

Improved Tilting Method for Automobile Mass Center Measurement Based on Simulation Analysis

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Abstract. The Tilting Method(TM) is applied to measure the automobile mass center position widely for simple principles and easy operations. However, the TM has some problems, such as inaccurate calculation of tire force point and large tilting angle of the vehicle, so the Improved Tilting Method (ITM) is proposed in this paper. In the process of running ITM, the tire force direction is always straight up, so the friction and other adverse factors are less than that in TM. ITM applies a combined parallelogram mechanism to keep the supporting plates horizontal. In this research, we study the ITM measurement process by simulation analysis. The research results show that the design scheme and the equipment movement outcomes prove the feasibility and practicability of the ITM.

Keywords: vehicle; mass center measurement; improved tilting method; simulation analysis.

1. Introduction

The position of a vehicle mass center has a great impact on the overall design and layout of the vehicle [1], and it also affects the handling stability, ride performance and driving safety of automobiles [2]. At present, the main methods to measure the mass center of vehicles include the swing method [3], the tilting method (TM) [4], the three-point force measurement method [5] and the mass reaction method [6]. In addition, scholars around the world have also explored and studied other vehicle mass center measurement methods [7, 8]. The tilting method is used in measuring the position of vehicle mass center widely because of its simple principle and easy operation. However, in the measuring process of TM, there are some issues such as inaccurate calculation of tire force point and large tilting angle of vehicle. So the Improved Tilting Method (ITM) is proposed in this paper to measure the position of vehicle mass center.

2. Improved Tilting Method (ITM)

2.1 Tilting Method for Automobile Mass Center Measurement

When measuring the vehicle mass center, the test bench and vehicle rotate synchronously. The load collecting instruments or the force sensors under the test bench can collect the force value. Due to the redistribution of vehicle wheel load in the process of rotation, the deformation of tire and suspension will change in different degrees. In addition, the vehicle tilting angle varying can lead to the change of the liquid level of fuel and other liquids, the final mass center position will produce a certain error. Fig. 1 shows the TM testing process to measure the position of vehicle mass center.

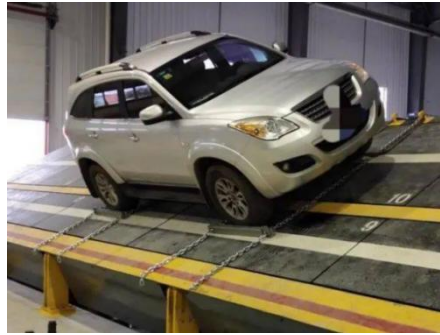


Fig. 1 The measuring process of TM

2.2 Advantages of ITM

In the process of TM, the exact force point of tire can not be obtained, due to the tire and suspension dynamical deformations and the level changes of the fuel and other liquids in the vehicle. Different from the TM, when measuring the mass center position of the vehicle by ITM, the test bench rotates around the center bearing, and the supporting plates are always horizontal under the constraints of the combined parallelogram mechanism. Therefore, the final tire force is always upright. The ITM in measuring the position of vehicle mass center is shown in Fig. 2.

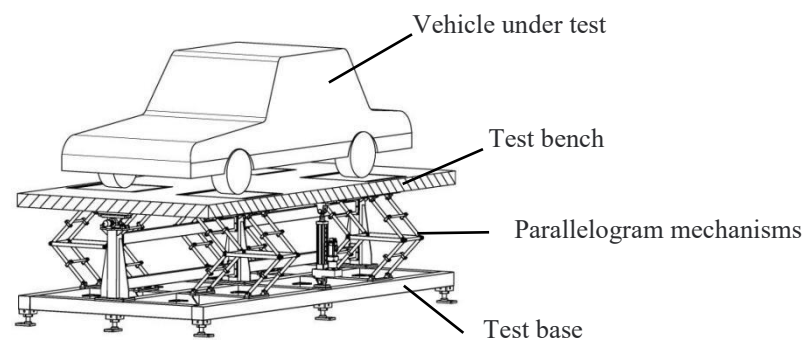


Fig. 2 Diagram of Improved Tilting Method (ITM) [9]

As shown in Fig. 2, the experimental equipment for ITM is composed of the test bench power system, the combined parallelogram mechanism support system and the data acquisition system. The power system of the test platform provides the rotating power of the test platform and is the overall supporting platform of the ITM. The combined parallelogram mechanism support system keeps the supporting plates level by its own characteristics, and force sensors are installed between the plates and the frame of the test bench. By measuring the force of the sensors and calculating the balance of the plane torque, the exact position of the force point of the automobile tire can be obtained. In terms of information collection, the ITM does not collect wheel load information in the measurement process, but output data uniformly through the force sensors under the supporting plates.

