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Research on Roll Variable Speed Grinding Based on Adaptive Fuzzy Control

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Abstract

The traditional method of improving the machining precision is mainly on account of changes in the work piece and the grinding wheel in grinding process, including, considered the weakest of the work piece from the axial stiffness, using center frame to increase the stiffness of the work piece, take error compensation, and analyze the mechanism of gear grinding and the suppression measures of variable speed grinding and grinding chatter. Based on the analysis of the relationship among gear grinding mechanism, variable speed grinding and grinding chatter suppression and grinding precision, the variable speed micro-feed grinding process strategy based on adaptive fuzzy control is put up, that is according to the roller material and structure to reasonably determine the characteristics of grinding wheel and the parameters of grinding process. And with full consideration of roll grinders, changes of roller system along the axial stiffness and the deformation control in the roll grinding process, a new strategy of variable speed grinding micro-feed adaptive control optimization based on adaptive fuzzy control is proposed, which Can effectively improve the roll grinding precision.

Keywords: *adaptive fuzzy control, transmission, roll grinding, micro feed*

1. Introduction

There are three main traditional methods to improve the machining precision roll grinding. The first is to consider the roll axial weak stiffness, to select the rotational speed of work piece V_w and the longitudinal feed speed V_f constant speed grinding, at the same time, the grinding depth as small as possible. The parameters V_w and V_f relative to the larger stiffness of the point of the value is not likely to be the most advantages, like this will inevitably bring about the grinding cost and waste of time. Second, by using the method of center frame to increase the rigidity of the work piece, the processing efficiency is low, the adjustment is complex ,but the higher requirement on the technology workers, improve the machining precision of the role is limited. Third is the two strategies about the error compensation measures, the process compensation strategy of adjust or repair and the group strategy of selection, calculated by the formula of grinding quantity for each processing point, for make the work piece's actual amount of grinding to achieve calculation in machining, in order to reduce the influence of the elastic deformation. But it is very difficult that calculated a time in grinding process of grinding and the elastic deformation.

In this paper, based on the study of the mechanism of variable speed grinding, variable speed grinding and grinding tremor suppression grinding precision on the relationship And in full consideration, the roll grinder and the change along the roll axial stiffness of roll system roll deformation in grinding, based on control the roll deformation in grinding, through the control of grinding force, finished the grinding speed, proposed The optimization strategy of roll grinding speed intelligent adaptive control based on fuzzy direct adaptive control.

2. The Roll of Variable Speed Grinding

The essence of variable speed grinding is continuously varying the speed of grinding wheel, the longitudinal feed speed, roll speed, not to let the grinding flutter vibration always in the maximum flutter growth rate of corresponding frequency flutter, but the flutter growth rate increase in the near maximum flutter rate continuous change, so as to ensure in the variable

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speed during grinding the average flutter growth rate less than maximum flutter growth rate, in order to inhibit or delay the purpose of the chatter growth, to improve the grinding accuracy [1].

When the continuous change of the work piece speed and grinding wheel speed, the ratio will change continuously, at the same time, the radial force also is continuously changed [2]. Optimization of the system to make analysis and processing on the numerical variation, adjusting the work piece speed and the output of wheel speed, cycle to begin, ensure to suppress tremor and always reach the optimal grinding. The grinding process of each component in the direction of velocity is shown in Figure 1.

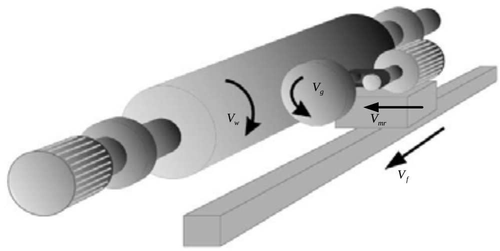

Figure 1. Schematic diagram of roll grinding work

2.1. Variable Speed Grinding and the Amount of Feed

The grinding roller is a kind of special grinding process formed between CNC roll grinder, grinding wheels, and the roller [3]. Therefore, in the study of roll grinding mechanism, contemplated under the grinding geometry relations, considering the influence of roll grinding motion parameters on the contact arc length, derivation of mathematical model for the motion of grinding roll contact length (as shown in Figure 2 below).

