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Manoeuvring behaviour of push convoys

Sub report 8
Additional Fast Time Validation of Class Va and Vb Vessels

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Manoeuvring behaviour of push convoys

Sub report 8 – Additional Fast Time Validation of Class Va and Vb Vessels

Vos, S.; Delefortrie, G.; Mostaert, F.

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Abstract

This report describes the validation process of the simulation vessels *Pêche Melba* and *Dame Blanche* which are the simulation names for the push convoys of (CEMT-)class Va and class Vb. The vessels consist of one or two barges with several loading conditions. Mathematical models were developed for a combination of empty (E, draft 3 m) and full (F, draft 4 m) barges.

The validation in the report is based on results of standard manoeuvres, performed with fast-time simulations. These simulations have been extended with unsteady turning manoeuvres. Skippers often have to manoeuvre in confined areas. During an approach of a lock or the execution of a turning manoeuvre in a swinging area, the manoeuvring model is often used beyond quadrant I. Sailing ahead with a negative thrust (propeller that runs astern) or sailing astern with a positive thrust are quite common. Because of that it was decided to perform turning manoeuvres in unsteady conditions. Normally a turning manoeuvre is started at a self-propulsion point. Because the speeds are rather small while approaching a lock or executing a turning manoeuvre, small initial negative and positive speeds have been applied for the turning manoeuvres.

In several conditions the rate of turn during these unsteady turning manoeuvres wasn't smooth. A drop of the rate of turn could be noticed. Starting with a negative speed, in some conditions it was not possible to reach a positive speed with the larger rudder angles. This was solved by reducing coefficient F_X . By reducing N_p , the drop issue of the rate of turn was improved. Additional to the reduction of N_p , a few outliers were removed in the tables YPBetaTabel and YPGammaTabel.

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1 Overview

This report describes the validation process of the simulations vessels *Pêche Melba* and *Dame Blanche* which are the simulation names for the push convoys of (CEMT-)class Va and class Vb. The modelling process of the vessels was reported in [1] and [2].

The configurations which have been tested and modelled of both vessels are shown in Table 1. Barges can be empty (E) or full (F). The draft of an empty barge corresponds to a draft of 3 m, a full draft equals 4 m. Depending on the loading condition, different models have been derived for different under keel clearances. The under keel clearance which is mentioned in the table is related to draft of the barge with the largest draft.

Table 1 – Configuration of the vessels *Pêche Melba* (Va) and *Dame Noire* (Vb)

Class Va <i>Pêche Melba</i>			Class Vb <i>Dame Noire</i>		
			F F		
			DON01/J0701 – J0101		
			A01 100% ukc	A02 50% ukc	A03 20% ukc
			F E		
			DON02/J0801 – J0201		
			A01 100% ukc		
E			E E		
DON0A/J1001			DON03/J0901 – J0301		
A02 100% ukc	A03 60% ukc	A04 33% ukc	A01 167% ukc		

2 Ship model's particulars

The ship model's particulars are presented in Table 2.

Table 2 – Main characteristics of Peche Melba and Dame Noire

Parameter	Pechel Melba	Dame Noire		
Simulation name	pechemelba_Va_empty_E	damenoire_Vb_coal_EE	damenoire_Vb_coal_FE	damenoire_Vb_coal_FF
Loa [m]	110	191		
Lpp [m]	108.6	182.9		
BWL [m]	11.4	11.4		
T / T_{fore}^1 [m]	3	3	3	4
T_{aft}^2 [m]		3	4	4
Volume [m ³]	2871.95	5209.76	6058.54	6800.00
CB [-]	0.773	0.82	0.73 ³	0.82
RM [kg]	2943750	5340000	6210000	6970000
XG [m]	6.8	7.15	3.80	9.93
RIXX [kg.m ²]	2943750	0.127E+09	0.156E+09	0.127E+09
RIYY [kg.m ²]	0.205E+10	0.124E+11	0.132E+11	0.162E+11
RIZZ [kg.m ²]	0.217E+10	0.126E+11	0.134E+11	0.164E+11
S [m ²]	1712	2949	3127	3283
GML [m]	374.2	1039	903.9	821.9
GMT [m]	3.07	2.75	2.59	2.49
Nb propellers	2	2		
Position bow thruster [m]	53	92		
Power bow thruster [kW]	350	350		
Position stern thruster [m]	/	/		
Power stern thruster [kW]	/	/		
A_{wx} [m ²]	52	52.00	52.00	52.00
A_{wy} [m ²]	419	667.00	667.00	667.0

¹ Fore: barge most in front

² Aft: barge closest to the pusher

³ Calculated with an overall draft of 4 m

3 Fast time simulations

3.1 Introduction

During the development process of the models different fast time simulations have been performed by G. Delefortrie (see [1] and [2]). Parameter tuning was performed to optimize the sailing behaviour. In the framework of the validation process (scope of this report), new fast time simulations were performed with a focus on non-steady turning circles.

Skippers often have to manoeuvre in confined areas. During an approach of a lock or the execution of a turning manoeuvre in a swinging area, the manoeuvring model is often used beyond quadrant I. Sailing ahead with a negative thrust (propeller that runs astern) or sailing astern with a positive thrust are quite common. Because of that it was decided to perform turning manoeuvres in unsteady conditions. Normally a turning manoeuvre is started at a self-propulsion point. Because the speeds are rather small while approaching a lock or executing a turning manoeuvre, small initial negative and positive speeds have been applied for the turning manoeuvres.

Not all intermediate steps of the tuning process, which was more or less iterative, are shown.

3.2 Peche Melba

The vessel was modelled with one draft (3 m) and three under keel clearances (100%, 60%, 33%). Following telegraph positions were defined:

- Full: 330 rpm;
- Half: 264 rpm;
- Slow: 198 rpm;
- Dead slow: 90 rpm.

3.2.1 Adaptation of coefficients

General adaptation

In Table 3 the tuning factors of the three different series are shown. The factors shown in **bold** correspond to the new factors based on the non-steady turning circles.

Table 3 – Applied tuning factors for Peche Melba

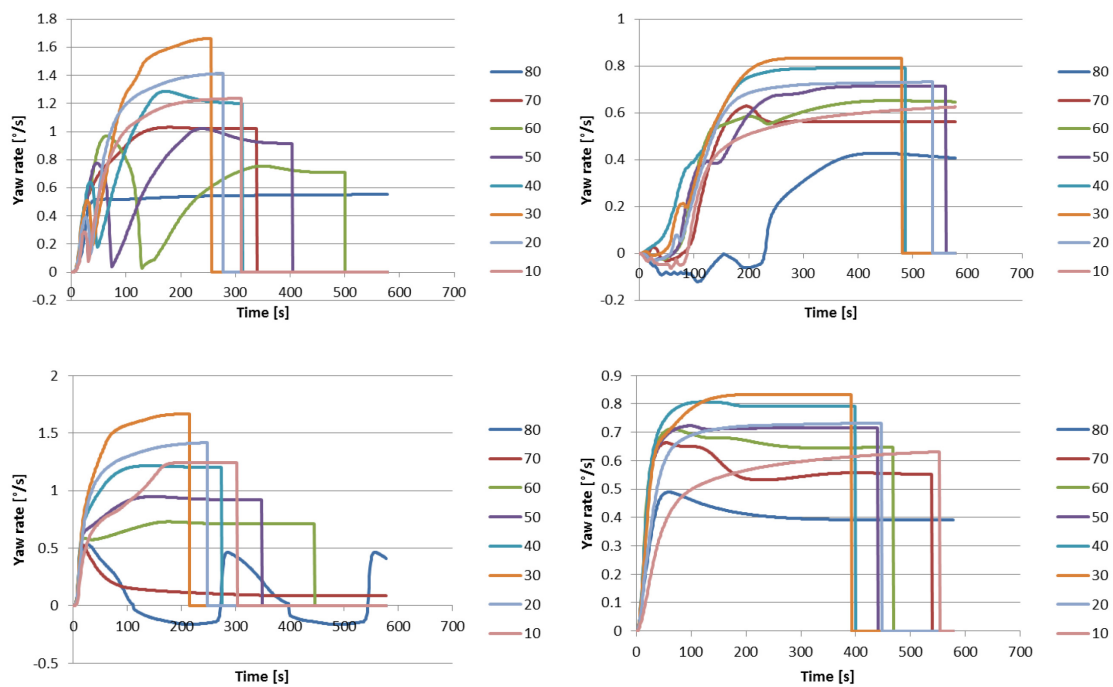
Series - %ukc	XP	Ngamma	NR	Ychi	Nchi	NP	Fx
J1001A02 – 100	1.00	0.90	1.00	1.00	1.00	0.3	0.75
J1001A03 – 60	0.80	1.00	0.80	1.00	1.00	0.3	0.5
J1001A04 – 33	1.00	1.50	1.00	0.50	0.75	0.3	0.8

In Figure 1 the rate of turn as a function of time for different rudder angles (varying from 10° to 80°) is visualised for non-steady turning manoeuvres. The initial speed of the manoeuvre is different from the self-propulsion speed. The rate of turn as a function of time was expected to be a smooth curve. Figure 2 shows the longitudinal speed as a function of time. The left figures are results before tuning, the right figures after tuning. The top figures visualise the results of simulations with initial speed -3.7 km/h, the bottom figures correspond to an initial speed of 1 km/h. In Annex 1 the results for different initial speeds are visualised for the tuned model.

The top figure in Figure 1 shows the phenomena of a turning manoeuvre, starting with a small negative speed of -3.7 km/h. The propeller was set to 3.3 rps (198 rpm – slow) which resulted in an increase of speed and rate of turn. At a certain moment the rate of turn dropped down again. Based on the non-steady turning circles N_p was reduced with 70% for all the series which solved the big drop of the rate of turn after a while. Because of the adaption of N_p , the maximum rate of turn decreased significantly. For a rudder angle of 30°, the maximum rate of turn decreased from about 1.6 °/s to about 0.8 °/s.

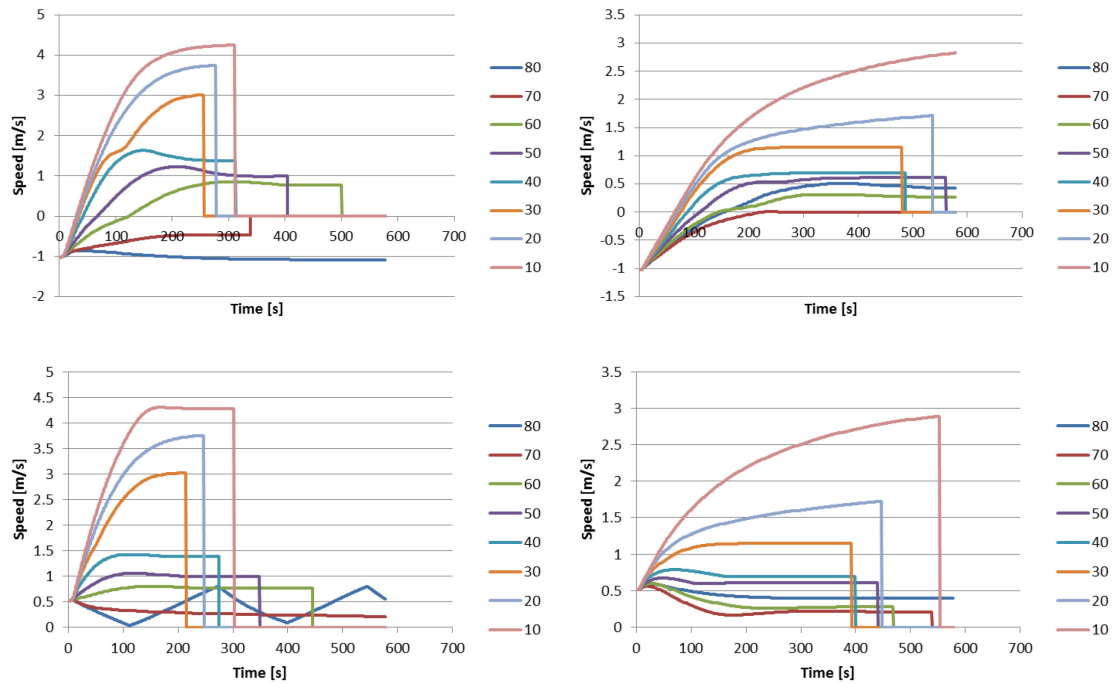
F_x was also reduced. Without modification of F_x , in some conditions the longitudinal speed did not increase during a turning manoeuvre. On the contrary, the longitudinal speed became even more negative when started with a negative initial speed.

Figure 1 – Rate of turn as a function of time for a non-steady turning manoeuvre (Peché Melba)



TOP: INITIAL SPEED -3.7 KM/H, BOTTOM: INITIAL SPEED 1.8 KM/H
LEFT: BEFORE TUNING NP AND Fx, RIGHT: AFTER TUNING NP AND Fx

Figure 2 – Longitudinal speed as a function of time



TOP: INITIAL SPEED -3.7 KM/H, BOTTOM: INITIAL SPEED 1.8 KM/H
 LEFT: BEFORE TUNING NP AND FX, RIGHT: AFTER TUNING NP AND FX

Adaptation of coefficients – outliers

J1001A02 – 100% ukc

Additionally to the modification of N_p and F_X , some coefficients have been changed in the coefficient file J1001A02.xml. Based on linear interpolation new coefficients for $Y_{PT}(\beta=10^\circ)$, $Y_{PT}(\beta=-10^\circ)$, $Y_{PT}(\gamma=10^\circ)$ and $Y_{PT}(\gamma=-10^\circ)$ for ε 0° and 90° were calculated. The coefficients of $Y_{PT}(\beta)$ and $Y_{PT}(\gamma)$ are the same in the first quadrant. The modification is visualised in Figure 3. The effect of this new coefficients on the yaw rate is shown in for a turning circle with a rudder angle of 10° to starboard and portside.

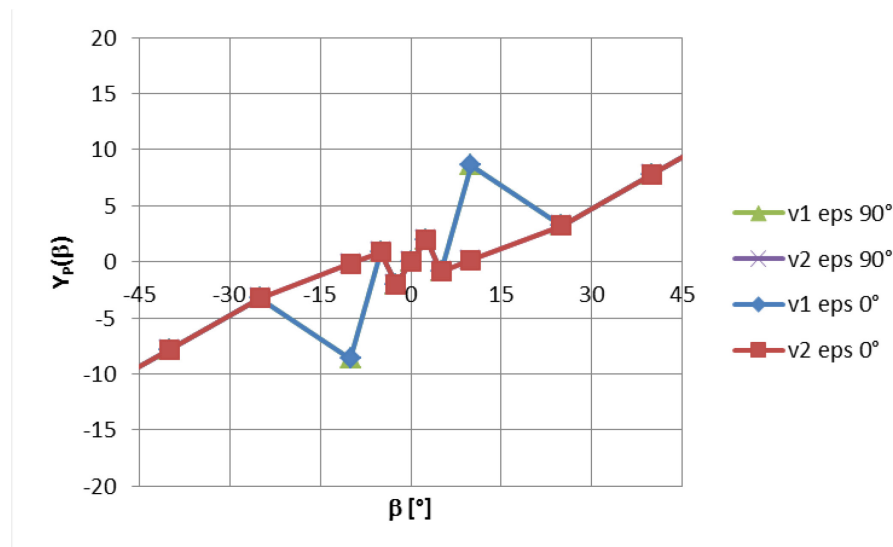
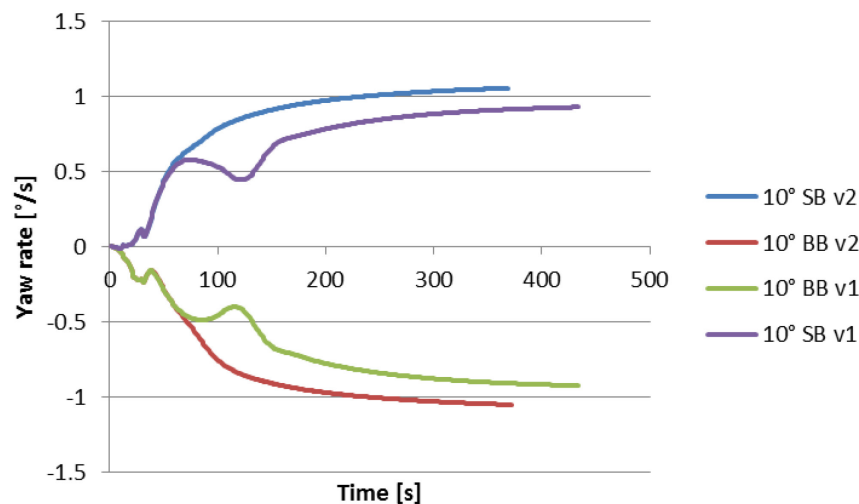
Figure 3 – Coefficients $Y_p(\beta)$ for ε 0° and 90° in J1001A02.xml (v1 original, v2 after modification)

Figure 4 – Comparison results turning circle 10° after modifying coefficients in table YPBetaTabel and YPGammaTabel

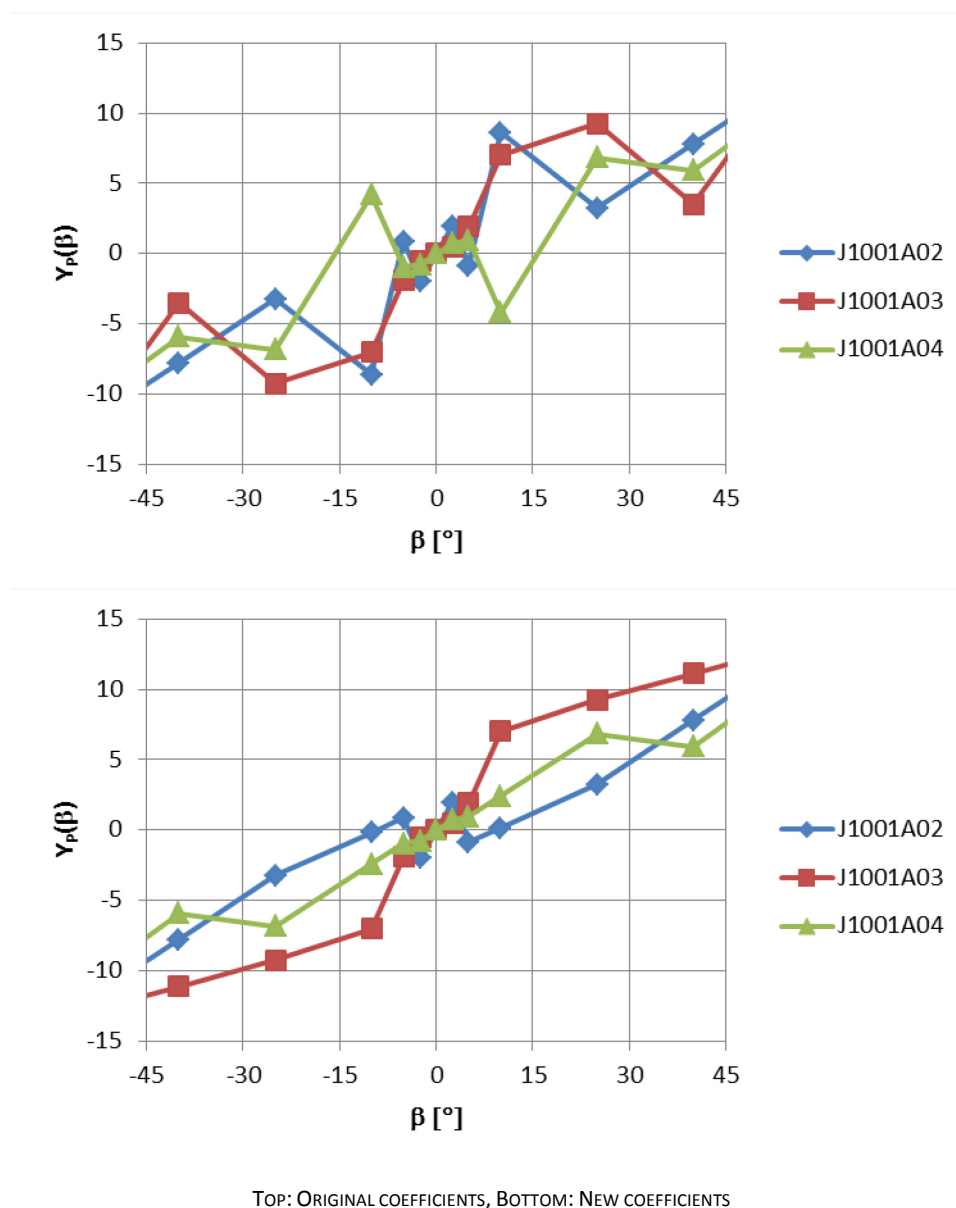


J1001A03 (60% ukc) and J1001A04 (33% ukc)

An overall investigation of coefficient outliers could be performed by repeating all the unsteady turning circles. It was decided to screen the tables YPBetaTabel and YPGammaTabel on outliers. The original and the new coefficients, calculated based on a linear interpolation are shown in Table 4 and Figure 5. Coefficients have been adapted for ε 0° and 90° in the tables YPBetaTabel and YPGammaTabel.

