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Improving the safety of beam trawlers

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Preface

After our the completion of our research project on the stability of beam trawlers (Conoship International, 2022) we were honored with the assignment of this follow-up research project on improving the safety of beam trawlers.

During this project we received valuable cooperation from representatives of designers, ILT, and the fishery organizations 'Nederlandse Vissersbond' and 'Sectorraad', our client and several fishermen. During and in between the workshops valuable discussions took place and we received the data of 13 beam trawlers < 24 m, forming a well-balanced reference fleet. We thank you all.

We respectfully dedicate this report to the crewmembers of the beam trawlers, that were lost at sea during fishing.

Groningen, November 30th, 2023

CONOSHIP
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Summary

As a follow-up of the research on the stability of beam trawlers (Conoship International, 2022), Conoship was assigned to develop measures to improve the safety of beam trawlers < 24 meter, including:

- An amendment to the existing statutory stability criteria;
- One or more operational measures;
- One or more measures to improve the crew's understanding of stability of the vessel.

For the development of the amendment to the existing stability criteria a reference condition was defined, the Basic Fishing Condition (Chapter 4.4). The Basic Fishing Condition is based on the free sailing condition with 50% consumables and 100% catch, but the effect of mass of the fishing gear suspended from fishing blocks at the outer ends of the derricks, as well as the resulting shift in center of gravity is taken into account.

More beam trawlers were added to the reference fleet used in the previous research, resulting in a reference fleet of 13 beam trawlers with a balanced range of properties, such as year of construction and dimensions (Chapter 4.3).

First the stability performance of the reference group in the Basic Fishing Condition was assessed. The result was a set of values for stability indicators, the base line criteria (Chapter 4.7), such maximum GZ and area under GZ-curve, at current the safety level. This safety level is the result of the current criteria.

Proposal amendment to existing criteria

The assignment was to improve the safety of the beam trawlers, so the next step was to add a safety margin to the stability indicators mentioned above. To determine the effect on the safety of the vessels, the Score-card was used. This Score-card with remaining righting moments for each vessel under various conditions has been developed during the previous investigation on the stability of beam trawlers and was used in this one as well (Chapter 4.7.2).

Based on the reference fleet and the stability performance of the fleet, the safety level was increased to the level were the Score-card showed no situations without remaining righting moment anymore. The corresponding criteria were tested on the reference fleet and the best five ships were able to comply, one without alterations and the others with minor alterations (Chapter 4.8.1).

The resulting proposal for the amendment to the existing stability criteria (Chapter 8.1) is:

'Seagoing fishing vessels up to 24 metres in length, engaged in beam trawling, must comply with the following:

In the Basic Fishing Condition the following criteria must be met:

1. *The maximum righting lever (GZ) should not be less than 0.225 metre;*
2. *The area under the righting lever curve (GZ-curve) up to* $\varphi = 30^0$ *should not be less than 0.060 metre-radians, and not less than 0.093 metre-radians up to* $\varphi = 40^0$*, or between* 30^0 *and the angle of flooding* φ_f*, if this angle is less than* 40^0 *.*
3. *The area under the righting lever curve (GZ-curve) between* $\varphi = 30^0$ *and* $\varphi = 40^0$*, or between* 30^0 *and the angle of flooding* φ_f*, if this angle is less than* 40^0*, should not be less than 0.027 metre-radians.*

Application:

Unless expressly provided otherwise, the provisions apply to new vessels.

Definition:

The angle of flooding φ_f *is the angle of heel at which openings in the hull, superstructure or deckhouses which cannot rapidly be closed watertight commence to immerse.*

Basic Fishing Condition:

- *50% consumables;*
- *100% catch in the hold;*
- *Derricks in store position or at 80 degrees, whichever is the highest position of the derricks in free sailing conditions;*
- *Both portside and starboard side beam trawl fishing gears, for the intended type of fishing operation, suspended from the fishing blocks at the outer end of the derricks.'*

In addition to the proposal of the amendment, calculation methods for dedicated stability information during fishing have been investigated. The aim was to develop a method for showing the stability information during fishing as a part of the stability information in the stability booklet, similar to the dredging chapter in the stability booklets of dredging vessels.

This resulted in the proposal for the Fishing-Module (Chapter 5.1.1), that gives values for the maximum pulling forces and pulling angles in the fishing lines, for the required stability of the beam trawler. The calculation method is based on the Anchor Handling Module, (IMO IS-code 2008 – Part B – Chapter 2.7 Ships engaged in anchor handling operations), but with two forces acting on both ends of the derricks of a beam trawler instead of only one pulling force for an anchor handling vessel.

Operational measures

The maximum values for the pulling forces in the fishing lines and their direction, calculated in the proposed Fishing-Module, can be used as threshold values for an alarm system on the vessel. This system, which can be added to existing data management systems on board, warns the skipper when the combination of pulling forces and their direction result in a dangerous heeling moment on the ship (Chapter 5.1.2).

Measures to improve the crew’s understanding of stability of the vessel

In addition to the already started improvement of the teaching material of the stability, it was found that a more practical approach of teaching of the subject stability is needed. Use of a large scale beam trawler model to experience the effects of gear and weights shifts on the stability is recommended (Chapter 6.1).

Also a substantial role for simulators of beam trawlers is recommended, such as the MARIN 24 meter beam trawler simulator and the 40 meter beam trawler simulator at VDAB. Training on these simulators will have a significant contribution to the understanding of stability and with that to the safety of the entire beam trawler fleet (Chapters 6.2 and 6.3).

Samenvatting

Als vervolg op het onderzoek 'Stability of beam trawlers' (Conoship International, 2022) heeft Conoship de opdracht gekregen om een voorstel te ontwikkelen voor een pakket maatregelen ter verkleining van het kapseisrisico van vissersvaartuigen, met gericht op boomkorkotters onder de 24 meter.

Dit pakket dient de veiligheid te bevorderen door:

1. aanpassing van de statutaire stabiliteitseisen voor nieuwe schepen,
2. één of meer operationele maatregelen en
3. één of meer maatregelen ter verbetering van het begrip van de stabiliteit van het schip bij de bemanning.

Voor de ontwikkeling van de wijziging van de bestaande stabiliteitscriteria werd een referentietoestand gedefinieerd, de Basis Visconditie (Hoofdstuk 4.4). De Basis Visconditie is gebaseerd op de vrij varende conditie met 50% voorraden en 100% vangst, maar is er rekening gehouden met het effect van de massa van het vistuig dat is opgehangen aan de visblokken aan de uiteinden van de gieken, evenals de resulterende verschuiving van het zwaartepunt.

Meer boomkorkotters zijn toegevoegd aan de referentievloot die werd gebruikt in het vorige onderzoek, resulterend in een referentievloot van 13 boomkorkotters met een evenwichtige reeks eigenschappen, zoals bouwjaar en afmetingen (Hoofdstuk 4.3).

Eerst is de stabiliteitsprestatie van de referentievloot in de Basis Visconditie beoordeeld. Het resultaat was een reeks waarden voor stabiliteitsindicatoren, de basiscriteria (Hoofdstuk 4.7), zoals maximale GZ en oppervlakte onder de GZ-curve, op het huidige veiligheidsniveau. Dit veiligheidsniveau is het resultaat van de huidige criteria.

Voorstel tot wijziging van bestaande criteria

De opdracht was om de veiligheid van de boomkorkotters te verbeteren, dus de volgende stap was het toevoegen van een veiligheidsmarge aan de hierboven genoemde criteria van de stabiliteit. Om het effect op de veiligheid van de schepen te bepalen, is de score kaart gebruikt. Deze score kaart, met resterende oprichtend momenten voor elk schip onder verschillende omstandigheden, is ontwikkeld tijdens het vorige onderzoek naar de stabiliteit van boomkorkotters en is ook in dit onderzoek gebruikt (Hoofdstuk 4.7.2).

Op basis van de referentievloot en de stabiliteitsprestaties van de vloot is het veiligheidsniveau verhoogd tot het niveau waarop de score kaart geen situaties meer liet zien zonder resterend oprichtend moment. De overeenkomstige criteria werden getest op de referentievloot en de beste vijf schepen konden hieraan voldoen, één zonder wijzigingen en de andere met kleine aanpassingen (Hoofdstuk 4.8.1).

Het resulterende voorstel voor de wijziging van de bestaande stabiliteitscriteria (Hoofdstuk 8.1) is:

'Zeegaande boomkorkotters met een lengte tot 24 meter moeten voldoen aan het volgende:

In de Basis Visconditie moet aan de onderstaande criteria worden voldaan:

- *De maximale oprichtende arm (GZ) mag niet minder zijn dan 0,225 meter;*
- *Het oppervlak onder de GZ-curve tot* $\varphi = 30^0$ *mag niet minder zijn dan 0,060 meter-radialen, en niet minder dan 0,093 meter-radialen tot* $\varphi = 40^0$*, of tussen* $\varphi = 30^0$ *en de hoek waarbij de openingen te water komen* φ_f*, als deze hoek minder is dan* 40^0*.*
- *Het oppervlak onder de GZ-curve tussen* $\varphi = 30^0$ *en* $\varphi = 40^0$*, of tussen* $\varphi = 30^0$ *de hoek waarbij de openingen te water komen* φ_f*, als deze hoek minder is dan* 40^0*, mag niet minder zijn dan 0,027 meter-radialen.*

Toepassing:
Tenzij anders besloten, is de wijziging van toepassing op nieuwe schepen.

Definities:

Basis Visconditie:

- *50% voorraden;*
- *100% vangst in het ruim;*
- *Gieken in de zeevast positie of gehesen tot 80 graden, welke de hoogste positie is van de gieken tijdens de vrij varende situatie;*
- *Zowel het bakboord als het stuurboord tuig, geschikt voor de voorgenomen vismethode, gehesen in het visblok aan de top van de giek.*

φ_f*,is de hellingshoek waarbij de openingen in de romp, dekhuizen of de opbouw te water komen, die niet snel waterdicht kunnen worden afgesloten.'*

Naast het voorstel voor de wijziging zijn berekeningsmethoden voor specifieke stabiliteitsinformatie tijdens het vissen onderzocht. Het doel was om een methode te ontwikkelen voor het tonen van de stabiliteitsinformatie tijdens het vissen als onderdeel van de stabiliteitsinformatie in het stabiliteitsboek, vergelijkbaar met de condities tijdens baggeren in de stabiliteitsboeken van baggerschepen.

Dit resulteerde in het voorstel voor de Vismodule (Hoofdstuk 5.4.1), die waarden geeft voor de maximale trekkrachten en trekhoeken in de vislijnen voor de vereiste stabiliteit van de boomkorkotter. De berekeningsmethode is gebaseerd op de Anchor Handling Module, maar dan met twee krachten, die werken op beide uiteinden van de gieken van een boomkorkotter in plaats van slechts één trekkracht voor een schip voor anchor handling.

Operationele maatregelen

Om tot een operationele maatregel te komen, is het voorstel voor de Vismodule ontwikkeld. De maximale waarden voor de trekkrachten in de vislijnen en hun richting, berekend in de voorgestelde Vismodule, kunnen worden gebruikt als drempelwaarden voor een alarmsysteem op de kotter. Dat systeem, dat kan worden ingebouwd in reeds bestaande systemen voor het verzamelen van data aan boord zoals DBMatic, waarschuwt de schipper wanneer de combinatie van trekkrachten en hun richting resulteert in een gevaarlijk hellend moment op het schip (Hoofdstuk 5.1.2).

Maatregelen om het begrip van de bemanning over de stabiliteit van het vaartuig te verbeteren

Naast de reeds gestarte verbetering van het lesmateriaal over stabiliteit, is vastgesteld dat een meer praktische benadering van het onderwerp stabiliteit nodig is. Het gebruik van een groot, varend model van een boomkorkotter om de effecten van verplaatsingen van de gieken en het tuig en andere gewichten op de stabiliteit te ervaren, wordt aanbevolen (Hoofdstuk 6.1).

Ook wordt het gebruik van simulatoren van boomkorkotters aanbevolen, zoals de 24 meter boomkorkotter-simulator van het MARIN en de 40 meter boomkorkotter-simulator bij VDAB. Training op deze simulatoren zal aanzienlijk bijdragen aan het begrip van stabiliteit en daarmee aan de veiligheid van de gehele vloot van boomkorkotters (Hoofdstukken 6.2 en 6.3).

Definitions & abbreviations

Definities

Cod-end	End of the net containing the catch. In Dutch this is called the ‘kuil’

Afkortingen

BadZ	Bekendmaking aan de Zeevisvaart (Announcement to the Sea fishing sector)
Bft	Beaufort (in wind force notation)
FMEA	Failure Mode Effect Analysis
IL&T	Inspectie Leefomgeving & Transport
IMO	International Maritime Organization
LCG	Longitudinal Centre of Gravity
LOA	Length over All
Lpp	Length between perpendiculars
LSW	Light Ship Weight
MCA	Maritime and Coastguard Agency
PIAS	Program for the Integral Approach of Ship Design (stability software that is used)
PS	Portside
SB	Starboard
TCG	Transverse Centre of Gravity
VCG	Vertical Centre of Gravity
Vvb	Vissersvaartuigenbesluit

Contents

1 Introduction

On November 28th, 2019, beam trawler UK-165 Lummetje capsized and sank, with the loss of two lives. During the investigation of this accident by the Dutch Safety Board (OVV) in December 2020 another beam trawler UK-171 Spes Salutis capsized and sank. The crew of this vessel was rescued.

The Dutch Safety Board combined the investigation of both accidents in her report (Dutch Safety Board, 2021). In this report the Minister of Infrastructure and Water Management was recommended to '*Investigate the scale of the safety risk of the capsizing and sinking of trawlers as a result of dangerous asymmetric loading conditions within the entire Dutch trawler fleet. Include all fishing vessels in this investigation, irrespective of their length. Take measures to counter this safety risk.*'.

The investigation in the safety risks of beam trawlers was assigned by the Ministry of Infrastructure and Water Management to Conoship International, resulting in the report 'Stability of beam trawlers' (Conoship International, 2022). A follow-up investigation was assigned to Conoship International, in which the improvement of the safety of beam trawlers was to be investigated. The results are described in this report.

The project has been divided in the following phases:

1. Orientation phase, during which together with stakeholders the measures were selected, that could be developed for the improvement of the safety,
2. Elaboration phase, during which the selected measures were developed,
3. Conclusion phase, during which final comments of the stakeholders the measures were finalized,
4. Reporting.

For every phase a workshop was organized with the stakeholders of the sector: representatives of designers, fishing organizations and Dutch flag state (ILT and Ministry of I&W). This led to valuable feedback and input on the foreseen measures, thus improving their value.

The contents of the report are:

Chapter 1	Introduction;
Chapter 2	Background of the project, with conclusions and recommendations of the previous research Conoship has carried out;
Chapter 3	Description of the research process itself;
Chapter 4	The background and development of the new stability criterium for beam trawlers engaged in fishing and a description of the reference fleet;
Chapter 5	Possibilities for using the anchor handling method as a base for the Fish-module and the practical application of the adapted module on beam trawlers
Chapter 6	Suggestions for improving the understanding of stability

Chapter 7	Other operation improvements of the safety, encountered during the research project.
Chapter 8	Conclusions
Chapter 9	Recommendations

2 Background

During the previous project on the safety risks of beam trawlers (Conoship International, 2022) the safety risks of beam trawlers were investigated and divided in three main categories:

- Ship’s factors, such as loading condition of the vessel, influence of the position of derricks and gear and wind and waves, that form a part of the stability calculation;
- Human factors, such as the training level of the crew and their understanding of the stability information;
- Rules and regulations and their enforcement by the authorities.

As a result of the project the following conclusions were made:

- Beam trawlers of less than 24 meter length are considerably more vulnerable to asymmetric loads than larger beam trawlers;
- The conditions during fishing are not included in the stability information made available to the crew, stability booklets only contain information on four loading conditions during sailing. Although it is requested to include any other, regularly happening condition, that is unfavorable than these conditions, no fishing conditions (lifting of the nets, moving derricks etc.) are included;
- Stability criteria for beam trawlers are defined for the free-sailing conditions of the vessel only, conditions during fishing operations are not included in the scope of the criteria;
- Mitigation of the risk of asymmetric loads on beam trawlers can partly be done by training of students and crew and also by law enforcement and review of stability information. However, to a certain extent, asymmetric loads form a part of normal fishing operations and cannot always be prevented.

In the report the following recommendations were made:

- Since the remaining righting moments are quickly decreasing above wind force 6 Bft. for the vessels examined, it is recommended to determine the limit of the wind force for the fishing operations for each vessel;
- In order to provide the fishermen with adequate information, developing guidelines for stability criteria during fishing operations is recommended, taking into account the fishing conditions in a way comparable to guidelines for other vessel types, such as the lifting code. This is best done together with other national authorities of the EU and UK.
- Since training of students and crew is of the utmost importance, special bridge simulators for beam trawlers must be used for training. They are being developed, amongst others by MARIN.
- An active safety system like the Marelec system significantly enhances the safety of the beam trawlers and also supplies data to the fishermen, enabling them to make the fishing more efficient. Since this is an expensive system, support from the authorities can help.
- The gap between the way the stability information is presented and the need of the crew is to be closed, stability information and training must be more accessible;

- Inspections on alterations of the vessels that influence the stability, such as added masts, lengthened derricks or stern trawl gear remaining on board during beam trawling have to be intensified;
- During document review more attention has to be given to the items included in the wind contour.
- Based on the new insight of the risks during operational conditions, risk-based designing will help to make beam trawlers safer;
- The dynamic effects of waves must be further investigated to assess the resulting stability risks.

After publication of the findings, we had the opportunity to discuss them with various stakeholders, such as the Ministry of Infrastructure and Water Management, the organization of the fishing industry (Sectorraad), teachers and several fishermen.

The situation of the Dutch beam trawler fleet is complicated: Some of the beam trawlers were scrapped as part of Dutch policy to balance the capacity of the trawler fleet with the fish quota. On the other hand, the fleet is confronted with rising prices of fuel and more strict emission rules, which makes investing in (new) vessels uncertain.

Therefore, the focus for improving the safety of beam trawlers is not only a new criterium for stability, which applies to new vessels, but also on operational measures and training of the crew. This way the safety of existing beam trawlers can be improved as well.

During this period the follow-up project was defined by the Ministry of Infrastructure and Water Management and awarded to Conoship.

3 Research project

This chapter will describe the project, its aims and the methods used.

3.1 Research assignment

The research assignment is to develop a combination of proposals for measures to reduce the risk of capsizing of beam trawlers, with a focus on vessels < 24 m. Proposals must include:

- An amendment to the existing statutory stability criteria;
- One or more operational measures;
- One or more measures to improve of the crew's understanding of stability of the vessel.

The combination must include one additional criterium for the beam trawler during fishing operations, in addition to the existing criteria for fishing vessels.

The impact of the stability criterium on the safety level and the design of a beam trawler must be investigated using design studies.

3.2 Research method

During this project the following methods were used:

- Study of literature and legislation,
- Calculations of the stability and heeling moments during fishing operations of the reference beam trawlers, using PIAS and Excel,
- Interviews with fishermen and representatives of the fishing industry,
- Interviews with relevant authorities,
- Visits of the simulator of the VDAB (*Vlaamse Dienst voor Arbeidsbemiddeling en Beroepsopleiding*) at Zeebrugge and the simulator of the MARIN (*Marine Research Institute Netherlands*)
- Contacts with SARC (*Scheepsbouwkundig Advies en Reken Centrum*), the developer of the stability program PIAS,
- A lot of brainstorm sessions, with colleagues and with external parties.

4 Stability criterium fishing conditions

One of the aims of this research was to develop a stability criterium in addition to the existing stability criteria, that will apply to the beam trawler in ‘fishing conditions’. The next chapters contain the existing stability criteria for beam trawlers < 24 m and a description of how the amendment criterium has been developed.

4.1 Dutch criteria for fishing vessels < 24 m

The legislation of the Dutch flag is issued by the Ministry of Infrastructuur en Waterstaat, based on the international legislation and, when deemed necessary, complemented with additional national rules, issued by the department Inspectie Leefomgeving en Transport (ILT), previous name Scheepvaartinspectie (SI). For beam trawlers < 24 m the applicable criteria are given in:

- Vissersvaartuigenbesluit 1989,
- Bekendmaking aan de Zeevisvaart 12/1989.

	Criterium	Value	Unit
1	Minimum metacentric height (GM’)	>= 0.35	m
2	Righting arm at 30º angle of heel	>= 0.20	m
3	Area under righting lever curve up to 30º angle of heel	>= 0.055	mrad
4	Area under righting lever curve up to 40º angle of heel	>= 0.090	mrad
5	Area under righting lever curve between 30º and 40º angle of heel	>= 0.030	mrad
6	Maximum righting arm should occur at an angle of heel preferably exceeding 30º but not less than 25º		

Table 1: Dutch stability criteria for fishing vessels < 24 m in length.

4.2 Specific criteria for beam trawlers

In (NSI, 1989) the following specific criteria for beam trawlers are stated:

1. The criteria values 2 – 5 mentioned in Table 1, are to be increased by 20%;
2. Minimum GM’: >= 0.50 m.

The resulting stability criteria for beam trawlers are as follows:

	Criterium	Value	Unit
1	Minimum metacentric height (GM’)	>= 0.50	m
2	Righting arm at 30º angle of heel	>= 0.24	m
3	Area under righting lever curve up to 30º angle of heel	>= 0.066	mrad
4	Area under righting lever curve up to 40º angle of heel	>= 0.108	mrad
5	Area under righting lever curve between 30º and 40º angle of heel	>= 0.036	mrad
6	Maximum righting arm should occur at an angle of heel preferably exceeding 30º but not less than 25º		

Table 2: Dutch stability criteria for beam trawlers <24 m in length.

Furthermore, it is required to increase the stability criteria values by the ratio of installed power to the 'standard power'. This ratio is called the *Stability factor*. For beam trawlers < 24 m the 'standard power' is calculated according to the following formula:

- 0.6 L_s^2 for vessels with a length equal to or smaller than 35 m.

  In which L_s is the length over all according to the international tonnage certificate or 112 percent of the length of the vessel, whichever is the smallest.

In case the installed engine power exceeds the value of this 'standard power', the criteria values 2 – 5 mentioned under Table 2, shall be increased by the proportion of increased engine power (Stability factor).

However, because Dutch beam trawlers of <24 m in length have a restriction on engine power of 221 kW (or 300 hp), the resulting *Stability factor* for these vessels is usually 1. This means that there is no allowance to the stability criteria for these beam trawlers. This is the case for all vessels of the reference fleet described in the next section.

4.3 Reference fleet

For the development of the amendment criterium as described in paragraph 4.7, a reference fleet was used. It consists of thirteen reference beam trawlers, that by their properties were a good representation of the entire beam trawler fleet. The purpose of the reference fleet was two-fold:

1. Establish the difference in stability between the free sailing conditions and the Basic Fishing Condition (Chapter 4.4);
2. The reality and practicality of the amendment to the stability criteria was tested on the reference fleet, to make sure that this would result in a set of criteria, where future designs of beam trawlers realistically can comply with.

This paragraph describes the general properties of the reference fleet. The subparagraphs especially show the scatter of certain properties of these vessels, like breadth. Furthermore, the scatter of the reference vessels among the EU-fleet has been picturized. The selection of the vessels has been done based on a representative scatter of vessels within the Dutch and EU-fleet and on the data that have been made available by a number of parties.

A number of general properties of the reference fleet are as follows:

- All of the vessels are currently sailing and fishing;
- All are vessels sailing under the Dutch flag;
- The year of construction ranges from approximately 1945 – 2020;
- The overall length ranges from 19.00 – 24.00 m;
- About 50% features an open aft deck and 50% a closed aft deck;
- Gross Tonnage ranges from 40 – 160 GT.

How the reference vessels are being used in the development of the amendment criterium is described in the next paragraphs.

In the paragraphs below, a number of properties have been depicted.

4.3.1 Overview of reference fleet

Table 3 below shows an overview of the reference fleet, including the most relevant particulars for this research.

