Research on Adaptive $H_{\infty}$ Control of Tank Gun Control System Based on Wavelet Neural Network Identification

Hong-Yan Wang$^{a,*}$ and Yang-Xia XIANG

Department of Information Engineering, Academy of Armored Force Engineering, China

$^{a}$zxywhy2000@sina.com

$^{*}$Corresponding author

Keywords: Tank Gun Control System, Wavelet Neural Network (WNN), $H_{\infty}$ Control; Robustness.

Abstract. Focusing on the unknown plant model, an adaptive wavelet neural network (WNN) identification robust control scheme of tank gun control system was proposed. According to input and output data, the unknown tank gun control system model parts were reconstructed using wavelet neural network (WNN). The parameters of online adaptive regulating law and output control laws were designed in the sense of Lyapunov, so the tank gun control system achieves dynamic decoupling. In order to reduce the effect of modeling errors and external disturbance, sliding mode variable structure control (SMVSC) was integrated into the adaptive control algorithm, and the robust compensator was added in order to achieve a robust tracking performance. Further the robust and steady performance of gun control system was analyzed. The results showed that wavelet neural network can be a good approximation nonlinear function, the system was insensitive to the parameters uncertainties and load disturbance and had shown a good track performance.

Introduction

The AC tank gun control system is a complex coupling nonlinear system, there are some differences between the mathematical model used in the system design and the characteristics of the actual system, all these will cause uncertainty in the system model.

The direct feedback linearization (DFL) control strategy was used to the AC all-electrical tank gun control system to achieve a completely dynamic decoupling model [1]. In order to reduce the effect of changes in the system parameters and load torque, an adaptive WNN compensator was use to compensate for DEF error, but the control system highly depend on the mathematical model of the object, and the robust performance is difficult to analyze. At the same time the design of tank gun control system, not only hope system robust stabilization, but also hope that the system has some certain robust performance. So it is necessary to study the adaptive $H_{\infty}$ control method when the system model is unknown.

Because the adaptive control can be adjusted with the change of the environment, it has better control performance when the system is uncertain. At the same time because the adaptive law can learn the dynamic performance of the controlled object in real time, so the requested information is not high. Therefore, the adaptive algorithm is applied into the WNN identifier, the WNN is used to estimate the unknown functions, and then construct the equivalent controller, further sliding mode variable structure controller is adopted to restrain and eliminate the external disturbances and the approximation errors, the system can obtain certain $H_{\infty}$ performance index by a robust compensation, and improve the tracking performance.

Problem Description

Mathematical model of permanent magnet synchronous motor in AC all-electric tank gun control system [2] can be described as:
\[
\begin{bmatrix}
\dot{i}_d \\
\dot{i}_q \\
\omega
\end{bmatrix} =
\begin{bmatrix}
-R/L & p_\omega & 0 \\
-p_\omega & -R/L & -p_{\psi q}/L \\
0 & 3p_{\psi q}/2J & BLJ
\end{bmatrix}
\begin{bmatrix}
i_d \\
i_q \\
\omega
\end{bmatrix} +
\begin{bmatrix}
u_d/L \\
u_q/L \\
-T_r/J
\end{bmatrix}
\]

(1)

In order to realize the decoupling of the system, and avoid the zero dynamics problem [4]. Select \(\omega_r, i_d\) as the system output, define a new output variable is

\[
\begin{aligned}
x_1 &= i_d, \\
x_2 &= i_q, \\
x_3 &= \omega_r, \\
y_1 &= i_d, \\
y_2 &= \omega_r \\
1 & 2 & 3 \\
2 & 2 & 2 \\
2 & 1 & 3 \\
2 & 3 & 3 \\
3 & 3 & 3 \\
2 & 2 & 2 \\
1 & 0 & 0 \\
3 & 0 & 0 \\
J & J & J \\
J & J & J
\end{aligned}
\]

(2)

