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The Design for Robust Controller of Anchoring Fixed-point and Location System

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Abstract: The automatic anchoring location system is a key device for fixed point and location on an ocean platform, however because of particularity in an ocean environment, there is lack of stability, safety and input delay, constraint. Therefore this paper took advantage of switchovers among anchoring machines with three chains gear to obtain the control for 12 anchor chains by four anchoring machines and designed the main controller by robust control law with section lag to resist against environmental disturbance at horizontal direction accordingly to gain the steadiness and safety. The validity and superiority in just mention were confirmed by the simulation.

Keywords: Fixed-point and location; robust controller; design

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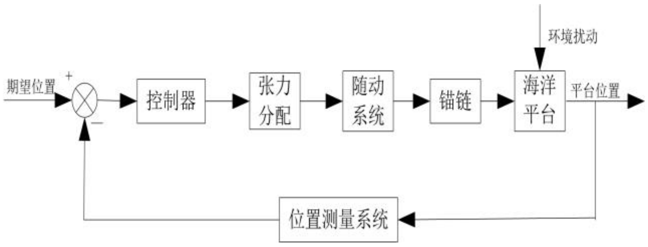

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Fig.1 Principle of anchoring fixed point and location system

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$$\begin{cases} \dot{\eta} = (\psi) \\ M \dot{} + D = + () \end{cases} \quad (1)$$

$=[\ ,\ ,\varphi]$ $=[\ ,\ ,\ ]$ [

( ) M

D $=[F, F, N]$

$\in$ 3)

$= (\ ) \cong I$

1

$$\begin{cases} \dot{\boldsymbol{x}}(\boldsymbol{t}) = \boldsymbol{A}\boldsymbol{x}(\boldsymbol{t}) + \boldsymbol{B}\boldsymbol{u}(\boldsymbol{t}-\tau) \quad \boldsymbol{B}\boldsymbol{w}(\boldsymbol{t}) \\ \boldsymbol{x}(\boldsymbol{t}) = \varphi(\boldsymbol{t}), \boldsymbol{t} \in [-\tau, 0] \end{cases} \quad (2)$$

$=[\ ,\ ]$ (-)

( ) $A = \begin{pmatrix} -M^{-1}D & 0_{3\ 3} \\ I_{3\ 3} & 0_{3\ 3} \end{pmatrix} \quad B = \begin{pmatrix} M^{-1} \\ 0_{3\ 3} \end{pmatrix}$ $\varphi()$

( ) $0 \le \tau_1 \le \tau(\ ) \le \tau_2, \dot{\tau}(\ ) \le \mu \ \ \tau_1 \ \tau_2, \mu$

1 0 $|\ (\ )| \le \ _{max}$ (3)

2

$$e(\ ) = y(\ ) - y_{\mathrm{d}} = x(\ ) - y_{\mathrm{d}}$$

$$(\ )=K\ (\ )+\ (\ ) \tag{4}$$

$$(\ -\tau(\ )) = K\ (\ -\tau(\ )) + \upsilon(\ -\tau(\ )) \qquad \boldsymbol{\upsilon}(\ -\tau) = -B^{+}A\ {}_{d}$$

$$\dot{}(\ ) = A(\ (\ )+\ \ ) + B(K\ (\ -\tau(\ )) + \boldsymbol{\upsilon}(\ -\tau(\ ))) + B\ \ (\ ) = A\ (\ ) + BK\ (\ -\tau(\ )) + B\ \ (\ ) \tag{5}$$