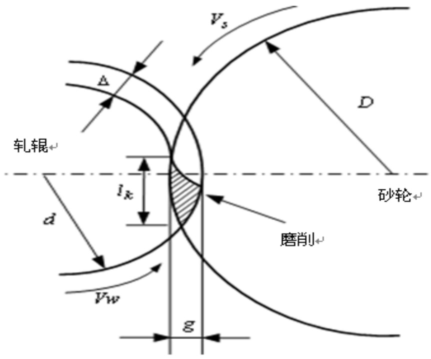

Figure 2. Roller and wheel contact arc length

$$l_k = K_r \times [(1 \pm \frac{V_w}{60V_s})^2 + (\frac{f_\alpha V_w}{60V_s})^2]^{1/2} \times [\frac{d_s d_w a_p}{d_s + d_w}]^{1/2} \quad (1)$$

In formula, l_k —The motion of grinding roller contact arc length correction value（mm）; V_w —Roller line speed（m/s）; V_s —The speed of the grinding wheel（m/s）; d_s —Grinding wheel diameter（mm）; d_w —Roll diameter（mm）; a_p —Grinding depth（mm）; f_α —Longitudinal feed（mm/min）; K_r —The revision coefficient related to roll shape ; "+"—Means "counterclockwise grinding", The grinding wheel and the roller speed in the opposite direction of the grinding zone; "—"—Means "clockwise grinding", The grinding wheel and the roller speed in the same direction of grinding zone. $\pm V_w / V_s$ is reflect that due to the roll line speed V_w caused the contact arc length changes. Excluding the impact of the linear speed of the roller(if $V_w = 0$),the contact arc length l_k becomes the geometric length of contact arc l_g for the grinding wheel and the roller [1].

2.2. Variable Speed Grinding and the Grinding Force

From the regenerative effect theory of self-excited vibration grinding, changes of grinding chatter is mainly caused by the corrugated surface of the roller or grinding wheel [4]. For the regeneration effect of roll, the specific process is as follows: In the roll grinding process, When cutting the roll surface produced a ripple in the previous rotary, the grinding wheel will be cutting in the surface with corrugated in the behind rotary, and the new ripple formation on the surface of the roller. If the self vibration frequency and velocity of roll into integer ratio, the grinding depth is basically unchanged, the grinding force is basically unchanged; if the self vibration frequency and velocity of roll not into integer ratio, it will produce dynamic grinding force. Change of rolling speed when the variable speed grinding, it make the roller surface corrugation phase changing, it is possible to make the system constantly leave flutter excitation region, thus suppress the flutter, improve the surface quality of grinding roll [5].

So as long as the variable amplitude, frequency appropriate when variable grinding, the grinding system can in a period of time to avoid flutter excitation region, to get better results than the constant speed grinding.

In rollers which are the grinding ratio of length to diameter l/d is different, the system stiffness influence on grinding accuracy will be not the same, long size bigger impact[6].In this paper, the strategy of adaptive control of variable speed grinding which based on the fuzzy direct adaptive control considering the roll system of roll grinder changes along the axial stiffness of the roll ,it can control the deformation of grinding rolls. In the vertical grinding roller, the deformation of the rollers in point of grinding force can be expressed as:

$$\begin{aligned} Y &= K_t F_n \\ &= 8rkK \tan \gamma\omega^{-2\varepsilon} [\alpha_p]^{1-\frac{\varepsilon}{2}} (\frac{V_f}{V_W^{\varepsilon}})(\frac{1}{V_S})^{1-\varepsilon} (\frac{r+R}{2rR})^{-\frac{\varepsilon}{2}} \\ &= K_a K_t (\frac{V_f}{V_W^{\varepsilon}})(\frac{1}{V_S})^{1-\varepsilon} (\frac{r+R}{2rR})^{-\frac{\varepsilon}{2}} \end{aligned} \quad (2)$$

$$K_a = 8rkK \tan \gamma\omega^{-2\varepsilon} (\frac{r+R}{2rR})^{-\frac{\varepsilon}{2}} \quad (3)$$

$$K_t = \frac{x^2 (l-x)^2}{3E(\pi d^4 / 64)l} + \frac{x^2}{l^2 K_T} + \frac{(l-x)^2}{l^2 K_H} \quad (4)$$