By \(x = \begin{bmatrix} x_1, x_2, x_3 \end{bmatrix}^T \in \mathbb{R}^3\) is defined as the state vector of the system, \(u_d = u_1, u_q = u_2\) as the input of the system, \(y_i (i=1,2)\) as the output of the system, \(d_i (i=1,2)\) as the uncertain external disturbance, the following equations can be obtained:

\[
\begin{bmatrix}
\dot{y}_1 \\
\dot{y}_2
\end{bmatrix} = f(x) + Gu + d(x)
\]

(3)

\[
\begin{bmatrix}
f(x) \\
f'(x)
\end{bmatrix} =
\begin{bmatrix}
\frac{R}{L} x_1 + p_\omega x_3 + \frac{1}{L} u_d \\
\frac{3p_{\psi q}}{2J} x_2 - \frac{3p_{\psi q} \omega}{2L} x_2 - \frac{3p_{\psi q} \omega^2}{2L} x_2 - \frac{3p_{\psi q} \omega^3}{2L} x_2 - \frac{B}{J} x_3 - \frac{T_r}{J}
\end{bmatrix}
\]

\[
G =
\begin{bmatrix}
s_{11} & s_{12} \\
s_{21} & s_{22}
\end{bmatrix}
\]

\[
\begin{bmatrix}
u_d \\
u_q
\end{bmatrix}
\]

\[
\begin{bmatrix}
d_{1}(x) \\
d_{2}(x)
\end{bmatrix} =
\begin{bmatrix}
0 \\
- \frac{B}{J} x_3 - \frac{p_\omega T_r}{J}
\end{bmatrix}
\]

(4)

In above formula, the system’s model is not precisely obtained and the external disturbance is unknown. The system control goal is to design an adaptive WNN identifier, make each output of system \(y_i\) to track the reference signal \(y_{ir}\), and let the tracking error has some \(H_\infty\) capability at a given disturbance attenuation level \(\kappa > 0\), where \(f(x), d(x)\) output \(y_i (i=1,2)\) are the smooth function and have boundary.

**Robust \(H_\infty\) Controller Design of Gun Control System Based on WNN Adaptive Identification**

**Design of WNN Identifier**

If the nonlinear function \(f(x)\) is known, then the feedback linear control input as:

\[
u = G^{-1}[-f(x) + v]
\]

(5)

We can choose the controller \(u\) to eliminate the nonlinear properties, and then according to the linear control theory to design the controller to make the output asymptotic convergences the reference input, and design the auxiliary control part \(v\) to meet the control precision. However, the exact value of \(f(x)\) is difficult to know in the practical engineering system, and considering the influence of system interference, so the ideal controller as formula (5) is not possible to obtain. Because the WNN can approximate any nonlinear function with arbitrary precision by a linear combination of father wavelets and mother wavelets[3], so we select the WNN to estimate the \(f(x)\).
A two-layer product WNN [4] shown in Fig.1, which is comprised of a product layer and an output layer. A family of wavelets is constructed by translations and dilations performed on a single fixed function called the mother wavelet \( \psi(x) = -xe^{-x^2/2} \).

The signal propagation and the basic function in the product layer are introduced as:

\[
\psi_i = \prod_{j=1}^{n} \psi\left(\frac{x_i - m_j}{c_j}\right)
\]

where \( x_i \) denote the inputs of the wavelet network; \( m_j \) and \( c_j \) are the translation and dilation parameters in the product layer. The output of wavelet network is:

\[
\hat{f}(\mathbf{x}|W_i) = \sum_{m} W_i^m \psi_i(m) = \Psi_i(m)W_i
\]

where \( \Psi_i(m) = \psi_i(m) \psi_i(m) \), \( W_i \) belong to a bounded closed set \( \Omega_{w_i} \), \( i=1,2 \), defined as: \( \Omega_{w_i} = \{ M_{w_i} | W_i | \leq M_{w_i} \} \), \( M_{w_i} \) is a parameter to be designed. \( \Omega_{\tilde{x}} \) is the reachable state space.