Table 4 – Coefficients $Y_{PT}(\beta)$ and $Y_{PT}(\gamma)$ of Peche Melba (new coefficients shaded in grey)

	β	...	-55	-40	-25	-10	-5	...	5	10	25	40	55	...
Original	J1001A02	...	-12.336	-7.791	-3.247	-8.613	0.874	...	-0.874	8.613	3.247	7.791	12.336	...
	J1001A03	...	-12.980	-3.507	-9.239	-7.016	-1.915	...	1.915	7.016	9.239	3.507	12.980	...
	J1001A04	...	-10.948	-5.934	-6.820	4.174	-0.951	...	0.951	-4.174	6.820	5.934	10.948	...
New	J1001A02	...	-12.336	-7.791	-3.247	-0.156	0.874	...	-0.874	0.156	3.247	7.791	12.336	...
	J1001A03	...	-12.980	-11.110	-9.239	-7.016	-1.915	...	1.915	7.016	9.239	11.110	12.980	...
	J1001A04	...	-10.948	-5.934	-6.820	-2.418	-0.951	...	0.951	2.418	6.820	5.934	10.948	...

Figure 5 – Coefficients of Peche Melba in β -region in which coefficients have been adapted


Results of the Peche Melba in the rest of the document will be based on the coefficient modifications as described above.

Results of the fast-time simulations can be found in the folder:

P:\16_026-ValSimSchepen\3_Uitvoering\PecheMelba\1_FT\SimFast\project\full_scale_test\vaarten

3.2.2 Standard manoeuvres

Acceleration test

Results of acceleration tests are visualised in Figure 6 and Figure 7. Numerical data can be found in Table 5. Speed increases with increasing rpm. If the under keel clearance decreases, the speed decreases as well.

Figure 6 – Acceleration test – speed as a function of rps (telegraph position) with varying under keel clearance

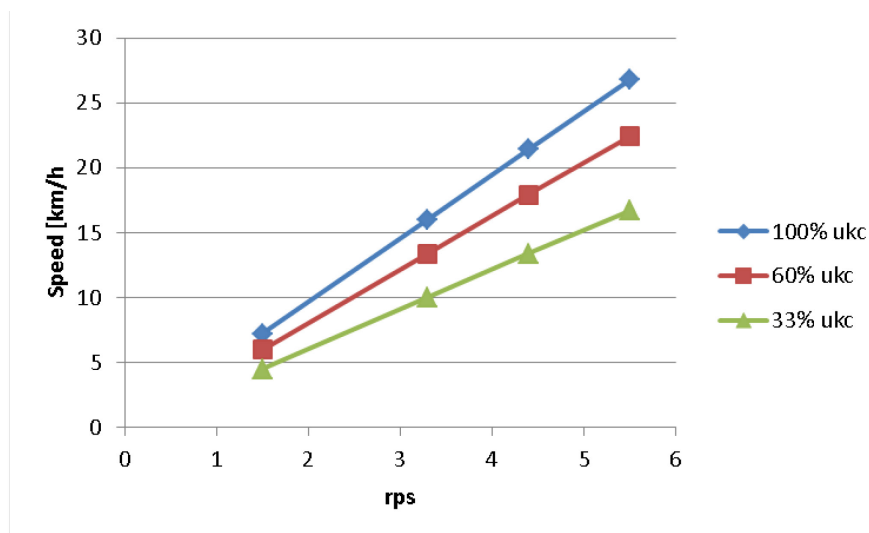


Figure 7 – Acceleration test – speed [km/h] as function of under keel clearance with varying telegraph position

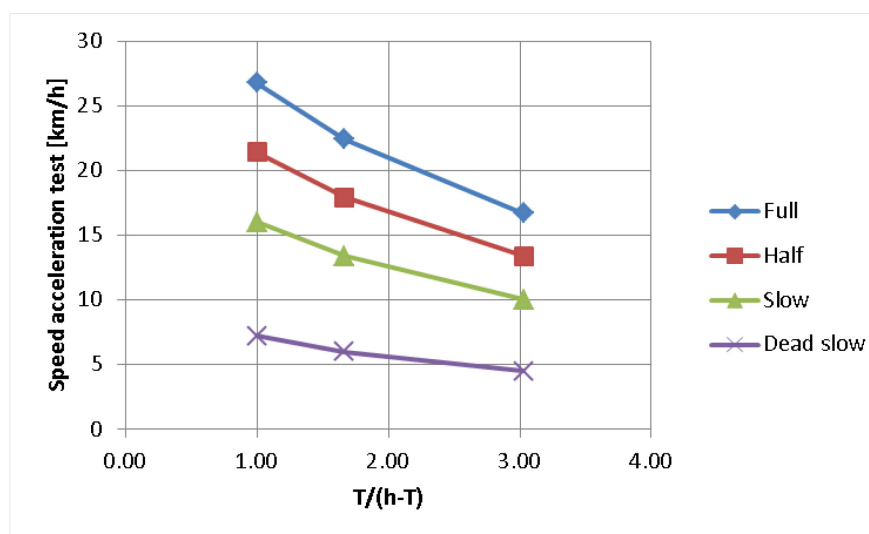


Table 5 – Acceleration tests – speed [km/h] for varying telegraph position and varying under keel clearance

Telegraph	Rpm	Ukc [%]		
		100	60	33
Full	330	26.8	22.4	16.7
Half	264	21.4	17.9	13.4
Slow	198	16.0	13.4	10.0
Dead slow	90	7.2	6.0	4.5

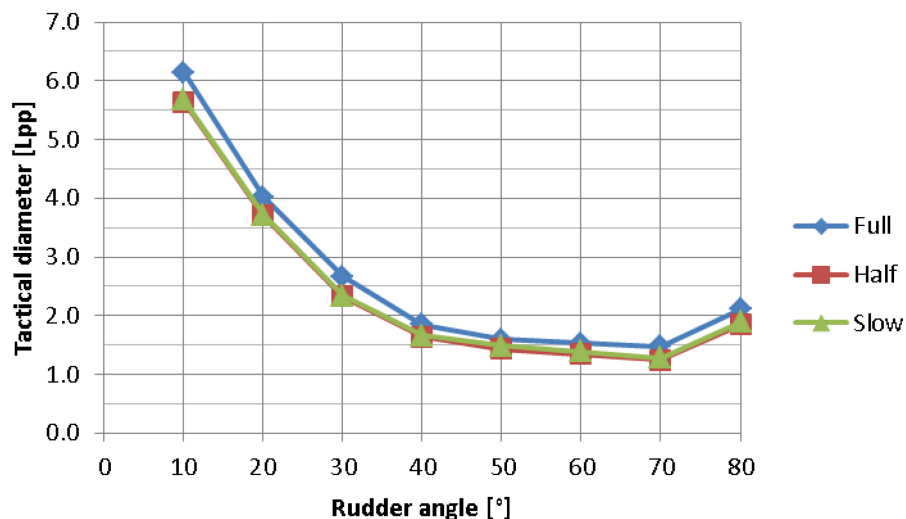
Turning circle

Standard turning circle (steady)

In Figure 8 the tactical diameters of turning manoeuvres, performed with different rudder angles, are shown. In general, the larger the rudder angle, the smaller the tactical diameter. The diameter decreases significantly from 10° up to 40°. Between 40° and 70° only a small difference can be noticed. A rudder angle of 80° results in a larger tactical diameter than a rudder angle of 70°. Telegraph position or rpm value has only a small influence on the tactical diameter.

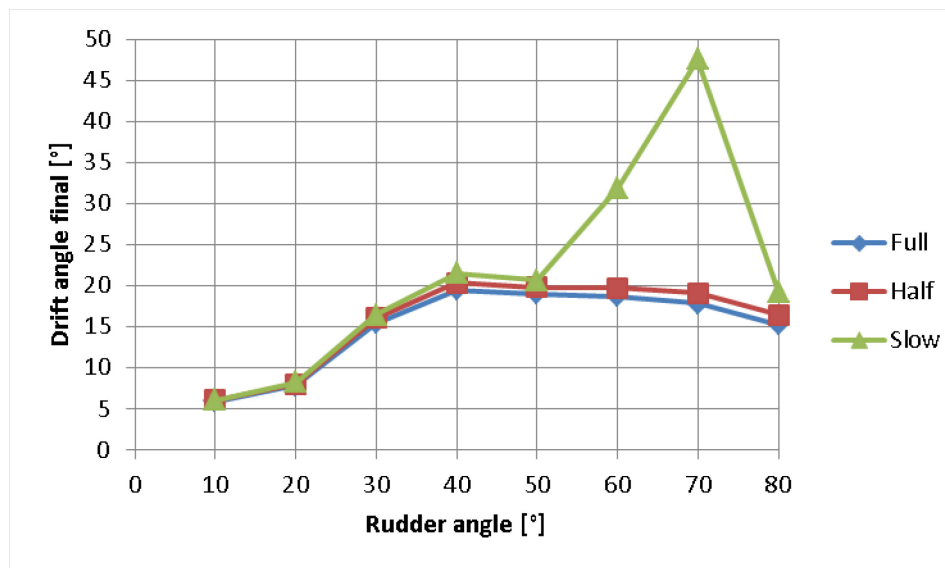
Figure 9 shows the final drift angle as a function of the applied rudder angle. The drift angle increases with an increasing rudder angle, up to 40°. From 40° up to 70° the drift angles remains more or less constant. A rudder angle of 80° results again in a decrease of the drift angle. Telegraph position has only a small influence on the final drift angle.⁽⁴⁾

Figure 8 – Turning circle – Tactical diameter as a function of applied rudder angle with varying telegraph position (ukc 100%)



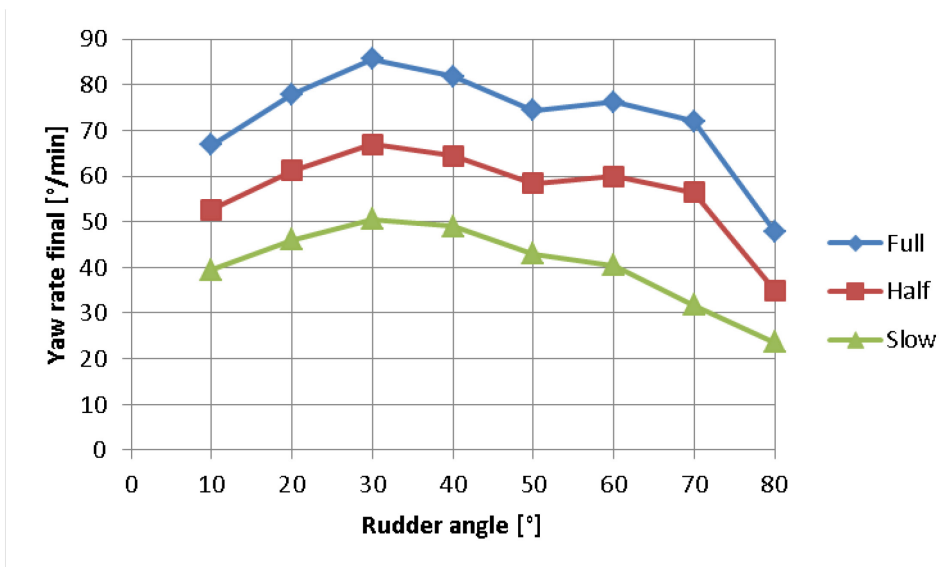
⁴ Reviewer remark: outliers can be observed at telegraph position slow. Probably they can be assigned to the small speed, but this needs further check.

Figure 9: Turning circle – Final drift angle as a function of applied rudder angle with varying telegraph position (ukc 100%)



The final yaw rate is shown in Figure 10. The influence of the telegraph position is clearly visible. The larger the rpm value, the larger the final rate of turn. An increase of final rate of turn up to a rudder angle of 30° can be noticed. For a rudder angle larger than 30°, the final rate of turn decreases with an increasing rudder angle.

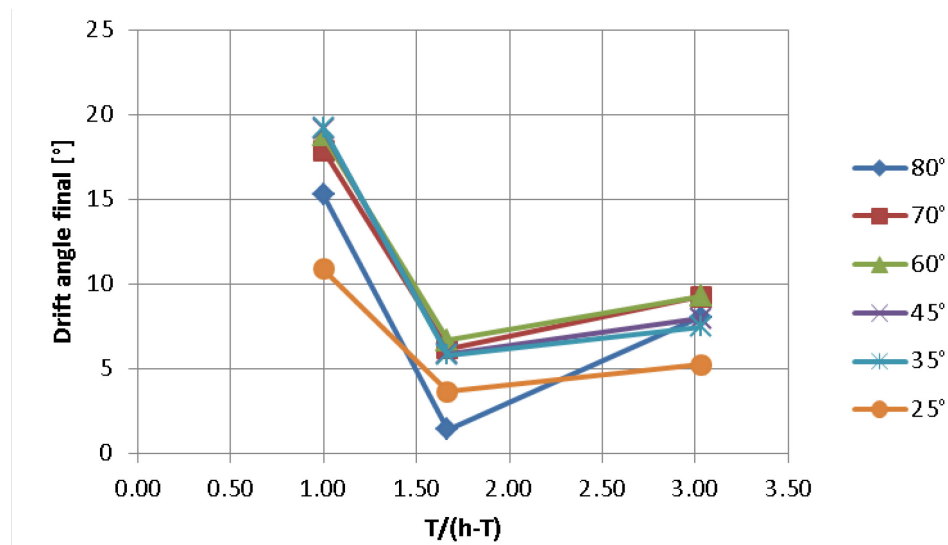
Figure 10 – Turning circle – Final yaw rate as a function of applied rudder angle with varying telegraph position (ukc 100%)



The final drift angle and final rate of turn are shown in respectively Figure 11 and Figure 12 as a function of the under keel clearance for varying rudder angles.

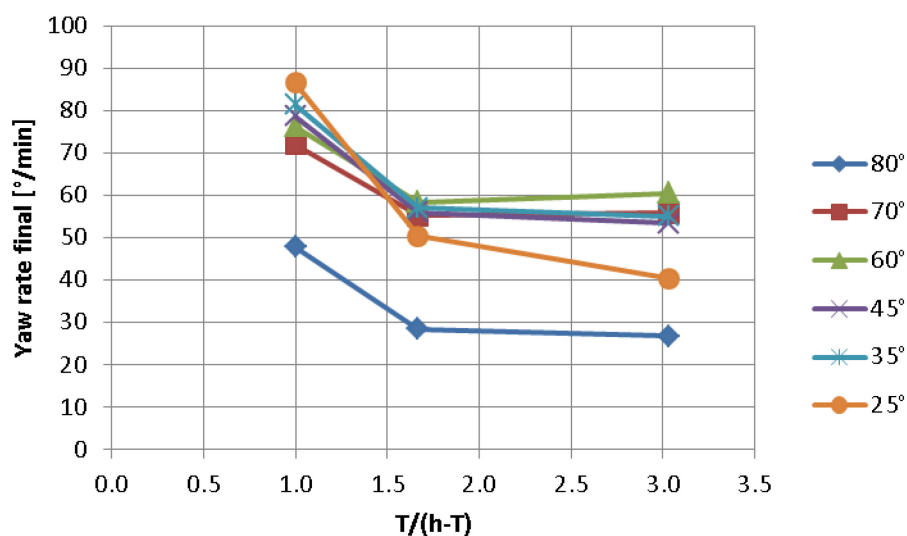
An under keel clearance of 100% results in the largest drift angle. The results with 60% ukc correspond with the smallest drift angles. Simulations with the smallest under keel clearances (33%) result in final drift angles between the results of 60% ukc and 100% ukc. The result of the simulation with a rudder angle of 80° is an outlier.

Figure 11 – Turning circle – Final drift angle as a function of under keel clearance with varying telegraph position (Full - 5.5 rps)



The smaller the under keel clearance, the smaller the final rate of turn, see Figure 12.

Figure 12 – Turning circle – Final yaw rate as a function of under keel clearance with varying rudder angle (Full - 5.5 rps)



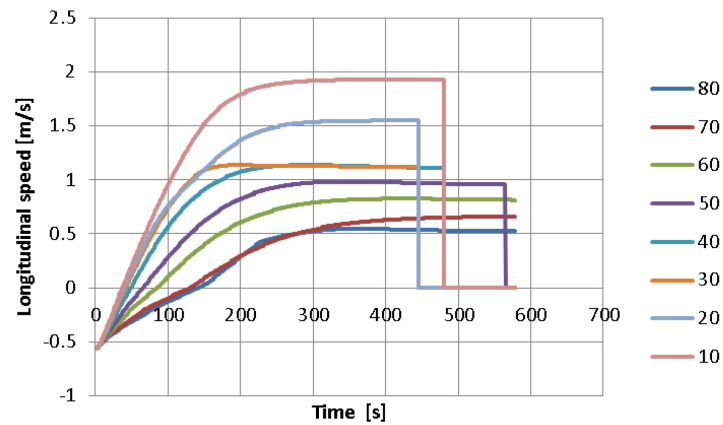
Non-standard turning circle (unsteady)

As described in the introduction of chapter 3, unsteady turning circles have been performed for series J1001A02 (100% ukc). Following initial speeds have been applied: -2 km/h, -1 km/h, 0 km/h, 1 km/h, 2 km/h. Most of the results are shown in Annex 1 for series J1001A02. Longitudinal speed, transversal speed and rate of turn are shown for turning circles started with an initial (longitudinal) speed of -2 km/h.

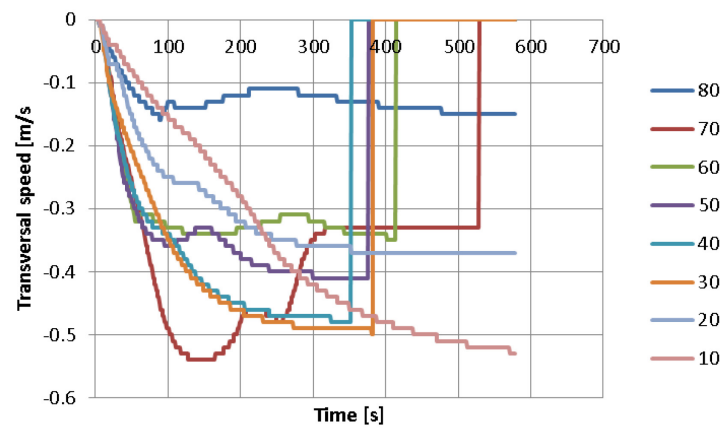
Up to a rudder angle of 60° it can be stated that the smaller the rudder angle is, the larger the final speed is. For some simulations with small rpm values, at the end of the turning manoeuvre, the speed is still increasing.

