as follows:

1) After reasonable material thinning and structure optimization, the total quality of auxiliary frame reduces 118 kg, and the lightweight ratio reaches almost 10%, which can meet the design requirements.

2) On the basis of the lightweight of auxiliary frame, the strength and stiffness is improved, thus the service life after optimizing is prolonged.

3) The finite element method is combining with test method, can provide basic tool for vehicle optimization design and analysis, and laid a solid foundation for energy conservation and emissions reduction and the development of vehicle industry.

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