Number	Name	Open/Closed Aftdeck	Moulded Breadth [m]	Gross Tonnage [GT]	Year of construction
1	EuroCutter 20m - v1	Open Aft deck	5.80	69	2003
2	EuroCutter 20m - v2	Open Aft deck	4.75	39	1959
3	EuroCutter 20m - v3	Open Aft deck	5.56	60	1983
4	EuroCutter 22m - v1	Open aft deck	5.20	50	1964
5	EuroCutter 22m - v2	Open Aft deck	5.00	46	1962
6	EuroCutter 22m - v3	Closed Aft deck	6.00	92	1990
7	EuroCutter 22m - v4	Closed Aft deck	6.20	97	2000
8	EuroCutter 24m - v1	Open Aft deck	6.20	96	2002
9	EuroCutter 24m - v2	Closed aft deck	6.85	154	2005
10	EuroCutter 24m - v3	Open Aft deck	5.58	69	1946
11	EuroCutter 24m - v4	Closed Aft deck	6.90	161	2000
12	EuroCutter 24m - v5	Closed Aft deck	6.50	114	2015
13	EuroCutter 24m - v6	Closed aft deck	7.00	160	1991

Table 3: Overview of reference fleet

4.3.2 Reference fleet compared to EU-fleet

The below scatter diagram (Figure 1) shows how the reference vessels are positioned in the EU and Dutch (NLD) beam trawler fleet. Beam trawlers sailing the Dutch flag have been distinguished and show separately in black.

As can be seen, the reference vessels are positioned quite evenly through the fleet, as well in length as GT value. This especially counts for the Dutch fleet, for which the criterium is developed in first instance.

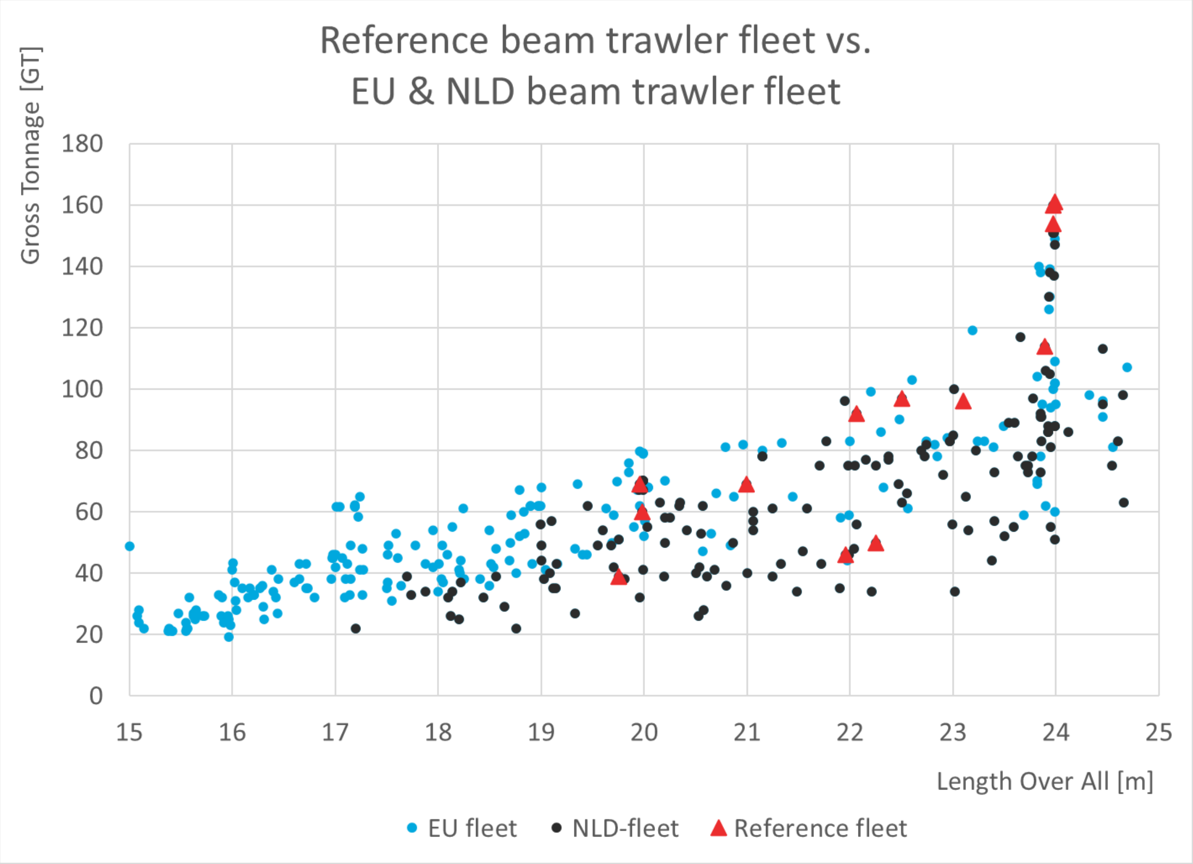


Figure 1: Reference beam trawler fleet (red) as compared to the whole EU and Dutch (NLD) beam trawler fleet (Lpp <24 m)

4.3.3 Year of construction of reference fleet

As can be seen in Figure 2, the contribution of older vessels (<2000) and newer vessels (>2000) to the reference fleet is well balanced. 7 vessels are older than 2000 and 6 vessels are of 2000 and newer.

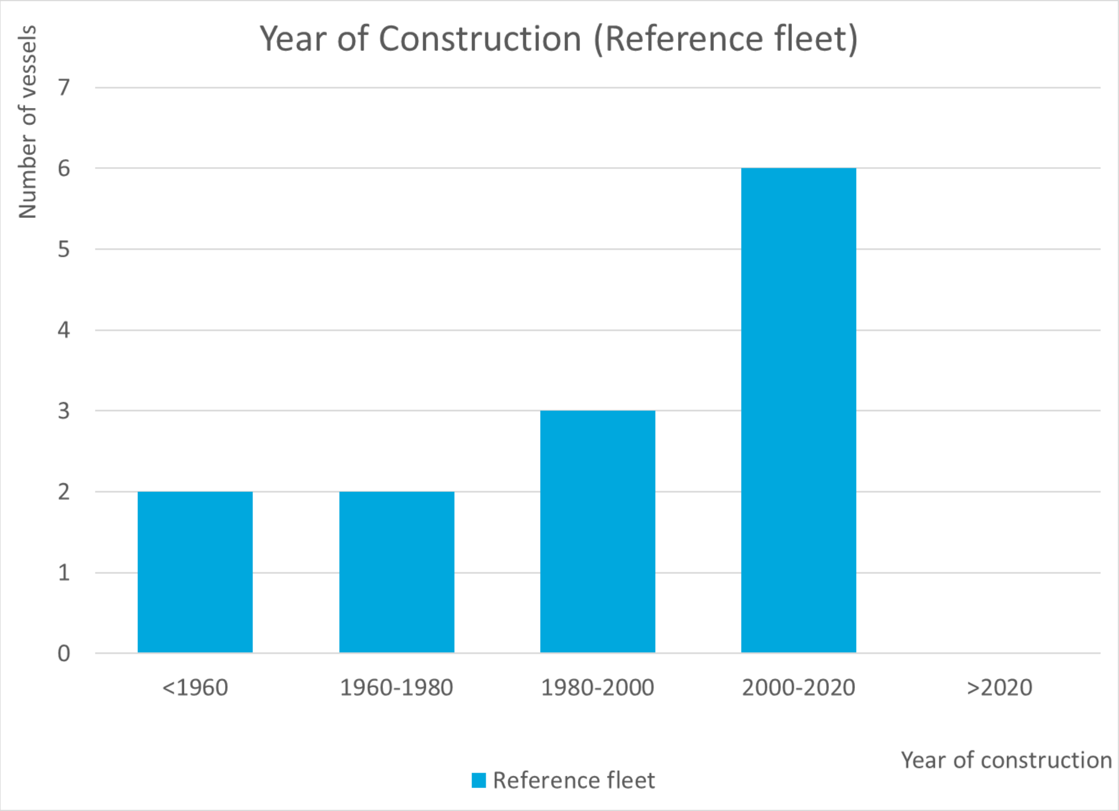


Figure 2: Distribution of construction date of reference fleet.

4.3.4 Open or closed aft deck

Beam trawlers can be clearly divided into two groups: ones that feature an open aft deck and ones that have a closed aft deck (poop). From Table 4, it is seen that the amount of open and closed aft deck vessels of the reference fleet is almost 50/50.

Open/Closed aft deck within reference fleet

	Number of vessels
Open aft deck	7
Closed aft deck	6
Total	13

Table 4: Number of vessels with open or closed aft deck

4.3.5 Length over all vs. breadth

As the breadth of a vessel is one of the more significant parameters in the stability performance of a vessel, it was considered to be important that the distribution of vessel breadth of the reference fleet was sufficient. The diagram in Figure 3 clearly indicates the differences in vessel breadth.

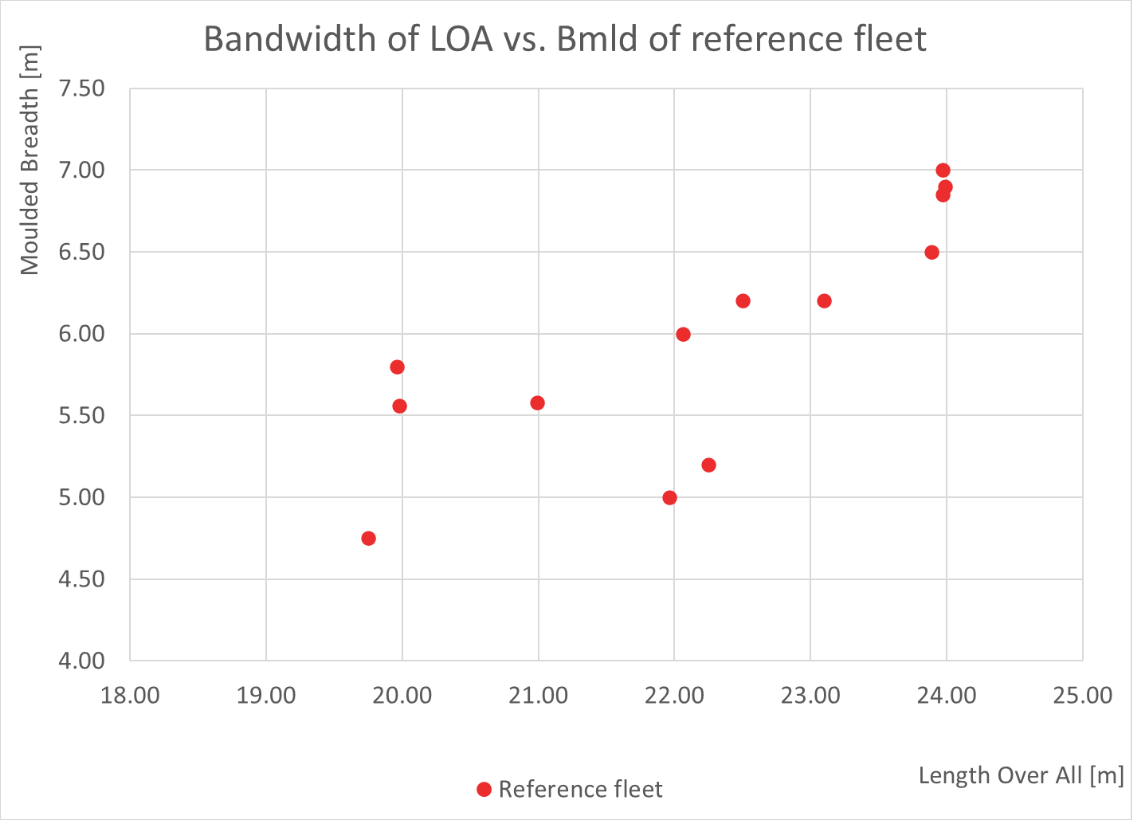


Figure 3: Distribution of vessel breadth among the reference fleet.

4.3.6 Scatter in Freeboard

Like for the breadth, the available freeboard of a vessel is an important indicator of the position that the deck edge will submerge, and therefore is considered to be a significant parameter that contributes to the available stability.

The scatter in freeboard among the reference fleet is quite large, ranging from 45 cm to 110 cm, and is shown in Figure 4.

In this case, the freeboard is defined as the difference between the moulded depth and the draught of the vessel in the *Condition* (as explained in paragraph 4.4).

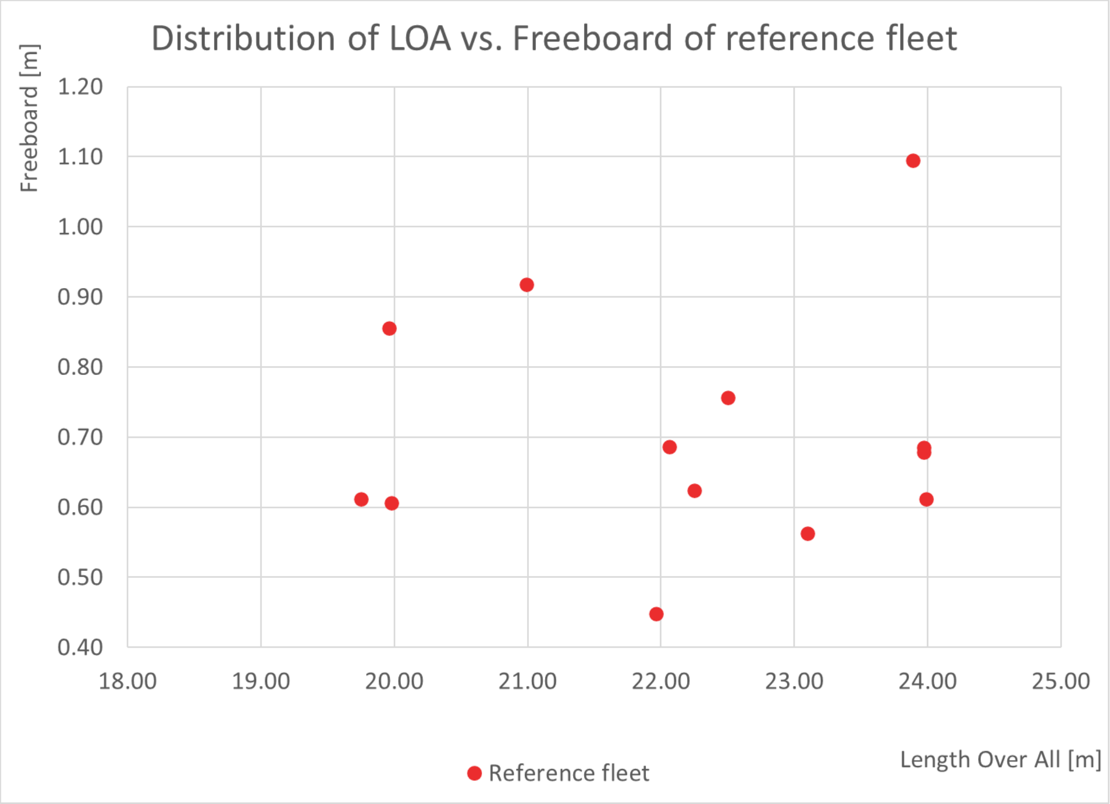


Figure 4: Distribution of available freeboard in Basic Loading Condition among reference fleet.

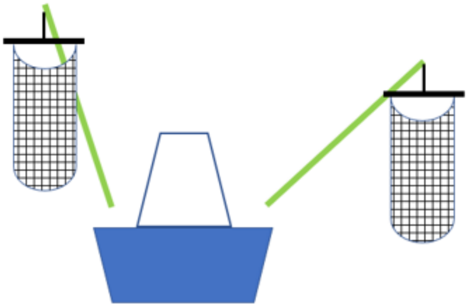
4.4 Basic Fishing Condition (reference condition)

From the previous research (Conoship International, 2022) it was concluded that the four loading conditions that are required by the current regulations are not sufficient because they are *free-sailing* conditions which lack any significant influence of derrick length and weight, and even more importantly, lack the influence of the weight of the beam trawl gear and its acting point.

It was recommended to develop stability criteria for the vessel in fishing conditions. Also, it was suggested by the Dutch Safety Board (OVV) (Dutch Safety Board, 2021) to specifically develop a set of criteria for asymmetrical loading conditions. Therefore, a new and specific reference loading condition has been developed, reflecting the fishing condition. This condition is named as *Basic Fishing Condition*.

The starting point for the Basic Fishing Condition was an asymmetrical condition, with the following properties:

- Derrick at one side in store position (topped)
- Derrick on the other side under an angle of 45 degrees
- Beam trawl fishing gear lifted and acting at the outer ends of the derricks
- No catch or debris in the nets



However, the research into the applicability of such a condition, including discussions at the several Workshops given, revealed concerns about the asymmetrical properties, and arguments came up which support not to use an asymmetrical condition as reference, but instead to use a symmetrical condition as a reference condition, because:

1. The angle of the derrick that is in the lower position is questionable. If for example 45 degrees is chosen, it is likely that there is another angle which gives a worse stability which will then not be covered; this is heavily depending on the vessel, derrick length, beam trawl gear weight, etc.
2. Following point one: too much variables are involved in asymmetrical conditions and many different conditions are possible;
3. If a symmetrical condition with derricks in their highest position is considered, then this will be the worst-case symmetrical condition, for each vessel. This is not the case for an asymmetrical condition. It is found that for one vessel, it the asymmetrical condition can be worse than the symmetrical condition, but for others the symmetrical condition is worse than the asymmetrical.
4. The method being used to develop the amendment criteria (as described in par. 0) already covers asymmetrical conditions. Those are the conditions described in 4.5. Moreover, it provided the freedom of including all asymmetrical conditions that were deemed relevant, including the one as shown above;
5. The chosen symmetrical condition is a more unambiguous condition which can easily be determined and checked with an inclining test; the fishing gear weight, but also derrick length etc. can easily be verified;

Moreover, during the research and the various discussions I became clear that a reference condition was needed, that would be a good starting point to cover all other fishing conditions and could be easily reproduced during an inclining test.

Considering the beam trawl gear and catch:

- The beam trawl gear has been included because that is always the case when a vessel is in fishing condition;
- The beam trawl gear weight can be measured, which also implicates that a change in gear will be directly reflected in the Basic Fishing Condition and therefore the stability performance of the vessel;
- In case of lengthened derricks, the effect of the lengthening on stability is taken into account. Not only the effect of the derricks weight and COG itself, but even more importantly, the effect of the change in acting point of the fishing gear;
- Catch and debris have been considered, but could not be made explicit as this is unambiguous: there is no fixed value and the weights of these items are different at each “trek” and vessel and are depending on many factors;
- Also the acting point of catch and debris is not fixed: it can either act at the end of the derricks, or when hauled, it acts at the mast on centerline of the vessel. Furthermore, catch in the water is hydrostatically neutral and thus has no weight that acts on the vessel in this situation;
- Therefore, catch and debris have not been included in the *Basic Fishing Condition,* but have been taken into account as factors in the Score-card and thus are covered by the amendment criteria;

It was decided to modify one of the four currently required loading conditions: *Departure of fishing grounds, 100% catch (in hold), 50% consumables* (hereafter indicated as *Basic Loading* Condition) into the *Basic Fishing Condition*. The condition was chosen because for a considerable amount of vessels in the reference fleet this was the less favourable condition. This condition features topped up derricks with the beam trawl gear lifted in the derricks and acting at the top/ends of the derricks. The below figure shows this schematically.

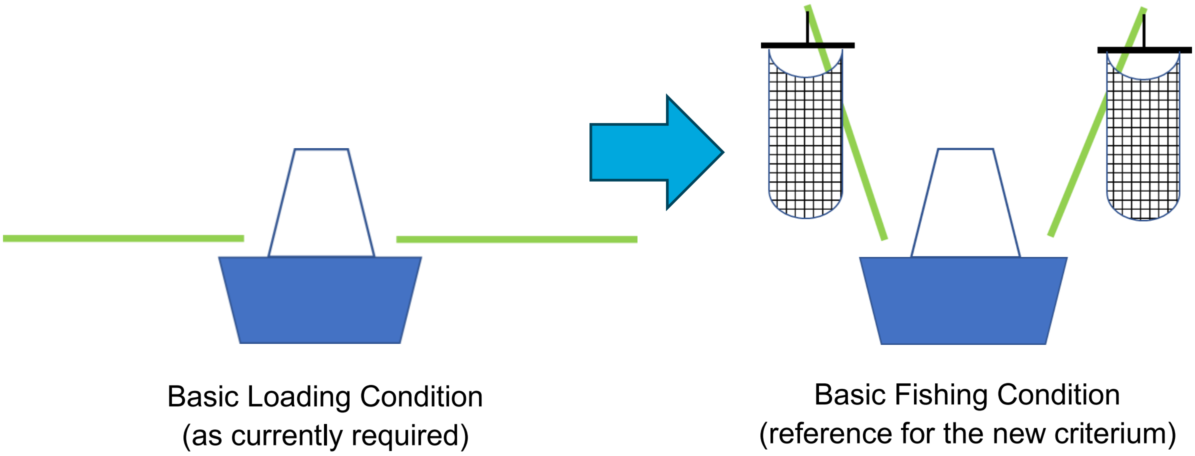


Figure 5: Basic Fishing Condition which is used as reference for the amendment criterium.

Besides the arguments depicted above, the choice for the Basic Fishing Condition can also be substantiated by the fact that this condition is occurring in reality. This became clear during various interviews with fishermen, that were held during the project. An example is shown in Figure 8.

The corresponding definition to be included in the amendment rules are then to be as follows:

Basic Fishing Condition:

- *50% consumables;*
- *100% catch in the hold;*
- *Derricks in store position or at 80 degrees, whichever is the highest position of the derricks in free sailing conditions;*
- *Both portside and starboard side beam trawl fishing gears, for the intended type of fishing operation, suspended from the fishing blocks at the outer end of the derricks.'*

4.5 Operational conditions

In this research, a number of operational conditions are considered; position of the derricks, beam trawl gear on deck or hanging in the derricks, catch in the net and/or being hauled etcetera. These operational conditions were based on the conditions that have been used in the previous research (Conoship International, 2022).

First, the overview of the operational conditions as used in the previous research, as well as the explanation of these has been recapped. In the following paragraph it is elaborated how these conditions have been used in the current research.

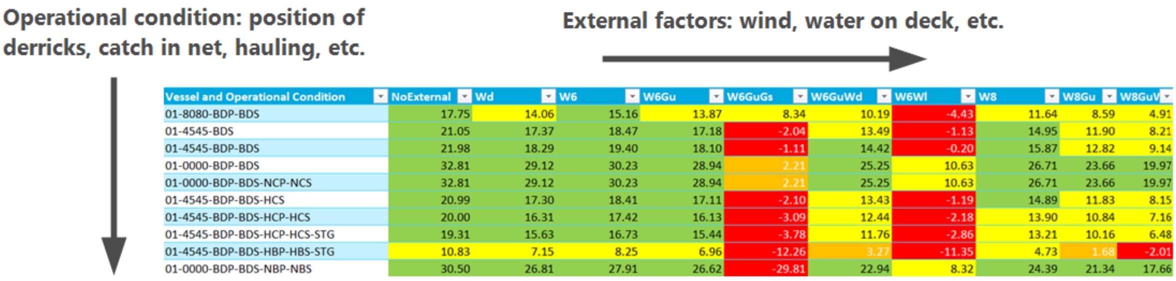
4.5.1 Summary and explanation of Operational conditions of previous research

Table 5 shows an overview of the operational conditions that were used in the previous research, together with an explanation of the codes used.

Condition	Code	Explanation
8080	80, 45, 00	Position of derrick: - 00 degrees (horizontal) - 45 degrees - 80 degrees (store position)
8080-STG		
8080-BDP-BDS		
8045-BDP-BDS		
4545-BDP-BDS	8080	Left 80 = derrick PS Right 80 = derrick SB
0000-BDP-BDS		
0000-BDP-BDS-NDS	BDP	Beam trawl gear acting at Derrick end Portside
0045-BDP-BDS-NDS	BDS	Beam trawl gear acting at Derrick end Starboard side
0045-BDP-BDS-HBS	BBP	Beam trawl gear acting at Bulwark at Portside (safety release system activated)
0045-BDP-BDS-NDS	BBS	Beam trawl gear acting at Bulwark at Starboard (safety release activated)
0045-BDP-BBS-NDS	STG	Stern Trawl Gear fitted
0045-BDP-BDS-NDS-STG	NDS	Net filled with Debris Starboard
0045-BDP-BBS-NDS-STG	HBP	Hauling Both catch+debris Portside net
4545-BDP-BDS-NDS	HBS	Hauling Both catch+debris Starboard net
4545-BDP-BDS-HBS	HCP	Hauling Catch Portside net
4545-BDP-BDS-NDS	HCS	Hauling Catch Starboard net
4545-BDP-BBS-NDS		
4545-BDP-BDS-NDS-STG		
4545-BDP-BBS-NDS-STG		
4545-BDP-BDS-HCS		
4545-BDP-BDS-HCP-HCS		
4545-BDP-BDS-HCP-HCS-STG		
4545-BDP-BDS-HBP-HBS-STG		
8045-BDS-STG		
8045-BDP-BDS-NDS		
8045-BDP-BDS-HCP-HCS		
8045-BDP-BDS-HCP-HCS-STG		
8045-BDP-BDS-HBP-NDS-STG		

Table 5: Operational conditions as used in the previous research.

