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Class Va and Class Vb Push Convoys Manoeuvring Model

Real Time Validation

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Class Va and Class Vb Push Convoys Manoeuvring Model

Real Time Validation

Villagómez, J.; Verwilligen, J.; Mostaert, F.

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Abstract

In order to validate the push convoy manoeuvring models Class Va and Class Vb a first real time validation day was performed on August 30th. In general, the more important issues detected included: self-propulsion speed both ahead and astern, low stopping capacity, low swinging capacity and a low manoeuvrability without propeller action.

A second day of real time validation was performed on November 6th after some model adaptations.

This report describes in detail the real time validation process and the main remarks of the skipper to the model performance and the way in that these issues were treated.

After the second validation day both models were considered validated.

Contents

Abstract	III
Contents	V
List of tables.....	VIII
List of figures	IX
1 General	1
2 Simulation models	2
2.1 Scenarios.....	3
2.2 Manoeuvring behavior of the push convoys.....	3
3 Validation days	8
3.1 Organization	8
3.2 Additional research after validation day 1	10
3.2.1 Self-propulsion speed	10
3.2.2 Low stopping capacity	11
3.2.3 Low swinging in spot capacity	11
3.2.4 Low manoeuvring capacity at low speeds without propeller action	12
3.2.5 Lost of rudder moment with more than 45deg rudder angle	13
3.3 Results of validation day 2.....	14
4 Tuning factors	20
5 Conclusions and recommendations	21
6 References	22
Annex A: Remarks and observations: Validation day 1.....	A1
A.1 DameNoire44 at 20% UKC.....	A1
A.1.1 Ocean_[20190830min0937min555Amin8521min1709ED1C1A04]	A1
-TIME: 00'00 TO 08'00	A1
- TIME: 09'00 to 12'00.....	A1
- TIME: 16'30 to 17'30.....	A1
- TIME: 18'30 to 19'00.....	A1
-TIME: 21'30 to 22'00	A1
-TIME: 22'00 to 40'00	A1
- TIME: 23'30 to 40'00.....	A1
- TIME: > 40'00	A1
A.1.2 Ocean_[20190830min1025min22F0min5F97minE04BEF1C1A04]	A2
- TIME: < 04'00	A2

A.2	DameNoire44 at 50% UKC	A2
6.2.1	Ocean_[20190830min1034min35B8minAE34min3BBCEF1C1A04]	A2
	- TIME: < 11'00	A2
	- TIME: 11'00 to 15'00	A2
	- TIME: 19'30 to 22'20	A2
	- TIME: 21'00 to 21'30	A2
	- TIME: 25'00	A2
	- TIME: 33'00 to 35'00	A2
6.2.2	Ocean_[20190830min1113min35C2min88C2minDC97F11C1A04]	A2
	- TIME: 00'00 to 07'00	A2
A.3	DameNoire44 at 100% UKC	A3
A.3.1	Ocean_[20190830min1142min124FminF8C7minC1F4F21C1A04]	A3
	- TIME: 11'20 to 13'30	A3
	- TIME: 16'00 to 17'30	A3
	- TIME: 20'00 to 20'20	A3
A.3.2	Ocean_[20190830min1209min559Cmin178CminD546F41C1A04]	A3
	- TIME: 02'30 to 03'30	A3
	- TIME: 04'30 to 05'40	A3
	- TIME: 11'00 to 11'40	A3
	- TIME: 13'50 to 15'10	A3
A.4	PecheMelba33 at 100% UKC	A4
A.4.1	Ocean_[20190830min1253min0319minC751minC154F61C1A04]	A4
	- TIME: 08'00	A4
A.4.2	Ocean_[20190830min1311min0788minF552min2D31F71C1A04]	A4
	- TIME: 03'40 to 4'50	A4
A.4.3	Ocean_[20190830min1322min2253min86FBmin54BAF71C1A04]	A4
	- TIME: 00'00 to 03'20	A4
	- TIME: 06'00 to 08'00	A4
	- TIME: 08'10 to 09'00	A4
A.5	PecheMelba33 at 60% UKC	A5
A.5.1	Ocean_[20190830min1337min1502minF2AFminC56FF81C1A04]	A5
	- TIME: 06'30 to 09'30	A5
	- TIME: 11'00 to 13'30	A5
	- TIME: 14'00 to 15'30	A5
A.5.2	Ocean_[20190830min1358min3007min095CminEE72F91C1A04]	A5
	- TIME: 07'10 to 07'50	A5
A.6	PecheMelba33 at 33% UKC	A5

A.6.1	Ocean_[20190830min1411min2984min047Amin5D11FA1C1A04].....	A5
	-TIME: 06'20 to 08'50	A5
	-TIME: 11'00 to 13'20	A5
	-TIME: 14'50 to 15'50	A5
A.6.2	Ocean_[20190830min1440min570EminA40FminA278FB1C1A04]	A5
	-TIME: 07'40 to 09'10	A5
A.7	DameNoire33 at 167% UKC.....	A6
A.7.1	Ocean_[20190830min1502min30DBmin0B41min9B7FFC1C1A04]	A6
A.7.2	Ocean_[20190830min1524min2421min7AECmin888AFD1C1A04].....	A6
	-TIME: 14'30 to 15'30	A6
A.8	DameNoire43 at 128% UKC.....	A6
Annex B:	Drawings provided by the skipper	A7

List of tables

Table 1 – Peche Melba main characteristics, $T = 3\text{m}$	2
Table 2 – Dame Noire main characteristics, $T_{\text{fore/aft barge}} = 4\text{m}$	2
Table 3 – Dame Noire main characteristics, $T_{\text{fore}} = 3\text{m}$, $T_{\text{aft}} = 4\text{m}$	2
Table 4 – Dame Noire main characteristics, $T_{\text{fore/aft barge}} = 3\text{m}$	2
Table 5 – Pilot card Peche Melba simulation model applied during validation day on 6 th November 2019	4
Table 6 – Pilot card Dame Noire - $T=4\text{m}$ - Simulation model applied during validation day on 6 th November 2019.....	5
Table 7 – Pilot card Dame Noire - $T_{\text{fore}} = 3\text{m}$, $T_{\text{aft}} = 4\text{m}$ - Simulation model applied during validation day on 6 th November 2019.....	6
Table 8 – Pilot card Dame Noire - $T=3\text{m}$ - Simulation model applied during validation day on 6 th November 2019.....	7
Table 9 – Conditions for which simulations were performed during the second validation day on 30th August 2019	8
Table 10 – Conditions for which simulations were performed during the second validation day on 6th November 2019.....	9
Table 11 – Peche Melba and Dame Noire full ahead speeds (Acceleration test) – Final model.....	10
Table 12 – Peche Melba and Dame Noire full astern speeds (Acceleration test) – Final model	10
Table 13 – Peche Melba and Dame Noire stopping capacity - Full ahead to full astern – Final model	11
Table 14 – Real Time Simulations – Peche Melba performance evaluation	18
Table 15 – Real Time Simulations – Dame Noire performance evaluation.....	19
Table 16 – Final Tuning factors – Peche Melba	20
Table 17 – Final tuning factors – Dame Noire	20

List of figures

Figure 1 – Trajectory for manoeuvring - Peche Melba.....	3
Figure 2 – Trajectory for manoeuvring – Dame Noire.....	3
Figure 3 – Swinging in spot manoeuvre : a) Approaching ahead and swinging of 360deg (left) and b) astern with swinging of 180deg (right).....	9
Figure 4 – Increased aH value for the initial angles of 4Q (where the speed is very small and negative).....	11
Figure 5 – Peche Melba trajectories for rudder angle of 35deg and initial speed of 15km/h for: Self-propulsion speed(blue), without propeller action (yellow) and ‘wry’ tuned without propeller action (red).	12
Figure 6 – Modification of lateral rudder wake for 90 deg (no propeller action)	12
Figure 7 – Drag and Lift rudder coefficients – Becker Module.....	13
Figure 8 – Dame Noire T=4m; UKC=100% - Turning rate for different rudder angles with and without Becker module.....	13
Figure 9 – Real Time Simulation PecheMelba T=3m; h=6m; UKC=100	14
Figure 10 – Real Time Simulation Peche Melba T=3m; h=4.8m; UKC=60	15
Figure 11 – Real Time Simulation Peche Melba T=3m; h=4m; UKC=33	15
Figure 12 – Real Time Simulation Dame Noire T=3.5m; h=8m; UKC=128.....	16
Figure 13 – Real Time Simulation Dame Noire T=4m; h=8m; UKC=100.....	16
Figure 14 – Real Time Simulation Dame Noire T=4m; h=4.8m; UKC=20 (Unique case in which it was not possible to swinging in spot)	17
Figure 15 – Real Time Simulation Peche Melba T=3m; h=6m; UKC=100 (Astern)	17
Figure 16 – Real Time Simulation Dame Noire T=3m; h=8m; UKC=167 (Astern).....	18
Figure 17 – Time evolution of the rate of turning for the swinging manoeuvre – Final Dame Noire model..	19

1 General

The 2018 tabular formulation (Delefortrie, et al., 2019) was used to build the push convoy manoeuvring models for Class Va and Class Vb. After a verification of the general behaviour of both models by using Fast Time Simulation (Villagomez, et al., 2020), it was decided to proceed with the real time tests in the FHR simulators.

This report describes the configuration of the real time simulations: scenarios, defined manoeuvres, tuning factors used and manoeuvring characteristics. As well, the main remarks for the first validation day (30th August 2019) are presented (Verwilligen, 2019). The adaptations to improve the push convoy model behaviour are described. Finally, the results of the second validation tests (November 6th 2019) are presented.

2 Simulation models

The main characteristics of both Class Va and Vb push convoy models are presented in Table 1 to Table 4 . Effective wind areas for each draft condition were calculated assuming coal as vessel's cargo. The bow thruster longitudinal position is 7m after the bow of the front barge of the push convoy.

Table 1 – Peche Melba main characteristics, T = 3m

Main Dimensions		
L _{OA}	[m]	110
L _{PP}	[m]	108.6
B	[m]	11.4
T	[m]	3
m	[ton]	2944
A _{wind frontal}	[m ²]	52
A _{wind lateral}	[m ²]	419

Table 2 – Dame Noire main characteristics, T_{fore/aft barge} = 4m

Main Dimensions		
L _{OA}	[m]	191
L _{PP}	[m]	182.9
B	[m]	11.4
T	[m]	4
m	[ton]	6970
A _{wind frontal}	[m ²]	50
A _{wind lateral}	[m ²]	711

Table 3 – Dame Noire main characteristics, T_{fore} = 3m, T_{aft} = 4m

Main Dimensions		
L _{OA}	[m]	191
L _{PP}	[m]	182.9
B	[m]	11.4
T	[m]	3 / 4
m	[ton]	6210
A _{wind frontal}	[m ²]	52
A _{wind lateral}	[m ²]	668

Table 4 – Dame Noire main characteristics, T_{fore/aft barge} = 3m

Main Dimensions		
L _{OA}	[m]	191
L _{PP}	[m]	182.9
B	[m]	11.4
T	[m]	3
m	[ton]	5340
A _{wind frontal}	[m ²]	53
A _{wind lateral}	[m ²]	624

2.1 Scenarios

A dedicated bounded trajectory was created by using buoys for testing the push convoys manoeuvrability. For the two push convoys configuration, different size of trajectories were needed. Figure 1 and Figure 2 show the drawings of the complete bounded circuits for Peche Melba and Dame Noire, respectively.

