Norwegian Safety Investigation Authority

Issued June 2023

REPORT MARINE 2023/04

Capsizing of the pleasure boat Malmhella in the archipelago off Kragerø, Norway on 25 October 2022

The Norwegian Safety Investigation Authority (NSIA) has produced this report exclusively for the purpose of improving safety at sea.

A safety investigation is conducted in order to determine the sequence of events and causal factors, study factors of importance for preventing marine accidents and improving safety at sea, and publish a report and any safety recommendations. It is not the NSIA's task to apportion blame or liability under criminal or civil law.

This report should not be used for purposes other than preventive maritime safety work.

Photo: Kragerø port authority

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

Table of contents

SUMMARY 4

ABOUT THE INVESTIGATION 5

1. FACTUAL INFORMATION 8
1.1 Sequence of events 8
1.2 Search and rescue 9
1.3 Operating conditions 9
1.4 Damage to the vessel and equipment 10
1.5 Shipowning company 11
1.6 Manufacturer 11
1.7 Craft 11
1.8 CE marking of X-27 SUV 14
1.9 Comparison of static stability for X-26 S and X-27 SUV 17
1.10 Spinout and capsizing 22
1.11 Supervisory scheme 24
1.12 Investigation of engine data from three accidents involving X-27 SUV craft 24
1.13 Implemented measures 26

2. ANALYSIS 28
2.1 Introduction 28
2.2 Assessment of the sequence of events 28
2.3 Trigger factors for spinout 28
2.4 Assessment of capsizing 29
2.5 The craft's design and stability 30
2.6 CE marking of the craft 30
2.7 Application and interpretation of standards in connection with CE marking 31
2.8 Stability requirements in the ISO standard 31
2.9 The training situation 32
2.10 Survival aspects 33

3. CONCLUSION 35

4. SAFETY RECOMMENDATIONS 37

REFERENCES 41

Summary

On 25 October 2022, the boat Malmhella was carrying a group of four course participants and one instructor who were taking the practical part of the high-speed course for operators of high-speed pleasure craft.

The incident occurred as the pleasure craft had completed a zig-zag run and was starting to turn to port to turn around. The speed was first reduced as the craft was approaching the turn, and then again once it had started to turn. The craft capsized and was left lying bottom up, with all persons on board inside the pilothouse. They were rescued from the boat, and two were taken to hospital for treatment. The craft was later salvaged.

The combination of high speed entering a turn and the reduction in speed caused a spinout and subsequent capsizing. The craft would probably not have capsized had its stability characteristics been good. A high centre of gravity and poor stability, combined with the heeling moment from the inertia and hydrodynamic forces, caused the craft to capsize.

Poor stability was a safety problem for the craft type Hydrolift X-27 SUV. In total, three of the 16 boats produced have capsized. The manufacturer has since temporarily ensured that the existing craft are not used, but the NSIA recommends that the manufacturer take steps to ensure good stability characteristics in this type of craft and that the Norwegian Maritime Authority carry out an audit of the manufacturer.

In the NSIA's assessment, the manufacturer's practice in connection with the tests conducted for the original CE marking of this pleasure craft was based on incorrect location of persons on board, and thus on an incorrect interpretation of the standard NS-EN ISO 12217-1:2017[1]. Consequently, the conditions for the CE marking were not met. The NSIA is of the opinion that if the tests had been correctly done, the result would have provided a clear indication of the craft's poor stability. This represents a safety problem, and the Norwegian Maritime Authority is recomended to carry out more frequent controls of CE marking of pleasure craft sold in Norway.

The investigation has also shown that the incorrect interpretation of NS-EN ISO 12217-1:2017, on which practical testing is based, contributes to making it possible to fictitiously improve the stability by using weights representing luggage placed below the craft’s centre of gravity as permanent ballast. The weights then become a prerequisite for meeting the stability requirements stipulated in the standard. The Norwegian Maritime Authority is recomended to implement measures to ensure that pleasure craft are correctly tested.

CE marking of pleasure craft is based on ISO standards, which for this group of craft are not well suited to assess the effect of dynamic stability factors on craft with potential speeds as high as the X-27 SUV. Moreover, the standard is inadequate because it does not require an overall mapping of static stability, particularly as regards requirements for residual stability under different loading conditions.

The NSIA submits a total of five safety recommendations following the investigation.

[1] Small craft – Stability and buoyancy assessment and categorization – Part 1: Non-sailing boats of hull length greater than or equal to 6 m (ISO 12217-1:2015)

About the investigation

Purpose and method

The NSIA has classified the incident as a serious marine accident. The purpose of this investigation has been to determine the cause of the craft capsizing. The NSIA has also considered what can be done to improve safety and prevent the recurrence of similar incidents in future.

The NSIA has no supervisory role, and it is not the NSIA's task to apportion blame or liability under criminal or civil law. Therefore, the report will not investigate or describe blame or liability issues.

The NSIA's investigations shall be conducted independently of other investigations or inquiries wholly or partly conducted for different purposes. This means that parties with an interest in the criminal or civil law aspects of an accident or incident must carry out their own investigations or inquiries, and that they cannot rely on the NSIA's safety investigation and report.

Any use of the report or information obtained in the course of the investigation for purposes other than preventive safety work will undermine the NSIA's remit.

The accident and the circumstances surrounding it have been investigated and analysed in line with the NSIA's framework and analysis process for systematic safety investigations (the NSIA method[2]).

Focus and delimitation of the investigation

The NSIA is of the opinion that the most useful safety lessons that can be drawn from this investigation relate to the craft's stability and CE marking.

The NSIA also considers topics relating to the training situation, notification/reporting and use of life jackets to have a bearing on safety.

The investigation report

The first part of the report, 'Factual information', describes the sequence of events, related data and information gathered in connection with the accident, what the NSIA has investigated and related findings.

The second part, the 'Analysis' part, contains the NSIA's assessment of the sequence of events and contributing causes based on factual information and completed investigations/examinations. Circumstances and factors found to be of little relevance to explaining and understanding the accident will not be discussed in any detail.

The final part of the report contains the NSIA's conclusions and safety recommendations.

[2] *See https://www.nsia.no/About-us/Methodology*

Sources of information

Information has been obtained from the Norwegian Maritime Authority, the shipowning company, the manufacturer, the engine manufacturer, owners of this type of craft and other sources.

The NSIA made repeated attempts to retrieve information from the chart plotter on board the craft, but due to water damage it was not possible to retrieve information directly from the unit. IBAS assisted in retrieving stored information, but the manufacturer was unwilling to assist by providing the technical expertise required to make the information accessible. Therefore, we have no sources of information about the craft's actual speed and position.

1. Factual information

1.1 Sequence of events 8
1.2 Search and rescue 9
1.3 Operating conditions 9
1.4 Damage to the vessel and equipment 10
1.5 Shipowning company 11
1.6 Manufacturer 11
1.7 Craft 11
1.8 CE marking of X-27 SUV 14
1.9 Comparison of static stability for X-26 S and X-27 SUV 17
1.10 Spinout and capsizing 22
1.11 Supervisory scheme 24
1.12 Investigation of engine data from three accidents involving X-27 SUV craft 24
1.13 Implemented measures 26

1. Factual information

1.1 Sequence of events

1.1.1 REVIEW OF THEORY THE DAY BEFORE THE ACCIDENT

On 24 October 2022, a group of four people reviewed the theoretical curriculum for the high-speed licence. The course instructor talked about several different topics, including navigation, handling the craft and risks such as high-speed spinout and how the operator of the craft could prevent this. The course participants were mostly experienced pleasure craft users who were already familiar with much of the curriculum.

1.1.2 SEQUENCE OF EVENTS LEADING UP TO THE ACCIDENT

The following day, 25 October 2022, was devoted to the practical check-out of course participants. The plan for the final day of the course was that they would first navigate in open waters and then drive between 6–8 buoys placed 20–30 metres apart in inshore waters. The instructor pointed out that it was not a competition and that the course participants were to drive at a speed they felt comfortable with.

Before departure, the instructor held a safety briefing and checked that the participants were wearing life jackets with crotch straps fastened. Several participants pointed out that they did not normally use the crotch strap, as they had experience of it catching and hindering their mobility. It was also pointed out by the participants that there was no requirement to wear a life jacket.

When the participants boarded Malmhella, it was remarked that the craft felt unstable with poor weight balance. The asymmetrical design with the pilothouse offset to starboard meant that the craft had a starboard list when they were all in the pilothouse. The instructor readied the craft, closed the pilothouse door and drove the vessel out the fjord. All the participants were then given the opportunity to familiarise themselves with the craft by testing it in slightly wavy conditions. The participants had to use the trim tabs before the craft had reached planing speed. This was done to avoid listing to starboard when applying throttle. Some of the participants pointed out that the craft also moved in an unusual way and felt wobbly and unstable when approaching planing speed compared with boat types they had experience of.