These conditions, in combination with the external factors as described in Paragraph 4.6, were used to calculate a Score-card for each of the reference vessels. For each combination, the remaining heeling moment was calculated and plotted in the Score-card. An example of such a Score-card is shown in Figure 6.



Vessel and Operational Condition	NoExternal	Wd	W6	W6Gu	W6GuGs	W6GuWd	W6Wl	W8	W8Gu	W8GuV
01-8080-BDP-BDS	17.75	14.06	15.16	13.87	8.34	10.19	-4.43	11.64	8.59	4.91
01-4545-BDS	21.05	17.37	18.47	17.18	-2.04	13.49	-1.13	14.95	11.90	8.21
01-4545-BDP-BDS	21.98	18.29	19.40	18.10	-1.11	14.42	-0.20	15.87	12.82	9.14
01-0000-BDP-BDS	32.81	29.12	30.23	28.94	2.21	25.25	10.63	26.71	23.66	19.97
01-0000-BDP-BDS-NCP-NCS	32.81	29.12	30.23	28.94	2.21	25.25	10.63	26.71	23.66	19.97
01-4545-BDP-BDS-HCS	20.99	17.30	18.41	17.11	-2.10	13.43	-1.19	14.89	11.83	8.15
01-4545-BDP-BDS-HCP-HCS	20.00	16.31	17.42	16.13	-3.09	12.44	-2.18	13.90	10.84	7.16
01-4545-BDP-BDS-HCP-HCS-STG	19.31	15.63	16.73	15.44	-3.78	11.76	-2.86	13.21	10.16	6.48
01-4545-BDP-BDS-HBP-HBS-STG	10.83	7.15	8.25	6.96	-12.26	3.27	-11.35	4.73	1.68	-2.01
01-0000-BDP-BDS-NBP-NBS	30.50	26.81	27.91	26.62	-29.81	22.94	8.32	24.39	21.34	17.66

Figure 6: Example Score-card.

The colours in the Score-card are explained as follows:

Remaining righting moment / Righting moment$_{basicfishingcondition}$	Category	Notes
<0%	🟥	Due to this combination of operational condition and external moments the vessel will have no remaining righting moment
<20%	🟧	
20 – 80%	🟨	
>80%	🟩	

Figure 7: Legend explaining the colours of the Score-card.

4.5.2 Operational conditions as used in current research

The list of operational conditions from Table 5 has been analyzed and several important changes has been made based on discussions and outcomes of the Workshops that were organized, but also with a discussion with fishermen. This to let the list of applied operational conditions better match common practice and actual conditions when fishing, but not to omit some extreme situations which might occur, which became clear from all the accident reports that were investigated in the previous research project.

Extra attention has been paid to the following:

- Non-fishing/free sailing conditions with beam trawl fishing gear stored on deck and not acting at derrick or bulwark are omitted because these are not part of the fishing operation (8080 condition);
- The situation with both derricks at 45 degrees is determined to be common practice before starting the actual fishing and lowering the gear in the water or when hauling catch. Asymmetrical conditions with one of the derricks at store position and the other at 45 degrees (8045 conditions) are considered unrealistic and no common practice. Thus, those are omitted;
- Illegal conditions have not been considered: for example, stern trawl gear when this is not allowed to have on board while beam trawling, when this is specifically mentioned in the stability documentation;
- Whether or not a safety release system (e.g. Van Damme patent) is installed on the particular reference vessel; if no safety release system is installed, the conditions in

which the safety system is activated, are not taken into account. Contrary to the previous research, every reference vessel was considered to have such a system.

The coding of the conditions in the score card, as shown in Table 5, has been taken over from the previous research and has not been altered.

Examples of these conditions are:

8080-BDP-BDS: Basic Fishing condition (the reference condition) Figure 8;

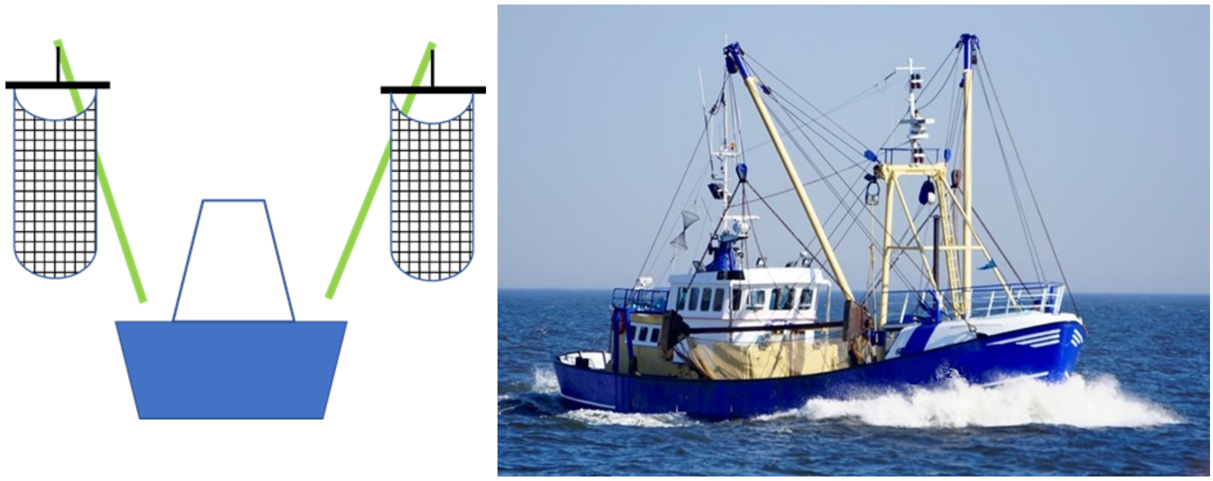


Figure 8: Condition 8080-BDP-BDS

0045-BDP-BDS SB derrick at 45 degrees, PS horizontal, both with gear (Figure 9).

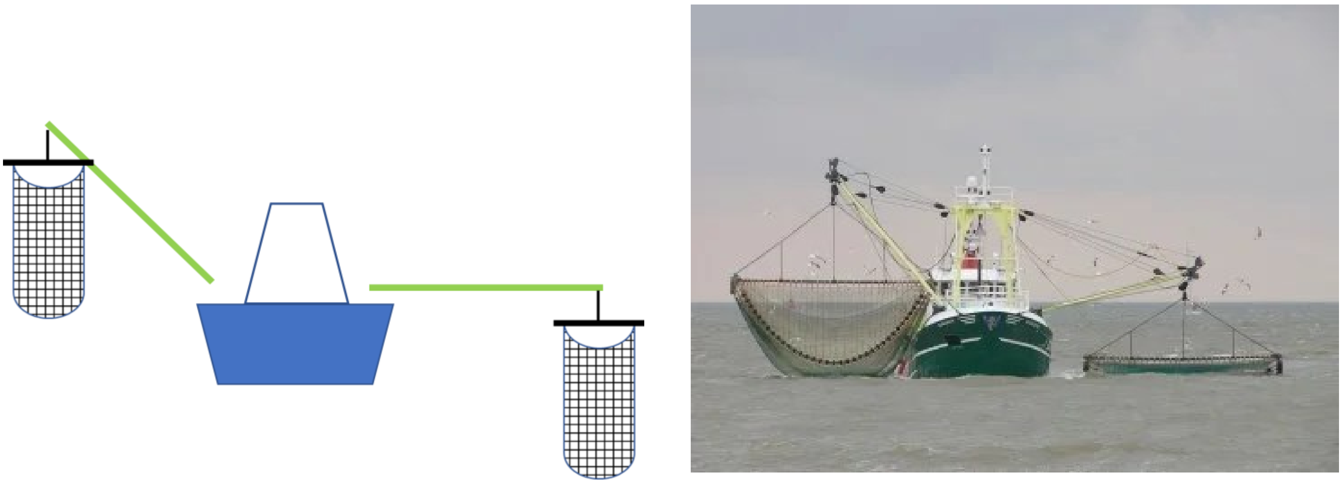


Figure 9: Condition 0045 BDP-BDS

For more examples refer to Appendix I.

4.6 External factors

External factors are events such as wind, water on deck and waves. The events that have been considered are based on the factors used in the previous research, however with several changes. In the previous research, the focus was on mapping all possible risks, also in non-fishing conditions, but now the focus is solely on the fishing conditions. Therefore, considering the actual conditions in which fishing operations are undertaken, reflecting common practice, is of more importance. Taking into account too (much) extreme conditions for developing the new criterium which is to be applied to actual fishing conditions, would result in unnecessary severe criteria.

4.6.1 External factors considered in previous research

The following external factors were considered in the previous research:

External factor	Explanation	Code
Wind	Wind force 6-10 Bft, transversely acting on the vessel.	W6, W8, W10
Wind gust	Pressure of wind x 1.5	Gu
Water on deck	Water on deck acting as free surface	Wd
Waves	Longitudinal: vessel on a longitudinal wave top	Wl
Gear Switched	Switch/flipping of gear from SB to PS	Gs

Table 6: External factors considered in the previous research.

4.6.2 Changes and resulting overview of external factors used

Based on analysis and discussions during the Workshops and discussions with fishermen, the following changes have been made to the external factors as used in the previous research (as described in paragraph 4.6.1):

- Wind force 10 Bft. has been omitted; this is not a realistic fishing condition. It is considered to be a survival condition, where fishing operations are not applicable. The chances that a beam trawler will encounter such a condition while fishing are assumed to be extremely low;
- Although it happens not very often, the capsize risk of a gear switch to the other side and the resulting flipping over of the derrick is very high. Mitigation of this risk by means of alternative and increased stability criteria is almost impossible and would result in criteria that are so severe, that no practical design of a beam trawler would be able to comply. However, instead of extra severe criteria, practical measures can be taken to prevent the derricks from flipping over, significantly reducing the risk of capsizing. This is an effective mitigation and is described in more detail in Chapter 7.3. Therefore the situation ‘Gear switched’ has been omitted as an external factor.

Table 7 shows a complete overview of the external factors used in determining the amendment criteria, including combinations of external factors.

Combination of external factors	Explanation
W6	Wind force 6 Bft
W6Gu	Wind force 6 Bft + wind gust
W6GuWd	Wind force 6 Bft + wind gust + water on deck
W6Wl	Wind force 6 Bft + longitudinal wave
W8	Wind force 8 Bft
W8Gu	Wind force 8 Bft + wind gust
W8GuWd	Wind force 8 Bft + wind gust + water on deck

Table 7: External factors that are included in the Score-card.

The choice of combinations to include is based on the assumption that fishing will still be performed in wind force 6 Bft., regardless of the location of the vessel at sea. Thus, the vessel will encounter wind, as well as longitudinal waves. Also a combination of transverse wind and longitudinal waves when for example on the open sea the wind blows from a different direction than the wave direction or when the vessel sails at an angle to the waves and wind.

Considering wind force 8 Bft.: It heavily depends on the situation if a vessel will stay or go fishing in such conditions. In situations in which a vessel is fishing at the wind side and/or in a sheltered area, it might occur that vessels stay or go fishing. As there will be less (extreme) waves in these situations, the chance of encountering critical longitudinal waves is neglected therefore omitted at W8. But it is considered that still the full wind force will act upon the vessel. At the contrary, if on open sea, it is assumed that the fishing operation will be terminated when W8 is coming up.

The above-mentioned assumptions were taken over from the previous research. They have been analyzed and discussed during the Workshops, but it was concluded that there was no reason to change these.

Furthermore, it is important to notice that, like in the previous research, no transverse waves have been considered. Transverse waves are largely a dynamic phenomenon, which could not be fully assessed using the calculation tools available to Conoship. It is added as a recommendation for further investigation, see chapter 0.

4.7 Development of the amendment criterium

This section describes how the above-described elements: the stability criteria for beam trawlers, the reference fleet, operational conditions and external factors are all used to develop a new criterium which is to be applied to the *Basic Fishing Condition.*

4.7.1 Selection and determination of the baseline criteria

The original stability criteria for beam trawlers in free sailing conditions, as described in chapter 4.2 and shown in Table 2, are taken as starting point for the selection and determination of the baseline criteria.

First, a selection has been made which of the criteria are to be included in the amendment criteria. These are considered to be representing the stability performance of a vessel to a sufficient extent.

	Criterium	**Selected**
1	Minimum metacentric height (GM')	No
2	Righting arm at 30º angle of heel	Yes, but the 30º has been omitted.
3	Area under righting lever curve up to 30º angle of heel	Yes
4	Area under righting lever curve up to 40º angle of heel	Yes
5	Area under righting lever curve between 30º and 40º angle of heel	Yes
6	Maximum righting arm should occur at an angle of heel preferably exceeding 30º but not less than 25º	No

Table 8: Selection of relevant criteria for the amendment criterium.

The reasons that criterium no. 1 and 6 have not been considered is:

- GM' values show a large scatter among the reference fleet. And it may be assumed that this is the case for the whole EU fleet;
- The GM' value does not say that much about the stability under heel;
- It is considered of less importance that the maximum righting arm (GZ) is met at a certain angle of heel. If for example the maximum GZ is occurring at 30 degrees or 40 degrees is of less importance. It is more important that the vessel somewhere has this maximum GZ which indicates the heeling moment that the vessel can handle. Besides, letting go the strict position of maximum GZ will provide more design freedom.
- Criteria 2 – 5 are considered to cover the stability performance under heel to a sufficient extent. Especially under larger angles of heel, which is considered important for the amendment criterium because asymmetrical load cases are considered as well.

4.7.2 Method

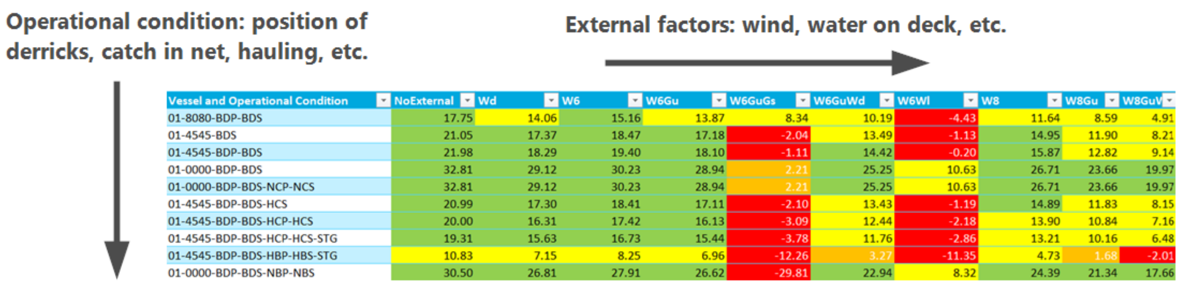
The Score-card method, as developed in the previous research (Conoship International, 2022), has been used. A summarized description of this method is found in paragraph 4.5.

The Score-card includes operational conditions and external events for every reference vessel, as described in the previous paragraphs.The development comprises of the following steps:

4.7.2.1 Step 1: Determine stability performance of reference fleet

For each vessel in the reference fleet, the stability performance is determined, using the *Basic Fishing Condition* with no external factors as a starting point, and adding operational conditions and external factors.

This results in a Score-card in which for each vessel and each possible combination of operational conditions and external factors, the remaining stability has been calculated. An example of a small part of the Score-card is shown in Figure 10.



Vessel and Operational Condition	NoExternal	Wd	W6	W6Gu	W6GuGs	W6GuWd	W6Wl	W8	W8Gu	W8GuV
01-8080-BDP-BDS	17.75	14.06	15.16	13.87	8.34	10.19	-4.43	11.64	8.59	4.91
01-4545-BDS	21.05	17.37	18.47	17.18	-2.04	13.49	-1.13	14.95	11.90	8.21
01-4545-BDP-BDS	21.98	18.29	19.40	18.10	-1.11	14.42	-0.20	15.87	12.82	9.14
01-0000-BDP-BDS	32.81	29.12	30.23	28.94	2.21	25.25	10.63	26.71	23.66	19.97
01-0000-BDP-BDS-NCP-NCS	32.81	29.12	30.23	28.94	2.21	25.25	10.63	26.71	23.66	19.97
01-4545-BDP-BDS-HCS	20.99	17.30	18.41	17.11	-2.10	13.43	-1.19	14.89	11.83	8.15
01-4545-BDP-BDS-HCP-HCS	20.00	16.31	17.42	16.13	-3.09	12.44	-2.18	13.90	10.84	7.16
01-4545-BDP-BDS-HCP-HCS-STG	19.31	15.63	16.73	15.44	-3.78	11.76	-2.86	13.21	10.16	6.48
01-4545-BDP-BDS-HBP-HBS-STG	10.83	7.15	8.25	6.96	-12.26	3.27	-11.35	4.73	1.68	-2.01
01-0000-BDP-BDS-NBP-NBS	30.50	26.81	27.91	26.62	-29.81	22.94	8.32	24.39	21.34	17.66

Figure 10: Example part of the Score-card

4.7.2.2 Step 2: Selection of the best performing vessels

As the amendment criterium will be applied to new vessels (as further explained in paragraph 4.9). The top five best performing reference vessels represent the 'best practice' currently available in the fleet. It was investigated to see if it was possible to develop a criterium where the best of the currently available vessels without any modifications, or with minor modifications, can comply with.

With the selection of the five vessels which are indicated in the table below, this could be accomplished. This is proven in paragraph 4.8. Furthermore, it is shown that worse performing vessels cannot or barely comply with the criteria, even with modifications, rendering these vessels and designs impossible to build anymore. This will cause a serious improvement in stability performance and therefore safety of the fishing fleet.

From the resulting score card from step 1, the five best performing vessels have been selected. Those are shown in Table 9.

Number	Name	Open/Closed Aftdeck	Moulded Breadth [m]	Gross Tonnage [GT]	Year of construction
3	EuroCutter 20m - v3	Open Aft deck	5.56	60	1983
6	EuroCutter 22m - v3	Closed Aft deck	6.00	92	1990
9	EuroCutter 24m - v2	Closed aft deck	6.85	154	2005
10	EuroCutter 24m - v3	Open Aft deck	5.58	69	1946
12	EuroCutter 24m - v5	Closed Aft deck	6.50	114	2015

Table 9: The five reference vessels featuring the best stability performance.

4.7.2.3 Step 3: Increasing the safety level

For the five best performing vessels, it was investigated what the values of the amendment criteria (the selected criteria from par. 4.7.1) should be in order to remove all the cases in which there is no stability (i.e. remaining righting moment) left. These are the red cases in Figure 10.

4.7.3 Resulting amendment stability criteria

The above-described process resulted in the criteria as shown in Table 10. These criteria are to be applied to the *Basic Fishing Condition.*

Resulting amendment stability criteria		
Maximum GZ-value	[m]	0.225
Area below GZ curve up to 30 degrees	[mrad]	0.0596
Area below GZ curve up to 40 degrees	[mrad]	0.0930
Area below GZ curve between 30 and 40 degrees	[mrad]	0.0273

Table 10: Resulting amendment criteria.

The proposed regulations text is found in paragraph 4.9. In the next paragraph, the feasibility and applicability of these new criteria are discussed.

4.8 Assessment of the amendment criteria

The amendment criteria have been assessed on practical feasibility and applicability. This is done in two steps:

1. Checking of the performance of the reference vessels and their compliance with the new criteria; which vessels already comply and to what extent? And why do they comply or do they not comply?
2. Investigation into a number of design variations and their effect on stability and the effect on compliance with the amendment criteria. If an existing vessel or design does not comply, are there feasible design variations possible with which such vessel or design can comply?

Both steps are described in detail in the next subparagraphs.

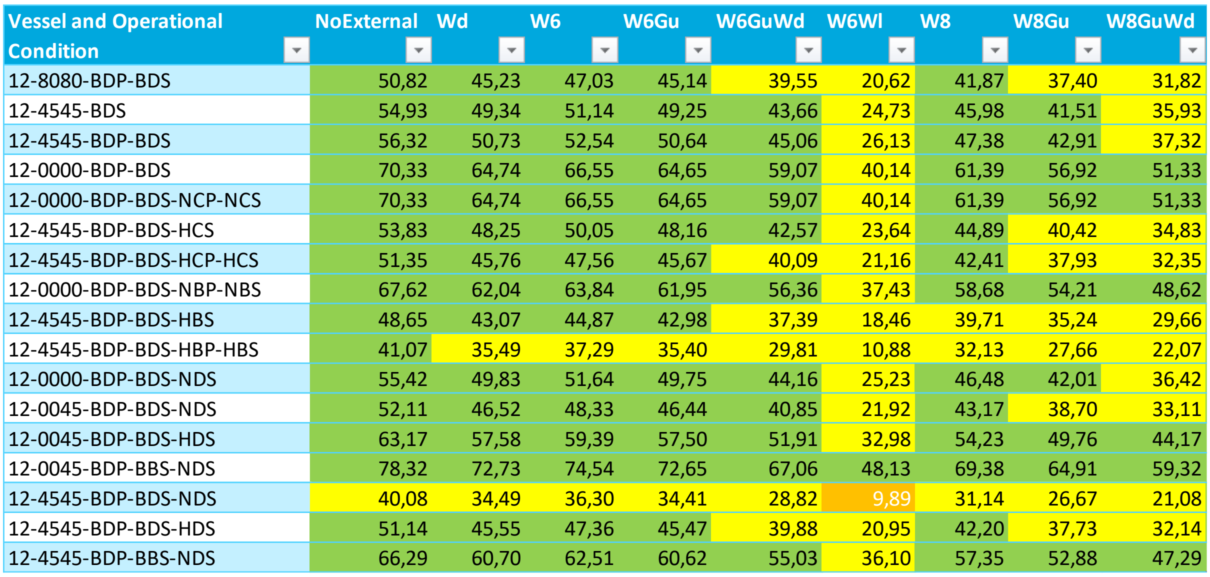
4.8.1 Compliance of the five best reference vessels

The *Basic Fishing Condition* of the original, unaltered (without increase of stability) five best performing reference vessels (as described in paragraph 4.7.2.2) have been checked against the amendment criteria. Table 11 shows which vessels comply with all criteria and which do not comply with one or more of the criteria.

Number	**Name**	**Complies with amendment criterium**			
		1 Max. GZ-value	**2 GZ-area φ<30°**	**3 GZ-area φ<40°**	**4 GZ-area 30°<φ<40°**
3	EuroCutter 20m – v3	No (90%)	Yes (125%)	Yes (110%)	No (95%)
6	EuroCutter 22m – v3	No (90%)	Yes (120%)	No (95%)	No (80%)
9	EuroCutter 24m - v2	No (80%)	Yes (103%)	No (90%)	No (95%)
10	EuroCutter 24m - v3	No (90%)	Yes (125%)	Yes (100%)	No (75%)
12	EuroCutter 24m - v5	Yes (145%)	Yes (170%)	Yes (160%)	Yes (190%)

Table 11: Compliance of five best reference vessels with amendment criteria. The percentages indicate how the vessel specific value is relative to the criterium value.

As can be seen, one reference vessel, which is, like all reference vessels, an existing vessel in service, does comply fully with the amendment criteria. This already indicates to a certain extent that the amendment criteria are feasible and realistic. For this vessel, the Score-card assessed for the amendment criteria is shown in Figure 11. As can be seen, there are no more situations without remaining righting moment (red).