Figure 1 – Trajectory for manoeuvring - Peche Melba

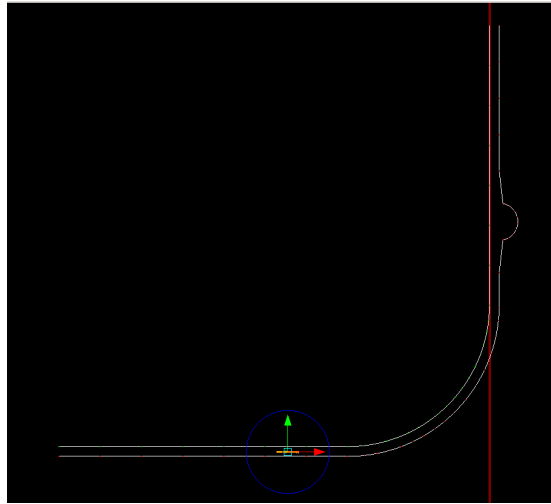
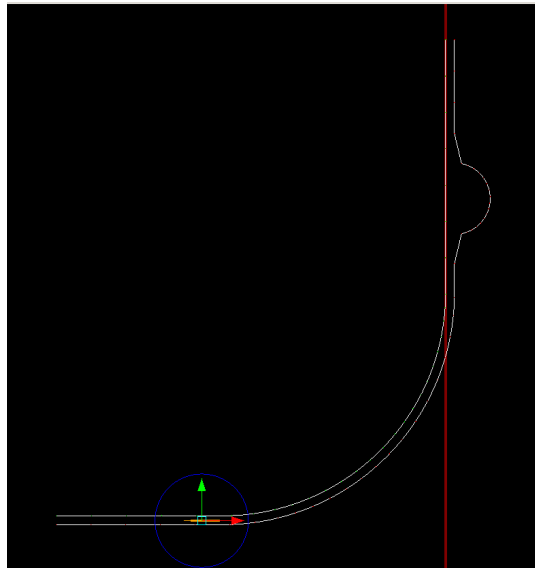


Figure 2 – Trajectory for manoeuvring – Dame Noire



2.2 Manoeuvring behavior of the push convoys

The speeds, stopping characteristics and distances and the turning specifications for all the under keel clearance tested are presented in the Table 5 to Table 8. These pilot cards were used as an input information for the skipper in the second validation days (6th November 2019).

Table 5 – Pilot card Peche Melba simulation model applied during validation day on 6th November 2019

PECHE MELBA - PRINCIPLE CHARACTERISTICS				
based on fast-time simulations				
Name	PechMelba_33.SHI			
Project	15_001			
Main Dimensions				
L _{OA}	[m]	110		
L _{PP}	[m]	108.6		
B	[m]	11.4		
T	[m]	3		
m	[ton]	2944		
A _{wind frontal}	[m²]	52		
A _{wind lateral}	[m²]	419		
Propeller				
Condition		Normal		
#	[-]	2		
n _{max}	[rpm]	330		
n variation	[rpm/s]	30		
Thruster				
Bow thruster	[-]	1		
Total Power	[HP]	350		
Max Propeller Rate	[°/min]	-		
Stern Thruster	[-]	-		
Total Power	[HP]	-		
Max Propeller Rate	[°/min]	-		
				
Manoeuvring speeds				
	RPM	UKC=100%	UKC=60%	UKC=33%
	[-]	[km/h]	[km/h]	[km/h]
Manoeuvring Full Ahead	330	23.0	18.3	14.1
Half Ahead	250	17.4	13.8	10.7
Slow Ahead	170	11.8	9.4	7.2
Dead Slow Ahead	90	6.2	4.9	3.8
Stopping specifications				
	Time		Distance	
UKC = 100%	[s]	[min]	[m]	
From Man. Full Ahead to Full Astern	103	1.72	283	
From Slow Ahead to to Full Astern	74	1.23	112	
UKC = 60%				
From Man. Full Ahead to Full Astern	94	1.57	196	
From Slow Ahead to to Full Astern	70	1.17	83	
UKC = 33%				
From Man. Full Ahead to Full Astern	74	1.23	135	
From Slow Ahead to to Full Astern	55	0.92	56	
Turning specifications				
	Advance	Transfer	Tact Diam	Yaw rate 270deg
UKC = 100%	[m]	[m]	[m]	[deg/min]
Full Ahead	280	125	314	75
Slow Ahead	276	126	314	38
UKC=60%				
Full Ahead	298	182	411	60
Slow Ahead	296	182	411	31
UKC=33%				
Full Ahead	309	217	469	44
Slow Ahead	307	217	469	23

Table 6 – Pilot card Dame Noire - T=4m - Simulation model applied during validation day on 6th November 2019

DAME NOIRE - PRINCIPLE CHARACTERISTICS				
based on fast-time simulations				
Name	DameNoire_44.SHI			
Project	15_001			
Main Dimensions				
L_OA	[m]	191		
L_PP	[m]	182.9		
B	[m]	11.4		
T	[m]	4		
m	[ton]	6970		
A_wind frontal	[m²]	50		
A_wind lateral	[m²]	711		
Propeller				
Condition		Normal		
#	[-]	2		
n_max	[rpm]	330		
n variation	[rpm/s]	30		
Thruster				
Bow thruster	[-]	1		
Total Power	[HP]	350		
Max Propeller Rate	[°/min]	-		
Stern Thruster	[-]	-		
Total Power	[HP]	-		
Max Propeller Rate	[°/min]	-		
				
Manoeuvring speeds				
	RPM	UKC=100%	UKC=50%	UKC=20%
	[-]	[km/h]	[km/h]	[km/h]
Manoeuvring Full Ahead	330	19.0	16.2	14.9
Half Ahead	250	14.4	12.2	11.3
Slow Ahead	170	9.7	8.3	7.7
Dead Slow Ahead	90	5.0	4.3	4.0
Stopping specifications				
	Time		Distance	
UKC = 100%	[s]	[min]	[m]	
From Man. Full Ahead to Full Astern	160	2.7	354	
From Slow Ahead to to Full Astern	112	1.9	141	
UKC = 50%				
From Man. Full Ahead to Full Astern	144	2.4	275	
From Slow Ahead to to Full Astern	100	1.7	110	
UKC = 20%				
From Man. Full Ahead to Full Astern	136	2.3	234	
From Slow Ahead to to Full Astern	96	1.6	96	
Turning specifications				
	Advance	Transfer	Tact Diam	Yaw rate 270deg
UKC = 100%	[m]	[m]	[m]	[deg/min]
Full Ahead	497	300	643	34.2
Slow Ahead	494	301	643	17.6
UKC=50%				
Full Ahead	500	320	686	23.5
Slow Ahead	497	321	686	12.1
UKC=20%				
Full Ahead	593	407	865	18.9
Slow Ahead	590	407	865	9.7

Table 7 – Pilot card Dame Noire - $T_{fore} = 3m$, $T_{aft} = 4m$ - Simulation model applied during validation day on 6th November 2019

DAME NOIRE - PRINCIPLE CHARACTERISTICS				
based on fast-time simulations				
Name		DameNoire_43.SHI		
Project		15_001		
Main Dimensions				
L _{OA}	[m]	191		
L _{PP}	[m]	182.9		
B	[m]	11.4		
T	[m]	3 / 4		
m	[ton]	6210		
A _{wind frontal}	[m²]	52		
A _{wind lateral}	[m²]	668		
Propeller				
Condition		Normal		
#	[-]	2		
n _{max}	[rpm]	330		
n variation	[rpm/s]	30		
Thruster				
Bow thruster	[-]	1		
Total Power	[HP]	350		
Max Propeller Rate	[°/min]	-		
Stern Thruster	[-]	-		
Total Power	[HP]	-		
Max Propeller Rate	[°/min]	-		
				
Manoeuvring speeds				
	RPM	UKC=128%		
	[-]	[km/h]		
Manoeuvring Full Ahead	330	19.8		
Half Ahead	250	15.0		
Slow Ahead	170	10.2		
Dead Slow Ahead	90	5.3		
Stopping specifications				
	Time		Distance	
UKC = 128%	[s]	[min]	[m]	
From Man. Full Ahead to Full Astern	158	2.6	327	
From Slow Ahead to Full Astern	119	2.0	138	
Turning specifications				
	Advance	Transfer	Tact Diam	Yaw rate 270deg
UKC = 128%	[m]	[m]	[m]	[deg/min]
Full Ahead	428	211	445	39.2
Slow Ahead	424	212	445	20.2

Table 8 – Pilot card Dame Noire - T=3m - Simulation model applied during validation day on 6th November 2019

DAME NOIRE - PRINCIPLE CHARACTERISTICS				
baed on fast-time simulations				
Name	DameNoire_33.SHI			
Project	15_001			
Main Dimensions				
LOA	[m]	191		
L _{PP}	[m]	182.9		
B	[m]	11.4		
T	[m]	3		
m	[ton]	5340		
A _{wind frontal}	[m²]	53		
A _{wind lateral}	[m²]	624		
Propeller				
Condition		Normal		
#	[-]	2		
n _{max}	[rpm]	330		
n variation	[rpm/s]	30		
Thruster				
Bow thruster	[-]	1		
Total Power	[HP]	350		
Max Propeller Rate	[°/min]	-		
Stern Thruster	[-]	-		
Total Power	[HP]	-		
Max Propeller Rate	[°/min]	-		
				
Manoeuvring speeds				
	RPM	UKC=167%		
	[-]	[km/h]		
Manoeuvring Full Ahead	330	20.1		
Half Ahead	250	15.2		
Slow Ahead	170	10.3		
Dead Slow Ahead	90	5.4		
Stopping specifications				
	Time		Distance	
UKC = 167%	[s]	[min]	[m]	
From Man. Full Ahead to Full Astern	131	2.2	293	
From Slow Ahead to to Full Astern	97	1.6	119	
Turning specifications				
	Advance	Transfer	Tact Diam	Yaw rate 270deg
UKC = 167%	[m]	[m]	[m]	[deg/min]
Full Ahead	456	229.5	491	36
Slow Ahead	452.6	229.3	490	19

3 Validation days

3.1 Organization

On August 30th 2019 the push convoys Class Va and Class Vb were tested on the inland simulator LARA, at FHR. The following persons participated to the first validation day.

