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RIGOROUS INVESTIGATION OF A CONTROLLABLE TORQUE LOADING SIMULATION TECHNIQUE FOR ASSESSING THE BRAKING PERFORMANCE OF VEHICLES INVOLVED IN ACCIDENTS

Grigory Volkov
Saint Petersburg State University of Architecture and Civil Engineering, Saint Petersburg, 190005, Russia.

Abstract: In order to more accurately test the braking performance of vehicles that have lost their driving ability, this paper conducts a simulation study on the torque loading method in the braking force detection of accident vehicles. First, the feasibility and characteristics of the single-wheel braking force detection method were analyzed through experiments; then, a torque loading model based on the electromagnetic slip clutch was established, and the loading torque, excitation current and rotor were deduced based on the mechanical characteristics of the asynchronous motor The relationship between the rotational speed and the PID control algorithm were combined to propose a controllable torque loading method; finally, the simulation of torque loading control was carried out in MATLAB/Simulink, and reasonable loading time intervals and other parameters were obtained. Through the torque The loading error analysis verifies the feasibility of the method proposed in this article and lays the foundation for the braking performance detection of accident vehicles.
Keywords: Accident vehicle; Braking force detection; Controllable torque

1 INTRODUCTION

The rapid growth of car ownership and the frequent occurrence of traffic accidents have led to an increase in car-related quality disputes and accident disputes. In these traffic accident disputes, the identification and testing of car braking performance is a key. However, due to the collision damage of the vehicle, it does not meet the conditions for road test or Taiwan test inspection. Appraisal agencies can only use appearance observation methods, and their conclusions lack scientificity and objectivity. Therefore, related research on the braking performance testing of accident vehicles is of great significance.

In terms of accident identification, there is a relatively mature forensic identification industry abroad [1], which can well reproduce the accident process and conduct collision analysis and auto parts safety research. In the process of identification and analysis, the slip velocity calculator and collision data recorder (EDR) are mainly used for highway collision data analysis [2], photogrammetry technology is used for on-site map drawing analysis, and software is used for collision simulation [3-6]. Mature forensic analysis of accidents focuses on reproducing the accident process, but lacks devices for detecting the accident vehicles. On the other hand, from the perspective of national standards, such as the U.S. Federal Motor Vehicle Safety Regulations, Japan's "Motor Vehicle Safety Standards" and the Russian Federation's national standard "Methods for Testing Requirements for Technical Conditions of Safe Driving of Vehicles", etc., do not involve the detection of accident victims. Braking performance testing of damaged vehicles. The current standard GB 7258-2012 "Technical Conditions for Motor Vehicle Operation Safety" [7] that is being implemented in our country requires that the ability to drive after an accident must be tested by road test or bench test. For accident vehicles that cannot drive normally, experienced vehicles must Professional technicians conduct disassembly and inspection, that is, static inspection is used to determine its status at the time of the accident, and at the same time, refer to the national standard GB/T 18344-2016 "Technical Specifications for Automobile Maintenance, Inspection, and Diagnosis" [8] to determine whether the technical condition of the vehicle meets the technical requirements. Requirements[9-10]. On the basis of national standards, literature [11] and literature [12] introduce in detail the methods of road test, bench test and static disassembly and inspection. At the same time, the latter also introduces a simple single-wheel braking force detection method; literature [13] used the method of dynamic simulation model to conduct research on accident vehicles equipped with ABS; in 2011, the document [14] made some innovations in the application of braking performance tester in the braking performance detection of accident vehicles.

In the above-mentioned literature, there are relatively few studies on the detection of braking performance of accident vehicles that have lost their driving ability. Accordingly, based on the single-wheel braking force detection method, this paper studies the torque loading method during the braking force detection process. Combined with the principle and mechanical characteristics of the electromagnetic slip clutch [15-16], the relationship between the torque loading parameters is analyzed, and the PID control algorithm [17-18] is combined to make the loading torque controllable. Finally, through the dynamic simulation of the loading process and The experiment verified the feasibility of the method used in this article.

2 TEST BASED ON SINGLE WHEEL BRAKING FORCE TEST METHOD

Accident vehicles often lose their driving ability after collision and do not have the technical conditions for road tests or bench tests, making it difficult to conduct routine testing. Therefore, the research method in this article is based on the single-wheel braking force test method and adopts an alternative method of measuring the brake braking force. , to approximately measure the ground braking force.

When testing, first loosen the wheel bolts, jack up the axle where the wheel to be tested is located, remove the wheel, and apply torque to the brake disc by pressing the brake pedal. When the applied torque is greater than the maximum static friction torque of the brake, the brake disc will rotate. On the axle with a larger axle load in the car, the maximum static friction torque is approximately equal to the torque generated by the ground braking force on the wheel. Finally divided by the wheel radius, the approximate ground braking force can be obtained. This method can approximate the ground braking force, but from the measurement process and principle analysis, it can be seen that the single wheel braking force detection method also has many shortcomings, such as the torque loading process is uncontrollable, it is a static detection, etc. Therefore, in this article, the torque loading process is innovated to make the torque loading controllable and realize dynamic detection.

