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Research Article

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The analysis and simulation of the corn thresher based on fuzzy control

Du Zhe and Li Xinping*

College of Agricultural Engineering, Henan University of Science and Technology, Luoyang, China

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ABSTRACT

In this paper, a collision style corn thresher is designed, and its performance is tested on the bench. The threshing process is simulated and analyzed by self-developed software based on PID control which is based on discrete element method. The results of the simulation and the experiments are compared and analyzed. The design of the threshing roller is optimized.

Key words: Fuzzy Control; simulation; corn Thresher

INTRODUCTION

China is a traditional agricultural country and corn thresher is widely used. Improving the corn thresher's performance has great significance for ensuring the quality of corn grain and increasing farmers' income. The main work and results of this paper are as follows.(1)A collision style corn thresher is designed. The threshing rollers have three different lengths. A generic intaglio is designed, which can be equipped with several different threshing rollers. Two observation windows are designed, and the windows made of organic glass (Acrylic). When the thresher works, the threshing process can be observed in real time from the axial and radial. A partition gate is designed, which divided the space below the gravure into several grain collection ranges. (2)A bench test of the threshing process is carried out. The test factors include the rotary speeds of threshing roller, the lengths of threshing roller, the corn varieties, the corn ear feeding, and the corn moisture content. The performance indicators include the grain threshed rate, the grain crushed rate, the axial distribution curve, and the threshing time.

Mathematical model of active suspension

In order to study the dynamic characteristics of active suspension in 1/4 active suspension for the study, its kinematic equations are[3][4]:

$$\begin{cases} m_2\ddot{z}_s = -k_2(z_l - z_s) - c(\dot{z}_l - \dot{z}_s) + u \\ m_1\ddot{z}_l = k_2(z_s - z_l) + c(\dot{z}_s - \dot{z}_l) - u + k_1(s - z_l) \end{cases} \quad (1)$$

Where:

x_l , x_s —Vertical displacement of wheels and body in the vertical direction;

m_1 , m_2 —Mass of tire and vehicle body;

k_1 , k_2 —Stiffness of tire and suspension;

c —Damping coefficient of shock absorber;

u —Control force of actuators produce.

Suppose there are state variables $x_1 = z_l , x_2 = z_s , x_3 = \dot{z}_l , x_4 = \dot{z}_s$,

then: $X = (x_1, x_2, x_3, x_4)^{\mathrm{T}}$, Input variables: $U=(u,s)^{\mathrm{T}}$, With body vertical acceleration, tire vertical displacement, tyre dynamic load three indicators for output, namely: $Y=(Y_1,Y_2,Y_3)^{\mathrm{T}}=(\ddot{Z}_s,\dot{Z}_s,Z_s)^{\mathrm{T}}$ .State space representation of active suspension is:

$$\begin{cases}\dot{X}=AX+BU\\ Y=CX+DU\end{cases} \tag{2}$$

Among them:

$$A=\begin{bmatrix}-\frac{c}{m_2} & \frac{c}{m_2} & -\frac{k_2}{m_2} & 0\\ \frac{c}{m_1} & -\frac{c}{m_1} & \frac{k_2}{m_1} & \frac{k_1}{m_1}\\ 1 & -1 & 0 & 0\\ 0 & -1 & 0 & 0\end{bmatrix},\quad B=\begin{bmatrix}\frac{1}{m_2} & 0\\ -\frac{1}{m_1} & 0\\ 0 & 0\\ 0 & 1\end{bmatrix},\quad C=\begin{bmatrix}-\frac{c}{m_2} & \frac{c}{m_2} & -\frac{k_2}{m_2} & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix},\quad D=\begin{bmatrix}\frac{1}{m_2} & 0\\ 0 & 0\\ 0 & 0\end{bmatrix}$$

1 Control Strategy

PID control. PID control is based on proportional - integral - derivative control mode, and its expression is:

$$u(t)=K_{\mathrm{P}}\left(e(t)+\frac{1}{T_{\mathrm{I}}}\int_0^t e(t)dt+\frac{T_{\mathrm{D}}de(t)}{dt}\right) \tag{3}$$

Where:

K_{P} —proportionality coefficient;

T_{D} —Derivative time constant;

T_{I} — Integral time constant;

$e(t)$ —deviation signal;

$u(t)$ —Output signal from the controller.

Conventional PID controller parameters cannot be automatically adjusted when changes in external conditions such as load control accuracy cannot be guaranteed, the scope of application subject to certain restrictions, conditions suitable for simple, less demanding precision applications.

Fuzzy PID Control.

1) Control theory

To improve the control precision, the fuzzy control and PID control are combined to design a fuzzy PID controller. Deviation of e and ec to change the deviation as input variables to ΔK_p, ΔK_i, ΔK_d as output variables, so that both retains the PID controller is simple, easy to implement merit, and PID control parameters can be adjusted online to meet the different conditions required parameters PID control system, to ensure the control precision, fuzzy PID controller structure is shown in Figure 1.

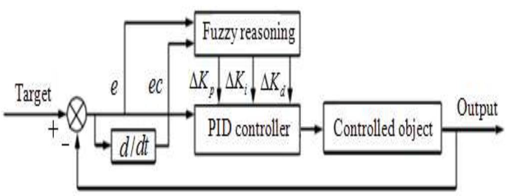

Fig.1 Structure of the fuzzy PID controller

2) Fuzzy control rules

Define the range of input variable is [-3,3], the range of output variables is [-1, 1], a fuzzy subset is: {Negative large, Negative medium, Negative small, zero, positive small, positive medium, positive large }, remember to {NB, NM, NS, ZE, PS, PM, PB}. Develop fuzzy control rules [5], as shown in table 1~3.