Vessel and Operational Condition	NoExternal	Wd	W6	W6Gu	W6GuWd	W6Wl	W8	W8Gu	W8GuWd
12-8080-BDP-BDS	50,82	45,23	47,03	45,14	39,55	20,62	41,87	37,40	31,82
12-4545-BDS	54,93	49,34	51,14	49,25	43,66	24,73	45,98	41,51	35,93
12-4545-BDP-BDS	56,32	50,73	52,54	50,64	45,06	26,13	47,38	42,91	37,32
12-0000-BDP-BDS	70,33	64,74	66,55	64,65	59,07	40,14	61,39	56,92	51,33
12-0000-BDP-BDS-NCP-NCS	70,33	64,74	66,55	64,65	59,07	40,14	61,39	56,92	51,33
12-4545-BDP-BDS-HCS	53,83	48,25	50,05	48,16	42,57	23,64	44,89	40,42	34,83
12-4545-BDP-BDS-HCP-HCS	51,35	45,76	47,56	45,67	40,09	21,16	42,41	37,93	32,35
12-0000-BDP-BDS-NBP-NBS	67,62	62,04	63,84	61,95	56,36	37,43	58,68	54,21	48,62
12-4545-BDP-BDS-HBS	48,65	43,07	44,87	42,98	37,39	18,46	39,71	35,24	29,66
12-4545-BDP-BDS-HBP-HBS	41,07	35,49	37,29	35,40	29,81	10,88	32,13	27,66	22,07
12-0000-BDP-BDS-NDS	55,42	49,83	51,64	49,75	44,16	25,23	46,48	42,01	36,42
12-0045-BDP-BDS-NDS	52,11	46,52	48,33	46,44	40,85	21,92	43,17	38,70	33,11
12-0045-BDP-BDS-HDS	63,17	57,58	59,39	57,50	51,91	32,98	54,23	49,76	44,17
12-0045-BDP-BBS-NDS	78,32	72,73	74,54	72,65	67,06	48,13	69,38	64,91	59,32
12-4545-BDP-BDS-NDS	40,08	34,49	36,30	34,41	28,82	9,89	31,14	26,67	21,08
12-4545-BDP-BDS-HDS	51,14	45,55	47,36	45,47	39,88	20,95	42,20	37,73	32,14
12-4545-BDP-BBS-NDS	66,29	60,70	62,51	60,62	55,03	36,10	57,35	52,88	47,29

Figure 11: Score-card of the best performing vessel assessed for the amendment criteria

Regarding the other vessels: two of the vessels do not comply with 2 of 5 criteria and three vessels do not comply with 3 of 5 criteria. However, as can be seen from the percentages indicated (the level of compliance), the values are relatively close to the required values: the lowest percentage of compliance is around 75%. As an example, this has been visualized in Figure 12, which shows the compliance with the required Maximum GZ-value. This provides a strong indication that by applying small design alterations, these vessels (designs) can comply with all criteria. This has been investigated and is elaborated paragraph 4.8.3.

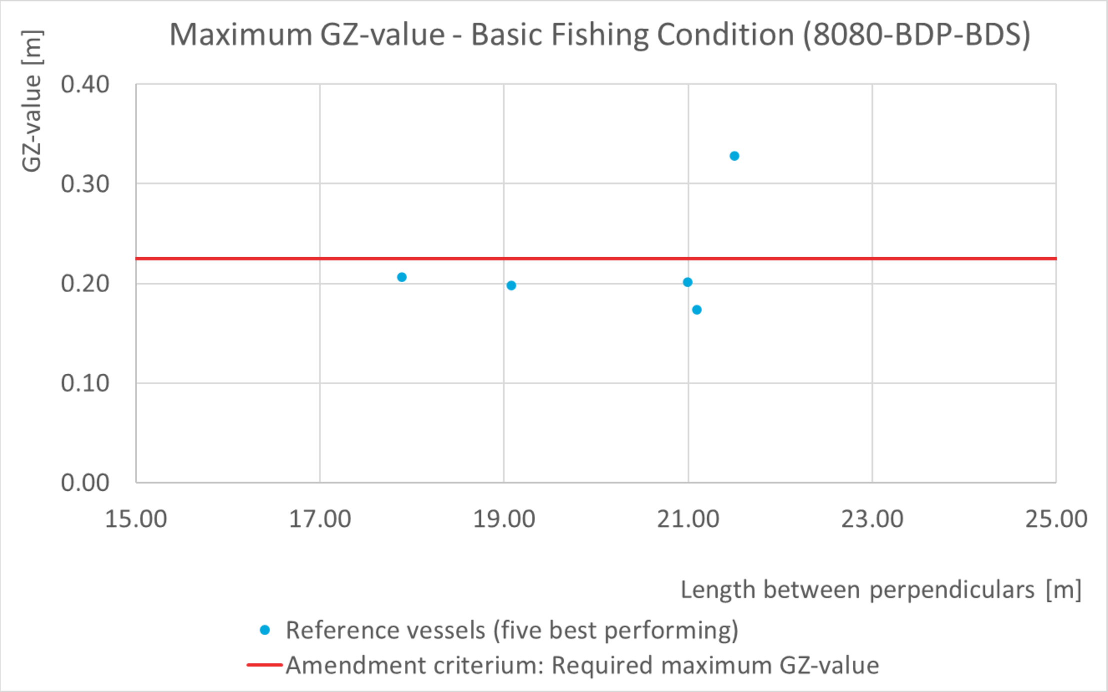


Figure 12: Compliance of reference fleet with amendment criterium: Required max. GZ-value

4.8.2 Compliance of the other reference vessels

As reference, the compliance has also been checked for the other reference vessels, to show the difference in compliance between the best vessels of the fleet and rest.

Number	Name	Complies with amendment criterium			
		1 Max. GZ-value	2 GZ-area φ<30°	3 GZ-area φ<40°	4 GZ-area 30°<φ<40°
1	EuroCutter 20m – v1	No (60%)	No (75%)	No (55%)	No (25%)
2	EuroCutter 20m – v2	No (60%)	No (80%)	No (65%)	No (50%)
4	EuroCutter 22m – v1	No (60%)	No (85%)	No (65%)	No (35%)
5	EuroCutter 22m – v2	No (55%)	No (75%)	No (60%)	No (40%)
7	EuroCutter 22m – v4	No (65%)	No (90%)	No (70%)	No (40%)
8	EuroCutter 24m – v1	No (80%)	Yes (110%)	No (90%)	No (60%)
11	EuroCutter 24m – v4	No (55%)	No (80%)	No (75%)	No (75%)
13	EuroCutter 24m – v6	No (75%)	No (95%)	No (90%)	No (95%)

Table 12: Compliance of the least performing reference vessels with amendment criteria. The percentages indicate how the vessel specific value is relative to the criterium value.

Comparing Table 12 with Table 11, it can be seen that almost all of the other vessels do not comply with even one of the criteria and that the level of compliance (percentages in the tables) is significantly lower than the five best performing vessels.

This provides strong evidence that a significant part of the current fleet cannot comply with the amendment criteria. This implies that it would be impossible to build new vessels according to those less safe designs, which will result in an increase of safer vessels in the future, when newly built vessels (or converted) vessels complying with the amendment criteria, are added to the fleet.

In the next paragraph, an example is given in which on two reference vessels design variations are applied to the existing design, to determine the effect on the stability performance. It was also assessed if it would be possible to comply with the amendment criteria with that design variation.

4.8.3 Design variations

A number of design variations has been developed. These are realistic design variations, such as adding a closed bulwark, which can all be applied on new designs, but also on existing vessels, to improve their stability performance and safety levels. In Appendix III, an overview of these design variations is given.

To get insight into the effects of these variations on the stability performance, each of the variations has been applied to one of the reference vessels. The effect on the GZ-curve has been picturized in Appendix III. An example is given in Figure 13.

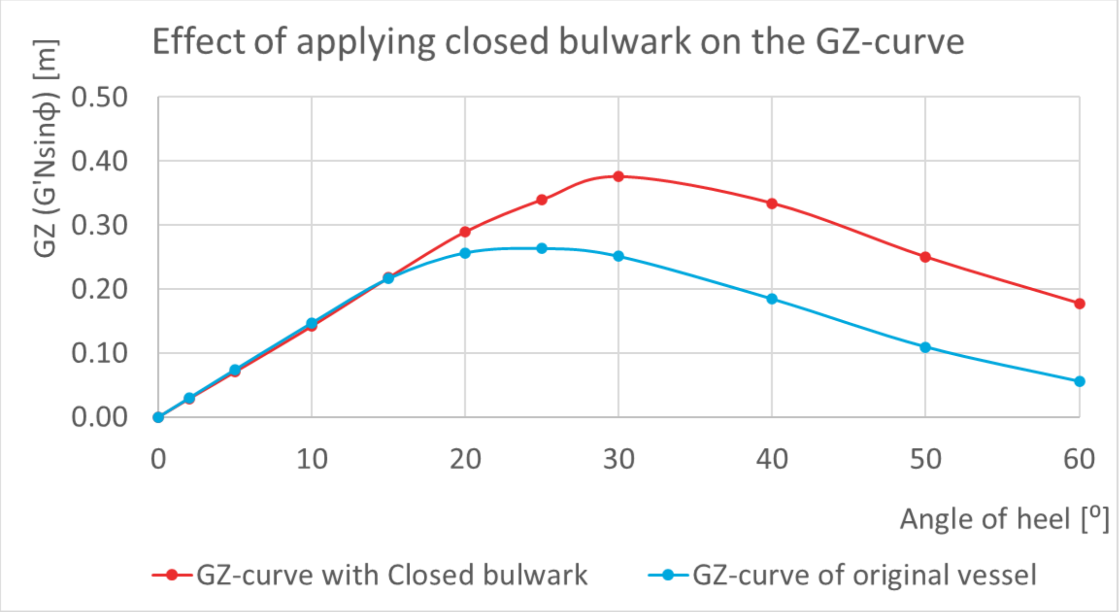


Figure 13: Effect of applying a closed bulwark on the GZ-curve.

One of the design variations, number 8, applying a closed bulwark (see Appendix III, Figure 40) has been applied to both one of the five best, but not complying, vessels (par. 4.8.1), and also to one of the worse performing vessels (par. 4.8.2).

With the closed bulwark applied to these vessels, they have been checked against the amendment criteria for the Basic Fishing Condition. The results are shown in Table 13.

Number	Name	Complies with amendment criterium			
		1 Max. GZ-value	2 GZ-area φ<30°	3 GZ-area φ<40°	4 GZ-area 30°<φ<40°
1a	EuroCutter 20m – v1 – Closed bulwark	No (90%)	No (85%)	No (85%)	Yes (105%)
9a	EuroCutter 24m - v2 – Closed bulwark	Yes (105%)	Yes (115%)	Yes (115%)	Yes (140%)
Original vessels, without modifications:					
1	EuroCutter 20m – v1	No (60%)	No (75%)	No (55%)	No (25%)
9	EuroCutter 24m - v2	No (80%)	Yes (103%)	No (90%)	No (95%)

Table 13: Compliance with amendment criteria of example design variations

As can be seen, one of the best performing vessels, number 9, will comply with all amendment criteria when it is fitted with a closed and buoyant bulwark. However, when the same is fitted on vessel number 1, the stability performance is significantly improved but this design is still complying with only one of four amendment criteria.

Furthermore, what stands out is that with this design variation, the GZ-area heeling angles between 30 and 40 degrees is increased significantly. This indicates that the amount of available stability is not only increased up to a heeling angle of 40 degrees, but also beyond a heeling angle of 40 degrees. This is considered to be important to mitigate the risks of asymmetrical loading.

4.9 Implementation of amendment criteria

Normally, new requirements only apply to new ships and ships undergoing a major conversion, unless the authorities decide otherwise in exceptional situations.

The requirements for beam trawlers < 24 meter are up to the flag state, so the Dutch flag state could implement the new requirements without consent of other flag states. However, to achieve a level playing field for the vessels under Dutch flag, it is recommended to synchronize the requirements with other flag states having beam trawlers, such as Belgium, Germany, UK and Ireland.

The proposal regulations text is found on the next page.

‘Seagoing fishing vessels up to 24 metres in length, engaged in beam trawling, must comply with the following:

In the Basic Fishing Condition the following criteria must be met:

1. *The maximum righting lever (GZ) should not be less than 0.225 metre;*
2. *The area under the righting lever curve (GZ-curve) up to* $\varphi = 30^0$ *should not be less than 0.060 metre-radians, and not less than 0.093 metre-radians up to* $\varphi = 40^0$*, or between* 30^0 *and the angle of flooding* φ_f*, if this angle is less than* 40^0*;*
3. *The area under the righting lever curve (GZ-curve) between* $\varphi = 30^0$ *and* $\varphi = 40^0$*, or between* 30^0 *and the angle of flooding* φ_f*, if this angle is less than* 40^0*, should not be less than 0.027 metre-radians.*

Application:

Unless expressly provided otherwise, the provisions apply to new vessels.

Definitions:

The angle of flooding φ_f *is the angle of heel at which openings in the hull, superstructure or deckhouses which cannot rapidly be closed watertight commence to immerse.*

Basic Fishing Condition:

- *50% consumables;*
- *100% catch in the hold;*
- *Derricks in store position or at 80 degrees, whichever is the highest position of the derricks in free sailing conditions;*
- *Both portside and starboard side beam trawl fishing gears, for the intended type of fishing operation, suspended from the fishing blocks at the outer end of the derricks.’*

5 Operational measures

A part of this research project was the development of an amendment to the existing stability criteria. Another part was to develop operational measures. Several other sets of regulations and criteria were observed, but the IMO rules for “Ships engaged in anchor handling operations” were deemed especially interesting to use as a starting point for new specific beam trawler operational measures that can be used during fishing operations, whereas the criteria discussed in chapter 4 are used for the design of the vessel.

This is because the anchor handling criteria are based around the operation of this vessel type, where the vertical and horizontal components of the tension on the (towing) wire generate a heeling moment on the vessel. In a very similar way forces in a fishing line of a beam trawler will act on the vessel.

The anchor handling rules were used as a starting point for the stability module for beam trawlers in PIAS, the Fishing-Module, which is intended to serve two purposes:

1. The Fishing-Module will be a design tool to determine maximum fishing gear weights for a given vessel, or the vessel’s stability for a given weight of the fishing gear. The output is intended to be a part of the stability information, comparable to the output of the anchor handling module in the stability booklet of anchor handling vessels;
2. For a specific vessel with specific weights of the fishing gear, the Fishing-Module can generate threshold values for maximum angles alpha and beta. In combination with the ship’s operational data that can be used for a real time warning system on board the vessel.

In chapter 5.1, the above mentioned applications of the Fishing-Module are shown. In chapters 5.2, 5.3 and 5.4, the existing anchor handling rules are explained and analyzed.

5.1 Practical applications

In chapter 5.1.1 the application of the Fishing Module is explained, and in chapter 5.1.2 As will be explained in the next chapters, the existing anchor handling criteria were analysed as is their use a base for the new Fishing-Module in PIAS. The output of the Fishing-Module can be used as threshold values for a warning system, that can be based on existing data management systems on-board.

5.1.1 ‘Fishing-Module’ in PIAS

Because the anchor handling module of PIAS has limitations for using it on beam trawlers, a new module should be created, once the criteria are fully developed and tested.

It should have the following functionalities:

Possibility to add more than one acting point on which the maximum allowable force can be calculated. It should work and look a bit like the crane module of PIAS: This tool is used for defining crane loads. Based on the predefined crane properties, the combined crane load and corresponding COG's are determined. In the fish module it defining the derrick properties should work the same way. With this functionality, it should be easier to define multiple acting points in different positions for different loading conditions.

It should give a designer a quick insight in the range of angles a concept can operate in safely with a given maximum pulling force. The designer can check if this range complies with the range the ship is designed for.

In a similar way to the dredging information or the anchor handling information, the output of the Fishing-Module can be made part of the required stability information in the stability booklet and as such be made available to the master.

For skippers the following chapter will explain how the generated output of this new module can be used while operating.

5.1.2 Operational measures

The output of the Fish-Module, can also be used as a safety / warning system on-board for the skippers. This can be done through a system like DBMatic. This system is already active on the entire Belgian fleet of beam trawlers. Because of this, it is used as an example. DBmatic translates the data being collected in Marelec system, navigational equipment and other machinery on-board and visualizes it in real-time on a dashboard:

GPS
Latitude dms: 49° 30' 32.82" N
Longitude dms: 5° 58' 36.63" W
Course over the ground: 92 ° (E)

Marelec D
Port Length: 304.00m
Starboard Length: 305.00m
Port Traction: 3900.00kg
Starboard Traction: 4100.00kg
Mode : Auto fishing

Main engine
Fuel consumption over the last hour: 157.87 l
Fuel consumption past 24 hours: 3788.83 l

Depth gauge
Depth below keel: 99.30 m
Depth below transducer: 101.10 m
Depth below waterline: 101.60 m

Weather station
Air temperature: 15.0°C
Barometric pressure: 994 mbar
True wind direction: 202.2 ° (SSW)
Wind speed: 7.9 m/s (4 bft)

Gyro comp
Heading: 79.1 °
Rate of turn: -1.3°/min

Gyro comp
Heading: 76.4 °
Rate of turn: -7.5°/min

Generator BB
Fuel consumption over the last hour: 14.60 l
Fuel consumption past 24 hours: 350.42l

Generator SB
Fuel consumption over the last hour: 0.39 l
Fuel consumption past 24 hours: 9.30l

Harbor set
Fuel consumption over the last hour: 0.00l
Fuel consumption past 24 hours: 0.00l

Main engine
Engine load: 97.5%
Turbocharger outlet temperature: 321.7°C
Run hours: 17901h

Figure 14: DBMatic system

The most important data collected through this system, is the force acting in the fishing lines. Angle ’β’ can be determined out of the water depth and fishing line length. Angle ‘α’ out of the difference between the course of the ship and the course of the fishing nets on the ground:

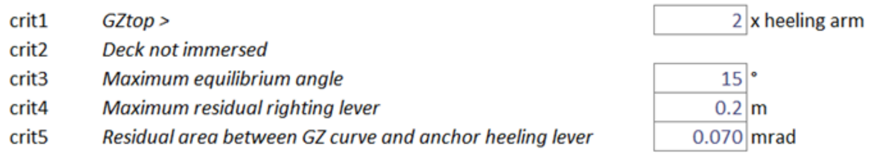
The warning system should be an addition to the existing data displayed on these kind of systems. It will show a maximum angle ‘α’ and ’β’ that’s still safe / permissible in combination with the forces acting in the fishing lines. 0 shows a few examples of permissible angles with different combinations of forces acting on the end of both derricks when positioned horizontally. These examples are from one of the beam trawlers out of the reference fleet. A box turns red when the heeling moment – resulting out of the corresponding angle combination and given forces - does not comply to the anchor handling criteria. The acting heeling moment is calculated according to the explanation given in 5.3.1.

With this range of permissible angles constantly changing with the differing forces acting in the fishing lines, the skippers can sail much more efficient. This is because they can use their ship to the limits of what's safe with every possible force in the fishing lines.

5.2 Anchor Handling rules

Anchor handling vessels are purpose built to have a large working deck that is located low above the water. They are equipped with powerful winches and strong propulsion installations. These factors combined makes the vessels able to create such a high moment (the result of their pulling power and the tension in the anchor/towing wire), that they can pull their own working deck into the water, resulting in loss of stability or even capsizing.

In order to stop capsizing, IMO developed regulations and criteria specifically for this ship type. (IMO IS-code 2008 – Part B – Chapter 2.7 Ships engaged in anchor handling operations) (IMO, 2008) In the regulations, the actual stability curve of the vessel (the black line in the graph below) is compared with the heeling moment curve which results from the pulling power of the vessel (the red line). Criteria are given for the vessel's own stability curve, height of the working deck above the water, and the area between the vessel's curve and the heeling moment curve.



crit1	*GZtop >*	2	x heeling arm
crit2	*Deck not immersed*		
crit3	*Maximum equilibrium angle*	15	°
crit4	*Maximum residual righting lever*	0.2	m
crit5	*Residual area between GZ curve and anchor heeling lever*	0.070	mrad

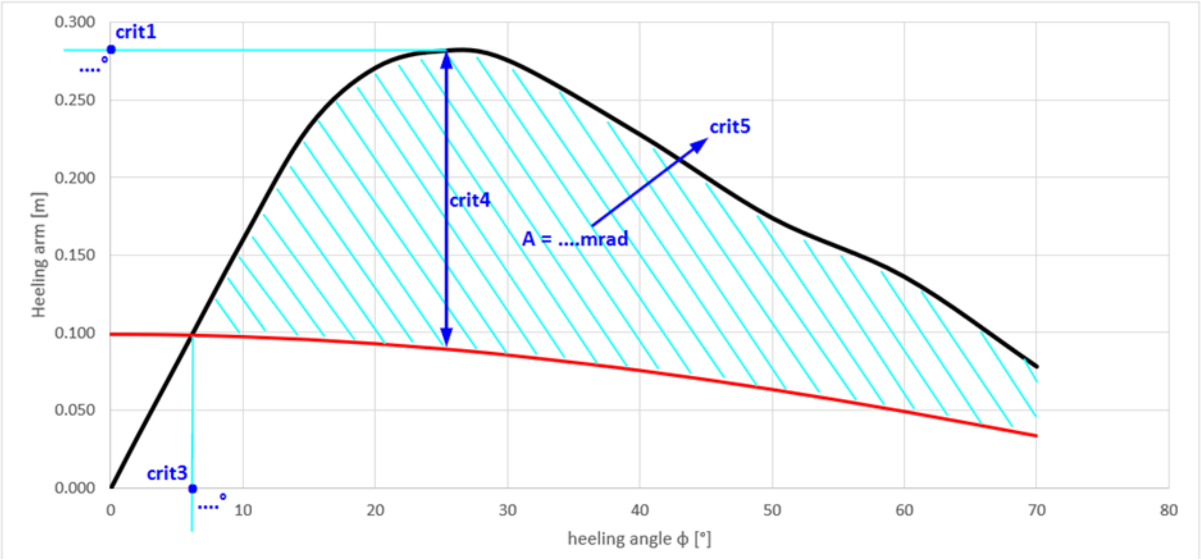


Figure 15: anchor handling criteria values

The anchor handling regulations & criteria would seem to be applicable on beam trawlers, albeit with some modifications. After all, like an anchor handler, a beam trawler has a low working deck, and has the possibility to create a heeling moment upon itself. For example, when the port- and starboard net are loaded unevenly, or when one of the nets gets stuck.

5.3 Applying anchor handling rules on fishing vessels

In the development of an adjusted version of the anchor handling rules, a start was made by analyzing the reference fleet using the existing anchor handler criteria. For this, the corresponding stability program module of PIAS is used.

5.3.1 Using the PIAS Maxchain module

As said, there is a module available in the stability program PIAS in which ships can be tested according to the anchor handling criteria described above. It works in an iterative way, where the force is being reduced until the created external moment complies to the stability criteria incorporated in the module. The force where all the criteria comply, is presented as permissible force Fb in the output.

The module consists of three parts:

‘’Hulldef’’ part:

hulldef is the part of PIAS in which the frames of a hullform and the main dimensions of the ship are defined. With the anchor handling option activated, an extra menu appears, in which the anchor handling vessel particulars can be defined. These particulars define the point on which the force of the single line acts.

For a beam trawler, the acting point of the force in the fishing line is the outer end of the derrick. Filling in an acting point outside maximum breadth of the vessel is not common in the anchor handling module. Therefore the specific anchor handling terms used in this input menu were filled in in such a way, that the end of one derrick on one side of a beam trawler is used as a fixed point on which the max allowable forces are calculated.

This means that this calculation only will give a valuable outcome when there is a difference in force between the starboard and portside. In this way, the calculated maximum permissible force shows the maximum possible difference in force between starboard and portside. Later in this report it is explained why this method isn’t fully correct, but because the module is as it is, there is no flexibility in changing the functions. Despite this inaccuracy, the results will already give an insight in the influence an external force in the fishing line will have on the ship’s stability.

‘’Loading’’ part:

Loading is the part of PIAS in which the loading conditions for a ship are tested to the selected criteria. With the anchor handling option activated, it is possible to calculate a maximum permissible force Fb, for the in Maxchain selected range of angles ‘α’ and ’β’ for each separate loading condition.