Before and during the voyage, the instructor told the participants that the craft needed high engine trim at high speed and during turns to push the stern down and thus lift the bow. Some of the participants found this uncomfortable and not in accordance with how they were used to driving a pleasure craft at high speed.

1.1.3 THE ACCIDENT OCCURS

During the final round around the buoys, the operator maintained a high speed through the buoys. The tabs had been put in neutral when the craft was planing.

The operator kept the left hand on the wheel and the right hand on the throttle lever. Approaching the final buoy at a speed of approx. 35 knots, the operator got ready and began a slight port turn and reduced the speed as the craft approached the buoy. The instructor observed the operator and the speed reduction. The instructor believed that the craft was approaching the buoy too fast and that the operator was turning too hard, but was unable to grab the wheel before it was too late.

The operator felt the weight of the craft shift towards the bow and to port. The engine data showed a slight throttle reduction at this moment. The craft kept turning to port at an even sharper angle.

The stern of the craft lost contact with the water and rose above the water. Those on board could hear that the propeller was no longer in contact with the water and was making a loud noise. The operator felt the stern of the craft make an uncontrolled turn of as much as 45 degrees before it made contact with the water again and came to a sudden stop. The stored engine data showed high throttle just before the boat came to a halt. The operator has stated that he was thrown forward and to starboard and hit his forehead against a panel in front of him. This could explain the final throttle registered.

The others on board felt a strong jolt where the craft continued to rotate and capsized to starboard. The persons on board were thrown around the pilothouse, while the starboard pilothouse window broke. The boat was left lying bottom up, and they were all disorientated for a while immediately after the capsizing.

1.2 Search and rescue

Several life jackets inflated, which made it difficult to get out of the pilothouse. Several people had suffered head injuries in connection with the capsizing.

After a while, and with each other's assistance, they all got out of the pilothouse and made their way onto the bottom of the overturned boat. One of their mobile phones was still working, and they managed to call an employee at a local marina who came to pick them up approx. 15 minutes after the craft capsized. Ambulances were called and arrived just after they arrived at the marina. Two course participants were admitted to hospital for overnight observation.

The boat was later retrieved by a local workboat owned by Kragerø port authority, brought to Kiil-Sandtangen and lifted out of the water. When the boat was located, only a small part of the bow was visible above the water, see Figure 1.

Figure 1: Only the bow of the craft was visible when the salvage operation started. Photo: Kragerø port authority

1.3 Operating conditions

The accident occurred in sheltered waters in an archipelago, see Figure 2. The instructor and participants have stated that the sea was calm and visibility good. The only waves were those made by the craft itself, see Figure 1. The instructor and participants, who worked close by, were all familiar with the area.

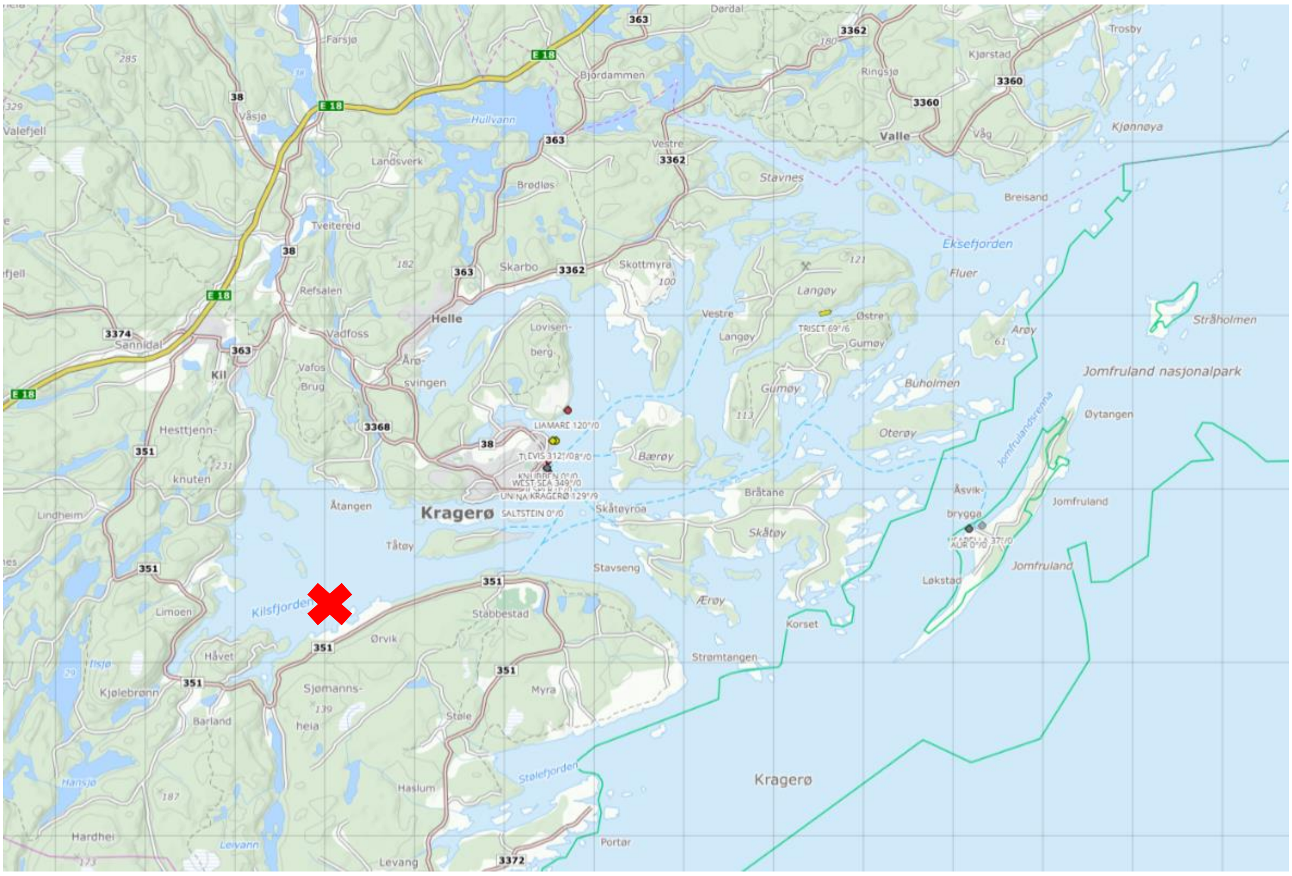

Figure 2: The red cross indicates where the accident occurred. Map: Kystinfo, the Norwegian Coastal Administration

1.4 Damage to the vessel and equipment

The boat sustained minor structural damage. The superstructure on the starboard side came away from the underwater hull as several pop rivets were out of position, see Figure 3 and Figure 4. The starboard pilothouse window broke when the vessel capsized, the radar mast broke off and the soft top that functions as a roof came loose, see Figure 5. There was also some minor cosmetic damage that could have been inflicted during the salvage operation.

Figure 3: Pop rivets out of position, view from the rear. Photo: NSIA

Figure 4: Pop rivets out of position, view from the front. Photo: NSIA


Figure 5: The boat was raised after towing. Photo: Kragerø port authority

1.5 Shipowning company

The company Malmhella Maritim AS was established in 2021. Malmhella Maritim AS specialises in providing courses that qualify participants to apply for a high-speed licence from the Norwegian Maritime Authority.

The company was approved as a course provider on 1 July 2022.

1.6 Manufacturer

Hydrolift AS is a Norwegian boat manufacturer based in Fredrikstad. They design, manufacture and sell boats in the high-speed segment.

1.7 Craft

The craft used was a Hydrolift X-27 SUV, see Figure 6 and Figure 9. It was equipped with a 450-hp outboard engine and had a top speed of 65 knots. The hydraulic and steering systems were from the same manufacturer as the engine. The safety equipment on board comprised life jackets for everyone and a stationary DSC-VHF. The craft did not have a life raft or portable VHF radio. A total of 16 such craft have been manufactured. This type has the same hull as the Hydrolift X-26 S – the only difference is that the X-27 SUV has a pilothouse. A total of 106 units had been produced of the X-26 S type, but no capsizing accidents had been recorded.

