Durability Test Bench Design for Electric Lock of Sliding Door

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Abstract: With the rapid development of automobile industry, electric door locks have widely used in various vehicle doors, especially for sliding doors. Among all performances, durability performance for electric locks is virtual for safety, so miniaturized durability test bench has been designed in the research according to the national standard of electric lock. Firstly, four-bar linkage mechanism has been adopted as the main actuator for the motion track achievement, the real motion track of sliding door can be guaranteed through the verification of ADAMS simulation. Secondly, the compression test has been carried out to calculate the reaction force of door sealing strips, thus the resistance device of test bench for simulating reliable locking process of electric lock has been designed. The miniaturized durability test bench can replace the existing durability test method which only performed by the whole vehicle testing, thus providing a low-cost and reliable test device for relevant manufacturers.

1. Introduction

With the rapid development of driverless cars, sliding doors are inevitably used widely because the stable motion track and its relatively simple transmission path [1]. Therefore, the electric door lock matched with the electric sliding door has become an indispensable part. The durability of the door lock is related to the safety and comfort of the whole vehicle, thus, durability evaluation is the key detection technology in the quality inspection system of automobile electric door lock. According to the standard requirements of Performance Requirements and Experimental Methods for Automotive Door Lock and Door Holders (GB 15086-2013) and Automotive Electric Door Lock Device (QC/T 627-2013), electric door locks must perform durability tests both at ambient and high/low temperatures. Most electric locks are mounted on the vehicle in the existing durability tests, using ABB arm or similar drive device for testing [2-3]. Also due to the demands for the temperature laboratory (high temperature (70°C) and low temperature (-40°C) durability test) of the whole vehicle testing, the cost of the test is higher.

Based on the design concept of miniaturizing a durability test bench, simulating the true operating process of the sliding door, shortening the testing period through automated control and optimizing detection method, a miniaturized durability test bench has been designed. With the aid of miniaturized durability test bench, the cyclic load of electric door lock can be simulated accurately, the durability of electric door lock can be easily tested at ambient and high/low temperatures, the accuracy and reliability of durability test results are guaranteed, and the cost of experimental equipment are significantly reduced.

2. Experiments and design technical scheme

The working principle of electric door lock of sliding door is different from ordinary door lock. When the sliding door enters the closed position, the lock plate contacts with the lock body, thus the relevant
sensors will send out a closing signal, the electric door lock will automatically "pull" the door lock to the locking position; Otherwise the electric door lock receives the opening signal, the lock plate will release the lock, the lock “spring opening” with the help of the pressing force of the sealing strips at the same time, so the sliding door can be opened along the track of the lower guideway by the sliding force of the door’s driving motor.

The simulation of the real motion track and the mechanical characteristics of the sliding door electric lock in the opening and closing stage are two urgent technical problems to be solved for the durability test bench design.

(1) Simulation of motion tracks: ADAMS is used to simulate the motion track of the corresponding position during the opening and closing stage of the sliding door, and the structure of the test bench is designed to ensure the test bench can simulate the motion process of the electric door lock;

(2) Calculation of resistance force provided by sealing strips: The electric lock endures the sealing reaction of the sealing strips in the working process. The SANS universal testing machine is used to carry out the pressure test on the sealing strips, and the corresponding compression load deflection (CLD) of the sealing strip has been measured, the resistance force provided by sealing strips can be calculated, the resistance device of test bench can be designed to simulate the mechanical condition when the electric door working.

Through the combination of mechanical parameters determined by experiments and CAE simulation analysis, the test bench design can match with the dynamic characteristics of the working process of the electric lock.

3. Structural design of test bench

3.1 Track fitting of test bench
The common sliding door has the upper, middle and lower guideways fixed on the body, the three guideways are not coplanar with each other and have different spatial positions (as shown in Fig. 1), the three guideways are all composed of two straight lines and one arc. In order to keep lock force in the whole vehicle, the electric door lock should be fixed near the middle guideway. When the electric door lock is pulled in, there is a relatively rapid arc movement, so the arc section of the middle guideway must be simulated as the traveling track of the test bench.

![Fig. 1 Framework diagram of sliding door](image)

Two four-bar linkage mechanisms have been adopted for track simulation, the motion of the linkage mechanism of the test bench can realize circular reciprocating motion, which has high fitting degree
with the locking and unlocking process of the electric lock in the real vehicle, thus can ensure the consistency between the motion track of the test bench and the real motion track of the sliding door.