All the forces are visualised in a polar diagram as seen below:

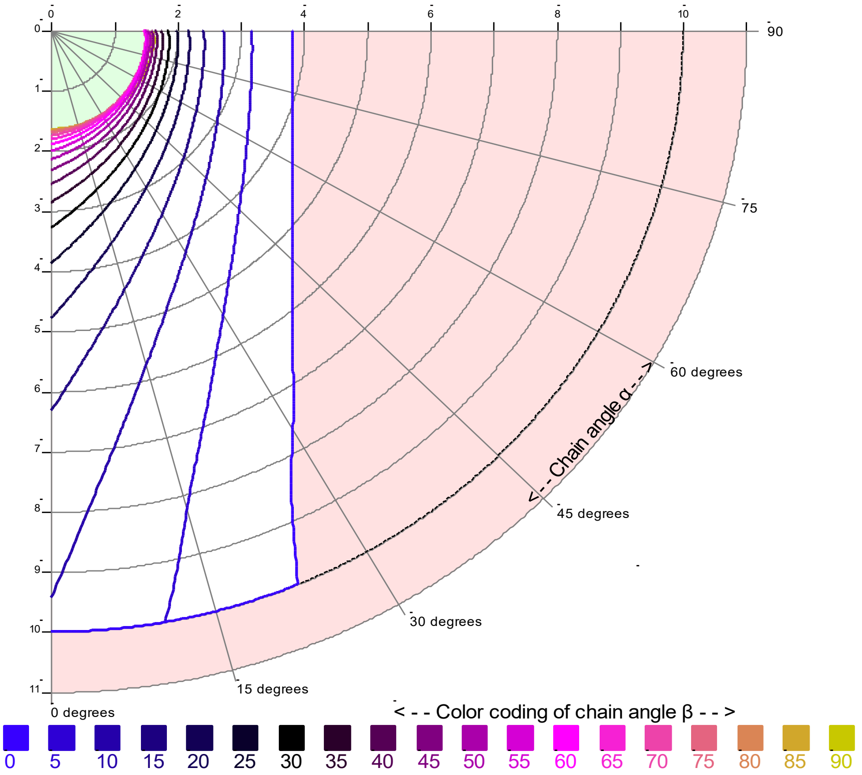
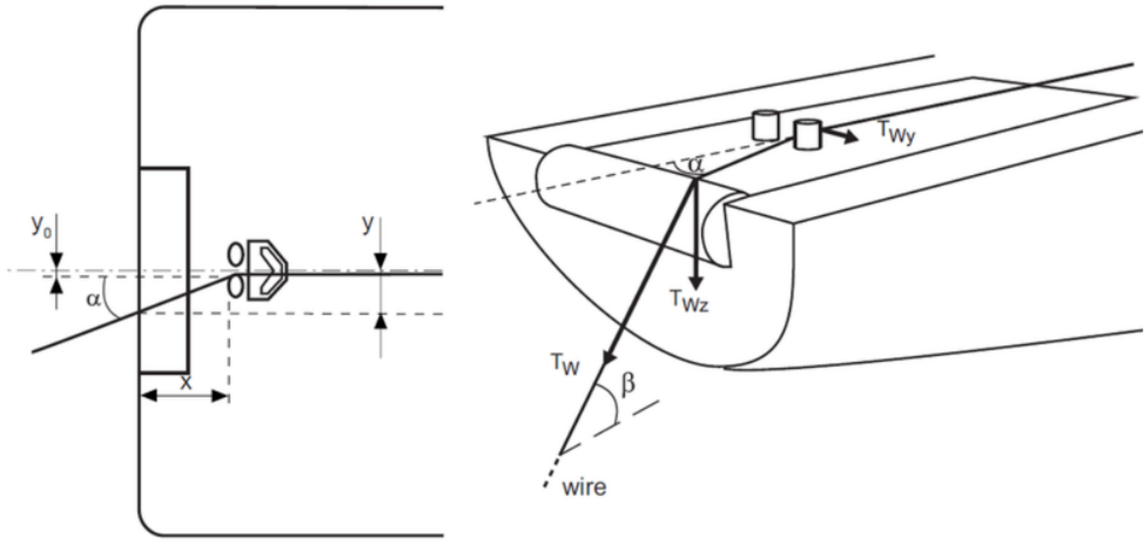


Figure 16: output of PIAS anchor handling module (Loading part)

In this way you can get an insight of the workable area of the ship in a specific loading condition

The angles ‘α’ and ’β’ are interpreted as shown in the figure below:



Definitions of angles, BV-2014 and IS-2020.

Figure 17: Anchor handling interpretation of angles 'β' and 'α'

’’Maxchain’’ part:

Maxchain is a separate module in PIAS, in which a user defined range of VCG’s, trims and displacements (comparable to a range of loading conditions), can be tested accorded to the anchor handling criteria. The output shows the maximum permissible force for every loading condition meeting the user defined range. The output is shown in a tabular format instead of a polar diagram. It’s also possible to generate tables for ach separate criterium. When this option is selected, a maximum force for each criterium is calculated. This gives insight in the most critical / determining criterium value.

5.3.2 Analysing output results

Because its limitations for the application on beam trawlers (discussed in 5.2.3), the use of the anchor handling criteria (IMO, 2008) for beam trawlers had to be validated. To do this, the beam trawler reference fleet was tested according to the anchor handling criteria used by the PIAS Maxchain module.

The validation focusses on the influence of each separate criterium value on the resulting allowed pulling forces and their directions. Every ship in the reference fleet was tested in two conditions (derricks horizontal and at 45 degrees) according to the anchor handling criteria. The minimum remaining righting lever of 0.200 meter proved to be the most critical criterium in most conditions, as can be seen in Figure 18. Further investigation in this value should be done. This will be explained in chapter 5.4.2.

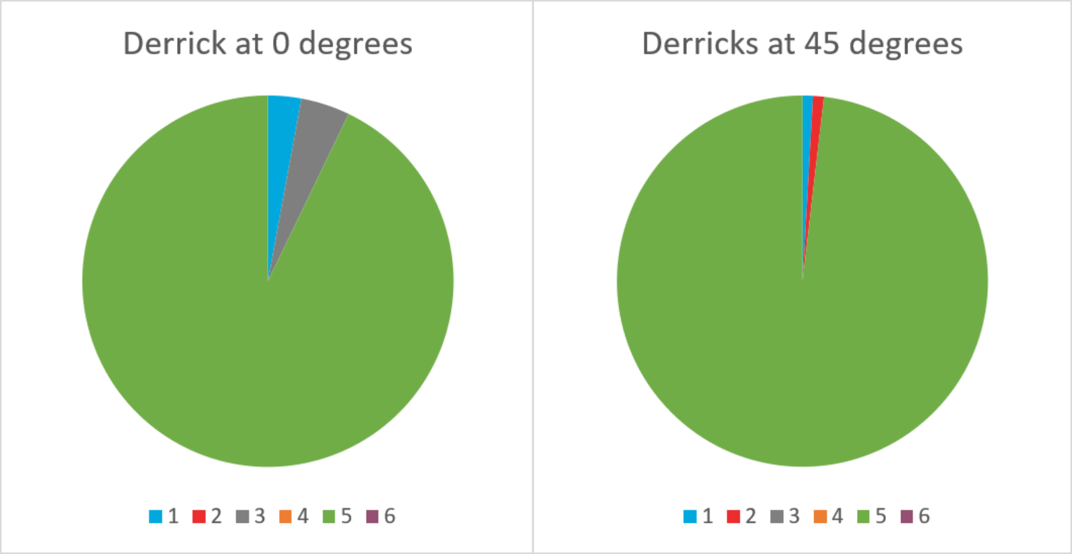


Figure 18: Distribution of most critical anchor handling criteria value

Legend	criteria	0	45
1	Max force complies	2.9%	0.9%
2	GZ-top > 2 x heeling arm @ equilibrium angle	0.0%	0.9%
3	Deck not immersed	4.3%	0.0%
4	Maximum equilibrium angle 15	0.0%	0.0%
5	Maximum residual righting lever > 0.200m	92.8%	98.1%
6	Residual area between GZ-curve and anchor heeling lever > 0.070 mrad	0.0%	0.0%

Table 14: distribution of most critical anchor handling criteria value

5.3.3 Limitation of Anchor handling Module in PIAS

A few concessions have been made to make the anchor handling module workable for a beam trawler. These concessions are caused by some limitations of the module and the anchor handling rules itself:

It's only possible to calculate one force acting in one single point. With beam trawlers, a second force acting on the other side is also causing a moment, even when the forces in both lines are the same. In the next chapter this will further be explained.

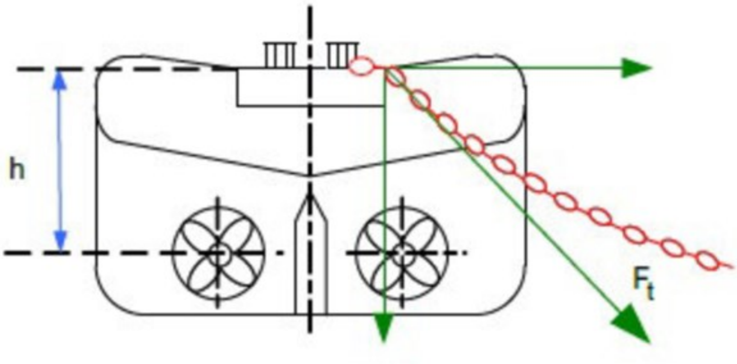


Figure 19: input limitation anchor handling module

It is not possible to have different acting points for different loading conditions. For example: if you want to change the angle of the derrick and with this the coordinates of the acting point, you need to do separate calculations because you have to change the input values in hulldef in between. Because a derrick is used in different angles - sometimes also in fishing conditions – throughout different loading conditions, it should be easier to adjust this.

In the anchor handling rules, the maximum y-position of the acting point is limited by the breadth of the ship. This is also taken into account in the way the PIAS module is programmed, so it is not possible to choose an acting point far outside the ship. In a fishing condition, the acting point is always far outside the ship, at the end of the derrick, so this limitation should be ignored.

For designing a realistic criterium for beam trawlers, it is necessary to be able to adjust the criteria values. Because these values are now closed off, it's not possible.

5.4 Required adjustments to come to Fishing-Module

Now that the anchor handling rules and the corresponding module of PIAS are fully tested, the needed adjustment to both can be investigated.

5.4.1 Adjusted heeling moment

In the calculations the assumption was made that the difference between the force in the starboard and portside fishing line was the only force that caused the external moment (M_{AH}) on which the criteria are tested. The sketch shown below shows, that this isn't the case:

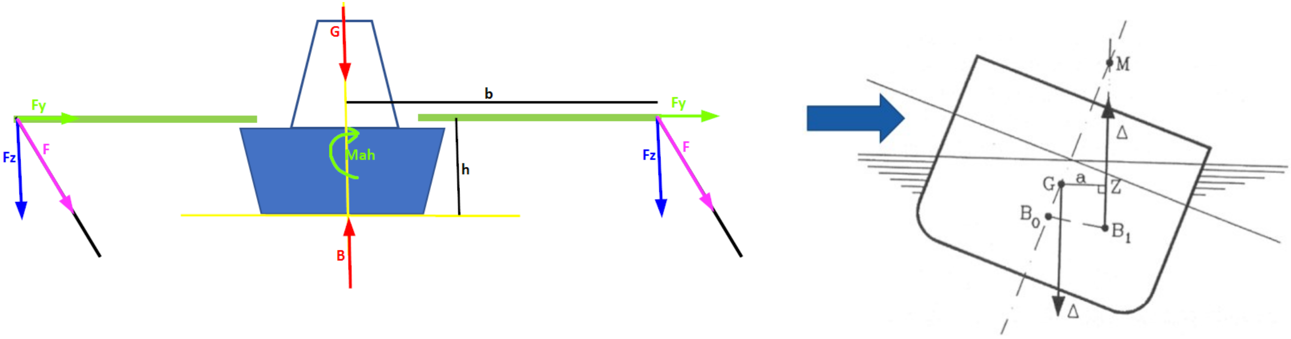


Figure 20: Acting moments and forces on a beam trawler

In the sketch is visible that even with a symmetric force acting on both ends, the y-component of the force on both sides in the fishing lines causes a heeling moment. What also should not be forgotten, is that the z-component of both sides causes an increase in displacement. This causes a slight change of the GZ-curve, which means the hydrostatic transverse stability of the ship also changes.

With this new forces included, the way the moment M_{AH} is calculates is adjusted from:

$$M_{AH} = F_p \times (h \sin \alpha \times \cos \beta + y \times \sin \beta);$$

To:

$$\sum M_{CoG(yz)} = F_{BB} * (b * \sin(\text{ß}) + (h - VCG) * \cos(\text{ß}) * \sin(\alpha)) - F_{SB} * (b * \sin(\text{ß}) - (h - VCG) * \cos(\text{ß}) * \sin(\alpha))$$

With the assumption that:

- The heeling moments act around the centre of gravity
- Starboard side = positive x-direction
- a positive angle α means a force facing starboard
- a positive angle β means a force facing down (facing in a negative z-direction)
- $\alpha = \alpha_{SB} = \alpha_{PS}$
- $\beta = \beta_{SB} = \beta_{PS}$
- α => 0
- β => 0

The possibility to have a difference between the angles α and β and a force facing portside can be considered in a next study because:

- Adding the possibility to have a difference will make the variety of angle combinations unnecessarily complex.
- Adding the possibility to have forces facing portside will not change anything to results in this study, because the hull form is symmetric.

The newly created moment will be used in the same way as it did in the original anchor handling criteria: it is drawn as a cosinus function of the heeling angle φ.

5.4.2 Validation of Fish-Module output

In the previous chapters, it is already explained how the new criteria values are based on a Score-card. Because the anchor handling criteria are made for a specific type of ship, these values are probably also based on specific situations for anchor handling vessels. To make these values more fitting for beam trawlers, they should be tested according to specific situations for beam trawlers, while fishing. This testing should be done with data collected from beam trawlers through systems like DBmatic. The following particulars are important to test the criteria values in the right way:

- Angle ‘α’ : difference between ground course of the nets and course of the ships?
- Angle ’β’ : can be calculated when water depth and fishing line length are known
- Forces in both fishing lines
- Heeling angle

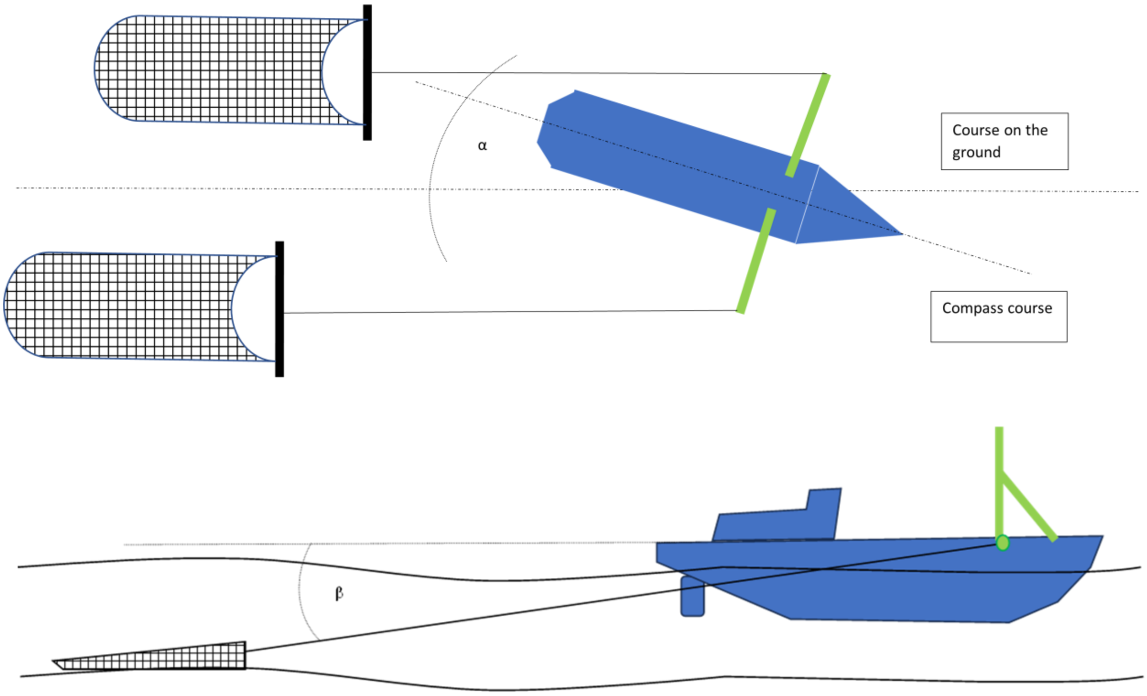


Figure 21: interpretation of angles 'α' and 'β' for beam trawlers

With enough of this data available, it can be concluded which angles ‘α’ and ’β’ and forces really occur during fishing operation. This conclusion can have two different outcomes:

The current anchor handling criteria are:

- Not strict enough, which means that the by the rules given maximum allowable forces are to big: this can be concluded through the collected data when the forces on certain angle combinations of angles ‘α’ and ’β’ never exceed the value given through the rules.
- Too strict, which means that the by the rules given maximum allowable forces are to small: this can be concluded through the collected data when the forces on certain angle combinations of angles ‘α’ and ’β’ regularly exceed values given by the rules.

Within this research, there was not enough time to collect this data of a wide enough spectrum of ships. More will be explained in the recommendations chapter.

6 Improving the understanding of stability

During the previous project on the stability of beam trawlers (Conoship International, 2022) it was concluded that there was a significant gap between the available stability information and the understanding of it by the crew of beam trawlers.

The human factor has a significant role in the stability and safety of the beam trawlers. Improving the understanding of stability will immediately improve the safety of the vessels. Especially because there is a large fleet of existing vessels, that cannot be required to comply with a new stability requirement to improve the safety, this is a very important topic.

A new approach is needed to improve the understanding of stability. This approach should consist of two parts:

1. Development of teaching materials on stability at the fishery schools, which include more practical elements, such as large scale models of beam trawlers;
2. Use of simulators of beam trawlers for training.

In the next chapters both parts of the approach will be explained.

6.1 Development of teaching materials on stability

Stability calculations are complex and theoretical and interviews with teachers of fishery schools learned that students at the MBO 2-level, being trained to be skipper at a beam trawler < 24 m, are struggling hard to pass the tests on this subject. As a result, once they have passed the test, they tend to never look at stability calculations again. They are used to a more practical approach: working with their hands suits them more than performing complicated calculations.

Dedicated teaching material for beam trawlers is being developed by ProSea, to instruct the students of the fishery schools on stability. In the material an illustration of a beam trawler model is used, instead of the more commonly used illustration of a merchant vessel, enabling the students of the fishery schools to identify themselves with it. Figure 22 shows an example of a GZ-curve, as it is depicted in the teaching material.

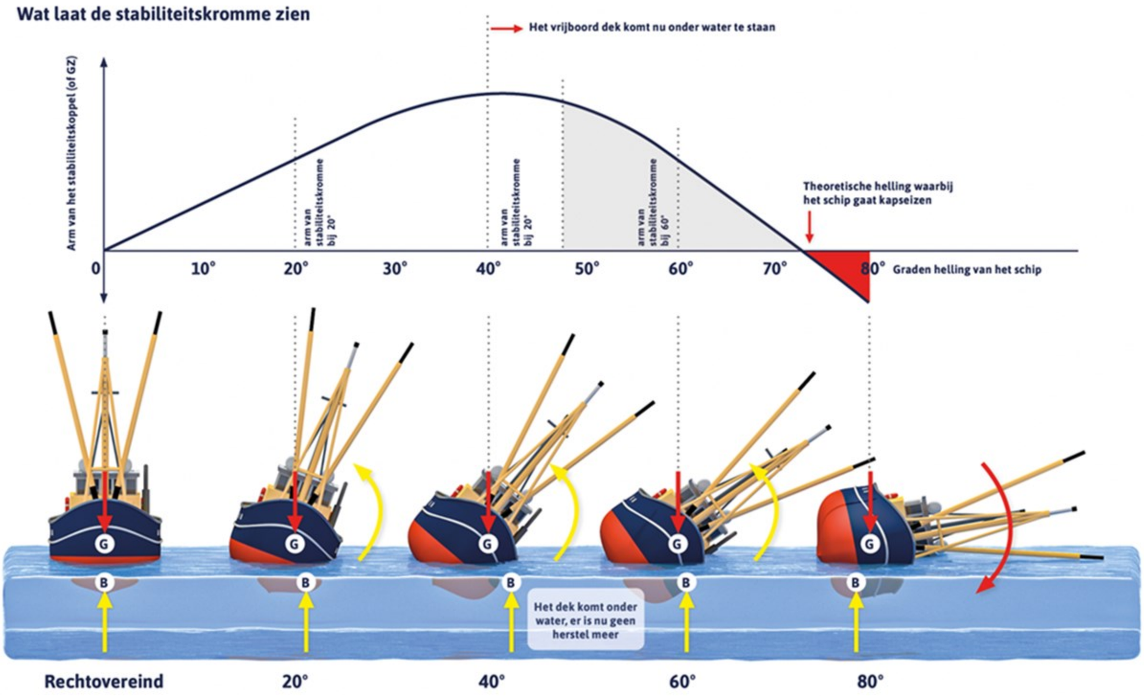


Figure 22: Example of the dedicated teaching material for beam trawlers

Using this information and practical demonstration with models etc. will let the students get acquainted with the influence of the loads in the derricks on the stability of the vessel. Already, many training institutions use models in a water basin to demonstrate the effects of weight changes on the stability.

In addition a large scale model, the size of a rowing boat, can be used for practical instruction in the harbor. During this instruction students can experience the capsizing of the model due to asymmetrical loads and fall in the water themselves. This will be a lifetime experience, that will help to learn the effects of asymmetrical loads.

The curriculum can be concluded with an exam on stability, set up as a risk assessment. Since they will be asked to do many risk assessments in their professional career, they will get acquainted with the terms and principles of such an assessment as well.

6.2 Use of simulators for training

Bridge simulators are widely used for training of both students and seafarers, for navigating mostly merchant vessels and the use of navigation equipment. Students and trainees learn to use the equipment and navigate, but also to cope with difficulties like the effects of wind, current, limited visibility and failure of navigation equipment.

The number of simulation models of beam trawlers however, is very limited. At this moment there are only two fully functional simulators of beam trawlers: the 24 m beam trawler simulator at the Maritime Research Institute Netherlands (MARIN) at Wageningen and the 40 m beam trawler simulator at the Vlaamse Dienst voor Arbeidsbemiddeling en Beroepsopleiding (VDAB) at Zeebrugge. With these two models trainees not only use to navigate, but they also learn to learn fishing operations with the beam trawler, like handling the derricks and fishing gear.

The simulator at MARIN provides a very realistic experience of fishing with a 24 meter beam trawler, because the bridge is mounted on a hexapod. This allows the trainee to feel the ship's motions and actually experience heeling angles.

The VDAB-simulator at Zeebrugge includes a full mock-up of the bridge of a 40 m beam trawler, including the controls of winches and derricks. This simulator can be used for training of the fishing operations and their special requirements, and even allows the trainees to experience a full capsize under realistic circumstances. (Figure 23)

Figure 23: The beam trawler simulator at VDAB during capsizing of the vessel

During the writing of this report the MARIN-simulator was not yet ready to simulate a capsize, but that is only a matter of time. Then both simulators together give the fishery schools a wide range of possibilities for realistic training situations.

Training with the simulators will be a valuable addition to the theoretical training materials. Not only will they be able to experience the effects of the fishing gear on the stability, they will also be able to train various situations during fishing operations and their difficulties under the supervision of an experienced fisherman. This way they are able to make mistakes, without the dangerous consequences of the real life situation.

6.3 Use of simulators for accreditation

For Belgium seafarers additional training of various aspects of their work is mandatory at the 5-yearly renewal of their certificate of competency. In the Netherlands this is not mandatory, but a simulator training could be made mandatory at the renewal of a the certificate. Experience gained during simulator training is a welcome addition for the seafarer.

7 Other operational improvements

During this research several potential improvements for safety were observed, apart from the main questions of the research. In this chapter they are described.

7.1 Stowage of safety equipment

Investigation of the reports of the capsizing of beam trawlers learn that these vessels capsized very fast. The life raft and the *Emergency Position Indicating Radio Beacon* (EPIRB) are equipped with a hydrostatic release unit, to free them from the vessel in emergency situations. From the accident reports it became clear that on several occasions the EPIRB and the life raft got stuck under the deck under water as a result of the rapid capsizing and thus were of no use to the crew.

Figure 24: Hydrostatic release unit

A solution to this problem would be to install two life rafts with 100% capacity and two EPIRB’s, one at portside and one at starboard side. For beam trawlers under Belgian flag this already is a requirement.

7.2 Inclining test requirements

During the inclining test many variables such as position of the gear and derricks need to be recorded. By laying down a standard procedure for beam trawlers, ILT can improve the quality of the inclining tests.

7.3 Reducing the risk of derrick flipping to other side

Sometimes, one of the fishing gears is drawn to the other side of the vessel. This happened with UK-171 Spes Salutis, resulting in the fishing line flipping over the aft side of her deck and finally her capsizing.

The derricks are normally suspended in their hoisting lines, kept in position by the weight of the fishing gear. However, in the situation where one fishing gear goes over to the other side of the vessel, the derrick finally will go to upright position and flip over to the other side. This leads to an uncontrolled situation, that induces even more heeling moment on the vessel.