1 $0 \le \tau_1 < \tau_2$, $\rho > 0$, μ λ_2 $\lambda_3 \neq 0$

P, $\boldsymbol{Q}\ (\ =1,2,3)$, $\boldsymbol{R}\ (\ =1,2)$, $\boldsymbol{T}\ (\ =1,2,3)$ $M\ , N\ , \boldsymbol{S}\ (\ =1,\cdots,4)$

$$\psi = \begin{bmatrix} \psi & \psi & N+M & N- & \psi & B & \tau N & \tau & \tau M \\ * & \psi & \psi & \psi & \psi & B & \tau N & \tau & \tau M \\ * & * & -Q+M+M & -\ +M & M & & \tau N & \tau & \tau M \\ * & * & * & -Q-\ - & & & \tau N & \tau & \tau M \\ * & * & * & * & \psi & B & \tau & \tau & \tau M \\ * & * & * & * & * & -\gamma I & & & \\ * & * & * & * & * & * & -\tau & & \\ * & * & * & * & * & * & * & -\tau(\ +\ ) & \\ * & * & * & * & * & * & * & * & -\tau \end{bmatrix} < \tag{6}$$

$$\begin{bmatrix} \boldsymbol{-I} & \sqrt{\varepsilon}\boldsymbol{K} \\ * & -\ {}^{2}_{\max}\boldsymbol{P} \end{bmatrix} < 0 \tag{7}$$

6

$\boldsymbol{w}(\ ) = 0$ Lyapunov

$$(\ ) = {}^{\mathrm{T}}(\ )P\ (\ ) + \sum_{=1}^{2}\int_{-\tau} {}^{\mathrm{T}}(\ )Q\ (\ )\mathrm{d}\ + \int_{-\tau(\ )} {}^{\mathrm{T}}(\ )Q_3\ (\ )\mathrm{d}\ + \int_{-\tau_2}^{0}\int_{+\theta} \dot{}^{\mathrm{T}}(\ )\ {}_1\dot{}(\ )\mathrm{d}\ \mathrm{d}\theta + \int_{-\tau_2}^{-\tau_1}\int_{+\theta} \dot{}^{\mathrm{T}}(\ )\ {}_2\dot{}(\ )\mathrm{d}\ \mathrm{d}\theta \tag{8}$$

$P = P^{\mathrm{T}} > 0$, $Q = Q^{\mathrm{T}} > 0$, $=1,2,3$ $\ = {}^{\mathrm{T}} > 0$ $=1,2$ $V(\ )$

$$\dot{}(\ ) = 2\ {}^{\mathrm{T}}(\ )\ \dot{}(\ ) + \sum_{=1}^{2}[\ {}^{\mathrm{T}}(\ )Q\ (\ ) - {}^{\mathrm{T}}(\ -\tau\ )Q\boldsymbol{e}(\ -\tau\ )] + {}^{\mathrm{T}}(\ )Q_3\ (\ ) - (1-\dot{\tau}(\ ))\ {}^{\mathrm{T}}(\ -\tau(\ ))Q_3\ (\ -\tau(\ )) \tag{9}$$

$$+\tau_2\ \dot{}^{\mathrm{T}}(\ )\ {}_1\dot{}(\ ) - \int_{-\tau_2} \dot{}^{\mathrm{T}}(\ )\ {}_1\dot{}(\ )\mathrm{d}\ + (\tau_2-\tau_1)\ \dot{}^{\mathrm{T}}(\ )\ {}_2\dot{}(\ ) - \int_{-\tau_2}^{-\tau_1} \dot{}^{\mathrm{T}}(\ )\ {}_2\dot{}(\ )\mathrm{d}$$

- (13)

$$\dot{}(\ ) \le \zeta^{\mathrm{T}}(\ )[\psi + \tau_2 N\ {}_1^{-1}N^{\mathrm{T}} + \tau_{12}\ (\ {}_1 +\ {}_2)^{-1}\ {}^{\mathrm{T}} + \tau_{12}M\ {}_2^{-1}M^{\mathrm{T}}]\zeta(\ ) \tag{10}$$

Schur (7) $\psi + \tau_2 N\ {}_1^{-1}N^{\mathrm{T}} + \tau_{12}\ (\ {}_1 +\ {}_2)^{-1}\ {}^{\mathrm{T}} + \tau_{12}M\ {}_2^{-1}M^{\mathrm{T}} < 0$