3.2 Resistance system Design of test bench
In the vehicle body system, the actual sliding door needs to be soundproof and waterproof providing by the sealing strips [5], so the working process of the door lock is accompanied by the reaction force of the sealing strips. The sealing reaction force is determined by compression test. The 4800 mm long sealing strips (among which, there are 4400 mm hollow sealing strip and 400 mm sponge core sealing strip) for the whole vehicle door is divided into 100 mm segments. The CLD curve with the unit length of 100 mm is measured by the pressure testing machine. The sealing reaction force 435N has been calculated.

Through measuring and calculating, the working distance of the electric door lock is 19 mm. Four cylindrical springs are selected to equivalent the force provided by the sealing strips, the 19mm compression displacement of the spring can be preloaded for achieving actual working distance.

Taking 435N as the resistance force, and according to the calculation Eq.1 of spring force, selecting the material of cylindrical spring is 65Mn, its elastic modulus is 206 GPa.

\[
F = kx
\]

\[
k = \frac{Gd^4}{8nD^3}
\]

Where: \(x\) - spring displacement [mm]; \(k\) - spring coefficient [N/mm], \(G\) - elastic modulus [MPa]; \(d\) - wire diameter [mm]; \(n\) - effective number of turns; \(D\) - center diameter [mm];

Through Eq. 2, the spring parameters are determined as follows: \(L=70\text{mm}, D=28\text{mm}, d=2.5\text{mm}, n=10\) (effective turns is 8) , \(k=5.728\text{N/mm}\). The average spring force is 108.8N providing by each spring.

3.3 The overall design scheme of test bench

![Framework diagram of test bench](image)

In order to ensuring be used in small or medium temperature box, the test bench size is designed as 650mm × 500mm × 680mm. Two groups of four-bar mechanisms are used to fit the moving track of the sliding door, four cylindrical springs are adopted to simulate the resistance force provided by door sealing strips, a T-shaped bench frame (galvanized square steel pipe) is set to simulate the supporting
effect of the door frame (As shown in Fig. 2). A flexible cylinder controlled by PLC program is selected as the power source, the cylinder push rod is connected to the cylinder shaft for driving the T-shaped bench frame to move back and forth. Through the movement speed controlled by PLC program, the fast durability test can realize.

4. Simulation verification of test bench working process

![Fig. 3 Schematic diagram of simulating track of test bench](image)

The 3D model in Fig. 2 is imported into ADAMS for simulating motion tracks and verifying whether structural interference occurs. The three tracks are the centroid tracks of the two Y-shaped interfaces and the track of the door lock as in Fig. 3. The cycle action of the durability test bench can be actuated smoothly from 0° to 90°.

![Fig.4 Working angle of electric door lock](image)

The maximum opening angle of test bench can reach 90°, but according to the structural dimension of the door lock, the traveling between the two angles (from 10° to 30°) is the actual working travel of the electric door lock. As shown in Fig. 4, the connecting rod angle can be used to represent the corresponding position of test bench. When the connecting rod angle reaches 30°, it corresponds to the contact position of the primary lock; when the connecting rod angle is 10°, it corresponds to the secondary locking position. So, the traveling angle of the connecting rod from 0° to 90° can be judged unsuitable. In order to further speeding up the test, the motion travel angle of the connecting rod finally has been optimized from 0° to 45°. A cycle of test bench motion from “open” to “close” can be described as: triggering door opening signal → unlocking the electric lock → cylinder pushing connecting rod to 45° → ending the opening → triggering door closing signal → cylinder pulling connecting rod to 30° → operating the electric lock → locking the primary lock → electric door lock working → locking the secondary lock → ending the closing. With speed control of PLC programming, the rapid durability test can realize.

5. Conclusion

A small test bench has been designed for the durability test of electric lock of sliding door. Through the solutions for the key problems of the test bench design and the simulation analysis results of CAE, the
designed test bench can meet the test requirements of the durability detection for the electric door lock, and can better evaluate the durability of the electric door lock under the high/low temperature environment through miniaturization design. The durability test cycle can be effectively shortened and the reliable test data can be obtained by further optimization design and automatic control design of test bench.

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