2.3 System Composition of ITM

The mechanical system in the scheme of ITM is composed of test bench and combined parallelogram mechanism. The test bench is an upper frame structure of the ITM equipment, which can rotate at a certain angle around the center bearing. The combined parallelogram mechanism, which upper part is fixed on the supporting plates through the bearing and the lower part is installed on the base, is a key mechanism to realize the motion of ITM. The control system of the ITM is composed of sensors and software. For the convenience and safety of the test vehicle operation in the process of measuring the mass center position, the whole experimental equipment can be placed in the pit to keep the test bench at the same level with the ground. The overall composition of the ITM test system is shown in Fig. 3(a) and Fig. 3(b) shows the specific design of the supporting plate and the combined parallelogram mechanism.

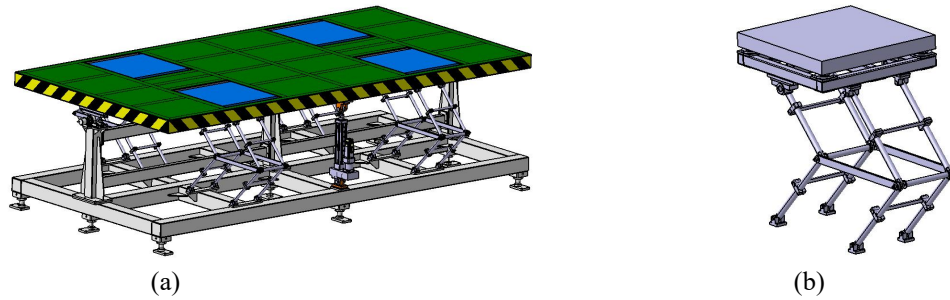


Fig. 3 Design Model of ITM Test bench

Parallelogram mechanism, as a plane linkage mechanism in common use in the mechanical industry commonly, is applied for transmitting force and motion mainly. In a parallel four-sided row mechanism, the connecting rod always does translation motion [10]. Utilizing the characteristic of parallelogram mechanism to constrain the motion of supporting plate is the critical component to improve the motion characteristic of ITM. In the design scheme, the material of supporting plate is Q235 steel, and that of the key shaft of the parallelogram mechanism is high-carbon chromium bearing steel GCr15.

2.4 Measuring Process of ITM

When we use the ITM to determine the vehicle mass center, it is necessary to check the system first, including blank plate calibration and system self-checking. After the checking, we can obtain the coordinates of the mass center mass in the horizontal plane. Then the test bench rotates and the workstation can solve the height coordinates. Fig. 4 displays the system flow chart to determine the position of vehicle mass center by the ITM.

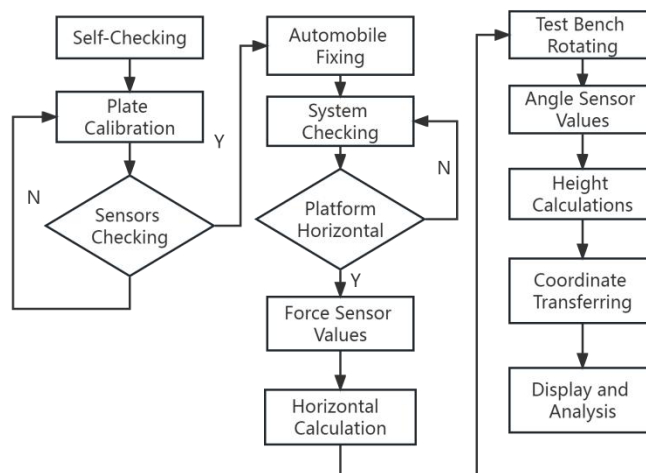


Fig. 4 Test process of ITM

Several key steps in the mass center determination process:

Blank plate calibration

We can use blank plate calibration to check the system state, and determine whether the system is operating normally according to the output of the sensors before the formal measurement. The calibration process can be carried out by blank plates completely or placing corresponding weights according to the requirements. The system state is determined based on the measurement principle and sensor output finally.

