LAMPIRAN A
PEMODELAN DINAMIKA KAPAL

Dinamika kapal dimodelkan berdasar dari spesifikasi kapal. Kapal yang digunakan adalah kapal PKR KRI Diponegoro Kelas SIGMA. Berikut spesifikasi umum dari kapal PKR KRI Diponegoro Kelas SIGMA:

L_{pp} = 90.71 m
B = 13.02 m
T = 3.75 m
Δ = 1818 ton
U = 14 m/s
C_B= 0.41
X_G = 2.25
A_δ = 3.14 m^2
r = 12.28 m
m'= 0.00000654

Pemodelan dilakukan berdasarkan model matematik ysng diturunkan Nomoto:

$$\frac{-Y'_{\dot{v}}}{\pi(T/L)^2} = 1 + 0.16\frac{C_B B}{T} - 5.1\left(\frac{B}{L}\right)^2$$

$$\frac{-Y'_{\dot{r}}}{\pi(T/L)^2} = 0.67\left(\frac{B}{L}\right) - 0.0033\left(\frac{B}{T}\right)^2$$

$$\frac{-N'_{\dot{v}}}{\pi(T/L)^2} = 1.1\left(\frac{B}{L}\right) - 0.041\left(\frac{B}{T}\right)$$

$$\frac{-N'_{\dot{r}}}{\pi(T/L)^2} = \frac{1}{12} + 0.017\frac{C_B B}{T} - 0.33\left(\frac{B}{L}\right)$$

$$\frac{-Y'_v}{\pi(T/L)^2} = 1 + 0.4\frac{C_B B}{T}$$

$$\frac{-Y'_r}{\pi(T/L)^2} = -\frac{1}{2} + 2.2\left(\frac{B}{L}\right) - 0.08\left(\frac{B}{T}\right)$$

$$\frac{-N'_v}{\pi(T/L)^2} = \frac{1}{2} + 2.4\left(\frac{T}{L}\right)$$

$$\frac{-N'_r}{\pi(T/L)^2} = \frac{1}{4} + 0.039\frac{B}{T} - 0.56\left(\frac{B}{L}\right)$$

Berdasar spesifikasi yang diketahui, koefisien-koefisien tak berdimensi dengan notasi (') dapat diketahui.

$\boldsymbol{Y'_{\dot{v}}}$	$\boldsymbol{Y'_{\dot{r}}}$	$\boldsymbol{N'_{\dot{v}}}$	$\boldsymbol{N'_{\dot{r}}}$
-0.00603	-0.000303	-0.0000834	-0.000321
$\boldsymbol{Y'_v}$	$\boldsymbol{Y'_r}$	$\boldsymbol{N'_v}$	$\boldsymbol{N'_r}$
-0.00843	0.00248	-0.00322	-0.00164
$\boldsymbol{Y'_\partial}$	$\boldsymbol{N'_\partial}$	$\boldsymbol{I'_z}$	$\boldsymbol{I'_r}$
12.566	-6.283	0.00099	0.00099

Kemudian dapat dibentuk menjadi matrik sebagai berikut:

M'=	$m' - Y'_{\dot{v}}$	$m'.X_G - Y'_{\dot{r}}$
	$m'.X_G - N'_{\dot{v}}$	$I'_z - N'_{\dot{r}}$
M'=	0.00603	0.000303
	0.0000835	0.00131

N'=	$-Y'_v$	$m'u' - Y'_r$
	$-N'_v$	$m'.X_G.u' - N'_r$
N'=	0.00843	-0.00239
	0.00322	0.00164

Matrik di atas dilinierisasi menjadi

M=	m'11 x L/U^2	m'12 x L^2/U^2
	m'21 x L/U^2	m'22 x L^2/U^2
M=	0.00264	0.012
	0.0000365	0.0519

N=	n'11 /U	n'12 x L/U
	n'21/ U	n'22 x L/U
N=	0.000585	-0.015
	0.000223	0.0103

Determinan dari matrik M dan N adalah sebagai berikut:

det(M)	0.0001366
det(N)	0.00009397

Persamaan di bawah ini digunakan untuk mencari fungsi transfer kapal berdasar pada pehitungan di atas.