In formula, Y is the roll deformation error of distance from the machine's top x; k_α is The tangential coefficient; r is the Minimum radius; γ is the tangential angle; k is deformation coefficient; ω is angular velocity; ε is constant; α_p is depth of cut ; V_S is roll speed; R is the maximum radius of roller; K_a is correction coefficient of longitudinal; F_n is normal grinding force; E is modulus of elasticity; K_T is the rigidity of the tail stock; K_H is frame stiffness; l is roll length.

By the empirical model by grinding force, in the process of roll grinding normal grinding force F_n (as shown in Figure 3) can be expressed as:

$$F_n = K \frac{V_w}{V_s} a + \frac{\bar{\delta} \bullet \bar{P} A_N}{1+a} (C_1)^{\beta} \left(\frac{V_w}{V_s}\right)^{\alpha} a^{\frac{1+\alpha}{2}} D_e^{\frac{1-\alpha}{2}} \quad (5)$$

In formula, a is the flutter growth rate; $\overline{\delta}$ is mean value of index; A_N is normal flutter amplitude; C_1 is cutting coefficient (also known as the constant of proportionality); β is constant; α is grinding thickness; D_e is grinding diameter.

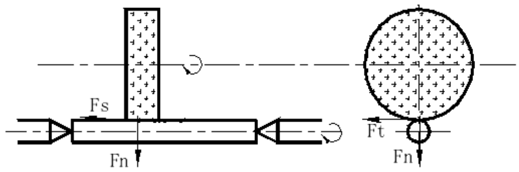

Figure 3. Schematic diagram of the grinding force in grinding process of the roll

According to the longitudinal feed speed is V_f, from the relation $f = 2\pi r V_f / V_w$ between longitudinal feed per revolution of roll f and the type (13), when the V_s constant, after grinding thickness α is determined. it can change V_w and V_f to control the roll deformation. In practice, due to the limitation of the grinding system by many conditions, for any roll axial position, there exists a best of V_w and V_f [7].

In summary, the proposed control strategy is in the grinding process,the relative motion of roller and wheel, by using the direct adaptive fuzzy control, real time optimization control of grinding parameters V_w and V_f ,through continuous changes of V_w and V_f to control the grinding force of points, to control the deformation of the work piece, in order to limit error in range of process parameters is allowed.

3. Direct Adaptive Fuzzy Control

Direct adaptive fuzzy control is fuzzy logic systems with adaptive learning algorithm, the learning algorithm is relying on data information to adjust the parameters of the fuzzy logic system, and it can guarantee the stability of the control system [8]. The system of adaptive is as follows.

3.1. Problem Description

Considering the research object described by the following equation:

$$\begin{aligned} x^{(n)} &= f(x, \dot{x}, \cdots, x^{(n-1)}) + bu \\ y &= x \end{aligned} \tag{6}$$

In formula, f is functions of formula (5) on the rotational speed of the rolls V_S , b is the normal number of unknown.

Direct adaptive fuzzy control use the following IF-THEN fuzzy rules to describe the control knowledge, That is: if x_1 is P_1^r and x_n is P_n^r , then u is Q^r , in formula: P_i^r , Q^r are fuzzy set in the set of real numbers, and $r = 1,2\cdots, L_u$.

