Virtual Sample analysis of concomitance fork’s stability and passing capacity

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Abstract. Based on such factors as positioning parameters, quality characteristics, stiffness and damping of suspension, steering train, drive train and tire, a multiple-body dynamics model of 14 DOF for one accompanying forklift is established with the 3D models and ADAMS software. In view of the driving environments of classified highways and fourth-class roads, four parameters including the speed, tilt stabilization angle, vertical tilt stability angle and channel width of the accompanying forklift are calculated, and high-speed driving stability and channel pass ability are analyzed and predicted during the design stage. The analysis results are useful for the design optimization of the traction rod and can provide a theoretical basis for the development of similar products.

1. Instruction
The accompanying forklift is developed to meet the needs of special users in the field fast loading and unloading materials and equipment, its core development content is to redesign and improve the suspension mechanism of ordinary forklifts, to meet the requirements of high-speed driving under the conditions of traction of forklifts and through the limit bends of low-grade highways.

Applying modern parallel design ideas, the performance of products should be expected during the design phase in order to shorten the development cycle and reduce unnecessary duplication. To this end, in the completion of engineering design at the same time, through simulation to calculate the accompanying forklift suspension and vehicle characteristics, the analysis of suspension in various operating conditions of the change characteristics, for the design and improvement of the car to provide a theoretical basis.

2. The Simulation analysis content
The use environment of military ambulances includes low-grade roads and off-road sections in the field, the situation of vibration of the injured and sick is very complex, and there are some shortcomings in the simple application of the national standard method:

1) Good road speed driving stability: analysis of the highest stable speed that a forklift can achieve when a good road surface is towed.

2) Four-stage highway pass capacity analysis: calculate the rolling angle of the end of the limit bend, the nod angle changes over time, and through the three-meter channel limit bend when the accompanying forklift is towed on the four-stage highway, to analyse its pass capacity.

3) Analysis of the effect of tow bar length on traction performance: By calculating the passing performance of forklifts at different traction rod lengths, reference is provided for the length design of the tow bar.
3. Analysis methods and simulation calculation models

3.1 Analysis methods
Using advanced virtual prototype technology, the calculation is used. VPT is a new technology in the field of design and manufacturing, involving multibody system dynamics, calculation methods and software engineering. It uses software to establish three-dimensional solid and mechanical models of mechanical systems, analyze and evaluate the performance of the system, to provide parameter basis for the design and manufacture of physical prototypes.\(^1\)\(^2\)

Virtual prototype technology can completely analyze the whole system in the initial stage of design-concept design stage and observe and test the mutual motion of each component. The use of system simulation software can be used in a variety of virtual environment to simulate the motion of the system, at the same time the computer convenient to modify the design defects, simulation experiments different design programs, the whole system continues to improve until the optimal design, and then make a physical prototype.

In order to accurately analyze the suspension characteristics and maneuvering stability of the accompanying forklift, the VPT design is completed using ADAMS software, which is commonly used in the international mechanical system dynamics simulation and analysis software. The analysis first needs to collect accurate and detailed suspension component parameters, and then through kinematic simplification, parametric modeling, simulation calculation and other steps, to obtain the results of the calculation.\(^3\)

3.2 Analysis model
In this analysis, the kinematic simplification of the accompanying forklift is first carried out, and the vehicle is simplified into a model consisting of 75 objects (wherein, the steel plate spring is connected by the beam force unit). Regardless of the degree of freedom of steel plate springs, a model of vehicle dynamics simulation with 14 degrees of freedom (DOF) is obtained.\(^4\)\(^5\)

The 14 DOFs (regardless of steel spring degrees of freedom) associated with the suspension/steering system in the model are:
- The front wheels are up and down (1DOF), the rotation of the front wheels (2DOF), and the steering movement of the front wheels (1DOF).
- The rear wheels are up and down (2DOF) and the rear wheels are rotated (2DOF). Free movement of the body (6 DOF). Specific vehicle (chassis) dynamic model (reference Figure 1).

3.3 Parameter Preparation
ADAMS is used in this paper to establish the vehicle's control stability analysis model, which requires the positioning parameters such as suspension, steering train, drive train and tire, and the characteristics of quality, stiffness, damping and so on.\(^6\)
In the simulation calculation, the method of obtaining the component parameters is measured by three-dimensional CAD modeling and test method. Data that cannot be measured by experimental method, either empirical data estimates are used or replaced with similar parameters. Such as the stiffness and damping characteristics of the steering system, structural parameters, etc.

4. Simulation results
First, the maximum speed of the good highway in a straight line is calculated, and then the three-stage highway limit bend ingesting capacity is simulated for the three-stage highway limit bend at the length of the towbar of 1.6m, 1.65m and 1.7m.

4.1 Analysis of the speed of good road in line
Reference to Figure 2, the maximum speed can reach 80Km/h or more.

4.2 Performance analysis of 1.6m long towbar vehicles on four-stage highway
The maximum speed can reach 34.45km/h, the rear shaft has a tilt of 3.2 degrees and a vertical inclination of 1.6 degrees (reference Figure 3, 4, 5).

The passage of the three-meter channel width of the four-stage road surface is analyzed, as shown in Figure 6, the rough solid line represents the boundary of the inner and outer side road, and the other curve shows the front and rear axles of the inner and outer wheel movement trajectory from the wheel movement trajectory and the road boundary analysis, in which case the accompanying forklift can pass the road surface.

According to the relevant experiments to measure the body in the stretcher position of the vehicle in the above three conditions of the head, hips, legs acceleration curve, into 1/3 octave analysis, get 1/3 octave acceleration.
4.3 Performance Analysis of 1.7m Long Traction Rod Vehicles on four-stage highway
The maximum speed can reach 33.34km/h and the rear axle inclination is 1.5 degrees (Figure 7-9). Analysis from the wheel movement trajectory and road boundary analysis (Figure 10), in which case the accompanying forklift can pass through the road surface.

5. Simulation results analysis and improvement suggestions
After simulation, the car can reach a speed of 80km/h when driving in a straight line on a good road surface, and can pass the 90-degree limit bend of 3 m wide channel on a four-stage road at a speed of no more than 30km/h. When the length of the towing lever is shortened from 1.7 meters to 1.6 meters, the maximum speed by bend is increased, but when the length of the towing lever is 1.65 meters, the simulation analysis shows the phenomenon of system instability, which needs to be paid attention to in the actual structure design.

Through the analysis of the stability of the four-stage highway limit bend, it can be seen that the inclination between the axle and the body is relatively large, which will affect the stability of driving. Therefore, it is recommended to add a lateral stabilizer bar to the suspension to improve driving stability, especially when passing through the limit bend.

6. Test results and conclusions
The first prototype uses a 1.6m towbar length and adds a lateral stabilizer, which has reached a maximum speed of 34km/h and pass through the 3m channel four-stage highway. This shows that the establishment of simulation model is scientific, and the results of more reliable calculation scored, which provide a strong basis for design improvement.
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