Modelling and Performance Analysis of Standard Carriers for New Types of Motor Vehicles

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Abstract. Along with the continuous advancement of global economic integration, international trade is gradually increasing, in global trade, more than 80% of goods are transported through the container, and the key to further improve the efficiency of global logistics and transport is to optimise and integrate the resources and advantages of different links in the smart container industry chain. This paper establishes a high-precision simulation model based on the new standard metal container and freshness container, carries out structural design and strength analysis, and further carries out lightweight optimisation; carries out design analysis of freshness preservation and cooling performance of freshness container.

Keywords: Standard container, freshness container, finite element, freight carriage.

1. Experimental background
At present, some enterprises in China have also conducted research and development of multi-functional containers, such as intelligent dry freight container systems, intelligent tank containers / tank trucks and their systems, intelligent refrigerated containers and their systems, security containers and their systems, and RFID electronic tag container identity automatic identification system, including the traditional transport equipment, such as intelligent container systems, intelligent and secure complete solutions to meet the intelligence and security of the traditional transport equipment, such as intelligent container systems, such as dry freight container systems, intelligent tank containers / tank trucks and their systems, intelligent refrigerated containers and their systems, security containers and their systems, and RFID electronic tag container identity automatic identification system, to meet the International counter-terrorism, freight security, modern logistics, the speed and convenience of world trade and other requirements for the next generation of transport equipment. In order to solve the current problems of high-speed rail freight transport, this question focuses on the development of key technologies for standardised containers for high-speed freight carriages, mainly in the following three areas.

1) Strength analysis and lightweight optimisation of standardised metal containers.
2) Refrigeration simulation analysis of fresh food containers.
3) Insulation simulation analysis of fresh containers.
2. Model development and material selection

2.1. Finite element modelling of metal carriers and selection of materials

2.1.1. Finite element models. In order to facilitate the study, the model of the collector has been simplified in this paper by retaining the upper and lower base, top, vertical sides, inclined sides, front and rear sides, the important internal skeleton and external connections, as well as some of the bolt holes. Selective neglect of most of the screw holes, the hooks on the external sides, the internal power lines, ventilation and lighting reduces the difficulty of the process without affecting the results of the finite element analysis. The final mesh size \( l=5\text{mm} \) with 891,056 meshes is shown in Figure 1.

![Figure 1 Grid model of the assembler](image)

2.1.2. Selection of metal materials. Aluminium alloy 5052 is used for the lower bottom surface and bottom supports, aluminium alloy 2A12 for the upper bottom surface and aluminium alloy Type 304 and aluminium alloy 6061 for the sides. The back side is made of various profiled materials and is laid in four layers at 0°, 90° and in cycles as shown in Table 1.

| Material name | Modulus of elasticity | Poisson\(\nu\) | Density | Yield strength |
|---------------|-----------------------|--------------|---------|---------------|
| 6061-T5       | 69GPa                 | 0.33         | 2.70g/cm³ | 240 MPa       |
| 304           | 193 GPa               | 0.25         | 7.93g/cm³ | 310 MPa       |
| AL5052        | 70 GPa                | 0.33         | 2.68g/cm³ | 195 MPa       |
| 2A12          | 75GPa                 | 0.33         | 2.77g/cm³ | 383 MPa       |

2.2. Finite element modelling of the freshness container and selection of materials

2.2.1. Finite element model of the freshness container. The internal media of the container are set to 800 kg of water and air. During high-speed rail journeys, the external ambient temperature is generally higher than the required temperature inside the container, and water turns to ice below 0 °C. Therefore, we tentatively set the initial internal temperature at 0 °C and liquid water, and the external ambient temperature at 35 °C. The temperature of the external ambient temperature is 35 °C. The temperature of the external ambient temperature is 0 °C and liquid water. For analytical purposes, we make the following assumptions about the model.