Set the position command is y_m , let,

$$e = y_m - y = y_m - x, \boldsymbol{e} = (e, \dot{e}, \cdots, e^{(n-1)})^T \tag{7}$$

Select $\boldsymbol{K} = (k_n, \cdots k_1)^T$, It is a polynomial $s^{(n)} + k_1 s^{(n-1)} + \cdots + k_n$ all roots in the left half plane of the complex plane. The control law for the selection:

$$u^{*} = \frac{1}{b}[-f(\boldsymbol{x}) + y_m^{(n)} + \boldsymbol{K}^T \boldsymbol{e}] \tag{8}$$

The formula (8) into formula (6).Get the closed loop control system of equation:

$$e^{(n)} + k_1 e^{(n-1)} + \cdots + k_n e = 0 \tag{9}$$

By the selection of $\boldsymbol{K}$ can be obtained $e(t) \to 0$ when $t \to \infty$, that is the output of the system y gradual convergence to the desired output y_m.

Direct adaptive fuzzy control to design a feedback controller $u = u(\boldsymbol{x} \mid \theta)$ and the adaptive rule is an adjustment parameter vector $\boldsymbol{\theta}$ based on fuzzy system, so that the output y of the system as much as possible to track the desired output y_m [10].

3.2. The Controller Design

Direct adaptive fuzzy controller:

$$u = u_D(\boldsymbol{x} \mid \boldsymbol{\theta}) \tag{10}$$

In formula, u_D is a fuzzy systems, $\boldsymbol{\theta}$ is the adjustable parameters.

Fuzzy systems u_D is composed of two steps to construct. Step 1: The variable $x_i (i = 1,2\cdots,n)$ is defined m_i fuzzy sets $A_I^{l_i} (l_i = 1,2\cdots,m_i)$. Step 2: Structure of fuzzy system $u_D(\boldsymbol{x} \mid \boldsymbol{\theta})$ with the following $\prod_{i=1}^{n} m_i$ rules, That is: if x_1 is $A_I^{l_i}$ and......and x_n is $A_n^{l_n}$,then u_D is $S^{l_1 \cdots l_n}$, in formula: $l_i = 1,2\cdots,m_i$, $i = 1,2\cdots,n$.

Using the product inference engine, the single-valued fuzzy control and the average solution center fuzzy controller to design fuzzy controller [11],

$$u_D(\boldsymbol{x} \mid \boldsymbol{\theta}) = \frac{\sum_{l_1=1}^{m_1} \cdots \sum_{l_n=1}^{m_n} \bar{y}_u^{l_1 \cdots l_n} (\prod_{i=1}^{n} u_{A_I}^{L_I}(x_i))}{\sum_{l_1=1}^{m_1} \cdots \sum_{l_n=1}^{m_n} (\prod_{i=1}^{n} u_{A_I}^{L_I}(x_i))} \tag{11}$$

Let $\bar{y}_u^{l_1 \cdots l_n}$ is the free parameters, on the $\boldsymbol{\theta} \in R^{\prod_{i=1}^{n} m_i}$ collection, the fuzzy controller is:

$$u_D(\boldsymbol{x} \mid \boldsymbol{\theta}) = \boldsymbol{\theta}^T \boldsymbol{\xi}(\boldsymbol{x}) \tag{12}$$

In formula, $\boldsymbol{\xi}(\boldsymbol{x})$ is $\prod_{i=1}^{n} m_i$ dimensional vector, the $l_1, \cdots, l_n$ elements are:

$$\xi_{l_1,\cdots,l_n}(\boldsymbol{x}) = \frac{\prod_{i=1}^{n} u_{A_I}^{L_I}(x_i)}{\sum_{l_1=1}^{m_1} \cdots \sum_{l_n=1}^{m_n} (\prod_{i=1}^{n} u_{A_I}^{L_I}(x_i))} \tag{13}$$

Among them, fuzzy control rule is embedded into the fuzzy controller, by setting the initial parameters.

3.3. The Design of the Adaptive Law

By formula (8):

$$f(\boldsymbol{x}) = -\boldsymbol{b}u^* + y_m^{(n)} + \boldsymbol{K}^T\boldsymbol{e} \tag{14}$$

Design of adaptive law:

$$\dot{\theta} = -\gamma \boldsymbol{e}^T \boldsymbol{P}\boldsymbol{b})\xi(\boldsymbol{x}) \tag{15}$$

In formula, γ is positive constant, $\boldsymbol{P}$ is positive definite matrix.