$$\frac{\psi}{\delta_R}(s) = \frac{K_R(1+T_3 s)}{s(1+T_1 s)(1+T_2 s)}$$

$$T_1 T_2 = \frac{\det(M)}{\det(N)}$$

$$T_1 + T_2 = \frac{n_{11}m_{22} + n_{22}m_{11} - n_{12}m_{21} - n_{21}m_{12}}{\det(N)}$$

$$K_R = \frac{n_{21}b_1 - n_{11}b_2}{\det(N)}$$

$$K_R T_3 = \frac{m_{21}b_1 - m_{11}b_2}{\det(N)}$$

T_1T_2	$T_1 + T_2$	K_R	K_RT_3
14.539	5.907	403.378	1060.369

Sehingga dapat diperoleh model dinamika kapal Ferry:

$$\frac{\psi}{\delta_R}(s)=\frac{1060.369+403.378s}{14.539s^3+5.907s^2+s}$$

LAMPIRAN B
PEMODELAN GANGGUAN KAPAL

Gangguan yang digunakan pada tugas akhir ini adalah gelombang laut state satu sampai tujuh. Gangguan gelombang laut bersifat mendorong kapal saat berlayar di lautan. Pemodelan gangguan gelombang lau state satu sampai tujuh adalah sebagai berikut:

Kode	Deskripsi	Ketinggian (m)
0	Calm (glassy)	0
1	Calm (rippled)	0-0.1
2	Smooth (wavelest)	0.1-0.5
3	Sligth	0.5-1.25
4	Moderate	1.25-2.5
5	Rough	2.5-4
6	Very rough	4-6
7	High	6-9
8	Very High	9-14
9	Phenomenal	>14

Wave height, m	Wave Period T_1, sec 2.5	6.5	8.5	10.5	12.5	14.5	16.5	18.5	20.5	Over 21	Total
0-1	24.0470	4.6416	0.9954	0.3316	0.1253	0.0440	0.0245	0.0147	0.1041	0.5480	30.8762
1-2	15.5208	17.0941	6.1091	1.7475	0.5498	0.1784	0.0626	0.0175	0.0194	0.0910	41.3902
2-3	1.3763	6.0543	6.0000	2.6736	0.8712	0.2668	0.0778	0.0188	0.0054	0.0057	17.3499
3-4	0.2008	1.2153	2.1165	1.6245	0.7848	0.2611	0.0817	0.0226	0.0026	0.0030	6.3129
4-5	0.0506	0.3278	0.6969	0.6998	0.4151	0.1726	0.0687	0.0196	0.0033	0.0020	2.4564
5-6	0.0187	0.0604	0.1469	0.1614	0.1063	0.0509	0.0180	0.0033	0.0012	0.0014	0.5685
6-7	0.0158	0.0587	0.1275	0.1551	0.1039	0.0490	0.0215	0.0039	0.0010	0.0011	0.5375
7-8	0.0032	0.0240	0.0622	0.0702	0.0501	0.0249	0.0120	0.0026	0.0008	0.0012	0.2512
8-9	0.0028	0.0102	0.0266	0.0380	0.0311	0.0169	0.0084	0.0018	0.0013	0.0011	0.1382
9-10	0.0013	0.0064	0.0182	0.0308	0.0247	0.0174	0.0093	0.0041	0.0022	0.0012	0.1156
10-11		0.0003	0.0002	0.0006	0.0006	0.0003	0.0001	0.0001			0.0022
11+		0.0001	0.0001	0.0004	0.0007			0.0001			0.0014
Totals	41.2373	29.4932	16.2996	7.5335	3.0636	1.0823	0.3846	0.1090	0.1414	0.6557	100.000

Gangguan Gelombang Sea State 1, Calm Water (0-0,1m) dan Gangguan Gelombang Sea State 2, Smooth Water (0,1-0,5m)

$\omega_0 = \frac{2\pi}{T} = \frac{2\ (3{,}14)}{2{,}5} = 2{,}512$

$K\omega = 2\ \xi\ \omega_0\ \sigma_m$

$= 2\ (0{,}1)(\ 2{,}512)(3{,}16)$

$= 1{,}8086$

$$h(s) = \frac{K\omega s}{s^2 + 2\xi\omega 0 s + {\omega_0}^2}$$

$$h(s) = \frac{1{,}8086s}{s^2 + 2(0{,}1)(2{,}512)s + (2{,}512)^2}$$

$$h(s) = \frac{1{,}8086s}{s^2 + 0{,}5024s + 6{,}31}$$

Gangguan Gelombang Sea State 3, Slight Water (0,5 – 1,25m) dan Gangguan Gelombang Sea State 4, Moderate Water (1,25 – 2,5m)