According to approximation error analysis, there exists an optimal parameter estimation value of wavelet network as:

\[
W_{f_i} = \arg \min_{W_i, x_i} \left\{ \sup_{x \in \Omega_{\tilde{x}}} |f_i(x) - \hat{f}(x|W_i)| \right\}
\]

### Design of Adaptive Rate and Compensation Controller Based on WNN

The following task is to design adaptive rate adaptive of the WNN weight \( W_i \), and variable structure compensation controller \( u_{j,i} \), \( i=1,2, j=1,2 \), it can achieve the control objectives of the system. Because of the influence of modeling errors and external load disturbance, the WNN identifier cannot guarantee the stability of the system, so a compensator is added to reject the external disturbance and WNN approximation error in order to achieve a robust tracking performance. The total system control input as:

\[
u = u_{\text{wNN}} + u_i + u_h
\]

\[
u_{\text{wNN}} = G^{-1}\hat{f}(\mathbf{x}|W_i) + v, \quad u_i = -G^{-1}u_i, \quad u_h = -G^{-1}u_h
\]

\( u_{\text{wNN}} \) is the equivalent WNN compensator, \( u_i \) is a variable structure controller, \( u_h \) is a robust
controller, and \( u = [u_1, u_2]^T \), \( v = [v_1, v_2]^T \), \( \hat{f}(\mathbf{x}|W_j) = [\hat{f}_1(\mathbf{x}|W_j), \hat{f}_2(\mathbf{x}|W_j)]^T \), \( u = [u_{1h}, u_{2h}]^T \). Here the \( \hat{f}(\mathbf{x}|W_j) \) is the approximation of \( f(\mathbf{x}) \) by WNN, and define:

\[
\begin{cases}
  v_1 = \dot{y}_1 + k_{i1}(y_1 - y_1) \\
  v_2 = \dot{y}_2 + k_{i2}(\dot{y}_2 - y_2) + k_{i3}(y_2 - y_2)
\end{cases}
\]  

(11)

Where \( k_{ij} (i=1,2; j=1,\ldots,r_j-1; r_1=1, r_2=2) \) is selected to make the root of the polynomial in the left half plane. The formula (9) is substituted into the formula (3):

\[
\begin{bmatrix}
  \dot{y}_1 \\
  \dot{y}_2
\end{bmatrix} =
G
\begin{bmatrix}
  u_2 \\
  v_2
\end{bmatrix} +
\begin{bmatrix}
  u_n + u_{n_0} \\
  u_n + u_{n_0}
\end{bmatrix}
\begin{bmatrix}
  d_1(\mathbf{x}) \\
  d_2(\mathbf{x})
\end{bmatrix}
\]  

(12)

Substitution formula (11) into (12) yields:

\[
\begin{bmatrix}
  \dot{e}_1 + k_{i1} e_1 \\
  \dot{e}_2 + k_{i2} e_2 + k_{i3} e_3
\end{bmatrix} =
\begin{bmatrix}
  \hat{f}_1(\mathbf{x}|W_j) - f_1(\mathbf{x}) \\
  \hat{f}_2(\mathbf{x}|W_j) - f_2(\mathbf{x})
\end{bmatrix} +
\begin{bmatrix}
  u_n + u_{n_0} \\
  u_n + u_{n_0}
\end{bmatrix}
\begin{bmatrix}
  d_1(\mathbf{x}) \\
  d_2(\mathbf{x})
\end{bmatrix}
\]  

(13)

Firstly, the adaptive robust control law of each subsystem is designed, and then the global asymptotic stability of the system (13) is considered. For the first subsystems:

\[
\dot{e}_1 + k_{i1} e_1 = [\hat{f}_1(\mathbf{x}|W_j) - f_1(\mathbf{x})] + u_{is} + u_{i0} - d_i(\mathbf{x})
\]  

(14)

Define \( e_{i-1} = [e_i] \), then the formula (14) is written as:

\[
\dot{e}_i = A_i e_i + B_i(u_n + u_{n_0}) + B_i[\hat{f}_1(\mathbf{x}|W_j) - f_1(\mathbf{x})] - B_i d_i(\mathbf{x})
\]  

(15)

where \( A_i = [-k_{i1}] \), \( B_i = [1] \). For the second subsystems:

\[
\dot{e}_2 + k_{i2} e_2 + k_{i3} e_3 = [\hat{f}_2(\mathbf{x}|W_j) - f_2(\mathbf{x})] + (u_n + u_{n_0}) - d_2(\mathbf{x})
\]  

