Design of Vehicle Safety Belt Motion Detection Platform Based on Digital PID Regulation

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***Abstract*—Parker linear motor, mounting plate, acceleration sensor and magnetic displacement sensor are designed in the platform.F28M35H52C1 processor, 410-4A-LC-WD1-S coil and 41026S linear motor were selected and the acceleration of 0.5g was tested. The experiment shows that the digital PID controller can reduce the steady-state error of the system and has good robustness. This platform can safely and efficiently complete the safety belt vehicle acceleration experiment, and has certain social and economic benefits.**

Keywords—safety belt; digital PID; motion platform

I. INTRODUCTION

By the end of 2017, China's civil automobile population has reached 217.43 million [1].According to statistics from the China association of automobile manufacturers, the production and sales of vehicles in China have been the highest in the world for nine consecutive years [2], However, the per capita car ownership is far lower than that of developed countries, so China's car ownership will continue to grow for a period of time. Every year, tens of thousands of people die in traffic accidents, so car safety has become a widely concerned problem. [3] According to the NHTSA statistics, With the increase of the utilization rate of seat belts, the death rate of traffic accidents decreases, so the performance test of seat belts is particularly important. [4] Safety belt performance test includes: corrosion test, wear and microslip test, double buckle test, retractor durability test and retractor emergency lock test. Dust test is Especially important. [5]The emergency lock test of retractor includes automobile acceleration test and belt acceleration test. According to GB14166-2013, the locking condition is acceleration≥0.45g or dip angle>27°. Within the range of 50mm of the drawn length of the ribbon, it can't be locked.

II. DIGITAL PID CONTROL OF LINEAR MOTOR

PID control is the longest history, the most widely used, the strongest vitality of the basic control mode. [6]

FIGURE I. PID CONTROL STRUCTURE DIAGRAM

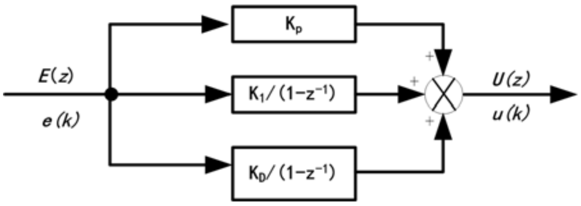


FIGURE II. STRUCTURE DIAGRAM OF DIGITAL PID CONTROLLER [7]

$$e(t) = r(t) - c(t) \tag{1}$$

The proportion, integral and differential of deviation $e(t)$ are combined linearly to form the control quantity, Control the controlled object, so called PID controller. The control law is as follows:

$$u(t) = K_P[e(t) + \frac{1}{T_I}\int_0^t e(t)dt + \frac{T_D de(t)}{dt}] \tag{2}$$

written as a transfer function:

$$G(s) = \frac{U(s)}{E(s)} = \mathrm{Kp}（1+\frac{1}{\mathrm{T_I s}}+\mathrm{T_D s}） \tag{3}$$

K_p: ratio; T_I :Integral time constant; T_D :Differential time constant.

Since computer control is a sampling control, it can only calculate the control quantity based on the deviation value at the sampling time. Therefore, the integral and differential terms in equation (2) need to be discretized. Now, a series of sampling time points kT represent continuous time t, and the integral is replaced by the sum, and the differential is replaced by the increment, then the following approximate transformation can be made:

$$\left\{\begin{array}{l} t \approx kT(k=0,1,2,) \\ \int_0^t e(t)dt \approx T\sum_{j=0}^{k} e(iT) = T\sum_{j=0}^{k} e(j) \\ \frac{de(t)}{dt} \approx \frac{e(kt)-e[(k-1)T]}{T} = \frac{e(k)-e(k-1)}{T} \end{array}\right\} \tag{4}$$

T is omitted for writing convenience. Substitute equation (4) into equation (2), and the discrete PID expression is

$$u(k) = K_P\left\{e(k) + \frac{T}{T_I}\sum_{j=0}^{k} e(j) + \frac{TD}{T}\left[e(k) - e(k-1)\right]\right\} \tag{5}$$

Or:

$$u(k) = K_P e(k) + K_I\sum_{j=0}^{k} e(j) + K_D\left[e(k) - e(k-1)\right] \tag{6}$$

Among them: k :The sampling sequence number, k=0,1,2…; $u(k)$: The computer output value at the time of the first sampling; $e(k)$:The deviation of the input at the time of the first sampling; $e(k-1)$: The $k-1$ deviation of the input at the time of the first sampling; K_I :Integral coefficient, $K_I = K_P T / T_I$; K_D : Differential coefficient, $K_D = K_P T_D / T$.

