

Identification of Vehicle Mass and Braking Force Distribution Algorithm for Electronic Braking System of Heavy-Duty Vehicle

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ABSTRACT

The active safety and stability of tractor and trailer (heavy-duty vehicle) have becoming big concern among the road transportation industry. The purpose of this paper is to specify the research differential braking force distribution control algorithm to improve braking safety of heavy-duty vehicle. The ideal braking force of each wheel axle should be proportional to vertical load of vehicle that is also related to the road adhesion coefficient, the load and the braking intensity. Reasonable braking force distribution can enhance its braking stability and shorten the braking distance by making full use of the road adhesion condition of each wheel. A braking force distribution algorithm is proposed, in which the objective braking force change with the axle load of vehicle.

A controller is built with Matlab® software and TruckSim® software on vehicles respectively equipped with electric braking system (EBS) on typical condition and the simulation results show that the control strategy can shorten the braking distance and improve vehicle safety.

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INTRODUCTION

At present, the active safety and stability of tractor and trailer (combination vehicle) have becoming big concern among the road transportation industry. In recent years, Electronic Braking System (EBS) of combination vehicle gets great development aboard and is gradually equipped to the bus and heavy duty vehicle. EBS enhances vehicle safety and improves the braking performance and the integrating brake system allows the reduction of operational costs.

In 1993 Scania and Bosch introduced the first world-wide small series production EBS Generation 1 to the European market. In 1996 this was followed by the 2nd Generation EBS2 based on new technology and with enhanced functions. Since then EBS has become a state of the art feature on the European heavy truck market. By the year 2000 almost all European manufacturers will offer EBS as standard or at least as an option. The following is a short summary of the present status and an outlook to future developments based on EBS; while in china, the research in this field is at very beginning. So, to study EBS system has great significance for our country and also has board application prospect [1].

At present, the active safety and stability of combination vehicle have becoming big concern among the road transportation industry. The purpose of this paper is to specify

the research braking control algorithm to improve active safety of combination vehicle. The braking systems of tractor and trailer are both under the control of the driver in combination vehicle. A braking force distribution algorithm is proposed for combination vehicle in this paper and the controller is built with Matlab/Simulink software. A co-simulation with Matlab/Simulink and TruckSim software on vehicles respectively equipped with conventional braking system, ABS and EBS running on both high and low adhesion roads is performed. The results show that the algorithm can shorten the braking distance of combination vehicle, enhancing its braking stability.

VEHICLE LOAD ESTIMATION

In order to achieve an ideal braking force distribution among axles, while the vehicle deceleration is just depend on the driver's intention, not affected by the variation of semi-trailer mass, the paper proposes a model based vehicle mass identification and braking force distribution strategy. The strategy identifies the driver's braking intention via braking pedal, estimates semi-trailer's mass during the building process of braking pressure in brake chamber, distributes braking force among axles by using the estimated mass.

$$T_i = T_{iq} i_g i_0 \eta_T = F_i r$$

Where T_{iq} is torque of engine, T_t is driving torque, i_g is the gear ratio of transmission box, i_o is the gear ratio of vehicle main reducer, η_T is mechanical efficiency of transmission box, r is wheel radius.

$$F_t = F_f + F_w + F_i + F_j = Gf + \frac{C_D A}{21.15} u_a^2 + Gi + m \frac{du}{dt} \quad (2)$$

Where F_t is rolling resistance, F_f is acceleration resistance, F_w is aerodynamics resistance, F_i is road slope resistance, G is vehicle load, f is road adhesion coefficient, u_a is vehicle speed.

The formula (2) can be reduced as

$$F_t = mgf + \delta m \frac{du}{dt} = m(gf + \delta \frac{du}{dt}) \quad (3)$$

Combined (1) and (2), the vehicle load can be described as

$$m = \frac{T_{iq} i_g i_o \eta_T}{r(gf + \delta \frac{du}{dt})} \quad (3)$$

The T_{iq} information can get by can bus that communication protocol is IEEE 1939. Thus, the vehicle load can be calculated and the estimated results is figure 1.