- On the behalf of Flanders Hydraulics Research
 - Jeroen Verwilligen (Expert)
 - Jose Villagomez (Researcher)
- Julien Vanhoyweghen (Push convoy skipper)

During the first validation day (10th August 2019) and second day (6th November 2019) 15 and 10 simulations were performed, respectively (see Table 9 and Table 10). All the available both loading and UKC conditions for both models were tested. In order to evaluate the steering, stopping and manoeuvring capabilities of the models, it was required to the skipper to accelerate in the straight part of the trajectory, then steer following the curve part, afterwards -again in the straight part- to start deaccelerating to enter to the semi-circular zone, where the vessel must stop and begin the swinging in spot manoeuvre (360deg) and then go out for the same route that it came (Figure 3a). It was defined to perform some tests going astern, in this case the swinging in spot is performed to turn the vessel 180deg and go out of the turning zone by using the another exit (Figure 3b). After the first validation day and due the raised remarks, it was needed to make important modifications to the models and to validate them in a second validation day (6th November 2019).

Table 9 – Conditions for which simulations were performed during the second validation day on 30th August 2019

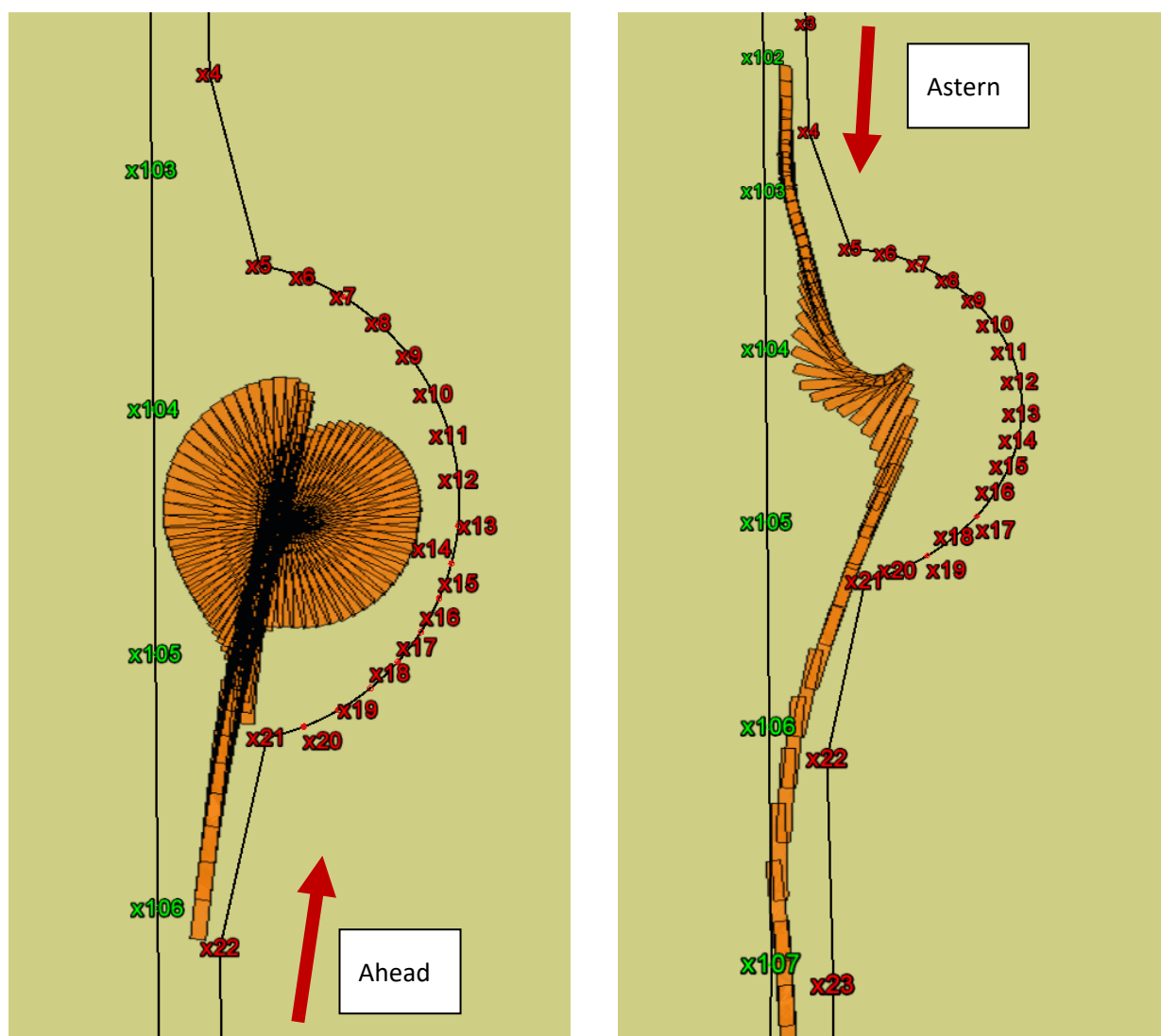
Vessel /Condition	Simulation file
DameNoire44 at 20% UKC	Ocean_[20190830min0937min555Amin8521min1709ED1C1A04]
	Ocean_[20190830min1025min22F0min5F97minE04BEF1C1A04]
DameNoire44 at 50% UKC	Ocean_[20190830min1034min35B8minAE34min3BBCEF1C1A04]
	Ocean_[20190830min1113min35C2min88C2minDC97F11C1A04]
DameNoire44 at 100% UKC	Ocean_[20190830min1142min124FminF8C7minC1F4F21C1A04]
	Ocean_[20190830min1209min559Cmin178CminD546F41C1A04]
PechMelba33 at 100% UKC	Ocean_[20190830min1253min0319minC751minC154F61C1A04]
	Ocean_[20190830min1311min0788minF552min2D31F71C1A04]
	Ocean_[20190830min1322min2253min86FBmin54BAF71C1A04]
PechMelba33 at 60% UKC	Ocean_[20190830min1337min1502minF2AFminC56FF81C1A04]
	Ocean_[20190830min1358min3007min095CminEE72F91C1A04]
PechMelba33 at 33% UKC	Ocean_[20190830min1411min2984min047Amin5D11FA1C1A04]
	Ocean_[20190830min1440min570EminA40FminA278FB1C1A04]
DameNoire33 at 167% UKC	Ocean_[20190830min1502min30DBmin0B41min9B7FFC1C1A04]
	Ocean_[20190830min1524min2421min7AECmin888AFD1C1A04]

Table 10 – Conditions for which simulations were performed during the second validation day on 6th November 2019

Simulation	Vessel/Condition	Initial heading
B9BC	PecheMelba_T3_h6_UKC100	Ahead
E835	PecheMelba_T3_h4.8_UKC60	Ahead
3FC1	PecheMelba_T3_h4_UKC33	Ahead
671D(*)	DameNoire_T3_h8_UKC167	Ahead
E84E	DameNoire_T3.5_h8_UKC128	Ahead
C428	DameNoire_T4_h8_UKC100	Ahead
7A47(*)	DameNoire_T4_h6_UKC50	Ahead
14C2	DameNoire_T4_h4.8_UKC20	Ahead
ECAE	PecheMelba_T3_h6_UKC100	Astern
5FCD	DameNoire_T3_h8_UKC167	Astern

Figure 3 – Swinging in spot maneuver :

a) Approaching ahead and swinging of 360deg (left) and b) astern with swinging of 180deg (right)



3.2 Additional research after validation day 1

The remarks raised of the first validation day can be summarized in the following points:

- Self-propulsion speed not according to the skipper's expectations
- Low stopping capacity
- Low swinging in spot capacity
- Low maneuvering capacity at low speeds without propeller action
- Lost of rudder efficiency with more than 45deg rudder angle

For more details about the first validation day, see (Verwilligen, 2019). The main remarks were reproduced in the Annex A.

Some adaptations were performed to improve the manoeuvring characteristics of both models. The following subsection describe these adaptations in each case.

3.2.1 Self-propulsion speed

The speeds of push convoys were not according to the skipper's expectations. Iterative modifications were performed in the longitudinal component of the hull forces depending on beta (X_b) for 0 deg and 180 deg until correct values for full ahead and full astern speeds were obtained. Table 11 and Table 12 show the corrected speeds respectively.

Table 11 – Peche Melba and Dame Noire full ahead speeds (Acceleration test) – Final model

	Draft [m]	UKC [m]	UKC [%]	Speed [km/h]
ClassVa (1 barge)	3	3	100	23.0
	3	1.8	60	18.3
	3	1	33	14.1
ClassVb (2 barges)	4	4	100	19.0
	4	2	50	16.7
	4	0.8	20	15.0
	3.5	4.5	129	19.9
	3	5	167	20.1

Table 12 – Peche Melba and Dame Noire full astern speeds (Acceleration test) – Final model

	Draft [m]	UKC [m]	UKC [%]	Speed [km/h]
ClassVa (1 barge)	3	3	100	-8.96
	3	1.8	60	-7.67
	3	1	33	-6.23
ClassVb (2 barges)	4	4	100	-7.67
	4	2	50	-6.88
	4	0.8	20	-6.16
	3.5	4.5	129	-6.88
	3	5	167	-8.75

3.2.2 Low stopping capacity

According to the skipper, the stopping distance should not be more than 300m in all the cases. This was not the case in simulations. The fast time simulations performed, showed stopping distances higher than 600m. This was corrected by using *negative values for thrust deduction in quadrant 2 (zogTabel)*. A negative thrust deduction means that the thrust will be increased in the second quadrant, improving the stopping capacity. This generated a more realistic behavior according to the skipper (see Table 13).

Table 13 – Peche Melba and Dame Noire stopping capacity - Full ahead to full astern – Final model

	Draft [m]	UKC [m]	UKC [%]	Stopping distance [m]
ClassVa (1 barge)	3	3	100	283
	3	1.8	60	196
	3	1	33	135
ClassVb (2 barges)	4	4	100	354
	4	2	50	275
	4	0.8	20	234
	3.5	4.5	129	327
	3	5	167	293

3.2.3 Low swinging in spot capacity

In most of the simulations, the push convoys were not be able to swinging in spot with asymmetric propulsion (port propeller ahead and starboard propeller astern or vice versa). It was implemented the module of asymmetric propulsion used in the QFlex manoeuvring numerical model. This allowed the push convoy models start swinging. An additional adaptation to the *aH* (SteeringLevers Table) in very low epsilon star values of the 4Q was necessary in some cases to compensate the difference of the rudder moment when velocity becomes negative in the swinging in spot maneuver (see Figure 4). Furthermore, the amplitudes of oscillatory terms in even quadrants were neglected to improve the continuity in this transition.