According to GB 7258-2012, automobile braking performance testing generally uses a reaction-type (or inertia-type) roller brake test bench for no-load testing. When there is any objection to the testing results, a full-load testing or road test testing will be performed. In order to analyze the reliability and characteristics of the single wheel braking force additional measurement method, the roller braking test bench was selected as a comparative test. Two sets of tests were conducted on cars of the same model. The test results of the roller test bench are shown in Table 1.

Table 1 Braking force test results of roller test bench

project	Left wheel braking force/N	Right wheel braking force/N	Brake pedal force at maximum braking force/N	Pipe pressure at maximum braking force/MPa
front axle	3 196	3 468. 5	488	8.2
rear axle	757	1 081	473	8

The single-wheel braking force detection method must be based on the test results of the roller test bench to find out the brake pedal force and pipeline oil pressure when the vehicle braking force reaches the maximum value, and use this value to simulate the brake pedal force in the test. test. The test results are the first set of test values in Table 2.

Table 2 Single wheel braking force detection test results N

project	First group		Second Group	
	Left wheel braking force	Right wheel braking force	Left wheel braking force	Right wheel braking force
front axle	3 178. 4	3 292. 6	3 237. 4	3 393. 6
rear axle	3 076. 4	3 049	3 170. 6	3 222. 2

(3)

GB 7258-2012 has clear requirements for brake pedal force, that is, the brake pedal force of four-wheel vehicles of 3.5t level and below cannot be greater than 500N. Accordingly, the upper limit of brake pedal force is set to 500N. Therefore, the second set of tests was conducted under the condition of 500N brake pedal force, and the measured pipeline pressure was 8.5MPa. The test results of the two groups are shown in Table 2.

Comparing Table 1 and Table 2, it can be seen that in the detection of front axle braking force, the detection results of the single wheel braking force detection method are relatively close to the results of the roller test bench, and the measurement results are credible. Since the single-wheel braking force detection method has nothing to do with axle load, the detection results are similar for the front and rear axles.

3 CONTROLLABLE TORQUE BRAKING FORCE LOADING METHOD

In view of the limitations of the current traditional single-wheel braking force detection method, a new method is designed in this article to achieve automation and dynamic measurement. After the testing equipment and the vehicle being inspected are installed and debugged, the testing system continuously provides torque to the brake disc of the vehicle being inspected for continuous loading. In this method, the braking force of the brake is approximately equal to the friction torque generated on the ground when the car is braking. When the brake disc rotates, the system can still load the brake disc, so that other indicators that can evaluate the braking performance, such as thermal decay resistance and ABS performance, can be obtained through dynamic measurement. Its applicability is more than traditional methods. has seen an increase.

3.1 Torque Loading Model Based on Electromagnetic Slip Clutch

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The key to the detection method in this article is to output a series of controllable torque values. Since the asynchronous motor cannot output a given value of torque, components for freely adjusting the torque must be added to the motor. In this article, an electromagnetic slip clutch is selected to complete the task of adjusting torque.

3.1.1 Model establishment

A torque loading model based on the electromagnetic slip clutch is established in Solidworks. The model is mainly composed of an asynchronous motor, an electromagnetic slip clutch, a torque sensor, a speed sensor, a reducer, a force-applying chuck, a support device and various connection accessories. . The system is connected to the vehicle brake disc and the asynchronous motor is started. The power is transmitted from the asynchronous motor to the vehicle brake disc through the electromagnetic slip clutch, torque sensor, reducer and force-applying chuck. Continuously load torque until the brake disc starts to rotate, and the speed sensor outputs a signal to end the loading. At this time, the torque value output by the system is the maximum static friction torque between the brake disc and the brake shoe, which is the braking torque on the ground. Then divided by the wheel radius, the ground braking force of the vehicle to be inspected is obtained.

It can be seen from the figure that the system needs to continuously load variable torque during the working process, so the relationship between the output torque and the input value must be found. In this article, based on the working principles and characteristics of each component, the influencing factors of the output torque are obtained through theoretical analysis.

3.1.2 Theoretical derivation

It can be known from the principle of the electromagnetic slip clutch that if the torque output by the electromagnetic slip clutch is required to be T, then: nd is the speed of the active part of the clutch; n1 is the speed of the driven part of the clutch, measured by the speed sensor; K is the clutch structure parameter.