(16)

Define \( e_{i-2} = [e_2, e_3]^T \), then the formula (16) is written as:

\[
\dot{e}_2 = A_2 e_2 + B_2(u_n + u_{n_0}) + B_2[\hat{f}_2(\mathbf{x}|W_j) - f_2(\mathbf{x})] - B_2 d_2(\mathbf{x})
\]  

(17)

where \( A_2 = \begin{bmatrix} 0 & 1 \\ -k_{i2} & -k_{i3} \end{bmatrix} \), \( B_2 = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \)

The minimum approximation error of WNN is defined as:

\[
\varepsilon_i = \hat{f}_i(\mathbf{x}|W_j) - f_i(\mathbf{x}), i = 1, 2
\]  

(18)

The formula (18) is substituted into (15) (17), and considered the formula (1) and (10):

\[
\dot{e}_i = A_i e_i + B_i(u_n + u_{n_0}) + B_i \hat{W}_i \mathbf{P}_i(\mathbf{x}) + B_i \hat{e}_i
\]  

(19)

where \( \hat{W}_i = W_i^* - W_i \), \( \hat{e}_i \) is compound disturbance, \( \hat{e}_i = B_i \hat{e}_i - d_i \).

In order to compensate the approximation error and the effect of load disturbance, at the same time to enhance the robustness of the system, the compensator is designed in the sense of Lyapunov. So the variable structure controller and \( H_\infty \) controller are respectively designed as:
\[ u_{is} = -\rho_i \text{sgn}(B_i^T P_i e_i) \]  

(20)

\[ u_{is} = -\frac{1}{\rho_i} B_i^T P_i e_i \]  

(21)

\( \rho_i > 0 \) refers to the variable structure control gain, \( P_i = P'_i > 0 \) is the solutions of Riccati equation:

\[ A'_i P_i + P_i A_i + Q_i + P_i B_i \frac{1}{\kappa} - \frac{2}{\rho_i} B_i^T P_i = 0 \]  

(22)

\( Q_i = Q'_i > 0 \) is the given weight matrix; \( \kappa > 0 \) represents the interference suppression level. In order to ensure that the equation(22) has a positive definite solution, \( \rho \) and \( \kappa \) should satisfy the inequality

\[ 2\kappa^2 \geq \rho \]  

(23)

Parameter adaptive rate is selected as:

\[ \dot{W}_{ji} = \gamma_f e_i^T P_i B_i \psi_j(x) \]  

(24)

\( \gamma_f > 0, i=1,2 \) is the adaptive learning rate.

### Stability Analysis

**Theorem:** for the given system (4), if the control law is designed as the formula (9), \( (i=1,\ldots,m) \), the wavelet network is used as (7) to identify, the adaptive learning algorithms of the wavelet network is designed as (24), sliding mode variable structure compensor and \( H_\infty \) controller are designed as (20), (21), then the closed-loop system can be satisfied the following performance index:

1. \( \xi \in L_\infty, \lim_{t \to \infty} \xi_i = 0 \)

2. for a given disturbance attenuation level \( \kappa \forall T \in [0, \infty) \), the system’s output tracking error satisfies the following \( H_\infty \) tracking performance index:

\[ \frac{1}{2} \int_{0}^{\infty} e^T_Q e^T e + \frac{1}{2} e^T(0) P e(0) + \sum_{i=1}^{2m} \frac{1}{2\gamma_i} \dot{W}_{ji}(0) W_{ji}(0) + \frac{1}{2} \dot{k}^T \kappa \geq 0 \]  

(25)

where \( e = [e_1, e_2]^T, Q = \text{Diag}(Q_1, Q_2), P = \text{Diag}(P_1, P_2), \varsigma = [\varsigma_1, \ldots, \varsigma_m]^T \).