The formula (6) into the formula (10) it can get the following closed-loop dynamic equations of fuzzy control system:

$$e^{(n)} = \boldsymbol{b}[u^* - u_D(\boldsymbol{x} \mid \boldsymbol{\theta})] - \boldsymbol{K}^T\boldsymbol{e} \tag{16}$$

Let:

$$\Lambda = \begin{pmatrix} 0 & 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & 1 \\ -k_n & -k_{n-1} & \cdots & \cdots & \cdots & \cdots & -k_1 \end{pmatrix} \boldsymbol{b} = \begin{pmatrix} 0 \\ 0 \\ \cdots \\ 0 \\ b \end{pmatrix} \tag{17}$$

The closed loop system dynamic equation (16) can be written as a vector of the form:

$$\dot{\boldsymbol{e}} = \Lambda\boldsymbol{e} + \boldsymbol{b}[u^* - u_D(\boldsymbol{x} \mid \boldsymbol{\theta})] \tag{18}$$

Defined the optimal parameter:

$$\boldsymbol{\theta}^* = \arg \min_{\boldsymbol{\theta} \in R^{\prod_{i=1}^{n} m_i}} \left[\sup_{x \in R^N} \mid u_D(\boldsymbol{x} \mid \boldsymbol{\theta}) - u^* \mid \right] \tag{19}$$

Defined the minimum approximation error:

$$\omega = u_D(\boldsymbol{x} \mid \boldsymbol{\theta}) - u^* \tag{20}$$

By the formula (18):

$$\dot{\boldsymbol{e}} = \Lambda\boldsymbol{e} + \boldsymbol{b}[u_D(\boldsymbol{x} \mid \boldsymbol{\theta}^*) - u_D(\boldsymbol{x} \mid \boldsymbol{\theta})] - u_D(\boldsymbol{x} \mid \boldsymbol{\theta}) - u^* \tag{21}$$

By the formula (12) error equation can be rewritten as (21):

$$\dot{\boldsymbol{e}} = \Lambda\boldsymbol{e} + \boldsymbol{b}[(\boldsymbol{\theta}^* - \boldsymbol{\theta})^T \xi(\boldsymbol{x}) - \omega] \tag{22}$$

Analysis of stability of this control algorithm is as follows, the definition of Lyapunov function [12]:

$$V = \frac{1}{2}\boldsymbol{e}^T\boldsymbol{P}\boldsymbol{e} + \frac{\boldsymbol{b}}{2\gamma}(\boldsymbol{\theta}^* - \boldsymbol{\theta})^T(\boldsymbol{\theta}^* - \boldsymbol{\theta}) \tag{23}$$

In formula, γ is positive constant, $\boldsymbol{P}$ is a positive definite matrix and conforms to the Lyapunov equation:

$$\Lambda^T \boldsymbol{P} + \boldsymbol{P}\Lambda = -\boldsymbol{Q} \tag{24}$$

In formula, $\boldsymbol{Q}$ is positive definite matrix of an arbitrary $n \times n$,The $\boldsymbol{\Lambda}$ formula (17) is given, the real part of the given value is negative.

Selected $V_1 = \frac{1}{2}\boldsymbol{e}^T \boldsymbol{P}\boldsymbol{e}$ ，$V_2 = \frac{\boldsymbol{b}}{2\gamma}(\boldsymbol{\theta}^* - \boldsymbol{\theta})^T(\boldsymbol{\theta}^* - \boldsymbol{\theta})$ 令 $\boldsymbol{M} = \boldsymbol{b}[(\boldsymbol{\theta}^* - \boldsymbol{\theta})^T \xi(\boldsymbol{x}) - \omega]$, formula (22) becomes:

$$\begin{aligned}
&\dot{\boldsymbol{e}} = \Lambda \boldsymbol{e} + \boldsymbol{M} \\
&\dot{V}_1 = \frac{1}{2}\dot{\boldsymbol{e}}^T \boldsymbol{P}\boldsymbol{e} + \frac{1}{2}\boldsymbol{e}^T \boldsymbol{P}\dot{\boldsymbol{e}} = \frac{1}{2}(\boldsymbol{e}^T \Lambda^T + \boldsymbol{M}^T)\boldsymbol{P}\boldsymbol{e} + \frac{1}{2}\boldsymbol{e}^T \boldsymbol{P}(\boldsymbol{e}\Lambda + \boldsymbol{M}) \\
&\quad = \frac{1}{2}\mathbf{e}^T(\Lambda^T \boldsymbol{P} + \boldsymbol{P}\Lambda\Lambda) + \frac{1}{2}\boldsymbol{M}^T \boldsymbol{P}\boldsymbol{e} + \frac{1}{2}\boldsymbol{e}^T \boldsymbol{P}\boldsymbol{M} \\
&\quad = -\frac{1}{2}\boldsymbol{e}^T \boldsymbol{Q}\boldsymbol{e} + \frac{1}{2}\boldsymbol{M}^T \boldsymbol{P}\boldsymbol{e} + \frac{1}{2}\boldsymbol{e}^T \boldsymbol{P}\boldsymbol{M} = -\frac{1}{2}\boldsymbol{e}^T \boldsymbol{Q}\boldsymbol{e} + \boldsymbol{e}^T \boldsymbol{P}\boldsymbol{M}
\end{aligned} \tag{25}$$

That is:

$$\begin{aligned}
&\dot{V}_1 = -\frac{1}{2}\boldsymbol{e}^T \boldsymbol{Q}\boldsymbol{e} - \boldsymbol{e}^T \boldsymbol{P}\boldsymbol{b}\,\omega + (\boldsymbol{\theta}^* - \boldsymbol{\theta})^T \boldsymbol{e}^T \boldsymbol{P}\boldsymbol{b}\,\xi(\boldsymbol{x}) \\
&\dot{V}_2 = -\frac{1}{\gamma}(\boldsymbol{\theta}^* - \boldsymbol{\theta})^T \dot{\boldsymbol{\theta}}
\end{aligned} \tag{26}$$

The derivatives of V :

$$\dot{V} = \dot{V}_1 + \dot{V}_2 \tag{27}$$

The adaptive law formula (15) into the formula (27), then:

$$\dot{V} = -\frac{1}{2}\boldsymbol{e}^T \boldsymbol{Q}\boldsymbol{e} - \boldsymbol{e}^T p_n \boldsymbol{b}\,\omega \tag{28}$$

Due to $\boldsymbol{Q} > 0$, ω is the minimum approximation error, through the design of fuzzy systems enough rules can make ω is sufficiently small, and in accordance with $\left|\boldsymbol{e}^T p_n \boldsymbol{b}\,\omega\right| < \frac{1}{2}\boldsymbol{e}^T \boldsymbol{Q}$,so that $\dot{V} < 0$. The structure of direct adaptive fuzzy control system is shown in Figure 4.

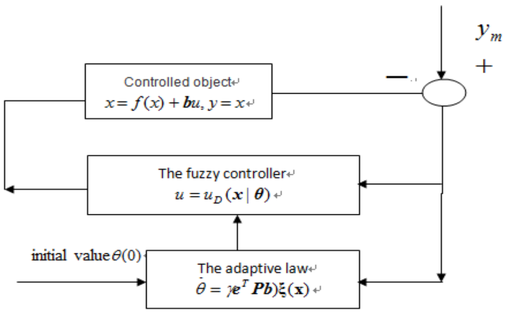

Figure 4. Direct adaptive fuzzy control system

4. System Simulation

Controlled device original formula $F_n = K\frac{V_w}{V_s}a + \frac{\bar{\delta} \bullet \bar{P} A_N}{1+a}(C_1)^\beta \left(\frac{V_w}{V_s}\right)^\alpha a^{\frac{1+\alpha}{2}} D_e^{\frac{1-\alpha}{2}}$,

Simplified as: $F_n = A^{'}V_w + B^{'}V_w^\alpha$, thereinto $A^{'} = K\, a/V_S$, $B^{'} = \frac{\bar{\delta} \bullet \bar{P} A_N}{1+a}(C_1)^\beta \frac{1}{(V)_S} a^{\frac{1+\alpha}{2}} D^{\frac{1-\alpha}{2}}$.