Horizontal operation

During formal measurements, the vehicle is placed on a supporting plate. The tilting sensors can be used to evaluate whether the platform is horizontal or not, and judge the horizontal state of the supporting plates.

Tilting state operation

After obtaining the position of the mass center in the horizontal state, turn the test bench to make the vehicle produce a certain tilt angle. The height of the mass center can be calculated by the combination of the sensor output and rotation angle. The height is independent of the coordinate system, so no coordinate transformation is required.

3. Simulation Analysis Research for ITM

Based on the ITM design scheme, the simulation and motion analysis were carried out by the professional simulation analysis software Ansys/workbench. Strength check was done for the whole test bench frame. When the rotation Angle was 15 degrees, the maximum equivalent stress of the whole frame was no more than 40Mpa, and the relative deformation was less than 1mm, as shown in Fig. 5. From the above analysis, it can be seen that the stiffness and strength of the ITM design scheme meet the requirements.

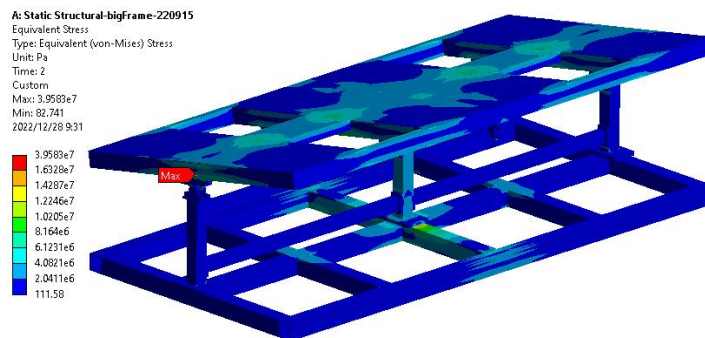


Fig. 5 Stress state of test bench frame

The motion process of the ITM was also simulated by simulation analysis. Fig. 6 shows the whole simulation analysis model for ITM. Many components, which had a large size variation, were in the model, so the size of the model components was adjusted, and the minimum size is 5 mm. The model was refined at some local individual areas. The Adaptive mode of mesh was used and the Relevance value was adjusted to 80. The model was built up by solid mesh, and the rotating shaft was applied as rotation pair.

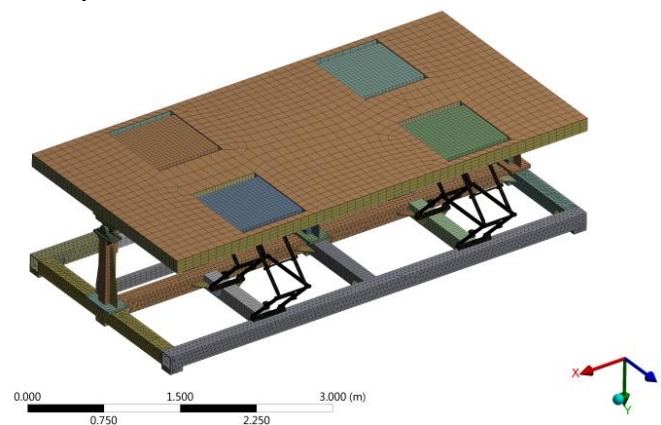


Fig. 6 Finite Element Model of ITM

As shown in Fig. 7, the boundary and force conditions in the motion simulation analysis of the ITM are set as followings: The Remote Force was adopted to set in the center at the ideal vehicle mass center position, and the force was put on the upper surface of the four supporting plates. The force value was converted according to the weight of the vehicle, about 2 tonnes. The four support points of the test bench base are restrained at the same time.