**Proof:** Define:

\[ V_i(t) = \frac{1}{2} e_i^T P_i e_i + \frac{1}{2\gamma_i} \dot{W}_{ji}^T \dot{W}_{ji} \]  

(26)

Construct Lyapunov function as:

\[ V(t) = V_1(t) + V_2(t) \]  

(27)

Differentiating (27) with respect to time:

\[ \dot{V}(t) = \dot{V}_1(t) + \dot{V}_2(t) \]  

(28)

The 1th component is as:

\[ \dot{V}_1(t) = \frac{1}{2} e_i^T P_i e_i + \frac{1}{2} e_i^T P_i e_i + \frac{1}{\gamma_i} \dot{W}_{ji}^T \dot{W}_{ji} \]  

(29)
Because $\dot{W}_\beta = -\dot{W}_\beta$, according to formula (19) - (21), and adaptive rate (24), (25), we can obtain:

$$\dot{V}(t) = \frac{1}{2} e^T \dot{e} A^T P e + \dot{W}_\beta e^T P e + \frac{1}{2} \dot{e}^T P B B^T P e + \frac{1}{2} \dot{e}^T P B B^T e B P e + \frac{1}{2} \dot{e}^T P B B^T e B P e + \frac{1}{2} \dot{e}^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}{2} \dot{e} e^T P B B^T e B P e + \frac{1}{2} \dot{e} e^T P B B^T e B P e - \frac{1}
Simulation Study

In order to verify the effectiveness of the proposed method, AC tank gun control system is used to simulation research. The robust adaptive control scheme based on WNN is shown in Figure 2[5], in which the WNN is used to reconstruct the unknown part of the system $f_1(x)$ and $f_2(x)$. For the current $i_d$ tracking, according to the tracking error equation, the ratio coefficient is designed as $k_{11}=30$, $A_1=-k_{11}$, $B_1=1$, and select the parameters $\kappa=0.05$, $r=0.001$, $Q_1=1$, according to formula (22) can be obtained $P_1=0.0177$. Therefore, the robust control term can be obtained as $u_{ct}=-R_P e_{ct}/r=-17.7e_t$.

![Figure 2. Robust Adaptive Control System Structure Based on WNN Identifier.](image)

For the speed tracking, the ratio coefficient $k_{21}=350$, differential coefficient $k_{22}=30; \begin{bmatrix} A \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -k_{11} & -k_{22} \end{bmatrix}$, \begin{bmatrix} B \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$, select $\kappa=0.05$, $r=0.001$, $\begin{bmatrix} Q_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$. According to formula (22), $P_2 = \begin{bmatrix} 7884 & 0.0035 \\ 0.0035 & 336 \end{bmatrix}$ can be obtained. Neural network selects 11 hidden layers. Initial conditions: learning rate $\gamma_W=2.0, M_{f1}=10, M_{f2}=15$.

The simulation is obtained from the following situations:

1. Fig.3. (a) and (b) respectively represent the velocity tracking curve and error curve, (c) and (d) represent $f_1(x)$, $f_2(x)$ and their corresponding estimators.

2. Under the system parameters are uncertain, $R_s=1.5R_{sn}$, $R_{sn}$ is the nominal value. Fig.4. (a) and (b) respectively represent the velocity tracking curve and error curve, (c) and (d) represent $f_1(x)$, $f_2(x)$ and their corresponding estimators.

The simulation results show that the adaptive robust control scheme based on WNN has good tracking performance and strong robustness.
Summary

Without knowing the precise tank gun control system mathematical model and parameters, taking advantage of the high precision approximation of WNN, an adaptive $H_{\infty}$ control scheme is presented. The unknown model of the system can be identified by the wavelet neural using the input and output data, and on the sense of Lyapunov the adaptive law of parameters on-line adjustment is designed; On the other hand, the variable structure control shows strong robust to the uncertainty structure and variable parameters, $H_{\infty}$ control can suppress the external disturbances, so the SMCVC and $H_{\infty}$ control is combined to the above WNN adaptive control algorithm. So that the influences of modeling errors and external disturbances can be effectively reduced, and the desired performance index can be obtained. Simulation results show that the proposed method can precisely identify the unknown models in the gun control system, SMVSC and $H_{\infty}$ control can further enhance the system robustness.
References