$\omega_0 = \frac{2\pi}{T} = \frac{2\ (3{,}14)}{6{,}5} = 0{,}966$

$K\omega = 2\ \xi\ \omega_0\ \sigma_m$

$= 2\ (0{,}1)(\ 0{,}6105)(3{,}16)$

$= 0{,}6105$

$$h(s) = \frac{K\omega s}{s^2 + 2\xi\omega 0 s + {\omega_0}^2}$$

$$h(s) = \frac{0{,}6105s}{s^2 + 2(0{,}1)(0{,}966)s + (0{,}966)^2}$$

$$h(s) = \frac{0{,}6105s}{s^2 + 0{,}1932s + 0{,}933}$$

Gangguan Gelombang Sea State 5, Rought Water (2,5 – 4m)

$\omega_0 = \frac{2\pi}{T} = \frac{2\ (3{,}14)}{8{,}5} = 0{,}738$

$K\omega = 2\ \xi\ \omega_0\ \sigma_m$

$= 2\ (0{,}1)(\ 0{,}738)(3{,}16)$

$= 0{,}4664$

$$h(s) = \frac{K\omega s}{s^2 + 2\xi\omega 0 s + {\omega_0}^2}$$

$$h(s) = \frac{0{,}4664s}{s^2 + 2(0{,}1)(0{,}738)s + (0{,}738)^2}$$

$$h(s) = \frac{0{,}4664s}{s^2 + 0{,}1476s + 0{,}544}$$

Gangguan Gelombang Sea State 6, Very Rought Water (4 – 6m) dan Gangguan Gelombang Sea State 7, high Water (6 – 9m)

$\omega_0 = \frac{2\pi}{T} = \frac{2\ (3{,}14)}{10{,}5} = 0{,}598$

$K\omega$ $= 2\ \xi\ \omega_0\ \sigma_m$

$= 2\ (0{,}1)(\ 0{,}598)(3{,}16)$

$= 0{,}3779$

$$h(s) = \frac{K\omega s}{s^2 + 2\xi\omega 0 s + {\omega_0}^2}$$

$$h(s) = \frac{0{,}3779s}{s^2 + 2(0{,}1)(0{,}598)s + (0{,}598)^2}$$

$$h(s) = \frac{0{,}3779s}{s^2 + 0{,}1196s + 0{,}346}$$

LAMPIRAN C
PEMODELAN ROLL DAMPER

$M\dot{\nu} + N\nu + G\eta = Bu$

Dimana $\nu = [v, p, r]^T$ dan $\eta = [y, \phi, \psi]^T$ adalah keadaan dan $u = [\alpha, \delta]^T$ adalah vektor kontrol

$$M = \begin{bmatrix} m - Y_{\dot{v}} & -mz_G - Y_{\dot{p}} & mx_G - Y_{\dot{r}} \\ -mz_G - Y_{\dot{v}} & I_x - K_{\dot{p}} & mx_G - K_{\dot{r}} \\ mx_G - N_{\dot{v}} & mx_G - N_{\dot{p}} & I_z - N_{\dot{r}} \end{bmatrix}$$

$$N = \begin{bmatrix} -Y_v & -Y_p & mu_o - Y_r \\ -K_v & -K_p & -mz_G u_o - K_r \\ -N_v & -N_p & mx_G u_o - N_r \end{bmatrix}$$

$$G = \begin{bmatrix} 0 & 0 & 0 \\ 0 & W\overline{GM_T} & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} Y_\alpha & Y_\delta \\ K_\alpha & K_\delta \\ N_\alpha & N_\delta \end{bmatrix}$$