Figure 6: X-27 SUV seen from the port side. Source: The manufacturer

The boat was 8.11 metres long and 2.4 metres wide. It was CE marked for 8 persons, see Figure 7, and a pilothouse was fitted, offset to starboard, see Figure 8

Figure 7: CE label for Hydrolift X-27 SUV. Photo: NSIA

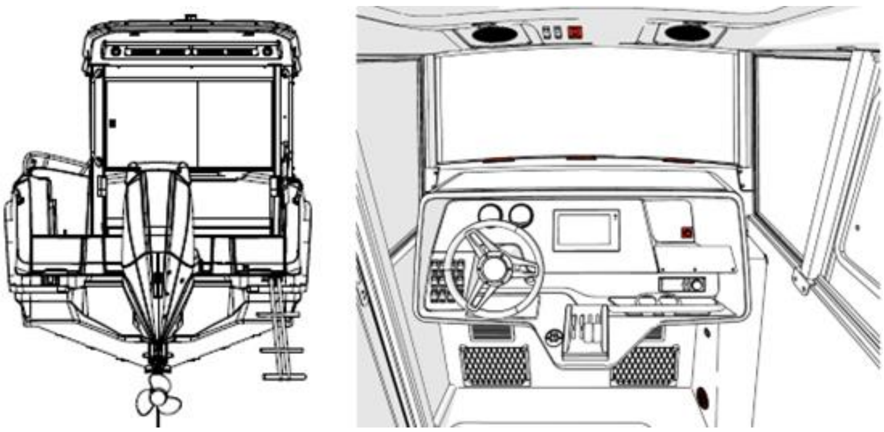

Figure 8: Illustration of the boat viewed from the rear and illustration of the control console in the pilothouse. The pilothouse is placed on the starboard side. Drawing: The manufacturer

The boat had a stepped hull design that differs from a conventional hull, see Figure 9. This hull shape is intended to distribute the hydrodynamic lift over several planing surfaces with a low length to breadth ratio as this provides good lift, less wetted surface, less water resistance and improved longitudinal stability. The hull will glide more easily through the water (less friction) because the steps provide air to the buoyancy volume, and higher speeds can be achieved.

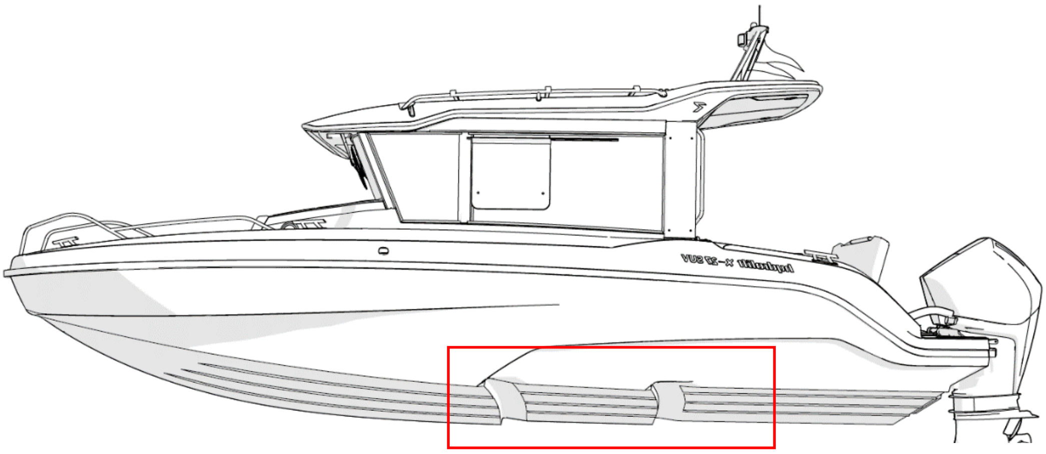

Figure 9: The red marking indicate the two steps. Drawing: The manufacturer

The shape of the hull is important to the boat's characteristics. Fast planing boats need a V-shaped hull with straight lines going backwards from the bow to separate the water flow from the hull both at the stern and along the sides, thus achieving stable hydrodynamic lift. Good seagoing characteristics and dynamic stability are achieved by means of the design of the V-shaped bottom, the location and design of spray rails and the location of the boat's centre of gravity. The length to breadth ratio is also important, as a high length to breadth ratio makes for a less stable hull than a lower length to breadth ratio.

There are many challenges associated with the dynamic stability of high-speed boats. These challenges are well described in the literature, see, e.g., Faltinsen (2005),[3] and must be taken into consideration when new boat models are developed.

[3] *Faltinsen, O.M. (2005). Hydrodynamics of High-Speed Marine Vehicles. Cambridge University Press.*

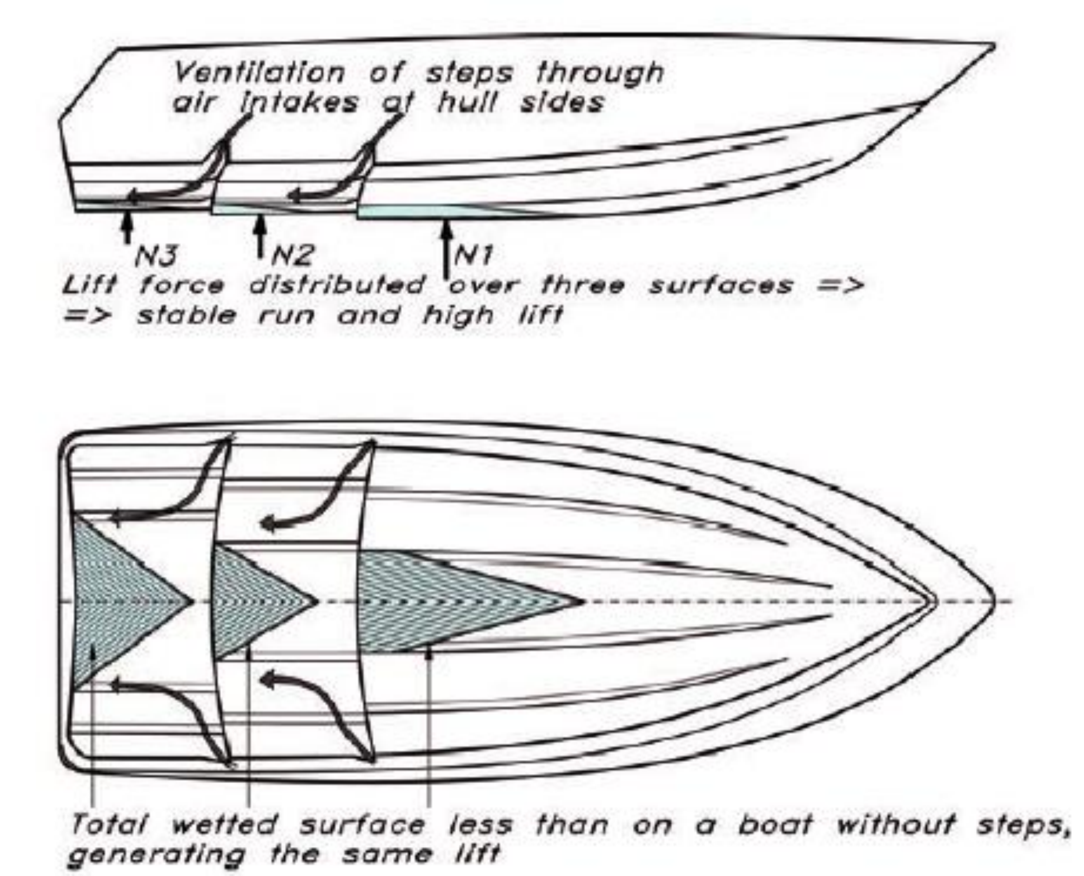

Figure 10: Wetted surface of a hull with two steps and spray rails. Source: Eliasson et al. 2014[4]

1.8 CE marking of X-27 SUV

1.8.1 GENERAL INFORMATION

Boats manufactured in Norway must be built in accordance with Act No 79 of 11 June 1979 relating to the control of products and consumer services (Product Control Act) and Regulations No 35 of 15 January 2016 on the manufacturing and the placing on the market of recreational craft and personal watercraft (the Regulations on Manufacturing etc. of Recreational Craft etc.). The boats must be CE marked, and an EU conformity certificate must be obtained. This means that craft in the EU/EEA area must be built in accordance with the same regulatory framework as in other EU/EEA countries.

1.8.2 DESIGN CATEGORY AND MODULE

The Regulations on Manufacturing etc. of Recreational Craft etc. apply to recreational craft of hull length from 2.5 m to 24 m, among other things. Section 4 of the Regulations makes reference to Annex I, which covers the essential requirements that apply to the design and manufacturing of recreational craft. CE marking shall be affixed to recreational craft that meet these standards and are placed on the market, cf. the Regulations Section 7. Products bearing the CE marking are presumed to comply with these Regulations and indicate that the manufacturer assumes responsibility for the product's compliance with all requirements set out in these Regulations, cf. the Regulations Section 7 second paragraph.

X-27 SUV falls into design category C, see Table 1.