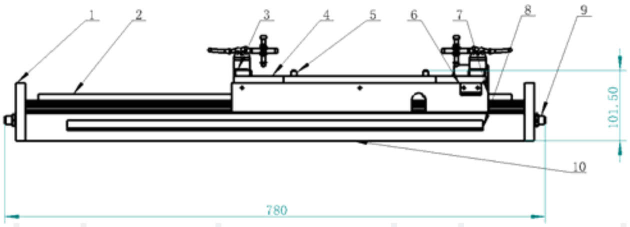
III. SELECTION OF LINEAR MOTOR AND DESIGN OF MOVING PLATFORM

The principle of linear motor is similar to that of horizontal rotary motor。[7] Drivers and passengers may encounter sudden changes in acceleration caused by sudden braking, salient start and collision in actual vehicle driving. In order to simulate such sudden changes in acceleration, linear motor is used to drive the experimental platform. Since the moving platform and the linear motor do variable speed linear motion together, Newton's second law is as follows:

$$F - f - f_1 = ma \tag{7}$$

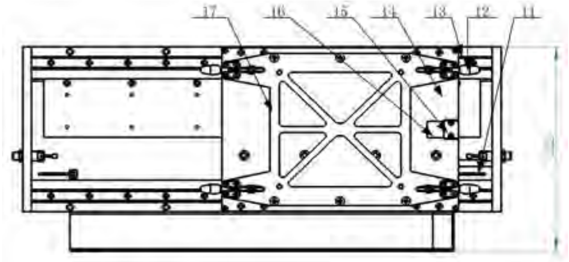
F -Linear motor endurance; f -Sliding block, guide rail, friction of air; m -Total mass installed in linear motor parts(20kg); f_1 -Average resistance to belt stretch(10N); a -Maximum acceleration of linear motor(2g).

The maximum duration of the linear motor is 410N by substituting the value into formula (7). So choose PARKER410-4, sustaining force is 448.9N, Peak force is 2006.3N.The coil model is: 410-4A-LC-WD1-S.It means 410 series of coils, the size of the coil is 4 levels, the top of the inch system is installed, the cooling method is LC, the winding is connected in series. The magnetic track model is: 41026S.



1. plate 2. Linear motor 3. Quick clamp base 4. floor 5. Steering column 6. Drag chain mounting plate 7. The side guard plate 8. Drag chain frame 9. Hydraulic buffer 10. Motor underplatform

FIGURE III. MAIN VIEW OF VEHICLE SENSE DETECTION PLATFORM



11. Photoelectric switch 12. Quick clamp 13. Guide rail sliding block 14. On the rung 15. Acceleration sensor is installed quickly 16. Acceleration sensor 17.Mounting plate

FIGURE IV. TOP VIEW OF VEHICLE SENSE DETECTION PLATFORM

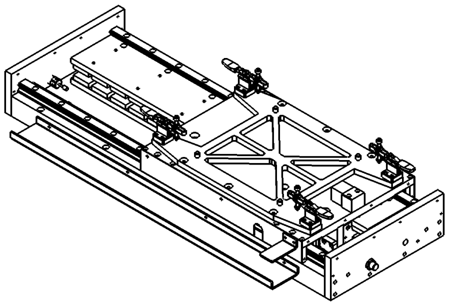


FIGURE V. AXLE MAPPING OF VEHICLE SENSE DETECTION PLATFORM

As shown in figure 3 and 4, the car seat belt retractor is fixed on the 17 mounting plate by retractor clamp and bolt, and then strengthened by 12 quick clamps. The linear motor starts to move according to the instructions of the industrial PC, and the rewinder also starts to move along the direction of the guide rail slider. The acceleration of the linear motor changes suddenly and that of the rewinder changes abruptly. The change of acceleration of linear motor simulates the sudden change of acceleration caused by starting, braking and accident in real vehicle. The platform can meet the requirements of 0.3g, 0.45g, 0.5g, 0.6g, 0.6g, 0.7g, 0.8g, 1.0g, 1.2g and 8 gears of the vehicle sense test. At the same time, the test acceleration value can be set arbitrarily as required. The hydraulic buffer can act as a buffer for linear motor and platform.

IV. MEASUREMENT AND CONTROL PRINCIPLE AND PID PARAMETER ADJUSTMENT

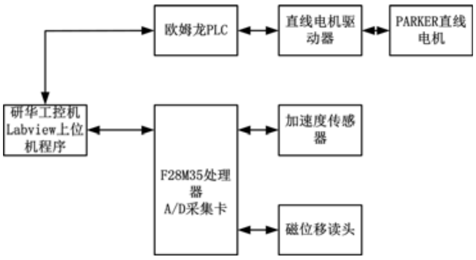


FIGURE VI. FIG.6 MEASUREMENT AND CONTROL SCHEMATIC DIAGRAM

FIG. 6 shows the schematic diagram of vehicle sensing and control. The industrial PC gives instructions and the linear motor starts to move.