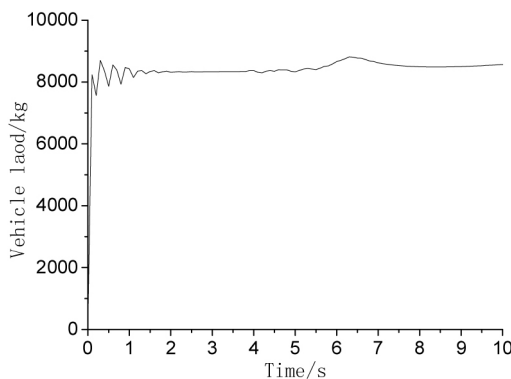


Figure 1. Vehicle load estimation result.

The initial phase of the speed is lower and more volatile, resulting in a certain oscillation estimates. The intermediate phase shift due to continuous estimation results appear to make some errors, and the result estimates the overall stability of the mean value. The estimated value of the vehicle load is 8353.9kg, the actual load is 8690kg, the error is only 3.9%.

CONTROL ALGORITHM

There are three stability loss situations which are rollover, trail swing and jack knife, have often happened by bus, tractor and trailer. By reviewing the previous research, the stability of tractor and trailer has been put into categories that yaw stability and roll stability control algorithms had been studied [2, 3, 4,

5]. In fact, the ideal braking force of each wheel should be proportional to the its vertical load, which is also related to the road adhesion coefficient, the load and the braking intensity. Reasonable braking force distribution can enhance its braking stability and shorten the braking distance by making full use of the road adhesion condition of each wheel. A braking force distribution algorithm is proposed for combination vehicle in this paper, in which the objective slip rates of tractor's rear wheels and semitrailer's wheels change with the slip rate of tractor's front wheel. Increasing the brake pedal displacement, the braking force of each wheel is also growing larger. Because of the vehicle vertical load of each wheel are different, the each wheel slip rates also are different. When the slip rate of the wheel reached 8%, the control algorithm of brake force distribution had began to take effect. A controller is built with Matlab/Simulink software. The EBS control algorithm can be described as figure 2.

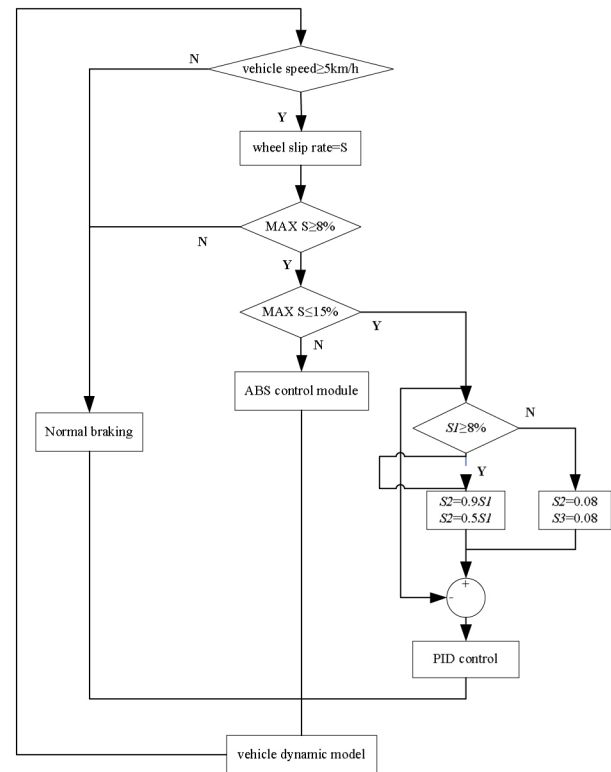


Figure 2. Flow chart of braking force distribution control strategy.

Where S_1 is slip rate of front axle by tractor' wheel; S_2 is lateral axle by tractor' wheel; S_3 is slip rate of trailer' wheel.

SIMULATION RESULTS

The EBS controller was built by Matlab®/Simulink. The controller included some modules of velocity, slip rate, brake pedal, braking force distribution, ABS controller and EBS controller. The input signals was wheel speed, pressure sensor signals and output signals was braking force of each wheel.