1) Ignore changes in thermal conductivity due to changes in temperature, humidity and the medium within the insulation.
2) Ignore changes in volume, density and specific heat capacity before and after the phase change of the material.
3) Ignore heat losses due to the fact that the container frame and skins are mainly made up of riveted or welded aluminium alloys. Each side is considered as a whole for calculation purposes.

Taking into account the different internal and external structures of the freshness container and the different requirements for calculation accuracy, it is necessary to choose the right size to divide the grid. At the same time, under the condition that the accuracy of the simulation results is not affected, the internal air is considered as a whole and a larger mesh is divided to facilitate the calculation, so the outer wall mesh size is set to a maximum of 10mm and the internal air mesh size is set to a maximum of 30mm.

![Grid model of a refrigeration container](image)

**Fig. 2 Grid model of a refrigeration container**

### 2.2.2. Selection of insulation materials

The total wall thickness of the insulated container is 60mm, and the insulation layer is sandwiched between two layers of aluminium. Automotive, defence, aerospace, aviation, etc. Especially in the cold chain transport industry, on the outer walls of refrigerators, freezers, cold storage, refrigerated trucks, polyurethane rigid foam is the ideal insulation material for freezing and refrigerating equipment, at present, it has replaced most of the glass fibre insulation material, so the fresh food container also choose PU to act as insulation material, to maximize the refrigeration effect and energy savings, has a good economic model.

(1) The parameters for rigid polyurethane foam are shown in Table 1.

| Thermodynamic parameters | Numerical values |
|--------------------------|-----------------|
| Thermal conductivity     | ≤24W/(m-K)      |
| Specific heat capacity   | 1.38J/(kg/K)    |
| Density                  | 40kg-m²         |

(2) The parameters for the other commonly used materials are shown in Table 2

| Parameter | Materials     | Thermal conductivity | Specific heat capacity | Density  |
|-----------|---------------|-----------------------|------------------------|----------|
| Air       | (0°C)         | 0.24W/(m-K)           | 1.005J/(kg°C)          | 1.293g/L |
| Water     | (0°C)         | 0.55W/(m-K)           | 4.2J/(kg°C)            | 1000g/L  |
3. Strength analysis and lightweight optimisation of metal carriers

3.1. Boundary condition setting
In stable operation the pressure on the upper bottom surface is 2000N and on the lower bottom surface 5000N; during acceleration the pressure is calculated to be 8000N on the vertical side and 3200N on the inclined side; in case of an emergency a force of approximately 2000N + 5000N is applied to the rear of the collector.

3.2. Stress distribution patterns in metal carriers

3.2.1. Limiting loads when bearing on both undersides. Load analysis of the upper and lower surfaces
When the HSR is in stable operation, the container is not subjected to any other external loads, because the container is full of cargo, so that only the upper and lower bottom surfaces are subjected to the pressure of the cargo, as specified, when the container is fully loaded with 200 kg of cargo in the upper part and 500 kg of cargo in the lower part. When a uniform load of 2000N is applied, the finite element analysis is shown in Figure 1.

![Fig. 3 Force cloud on the upper floor](image1)

**Lower floor load analysis**
When a uniform load of 5,000 N is applied to the underside, the forces are shown in Figure 2.

![Fig. 4 Force cloud diagram on the underside](image2)
Conclusion: The cloud diagram shows that the forces on the top and bottom faces are within the tolerance range, the structure is undamaged and structurally sound.

3.2.2. Analysis during fixed acceleration. As a special container of the Fuxing high-speed rail, in addition to the long uniform speed of operation there is an acceleration phase, it is known that China's Fuxing high-speed rail can increase the speed to 350km/h in just a few seconds, the study, we assume that the acceleration of high-speed rail is 16m/s², the calculation is that at the maximum acceleration, the goods inside the container will be subjected to lateral forces, according to the laws of mechanics. At this time, the vertical side will be subjected to a horizontal pressure of approximately 8000 N and the inclined side to a horizontal pressure of approximately 3200 N. The results of the finite element solution analysis for both sides are shown in Figure 5 and Figure 6.