---

[4] *Eliasson, R., Larsson, L. and Orych, M. (2014). Principles of Yacht Design. Bloomsbury Publishing.*

Table 1: Design categories for recreational craft and personal watercraft, cf. the Regulations on Manufacturing etc. of Recreational Craft etc. Annex I A. Essential requirements for the design and construction of products referred to in Section 1.

Category of construction	*Windforce (Beaufort scale)*	*Significant wave height (H 1/3, meter)*
A	above 8	above 4
B	up to 8	up to 4
C	up to 6	up to 2
D	up to 4	up to 0,3

Recreational craft in each design category shall be designed and constructed to withstand the wind force and significant wave height specified for their category. The design category and what it means must be clearly stated in the owner’s manual.

Another important parameter for the production of recreational craft is which ‘module’ to use. The module chosen determines which production control and testing requirements apply to the product. The choice of module is governed by the Regulations on Manufacturing etc. of Recreational Craft etc. Section 17(1), see Table 2.

Table 2: Modul choice by design category

<table>
<tr><th rowspan="2">Category of construction</th><th colspan="3">Selection of Module</th></tr>
<tr><td colspan="2">Boat length equal to or above 2.5 m up to 12 m</td><td>Boat length equal to or above 12 m up to 24 m</td></tr>
<tr><td>A</td><td colspan="2" rowspan="2">A1 or
B + C or B + D or
B + E or B + F or
G or H</td><td rowspan="4">B + C or
B + D or
B + E or
B + F or
G or H</td></tr>
<tr><td>B</td></tr>
<tr><td rowspan="2">C</td><td>When the boat meets harmonized standards for stability and buoyancy (appendix 1, part A, no. 3.2 and 3.3)</td><td>A or A1 or
B + C or B + D
or B + E or
B + F or G or H</td></tr>
<tr><td>When the boat meets harmonized standards for stability and buoyancy (appendix 1, part A, no. 3.2 and 3.3)</td><td>A1 or B + C or
B + D or B + E
or B + F or G or
H</td></tr>
<tr><td>D</td><td colspan="3">A or A1 or B + C or B + D or B + E or B + F or G or H</td></tr>
</table>

The design category and choice of module are not determined by the craft’s potential speed. As long as the craft complies with a harmonised standard for stability and buoyancy, module A can be chosen for craft in design category C. This module entails internal production control only, cf. the Regulations on Manufacturing etc. of Recreational Craft etc. Section 17(1), cf. Annex 5. For other module choices, see the Regulations Annexes 6–16.

1.8.3 PRODUCTION CONTROL OF STABILITY AND BUOYANCY

Hydrolift assessed the X-27 SUV model's stability in accordance with NS-EN ISO12217-1:2017, 'Small craft – Stability and buoyancy assessment and categorization – Part 1: Non-sailing boats of hull length greater than or equal to 6 m (NS-EN ISO 12217-1:2017)'.

Based on this standard in Annex B, the manufacturer carried out an inclining test to port using eight people. The test showed an angle of heel of 14 degrees and a freeboard of 33 cm. These values were satisfactory in relation to the standard chosen. It was stated that of the eight persons on board, two were placed at the craft's centreline. Circumstances relating to the regulatory framework, testing and documentation are assessed in more detail in sections 2.6–2.8.

1.8.4 THE NSIA'S PRACTICAL INCLINING TEST

The NSIA carried out a practical inclining test of Malmhella on 3 April 2023 to obtain an indication of its stability.

The boat was set afloat at Kongen Marina in Oslo, and the test was carried out using only six people with no luggage.

The starboard heel showed that with five persons placed at the side of the craft, it listed more than the required maximum of 19.2 degrees. The stability was also tested with six persons at the starboard side, which resulted in seawater entering the aft deck over the stern freeboard with additional list.

The results when testing to the port side were somewhat better, but were also in excess of the limits the craft was supposed to withstand.

There were some non-conformities in the inclining test compared to how the test is supposed to be done according to NS-EN ISO 12217-1:2017. For example, no luggage weights were used and there was uncertainty regarding the content of the fuel tank. The location of two persons at the side may have been somewhat conservative, and the engine was tilted into lay-up position during the test. The test results nevertheless provided clear indications of weak stability characteristics.

1.8.5 SUPPLEMENTARY INCLINING TEST CARRIED OUT ON 19 APRIL 2023 IN FREDRIKSTAD

A supplementary inclining test was carried out in accordance with NS-EN ISO 12217-1:2017, with the NSIA and the Norwegian Maritime Authority (NMA) present in an observer capacity. Weights were used for this test to ensure accurate control of weight and location in relation to the centreline. The weights were loaded onto the craft at an increasing number corresponding to the weight of a person each time weight was added. In addition, weights corresponding to 148 kg of luggage were placed under the pilothouse, centred at the bottom of the craft.

After weights corresponding to five persons had been loaded near the side, the resulting angle of heel was 14.2 degrees to starboard. This was within the requirement of 19.22 degrees. The aft freeboard measurement on the starboard side was 27 cm, which did not fulfil the requirement of 30 cm. The weight distribution was such that weights corresponding to three persons, a total of 259.7 kg, which gives an average weight of 86.5 kg, were placed on the aft deck. The remaining weights, corresponding to two persons with an average weight of 84.3 kg, or 168.6 kg in total, were placed in the pilothouse.

The test results showed that the craft did not meet the requirements for its CE marking, even with three persons fewer than it was CE marked for. Following this test, the manufacturer has asked end users not to use the craft, and the NMA has followed up the prohibition on use, see section 1.13.

1.9 Comparison of static stability for X-26 S and X-27 SUV

1.9.1 GENERAL INFORMATION ABOUT STABILITY

Stability is traditionally expressed using GZ curves, and formal stability requirements are normally linked to characteristics of a craft's GZ curves. GZ is the horizontal distance between a craft's centre of gravity (G) and its centre of buoyancy (B) at a given angle of heel and makes up a righting arm, see Figure 11. The righting arm multiplied by the weight of the craft is the righting moment.

A GZ curve shows a craft's ability to withstand heeling at different angles of heel. The area under the GZ curve expresses the energy required to heel the craft to a certain angle of heel.

Figure 11 shows that the illustrated craft's capacity to resist heeling is greatest at approx. 30 degrees (highest GZ value), and at approx. 50 degrees the craft is no longer capable of resisting heeling (GZ = 0) – in other words, it will capsize at this angle of heel.

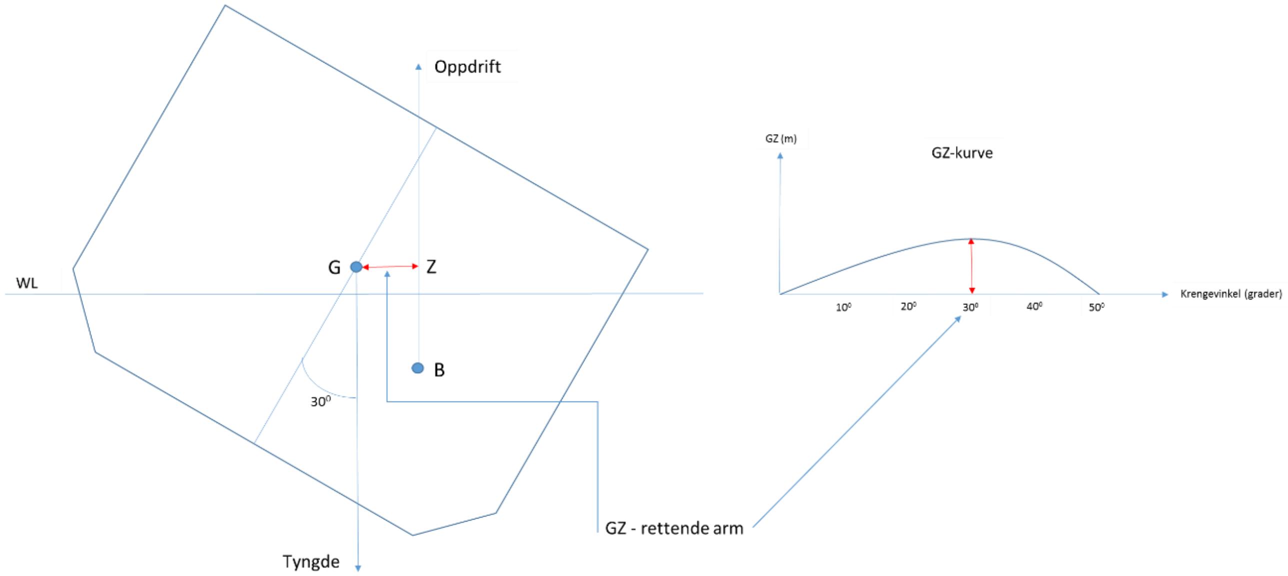

Figure 11: Explanation of the GZ curve. Illustration: NSIA

1.9.2 COMPARISON BETWEEN X-26 S AND X-27 SUV

Manufacturers of recreational craft of between 2.5 and 12 metres in design category C are not required to prepare complete stability calculations with GZ curves, but the NSIA has chosen to calculate the stability to investigate the boat's stability reserves. Flooding points and whether the hatches meet the requirements for weathertightness have not been assessed. The pilothouse has not been included in buoyancy calculations, as it cannot be considered weathertight.

