Control Algorithm Research of Speed Compensator in Motor Synchronization System

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Abstract. Although motor synchronization control system has already met high precision and high synchronization control based on virtual main spindle and relative coupling, it's time-consuming to set parameter when most popular algorithm PID is applied in speed compensators to control relative coupling. To solve this problem, speed compensators based on fuzzy control is proposed. Matlab/Simulink is used to build system simulation platform on this strategy. The result reveals that system robustness increases and synchronization error is effectively overcome under external disturbance and parameter changes in improved synchronization control strategy. In addition, system performance gets further optimized compared to virtual main spindle and relative coupling control.

Introduction

Motor synchronization control is widely used in all kinds of motion control system like paper machine, dyeing and finishing machinery, textile and tobacco industry. Its synchronization directly affects the products quality[1]. In practice, motor synchronization performs worse under mismatched shaft driving characteristics and load disturbance. Conventional synchronous control scheme is difficult to obtain satisfactory result. So virtual main spindle and relative coupling control can be used to improve performance to meet high synchronization performance[2]. However, its time-consuming to set parameters of multiple loop speed compensators in relative coupling control, and fuzzy control is robust, which affect little on disturbance and parameter changes. Thus, speed compensators based on fuzzy control strategy is considered in this paper. Simulation results show that the system robustness improves, and synchronization error caused by disturbances and parameter change can be overcome effectively.

The speed compensator design based on fuzzy control

Control system study based on virtual main spindle and relative coupling

Combine virtual main spindle and relative coupling in [2], a better control performance achieved compared to the independent control respectively. What's more, anti-jamming and synchronicity are improved. The system structure is shown in figure 1, in which virtual main spindle functioned as synchronous coordination transfer driving force to each motor shaft. While a certain motor shaft changes speed by disturbance, it will affect virtual main spindle output through torque feedback, so that other shafts change in the same trend [3]. Every auxiliary shaft control part is composed of mixed signal module, speed compensator and its own imaginary axis controller, where ω^* is reference angular velocity signal, ω_n (n=l，2，3…) are angular velocity of each shaft output respectively and the speed compensator structure is shown in Fig.2. At running time, motor shaft speed is subtracted from one another shaft respectively by their controlling speed compensator. Then, the deviations obtained are added by compensation algorithm (usually the PID algorithm) in speed compensator. That is speed compensation signal we calculated[4,5].

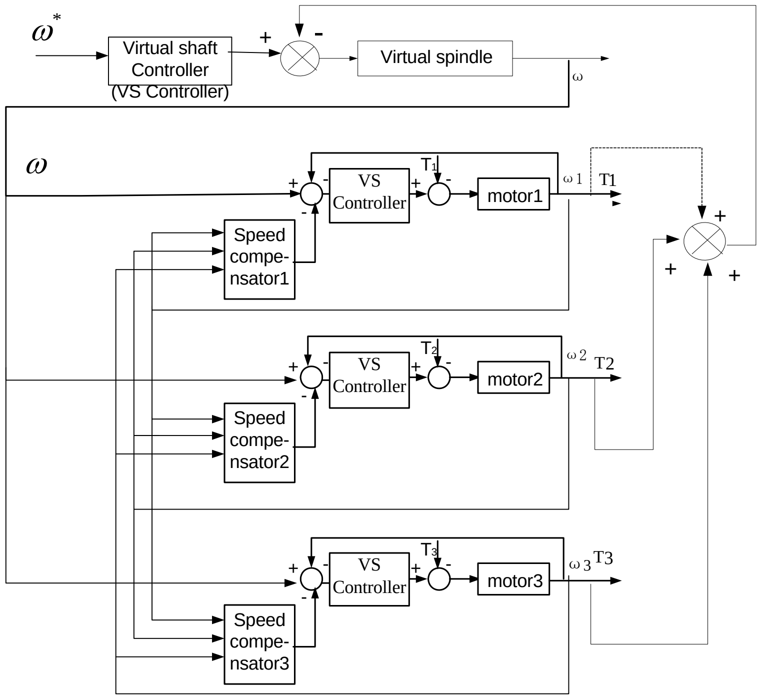

Fig.1 virtual main spindle and relative coupling diagram

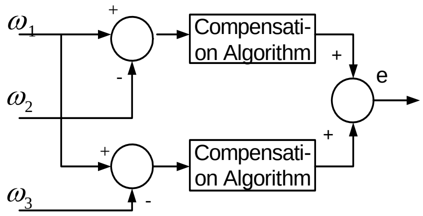

Fig.2 Speed compensator

Blur speed compensator

Generally, fuzzy-control realizes its object control according to system deviation and deviation change rate. The basic structure of fuzzy controller includes fuzzification, fuzzy rules, fuzzy inference, defuzzification and quantitative input and output[7].