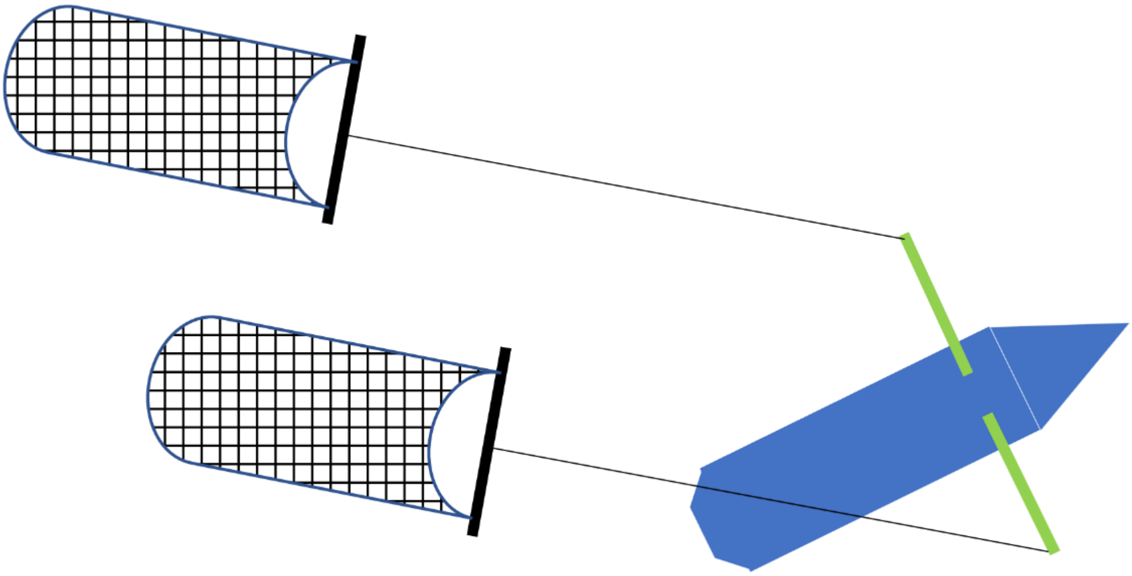


Figure 25: Fishing gear being drawn to the other side of the vessel

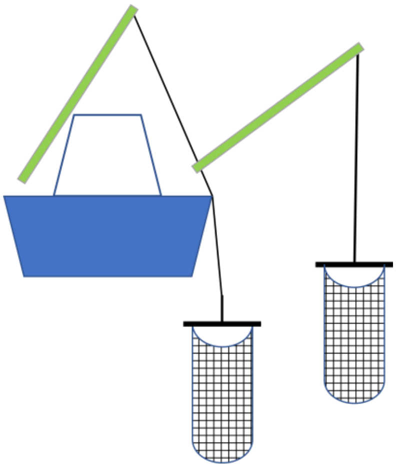


Figure 26: Derrick flipping over to the other side

To prevent this, a stopper could be fitted on the mast or the derrick, preventing the derrick to be topped up more than 90 degrees, thus preventing it from flipping over.

8 Conclusions

The research assignment was: ‘To develop a combination of proposals for measures to reduce the risk of capsizing of beam trawlers, with a focus on vessels < 24 m. Proposals must include:

- An amendment to the existing statutory stability criteria;
- One or more operational measures;
- One or more measures to improve of the crew’s understanding of stability of the vessel.

The combination must include one additional criterium for the beam trawler during fishing operations, in addition to the existing criteria for fishing vessels. The criterium could be based on chapter 2.9 of the IMO Intact Stability Code 2008, part B (ships engaged in lifting operations).

The impact of the stability criterium on the safety level and the design of a beam trawler must be investigated using design studies.

In the following chapters the conclusions are given.

8.1 Proposed amendment to the existing statutory stability criteria

The aim was to design a criterium for a beam trawler based on a fishing condition, that would increase the safety of the vessel. The first step was to define a reference condition of a beam trawler, the basic fishing condition (Chapter 4.4). Based on this condition, for each reference vessel the Score-card was made, showing the remaining righting moments of the vessel under various conditions (Chapter 4.7), that were verified as being practical and legal. These scores represent the performance of the vessels, that are in line with the safety level of the existing statutory stability criteria. The red in the Score-card indicates that there is no remaining righting moment in that particular situation.

Then an extra margin was introduced on top of the existing safety level, resulting in higher scores on the Score-card. The stability performance of the five best beam trawlers was used to determine the new stability criterium, resulting in a Score-card without red situations.

The proposed amendment to the statutory criteria applicable to the Basic Fishing Condition (Chapter 4.4) is:

‘Seagoing fishing vessels up to 24 metres in length, engaged in beam trawling, must comply with the following:

In the Basic Fishing Condition the following criteria must be met:

4. *The maximum righting lever (GZ) should not be less than 0.225 metre;*
5. *The area under the righting lever curve (GZ-curve) up to* $\varphi = 30^0$ *should not be less than 0.060 metre-radians, and not less than 0.093 metre-radians up to* $\varphi = 40^0$*, or between* 30^0 *and the angle of flooding* φ_f*, if this angle is less than* 40^0*;*
6. *The area under the righting lever curve (GZ-curve) between* $\varphi = 30^0$ *and* $\varphi = 40^0$*, or between* 30^0 *and the angle of flooding* φ_f*, if this angle is less than* 40^0*, should not be less than 0.027 metre-radians.*

Application:
Unless expressly provided otherwise, the provisions apply to new vessels.

Definitions:
The angle of flooding φ_f *is the angle of heel at which openings in the hull, superstructure or deckhouses which cannot rapidly be closed watertight commence to immerse.*

Basic Fishing Condition:

- *50% consumables;*
- *100% catch in the hold;*
- *Derricks in store position or at 80 degrees, whichever is the highest position of the derricks in free sailing conditions;*
- *Both portside and starboard side beam trawl fishing gears, for the intended type of fishing operation, suspended from the fishing blocks at the outer end of the derricks.’*

For new Dutch flag beam trawlers and Dutch flag vessels undergoing major conversion these criteria can apply, preferably together with other flag states having beam trawlers. Similar to vessels engaged in anchor handling, or dredging the outcome of this criterium should be entered as a separate condition in the stability booklet.

The existing fleet however, does not benefit from this method to improve the safety. Therefore Operational measures have been investigated also, as described in chapter 8.2.

8.2 Proposed operational measures

During operation of a beam trawler the vessel encounters heeling moments on the vessel due to the pulling forces in the fishing lines, induced by the fishing gear, acting at the outer ends of the derricks. To enhance the safety of beam trawlers during operation a better insight in the effect of these forces on the vessel during fishing is crucial.

To determine the magnitude of these forces and permissible combinations of magnitude and direction, the approach of the anchor handling rules (IMO, 2008) and the anchor handling module of the stability calculation program PIAS were used. Based on data received from fishermen, the pulling forces in the fishing lines were analysed, including magnitude and direction of these forces. Figure 27 shows the schematics of these forces. The heeling moments induced by these forces were checked checked against the stability requirements (Chapter 5).

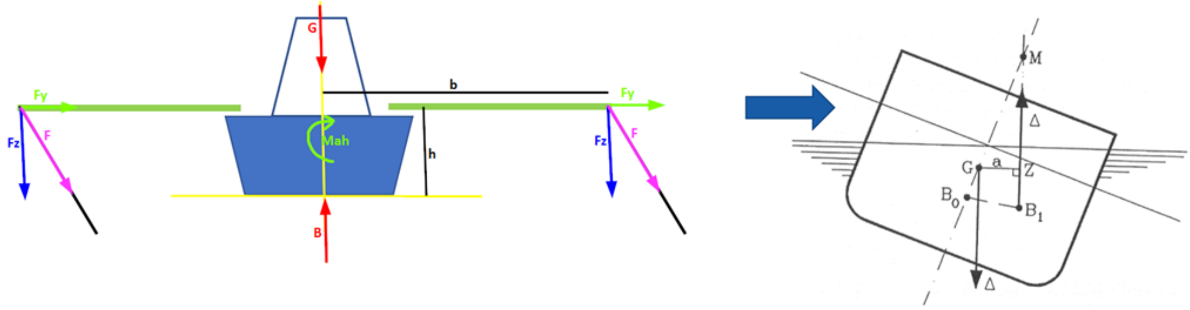


Figure 27: Forces induced by the fishing lines acting on a beam trawler

From the analysis the following conclusions were drawn:

- The anchor handling rules take only the force of one anchor chain in account, whereas the beam trawler experiences the effects of two forces, one from each fishing gear. The difference can be seen in Figure 27 and Figure 28.

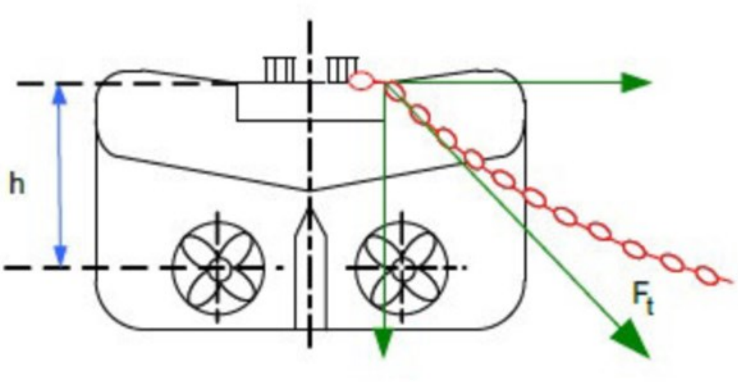


Figure 28: Forces acting on an anchor handling vessel

- The anchor handling module in PIAS is not suitable to calculate the effects of two gears, because it doesn't take the resulting side forces (the green vectors in Figure 27). This means the Fishing-Module must be developed, as described in Chapter 5.1.1.

A calculation sheet was made, which calculated the heeling forces induced by the combination of the pulling forces and their directions. It takes into account all effects of both pulling forces of the fishing gear on the beam trawler. This forms the base for the Fishing-Module, that has to be developed.

The pulling forces of the gear were used as input for this sheet. The output was a set of threshold values for maximum angles α and β (Figure 29) for a beam trawler for given pulling forces in the fishing lines, based on the stability requirements.

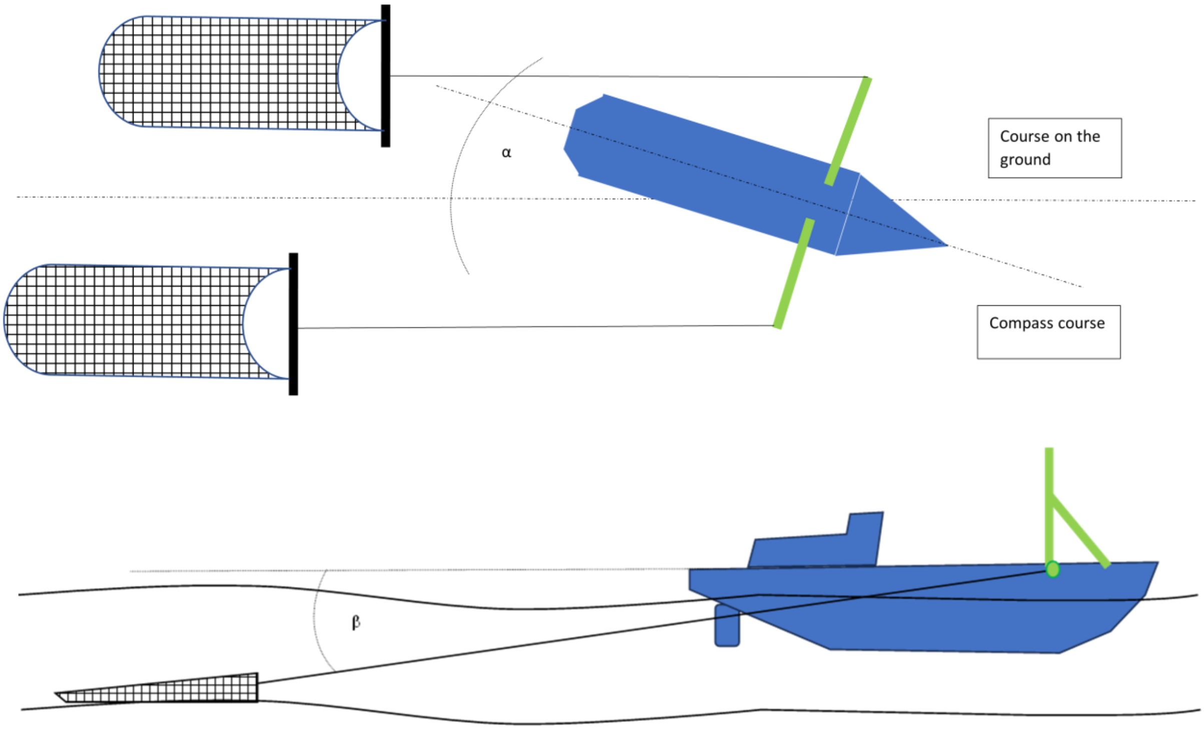


Figure 29: Alpha and beta angle for a beam trawler

The value for alpha can be derived from the difference between the compass course and the course over the ground. Since both values can be obtained from the navigation equipment, the value for alpha can be determined at every moment.

The value for beta can be derived from the length of the fishing line and the water depth, which are also constantly monitored.

This means that a warning system can be set up, which gives an audible warning when the combination of the pulling forces and pulling direction leads to a heeling force on the beam trawler, that nears the threshold value. This will be a valuable safety feature, that gives real time insight in the heeling moments induced by the fishing gear.

An existing system that could handle this feature is DBMatic, a system that in real time gathers all data on board of a beam trawler, such as navigational data, engine power, pulling forces in the fishing lines and length of fishing line. This system has already been installed on over 40 beam trawlers, helping to make the operation more effective, so adding this safety feature will be relatively cost-friendly.

8.3 Improving the understanding of stability

The human factor plays a big role in the safety of ships and beam trawlers in particular. Training is crucial to improve the understanding of stability by the crew. In our research we came to the following conclusions:

- A shift is needed from the theoretical approach of a stability calculation to a more general knowledge of the risks of asymmetrical loads and influence of the position of derricks and fishing gear on the stability. A very practical approach, using small scale models in a basin and large scale models of a beam trawler in the harbour, to let the students experience the effects of shifting gear and derricks, will have a positive effect on safety.

  Already, risk assessments have to be carried out by the crew, but they are focussed on safety and health of the crew. Adding risks involving stability and incorporating the risk assessment in the training will help to improve the awareness for stability of stability.

- The Maritime Research Institute Netherlands (MARIN) at Wageningen possesses a simulator model of a 24 meter beam trawler, with a moving bridge. That is a very realistic model for training students and crew.
- The Vlaamse Dienst voor Arbeidsbemiddeling en Beroepsopleiding (VDAB) at Zeebrugge possesses a simulator of a 40 m beam trawler, that is able to simulate a full capsize. This provides a very realistic experience of what can go wrong (Figure 30).

Figure 30: Capsizing of a beam trawler in the simulator of VDAB

9 Recommendations

During the research we found some subjects that need to be further investigated or developed. This chapter will describe them.

9.1 Verification of the Score-card

The Score-card, described in chapter 4.7.2, is based on static stability calculations. The dynamic effects of a beam trawler under these conditions could not be calculated. Verification of at least some of the conditions on the Score-card using model testing at MARIN is recommended.

9.2 Investigation dynamic effects waves

The dynamic effects of waves, both longitudinal and transverse, including the dynamic effects of the immersed fishing gear, have significant effect on the stability of beam trawlers. However, this could not be fully assessed using the calculation tools available to Conoship. Static stability calculations are of limited use for these calculations. It is recommended that further investigation is carried out with model tests by MARIN or calculation methods that can fully address the described dynamic effects.

9.3 Verification of the MARIN simulation model

During a visit at MARIN the simulation model was discussed. Although very realistic, especially because of the hexapod used, simulating a capsize was not (yet) possible. The data gathered during this research can help to calibrate the model. We recommend to investigate the possibilities for doing this.

9.4 International implementation of the stability amendment

When the amendment is put into force for new beam trawlers under Dutch flag, it is recommended to implement it also in other countries having beam trawlers in their fleet, to ensure a level playing field.

9.5 Development of the Fishing-Module in PIAS

During the research project it became clear that the anchor handling module is not suitable for the calculation of the effect of two instead of one pulling force on the vessel. E.g.: For the anchor handling module, the acting point of the chain force cannot be entered outside the maximum breadth of the vessel. To be able to enter the acting point of the fishing lines at the outer end of both derricks, adaptations must be made to the input-form of the module.

Because an anchor handling vessel experiences only one pulling force, the module doesn't take into account the combined effect of two forces at $\alpha > 0$.

To develop the Fish-Module in PIAS, follow-up research is recommended to be done by SARC, the developer of PIAS. Once completed, the output of the Fishing-Module should be included in the stability booklet, as the anchor handling module is for anchor handling vessels.

9.6 Implementing the Fishing-Module in a warning system

Since the foreseen Fishing-Module will give threshold values for the combination of permissible pulling forces and their directions in the fishing lines, these values can be used to set up a warning system for the skipper, as described in Chapter 8.2, that warns the skipper when these values reach a preset danger level. Development of this warning system is recommended, possibly together with DBMatic, the company that has a running software system installed on over 40 beam trawlers, that handles input data from navigation and fishery equipment.

9.7 Include simulators in mandatory crew training

The use of the simulators of beam trawlers for training of students and crew of beam trawlers offers valuable experience, as described in Chapter 6.2. It is recommended to include a requirement for training on these simulators in the curriculum.

9.8 Reconsidering the number and location of life raft and EPIRB

As explained in Chapter 7.1, the rapid capsizing of beam trawlers require a special approach for the life raft and *Emergency Position Indicating Radio Beacon* (EPIRB). This safety equipment is intended to float free when the hydrostatic release unit is immersed. However, in several accidents the life raft and / or the EPIRB were trapped under the deck and were of no use to the crew. Two life rafts of 100% capacity and two EPIRB’s, one at starboard and one at portside of the vessel, make sure that at least one of each can float free in case of a (rapid) capsize.

10 Bibliography

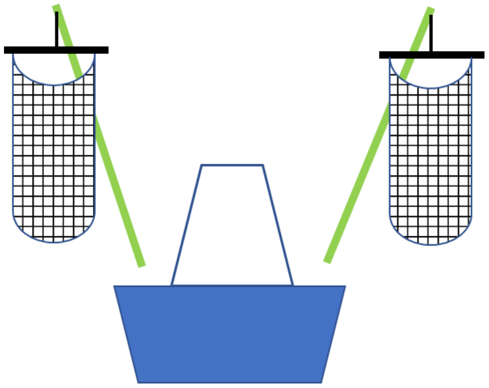
Conoship International. (2022). *Stability of beam trawlers.*

Dutch Safety Board. (2021). *Capsizing and sinking of fishing vessels.*

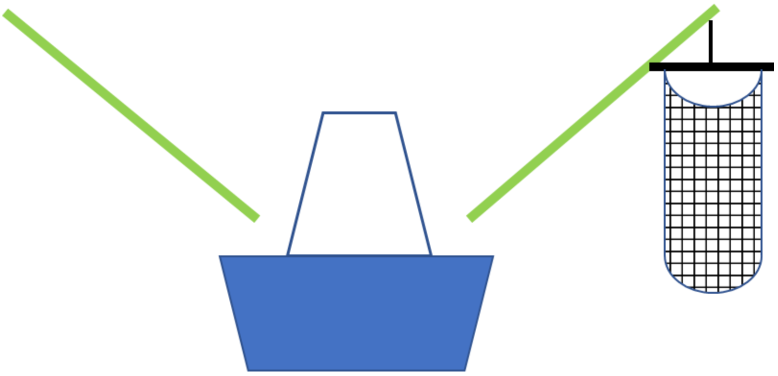
IMO. (2008). *2008 IS-Code - Part B - Chapter 2.7 Recommended Design Criteria for ships engaged in anchor handling operations.*

Appendix I. Examples Score-card codes

8080-BDP-BDS



4545-BDS



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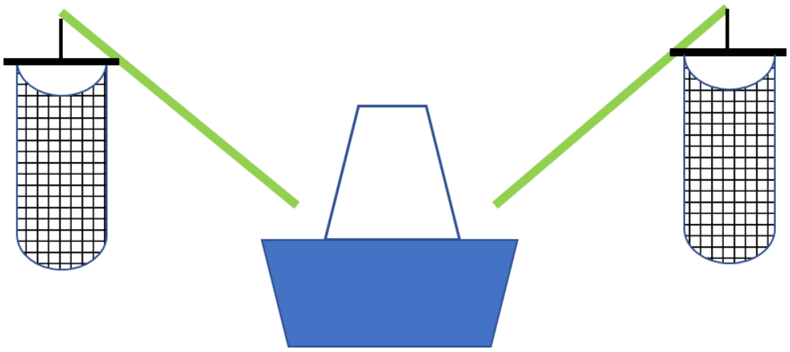
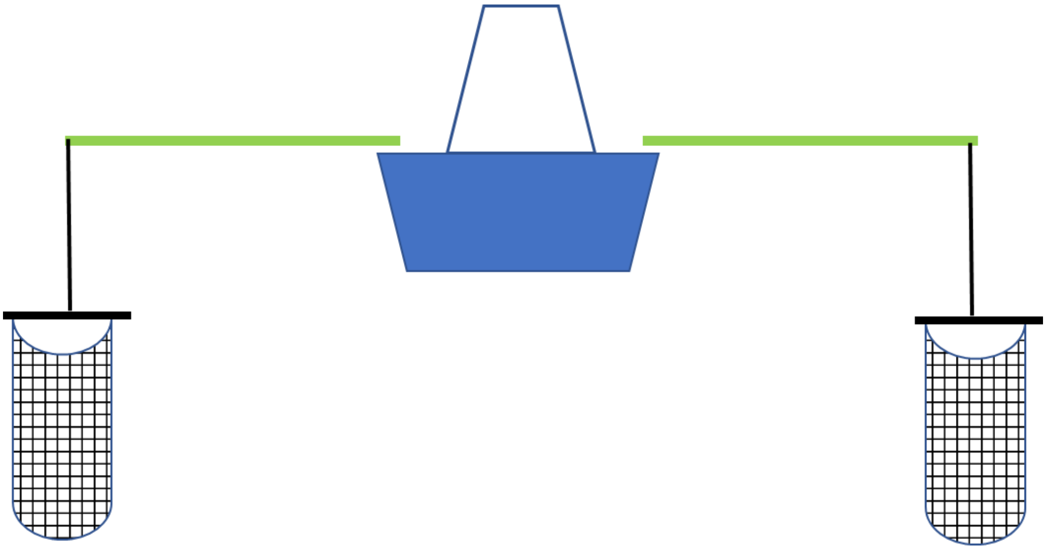
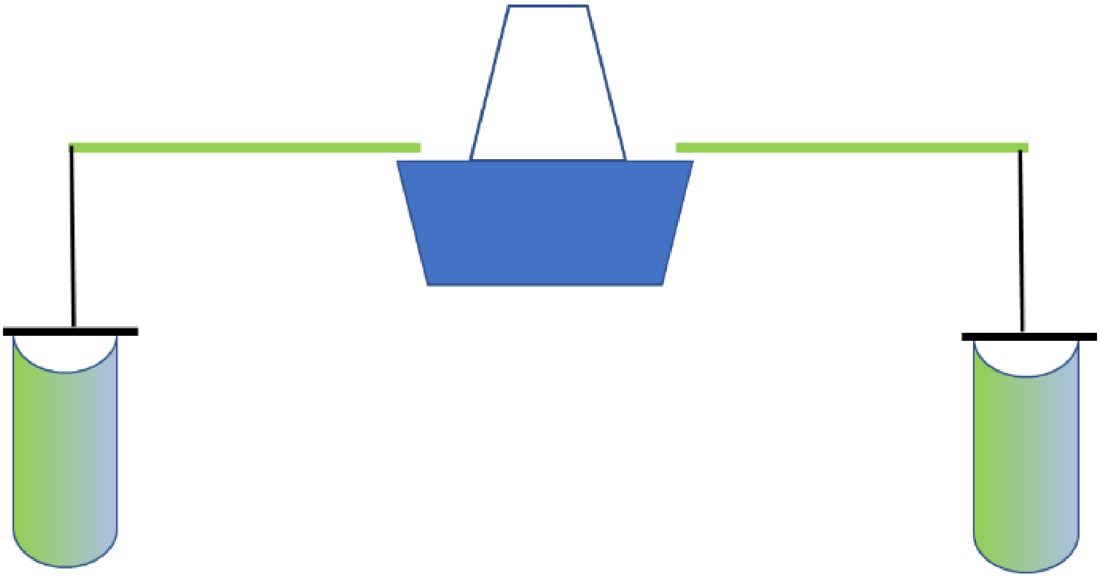


