Stability Control Design of Sigma Class Ship Firing Mode using Fuzzy Gain Scheduling-PID

Ii Munadhif[1], Aulia Siti Aisjah[1], A.A. Masroeri[2]

***Abstract** – Sigma class ship of Hasanuddin 366 is one of Indonesian battle ship. When the ship operates, shipwreck can be happened because impact force disturbance can increase the angle of yaw and roll. In this research, the system of rudder roll stabilization is designed to keep the ship heading/yaw and decrease the roll angle using ship nonlinear dynamic model of 4 degree of freedom (DOF) that contains surge, sway, yaw, and roll. Fuzzy gain scheduling–PID (FGS-PID) controller is used to control rudder angle as the steering control. The value of the cannon impact force disturbance is 1062.525 Newton with angle variation of 30^o from the direction of ship surge. The FGS-PID controller is compared with the PID Ziegler Nichols (PID-ZN) controller as reliability test. According to simulation result, the FGS-PID controller is better than PID-ZN in keeping the heading and decreasing the roll. The performance of FGS-PID controller with heading input of 20^o and 30^o is compatible with the stability parameter of IMO (International Maritime Organization).*

***Index Terms** – KRI Hasanuddin 366, rudder roll stabilisation, 4DOF, FGS-PID controller, PID-ZN controller.*

INTRODUCTION

KRI Hasanuddin 366 is one of Indonesian battleship that is used in maritime defense [1]. Great maneuvering capability is needed in this ship to keep the ships stability. The steering/rudder system is the actuator to control ship heading/yaw angle and decrease ship roll angle. In operating mode, the threshold standard of this battle ship are 28^o of ship dynamic rolling trim angle and wave disturbance of sea state 6 [2]. In this research, the system uses the Otomelara 76 as model of cannon impact force internal disturbance. FGS-PID is used as controller by using its capability to adapt in environment change and its ability to determine PID parameters in order to decrease the error signal to the desired value [3].

METHOD

A. The Specification Data of KRI Hasanuddin 366

The detail of KRI Hasanuddin 366 specification is described in table 1.

Table 1. Ship Specification Data [2].

Specification	Size
Overall Length of the Ship (L_{OA})	90.71 m
Length between perpendiculars (L_{pp})	84 m
Breadth (B)	13.02 m
Breadth of the Waterline (B_{WL})	12.21 m
Mass of Ship (m)	1.818x10^{6}Kg
Velocity (U)	9.53 m/s
Draught (D)	3.5 m
Volume of Displacement (∇)	1793 m^3
Coefficient Block (CB)	0.491
Nominal inertia in roll (I_{xx})	2.43x10^{7}Kgm^2
Nominal inertia in yaw (I_{zz})	1.07x10^{8}Kgm^2

B. The Ship Model

Perez [4] ship nonlinear dynamic model of 4 degree of freedom (DOF) is used. The model is then transformed into the state space matrix.

$$\begin{bmatrix} \dot{v} \\ \dot{p} \\ \dot{r} \\ \dot{\phi} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} -0.8563 & 0.026367 & 0.889808 & 1.351474 & 0 \\ 0.006979 & -0.121443 & -0.137992 & -6.249712 & 0 \\ 0.000447 & 0.00005 & 0.006931 & 0.0003715 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} v \\ p \\ r \\ \phi \\ \psi \end{bmatrix} + \begin{bmatrix} 0.420918 \\ 0.023502 \\ 0.008185 \\ 0 \\ 0 \end{bmatrix} \delta \quad (1)$$

C. Cannon Impact Force Disturbance Model

The principal of the third Newton Law is used to determine the firing cannon impact force.
Cannonball specification:
Cannonball velocity (V_p) = 442.7188 m/s,
Impact force / impulse force (Fi) = 1062.525 N
Horizontal direction force (Fa) of $Fi = Fi\cos45$ = 751.318 N. If ai = 30^o , then $Fsway = Fa\sin30$ = 375.659 N

D. Rudder Model

The Rudder type of sigma class battle ship that is considered in this research is the type of Van Amorengen with rudder limiter of -35° – 35° and rudder rate limiter of -7°/s – 7°/s [5].