The centre of gravity is estimated based on the craft's weight estimate, see Table 3. No inclining test has been carried out to verify the centre of gravity.

Table 3: Lightship weight and centre of gravity for X-26 and X-27.

Model	Weight [kg]	LCG [m]	TCG [m]	VCG [m]
X-27	2,450	2.100	0.023	0.831
X-26	2,091	2.000	0.000	0.612

The differences in lightship weight and centre of gravity are a result of the weight of the superstructure only, which causes a significant increase in vertical centre of gravity that will have a negative effect on stability.

The difference between the two boat types is that the X-27 SUV has a pilothouse weighing 359 kg and optional radar equipment weighing 11 kg on the roof of the pilothouse. The X-26 S, by comparison, has a windscreen estimated to approx. 30 kg. The superstructure on the X-27 SUV model shifts its centre of gravity forward, up and slightly away from the centreline to starboard compared with the X-26 S.

The pleasure craft was CE marked for a maximum of 8 passengers. Calculations have been carried out with five persons weighing 85 kg on board, two standing near the bow and three sitting near the aft of the boat. The fuel tank was estimated to contain approx. 200 litres, the freshwater tank to be full, and the septic tank was assumed to be empty. These loading conditions correspond to the conditions on the day of the accident.

GZ curves for X-26 S and X-27 SUV are plotted in Figure 12 for heeling to starboard.

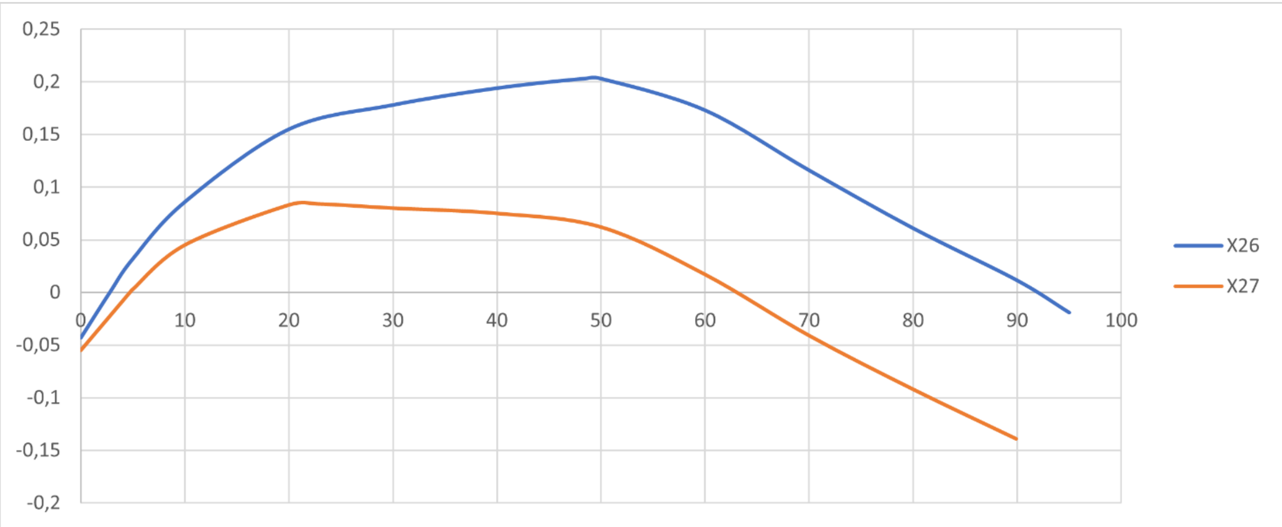

Figure 12: Comparison of the GZ curves for the boats where the capsizing condition has been assessed. Source: NSIA

The GZ curves show that the stability of the X-27 SUV is significantly reduced compared to that of the X-26 S. At an angle of heel of approx. 63 degrees, the X-27 SUV will be unable to right itself and will capsize. The X-26 S, on the other hand, can withstand significantly more heeling before it capsizes.

The area under the GZ curve represents a measurement of the boat's ability to withstand dynamic forces such as wind, waves and, in this case, a sudden sideways stop resulting from a spinout. As we can see from the two GZ curves, the X-26 S has a significantly greater area under its GZ curve compared with the X-27 SUV. This means that it will take about three times as much 'energy' for an X-26 S to capsize compared to an X-27 SUV.

As a consequence of the transverse centre of gravity (TCG) of the loading condition and lightship, the X-26 S will start with a heel of 2.8 degrees and the X-27 SUV with 4.7 degrees to starboard. This is the same side as the boat capsized towards.

This indicates that the stability is poorer to starboard than to port. The manufacturer only tested the craft's stability to port (i.e. the advantageous side). The requirements stipulated in NS-EN ISO 12217-1:2017 (section B.3.1.4) stated that «*In general boats shall be tested when heeled to both port and starboard. However, where it is clearly evident that one direction of heel is the most critical, only heel angles in this direction need be tested.*»

Since X-27 SUV listed slightly to starboard in lightship condition, the test should have been carried out to both sides or only to the starboard side.

1.9.3 DYNAMIC STABILITY

In the event of a spinout at high speed, dynamic forces will make the craft heel. The boat's GZ curve can therefore say something about the boat's ability to withstand these heeling forces. Dynamic stability is often defined as the energy required to heel a boat from one angle to another, and that thus counteracts the righting moment from static stability.

For planing craft, the hydrostatic forces, such as the hydrostatic righting arm (GZ), have less and less importance as the speed increases. The forces that do become very important are the forces from the rudder and propeller, inertia forces, hydrodynamic lift and aero-/hydrodynamic resistance. Aerodynamic lift can also be very important to some high-speed boats.

The results shown in 1.9.2 above only apply when the craft is stationary. When the craft is planing, other factors come to the fore. In that situation, the vessel's stability against heeling is determined by a static and a dynamic element.

$$C_{roll} = \rho g \nabla \overline{GM} + C_{roll}^{D}$$

where

∇ = Volume of displacement
GM = Metacentric height
C_{roll}^{D} = Dynamic stability in roll resulting from hydrodynamic pressure against the hull

The first term of the equation is the hydrostatic contribution, while the second is the hydrodynamic contribution.

The hydrostatic contribution in the equation will change when the craft reaches planing speed, as the displacement will be a lot smaller. The majority of the weight of the craft will be carried by the hydrodynamic pressure. The lifting forces can be compared to putting in negative weight, resulting in a virtual raising of the craft's centre of gravity. It will also significantly reduce the size of the wetted surface, change the static pressure situation and reduce the restoring moment in roll. As a result of all this, the hydrostatic GM will be reduced, meaning that the hydrodynamic term becomes more important in keeping the craft stable.

Using CFD calculations, Kokkonen (2018)[5] has shown the extent of wetted surface and pressure on two different 7.5-metre[6] stepped hulls from Hydrolift.[7] The wetted surface and distribution of static pressure under the hulls are shown in Figure 13 and Figure 14 for a speed of 30 knots travelling straight ahead.