The mechanical characteristics of asynchronous motors determine that when the load of the motor changes, its speed will inevitably change. The excitation current of the electromagnetic slip clutch changes the output torque, that is, the load of the motor is not constant, and the speed of the active rotor of the clutch is not constant. Therefore, the relationship between output torque and excitation current cannot be directly established through equation (1). To further solve the relationship between the two, the mechanical characteristics of the asynchronous motor must be considered to find the relationship between output torque and speed.

K1 is a constant related to the motor structural parameters and power supply frequency; U is the power supply phase voltage; S is the slip; R2 is the resistance of each phase winding of the rotor; X20 is the resistance of each phase winding of the rotor when the motor is stationary (nd = 0) Resistance.

Figure 1 shows the mechanical characteristics diagram of an asynchronous motor. It can be seen from Figure 1 that there is a maximum torque Tm in the asynchronous motor, which is the critical operating point of the motor. If the motor load exceeds this value, the motor will not work.

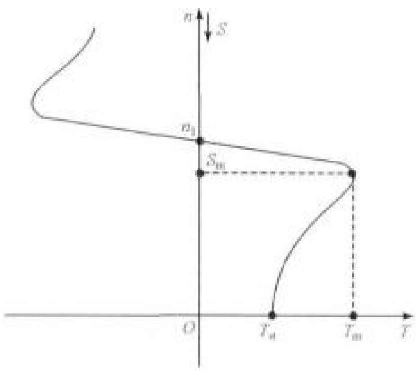

Figure 1 Mechanical characteristics of asynchronous motor

To find the maximum value of torque, equation (2) can be derived. When dT/dS = 0, the slip obtained is the critical slip Sm:

$$\text{Sm} = \frac{R_2}{X_{20}} \quad (1)$$

Asynchronous motors often encounter short-term impact loads during operation. If the impact load torque is less than the maximum torque, the motor can still run, and short-term overloading of the motor will not cause severe heating [28]. The ratio λm of the maximum torque of the inherent mechanical characteristics to the rated torque is usually called the overload capacity coefficient of the motor.

$$\lambda\text{m} = \frac{T_m}{T_N} \quad (2)$$

3.2 Braking Force Loading Control Based on PID Control Algorithm

It can be seen from the previous theoretical derivation process that the output torque of the electromagnetic slip clutch is affected by the rotor speed difference and the clutch magnetic induction intensity. The magnetic induction intensity of the electromagnetic slip clutch is directly proportional to the excitation current. The speed of the asynchronous motor rotor also changes with the input current. Therefore, if you want to output a specified torque, you must use a controller to adjust the excitation current in real time. The adjustment is based on the output torque, rotor speed and excitation obtained above. relationship between currents.

4 SIMULATION OF TORQUE LOADING CONTROL PROCESS

As can be seen from the above, in order to output a certain torque, a controller must be used to control the excitation current in real time. The control is based on the relationship between the three variables. That is, the relationship between the output torque of the electromagnetic slip clutch, the rotor speed and the excitation current, and the relationship between the output torque and speed derived from the mechanical characteristic curve of the motor selected in this article, plus the obtained output torque relationship with the excitation current.

During the simulation process, whether it is static loading simulation or dynamic continuous loading simulation, before the loading is terminated, the output rotor of the clutch is stationary, that is, n1 = 0, which is used as the initial state of the simulation.

4.1 Static Loading Test

During simulation, the structural parameter K of the electromagnetic slip clutch is 2500, the initial motor speed is 1440r/min, and the given output torque is 50N·m. First, a small initial current is passed through the excitation winding of the clutch, and the initial torque output is generated and then fed back. The PID control part controls the output current according to the formula, and takes the larger value than the initial current. The motor speed takes an initial value of 1440r/min, and after a period of time, the torque is output according to equation (1).

During simulation, the three parameters of PID control must be continuously selected and debugged in Simulink .

4.2 Dynamic Loading Test

After completing the simulation of the specified output torque, the actual detection process, that is, the dynamic continuous loading process, must be simulated. The simulation conditions and parameters are the same as the static simulation. The end torque is set, that is, the output rotation of the slip clutch when the maximum static friction torque is reached. moment.

In this article, the Jetta sedan is selected as the simulation object, and the relevant structural parameters are shown in Table 3.

Table 3 Braking related parameters of Jetta sedan

parameter	Maintenance quality Amount/kg	Full mass Amount/kg	Maximum mass of front axle/kg	Maximum mass of rear axle/kg	Tires are the most large size
numerical value	1 120	1 450	700	440	175/70R14

The braking force is calculated based on the braking force being 80% of the axle weight. Here we take the single wheel braking force of the front axle. After calculation, the braking force is 2 744N. The turning radius of the 175/70 R14 radial tire is 279mm, so the braking torque of the front axle single wheel is 2744 × 0. 279 = 765. 576N·m. Then, the end torque set in this simulation should be 766N·m.