$\dot{}(\ ) < 0$ (7) $(\ ) = 0$

$(\ ) \neq 0$ 10 Lyapunov

$\dot{}(\ )$

$$\dot{}(\ ) - {}^{\mathrm{T}}(\ )\ (\ ) \le \zeta(\ )[\tilde{\psi} + \tau_2\tilde{N}\ {}_1^{-1}\tilde{N}^{\mathrm{T}} + \tau_{12}\ (\ {}_1 +\ {}_2)^{-1}\ {}^{\mathrm{T}} + \tau_{12}\ {}_2^{-1}\tilde{M}^{\mathrm{T}} + \psi_7]\tilde{\zeta}(\ )$$

$$- \int_{-\tau(\ )} [\tilde{\zeta}^{\mathrm{T}}(\ )\tilde{N} + \dot{}^{\mathrm{T}}(\ )\ {}_1]\ {}^{-1}[\tilde{N}^{\mathrm{T}}\tilde{\zeta}(\ ) +\ {}_1\dot{}(\ )]\mathrm{d}\ - \int_{-\tau_2}^{-\tau(\ )} [\tilde{\zeta}^{\mathrm{T}}(\ ) + \dot{}^{\mathrm{T}}(\ )(\ {}_1 +\ {}_2)] \tag{11}$$

$$\times(\ {}_1 +\ {}_2)^{-1}[\ {}^{\mathrm{T}}\tilde{\zeta}(\ ) + (\ {}_1 +\ {}_2)\dot{}(\ )]\mathrm{d}\ - \int_{-\tau(\ )}^{-\tau_1} [\tilde{\zeta}^{\mathrm{T}}(\ )\tilde{M} + \dot{}^{\mathrm{T}}(\ )\ {}_2]\ {}_2^{-1}[\tilde{M}^{\mathrm{T}}\tilde{\zeta}(\ ) +\ {}_2\dot{}(\ )]\mathrm{d}$$

Schur 7

$\psi + A^{\mathrm{T}}(\tau_2 \quad _1 + \tau_{12} \quad _2)A + \tau_2 N \quad _1^{-1} N^{\mathrm{T}} + \tau_{12} \quad (\quad _1 + \quad _2)^{-1} \quad ^{\mathrm{T}} + \tau_{12} M \quad _2^{-1} M^{\mathrm{T}} < 0$ 12

$$\dot{}(\;) - \gamma^2 \quad ^{\mathrm{T}}(\;) \quad (\;) < 0 \tag{12}$$

(15) 0

$$(\;) - \quad (0) < \gamma^2 \int_0 \quad ^{\mathrm{T}}(\;) \quad (\;) \quad < \gamma^2 \| \quad \|_2^2 \tag{13}$$

(11) 0 $(\;)P(\;) < \varepsilon$ $\varepsilon = \gamma^2 \quad _{\max} + \quad (0)$ $> \tau(\;)$

$^{\mathrm{T}}(\; - \tau(\;))P \; (\; - \tau(\;)) < \varepsilon$

$$\max_{>0} \left| \; (\;) \right|^2 < \max_{>\mathrm{d}(\;)} \left\| \; ^{\mathrm{T}}(\; - \tau(\;)) K^{\mathrm{T}} K \; (\; - \tau(\;)) \right\|_2 < \varepsilon \cdot \theta_{\max}(P^{-1/2} K^{\mathrm{T}} K P^{-1/2}) \tag{14}$$

$\theta_{\max}(\cdot)$ 15 (4)

$$\varepsilon \cdot P^{-1/2} K^{\mathrm{T}} K P^{-1/2} < \; ^2_{\max} I \tag{15}$$

Schur 15 (7)