Position command is $\sin(\pi t)$.

Selected the following six kinds of membership function;

$$\mu_{N1} = 1/(1+\exp(5(x+2))) \,,\ \mu_{N2} = \exp(-(x+1.5)^2) \,,\ \mu_{N3} = \exp(-(x+0.5)^2) \,,$$
$$\mu_{p1} = \exp(-(x-0.5)^2) \,,\ \mu_{p2} = \exp(-(x-1.5)^2) \,,\ \mu_{p3} = 1/(1+\exp(-5(x-2))) .$$

The initial state of the system is [1,0], the initial value of each element were chosen 0 in $\boldsymbol{\theta}$, using control law (11), adaptive selection of formula (15). Selected $\boldsymbol{Q} = \begin{pmatrix} 50 & 0 \\ 0 & 50 \end{pmatrix}$, k_1=1, k_2=10, adaptive parameters should be selected $\gamma = 50$.

According to the membership function design program, which can get the membership function is shown in Figure below.

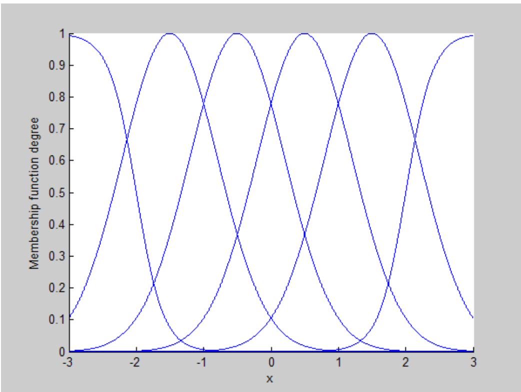

Figure 5. The membership function of rolling speed

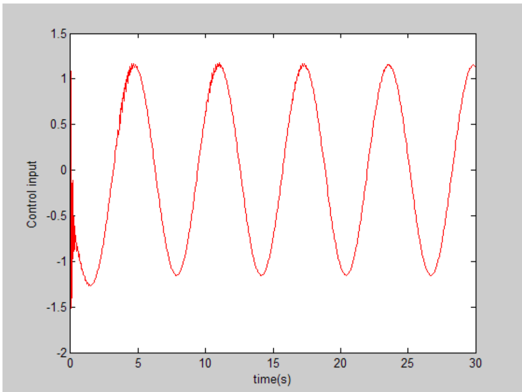

Figure 6. Control input signal

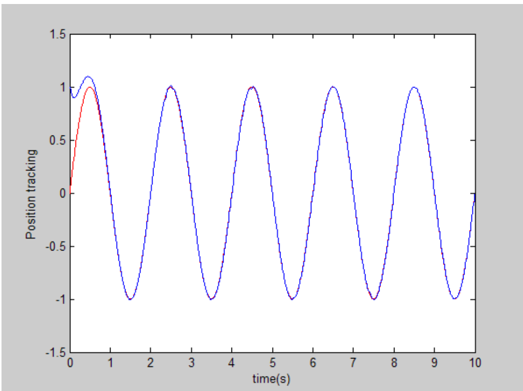

Figure 7. The position tracking

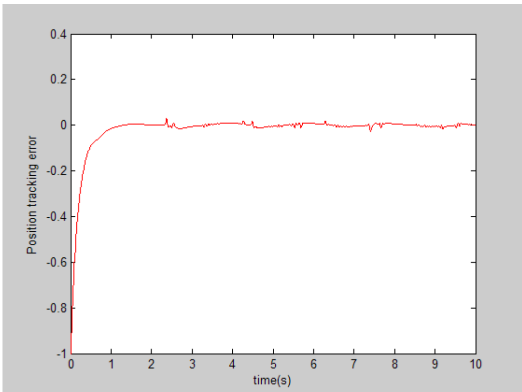

Figure 8. Tracking error

Flow chart of fuzzy direct adaptive control are as follows, in the premise of constructing adaptive system, initialization parameters, the adaptive control system operation can output the optimal speed of roller V_w, under the control of micro feed formula $f = 2\pi r V_f / V_w$ output the optimal feeding speed V_f, so that controlling motor and working machine, and feedback grinding wheel cutting force and roll roughness after processing, through the adaptive law ,it can real time control of the optimal output, in order to achieve the purpose of adaptive transmission, to improve the roll grinding roughness.