$\boldsymbol{Y'_{\dot{v}}}$	$\boldsymbol{Y'_{\dot{r}}}$	$\boldsymbol{N'_{\dot{v}}}$	$\boldsymbol{N'_{\dot{r}}}$
-0.00603	-0.000303	-0.0000834	-0.000321
$\boldsymbol{Y'_{v}}$	$\boldsymbol{Y'_{r}}$	$\boldsymbol{N'_{v}}$	$\boldsymbol{N'_{r}}$
-0.00843	0.00248	-0.00322	-0.00164
$\boldsymbol{Y'_{\delta}}$	$\boldsymbol{N'_{\delta}}$	$\boldsymbol{I'_{z}}$	$\boldsymbol{I'_{r}}$
12.566	-6.283	0.00099	0.00099
$\boldsymbol{K'_{\delta}}$	$\boldsymbol{Y'_{p}}$	$\boldsymbol{K'_{p}}$	$\boldsymbol{N'_{p}}$
-0.02375	0.000062	0.000062	0.000062
$\boldsymbol{K_{\alpha}}$	$\boldsymbol{Y_{\alpha}}$	$\boldsymbol{N_{\alpha}}$	$\boldsymbol{K'_{\dot{p}}}$
0.001	0.001	0.001	0.000006
		$\boldsymbol{K'_{\dot{v}}}$	

$\boldsymbol{Y'_{\dot{p}}}$	$\boldsymbol{N'_{\dot{p}}}$	0.000006	$\boldsymbol{K'_{v}}$
0.000006	0.000006		0.00006

$$M = \begin{bmatrix} 1818.007 & 9544.49 & 9544.5 \\ 0.000028 & 0.00098 & 0.000028 \\ 9544.50 & 9544.49 & 274037.2 \end{bmatrix}$$

$$N = \begin{bmatrix} 0.0102 & 0.000062 & 26179.203 \\ 0.000062 & 0.000062 & 0.000433 \\ 0.00321 & 0.000062 & 1374440.802 \end{bmatrix}$$

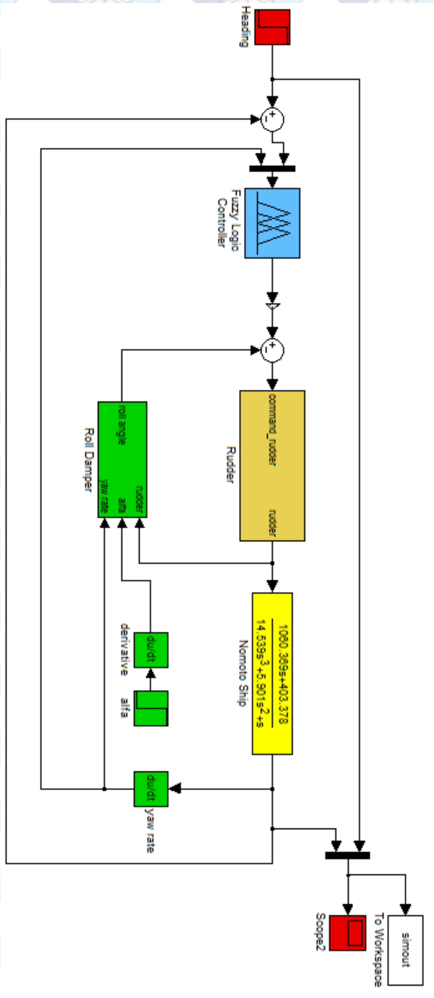
$$G = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 2.94 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0.001 & 12.566 \\ 0.001 & -0.0237 \\ 0.001 & -6.283 \end{bmatrix}$$

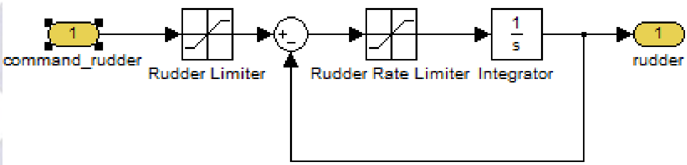
$$\phi(s) = \frac{-0.07\delta(s)+0.003\alpha(s)-0.8r(s)}{0.001s^2-0.00006s+2.94}$$