Figure 4 – Increased aH value for the initial angles of 4Q (where the speed is very small and negative)

```

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3.2.4 Low manoeuvring capacity at low speeds without propeller action

According to the skipper the push convoys should have steering capacity even at low speeds (7km/h) without propeller action. After the validation day, this specific characteristic was investigated.

Figure 5 – Peche Melba trajectories for rudder angle of 35deg and initial speed of 15km/h for: Self-propulsion speed(blue), without propeller action (yellow) and 'wry' tuned without propeller action (red).

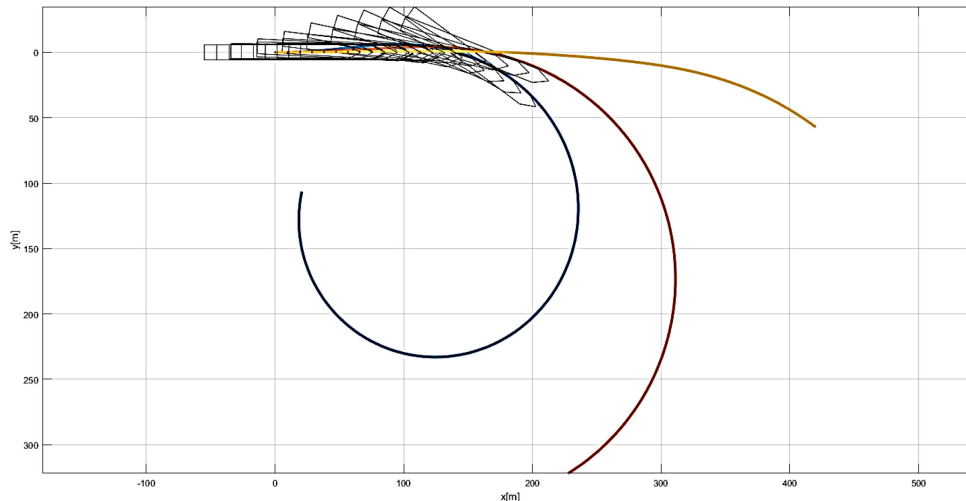


Figure 5 presents the increased turning capacity. The turning trajectory without propeller action (yellow) is compared with the trajectory by using its self-propeller speed (blue). The lateral rudder wake at epsilon star equals to 90deg was tuned (see Figure 6) in order to obtain a trajectory between both of them (red).

Figure 6 – Modification of lateral rudder wake for 90 deg (no propeller action)

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  <row>170;0.5009;0.5026</row>
  <row>180;0.40635;0.4076</row>
</table>
```

An information provided by the skipper was used as a reference for turning rates without propeller (see Annex B), but of the provided yaw rates (90deg in 30s) were higher than those resulting from fast simulations with propulsion. As a result the maneuverability of the convoy not tuned to the exact values provided by the skipper. It can be stated that the manoeuvring model is more conservative than the expectations of the skipper.

3.2.5 Lost of rudder moment with more than 45deg rudder angle

It was detected that in many cases the turning rate decreased with rudder angles higher than 45deg. From the lift curve of the rudder it is clear that the lift start decreasing after an angle around 30 deg. It was decided to apply a correction to avoid the drop of lift by using the Becker module with a cut angle of 25deg (see Figure 7). In Figure 8 the maximum turning rates for different rudder angles are plotted before and after the Becker module is implemented as example.

Figure 7 – Drag and Lift rudder coefficients – Becker Module

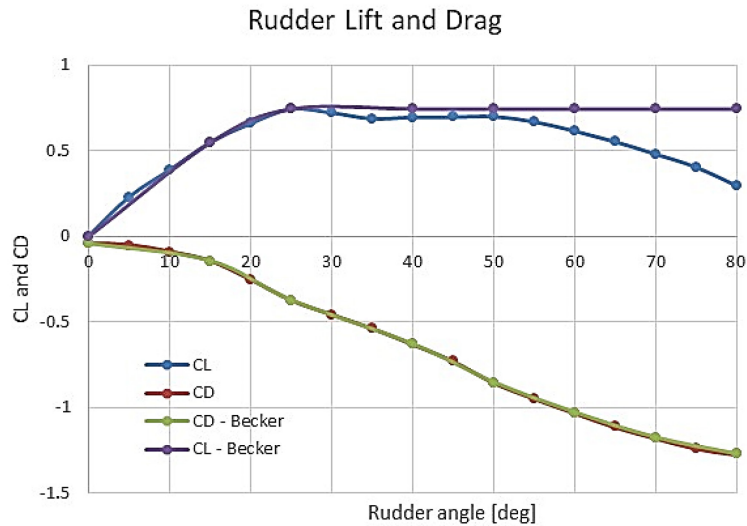
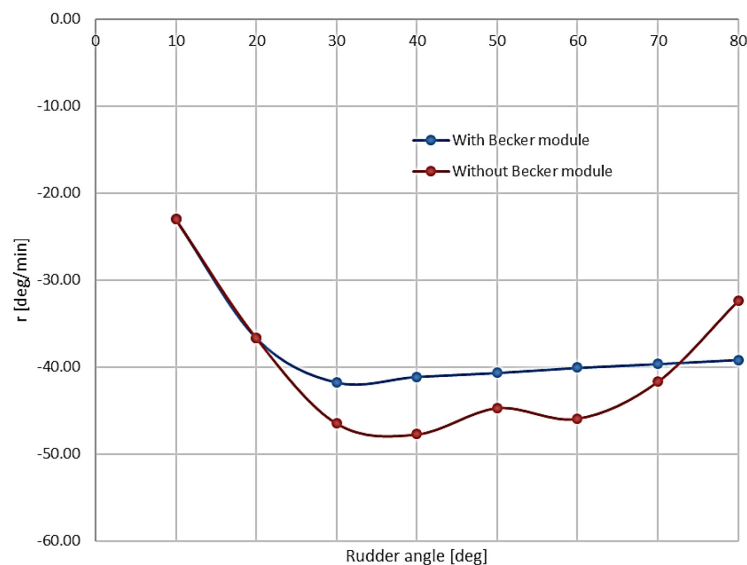


Figure 8 – Dame Noire T=4m; UKC=100% - Turning rate for different rudder angles with and without Becker module



3.3 Results of validation day 2

The optimization of the model was assessed after the performed modifications. All the changes were previously tested by using fast time simulations. The focus was to evaluate if the performed modifications in the model work well in real time mode. Some criteria were selected in order to assess more systematically all conditions. Once again all the UKC and loading condition for both push convoys were tested.

The criteria for evaluation were the following:

- Manoeuvring and steering in the curve
- Acceleration
- Stopping capacity
- Swinging in spot performance
- Steering without propulsion

The trajectories of simulations are presented in Figure 9 to Figure 16.