The domain of speed error e is [-0.012,0.012], after transformation by quantitative factor k1=500, its fuzzy domain is [-6,6], linguistic value is set as {NB，NM，NS，ZO，PS，PM，PB}; The domain of speed error rate is [-6,6], after transformation by quantitative factor k2=1, the domain of ec is [-6,6], linguistic value is set as {NB，NM，NS，ZO，PS，PM，PB} too; Output domain of controller is [-6,6], linguistic value is set as {NB，NM，NS，ZO，PS，PM，PB}. Input e and ec and output use triangle as their subordinating degree function.

And next, realize fuzzy inference by developing fuzzy control rule table according to motors running requirements and experience summary.

Defuzzification is opposite to fuzzification, it’s from fuzzy reasoning result we need and use weighted average method to defuzzificate on simulation. So fuzzy control structure diagram is shown in Fig.3.

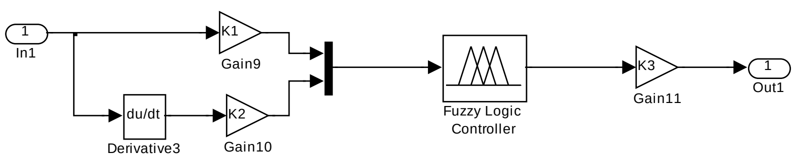

Fig.3 Fuzzy controller

Synchronous control simulation analysis of compensation controller by fuzzy controller

Build motors synchronization control system on Matlab/Simulink with three motors as example. It's shown in Fig.4. Through simulation, we can observe dynamic response of motor startup, steady response while entering stable operation and synchronization error between mots under disturbed motion.