Tab.1 Fuzzy control rules of ΔK_p

e	*ec*						
	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PB	PM	PM	PS	PS	ZE
NM	PB	PB	PM	PM	PS	ZE	ZE
NS	PM	PM	PM	PS	ZE	NS	NM
ZE	PM	PS	PS	ZE	NS	NM	NM
PS	PS	PS	ZE	NS	NS	NM	NM
PM	ZE	ZE	NS	NM	NM	NM	NB
PB	ZE	NS	NS	NM	NM	NB	PB

Tab. 2 Fuzzy control rules of ΔK_i

e	*ec*						
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NM	ZE	ZE
NM	NB	NB	NM	NM	NS	ZE	ZE
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	ZE	ZE	PS	PM	PM	PB	PB
PB	ZE	ZE	PS	PM	PM	PB	PB

Tab.3 Fuzzy control rules of ΔK_d

e	*ec*						
	NB	NM	NS	ZE	PS	PM	PB
NB	PS	PS	ZE	ZE	ZE	PM	PB
NM	NS	NS	NS	NS	ZE	NS	PM
NS	NB	NM	NM	NS	ZE	PS	PM
ZE	NB	NM	NM	NS	ZE	PS	PM
PS	NB	NM	NS	NS	ZE	PS	PS
PM	NM	NS	NS	NS	ZE	PS	PS
PB	PS	ZE	ZE	ZE	ZE	PB	PB

2 Simulation Analysis

Because motivation is a major factor causing road vehicle vibration, so the random signal during the simulation as road input, shown in Figure 2.

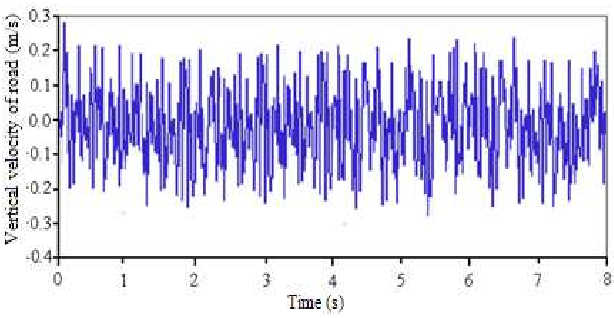

Fig.2 Random input signal

ADAMS software to build three-dimensional models using active suspension, and body vertical acceleration, tire load and tire vertical displacement as the evaluation index, joint simulation in MATLAB environment. Meanwhile, for the inspection and control effect, the traditional PID control and fuzzy PID contrast, the results shown in Figure 3-5.

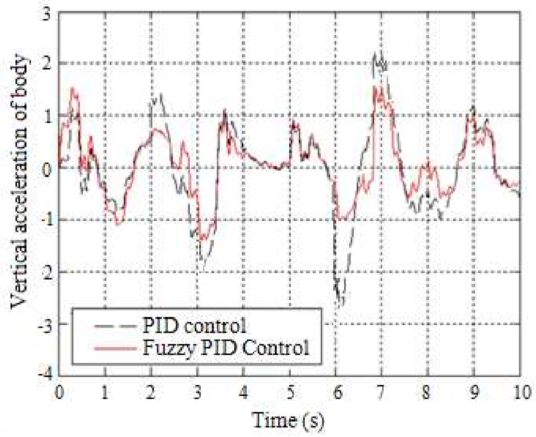

Fig.3 Vertical acceleration of body

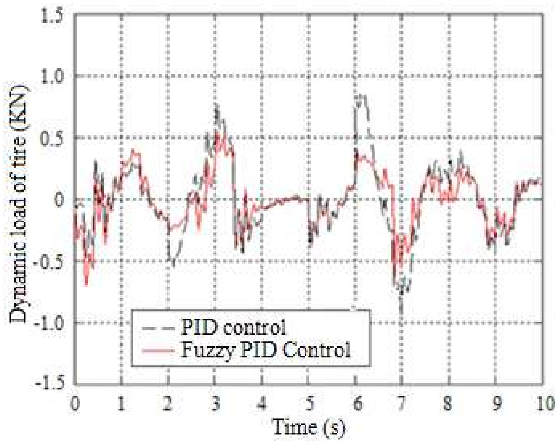

Fig.4 Dynamic load of tire

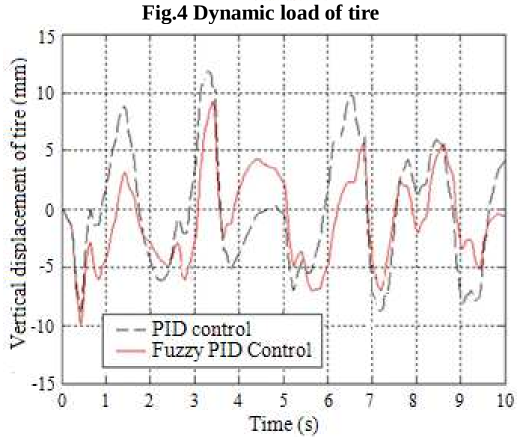

Fig.5Vertical displacement of tire

The results show that, compared with conventional PID control, fuzzy PID control strategy to control high precision, robustness, the model is correct.

CONCLUSION

The threshing process is simulated and analyzed by self-developed software.Those three-dimensional discrete element analysis models based on PID control and thresher are established. The results of the simulation and the experiments are compared and analyzed.

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