2 $0 \le \tau_1 < \tau_2$, $\varepsilon > 0$, μ $\lambda_2 \quad \lambda_3 \ne 0$ $\bar{P}$, $\bar{\boldsymbol{Q}}$, $\bar{\boldsymbol{R}}$, $\boldsymbol{X}$, $\bar{\boldsymbol{M}}$, $\bar{\boldsymbol{N}}$, $\bar{\boldsymbol{S}}$ ($= 1, \cdots, 4$), $\boldsymbol{Y}$

$$\bar{\psi} = \begin{bmatrix} \bar{\psi}_{11} & \bar{\psi}_{12} & \bar{N}_3^{\mathrm{T}} + \bar{M} & \bar{N}_4^{\mathrm{T}} - \bar{\;}_1 & \bar{\psi}_{15} & B & \tau_2 \bar{N}_1 & \tau_{12} \bar{\;}_1 & \tau_{12} \bar{M}_1 \\ * & \bar{\psi}_{22} & \bar{\psi}_{23} & \bar{\psi}_{24} & \bar{\psi}_{25} & \lambda_2 B & \tau_2 \bar{N}_2 & \tau_{12} \bar{\;}_2 & \tau_{12} \bar{M}_2 \\ * & * & -\bar{Q}_1 + \bar{M}_3 + \bar{M}_3^{\mathrm{T}} & -\bar{\;}_3 + \bar{M}_4^{\mathrm{T}} & \bar{M}_5^{\mathrm{T}} & \boldsymbol{0} & \tau_2 \bar{N}_3 & \tau_{12} \bar{\;}_3 & \tau_{12} \bar{M}_3 \\ * & * & * & -\bar{Q}_2 - \bar{\;}_4 - \bar{\;}_4^{\mathrm{T}} & \bar{\;}_5^{\mathrm{T}} & \boldsymbol{0} & \tau_2 \bar{N}_4 & \tau_{12} \bar{\;}_4 & \tau_{12} \bar{M}_4 \\ * & * & * & * & \bar{\psi}_{55} & \lambda_3 B & \tau_2 \bar{N}_5 & \tau_{12} \bar{\;}_5 & \tau_{12} \bar{M}_5 \\ * & * & * & * & * & -\gamma^2 I & \boldsymbol{0} & \boldsymbol{0} & \boldsymbol{0} \\ * & * & * & * & * & * & -\tau_2 \bar{\;}_1 & \boldsymbol{0} & \boldsymbol{0} \\ * & * & * & * & * & * & * & -\tau_{12}(\bar{\;}_1 + \bar{\;}_2) & \boldsymbol{0} \\ * & * & * & * & * & * & * & * & -\tau_{12} \bar{\;}_2 \end{bmatrix} < 0 \tag{16}$$

$$\begin{bmatrix} -I & \sqrt{\varepsilon} \\ * & - \; ^2_{\max} \end{bmatrix} < 0 \tag{17}$$

$\bar{\psi}_{11} = A \quad + \quad A^{\mathrm{T}} + \sum_{=1}^{3} \bar{Q}_i + \bar{N}_1 + \bar{N}_1^{\mathrm{T}}$ $\bar{\psi}_{12} = B \quad + \lambda_2 \quad A^{\mathrm{T}} - \bar{N}_1 + \bar{N}_2^{\mathrm{T}} + \bar{\;}_1 - \bar{M}_1$

$\bar{\psi}_{15} = \bar{P} + N_5^{\mathrm{T}} + \lambda_3 \quad A^{\mathrm{T}} - \quad ^{\mathrm{T}}$ $\bar{\psi}_{22} = -(1-\mu)\bar{Q}_3 - \bar{N}_2 - \bar{N}_2^{\mathrm{T}} + \bar{\;}_2 + \bar{\;}_2^{\mathrm{T}} - \bar{M}_2 - \bar{M}_2^{\mathrm{T}} + \lambda_2 B \quad + \lambda_2 \quad ^{\mathrm{T}} B^{\mathrm{T}}$

$\bar{\psi}_{23} = -\bar{N}_3^{\mathrm{T}} + \bar{\;}_3^{\mathrm{T}} + \bar{M}_2 - \bar{M}_3^{\mathrm{T}}$ $\bar{\psi}_{24} = -\bar{N}_4^{\mathrm{T}} - \bar{\;}_2 + \bar{\;}_4^{\mathrm{T}} - \bar{M}_4^{\mathrm{T}}$ $\bar{\psi}_{25} = -\bar{N}_5^{\mathrm{T}} + \bar{\;}_5^{\mathrm{T}} - \bar{M}_5^{\mathrm{T}} - \lambda_2 \quad ^{\mathrm{T}} + \lambda_3 \quad ^{\mathrm{T}} B^{\mathrm{T}}$