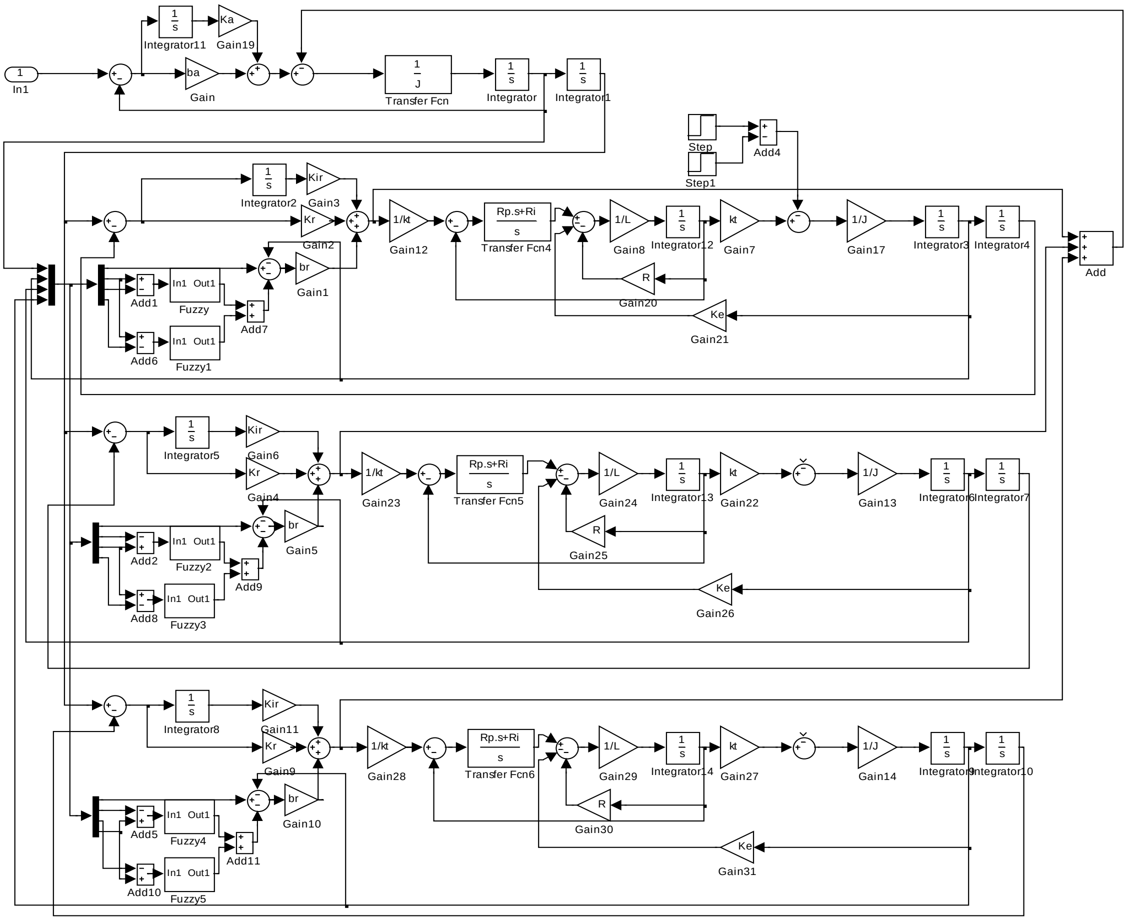

Fig.4 system simulation diagram of speed compensator used fuzzy controller

Set simulation time as 15s, speed as 10r/s. Shaft 1 receive any disturbance at t=10s, while others don't get any. Related parameters list in Tab.1.

Tab.1 parameters table

parameters	values	illustration
Ke	0.1	The coefficient of motor potential
Kt	0.01	The coefficient of motor torque
R	0.2	Motor armature circuit resistance
Ka	3	Elastic coefficient of virtual main spindle
ba	35	Attenuation coefficient of virtual main spindle
J	50	Unit motor and Moment of inertia of the load
Ri	13.5	Current integral part
Rp	100	Current ratio
L	0.01	Motor inductance coefficient
Kir	0.25	The controller integral stiffness gain
Kr	40	The controller stiffness coefficient
br	100	The controller damping coefficient

In Fig.5 and 6, it gives speed response of shaft 1 under disturbance at 10s and speed error compared to other shafts by fuzzy control and PID, where dotted line is PID and solid one is fuzzy under control.

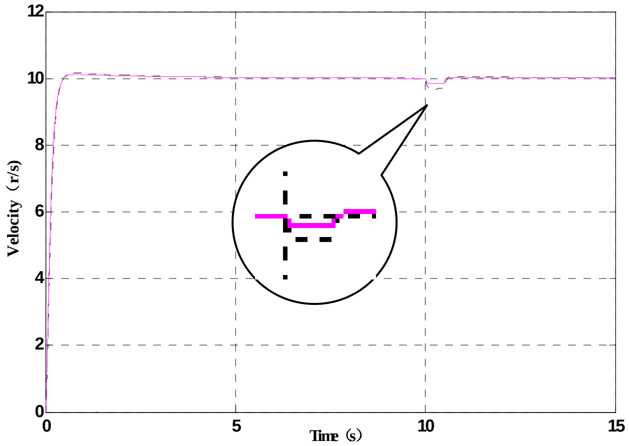

Fig.5 speed response of shaft 1 with disturbance under different control algorithms

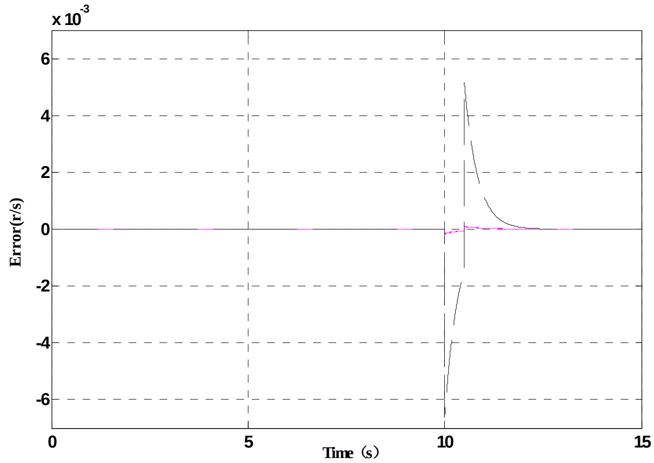

Fig.6 speed error between shaft 1 and others under different control algorithms

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From Fig.5, it can be seen that improved synchronization control significantly has smaller volatility than before under same disturbance. Also, conclusion can be drew in Fig.6 that fuzzy control has more strong anti-interference ability than PID in synchronization control. Hence, fuzzy control algorithm applied to speed compensator is feasible and effective. It has better synchronization performance and anti-interference under certain conditions.

Conclusion

Fuzzy control algorithm is applied to speed compensator in virtual main spindle and relative coupling control system based on system modelling and simulation study. The method has been compared to PID algorithm in [2]. Simulation results show that fuzzy control algorithm applied to speed compensator is feasible and effective. It can achieve better synchronization performance and anti-interference under certain conditions.

The above theoretical results have played an effective role in guiding binary compound machine multi-axis synchronous control electrification of composite filter rod processing in tobacco industry.

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