Figure 13 c) shows that the way of the increasing rate of turn is more or less similar for the different rudder angles. The slopes of the curves in the first 60 seconds are more or less the same. During real time simulations, this part of the curve is an important working area. In most cases the results with simulations with the rudder angle of 80° is an outlier.

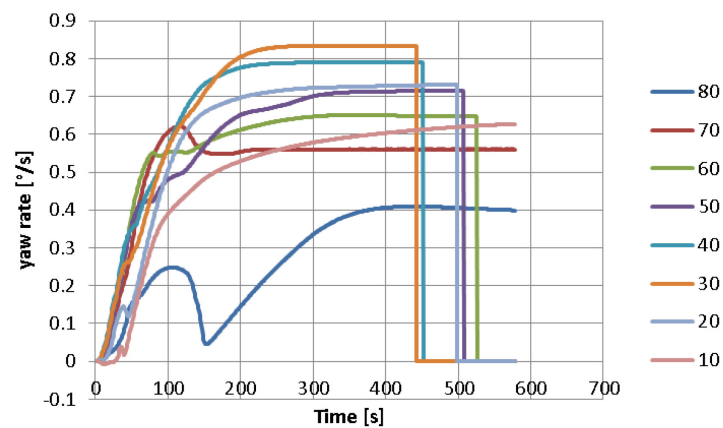
Figure 13 – Turning circles with varying rudder angle – initial speed -2 km/h; telegraph Slow (3.3 rps)



a) Longitudinal speed as a function of time



b) Transversal speed as a function of time



c) Yaw rate as a function of time

Zig-zag test

Zig-zag manoeuvres have been performed. Figure 14 shows the general characteristics of a zig-zag manoeuvre. Figure 15 to Figure 18 give results of the zigzag manoeuvres as a function of the under keel clearances.

Figure 14 – Zigzag manoeuvre – general characteristics.

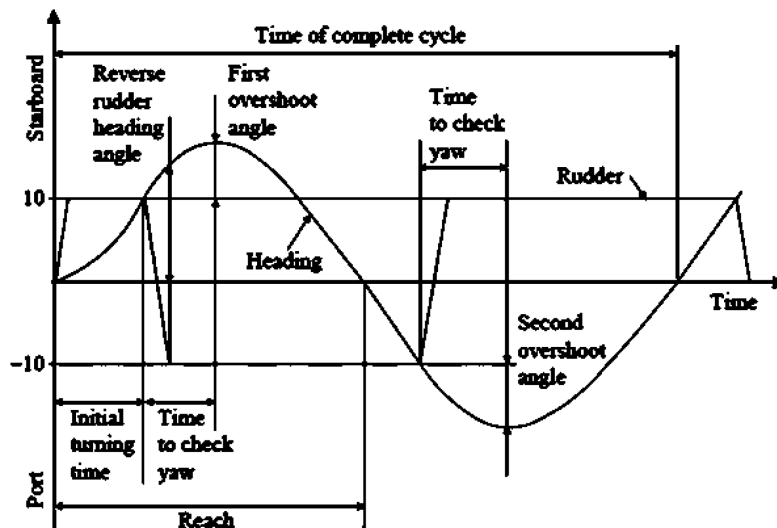


Figure 15 – 20/20-Zigzag manoeuvre – time to check yaw 1

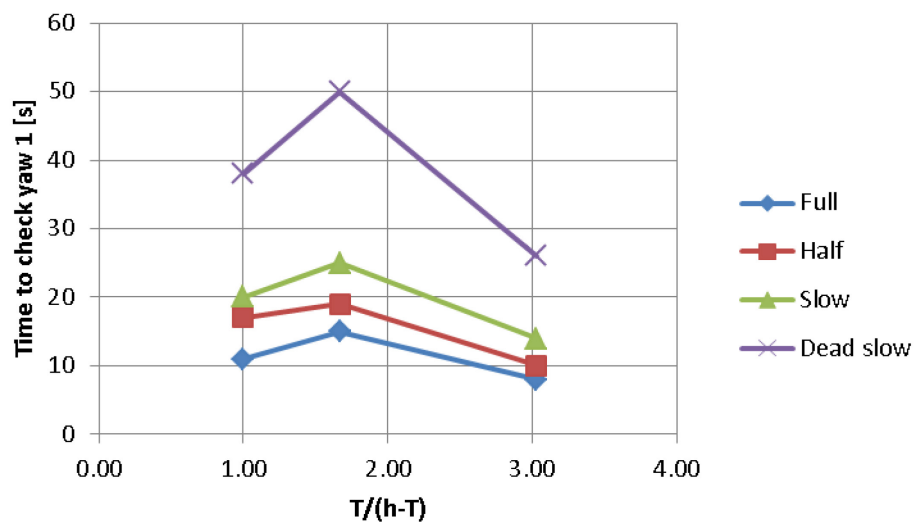


Figure 16 – 20/20-Zigzag manoeuvre – time to check yaw 2

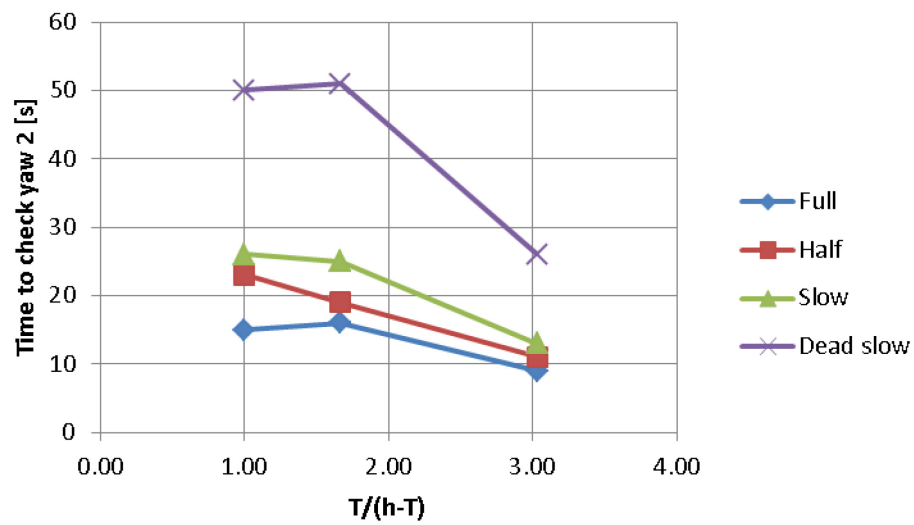


Figure 17 – 20/20-Zigzag manoeuvre – overshoot angle 1

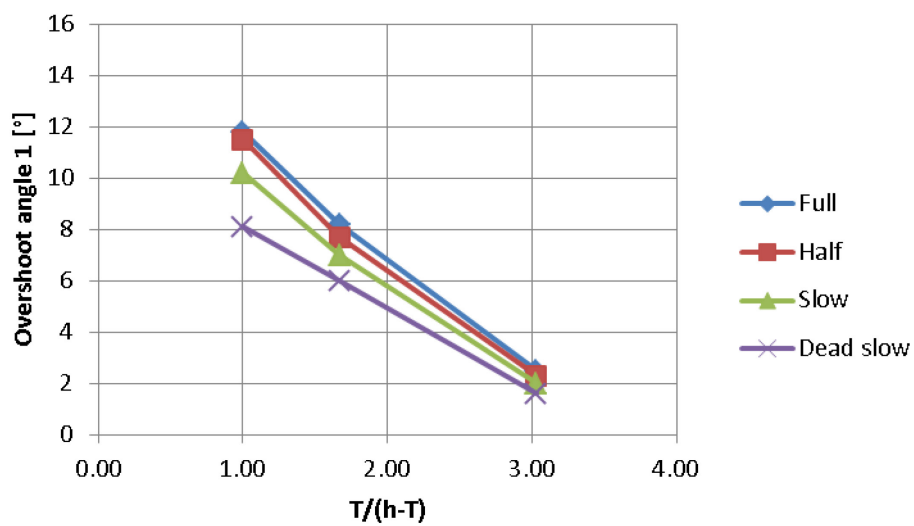
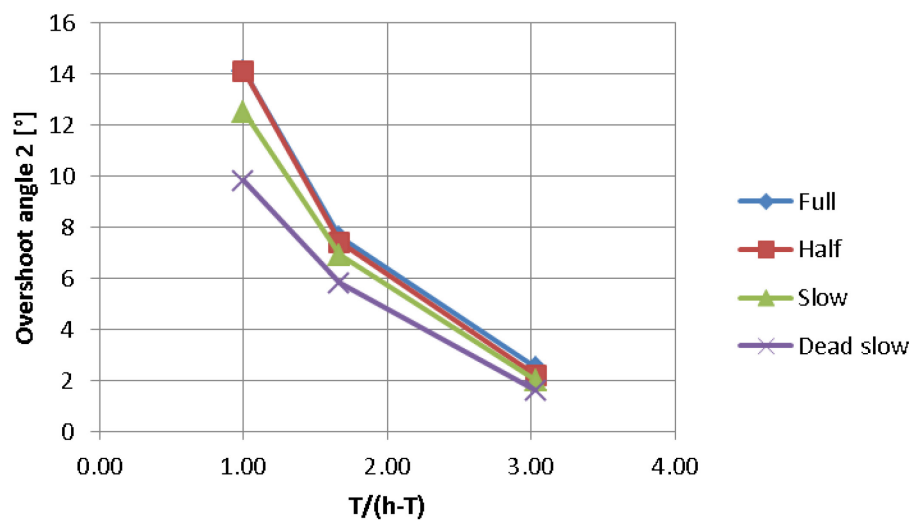


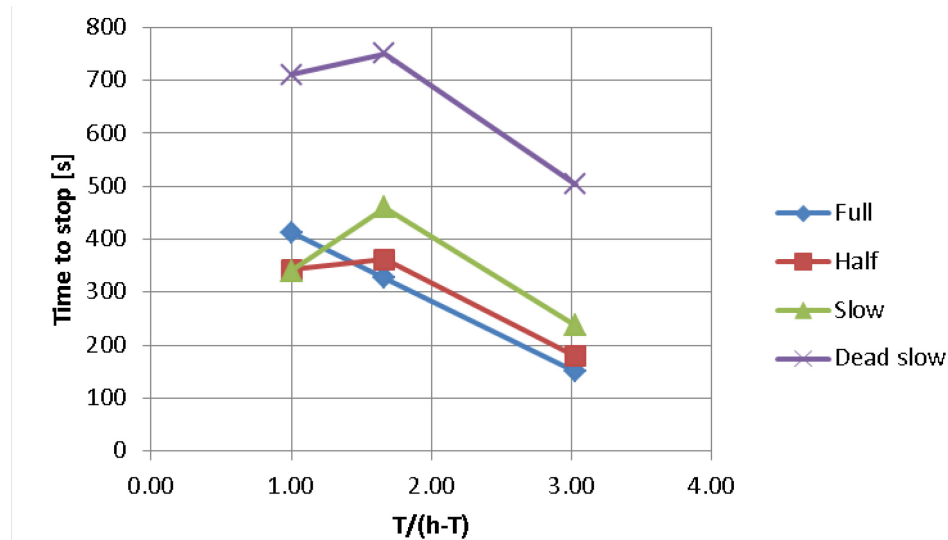
Figure 18 – 20/20-Zigzag manoeuvre – overshoot angle 2



Crash stop test

Figure 19 shows the time to stop with a crash stop with varying telegraph position. In the test the propeller was set astern with the same rpm value as the rpm value which was used ahead.

Figure 19 – Crash stop test – time to stop by using the engine astern with the same rpm as used ahead



3.3 Dame Noire

The Dame Noire was modelled with different drafts and different under keel clearances. Because it is the same pusher as the pusher of the Peche Melba, the same telegraph positions can be defined.

- Full: 330 rpm;
- Half: 264 rpm;
- Slow: 198 rpm;
- Dead slow: 90 rpm.

3.3.1 Adaptation of coefficients

General adaptation

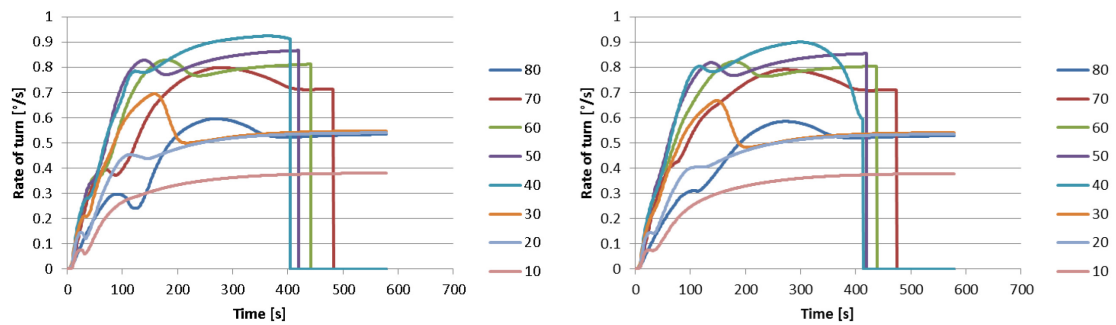
In Table 6 the tuning factors of the different series are shown. The factors shown in **bold** correspond to the new factors based on the non-steady turning circles. Unsteady turning circles were performed with series J0701A01. Based on that result and the result of the Peche Melba, all N_p -coefficients were decreased with 70% (factor 0.3).

Table 6 – Applied tuning factors for Dame Noire

Series	%ukc	$T_{fore\ barge}$	$T_{aft\ barge}$	Y_{beta}	N_{gamma}	N_P
J0701A01	100	4	4	0.9	1.0	0.3
J0701A02	50	4	4	1.0	1.0	0.3
J0701A03	20	4	4	1.0	1.5	0.3
J0801A01	100	3	4	1.0	1.0	0.3
J0901A01	167	3	3	1.0	1.0	0.3

The result on the rate of turn of changing the N_p -coefficient from 1.0 to 0.3 is visualised in Figure 20. For some rudder angles, the rate of turn becomes more smooth. In Annex 2 the results are shown of all performed unsteady turning circles with series J0701A01 (Draft 4 m, under keel clearance 100%).

Figure 20 – Rate of turn as a function of time for a non-steady turning manoeuvre with initial speed -2 km/h. (Dame Noire)



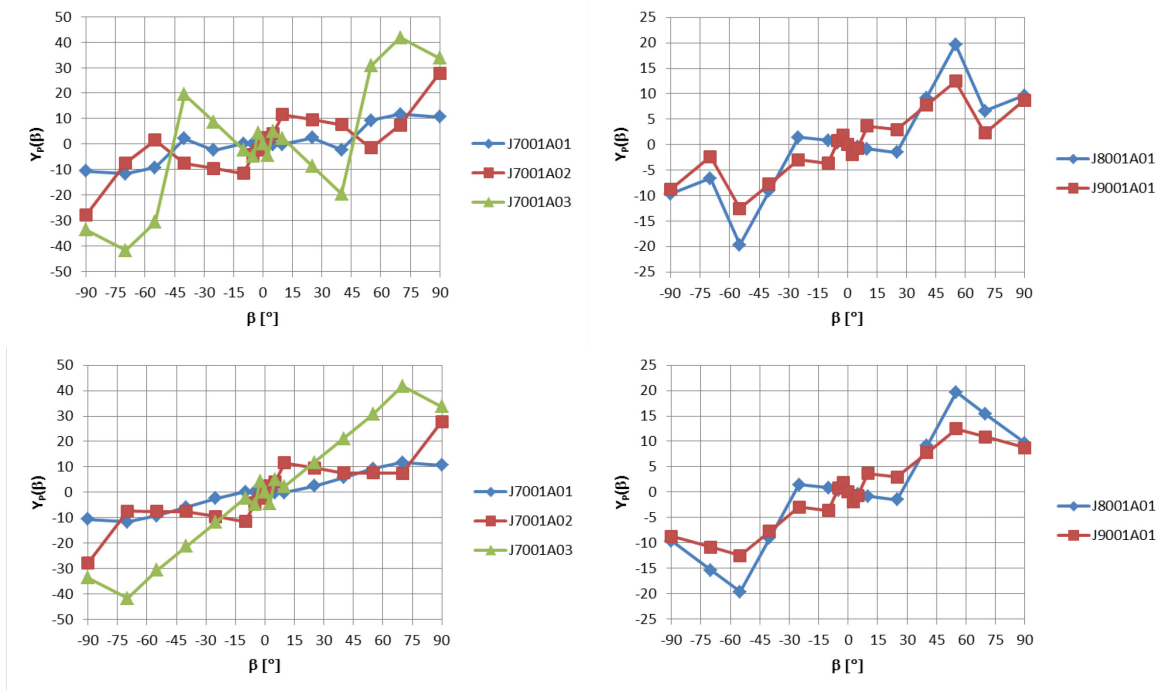
LEFT: BEFORE TUNING NP, RIGHT: AFTER TUNING NP

Adaptation of coefficients – outliers

Similar to the procedure which was followed for the Peche Melba, some outliers in the tables YPBetaTable and YPGammaTable have been adapted. For all the series, the modifications are shown in Table 7 and Figure 21.

Table 7 – Coefficients $Y_{PT}(\beta)$ and $Y_{PT}(\gamma)$ of Dame Noire (new coefficients shaded in grey)

	β	...	-90	-70	-55	-40	-25	-10	...	10	25	40	55	70	...
Original	J0701A01	...	-10.636	-11.690	-9.276	2.204	-2.443	0.201	...	-0.201	2.443	-2.204	9.276	11.690	...
	J0701A02	...	-27.760	-7.483	1.499	-7.641	-9.585	-11.530	...	11.530	9.585	7.641	-1.499	7.483	...
	J0700A03	...	-33.660	-41.750	-30.630	19.510	8.604	-2.303	...	2.303	-8.604	-19.510	30.630	41.750	...
	J0801A01	...	-9.635	-6.602	-19.680	-9.100	1.480	0.832	...	-0.832	-1.480	9.100	19.680	6.602	...
	J0901A01	...	-8.734	-2.312	-12.480	-7.728	-2.975	-3.659	...	3.659	2.975	7.728	12.480	2.312	...
New	J0701A01	...	-10.636	-11.690	-9.276	-5.859	-2.443	0.201	...	-0.201	2.443	5.859	9.276	11.690	...
	J0701A02	...	-27.760	-7.483	-7.562	-7.641	-9.585	-11.530	...	11.530	9.585	7.641	7.562	7.483	...
	J0701A03	...	-33.660	-41.750	-30.630	-21.188	-11.745	-2.303	...	2.303	11.745	21.188	30.630	41.750	...
	J0801A01	...	-9.635	-15.375	-19.680	-9.100	1.480	0.832	...	-0.832	-1.480	9.100	19.680	15.375	...
	J0901A01	...	-8.734	-10.875	-12.480	-7.728	-2.975	-3.659	...	3.659	2.975	7.728	12.480	10.875	...

Figure 21 – Coefficients of Dame Noire in β -region in which coefficients have been adapted

TOP: ORIGINAL COEFFICIENTS, BOTTOM: NEW COEFFICIENTS

Results of the Dame Noire in the rest of the document will be based on the coefficient modifications as described above.

Results of the fast-time simulations can be found in the folder:

P:\16_026-ValSimSchepen\3_Uitvoering\DameNoire\1_FT\SimFast\project\full_scale_test\vaarten

3.3.2 Standard manoeuvres

Acceleration test

Results of acceleration tests are visualised in Figure 22. Numerical data can be found in Table 8. Speed increases with increasing rpm. If the under keel clearance decreases, the speed decreases as well.