$\bar{\psi}_{55} = -\tau_2 \bar{\;}_1 + \tau_{12} \bar{\;}_2 - 2\lambda_3 \quad ^{\mathrm{T}}$

$(\;) = \quad ^{-1}(\;) - B^{+} A \boldsymbol{y}_{\mathrm{d}}$ (2)

1 $= \; _1^{-1}$ $= K$ $\bar{Q} = \quad Q$ $\bar{\;} =$

$\bar{N} = \quad N$ $\bar{\;} =$ $\bar{M} = \quad M$ $= \lambda_i \; _1$ (7) 2

3

7 m 26.3 m/s 1.03 m/s

LMI [11]

$$M = \begin{bmatrix} 1.0653 & 0 & 0 \\ 0 & 2.0672 & -0.4093 \\ 0 & -0.4093 & 0.2108 \end{bmatrix} \quad D = \begin{bmatrix} 0.0853 & 0 & 0 \\ 0 & 0.0772 & 0.0153 \\ 0 & 0.0153 & 0.0048 \end{bmatrix}$$

$\lambda_2=0.05,\lambda_3=50,\varepsilon=1,\mu=0.9$ $\tau_1=2$ $\tau_2=2.3$

$$K= \quad {}^{-1}=\begin{bmatrix} -0.0642 & -0.0881 & 0.0736 & 0.2253 & 0.1470 & -0.1718 \\ -0.0324 & -0.2881 & 0.1921 & 0.1451 & 0.6275 & -0.4611 \\ 0.0049 & 0.0547 & -0.0450 & -0.0283 & -0.1191 & 0.1112 \end{bmatrix}$$

$$\boldsymbol{u}(\ )=\boldsymbol{YX}^{-1}\boldsymbol{e}(\ )-\boldsymbol{B}^{+}\boldsymbol{A}\boldsymbol{y}_{\mathrm{d}}=\boldsymbol{Ke}(\ )-\begin{bmatrix} -0.0853 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.0772 & -0.0152 & 0 & 0 & 0 \\ 0 & -0.0153 & -0.0048 & 0 & 0 & 0 \end{bmatrix}\boldsymbol{y}_{\mathrm{d}}$$

=[0 2 0 1 0 0]

2

$_2$=6.8674 s

$'_2$=2.33 s

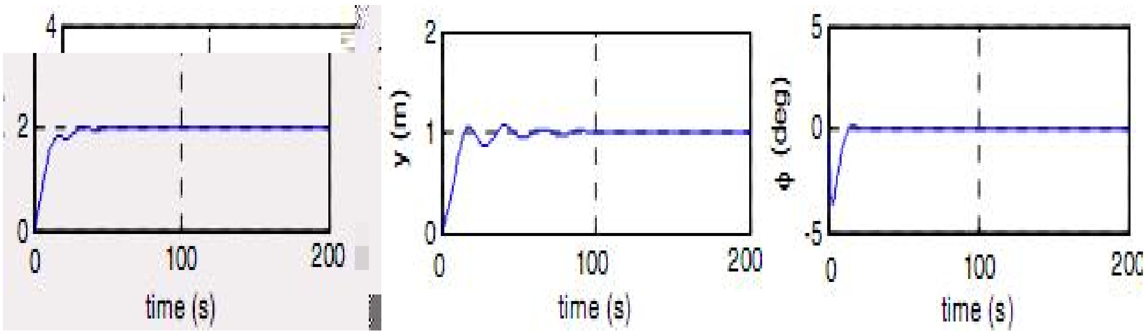

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Fig.2 Position output of the platform in horizontal direction

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Lyapunov Lyapunov

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