During the continuous loading process, there are two important parameters: loading torque increment and loading interval time. These two parameters play a decisive role in the accuracy and stability of the system.

The loading torque increment determines the accuracy of the system. In order to improve the accuracy, the loading torque increment must be reduced. Although the smaller the loading torque increment, the higher the accuracy, but if the loading torque increment is too small, it will result in too many loading times required to output a certain torque value. Therefore, taking the accuracy of the roller test bench as the standard, when the vehicle model is Jetta, the system loading torque increment is 0. 28N·m. It can be seen that under the loading torque increment of 0. 28N·m, the output of 766N·m requires 2,735 loading times.

The loading interval determines the stability of the system. The shorter the loading interval, the faster the time to reach the maximum static friction torque. But the loading interval time is not as short as possible, because the PID control torque output has a response time. In this article, the controller controls and adjusts the excitation current according to the difference output signal, thereby adjusting the clutch output torque. This series of processes requires a certain response time. If the loading interval is too short, the PID control output has not yet reached the load. Continue loading if the torque value is reached. In this case, even if the torque loaded by the loading system has reached the maximum static friction torque of the brake disc, the PID control torque will not output a corresponding value, which will

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eventually lead to the system being unable to detect the braking torque of the brake disc. Therefore it is very important to calculate a reasonable time interval. Regarding the value of the time interval, first determine a specific time interval, that is, the time when the output value first appears during the PID control process. Under the previously set PID parameters, the value is 0. 031 7s. When the end torque is 766N·m, the loading torque increment is 0.28N·m, and the loading interval time is 0.025, 0.03, 0.045 and 0.06s respectively, the simulation line is For a straight line that passes through the origin of the coordinate axis and whose slope is the ratio of the loading termination value to the loading time, the acceptable ratio of the stability standard deviation to the total range is less than 5%. The results are shown in Table 4.

Table 4 Time deviation results of different loading intervals

Loading interval/s	Variance/ (N·m) 2	Standard deviation/(N·m)
0.025	3 002. 50	54. 795
0.030	1 114. 58	33. 385
0.045	319. 44	17.873
0.060	6.58	2. 565

The maximum allowable deviation is calculated from the final torque of 766N·m to 38.3N·m. It can be seen from the above results that under the loading accuracy of 0.28N·m and the interval time of 0.03s, the loading situation is different from the ideal The deviation of the conditions is within the allowable range, and the deviation of the 0. 025s time interval is greater than 5%, indicating that the minimum interval allowed by this system is around 0. 03s. The testing accuracy and system stability of the loading method at this time interval will achieve satisfactory results.

It can be seen from the torque loading test in this section that according to the method in this article, choosing a reasonable loading amplitude and loading time interval can make the output torque controllable and the deviation within the acceptable range.

5 CONCLUSION

In this paper, in response to the demand for braking performance detection of vehicles that have lost their driving ability, the torque loading problem is studied based on the single-wheel braking force detection method, and a torque loading model based on electromagnetic slip clutch is proposed, combined with the PID control algorithm. Controllable torque loading method. In order to verify the feasibility in principle of the single-wheel braking force detection method, before designing the test plan, a comparative test of benchtop testing and single-wheel braking force detection was first conducted, and the characteristics and precautions of the detection method were analyzed. In order to achieve controllable loading torque, a torque loading model based on electromagnetic slip clutch was established. Based on the principle of electromagnetic slip clutch and the mechanical characteristics of asynchronous motor, the relationship between its output torque, excitation current and rotor speed was found. The relationship between the two, combined with PID control theory, achieves the purpose of torque controllable. Finally, the control model was established by analyzing the system, and torque loading simulation was carried out in MATLAB/Simulink. The dynamic response time and other parameters of the controlled object were determined and optimized, and a loading method that met the requirements was obtained. The analysis of the torque error showed that this method can achieve deviations in the deviation. Within the acceptable range, the controllable torque loading model proposed in this article has certain feasibility.

The torque loading model based on the electromagnetic slip clutch established in this article can not only measure the braking force of the accident vehicle, but also obtain other indicators for evaluating the vehicle's braking performance. Since the model proposed in this article can achieve controllable loading torque, it can continuously apply torque to the wheels to make the wheels reach a certain rotational speed, simulating the vehicle speed when the car's ABS system takes effect, and then the vehicle's ABS can be measured by braking the vehicle. performance. When the brake disc rotates and the torque is continued to be applied, the thermal degradation resistance of the automobile brake disc can be measured. Due to limited space, the controllable torque loading model proposed in this article is only used as a basic research for the detection of braking performance of accident vehicles. As for the acquisition of other indicators of braking performance, it will be included in the next research plan.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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