Figure 9 – Real Time Simulation PecheMelba T=3m; h=6m; UKC=100

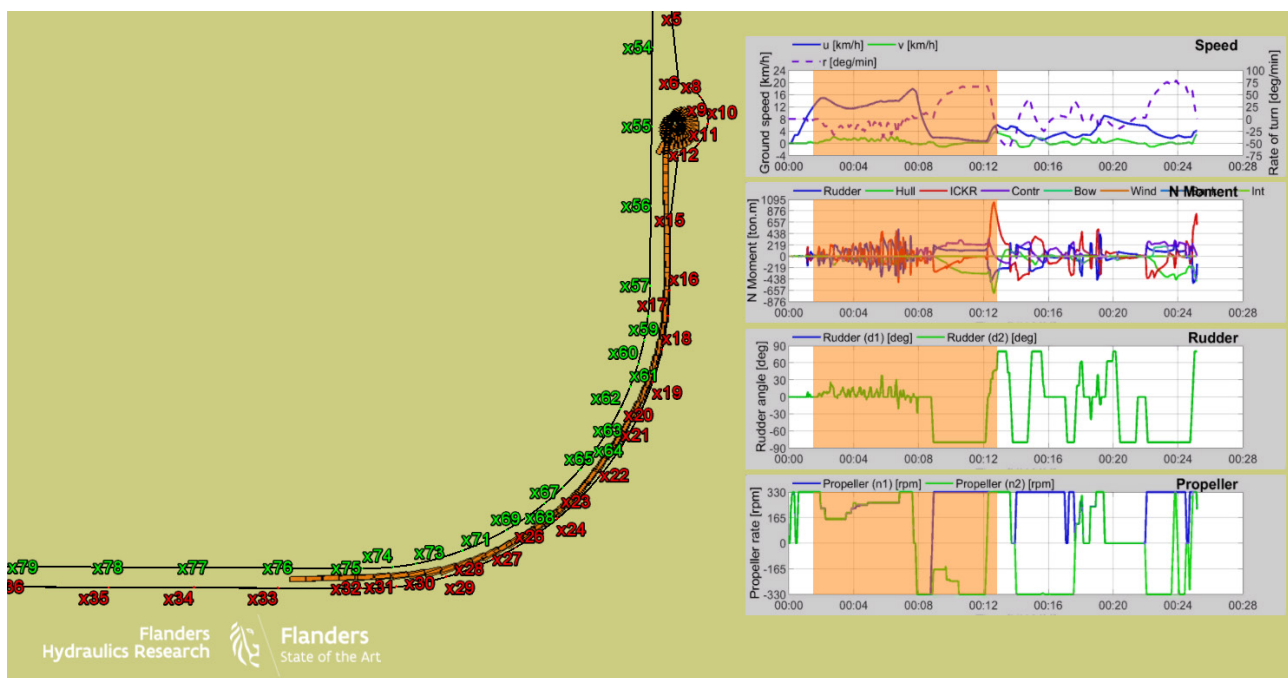


Figure 10 – Real Time Simulation Peche Melba T=3m; h=4.8m; UKC=60

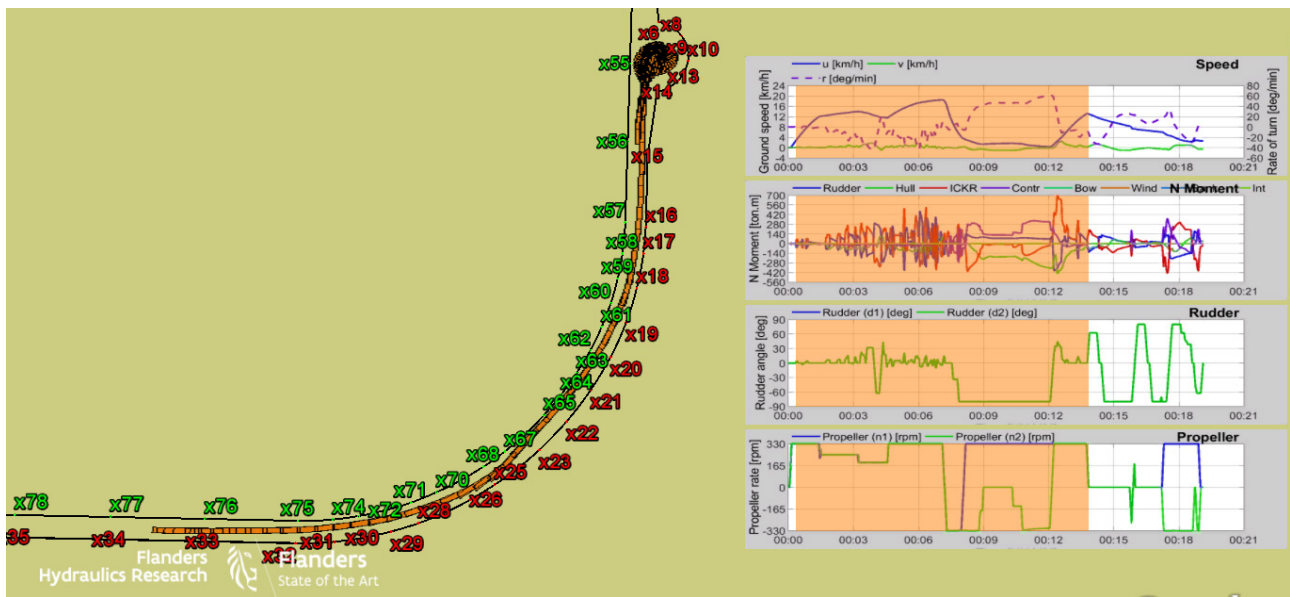


Figure 11 – Real Time Simulation Peche Melba T=3m; h=4m; UKC=33

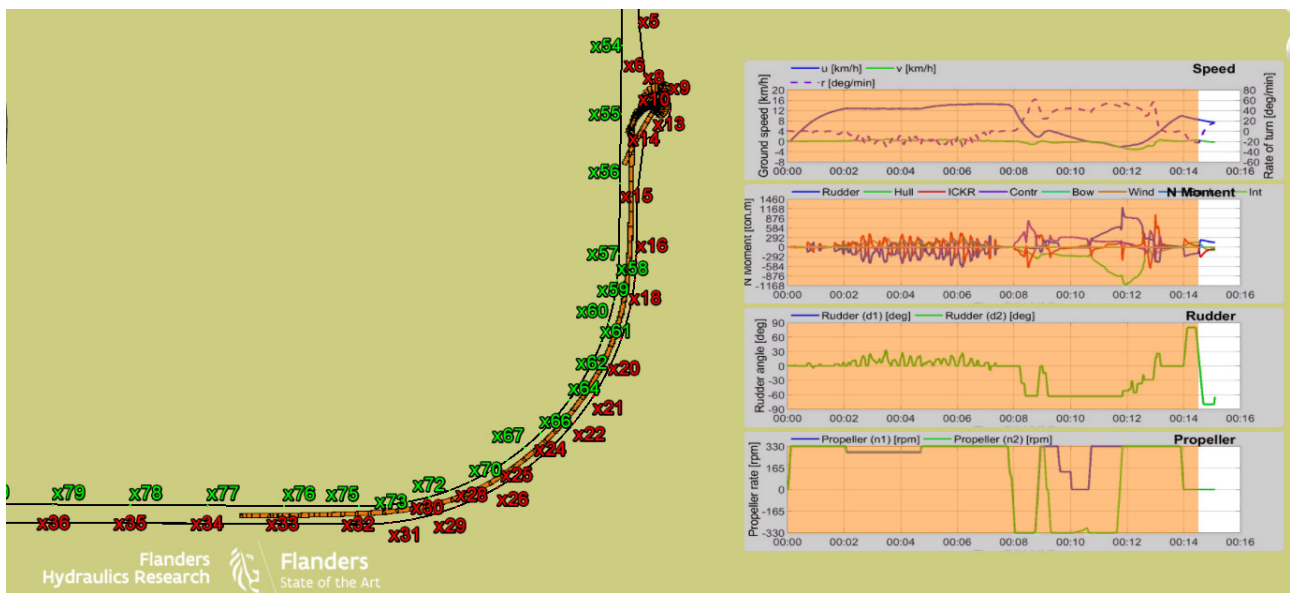


Figure 12 – Real Time Simulation Dame Noire T=3.5m; h=8m; UKC=128

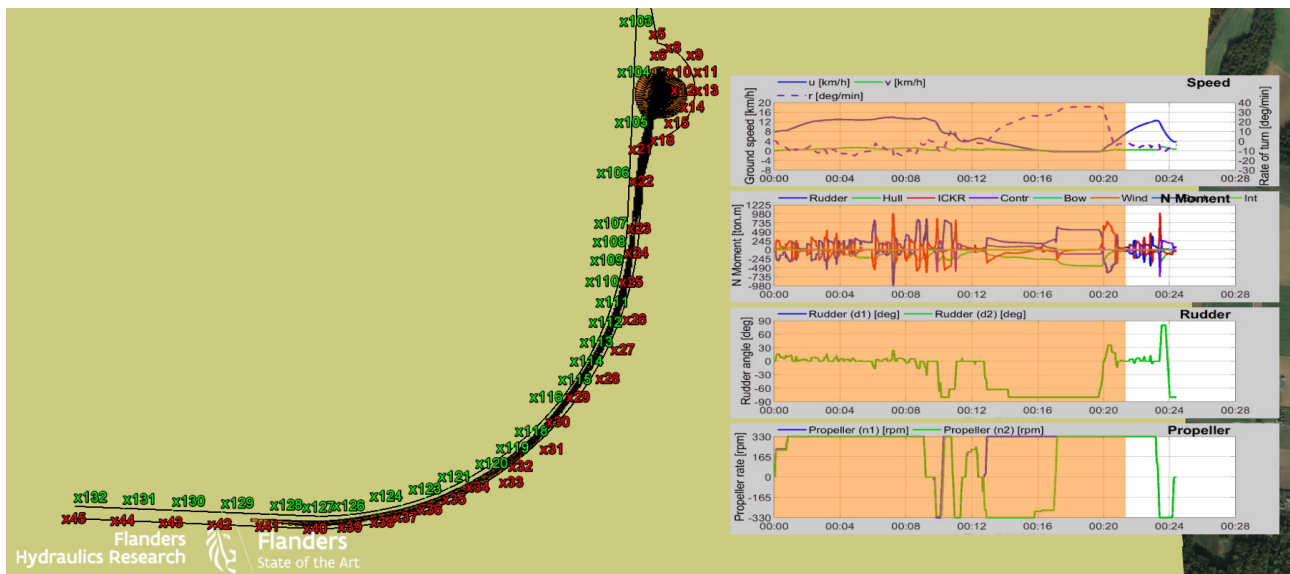


Figure 13 – Real Time Simulation Dame Noire T=4m; h=8m; UKC=100

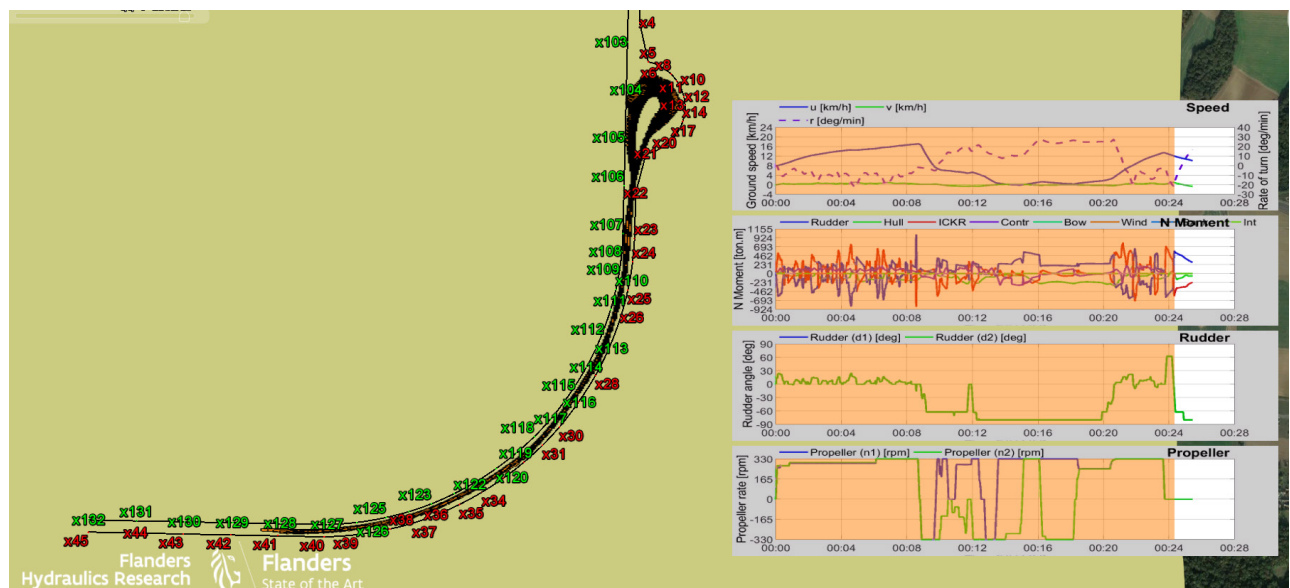


Figure 14 – Real Time Simulation Dame Noire T=4m; h=4.8m; UKC=20 (Unique case in which it was not possible to swinging in spot)