FIGURE VII. PID PARAMETER ADJUSTMENT DIAGRAM

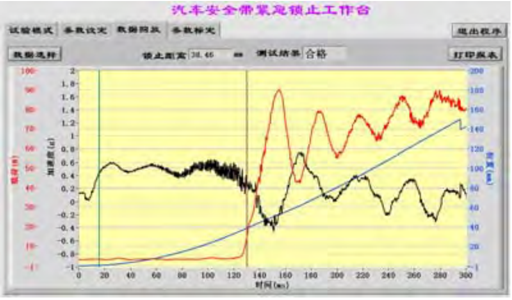


FIGURE VIII. ADJUST THE OSCILLATION

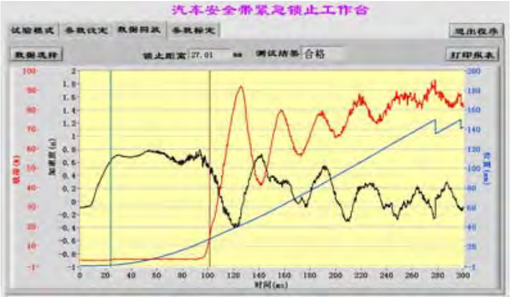
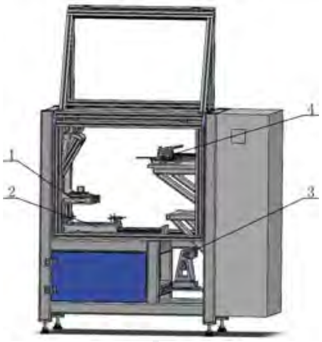


FIGURE IX. AFTER THE ADJUSTMENT

As shown in figure 7, the parameters mainly include K_p , K_i , K_d , and. If the overshoot is too large, K_p will shrink. If the acceleration cannot reach the given value, increase and increase K_p and K_i appropriately. If the acceleration curve vibrates too much, it will increase K_d appropriately. As shown in FIG. 8, the acceleration curve shows an oscillation, and then reduce the value of K_p and K_i .

The oscillations of the acceleration curve as shown in the figure have weakened after the reduced K_p values and the reduced K_i values. If the acceleration is given as 0.8g, but it does not reach 0.8g in the process of motion, it indicates that it is too small at this time and the value of sum needs to be appropriately increased. If the acceleration is given as 0.8g, but it does not reach 0.8g in the process of motion, it indicates that K_p is too small at this time and the value of K_p and K_i needs to be appropriately increased. [9]

V. EXPERIMENT AND CONCLUSION



1. Electric turntable 2. Linear motion platform
3. Rewinder clamp 4. Ribbon jig

FIGURE X. TEST BENCH

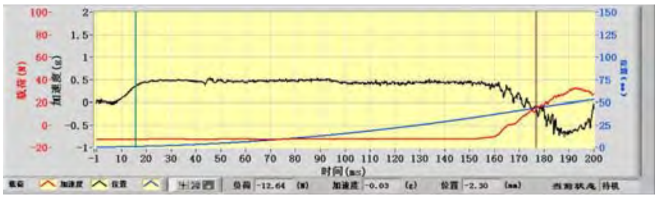


FIGURE XI. 0.5G ACCELERATION TEST

As shown in figure 11, the rewinder is fixed on the rewinder clamp, and then taken down and fixed on the electric turntable together. Finally, the rewinder, rewinder clamp and the electric turntable are fixed on the linear motion platform together. The free end of the webbing is fixed on the webbing clamp by the guide wheel.

As shown in figure 11, 0.5g acceleration test is completed， K_p is 0.0024, K_D is 0.00001.In order to restrain overshoot, the differential coefficient is increased. Increasing the integral coefficient allows the integrator to correct for steady-state errors. The step sound is completed within 30ms, and the acceleration reaches 0.5g at 20ms.The experimental results show that the digital PID regulation is robust, and the steady-state error of the system is well dealt with. The design of the test platform is reasonable, and it can safely and efficiently complete the vehicle sensible energy detection test.

Based on the locking requirements of GB14166-2013, this study designed a motion platform that can complete the vehicle safety belt feeling test. The platform USES parker410 series linear motor as the power source, and designed the upper transverse plate and the mounting plate to facilitate the installation of electric turntable. Magnetic displacement reading head and acceleration sensor are installed on the moving platform to measure the acceleration and displacement of the moving platform in real time. The hydraulic buffer can act as a buffer.

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