LAMPIRAN D

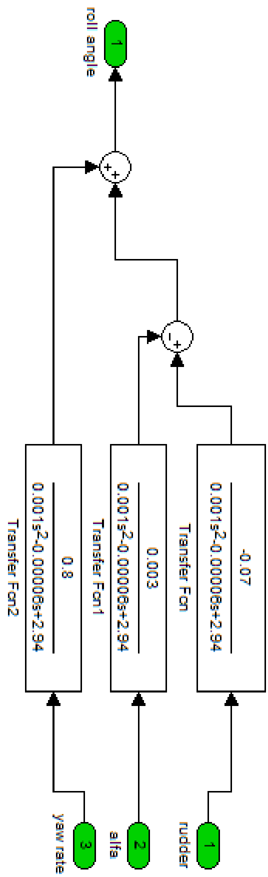
PEMODELAN SIMULINK SISTEM STABILISASI RUDDER ROLL TANPA GANGGUAN



- Pemodelan Subsistem Rudder



- Pemodelan subsistem Roll Damper



➢ LAMPIRAN E
➢ RULE BASE KONTROL LOGIKA FUZZY

➢

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- *1. If (e is NB) and (r is PB) then (Rudder is NB) (1)*
- *2. If (e is NB) and (r is PM) then (Rudder is NB) (1)*
- *3. If (e is NB) and (r is PS) then (Rudder is NB) (1)*
- *4. If (e is NB) and (r is Z) then (Rudder is NB) (1)*
- *5. If (e is NB) and (r is NS) then (Rudder is NM) (1)*
- *6. If (e is NB) and (r is NM) then (Rudder is NS) (1)*
- *7. If (e is NB) and (r is NB) then (Rudder is Z) (1)*
- *8. If (e is NM) and (r is PB) then (Rudder is NB) (1)*
- *9. If (e is NM) and (r is PM) then (Rudder is NB) (1)*
- *10. If (e is NM) and (r is PS) then (Rudder is NB) (1)*
- *11. If (e is NM) and (r is Z) then (Rudder is NM) (1)*
- *12. If (e is NM) and (r is NS) then (Rudder is NS) (1)*
- *13. If (e is NM) and (r is NM) then (Rudder is Z) (1)*
- *14. If (e is NM) and (r is NB) then (Rudder is PS) (1)*
- *15. If (e is NS) and (r is PB) then (Rudder is NB) (1)*
- *16. If (e is NS) and (r is PM) then (Rudder is NB) (1)*
- *17. If (e is NS) and (r is PS) then (Rudder is NB) (1)*
- *18. If (e is NS) and (r is Z) then (Rudder is NS) (1)*
- *19. If (e is NS) and (r is NS) then (Rudder is Z) (1)*
- *20. If (e is NS) and (r is NM) then (Rudder is PS) (1)*
- *21. If (e is NS) and (r is NB) then (Rudder is PM) (1)*
- *22. If (e is Z) and (r is PB) then (Rudder is NB) (1)*
- *23. If (e is Z) and (r is PM) then (Rudder is NM) (1)*
- *24. If (e is Z) and (r is PS) then (Rudder is NS) (1)*
- *25. If (e is Z) and (r is Z) then (Rudder is Z) (1)*
- *26. If (e is Z) and (r is NS) then (Rudder is PS) (1)*
- *27. If (e is Z) and (r is NM) then (Rudder is PM) (1)*
- *28. If (e is Z) and (r is NB) then (Rudder is PB) (1)*
- *29. If (e is PS) and (r is PB) then (Rudder is NM) (1)*
- *30. If (e is PS) and (r is PM) then (Rudder is NS) (1)*
- *31. If (e is PS) and (r is PS) then (Rudder is Z) (1)*

- *32. If (e is PS) and (r is Z) then (Rudder is PS) (1)*
- *33. If (e is PS) and (r is NS) then (Rudder is PM) (1)*
- *34. If (e is PS) and (r is NM) then (Rudder is PB) (1)*
- *35. If (e is PS) and (r is NB) then (Rudder is PB) (1)*
- *36. If (e is PM) and (r is PB) then (Rudder is NS) (1)*
- *37. If (e is PM) and (r is PM) then (Rudder is Z) (1)*
- *38. If (e is PM) and (r is PS) then (Rudder is PS) (1)*
- *39. If (e is PM) and (r is Z) then (Rudder is PM) (1)*
- *40. If (e is PM) and (r is NS) then (Rudder is PB) (1)*
- *41. If (e is PM) and (r is NM) then (Rudder is PB(1)*
- *42. If (e is PM) and (r is NB) then (Rudder is PB) (1)*
- *43. If (e is PB) and (r is PB) then (Rudder is Z) (1)*
- *44. If (e is PB) and (r is PM) then (Rudder is PS) (1)*
- *45. If (e is PB) and (r is PS) then (Rudder is PM) (1)*
- *46. If (e is PB) and (r is Z) then (Rudder is PB) (1)*
- *47. If (e is PB) and (r is NS) then (Rudder is PB) (1)*
- *48. If (e is PB) and (r is NM) then (Rudder is PB) (1)*
- *49. If (e is PB) and (r is NB) then (Rudder is PB) (1)*