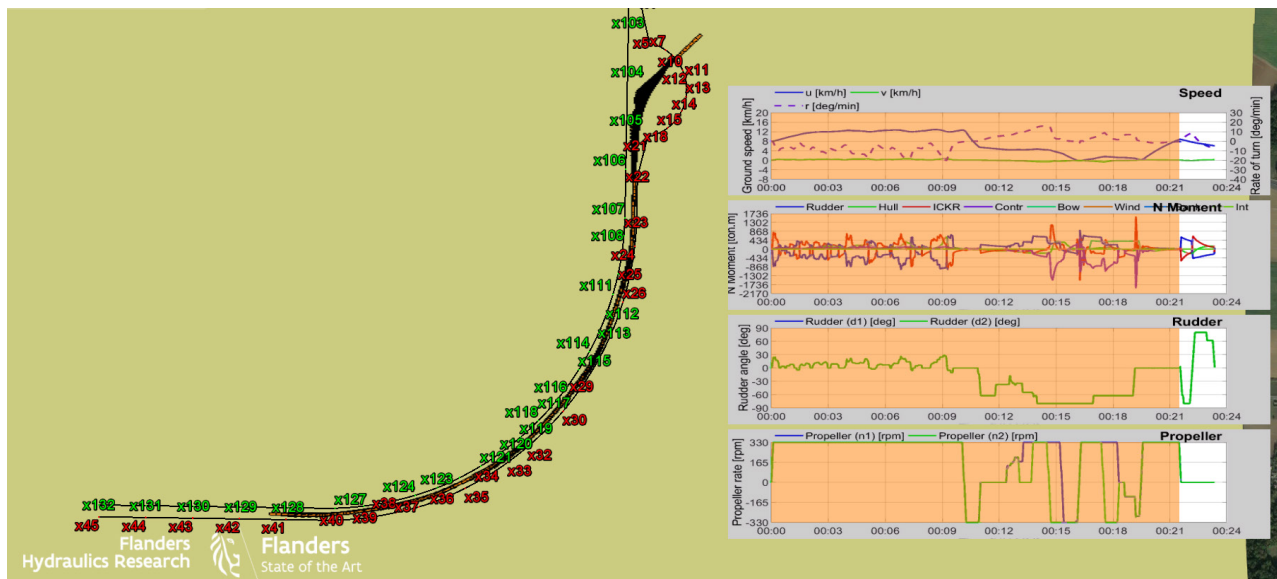


Figure 15 – Real Time Simulation Pêche Melba T=3m; h=6m; UKC=100 (Asteron)

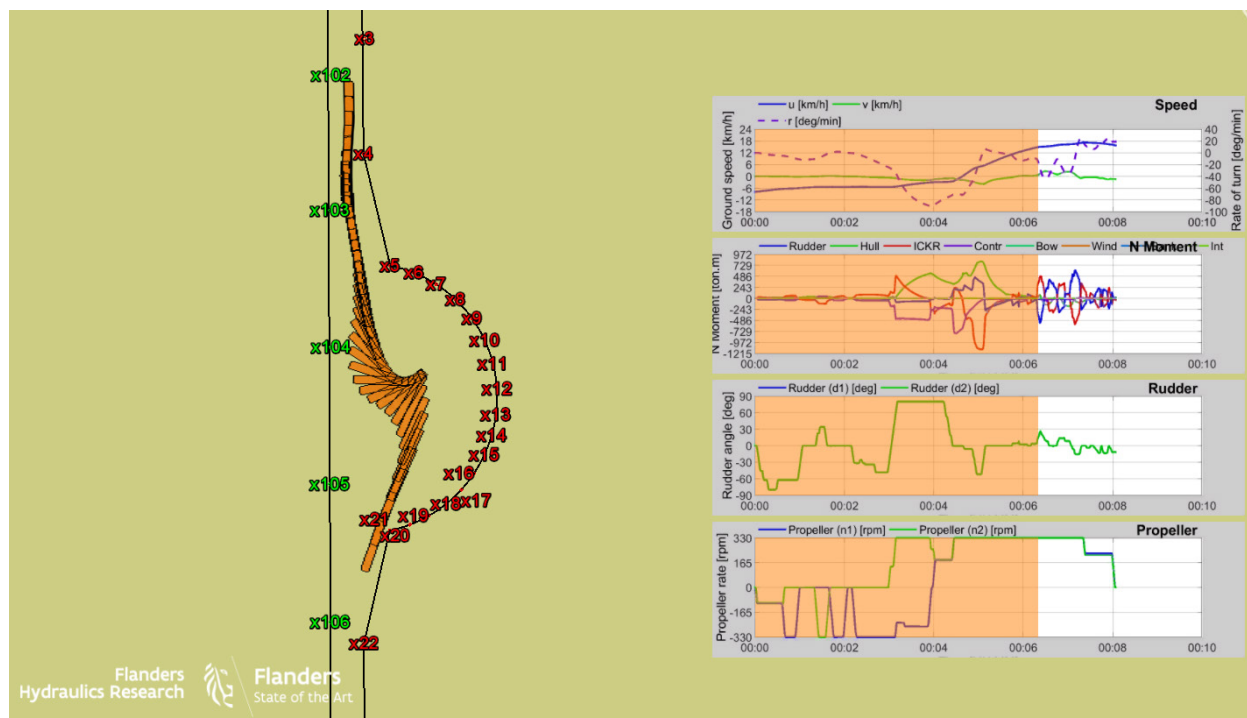
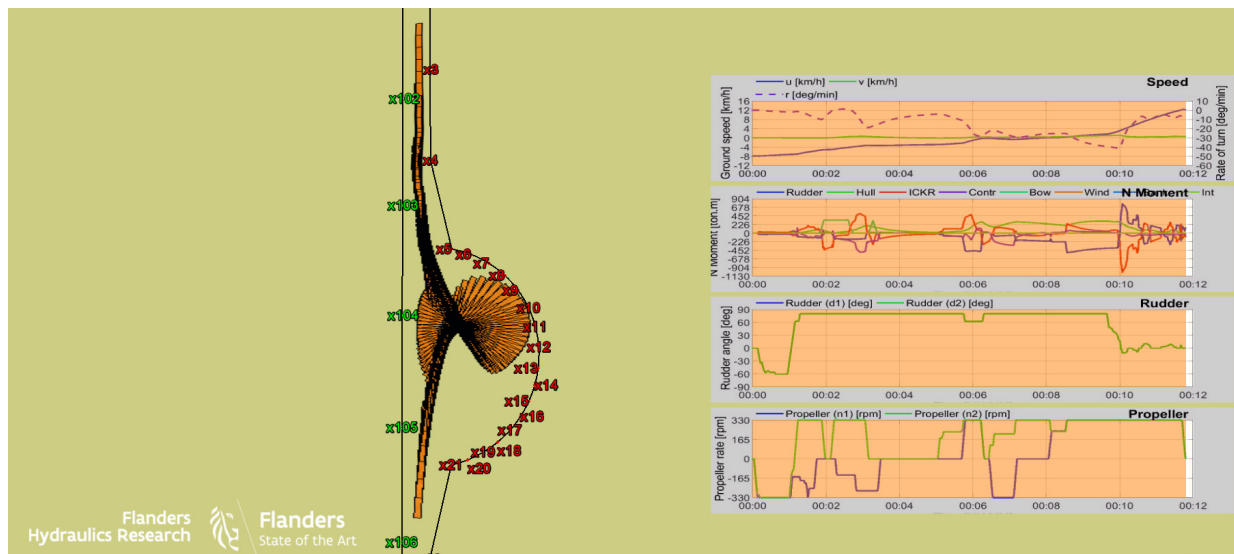


Figure 16 – Real Time Simulation Dame Noire T=3m; h=8m; UKC=167 (Astern)



The tables containing the final evaluation are presented as following:

Table 14 – Real Time Simulations – Peche Melba performance evaluation

	PechMelba_T3_h6_UKC100	PechMelba_T3_h4.8_UKC60	PechMelba_T3_h4_UKC33
Manoeuvring and steering in the curve	Realistic	Realistic	Realistic
Acceleration	Realistic	Realistic	Realistic
Stopping capacity	Realistic	Realistic	Realistic
Swinging in spot	Acceptable(1)	Acceptable(2)	Realistic
Action of the rudder without propulsion	Acceptable(3)	Acceptable(3)	Acceptable(3)
Others(*)	-	-	-

(1) Yaw rate quite acceptable but negative speed should be reached faster (Max negative speed -3km/h)

(2) Yaw rate quite realistic but at the end of the swinging a significant drift occurs.

(3) In general the action of the rudder without propulsion was improved. Although the yaw rate is slightly lower than expected. This was considered acceptable.

Table 15 – Real Time Simulations – Dame Noire performance evaluation

	DameNoire_T3_h8 UKC167	DameNoire_T3.5_h8 UKC128	DameNoire_T4_h8 UKC100	DameNoire_T4_h6 UKC50	DameNoire_T4_h4.8 UKC20
Manoeuvring and steering in the curve	Realistic	Realistic	Realistic	Realistic	Realistic
Acceleration	Realistic	Acceptable (1)	Realistic	Acceptable(1)	Realistic
Stopping capacity	Realistic	Realistic	Realistic	Realistic	Realistic
Swinging in spot	Realistic	Realistic	Realistic	Realistic	Unable to swing in spot
Action of the rudder without propulsion	Acceptable (2)	Realistic	Realistic	Realistic	Acceptable(2)
Other(*)	-	(3)	(3)	-	(4)

(1) In some cases the acceleration takes more time to reach the final speed but it was considered acceptable.

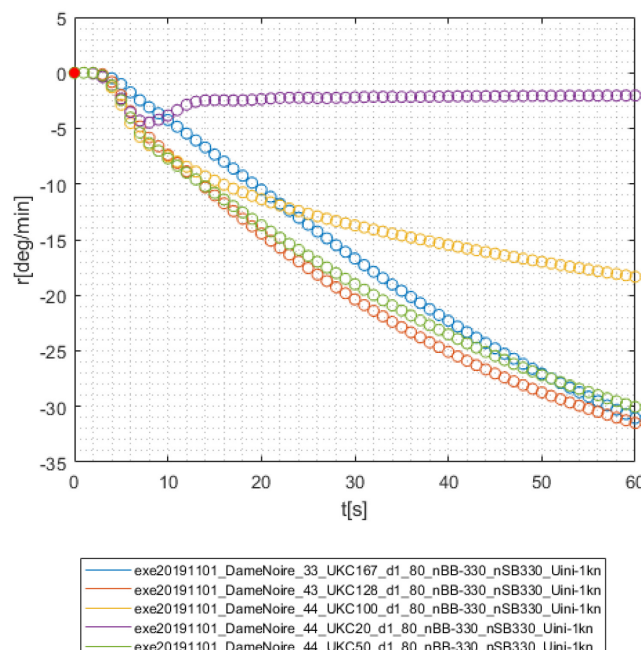
(2) In general the action of the rudder without propulsion was improved. Although the yaw rate is slightly low than expected this was considered acceptable.

(3) With positive speed and full astern propulsion, the vessel presented still low steering capacity and a significant drift. It was decided to perform no additional tuning in order to avoid compromising the good behavior achieved.

(4) Unexpected roll motion in the attempt to swinging in spot.

It could be verified that for the case of UKC 20% the Dame Noire model is not able to swing. A further research is needed in this case to identify the source of this issue. A time evolution graphic of the rate of turning for the Dame Noire model in different conditions is showed in Figure 17, as required for the reviewer. These fast-time simulations were configured with asymmetrical propulsion, maximum rudder angle (80deg) and an initial speed of 1 knot astern.

Figure 17 – Time evolution of the rate of turning for the swinging manoeuvre – Final Dame Noire model



4 Tuning factors

The final tuning factors used in the model for validation are presented in the following table. For more details about the tuning process see (Villagomez, et al., 2020). Table 16 and Table 17 present the tuning factors for the Peche Melba and Dame Noire models, respectively.