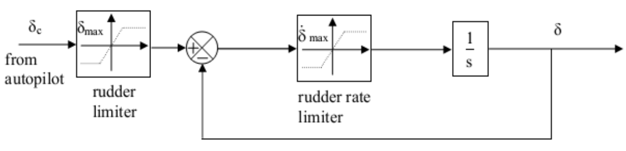

Figure 1. Rudder block diagram

E. Rudder Roll Stabilization

Rudder roll stabilization is one of the devices to control the angle of yaw and roll. The rudder signal is the additions result of the output of yaw and roll controller. The rudder roll stabilization block diagram is shown in figure 2.

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[1]Ii Munadhif and Aulia Siti Aisjah are with Department of Engineering Physics, Faculty of Industrial Engineering, Institut Teknologi Sepuluh Nopember, Surabaya. Email: iimunadhif.its@gmail.com; auliasa@ep.its.ac.id.
[2]A.A. Masroeri is with Departement of Naval Architecture, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Surabaya. Email : mesroeri@its.ac.id,

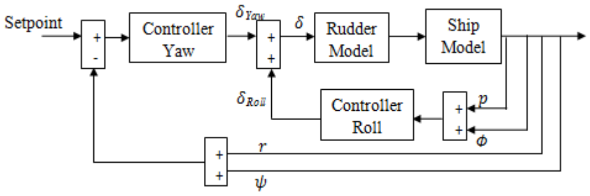

Figure 2. Rudder roll stabilization block diagram

RESULT AND DISCUSSION

The close loop system uses the step function as input. The regulation of International Maritime Organization (IMO) states the heading angle input to be 20° and 30°. This simulation uses the heading angle input of 30°. The cannon is assumed to be fired once with 2 seconds of time delay after the heading has started. Figure 3 and 4 show the response of cannon impact disturbance of yaw and roll.

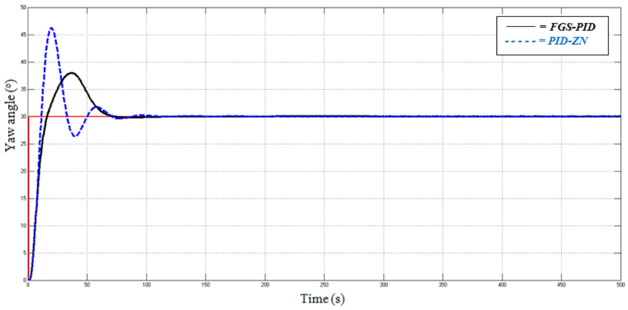

Figure 3. Yaw response of cannon impact disturbance 30° heading 30°.

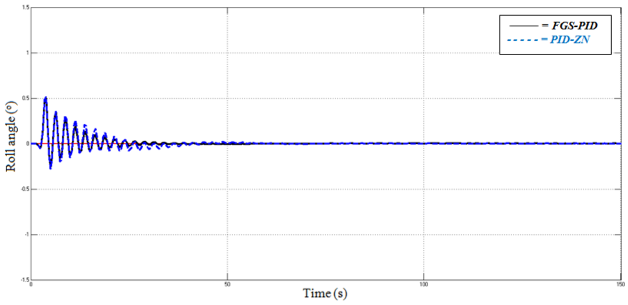

Figure 4. Roll response of cannon impact disturbance 30° heading 30°.

Table 2. Response of disturbance 30° and wave state 1

Controller	Maximum *over shoot* (%)	Settling time (s)	RMSE *yaw over all*	*Roll steady state* (s)
FGS-PID	26.556	64.694	4.599	42
PID-ZN	54.07	67.228	9.656	66

Figure 3 and 4 and table 2 shows that FGS-PID controller is more reliable since its maximum overshoot and the RMSE yaw over all are less, and also the settling time and roll steady state are faster than the result of PID-ZN controller.

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