Figure 22 – Acceleration test – speed [km/h] as function of under clearance with varying telegraph position

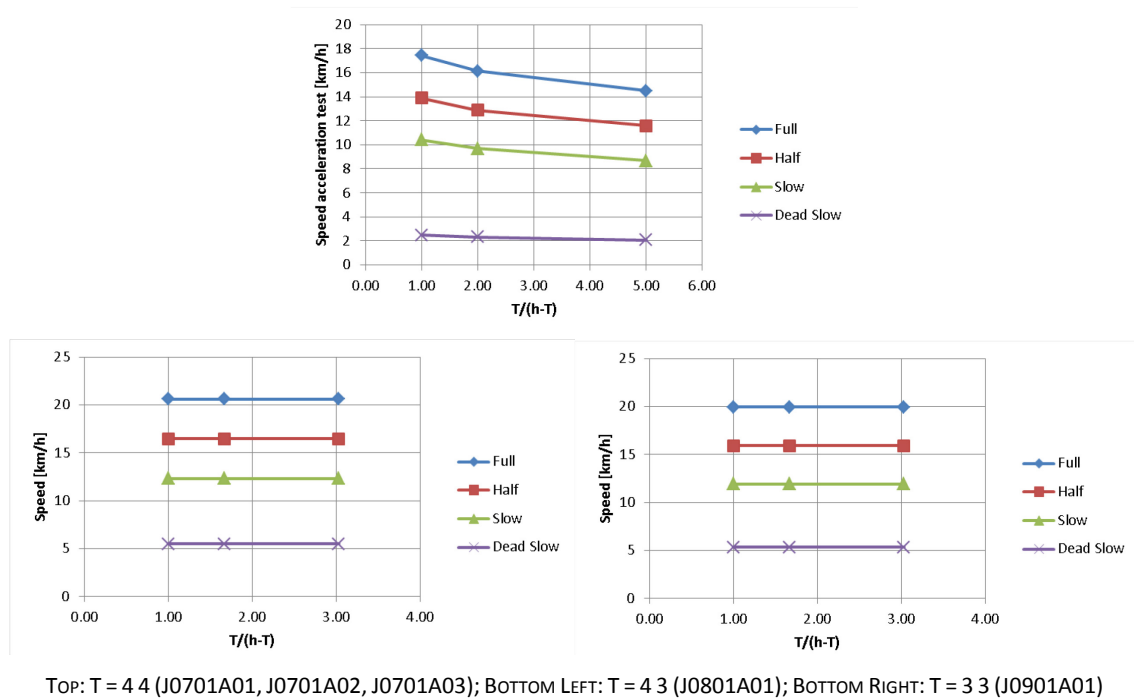


Table 8 – Acceleration tests – speed [km/h] for varying telegraph position and varying under keel clearance

Telegraph	Rpm	T = 4 4			T = 4 3	T = 3 3
		Ukc [%]				
		100	50	20	100	100
Full	330	17.42	16.13	14.51	20.59	19.94
Half	264	13.9	12.89	11.59	16.45	15.91
Slow	198	10.4	9.68	8.68	12.31	11.92
Dead slow	90	4.61	4.28	3.85	5.47	5.33

Turning circle

Standard turning circle (steady)

In Figure 23 the tactical diameters of turning manoeuvres, performed with different rudder angles, are shown. In general, the larger the rudder angle, the smaller the tactical diameter. Telegraph position or rpm value has only a small influence on the tactical diameter.

Figure 24 shows the final drift angle as a function of the applied rudder angle. The drift angle increases with an increasing rudder angle, up to 40°. From 40° up to 70° the drift angles remains more or less constant. A rudder angle of 70° results in series J0901A01 in a outlier. Telegraph position has only a small influence on the final drift angle.

Figure 23 – Turning circle – Tactical diameter as a function of applied rudder angle with varying telegraph position (ukc 100%)

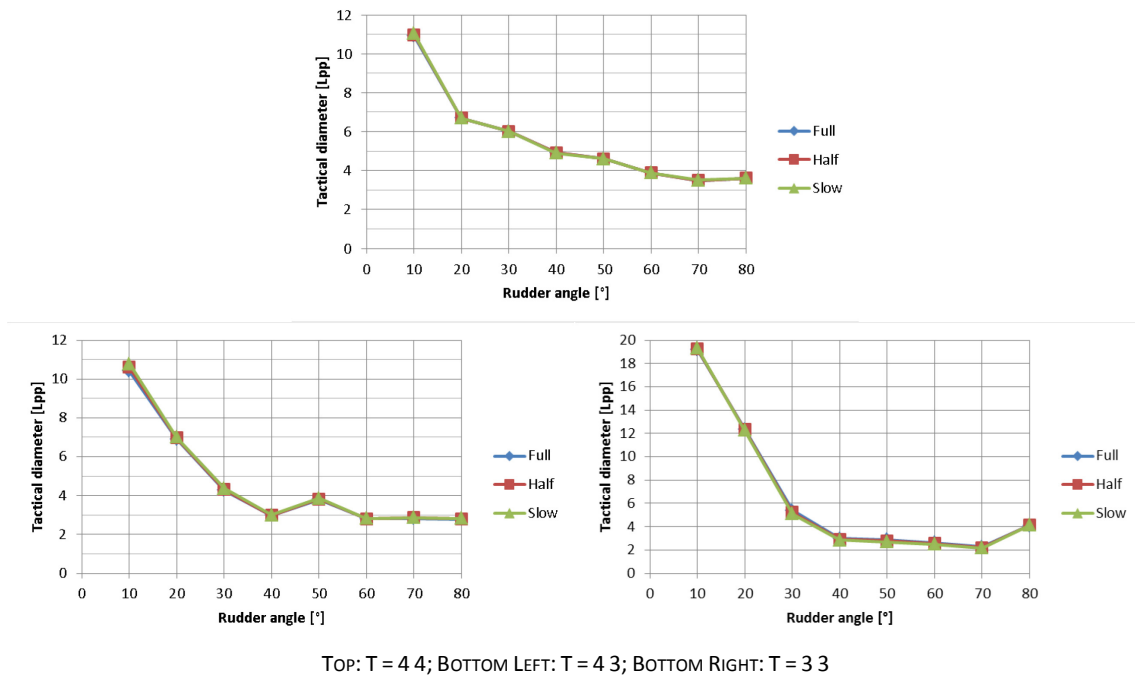
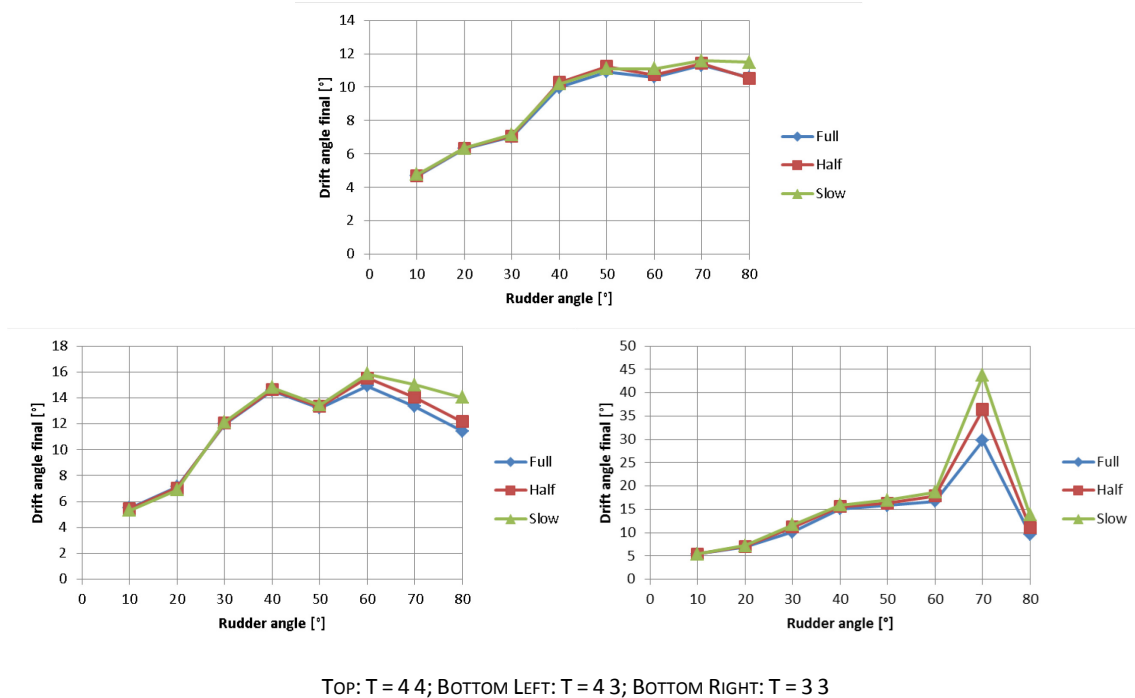
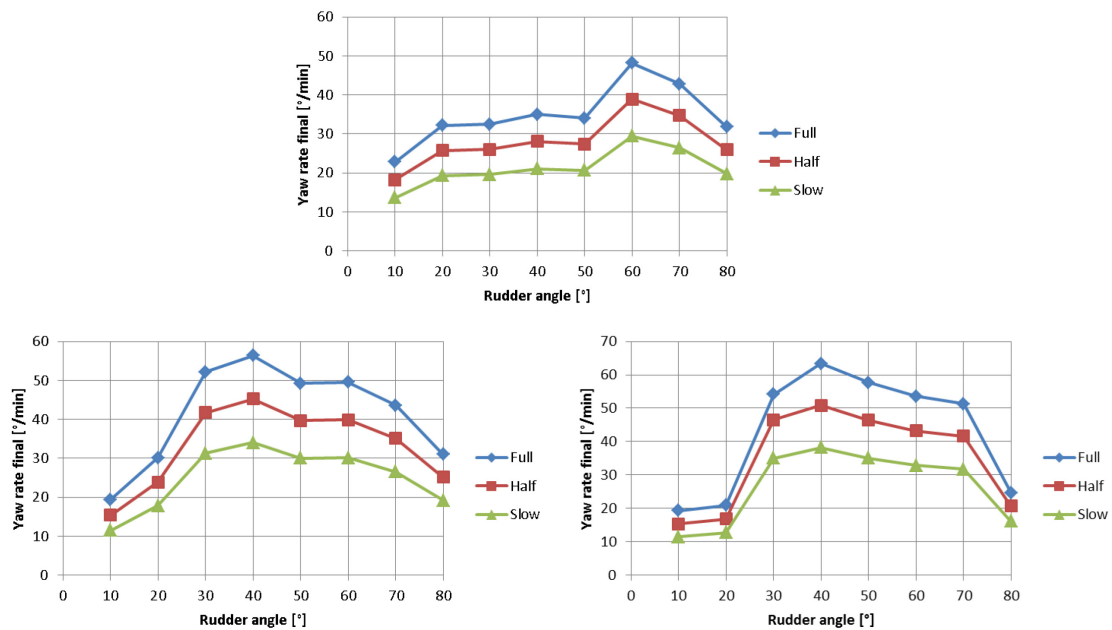


Figure 24 – Turning circle – Final drift angle as a function of applied rudder angle with varying telegraph position (ukc 100%)



The final yaw rate is shown in Figure 25. The influence of the telegraph position is clearly visible. The larger the rpm value, the larger the final rate of turn.

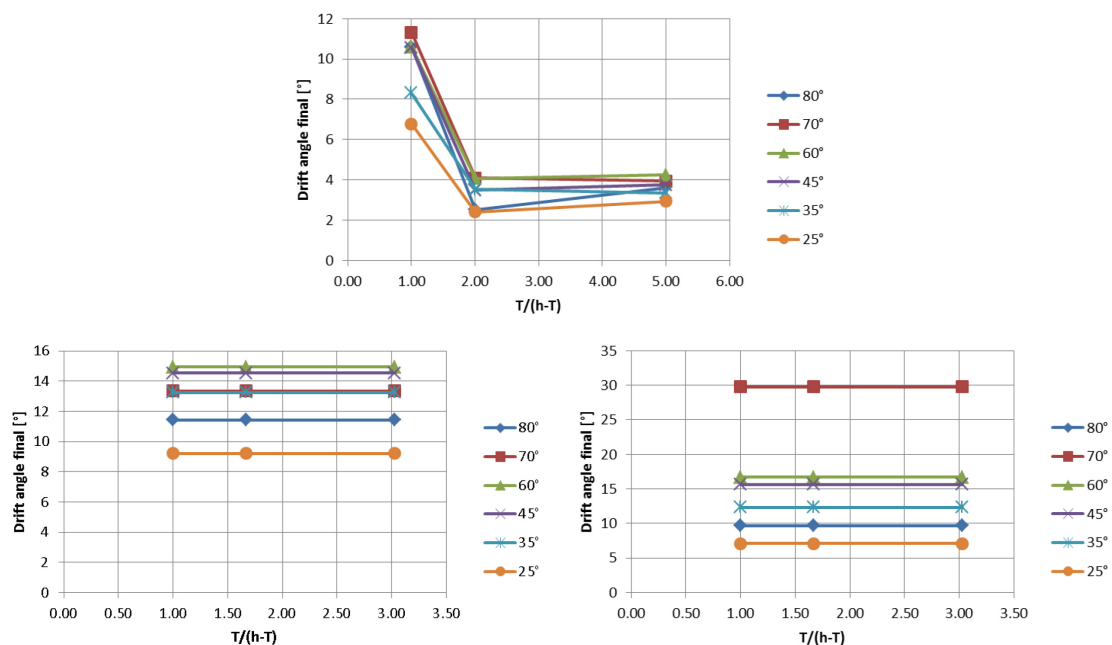
Figure 25 – Turning circle – Final yaw rate as a function of applied rudder angle with varying telegraph position (ukc 100%)



TOP: T = 4.4; BOTTOM LEFT: T = 4.3; BOTTOM RIGHT: T = 3.3

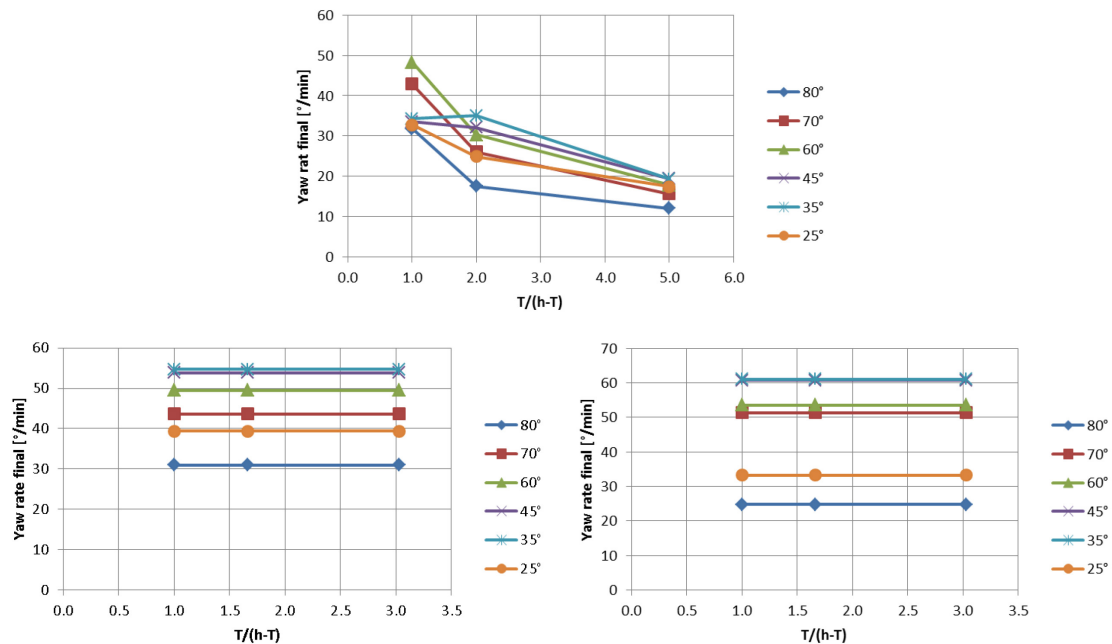
The final drift angle and final rate of turn are shown in respectively Figure 26 and Figure 27 as a function of the under keel clearance for varying rudder angles.

Figure 26 – Turning circle – Final drift angle as a function of under keel clearance with varying telegraph position (Full - 5.5 rps)



TOP: T = 4.4; BOTTOM LEFT: T = 4.3; BOTTOM RIGHT: T = 3.3

Figure 27 – Turning circle – Final yaw rate as a function of under keel clearance with varying rudder angle (Full - 5.5 rps)



TOP: $T = 4.4$; BOTTOM LEFT: $T = 4.3$; BOTTOM RIGHT: $T = 3.3$

Non-standard turning circle (unsteady)

Unsteady turning circles were performed for series J0701A01 (100% ukc). Following initial speeds have been applied: -2 km/h, -1 km/h, 0 km/h, 1 km/h, 2 km/h. Results (longitudinal and transversal speed, rate of turn) are shown in Annex 2 for series J0701A01.

Zig-zag test

Zig-zag manoeuvres have been performed. Figure 28 to Figure 31 give results of the zigzag manoeuvres as a function of the propeller speed (telegraph position).

