Estimation of Vehicle Sideslip Angle for Four–wheel Steering Passenger Cars

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Abstract

This paper deals with an estimation method for sideslip angle by using an unknown input observation technique in 4WS passenger car systems. Firstly, a 4WS vehicle model with 3DOF is derived under the constant velocity and same tyre's properties. The induced model is transformed into the linear state space model with considering the external disturbance. Secondly, an unknown input observer is introduced and its property which estimating the states of system without any disturbance information is shown. Lastly, the estimated sideslip angle of the 4WS system is verified through numerical simulation.

1. Introduction

The research and development of vehicle control systems for highway automation have been focused over recent decades [1]-[99]. Among these control fields, the vehicle steering control is most basic control for improving ride comfort and manoeuvrability [1]-[2].

In vehicle steering control fields, the simplest model which leads to a fundamental understanding of vehicle handling has two degrees of freedom(2DOF): the lateral and yaw velocities as state variables [3]-[7].

The vehicle systems use the vehicle body sideslip angle as the state variable for control purposes. It is possible to measure the sideslip angle directly by using dedicated measuring devices capable of performing optical measurements. At present, however, there are still various issuers that prevent the use of such devices in the control systems used on production vehicles. Thus, it is necessary to estimate the sideslip angle on the basis of information obtained with sensor for detecting such parameters as yaw rate or lateral acceleration.

With 2 DOF vehicle models a few sideslip estimation methods are proposed, and the estimated value is applied to improve the direct yaw moment control. In 1997, an estimation method for lateral vehicle dynamics using non-linear observer is presented [3], and a combined method which is used by model observer and direct integration is proposed where two kind of values of the side force of the wheels are assumed [4]. An estimation method for vehicle position is developed by using the Kalman filter and disturbance observer [5]. An adaptive observer for estimating the vehicle body slip angle is proposed [6]. Also the sliding mode control theory is apply to improve the direct yaw moment control, where the sideslip angle and the road fraction are estimated by using conventional observer [7].

However, it is difficult to express complex vehicle motions accurately with a 2DOF model. It is also well known that one way to enhance the steering performance is a four-wheel steering(4WS) system [8,9]. The 4WS systems for automobiles are being widely studied as a means of improving stability and handling characteristics and have been the subject of various investigations. For estimating the sideslip angle in 4WS vehicle systems, an adaptive yaw rate feedback control system which involves a tyre and road fraction estimator is presented [8]. A robust active rear steering system is presented, where the side slip angle is estimated using conventional observer with frequency filter [9].

In this paper, we propose an estimation method for sideslip angle by using an unknown input observation technique in 4WS passenger cars. Firstly, a 4WS vehicle model with 3DOF is derived under the constant velocity and same tyre's properties. The induced model is transformed into the linear state space model with external input. Secondly, an unknown input observer is introduced and its properties are shown. As one of the properties, the states of system can be estimated without any disturbance information. Lastly, the estimated sideslip angle of 4WS systems is verified through numerical simulations by using proposed estimation method.

Nomenclature

b_f, b_r	time constant of (front, rear) steering actuator; $b_f = C_{sf}/\kappa_{sf}$, $b_r = C_{sr}/\kappa_{sr}$
C_f, C_r	(front, rear) tyre cornering stiffness
C_{sf}, C_{sr}	steering stiffness of (front, rear) actuator
$C_{\phi f}, C_{\phi r}$	(front, rear) roll damping
d_f, d_r	distance from (front, rear) axis to vehicle center of gravity (CG)
F_{xi}, F_{yi}	longitudinal and lateral forces, $i \in \{1,4\}$ ($F_{xi} \approx \tau_{bi}/R_t$)
g	gravitational acceleration
h_s	height of sprung mass CG on roll axis
J_{xx}	roll moment of inertia of the sprung mass above roll axis
J_{xz}	product of inertia of the sprung mass about the roll and yaw axes
J_{zz}	principal yaw moment of inertia
m_s	sprung mass
m_{uf}, m_{ur}	(front, rear) unsprung mass
m_v	total lumped mass $= m_s + m_{uf} + m_{ur}$
p	angular velocity of the roll
r	angular velocity of the yaw