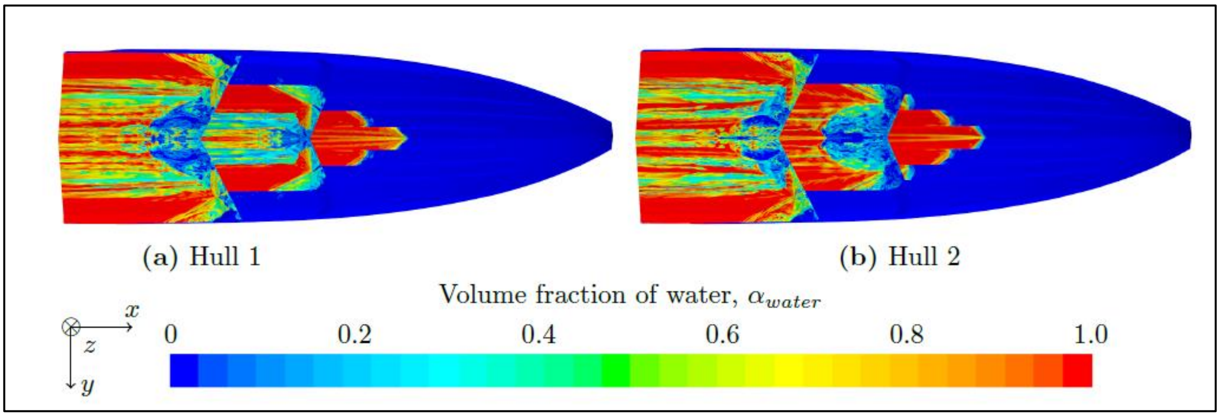

Figure 13: Wetted surface – red denotes water, blue denotes air. Source: Kokkonen (2018)

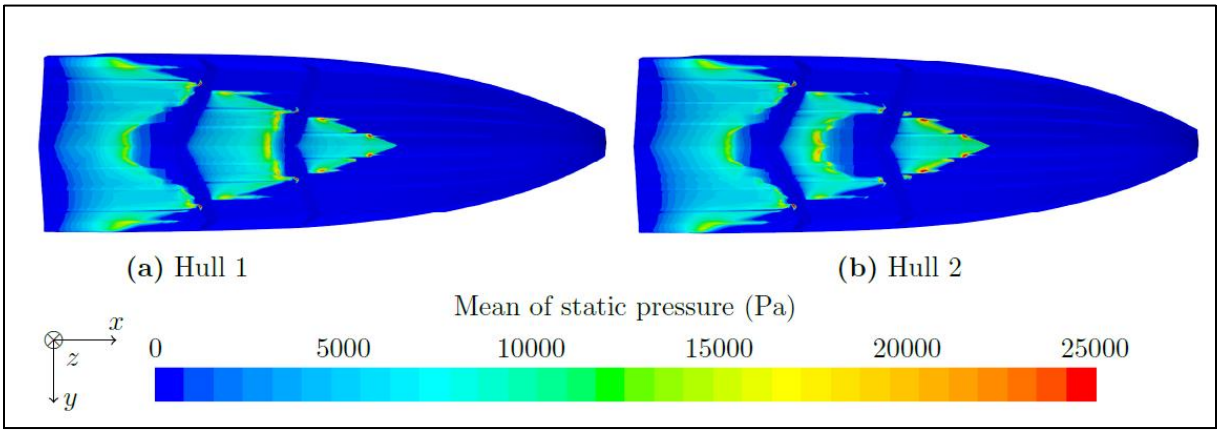

Figure 14: Contour plots of the mean positive relative pressures on the hull. Source: Kokkonen (2018)

The figures show that the wetted surface consists of three surfaces with a significantly smaller wetted area than when the vessel is stationary. We also see significant air pockets behind the steps, which makes the hydrostatic pressure situation below the vessel fairly complicated.

The claim that GM will decrease as the speed increases is in line with results from Blount et al. (1992),[8] which showed through systematic experiments that the GM, and thus the righting moment arm, decreased with increasing speeds for different hulls, see Figure 15.

---

[5] Kokkonen, T. (2018). CFD Analysis of Stepped Planing Vessels. Master's Thesis, Chalmers University of Technology
[6] The hulls of X-26 S and X-27 SUV are also 7.5 metres long.
[7] 'Hull 2' has a slightly higher step height than 'Hull 1'. 'Hull 2' has experienced a higher degree of 'porpoising' than 'Hull 1'.
[8] Blount, D.L., Codega, L.T. (1992). Dynamic Stability of Planing Boats. Marine Technology, Vol. 29, No. 1, Jan. 1992, pp. 4–12.

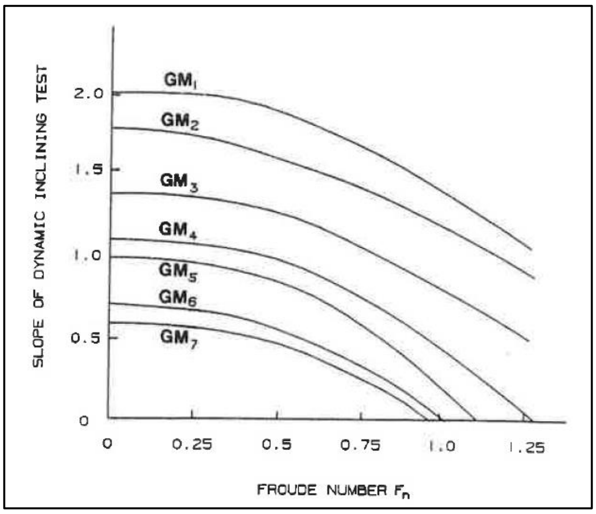

Figure 15: Reduction of GM with increasing speed – 'Dynamic Transverse Instability'. From Blount et al. (1992)

Such dynamic transverse instability (DTI) can be demonstrated through experiments where a certain angle of heel occurs without the craft being subjected to force. Blount points out that dynamic stability tests should be carried out for high-speed boats in order to map their stability at increasing speeds. It is also pointed out that there must always be sufficient hydrostatic stability to begin with.

According to Lewandowski (2004),[9] the hydrodynamic roll moment is proportional to the square of the craft's velocity (U), and the wetted breadth (B) of the craft, see the equation.

$$C_{roll}^{d} = 2 \cdot h \cdot F_{\phi}$$

where the normal force (on each side) is $F_{\phi} = f(\lambda, \beta, \tau) \cdot \frac{1}{2}\rho U^2 B^2$, and the moment arm is $h = \frac{0.8\pi B}{8cos\beta} - KGsin\beta$. We see that in addition to the importance of breadth, a smaller KG will also contribute to a greater moment arm and thereby improved stability. $f(\lambda, \beta, \tau)$ is a function of the craft's wetted length/breadth ratio (λ), dead rise angle (β) and dynamic trim (τ).

Since the X-27 SUV has higher KG than the X-26 S, this means that the hydrodynamic moment arm will be somewhat reduced (~11% reduction).

If the hydrodynamic pressure was to be disturbed, for example by the wetted surface being moved by a sharp turn or a wave, this roll moment could bring the craft out of balance and cause it to capsize. The probability of this outcome will increase if the craft's static stability margin is low (high KG, low GM).

1.9.4 LONGITUDINAL STABILITY

The figures in section 1.9.2 show that the LCG is 0.1 m further forward in the X-27 SUV model compared with the X-26 S. According to Blount et al. (1992), the LCG location is important to the dynamic stability of high-speed boats. The LCG should preferably be located aft of the centre of the wetted surface when the craft is planing. The further forward the LCG is located, the greater the probability of forward trim and loss of stability. Blount points out that a high length/breadth ratio increases the probability of loss of stability. The latter statement supports the argument in section 1.9.3, which discussed the importance of the craft's breadth. The X-27 SUV has a stepped hull,

[9] Lewandowski, E.M. (2004). The Dynamics of Marine Craft. Maneuvering and Seakeeping. Advanced Series on Ocean Engineering – Volume 22. World Scientific.

which means that its longitudinal stability is less sensitive to the LCG location compared with an ordinary V-shaped bottom design. Because it has a stepped hull, the craft will nevertheless have less trim than hulls with an ordinary V-shaped bottom, which increases the probability that the bow will sink/drop into the water, for example during a sharp turn.

1.9.5 MANOEUVRING CHARACTERISTICS

Requirements for quick turn test and avoidance line test apply to recreational craft pursuant to NS-EN ISO 11592-2:2019 Small craft — Determination of maximum propulsion power rating using manoeuvring speed – Part 2: craft with a hull length between 8 m and 24 m (ISO 11592-2:2019). According to the manufacturer, the tests were carried out, but the test documentation the NSIA has been given access to does not adequately document at what speed the tests were passed and what the craft's loading condition was. Blount et al. (1992) also point out the importance of sufficient instrumentation during such testing.

Pursuant to section 9.1 of the standard, a warning label must be placed on board containing information about the highest tested speed in relation to manoeuvrability. There is such a warning label on board, which indicates 35 knots for such turns, see Figure 16. This is only a standard sticker that has been placed there, regardless of the results from the manoeuvring tests.

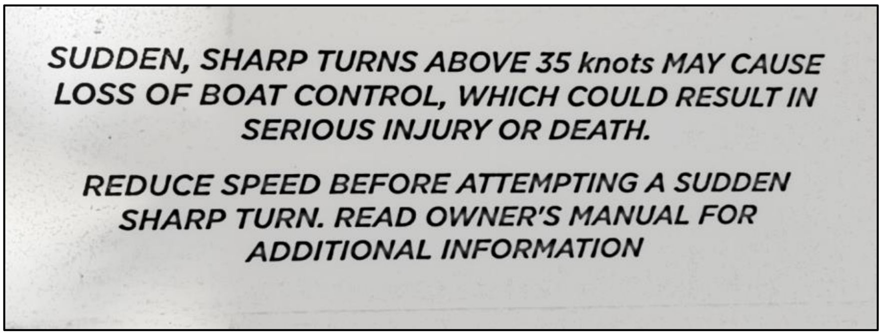

Figure 16: The warning sticker on board X-27 SUV. Source: The manufacturer

1.10 Spinout and capsizing

1.10.1 WHAT IS SPINOUT?

In connection with high-speed boats, a spinout refers to an undesirable incident where the boat loses contact with the water and spins around its own axis out of control. Pike (2004)[10] describes spinout as a serious consequence of unfortunate manoeuvring. A spinout at moderate speed is not normally dangerous. At high speed, a spinout can become more serious, and the forces involved can cause personal injury as well as material damage.