Figure 28 – 20/20-Zigzag manoeuvre – time to check yaw 1 (100% ukc)

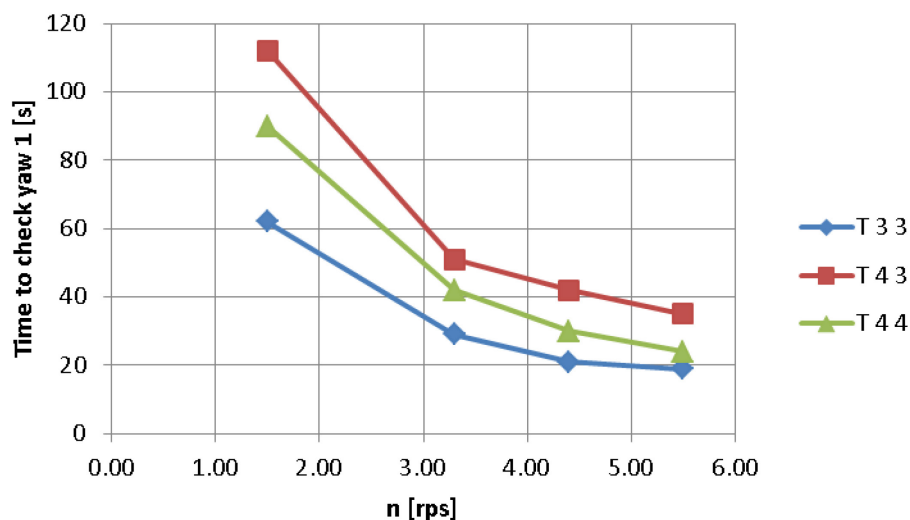


Figure 29 – 20/20-Zigzag manoeuvre – time to check yaw 2 (100% ukc)

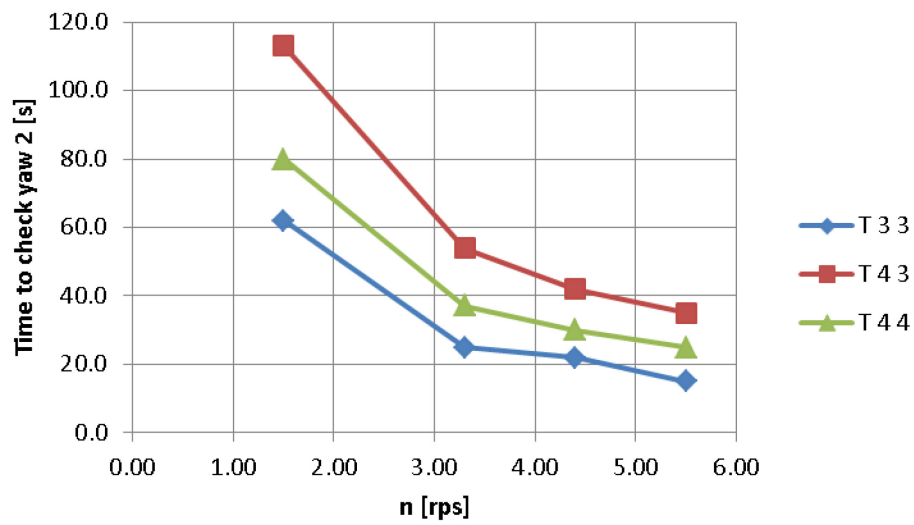


Figure 30 – 20/20-Zigzag manoeuvre – overshoot angle 1 (100% ukc)

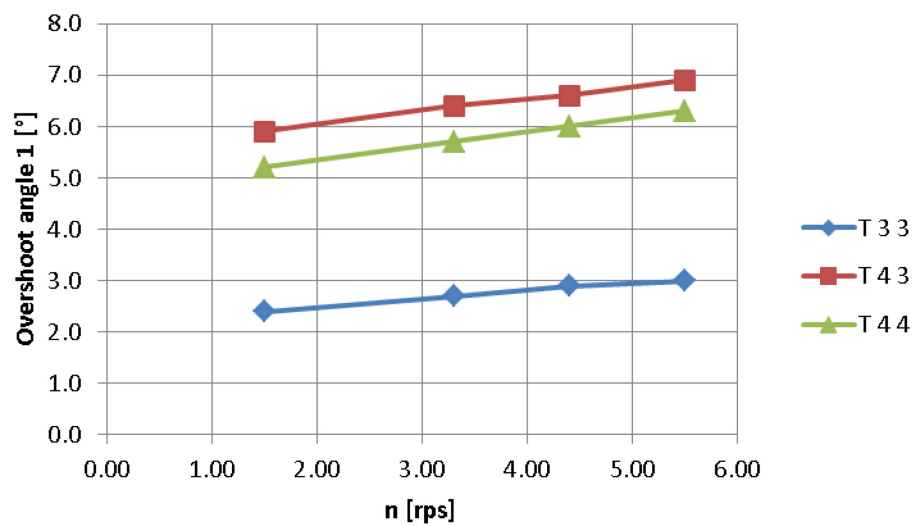
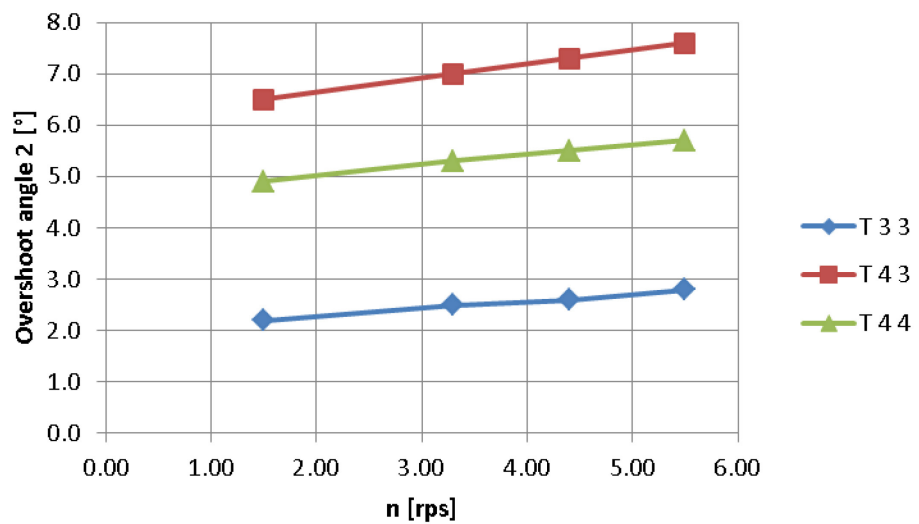


Figure 31 – 20/20-Zigzag manoeuvre – overshoot angle 2 (100% ukc)



Crash stop test

Figure 32 shows the time to stop with a crash stop with varying telegraph position. In the test the propeller was set astern with the same rpm value as the rpm value which was used ahead. In Figure 33 the stopping distance is shown.

Figure 32 – Crash stop test – time to stop by using the engine astern with the same rpm as used ahead

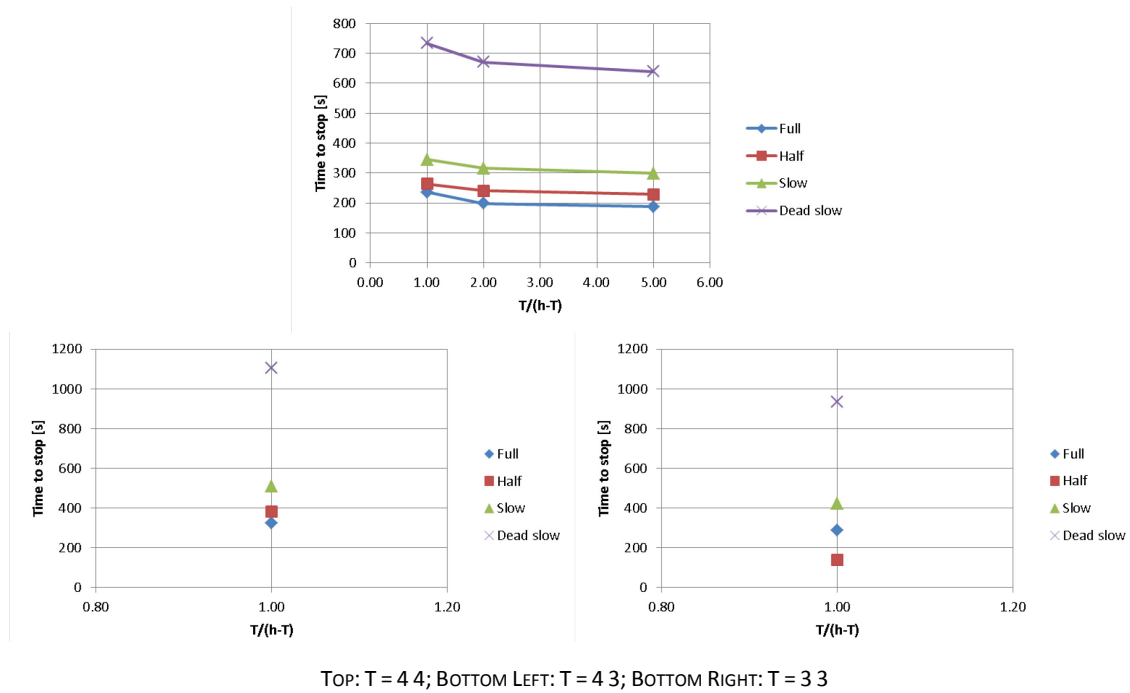
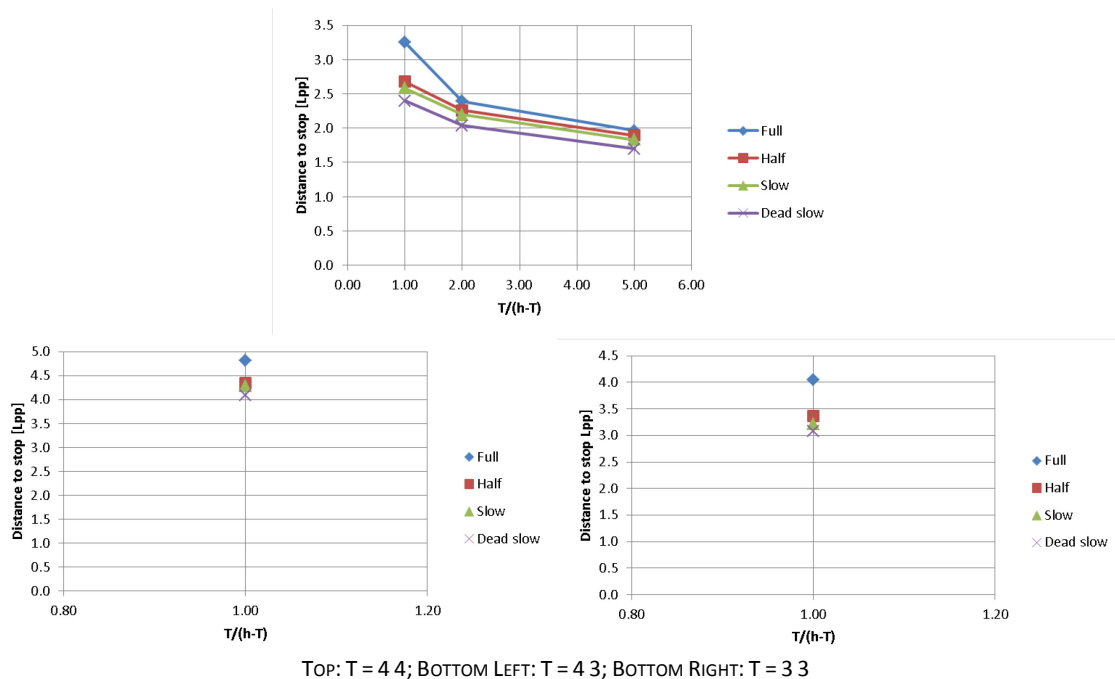


Figure 33 – Crash stop test – distance to stop by using the engine astern with the same rpm as used ahead



4 Implementation in simulator

3D-visuals of the vessels with all their drafts have been developed.

The pusher was developed based on the 3D-visual of a pusher, which was derived from the vessel “Lianco” (see Figure 33). The push boat was elongated to correspond with the dimensions of the pusher which was tested in the towing tank.

Figure 34 – Lianco (Photographer Frank Behrends)



Figure 34 and Figure 35 both show the 3D models of the Peche Melba and the Dame Noire.

Figure 35 – Peche Melba 3D model

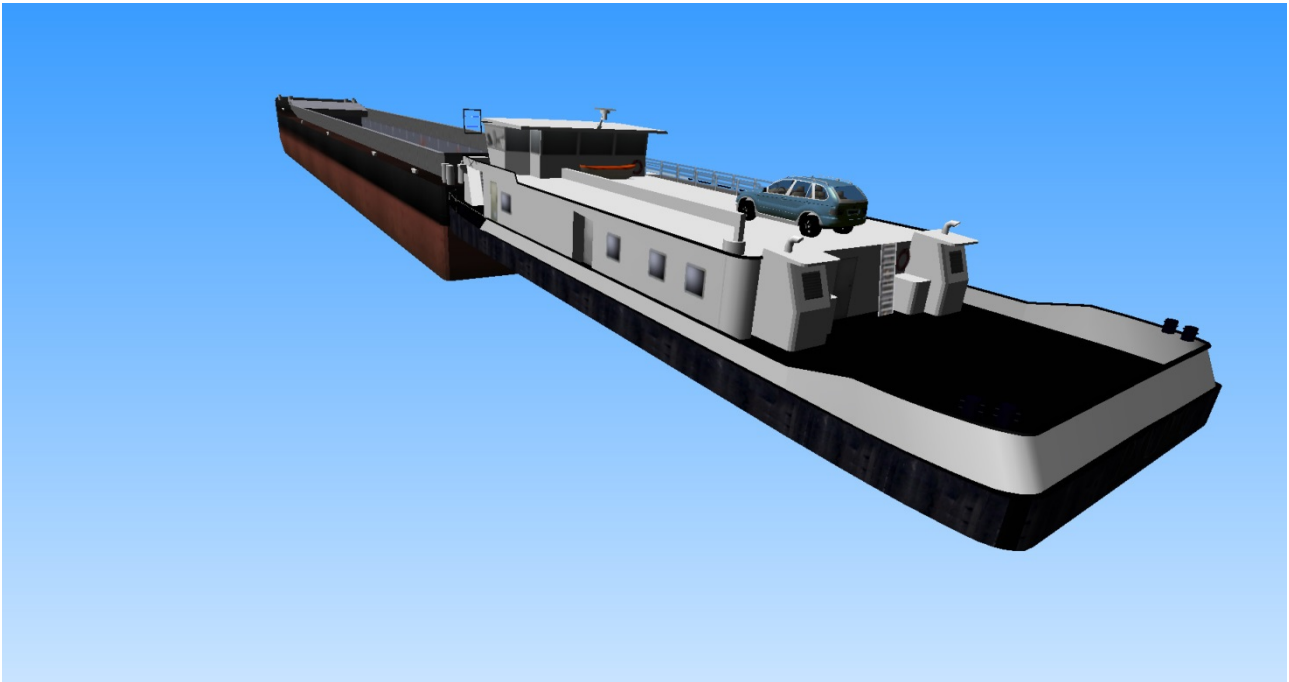
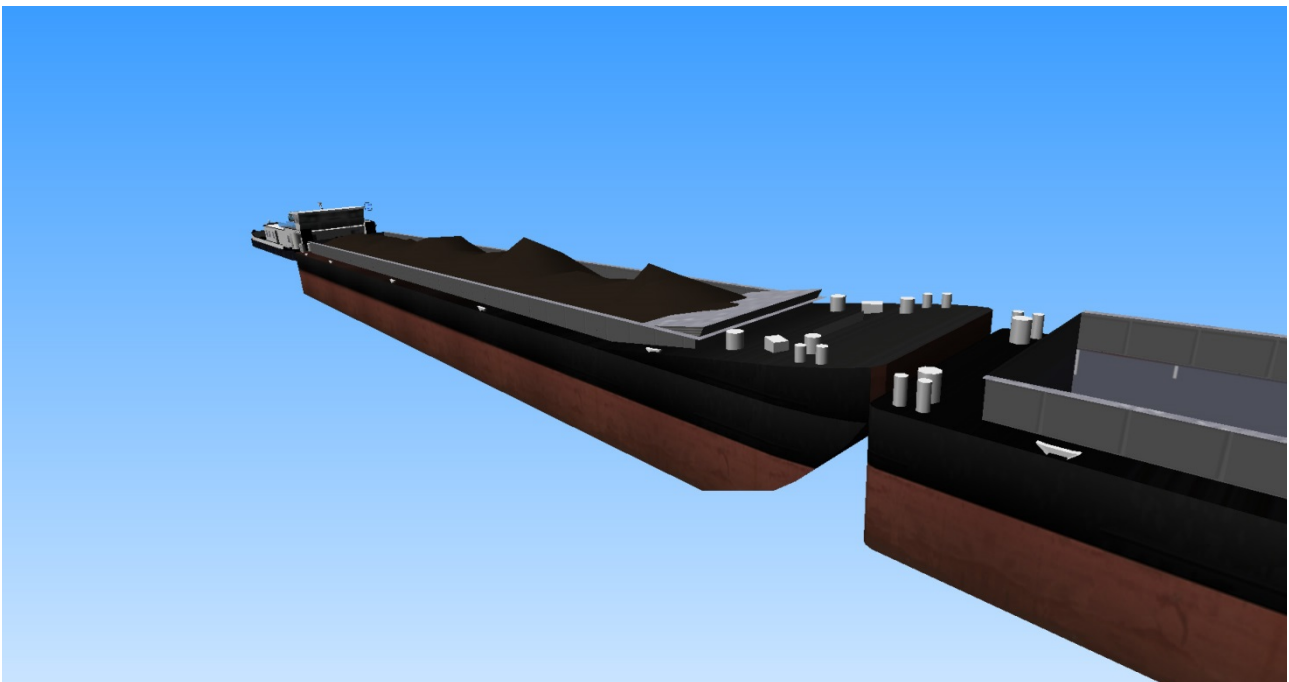


Figure 36 – Dame Noire 3D model



5 Real-time simulations

A real time simulation validation still has to be done.

It is advised to focus on unsteady manoeuvres e.g. the execution of a swinging manoeuvre or the entrance of a lock.

6 Conclusions

By modifying N_p , F_x and removing outliers in YPBetaTabel and YPGammaTabel the behaviour and especially rate of turn during turning manoeuvres has been improved. It should be noticed that modifications were implemented based on an improvement on especially rate of turn curves as a function of time. Not only the curves are smoother, but the maximum values of the rate of turn are influenced as well.

The following should be done in the future:

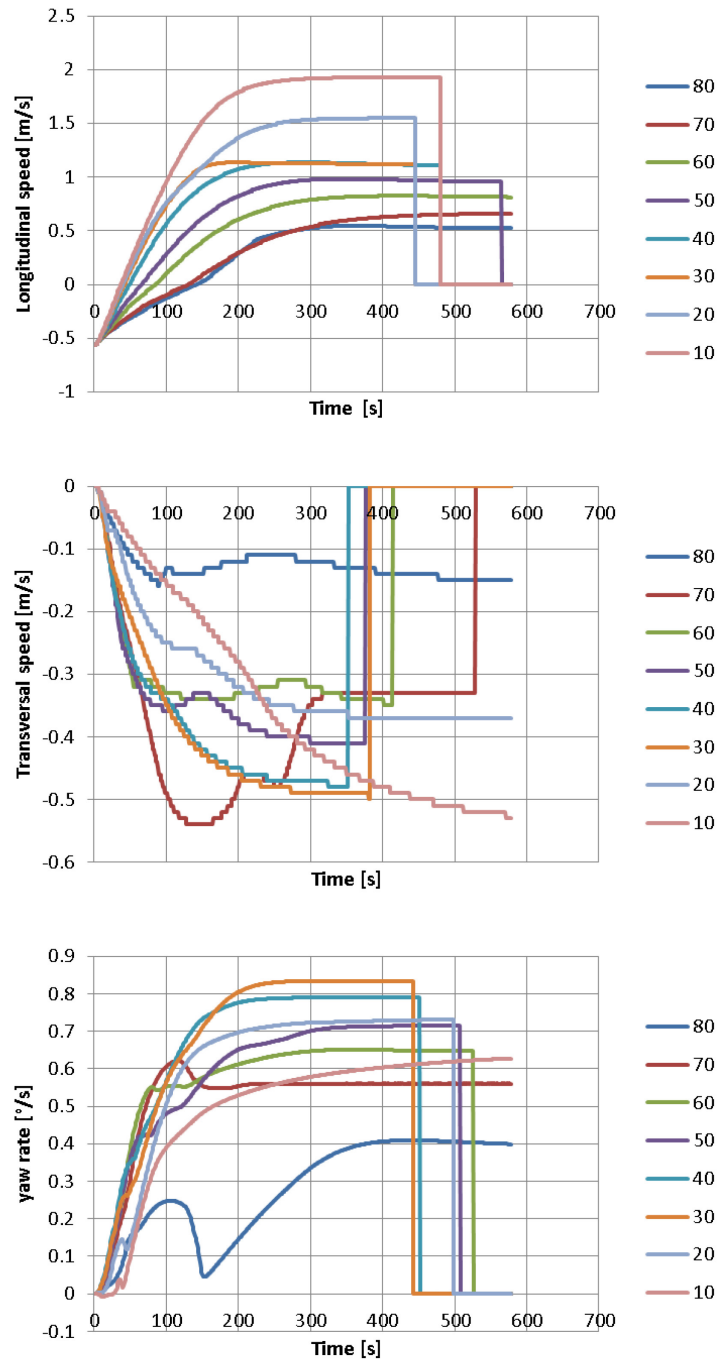
- Real time validation with skippers;
- Investigation of models and their behaviour around 'zero-speed'. Starting with a negative speed, the time series of rate of turn and longitudinal speed show that the point of crossing the 'zero-speed' is still a point to investigate. This is recommended for the remaining push convoys as well.