However, in practice there are many uncertain factors, for example, the grinding wheel of in homogeneous materials, roll with different materials, grinding machine and environmental uncertainty and so on. Both of them will affect the grinding with different degree, more importantly is for grinding roller surface roughness reached the ideal roughness is difficult to control, so the above described there are uncertainties in the model. So this paper adopted an adaptive control system to solve these problems. The variable micro feed optimization of adaptive control system is shown in Figure 9, in the process of grinding vibration transmitted directly to the grinding force F_n, from Figure 9, the system measured F_n as a model of the known numerical input direct adaptive control optimization model, optimization model of continuously according to the input value to calculate the optimal work piece speed V_w and optimal vertical feed rate V_f, and with determine the speed of grinding wheel V_s into the optimization model of surface roughness, through the optimization model of surface roughness to calculate the final optimal work piece speed V_w and the optimal vertical feed rate V_f, and sent to the control unit, ensure the optimum speed drive spindle and the feed components work.

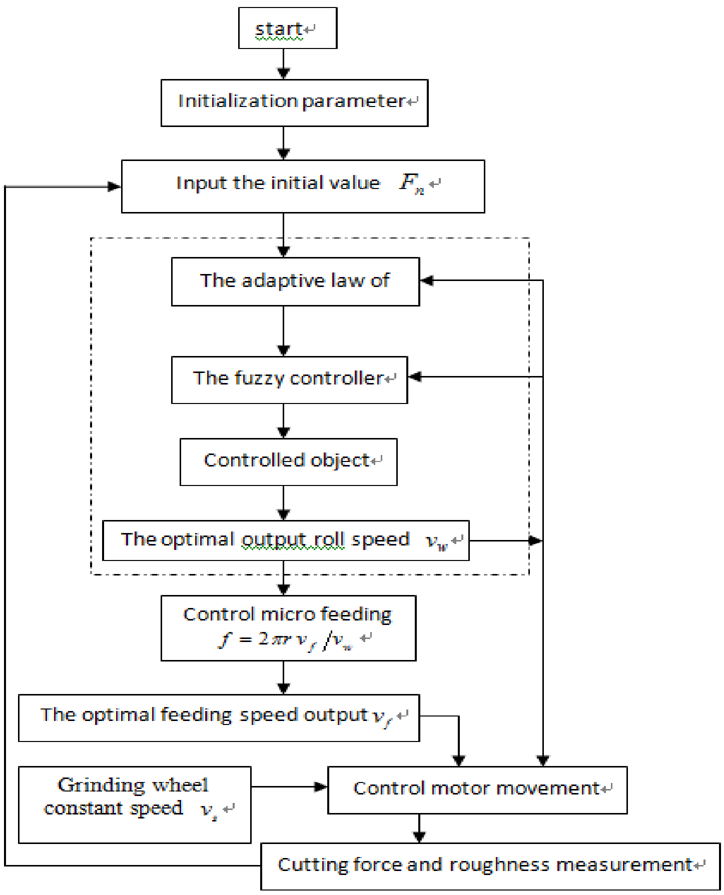

Figure 9. Flow chart of adaptive control

5. Conclusion

This paper is supported by Natural Science Foundation of Inner Mongolia Autonomous Region of china (ID: 2012MS0731). This paper analyzed the concept, the mechanism of variable speed grinding, the relationship between variable speed grinding and tangential force and the amount of feed, also described the direct adaptive fuzzy control principle, advantages and application ,and on this basis according to the technological conditions of roller mechanism principle, proposed the strategy of the variable micro feed optimization of self adaptive control based on the direct adaptive fuzzy control, through the simulation can effectively improve the roll grinding efficiency improved the roll grinding roughness.

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