When a craft with a V-shaped bottom or a stepped hull initiates a turn at high speed, several factors that could cause a spinout come into play.

1.10.2 HEELING AND YAWING MOMENTS

When turning, the steering forces subject the craft to heeling and yawing moments, and consequently the craft will heel inward in the turn and turn the way the operator wants. The propeller forces will also have a vertical element of force.

[10] *Pike, D. (2004). Fast Powerboat Seamanship. The complete Guide to Boat Handling, Navigation, and Safety. International Marine/McGraw-Hill*

1.10.3 SIDEWAYS VELOCITY

The craft will achieve a considerable sideways velocity through the water during the turn. According to Wines et al. (2017),[11] the vessel can slip/plane sideways through the turn at a course that could exceed 50 degrees in relation to the course the craft is steering. As long as the turn is not too sharp and the speed is not too high, the turn can still be done safely, and the craft will straighten out and stabilise when it has reached its new desired course.

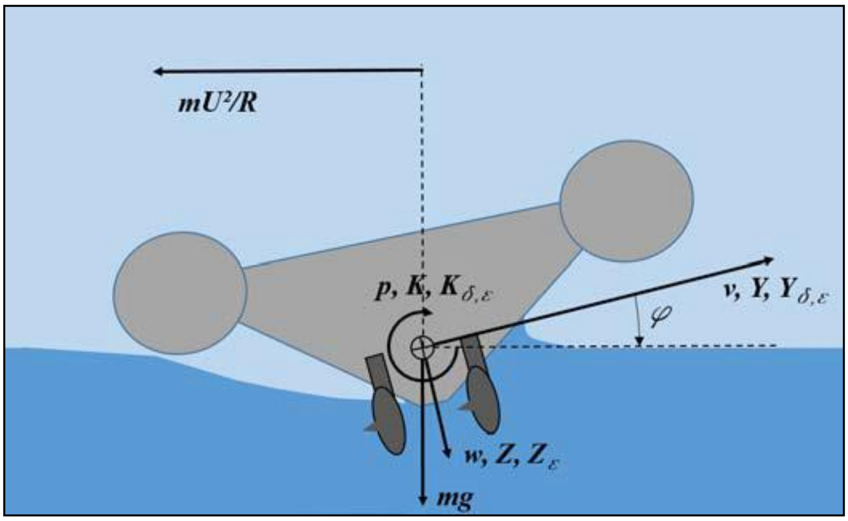

*Figure 17: Forces, moments and velocity components seen from aft in a body fixed coordinate system. **Y**, **Z** and **K** are forces/moments in sway, heave and roll, **δ** and **ε** are steering and power trim angles, while **v**, **w** and **p** are velocity components in surge, heave and roll. **U** is the RHIB's velocity vector and **R** s the turning radius. From Wines et.al (2017).*

1.10.4 HUMAN FACTORS

Problems can arise if the speed is too high when the turn starts. Once an operator realises that the boat's speed is too high, the natural reflex will generally be to reduce the throttle to lower the speed. This will cause the bow to drop, and the moment from the propeller heeling the vessel inward during the turn will be reduced. This could give rise to an imbalance of forces. Such a throttle reduction has been found in connection with this accident.

1.10.5 IMBALANCE OF FORCES

During a normal turn, the hull's 'point of rotation' and the forces from the propeller will reach an equilibrium during the turn. If an imbalance occurs and the bow suddenly drops, this point of rotation will suddenly shift forward, increasing the forces from the propeller's moment arm.

If this is combined with a throttle reduction, the moment from the propeller that heels the craft inwards during the turn will be reduced, and the craft could list in the opposite direction. This could cause a spinout, and this is more likely to happen with a stepped hull because the point of rotation in a turn is further forward for such craft than for those with an ordinary V-shaped bottom. If the outer side of the craft as it turns were to sink into the water during such a spinout incident, this would trigger intense hydrodynamic forces, causing a sudden sideways stop and possible capsizing.

---

[11] Wines, C., Hamstad, T.S. (2017). Experimental Exploration of Spinout Incidents with a Remote Controlled High-Speed RHIB. 14th International Conference on Fast Sea Transportation – FAST 2017, Nantes, France.

1.11 Supervisory scheme

The legal authority for supervision of pleasure craft is the Product Control Act Section 8, cf. the Regulations on Manufacturing etc. of Recreational Craft etc. Section 30. The Regulations on Manufacturing etc. of Recreational Craft etc. implements the Recreational Craft Directive 2013/53/EU. The Regulations and Directive have a market perspective, and consequently only new boats (i.e. boats placed on the market) and manufacturers are subject to supervisory activities.

The NMA uses three different control methods for pleasure craft through its supervisory scheme: audits of manufacturers, inspection of individual craft and document control.

On average, the NMA audits one manufacturer a year. The industry association Norboat has 49 enterprises registered as boat manufacturers. They are not all active, but there are also manufacturers that are not members of the industry association. There is no complete and accurate register over the exact number of manufacturers. Supervisory activities are largely limited to cases where accidents have occurred or the NMA otherwise becomes aware of deficiencies. Document control takes place in collaboration with Norwegian Customs and Excise in connection with import.

1.12 Investigation of engine data from three accidents involving X-27 SUV craft

The investigation has shown that a total of three craft of Malmhella’s type have capsized.

1.12.1 ENGINE DATA FROM MALMHELLA, BUILD NUMBER 4

Following the accident on 30 October 2022, engine data were sent to the manufacturer. The final 30 seconds the engine was in operation are shown in Figure 18.

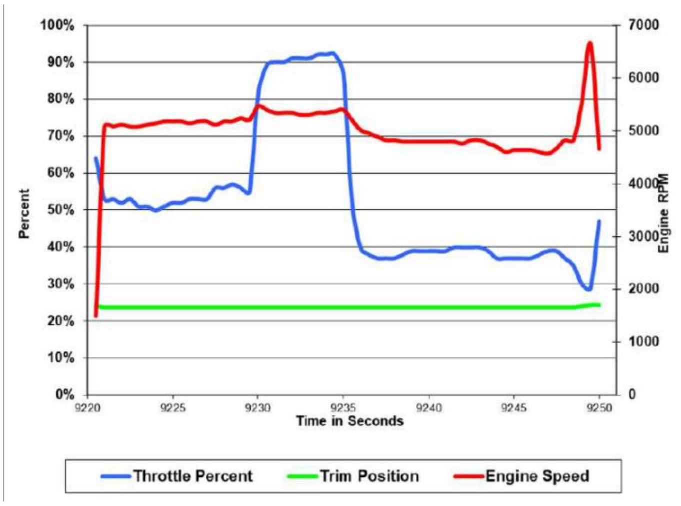

Figure 18: Engine data from Malmhella Source: Engine manufacturer

The engine’s trim is stated in per cent, but this is only a relative indication of changes of position, not the actual trim in per cent. The steep increase in rpm at the end of the graph is consistent with a propeller running out of water.

1.12.2 ACCIDENT INVOLVING TEST BOAT, BUILD NUMBER 1

On 27 November 2020 in Stavanger, sea conditions were calm and the craft was travelling at a speed of approx. 35 knots in a slight turn to port when it capsized. There were two persons on board. The starboard window was smashed and the sliding door bent. Both persons on board suffered minor injuries.

Figure 19 shows the final 30 seconds before the accident. The data show high throttle per cent, probably with the lever pushed as far as it would go, for 18 seconds, before it was reduced to approx. 20% over a period of 7 seconds before increasing again. This could be a result of the propeller briefly losing resistance before the boat made contact with the water again and capsized. This also tallies with information provided by the operator of the craft, who stated that the speed was reduced and a turn initiated before the accident occurred.