7 References

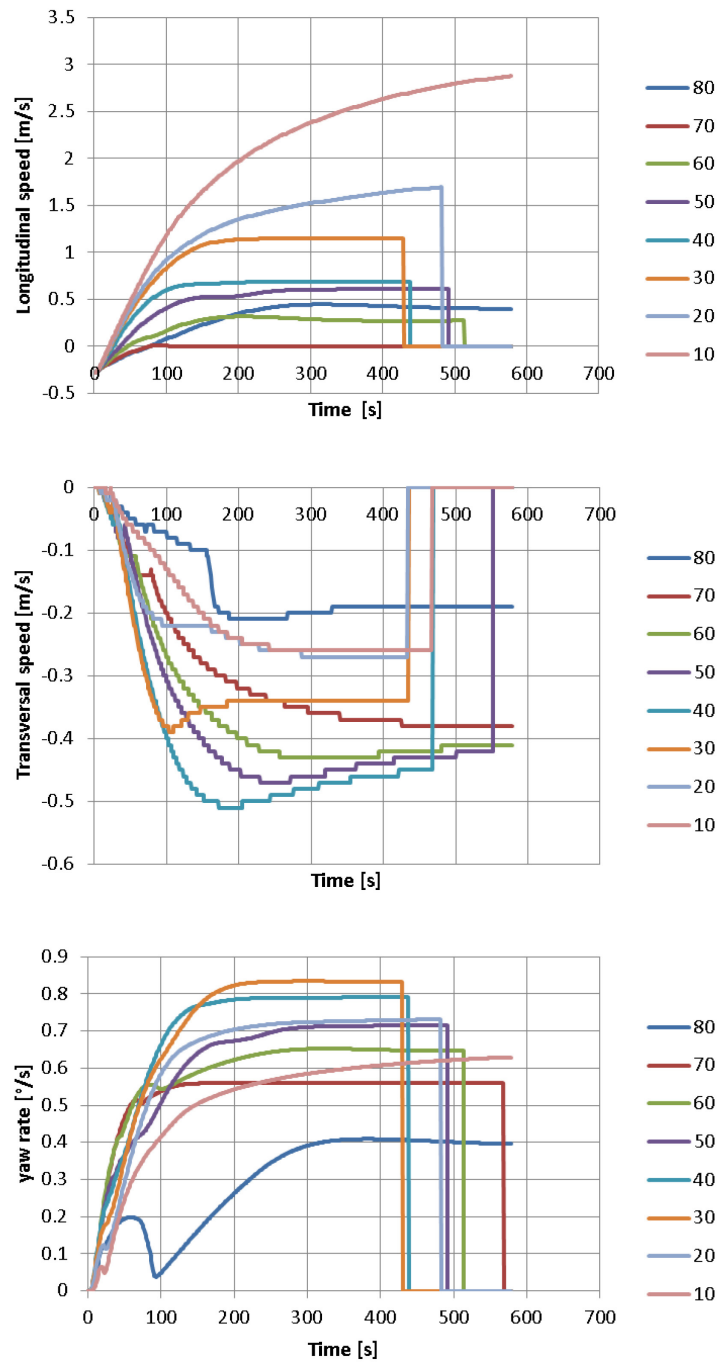
- [1] **Delefortrie, G.; Eloot, K.; Peeters, P.; Mostaert, F. (2016).** Manoeuvring behaviour of push convoys: Sub report 5 – Class Va: mathematical modelling and fast time simulations. Version 4.0. WL Rapporten, 15_001. Flanders Hydraulics Research, Antwerp, Belgium.
- [2] **Delefortrie, G.; Eloot, K.; Peeters, P.; Mostaert, F. (2016).** Manoeuvring behaviour of push convoys: Sub report 4 – Class Vb: mathematical modelling and fast time simulations. Version 4.0. WL Rapporten, 15_001. Flanders Hydraulics Research, Antwerp, Belgium.

Annex 1: Fast-time results Peche Melba – unsteady turning circles (J1001A02 ukc 100%)