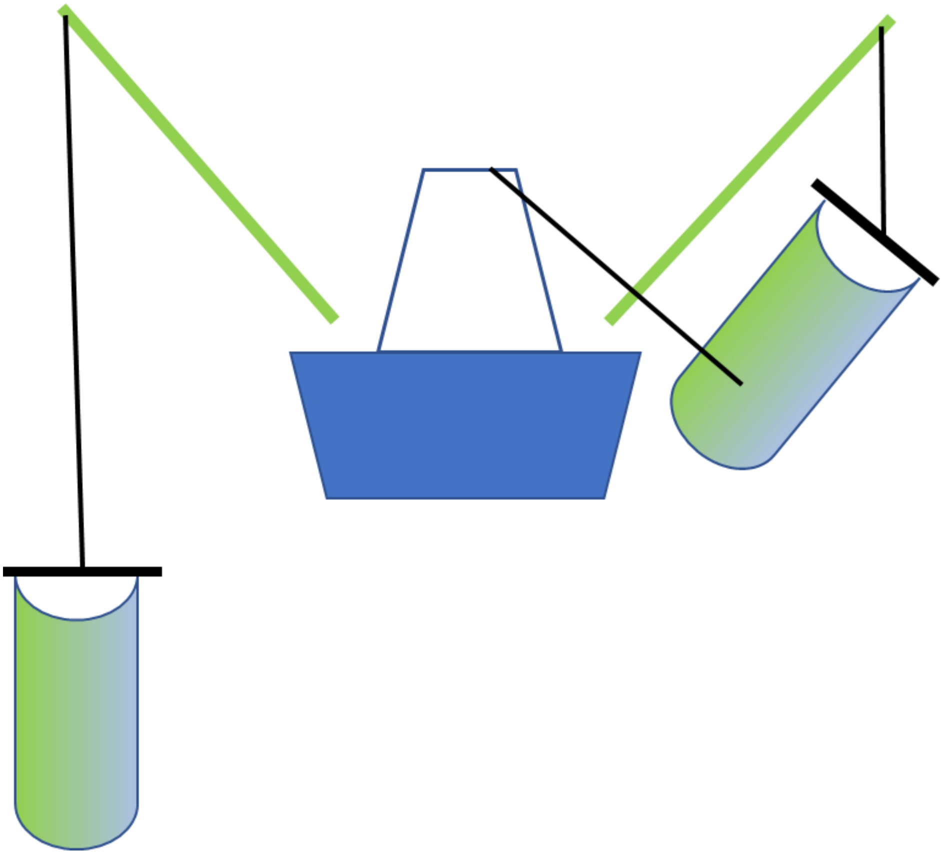
0000-BDP-BDS



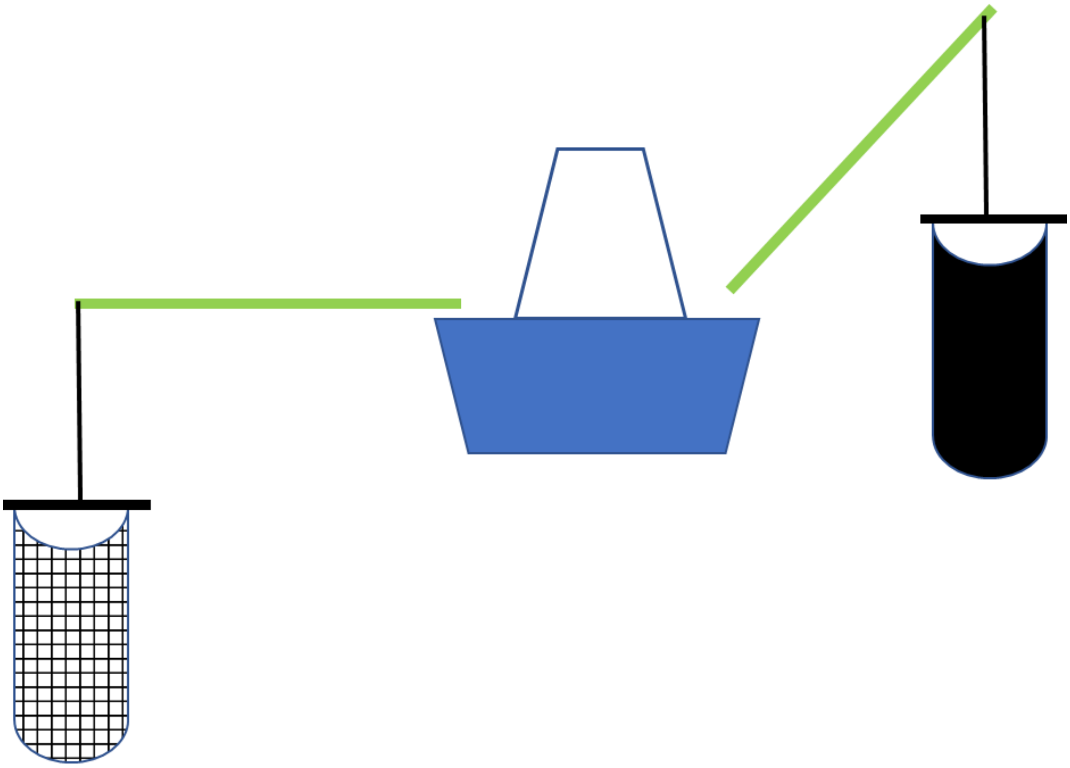
0000-BDP-BDS-NCP-NCS



4545-BDP-BDS-HCS



0045-BDP-BDS-NDS



Appendix II. Detailed description of development of amendment criteria

Here, a detailed description of the development of the amendment criteria will be added. It will consist of all the steps that were taken for the development. Below, the potential content of the appendix is roughly described.

To develop the amendment criteria, the first step was to analyse the stability of the beam trawlers in the reference fleet in the *Basic Fishing Condition*, (50% consumables, 100% fish in the hold, derricks topped up to 80 degrees and the fishing gear suspended from the blocks at the end of the derricks) shown in Figure 31.

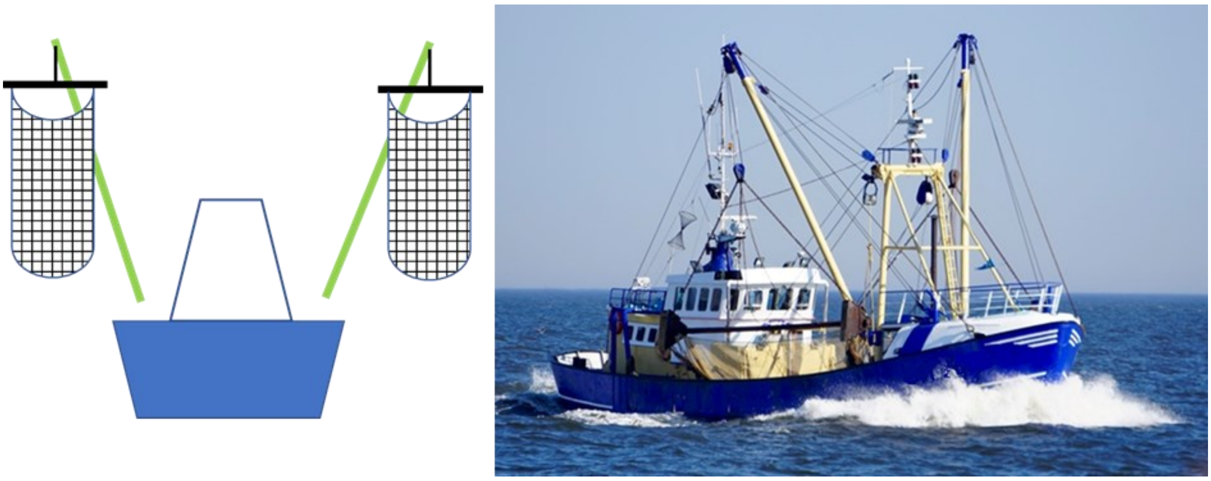


Figure 31: The Basic Fishing Condition

This resulted in the baseline criteria, reflecting the safety level as required in the free sailing condition, but for the *Basic Fishing Condition*. Table 15 shows the comparison between the existing requirements and the baseline criteria.

		Basic Loading condition original regulations criteria	Basic Fishing condition equal safety level criteria (baseline)
Maximum GZ-value	[m]	0.240	0.153
Area below GZ curve up to 30 degrees	[mrad]	0.0660	0.0418
Area below GZ curve up to 40 degrees	[mrad]	0.1080	0.0611
Area below GZ curve between 30 and 40 degrees	[mrad]	0.0360	0.0151

Table 15: Baseline stability criteria compared to free sailing criteria

For each vessel, the Score-card was made as is described in Chapter 4.7.2. These Score-cards show the remaining righting moments for each vessel in each condition at the safety level required for the free sailing conditions. For several conditions, there is no remaining righting moment left, resulting in a red marking.

The aim was to increase the stability requirements to such a level, that no cases without remaining righting moments were left, so no red marked situations. To remove all red situations for the entire reference fleet, would mean the criteria would have to be drastically increased, as shown in Table 16. Analysing these criteria learned that no realistic new design of a beam trawler < 24 meter could be made based on these criteria.

		Basic Loading condition original regulations criteria	Basic Fishing Condition increased safety level criteria
Maximum GZ-value	[m]	0.240	0.436
Area below GZ curve up to 30 degrees	[mrad]	0.0660	0.1018
Area below GZ curve up to 40 degrees	[mrad]	0.1080	0.1745
Area below GZ curve between 30 and 40 degrees	[mrad]	0.0360	0.0690

Table 16: Resulting criteria with increased safety level applied to entire reference fleet

After concluding this, it was decided to take the five best performing vessels of the reference fleet and increase the stability requirements to such a level, that only for these vessels no cases without remaining righting moments were left, so no red marked situations.

Since these vessels are already good ships in terms of stability performance, reducing the red situations required far less strict criteria. This resulted in the criteria shown in Table 17.

		Basic Loading condition original regulations criteria	Basic Fishing Condition increased safety level criteria
Maximum GZ-value	[m]	0.240	0.225
Area below GZ curve up to 30 degrees	[mrad]	0.0660	0.0596
Area below GZ curve up to 40 degrees	[mrad]	0.1080	0.0930
Area below GZ curve between 30 and 40 degrees	[mrad]	0.0360	0.0273

Table 17: Resulting criteria with increased safety level applied to the top five performing vessels

These criteria were tested on the reference fleet, which resulted in the conclusion that the best vessel already complied with these requirements and the other four best vessels needed minor adjustments to comply. This is described in Chapter 4.8.

Appendix III. Design variations

This appendix shows a description of the several design variations and their influence on the shape of the GZ-curve.

Variation number	Description
0	Original version
1	Lowered VCG (aluminum superstructure, heavy keel)
2	Breadth enlarged by 0.5 m
3	Smaller bilge radius (omitted)
4	Larger bilge keels
5	Increased freeboard (deck raised by 0.5 m)
6	Added volume in the sides above water ("sponsoons" added)
7	Enclosed fore deck and aft deck
8	Closed bulwark with buoyancy

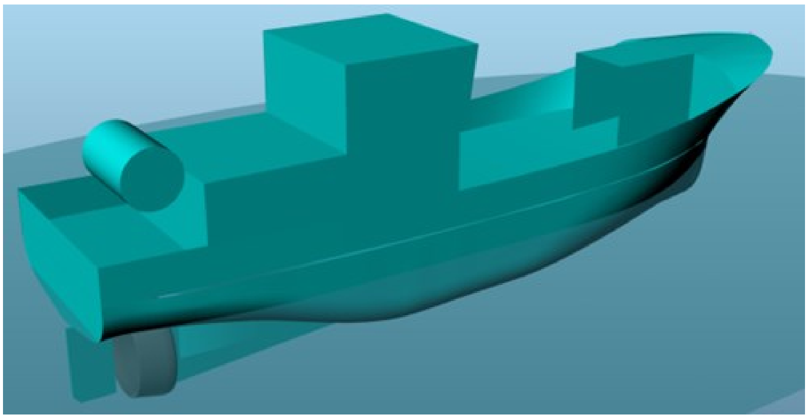


Figure 32: Design variation 0

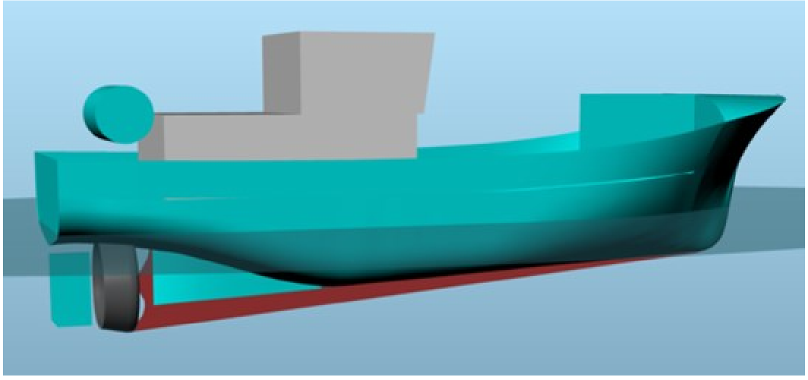


Figure 33: Design variation 1

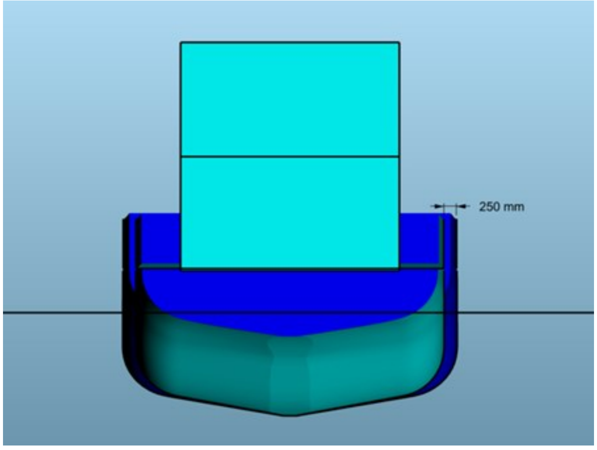


Figure 34: Design variation 2

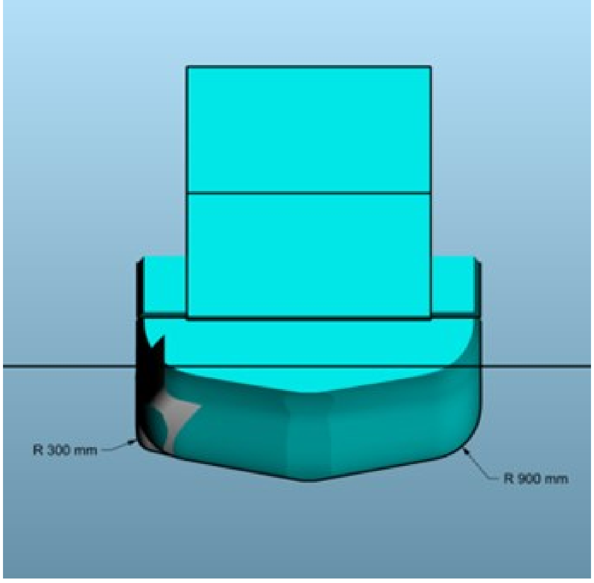


Figure 35: Design variation 3

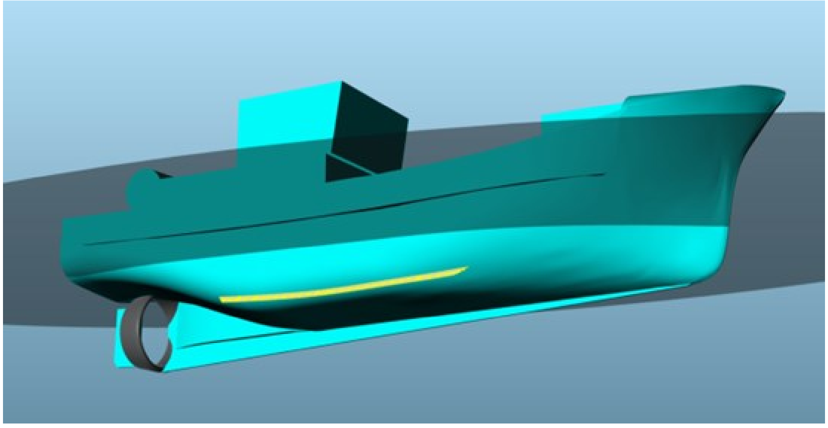


Figure 36: Design variation 4

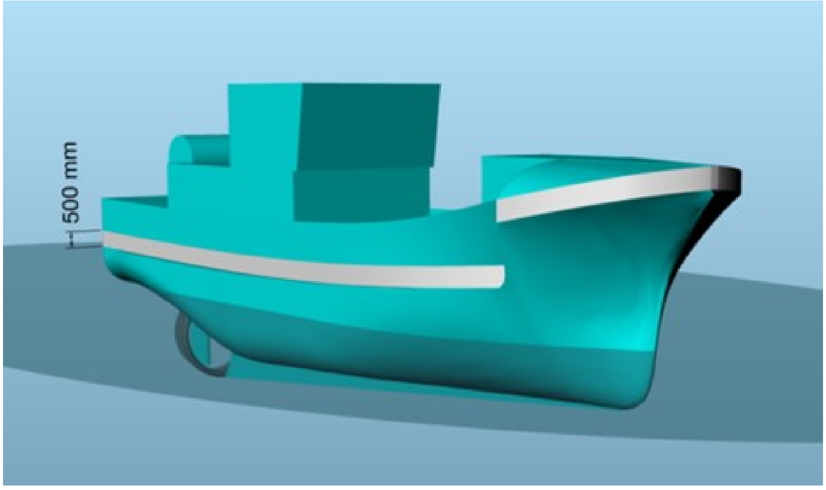


Figure 37: Design variation 5

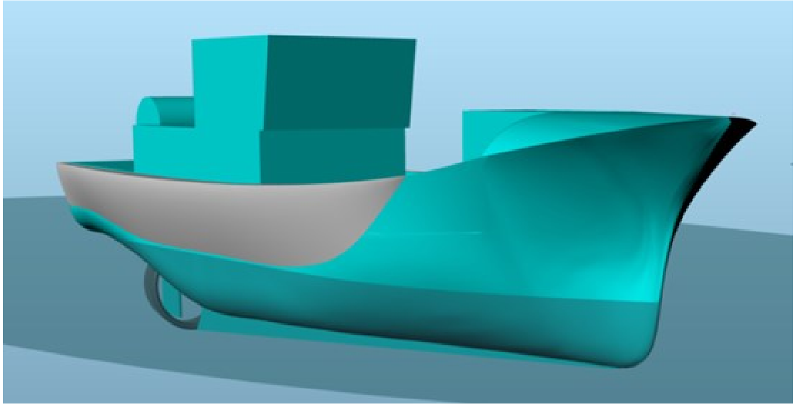


Figure 38: Design variation 6

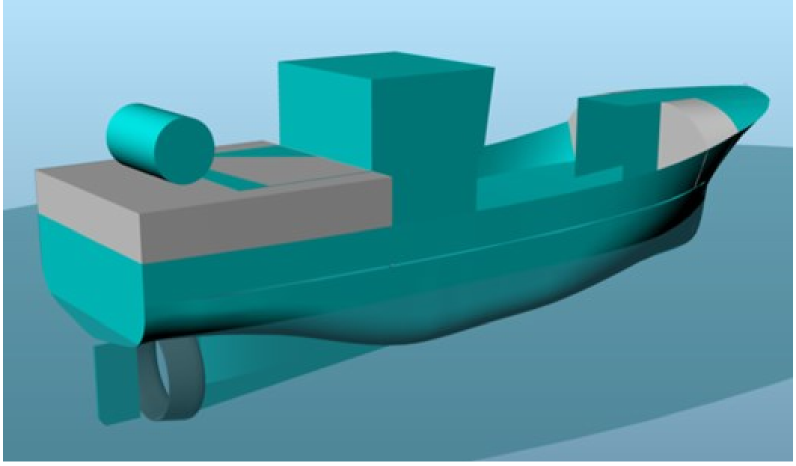


Figure 39: Design variation 7

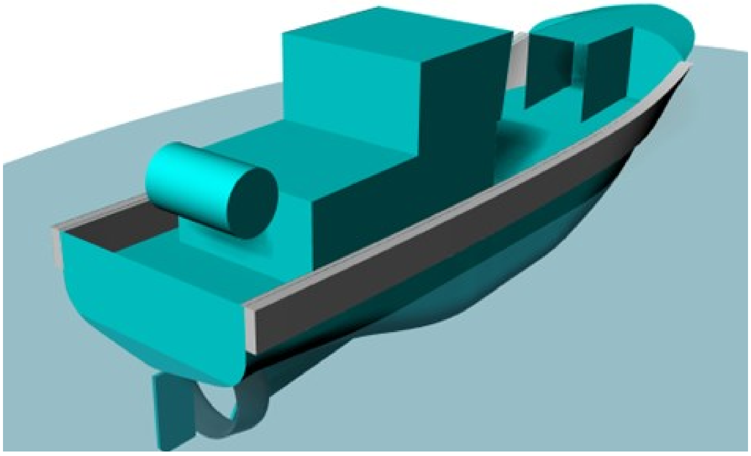
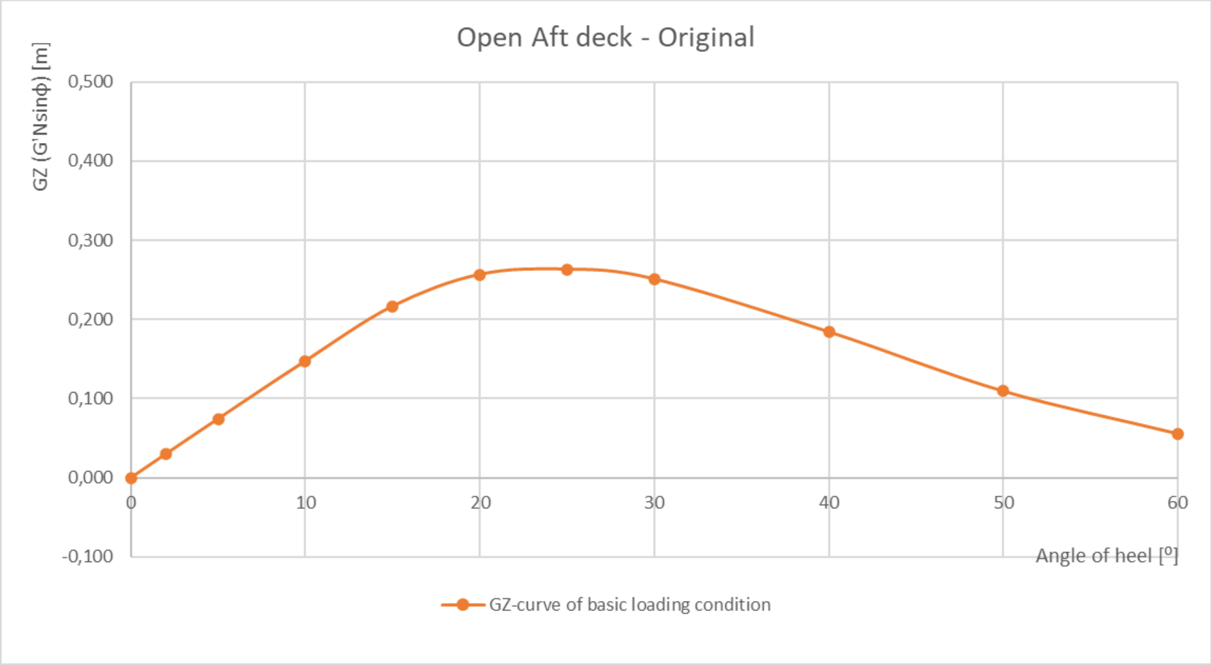
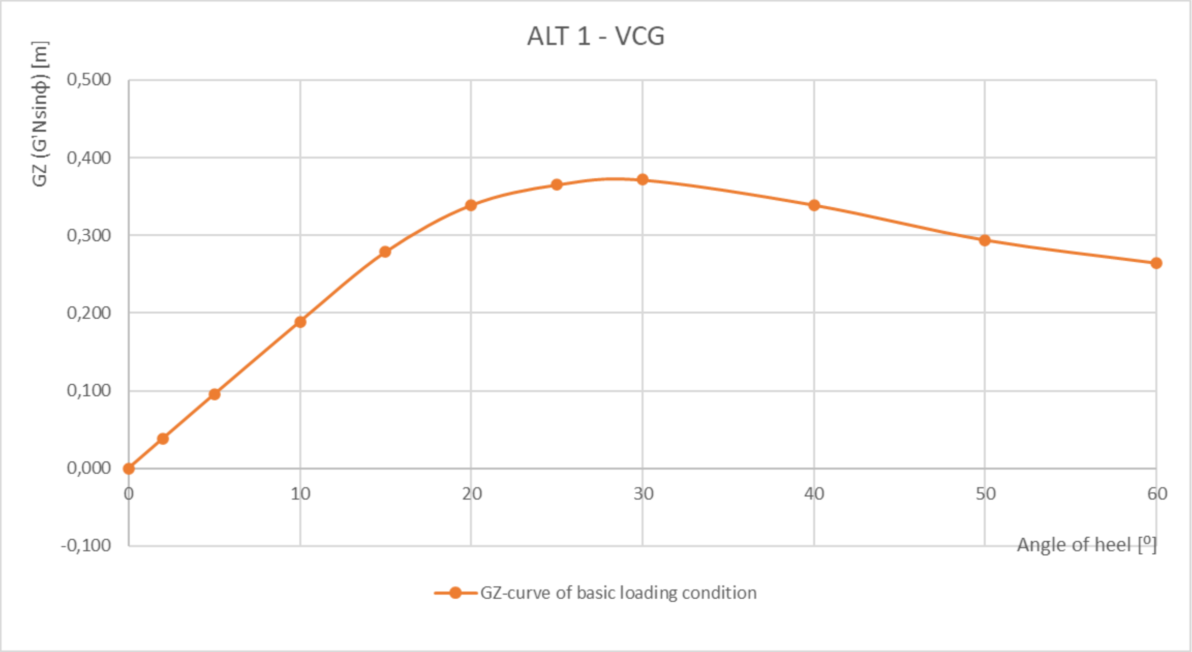