Table 16 – Final Tuning factors – Peche Melba

Series	UKC%	Ngamma	NR	Ybeta
J1001A02	100	1.20	1.00	0.80
J1001A03	60	1.00	0.80	1.00
J1001A04	33	1.70	0.90	1.00

Table 17 – Final tuning factors – Dame Noire

Series	UKC%	T_{fore}	T_{aft}	Ybeta	Ngamma	Ygamma	Nbeta
J0701A01	100	4	4	0.9	1	1	1
J0701A02	50	4	4	1	0.6	1.5	0.3
J0701A03	20	4	4	1	1.5	1	1
J0801A01	129	3	4	1	1	1	1
J0901A01	167	3	3	1	1	1	1

In order to improve the behavior in the swinging in spot manoeuvre, after the first validation day it was necessary to use $F_x=2$ for the J0701A02 file.

5 Conclusions and recommendations

After the performed adaptations based on the remarks from the first validation day, both models were assessed once again to verify their final behavior.

The Peche Melba sailing behavior was evaluated as realistic. In the swinging in spot manoeuvre, the responses of the model were quite acceptable. The yaw rate of the vessel was quite realistic, although a significant drift occurs at the end of the manoeuvre in some cases. This was considered acceptable. The vessel was able to perform the manoeuvres in all the cases.

The Dame Noire model sailing behavior was considered as realistic. The vessel was able to perform the swinging in spot in all the cases except one, in the case of under keel clearance of 20%. In all the other swinging tests, the push convoy response was considered acceptable. As an observation, the vessel with positive speed and full astern propulsion presented still low steering capacity and a significant drift in some cases. It was decided to perform no additional tuning in order to avoid compromising the good behavior achieved. Main comments were related to the action of the rudder without propulsion, it was considerable improved after the first day of validation, although the yaw rate is slightly lower than expected this was considered acceptable.

It is recommended to continue the validation of the other push convoy models: “Belle Helene” and “Poire Williams” models in the same way that both “Peche Melba” and “Dame Noire” push convoys were validated. At the same time, further research is needed to discover a way to fix the swinging manoeuvre for the Dame Noire model at 20%.

6 References

Delefortrie, G., Eloot, K. and Mostaert, F. 2019. *Manoeuvring behavior of push convoys. Sub report 10 - Computation of the manoeuvring coefficients with the 2018 tabular model formulation.* FHR reports, Flanders Hydraulics Research. 2019. WL2019R15_001_10.

Verwilligen, J. 2019. *Validation day 20190830.* Flanders Hydraulics Research. 2019. MEMO WL2019M15_001_1.

Villagomez, J., Delefortrie, G. and Mostaert, F. 2020. *Push Convoy 2018 model formulation: Sub report 11 - Class Va and Vb Fast Time simulation.* FHR Reporten, Flanders Hydraulics Research. 2020. WL2020R15_001_11.

Annex A: Remarks and observations:

Validation day 1

A.1 DameNoire44 at 20% UKC

A.1.1 Ocean_[20190830min0937min555Amin8521min1709ED1C1A04]

-TIME: 00'00 TO 08'00

Steering at first quadrant is realistic for speeds higher than 7 km/h in case that propeller is used (self-propulsion conditions)

- TIME: 09'00 to 12'00

Steering at low speed with stopped propeller is too low (almost zero in simulator, while in reality it is possible steer the vessel with speeds of 5 km/h).

- TIME: 16'30 to 17'30

For the swinging in spot manoeuvre setting ($U=3.7\text{km/h}$, $d=-80^\circ$, $n1=+330\text{ rpm}$, $n2=-330\text{ rpm}$) in simulation the rate of turn stays zero.

- TIME: 18'30 to 19'00

When both propeller were set to full ahead ($d=-80^\circ$, $n1=+330\text{ rpm}$, $n2=+330\text{ rpm}$) a rate of turn of $10^\circ/\text{min}$ is reached. Skipper expected approximately $25^\circ/\text{min}$.

-TIME: 21'30 to 22'00

For the swinging in spot manoeuvre setting in the other direction ($U=3.7\text{km/h}$, $d=80^\circ$, $n1=-330\text{ rpm}$, $n2=+330\text{ rpm}$) in simulation the rate of turn stays zero as well.

-TIME: 22'00 to 40'00

Bow Thruster (BT) is used to make the swing. The rate of turn is picking up slowly (max $12^\circ/\text{min}$). According to skipper this is too low. Even with 300 HP a higher rate of turn with the BT is expected.

Each time the propellers are used (astern or ahead) to control the speed, the rate of turn (resulting from the BT) drops to zero.

- TIME: 23'30 to 40'00

In the condition: $U=-0.5\text{ km/h}$, $rn1=rn2=330\text{ rpm}$, $d=0$ the rate of turn was zero. The effect of the BT was neglectable.

- TIME: > 40'00

Steering in the first quadrant is realistic.

A.1.2 Ocean_[20190830min1025min22F0min5F97minE04BEF1C1A04]

- TIME: < 04'00

When the push convoy is going astern it could not be steered (RoT =0) even at max rpm and max d.

When the push convoy is going astern, the rate of turn is picking up slowly (04'30 to 04'50)

General comment: turning behaviour of vessel is much too low at small ship speeds.

A.2 DameNoire44 at 50% UKC

6.2.1 Ocean_[20190830min1034min35B8minAE34min3BBCEF1C1A04]

- TIME: < 11'00

Steering in the first quadrant is realistic at $d < 55^\circ$ and $u > 8$ km/h.

- TIME: 11'00 to 15'00

Deceleration from 12 km/h to 2 km/h took much too long (4'00 over 500 m) (at the end also the bow thruster was used astern. In reality it is a requirement to stop the vessel (from full ahead = 19 km/h) to 0 km/h in 300 m (According to the skipper).

- TIME: 19'30 to 22'20

Especially at low speeds the stopping ability of the vessel is too weak.

- TIME: 21'00 to 21'30

N1 is increased but rate of turn decreases while you expect it to increase

-TIME:: 25'00

The reaction to BT is acceptable.

- TIME: 33'00 to 35'00

In 1Q ($u > 8$ km/h) the steering is worse at $d = 80^\circ$ than at $d = 35^\circ$. Skipper notes that the steering ability of the vessel rudder increases even for $d > 55^\circ$. Off course this comes with an important deceleration. The same comment was made by the skipper of the Elise, and was taken into account when tuning Myzako to Myzako_Elise.

6.2.2 Ocean_[20190830min1113min35C2min88C2minDC97F11C1A04]

-TIME:00'00 to 07'00

Not possible to steer the vessel when going astern and $\text{rpm} < 0$. In reality it is possible to control the lateral speed at the aft with the rudder when going astern (for Peche Melba this effect is captured correctly).

A.3 DameNoire44 at 100% UKC

A.3.1 Ocean_[20190830min1142min124FminF8C7minC1F4F21C1A04]

- TIME: 11'20 to 13'30

Stopping is faster but still not fast enough (According to the skipper the push convoy should stop in no more than 300 m).

During crash stop a rate of turn of $17^\circ/\text{min}$ occurs. This is reasonable according to the skipper.

- TIME: 16'00 to 17'30

In the swinging in spot manoeuvre with asymmetric propulsion ($U=2 \text{ km/h}$ and $d < 0$) is realistic ($25^\circ/\text{min}$) but when the speed decreases to smaller positive values than the rate of turn drops again to an unrealistically low value. At that point the BT was used.

- TIME: 20'00 to 20'20

In the swinging in spot manoeuvre with asymmetric propulsion when negative speeds are reached is not realistic: rate of turn too low (even decreasing although $rn1$ is put ahead)

A.3.2 Ocean_[20190830min1209min559Cmin178CminD546F41C1A04]

- TIME: 02'30 to 03'30

At $u < -4 \text{ km/h}$ and $rn1=rn2=330 \text{ rpm}$ the steering is acceptable. Steering with negative rpm is not possible (in reality the steering should be a bit better according to the skipper).

- TIME: 04'30 to 05'40

Acceleration astern is too slow with $rn1=rn2=-330 \text{ rpm}$. In general the astern power is very weak.

-TIME: 11'00 to 11'40

For $U = 0 \text{ km/h}$, $rn1=-330 \text{ rpm}$, $rn2=330 \text{ rpm}$, when d increases from 45° to 80° the rate of turn decreases (unexpected) also the rate of turn obtained at $d=45^\circ$ is too low ($10^\circ/\text{min}$, while skipper expects 25° to $35^\circ/\text{min}$)

-TIME: 13'50 to 15'10

For a speed of $U = -1.3 \text{ km/h}$, $d=55^\circ$ and asymmetric propulsion, no rate of turn is reached ($3^\circ/\text{min}$)

With both propellers ahead no turning rate is achieved until speeds become positive.

A.4 PecheMelba33 at 100% UKC

Skipper notes that the speeds are too high for the model.

Expected speeds:

Class Vb at 100% = 19km/h (DameNoire: 18 km/h)

Class Va at 100% = 23 km/h (PecheMelba 30 km/h)

Class Va at 1m UKC = 14 to 15 km/h

A.4.1 Ocean_[20190830min1253min0319minC751minC154F61C1A04]

-TIME: 08'00

Stopping the vessel is much too slow (even with BT astern). Vessel misses the swinging area. Simulation aborted and restarted again for swinging manoeuvre.

A.4.2 Ocean_[20190830min1311min0788minF552min2D31F71C1A04]

Skipper forgot to stop the BT at the beginning of the simulation.

-TIME: 03'40 to 4'50

It takes a long time (too long) to accelerate the yawing motion but in the end a RoT of 60°/min is reached. The skipper expects 70°/min in reality. Also in reality the ship should sail astern in this case.

When you perform a swinging manoeuvre with asymmetric propellers and max rudder angle, then you expect the vessel to go astern (the thrust of the ahead prop is blocked by the rudder). For all models this effect is too low (or even opposite).

A.4.3 Ocean_[20190830min1322min2253min86FBmin54BAF71C1A04]

-TIME: 00'00 to 03'20

When going astern (-5 km/h) the steering at negative rpm is realistic (although a bit less than expected: 5°/min were reached, while in reality this might be 15°/min).

-TIME: 06'00 to 08'00

Swinging manoeuvre was performed very realistic according to the skipper. Very high rate of turn was reached and the drifting during the swing was as in reality.

-TIME: 08'10 to 09'00

At the end of the swinging manoeuvre, very high lateral speeds occur (although the rate of turn is already decreasing). The lateral speed in this conditions was not considered realistic in this case.