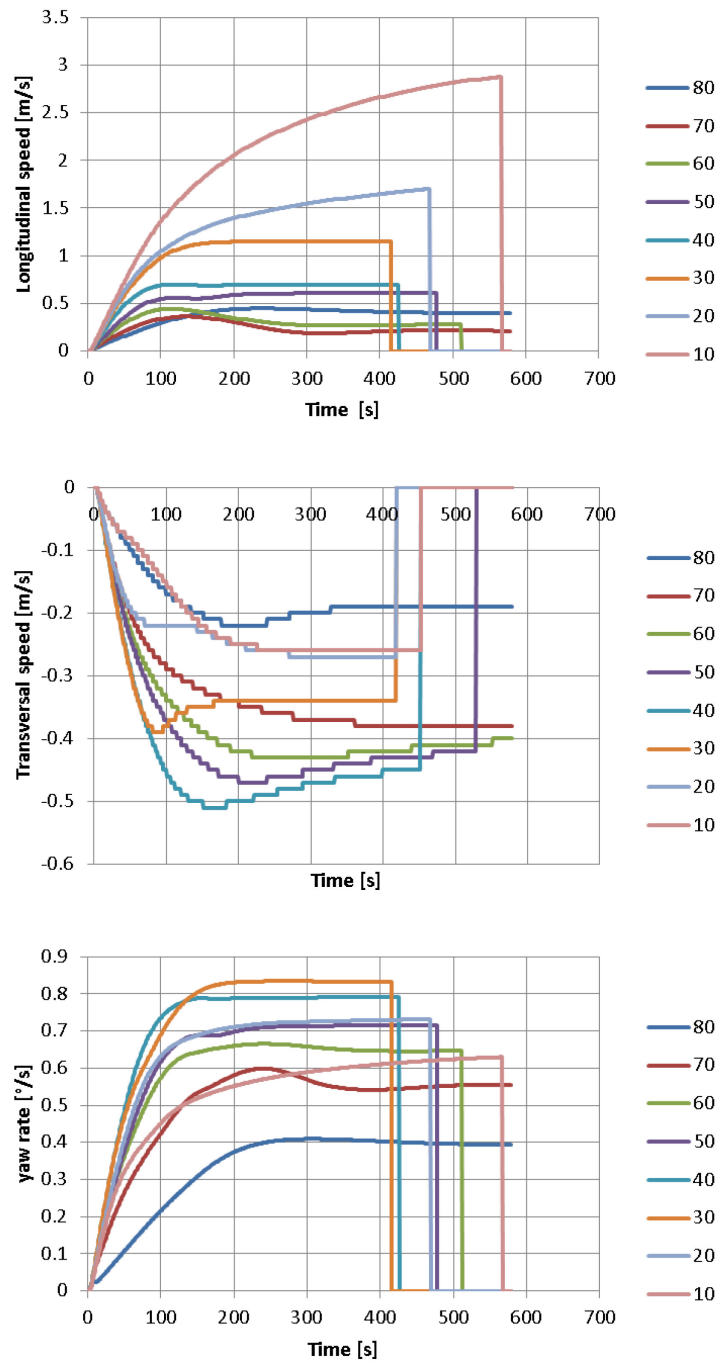
Initial speed -2 km/h, 3.3 rps



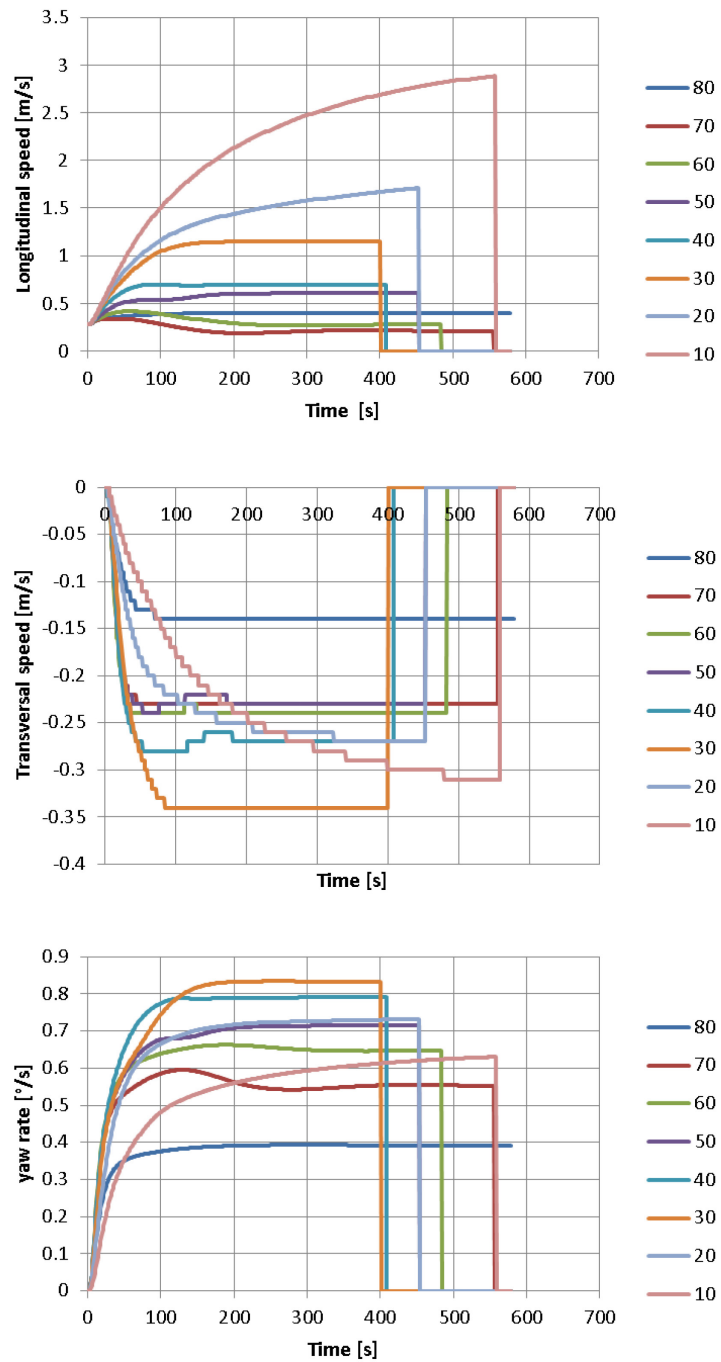
Initial speed -1 km/h, 3.3 rps



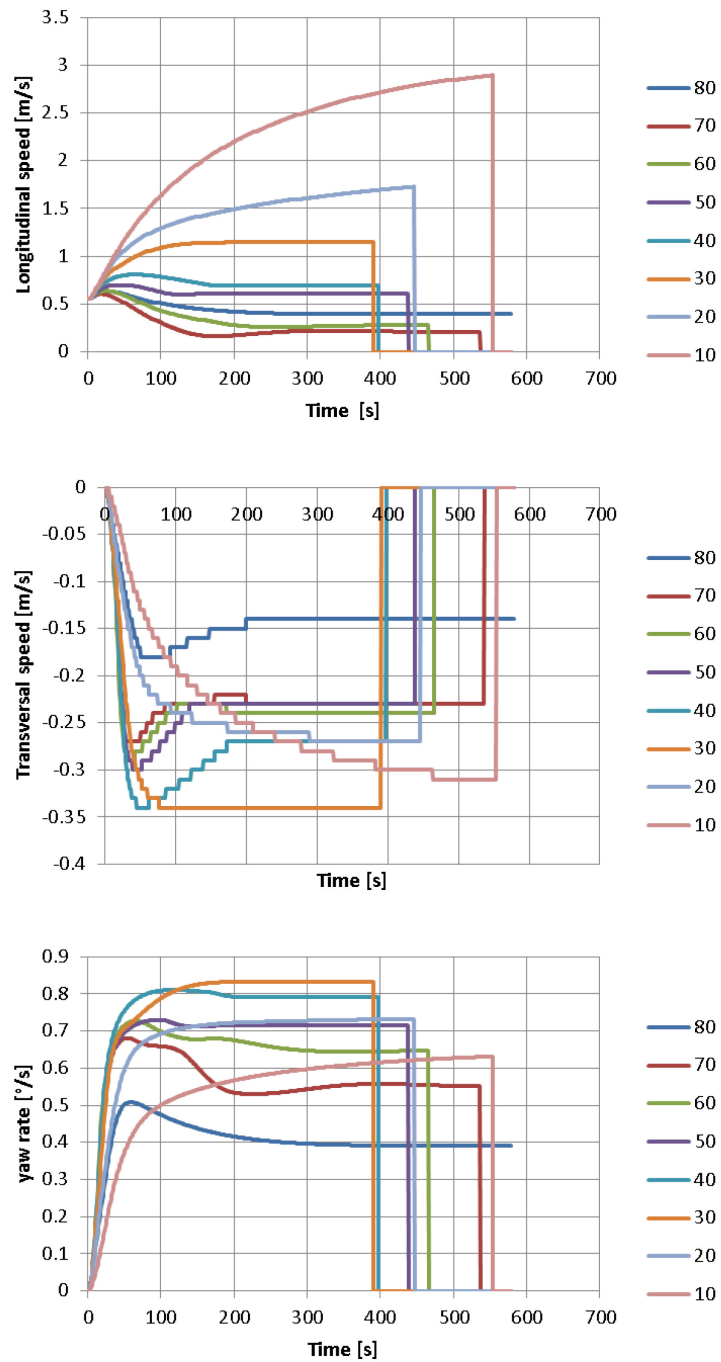
Initial speed 0 km/h, 3.3 rps



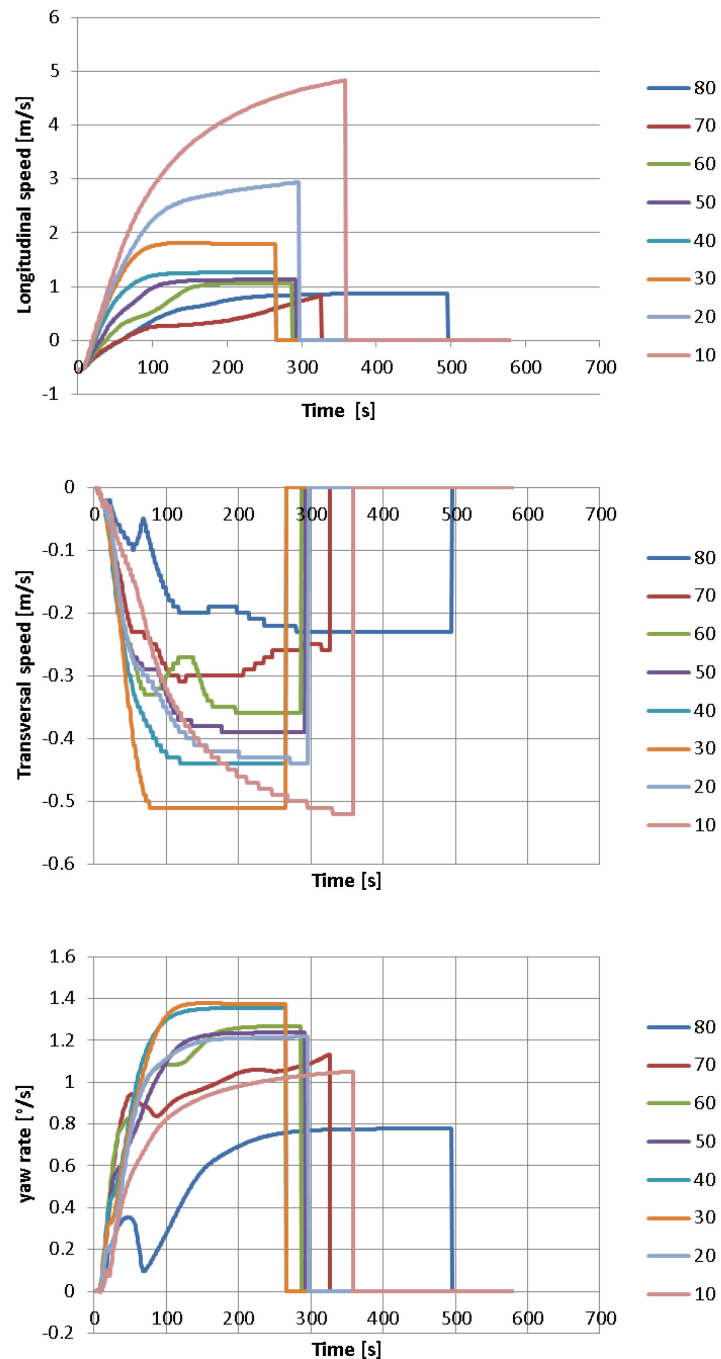
Initial speed 1 km/h, 3.3 rps



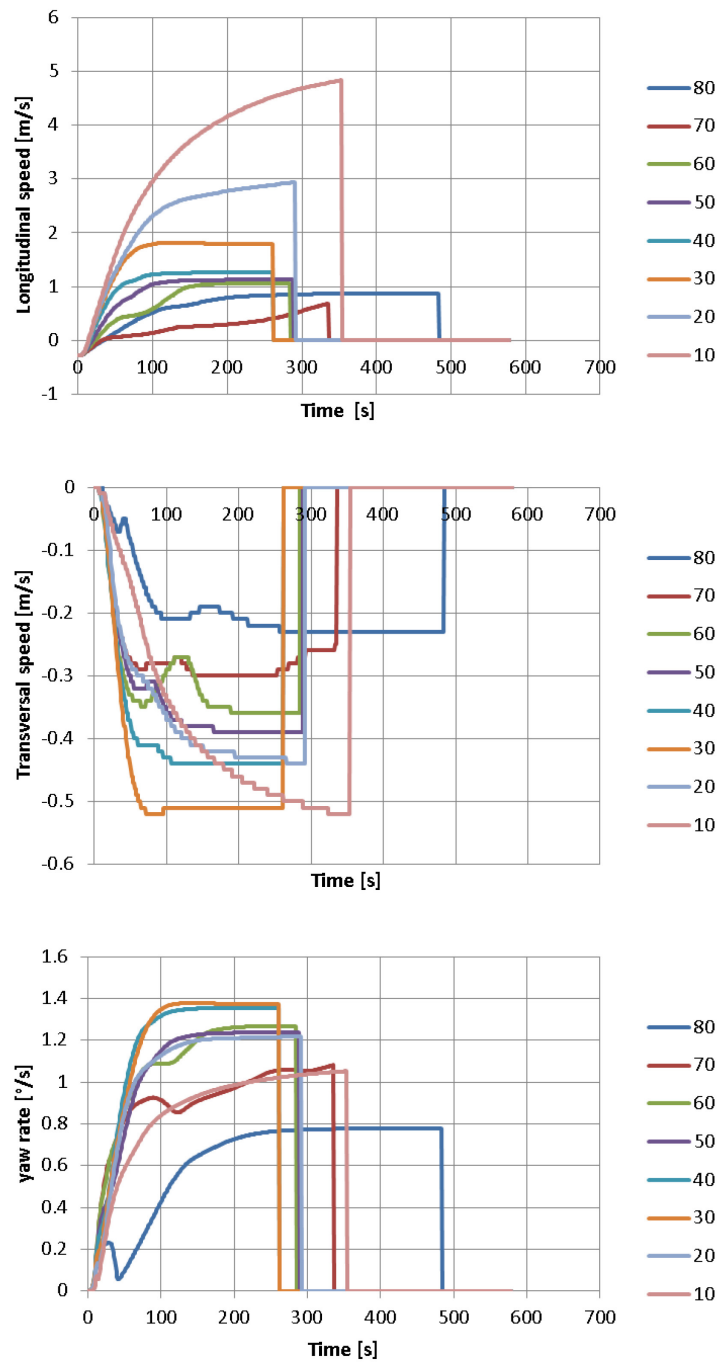
Initial speed 2 km/h, 3.3 rps



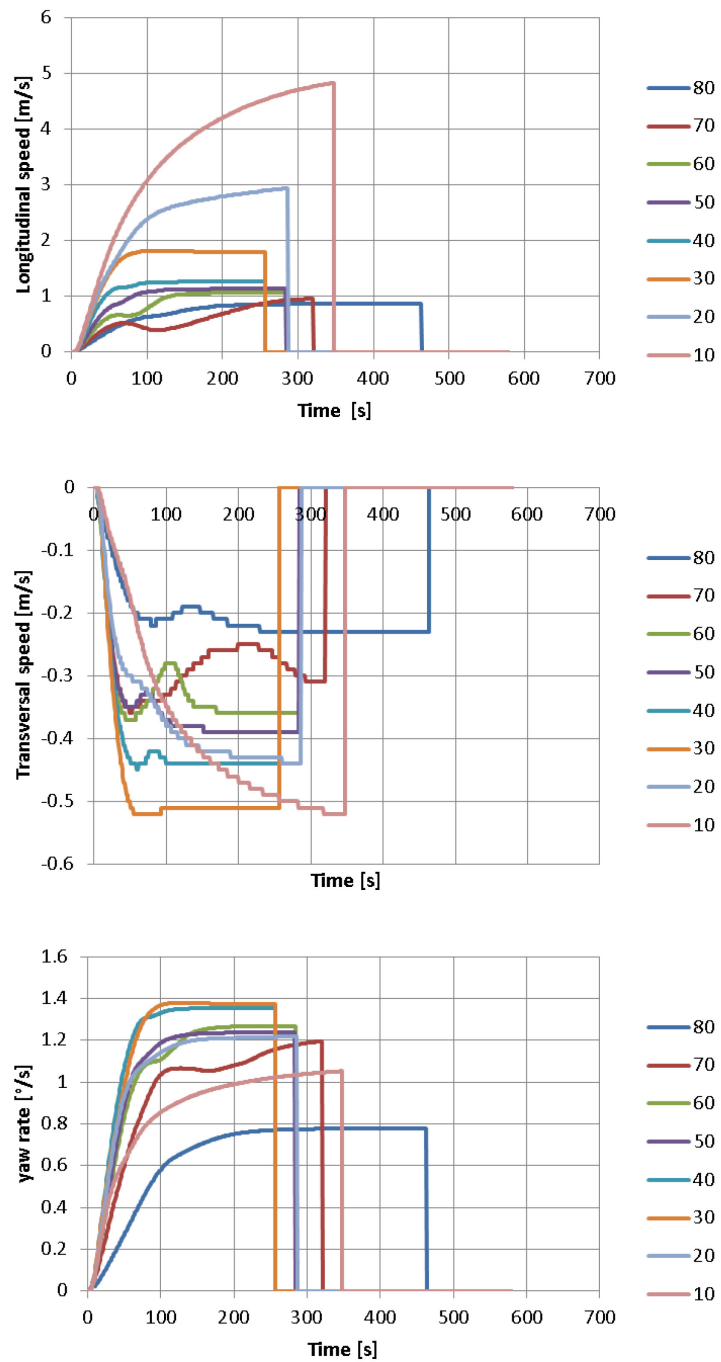
Initial speed -2 km/h, 5.5 rps



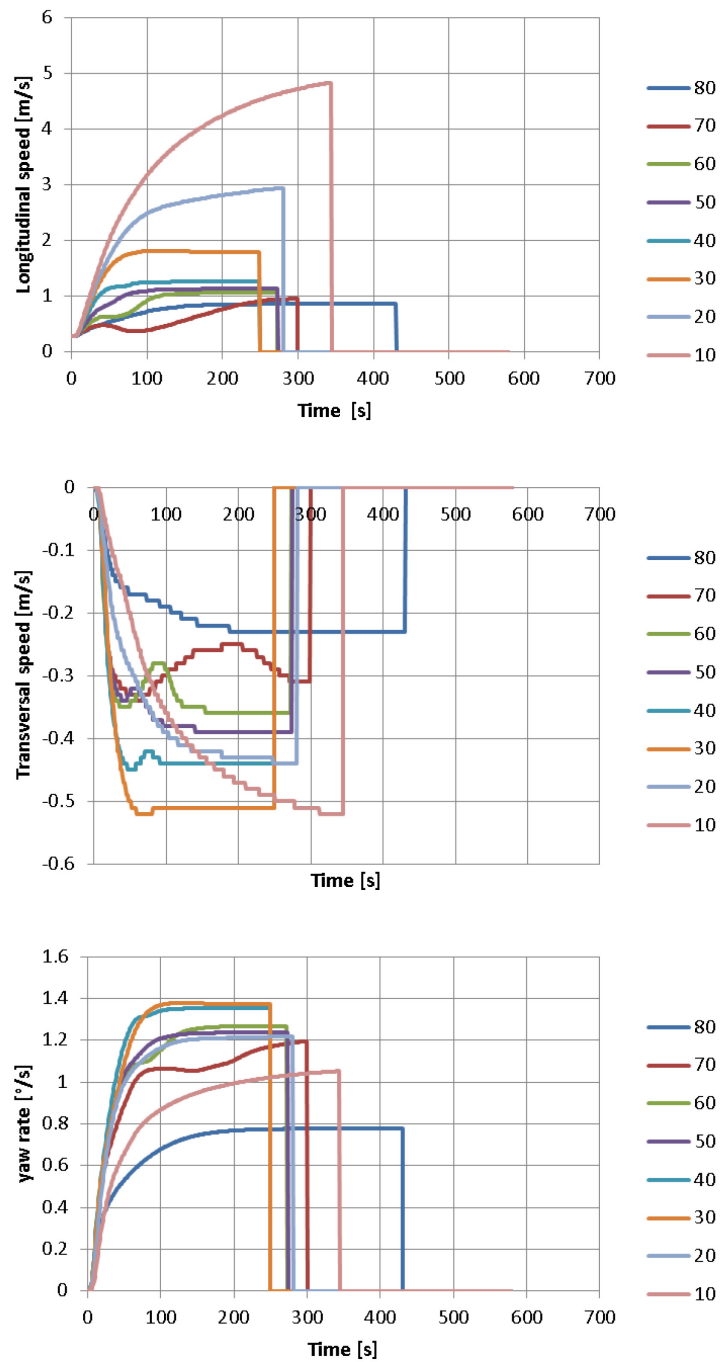
Initial speed -1 km/h, 5.5 rps



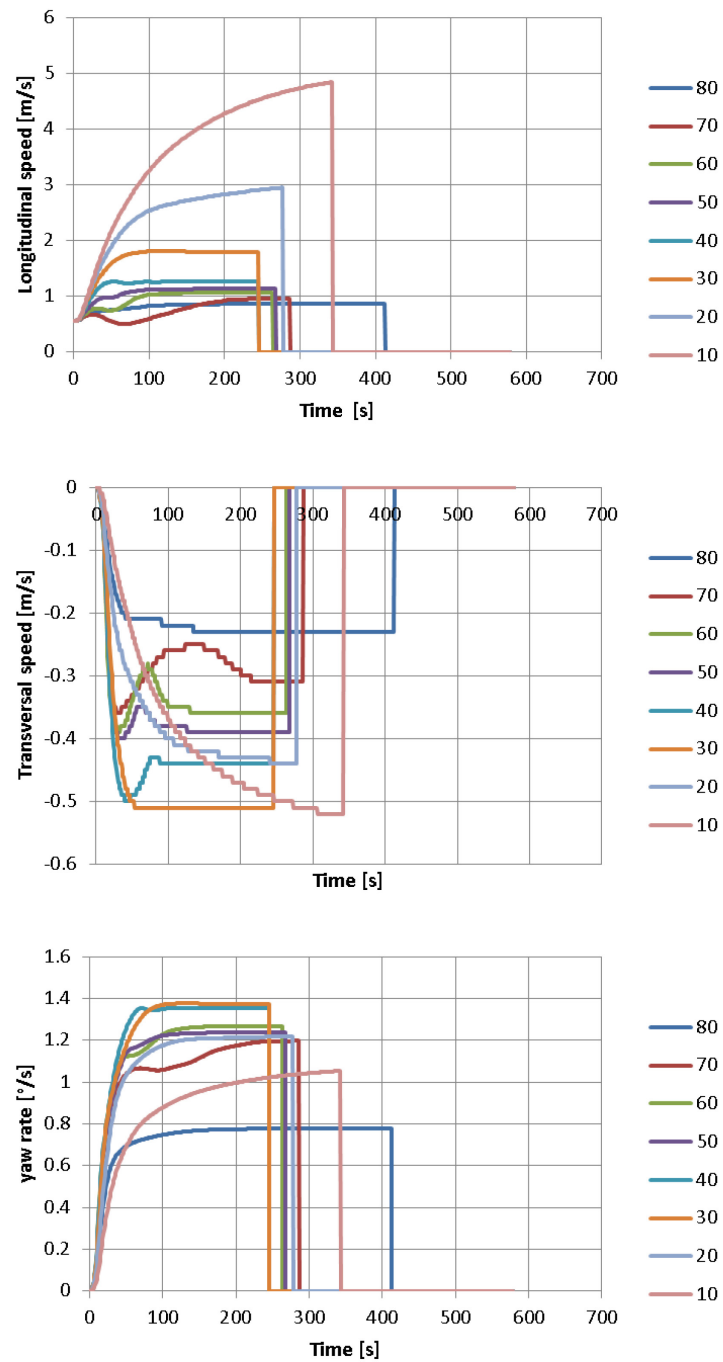
Initial speed 0 km/h, 5.5 rps



Initial speed 1 km/h, 5.5 rps

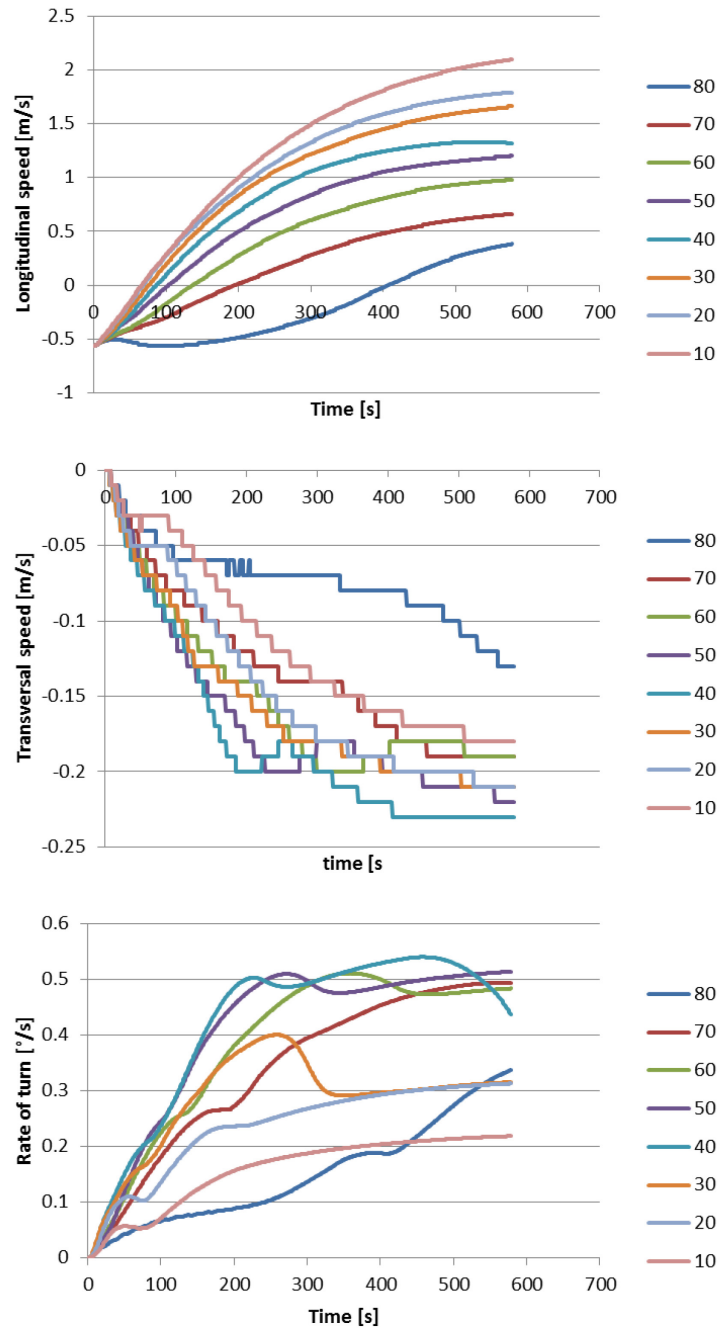


Initial speed 2 km/h, 5.5 rps

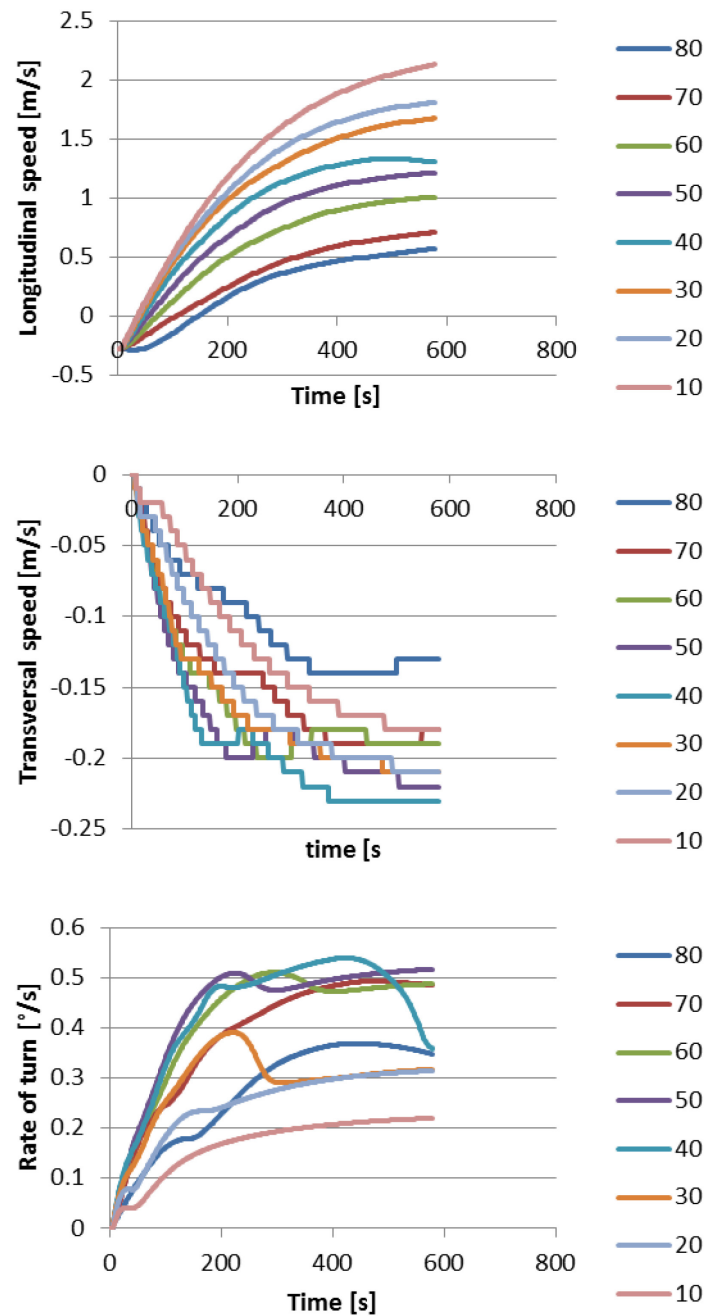


Annex 2: Fast-time results Dame Noire – unsteady turning circles (J0701A01 ukc 100%)