Figure. 5 Force cloud diagrams on the side of the collector at high-speed rail acceleration (1)

Figure. 6 Force cloud diagrams on the side of the collector at high-speed rail acceleration (2)

Conclusion: The side materials of the collector are all type 2A12 aluminium alloys with a tentative thickness of 4mm. According to the cloud diagram, the forces at the maximum stress do not exceed the ultimate stress of the material, the structure will not be destroyed and is structurally sound.

3.2.3. Contingency assembler stress analysis. In the process of placing and dismantling the container, it is inevitable to encounter the phenomenon of collision and container tipping.
Conclusion: The analysis of the common materials used in this design shows that the structure at maximum stress has not been damaged and is structurally sound.

3.3. Lightweight optimised design

Although the structural strength of all surfaces is within reasonable limits, there is still room to optimise the quality. Tests have shown that for every 10% reduction in the mass of a car, its fuel consumption drops by 3% to 5%. Therefore, one of the most effective ways to save energy and improve fuel economy is to reduce the mass of the car. This is also the case for moving vehicles, so lightweighting research is of great importance in addressing issues such as energy savings and improved economy [12]. It is therefore essential to optimise the lightweighting of the collector. According to the modal analysis theory, combined with practice, this study uses the modal analysis theory to optimise the thickness of the different force surfaces of the collector to achieve the purpose of lightweighting, and after many iterations of analysis, the optimal results are as follows.

1. For the lower bottom surface of the collector. As the material is 5052 aluminium alloy, which is originally 4mm thick and is only subjected to a pressure of 5000N from the load, it is clear that the finite element analysis results in a small stress, so here, according to the optimisation analysis, the thickness is suitably reduced to 3.25mm (up to 3mm is damaged, as shown in Figure 3) and the measured area of the underside of the container is approximately 2.7m$^2$ and the density of the 5052 aluminium alloy is 2.68g/m$^2$. When the thickness is reduced from 4mm to 3.25mm, the calculated reduction in weight is approx.

\[(270\times100) \times (4-3.25) \times 2.68 = 5.43\text{kg}\]

2. For the upper bottom of the container, choose 2A12 aluminium alloy, initial thickness 2mm, initial material is 5052 aluminium alloy, the whole process is only subjected to 2000N pressure from the cargo, and the finite element results show that the stress here is small, so the thickness is optimised.
to 1.5 mm, density of 5052 aluminium alloy is 2.68g/cm³, 2A12 density is 2.77g/cm³. When the thickness is reduced to 1.5 mm, the calculated weight is reduced by approx.

\[(240\times100) \times 0.2 \times 2.68 - (240\times100) \times 0.15 \times 2.77 = 2.90 \text{kg}\]

3. For the two side faces of the collector, the materials chosen are aluminium alloys of type 304 and 6061 respectively, both with an initial thickness of 4mm, and aluminium alloy 5052 as the initial material. 1mm as shown in Figure 4, the density of aluminium alloy 052 is 2.68g/cm³, aluminium alloy 304 is 7.93g/cm³ and aluminium alloy 6061 is 2.7g/cm³, resulting in a mass change of.

Upper side: \[(100\times75) \times 0.4 \times 2.68 - (100\times75) \times 0.35 \times 2.7\]
Lower side: \[(100\times80) \times 0.4 \times 2.68 - (100\times80) \times 0.1 \times 7.93\]

The final calculation results in a weight reduction of approximately 0.48 kg.

4. For the front and rear sides of the container, when the load is tipped, the force is about 2000N+5000N. The analysis shows that the maximum stress here is closer to the ultimate stress of the material, so no improvement is made.

In the end, the lightweighting result is that the container itself has a mass of approximately 150 kg when unloaded, and the optimisation reduces the mass by approximately 8.81 kg, resulting in a calculated mass optimisation of approximately 5.87%. The design objective of lightweighting has been achieved.

4. Summary

In this paper, in order to analyse different aspects of the performance of the same container, two finite element models with identical dimensions are built using the finite element method of simulation.

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