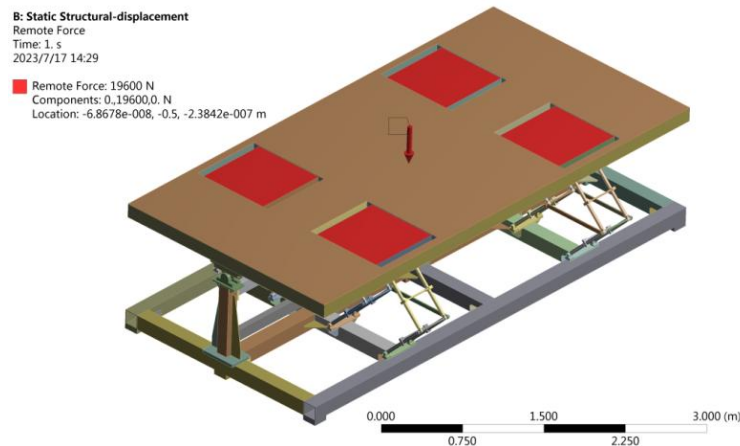


Fig. 7 Boundary condition of ITM Simulation

The number of steps in the simulation analysis process was two totally. The first step was to apply the weight of the vehicle to the supporting plates, and the second was to rotate the test bench to verify whether the ITM can perform normally. After rotating a certain angle, the results were displayed and checked whether met the expectations or not.

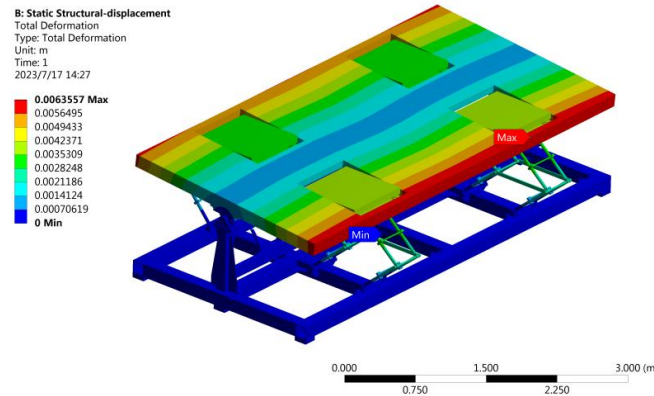


Fig. 8 Numerical simulation results for car ITM test process

Fig. 8 shows the result of numerical simulation analysis. Under the constraint of parallelogram mechanism, the supporting plates rotates with the test bench on one hand and maintains the horizontal state on the other hand. The simulation results are in agreement with the motion principle of the ITM, which verifies the rationality of the Improved Tilting Method for automobile mass center measurements.

4. Experimental Prototype of ITM

Based on the design scheme of the ITM mass center measurement, a physical test system was established in this paper. Fig. 9 shows the prototype of the ITM and the next plan is to do the experimental research.

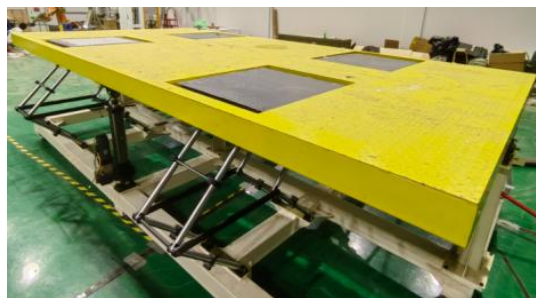


Fig. 9 Prototype of ITM

5. Summary

When the Improved Tilting Method is applied to determine the position of the vehicle mass center, the tire force is always upright and the position can be solved accurately. Based on the measurement principle of the ITM, this paper verified and studied the measurement process by simulation analysis. The ITM can be converted with TM or lifting method through simple upgrading, which improves the cross-verification convenience of vehicle mass center measurement greatly. In addition to the general commercial vehicle mass center measurement, the ITM can also measure the mass center position of special vehicles such as multi-axle vehicles.

Acknowledgement

The authors would like to acknowledge the financial support provided by Jilin Province Science and Technology Development Program(No. 20200401098GX).

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