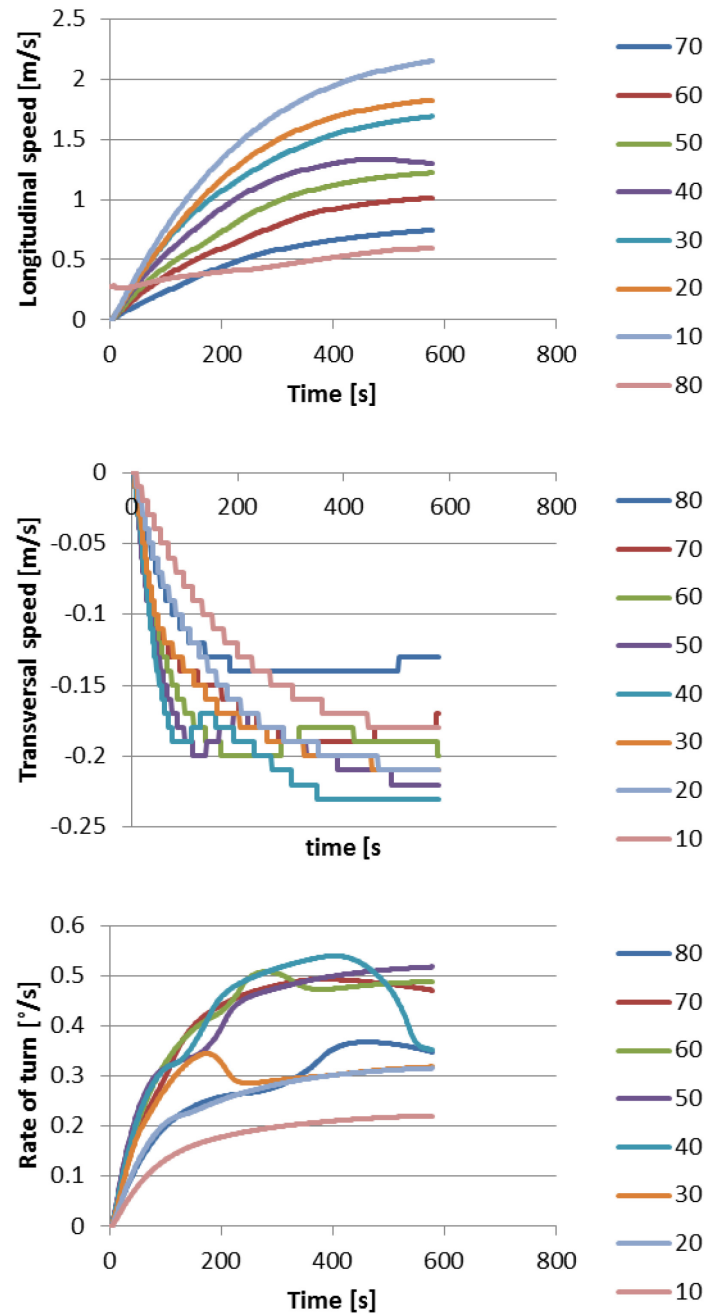
Initial speed -2 km/h, 3.3 rps



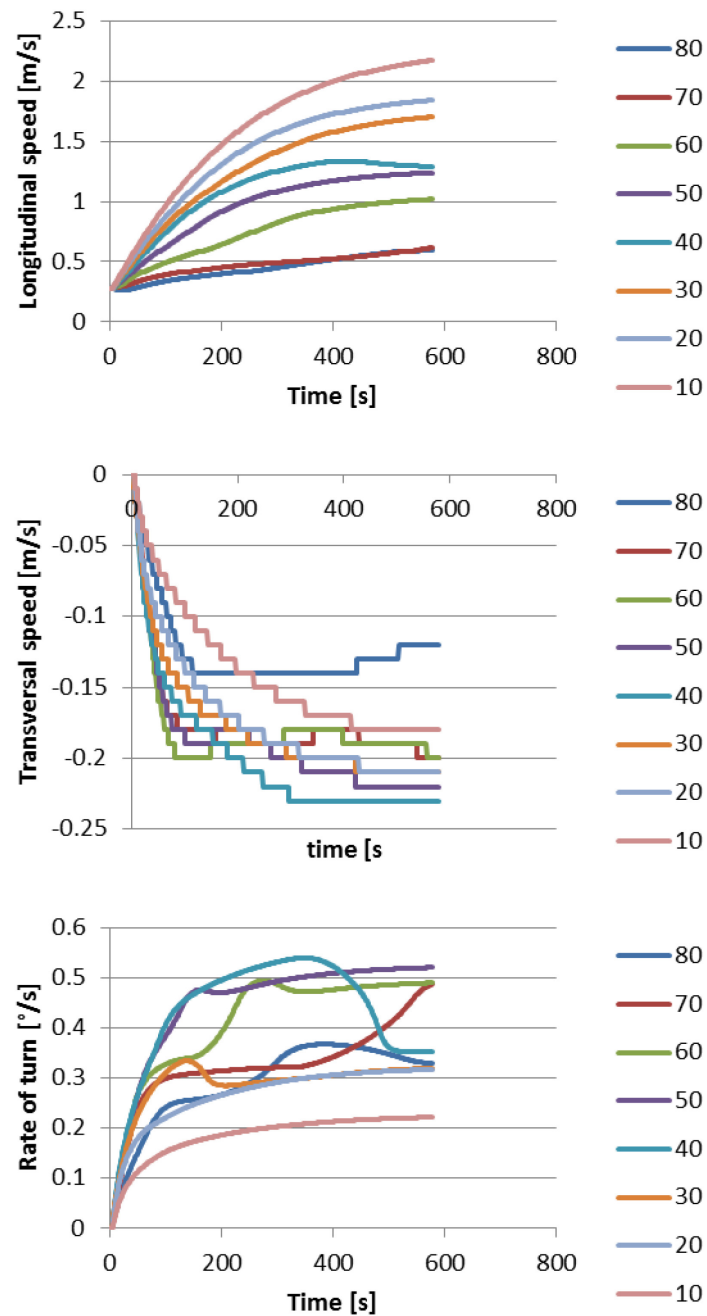
Initial speed -1 km/h, 3.3 rps



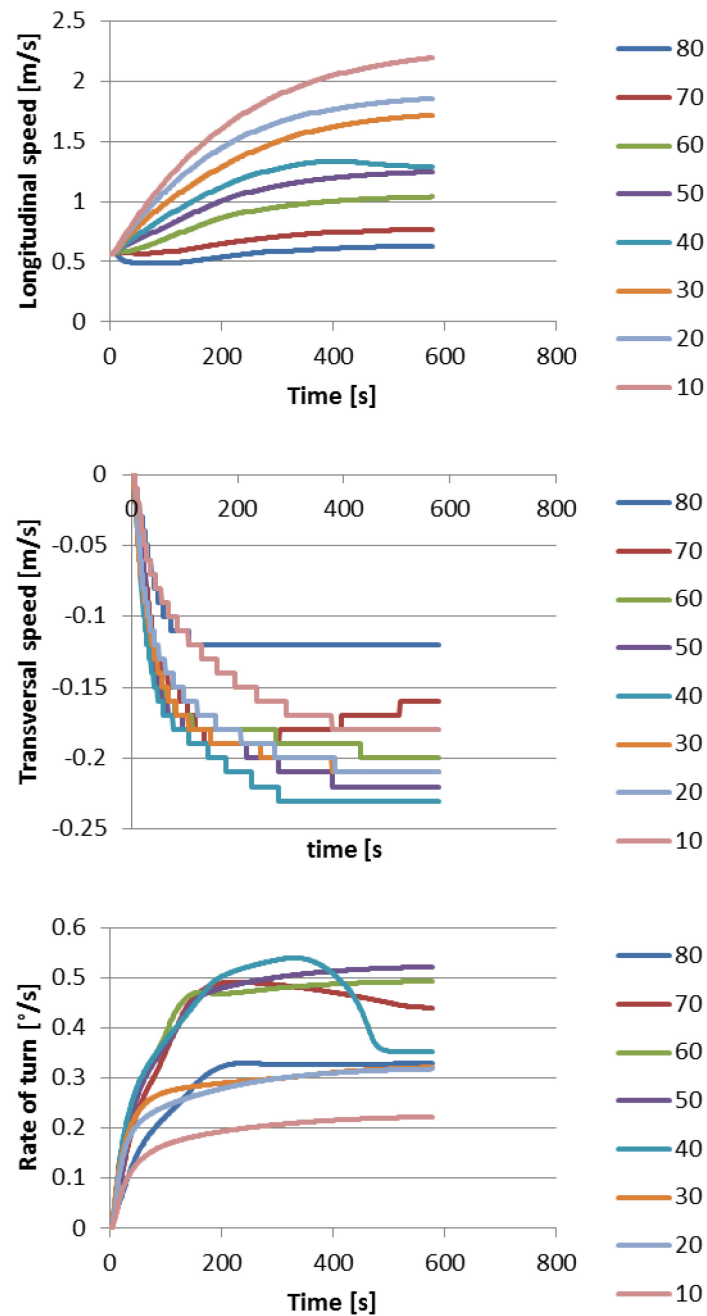
Initial speed 0 km/h, 3.3 rps



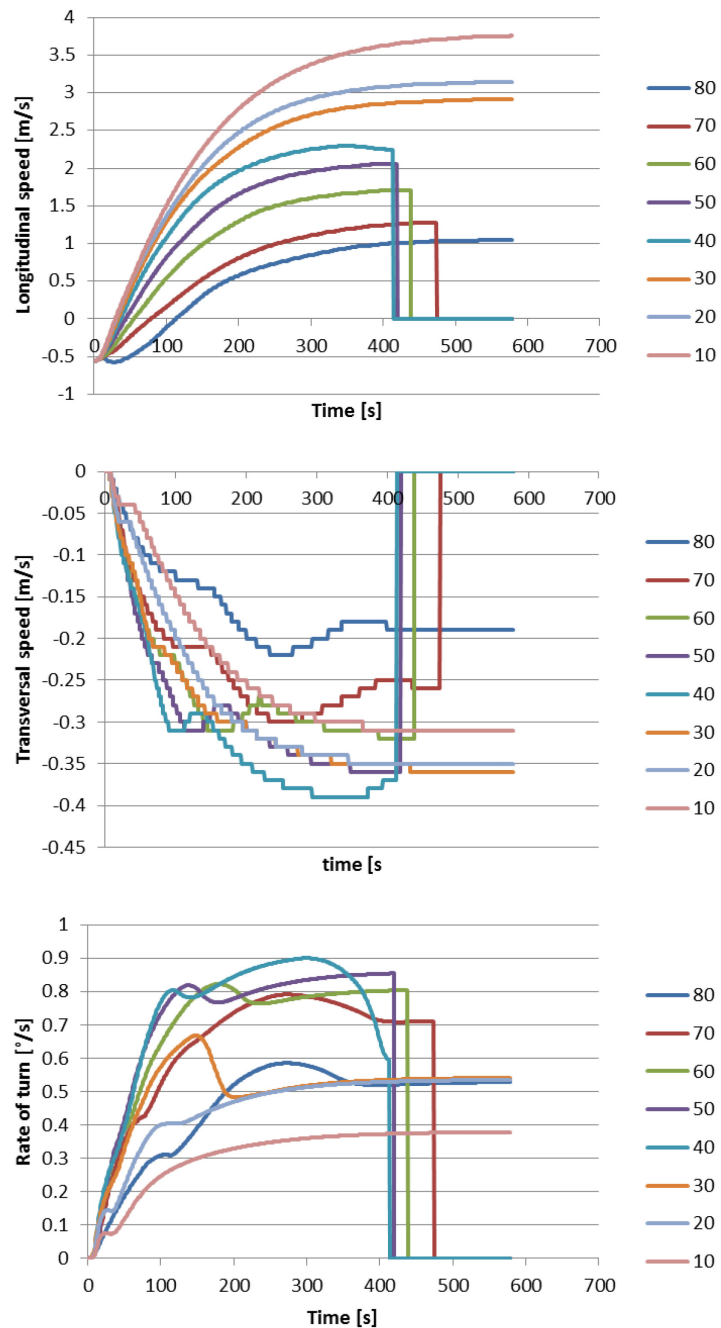
Initial speed 1 km/h, 3.3 rps



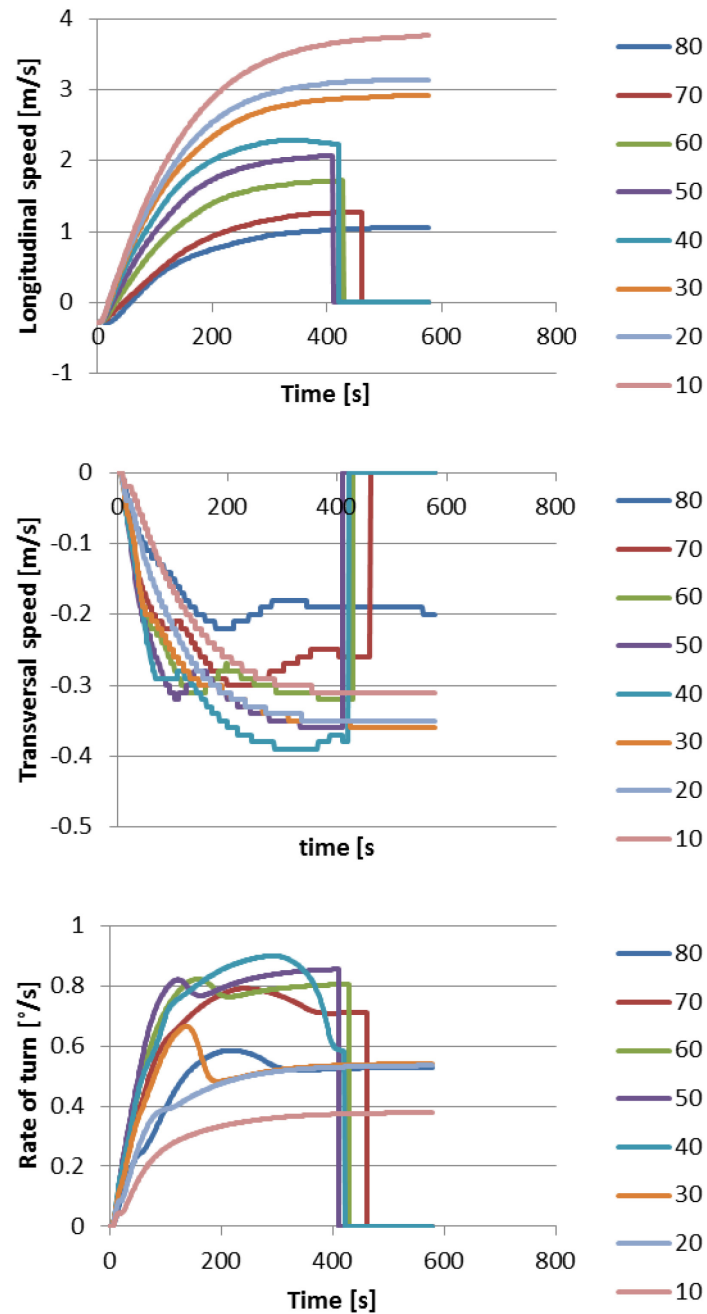
Initial speed 2 km/h, 3.3 rps



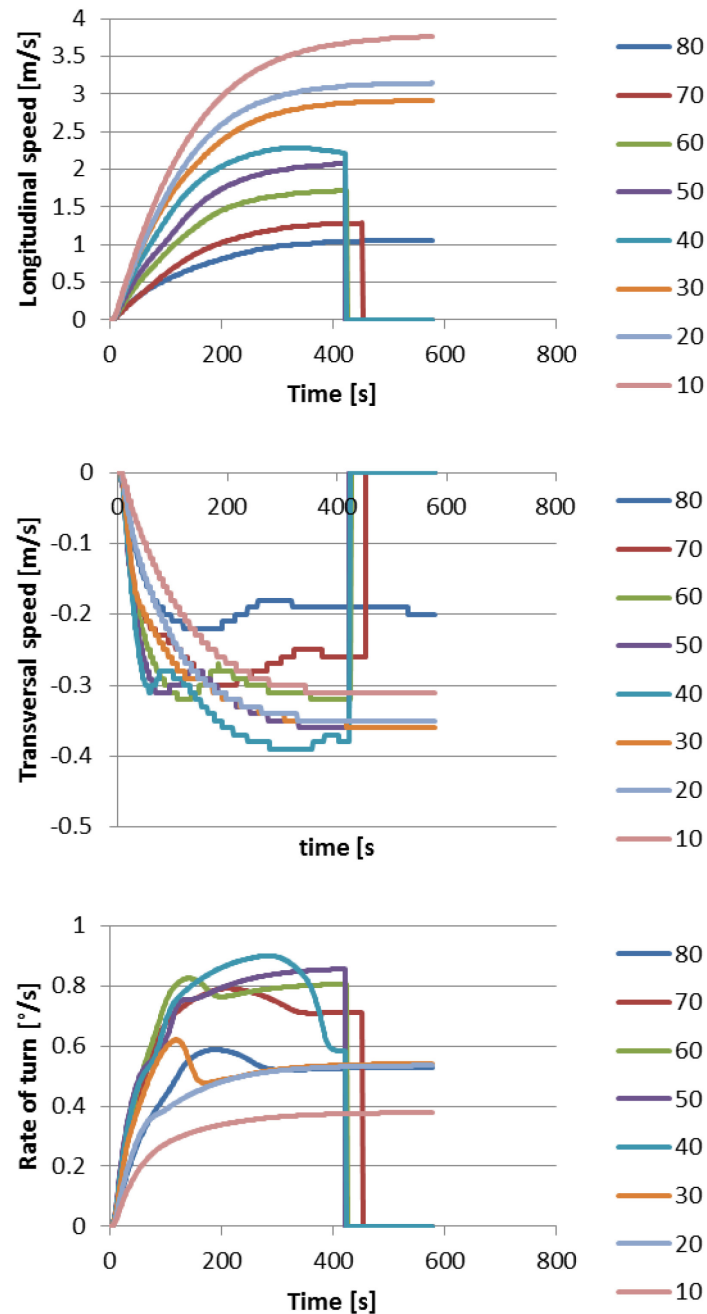
Initial speed -2 km/h, 5.5 rps



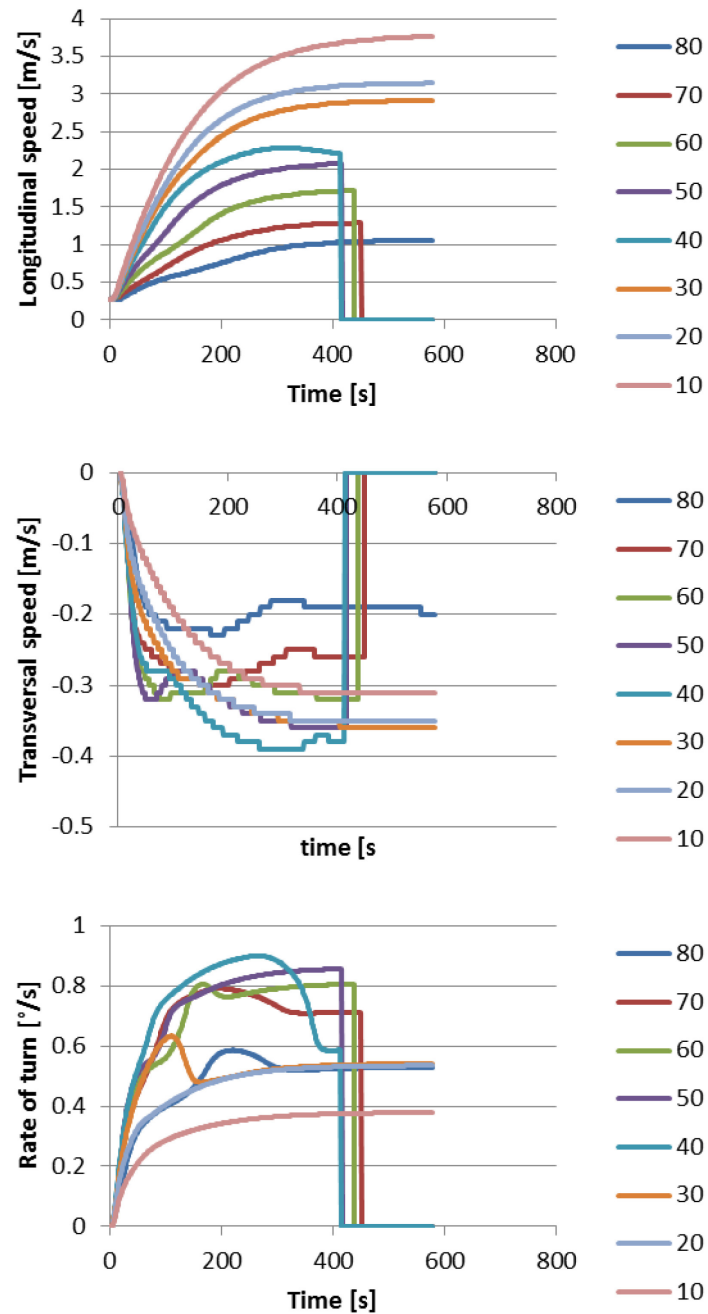
Initial speed -1 km/h, 5.5 rps



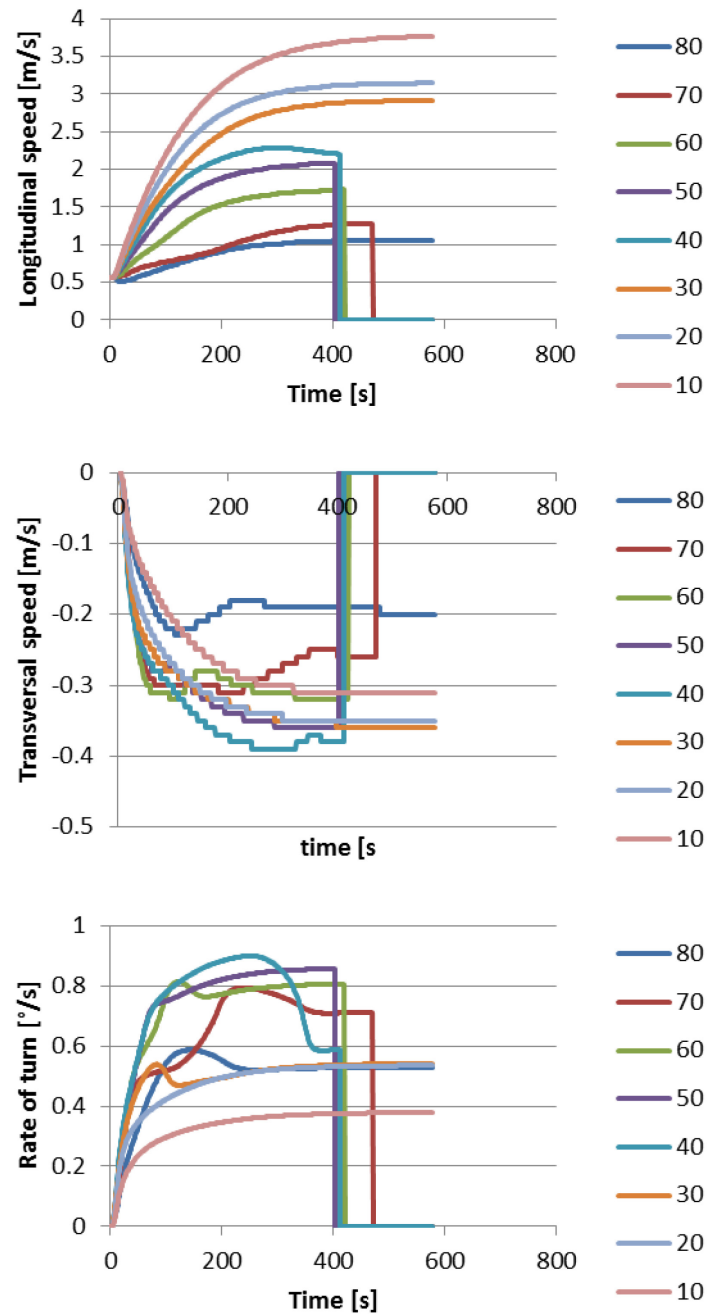
Initial speed 0 km/h, 5.5 rps



Initial speed 1 km/h, 5.5 rps



Initial speed 2 km/h, 5.5 rps



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