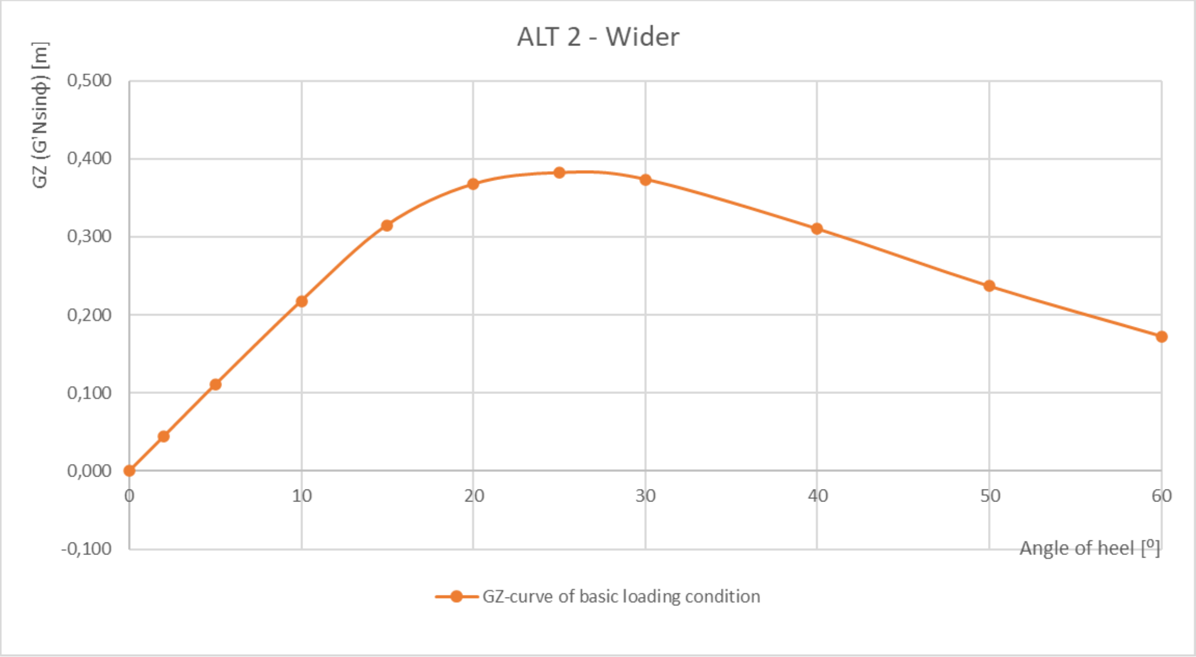
Figure 40: Design variation 8

Typical influence of the variations on the GZ-curve

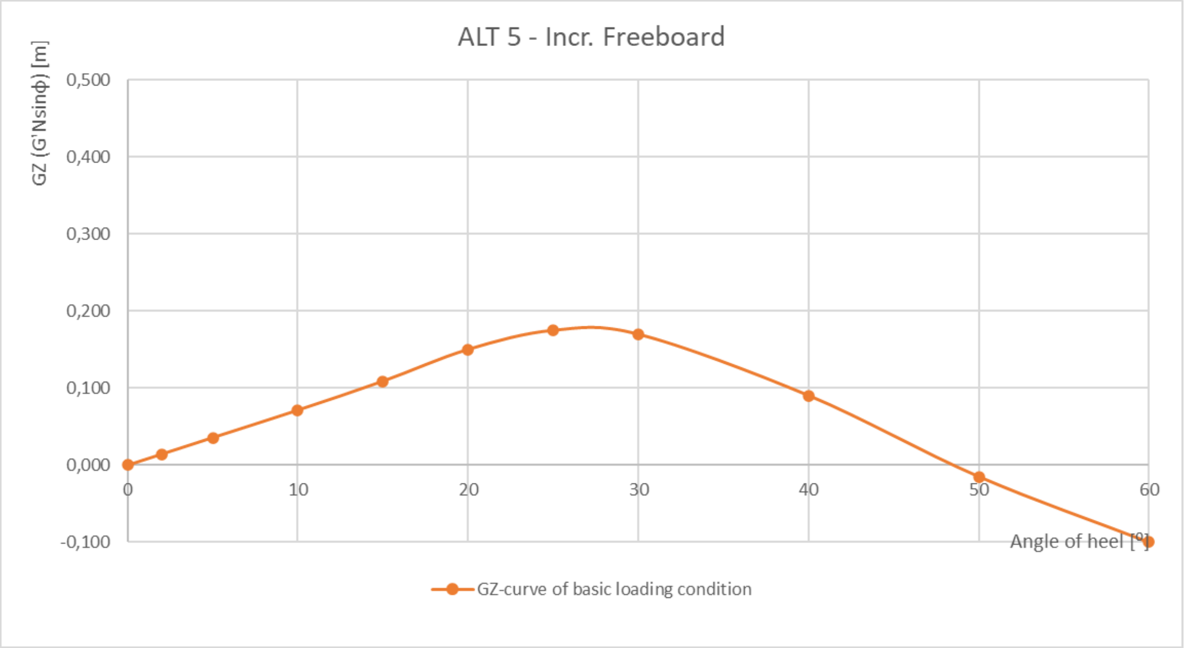
The following pictures show the typical GZ-curves of the design variations, showing the effect of the variation on the curve under similar circumstances:



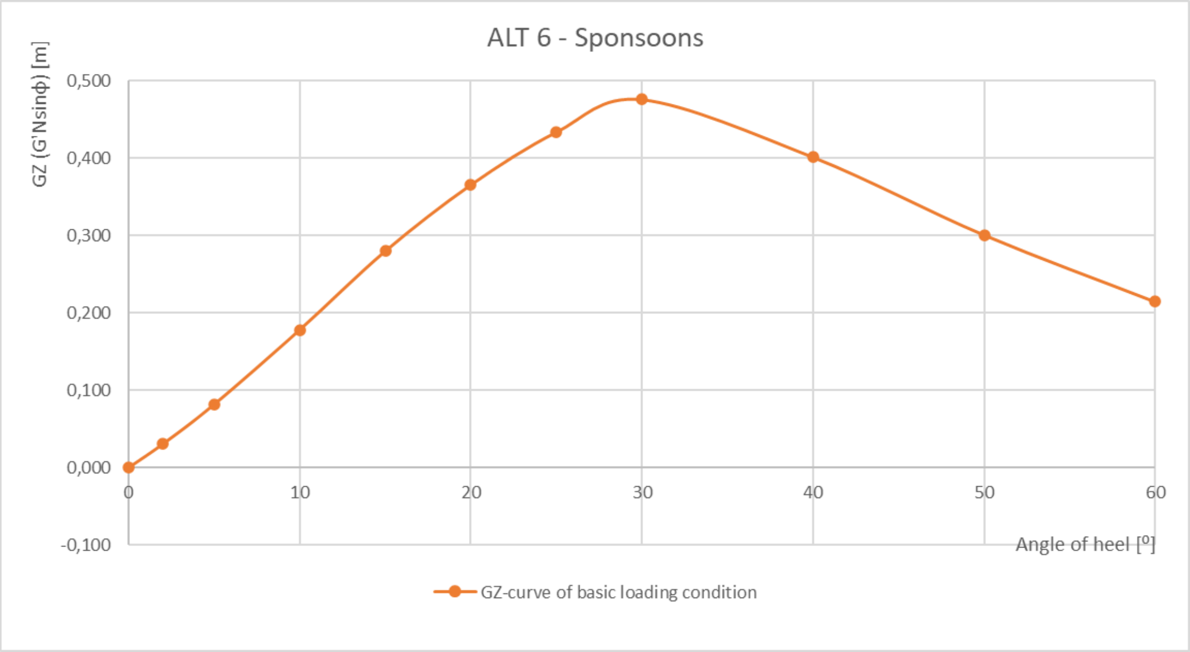


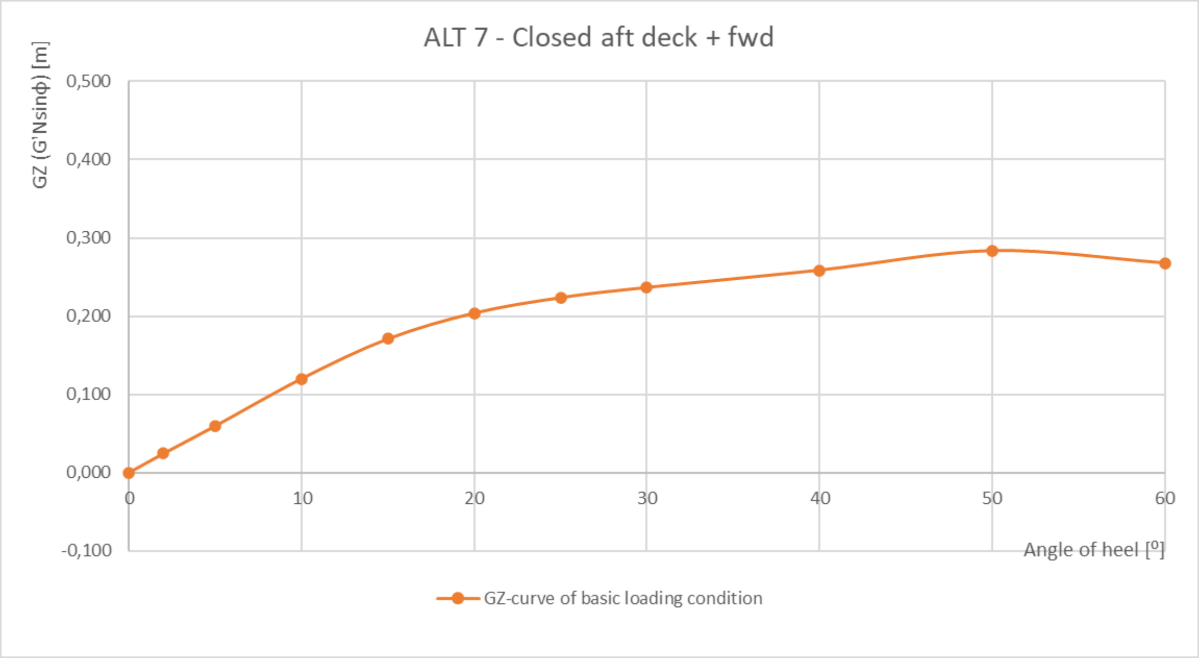


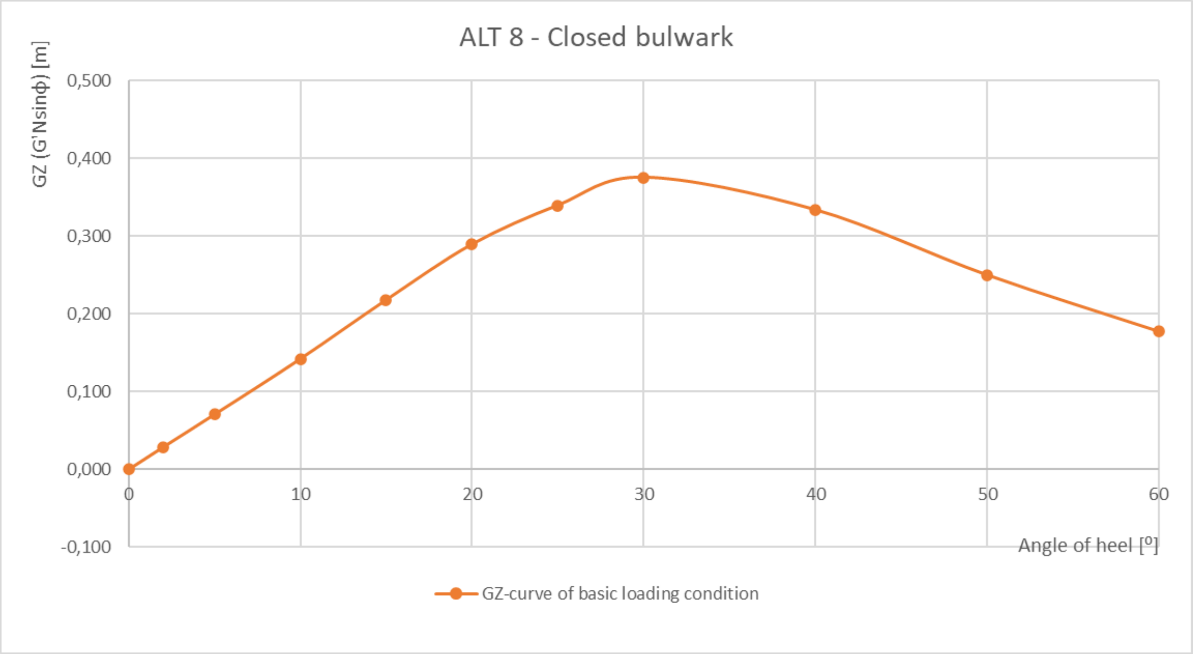
Variations 3 and 4 have no effect on the GZ-curve of the original vessel, so they have the same GZ-curve.



Note: For variation 5, only the depth of the vessel was increased, which resulted in a similar increase in VCG. The effect on the curve of the increased VCG is more significant than the effect of the increased freeboard.



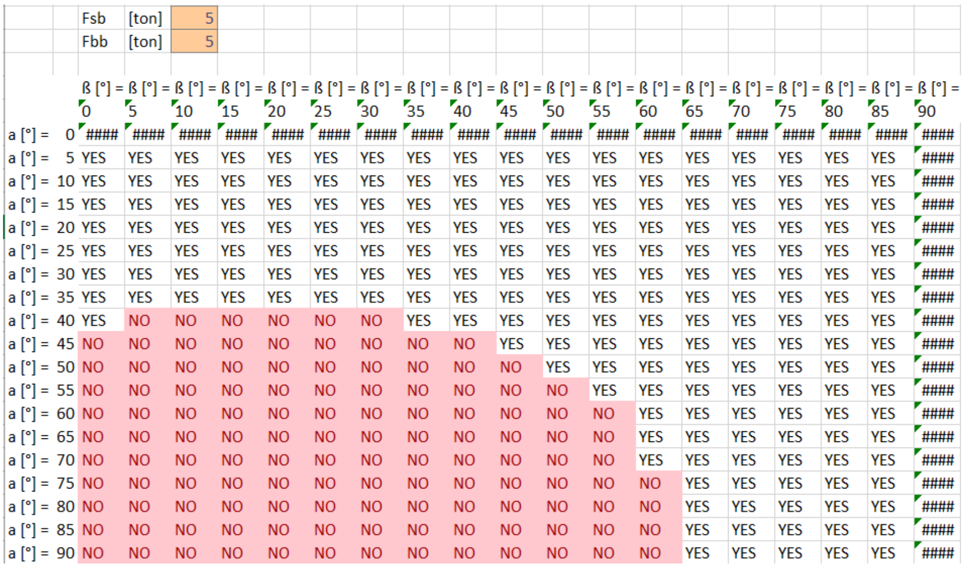




The GZ-curves of variation 8 shows that replacing the existing bulwark with a closed bulwark will significantly increase the safety of the vessel. Because it is a relatively low-cost solution, this can be applied to existing vessels to increase the safety of the vessel.

Appendix IV. Fish module output example

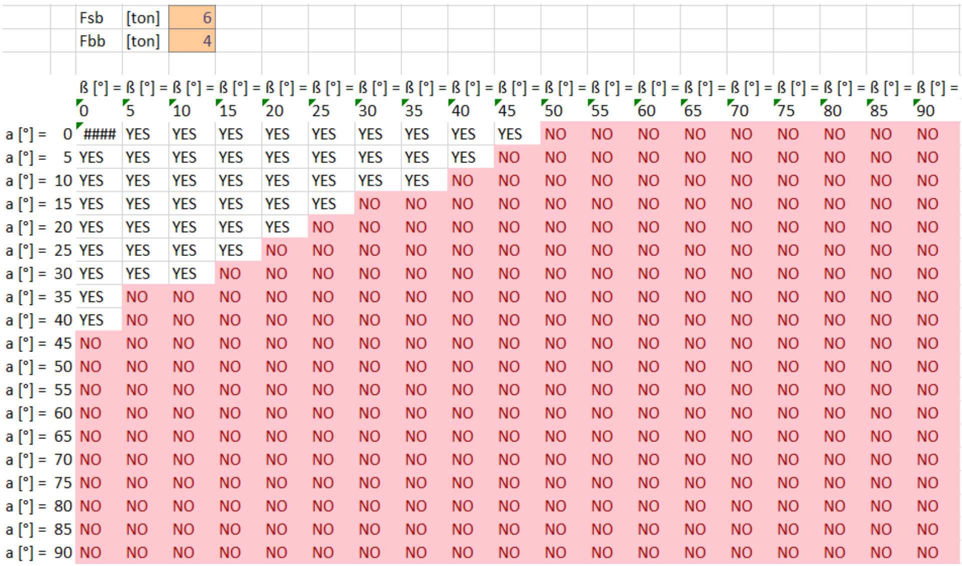
1. big symmetric force:



Fsb	[ton]	5
Fbb	[ton]	5

	ß [°] = 0	ß [°] = 5	ß [°] = 10	ß [°] = 15	ß [°] = 20	ß [°] = 25	ß [°] = 30	ß [°] = 35	ß [°] = 40	ß [°] = 45	ß [°] = 50	ß [°] = 55	ß [°] = 60	ß [°] = 65	ß [°] = 70	ß [°] = 75	ß [°] = 80	ß [°] = 85	ß [°] = 90
a [°] = 0	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####
a [°] = 5	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 10	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 15	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 20	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 25	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 30	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 35	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 40	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 45	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 50	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 55	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 60	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	####
a [°] = 65	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	####
a [°] = 70	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	####
a [°] = 75	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	####
a [°] = 80	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	####
a [°] = 85	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	####
a [°] = 90	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	####

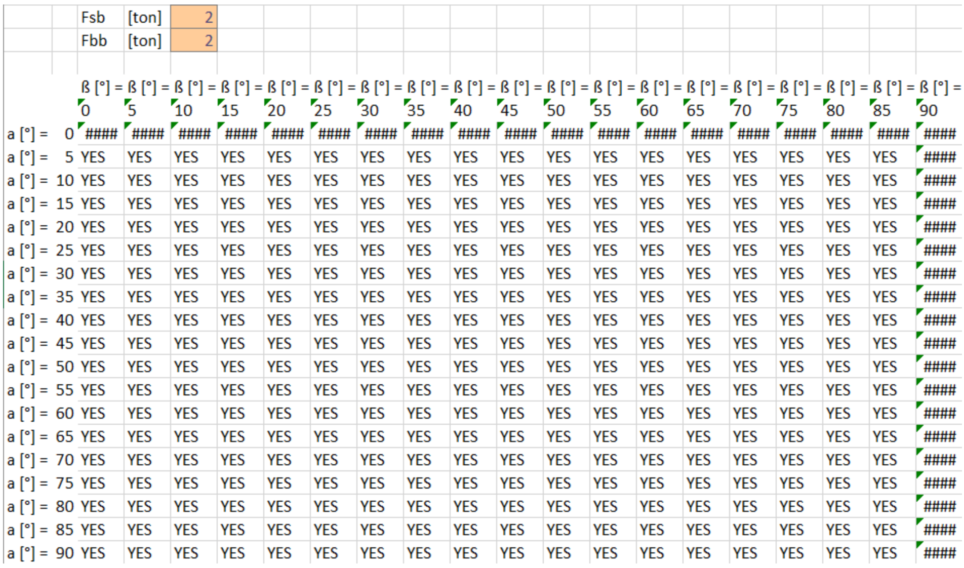
2. Big asymmetric force:



Fsb	[ton]	6
Fbb	[ton]	4

	ß [°] = 0	ß [°] = 5	ß [°] = 10	ß [°] = 15	ß [°] = 20	ß [°] = 25	ß [°] = 30	ß [°] = 35	ß [°] = 40	ß [°] = 45	ß [°] = 50	ß [°] = 55	ß [°] = 60	ß [°] = 65	ß [°] = 70	ß [°] = 75	ß [°] = 80	ß [°] = 85	ß [°] = 90
a [°] = 0	####	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 5	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 10	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 15	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 20	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 25	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 30	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 35	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 40	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 45	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 50	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 55	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 60	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 65	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 70	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 75	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 80	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 85	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 90	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

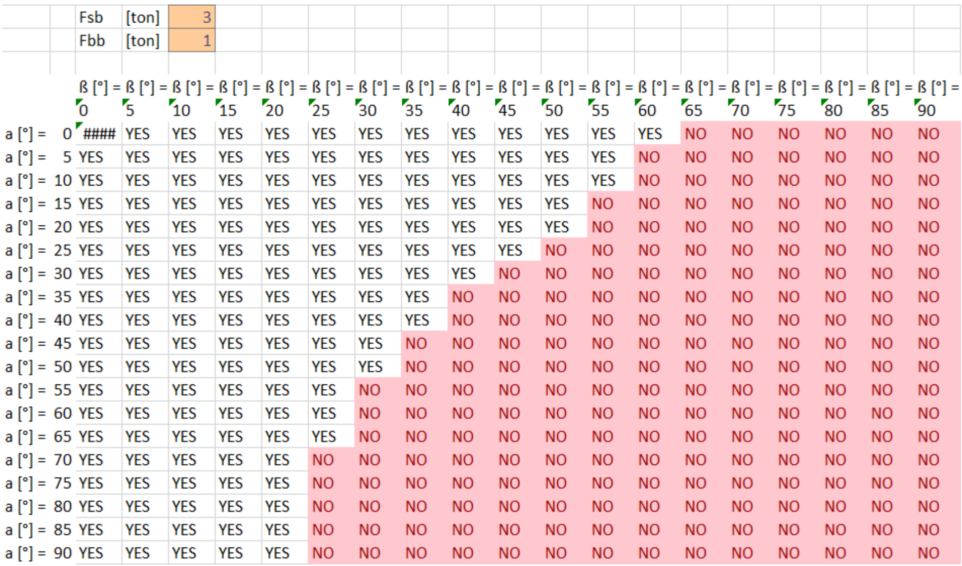
3. Small symmetric force:



Fsb	[ton]	2
Fbb	[ton]	2

	ß [°] = 0	ß [°] = 5	ß [°] = 10	ß [°] = 15	ß [°] = 20	ß [°] = 25	ß [°] = 30	ß [°] = 35	ß [°] = 40	ß [°] = 45	ß [°] = 50	ß [°] = 55	ß [°] = 60	ß [°] = 65	ß [°] = 70	ß [°] = 75	ß [°] = 80	ß [°] = 85	ß [°] = 90
a [°] = 0	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####
a [°] = 5	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 10	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 15	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 20	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 25	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 30	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 35	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 40	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 45	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 50	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 55	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 60	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 65	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 70	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 75	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 80	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 85	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####
a [°] = 90	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	####

4. Small asymmetric force



Fsb	[ton]	3
Fbb	[ton]	1

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a [°] = 0	####	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO
a [°] = 5	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO
a [°] = 10	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO
a [°] = 15	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 20	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 25	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 30	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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a [°] = 60	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 65	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 70	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 75	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 80	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 85	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
a [°] = 90	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Dutch Design Since 1952.

Founded in 1952 as the central design office for a group of Dutch shipyards, we have developed a wide range of ships, from general cargo vessels, tankers, and dredgers, to ferries and offshore vessels. Over 2,000 ships, operating all around the world, were built based on our designs, which at the time of their launch were unique in the world.

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en Waterstaat