In general the conclusion for the model were rather positive, but the following issues should be addressed:

- Max speed ahead
- Deceleration
- Lateral speed at swinging manoeuvre

A.5 PecheMelba33 at 60% UKC

A.5.1 Ocean_[20190830min1337min1502minF2AFminC56FF81C1A04]

-TIME: 06'30 to 09'30

The skipper started to decelerate the vessel earlier to compensate for the bad stopping ability of the models. This issue however is also present for this UKC.

-TIME: 11'00 to 13'30

After a long time the rate of turn with asymmetric propellers reached 40 °/min. The acceleration of the RoT is too slow and the max value should be 60 to 70 °/min. Speed astern is expected but not present.

-TIME: 14'00 to 15'30

Whit negative speeds ($u < 0$) the rate of turn with asymmetric propellers reached almost 60 °/min (while only 40 °/min ahead).

A.5.2 Ocean_[20190830min1358min3007min095CminEE72F91C1A04]

-TIME: 07'10 to 07'50

In this simulation a very realistic swinging manoeuvre was performed with rate of turn up to 80°/min (at negative speed: to be checked at positive speed). According to the skipper the vessel behaves realistic in this simulation.

A.6 PecheMelba33 at 33% UKC

A.6.1 Ocean_[20190830min1411min2984min047Amin5D11FA1C1A04]

-TIME: 06'20 to 08'50

When stopping the vessel important rate of turn to PS was observed. Skipper confirms that during crash stops the vessel can start yawing, but in this simulation the effect was exaggerated.

-TIME: 11'00 to 13'20

Turning ability was too low (especially the acceleration of yawing motion).

The rate of turn with asymmetric propeller was higher than with both engines full ahead which is not expected.

-TIME: 14'50 to 15'50

Rate of turn reduces if speed reduces. To be investigated: difference in RoT at $u > 0$ km/h and $u < 0$ km/h (at different speeds)

A.6.2 Ocean_[20190830min1440min570EminA40FminA278FB1C1A04]

-TIME: 07'40 to 09'10

Initiation of swinging manoeuvre was too slow.

A.7 DameNoire33 at 167% UKC

In several simulations very important lateral forces in the aft were noticed when the propeller was used astern. This was the case for both the stopping manoeuvre as for the astern sailing in the channel.

On the other hand the swinging manoeuvre at 2 km/h was performed at a rate of turn which was more realistic than for DameNoire44 (the rate of turn of 50°/min could be considered to be too high in this case).

The model was considered to be unrealistic.

A.7.1 Ocean_[20190830min1502min30DBmin0B41min9B7FFC1C1A04]

Stopping (unrealistic asymmetry) and swinging (considered to be realistic but should be investigated).

A.7.2 Ocean_[20190830min1524min2421min7AECmin888AFD1C1A04]

Very high drift speeds when sailing astern and no possibility to control the vessel.

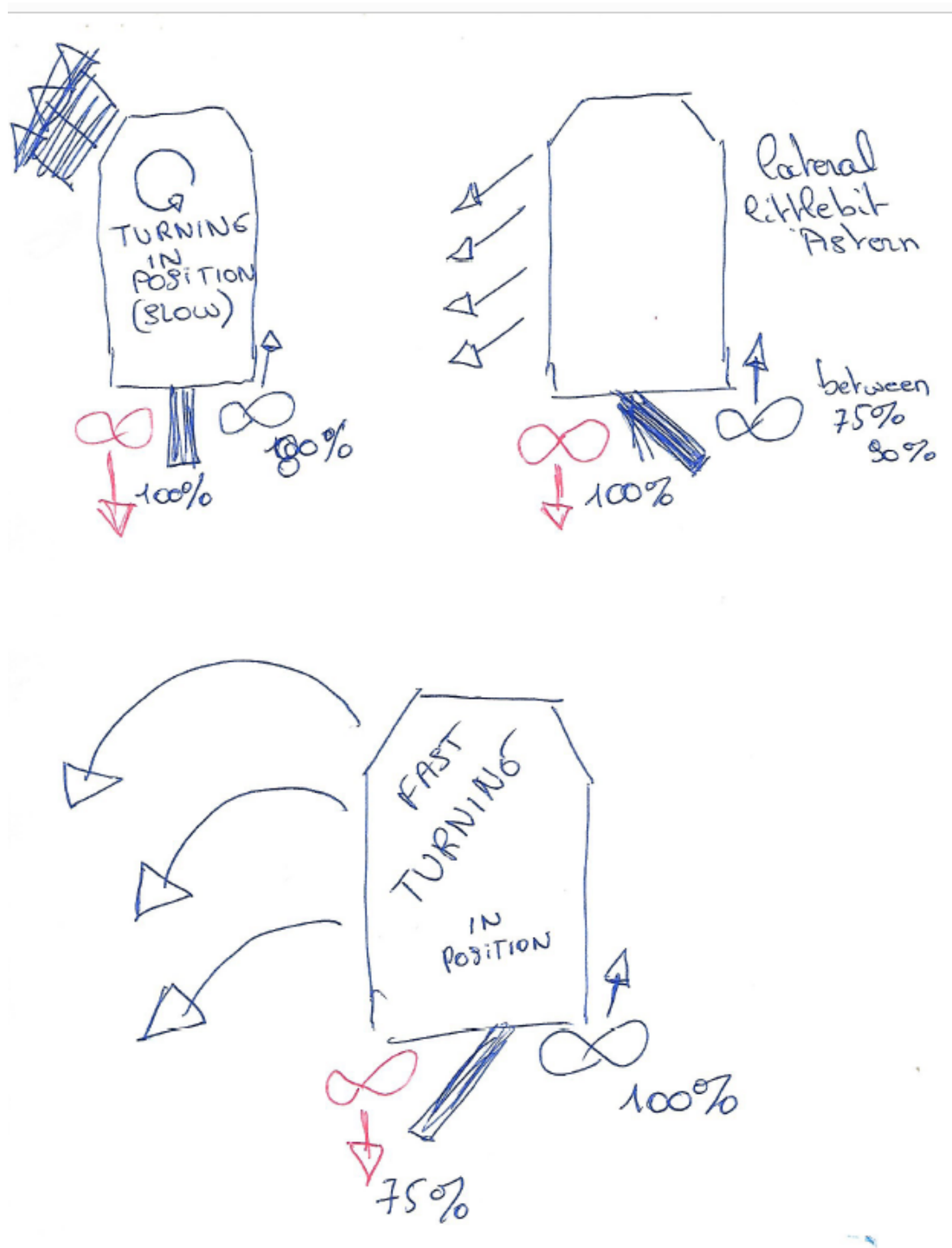
-TIME: 14'30 to 15'30

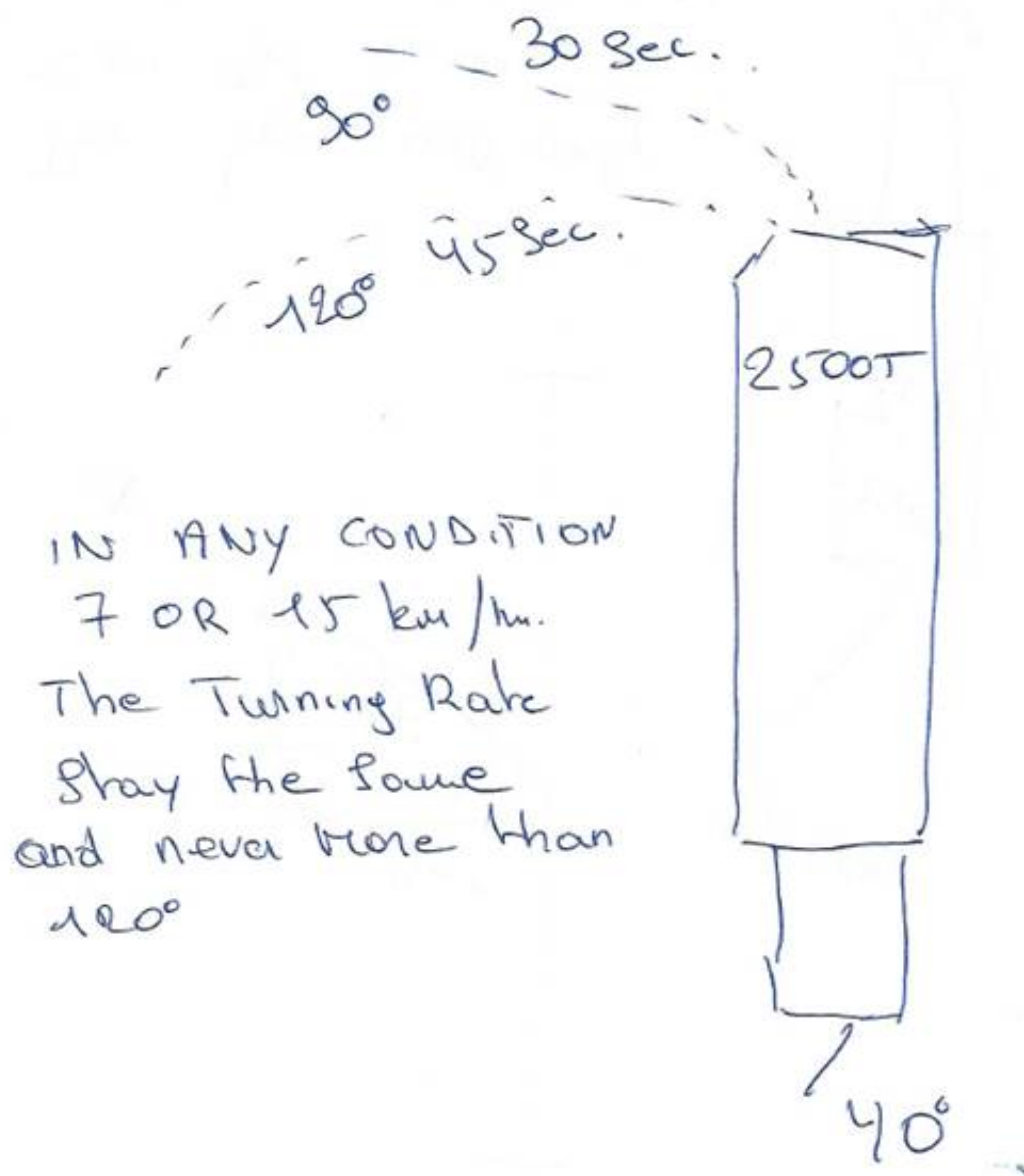
End of simulation is a good illustration of the lateral motions at the aft, when using the propellers astern (during this manoeuvre it was tried to steer the vessel with the BT).

A.8 DameNoire43 at 128% UKC

Final rate of turn during swinging was considered to be realistic (this was not the case for DameNoire44), but the time it takes to reach this rate of turn was too long.

Annex B: Drawings provided by the skipper





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