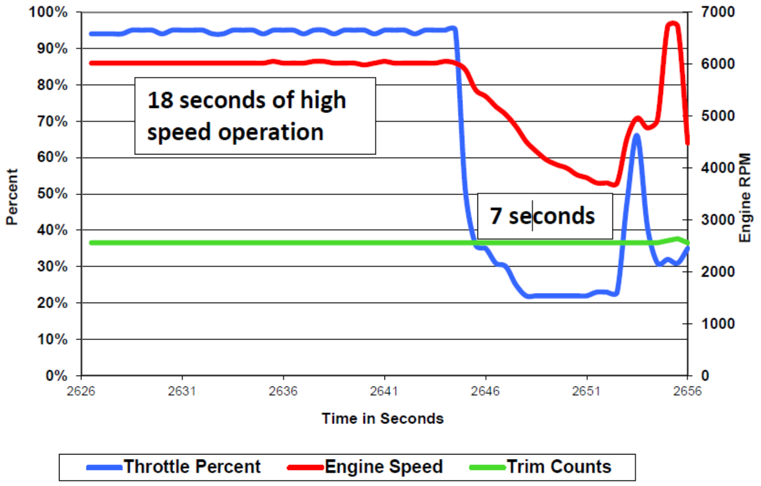

Figure 19: Engine data from the first incident involving the craft type. Source: Engine manufacturer

1.12.3 ACCIDENT IN FINLAND, BUILD NUMBER 9

On 26 June 2022, the craft was taken for a test run, and the operator has stated that the craft was travelling in a straight line at a speed of about 35 knots when the bow suddenly and unexpectedly moved sharply to port. The boat consequently capsized and started to sink. The operator was wearing an inflatable life jacket that inflated when the operator entered the water. The operator got out of the boat and was able to summon help.

Figure 20: Engine data from the first incident involving the craft type. Source: Engine manufacturer

1.13 Implemented measures

On 20 April 2023, Hydrolift AS distributed a temporary prohibition on use to owners and dealers of this type of craft, in which the following was stated:

> *Hydrolift AS is working on a safety update for Hydrolift X-27 SUV on the basis of reported accidents. Until we have received clarification from the Norwegian Safety Investigation Authority / the authorities and safety campaign, we have chosen to implement a full prohibition on the use of this model. We deeply regret this, but will get back to you with more information as soon as we have an update.*

The manufacturer has, in consultation with the NMA, arrived at measures that will allow X-27 SUV to be CE marked again. The measures mainly consist of improving the boat's stability by means of permanent ballast placed below its centre of gravity. At the time of publication of this report, the manufacturer had modified one craft and carried out internal practical testing. The NMA will take part in practical testing before the final CE marking.

The manufacturer has stated that they will check their own procedures for testing and documentation in connection with boat production.

2. Analysis

2.1 Introduction 28
2.2 Assessment of the sequence of events 28
2.3 Trigger factors for spinout 28
2.4 Assessment of capsizing 29
2.5 The craft's design and stability 30
2.6 CE marking of the craft 30
2.7 Application and interpretation of standards in connection with CE marking 31
2.8 Stability requirements in the ISO standard 31
2.9 The training situation 32
2.10 Survival aspects 33

2. Analysis

2.1 Introduction

The accident involving Malmhella took place in connection with the practical part of a high-speed course for operators of pleasure craft.

We start the analysis with an assessment of the sequence of events. The physical conditions relating to the pleasure craft, spinout and capsizing will then be considered. We go on to consider circumstances relating to the craft’s design and stability characteristics as well as the process related to CE marking and stability requirements. The analysis concludes with a discussion of the training situation and some survival aspects.

2.2 Assessment of the sequence of events

The incident occurred as the pleasure craft completed a zig-zag run and was just starting to turn to port to turn around. The speed was first reduced as the boat was approaching the turn, and then again once the turn had commenced and the craft was drawing level with the buoy. The actual training situation and interaction in this situation are assessed in section 2.9. The NSIA is of the opinion that a combination of high speed entering a turn and subsequent reduction of speed triggered a spinout and a sudden stop. This is considered in more detail in section 2.3. The energy involved, in combination with the design and stability characteristics of the craft, caused it to capsize. This will be discussed in detail in sections 2.4 and 2.5.

The course participants have stated that they found themselves in a chaotic situation where everyone was doing what they could to evacuate from the water-filled pilothouse. Some were injured and needed assistance to get out of the pilothouse. The five persons’ life jackets were fully or partly inflated. This made the space more crowded and gave rise to a stressful situation with buoyancy under the capsized boat. In the NSIA's opinion, the efforts of the persons on board themselves helped to ensure that no lives were lost. They all managed to get up on the keel of the sinking vessel and were rescued. Circumstances related to survival and rescue are considered in section 2.10.

2.3 Trigger factors for spinout

A number of unfortunate effects followed when the craft approached the final turn at a high speed which was then reduced through the turn. The heeling moment of the steering forces was reduced, which allowed the inertia and hydrodynamic forces to roll the craft out of the turn.

The reduction in speed caused the hull to lose hydrodynamic lift, and the bow was pushed down and forward by inertia forces. The bow of a stepped hull is already fairly low down compared with ordinary V-bottomed hulls, and when the throttle is reduced, this will cause the bow to sink even further.

The steps continued to provide air lubrication back under the hull. At the same time, the bow caught the water and became the craft's rotation point and point of attack for the lateral hydrodynamic forces. This caused the stern to lose contact with the water and rotate with the craft’s movement, see Figure 21. The hull came to a sudden stop when it made contact with the water again.

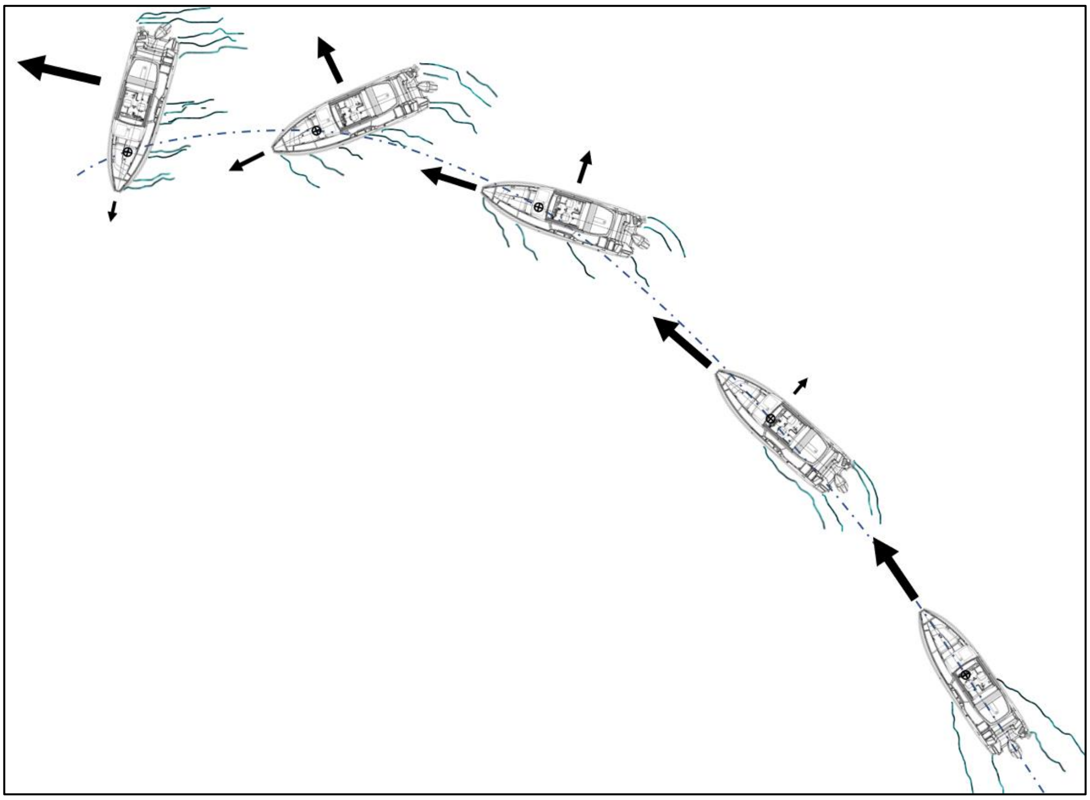

Figure 21: The figure illustrates a craft that enters a turn resulting in a spinout. The arrows illustrate the velocity vector and show how the sideways speed gradually increases. When the forward speed of the craft decreases, the boat's point of rotation is shifted forward because the reduced speed lowers the bow. The point of rotation is indicated by the black dot that the dotted line runs through. Source: NSIA

2.4 Assessment of capsizing

As the sideways movement suddenly stopped, the craft continued to list to starboard. This caused the starboard side of the pilothouse to make contact with the sea, and the window broke. The craft was unable to right itself and capsized. Findings on the craft, see section 1.4, indicate that great forces were at work on the outer side of the turning craft during the incident.

A high centre of gravity and poor stability increased the probability that the sum of inertia forces and hydrodynamic forces exceeded the righting moment, which in turn caused the craft to capsize, see Figure 22.

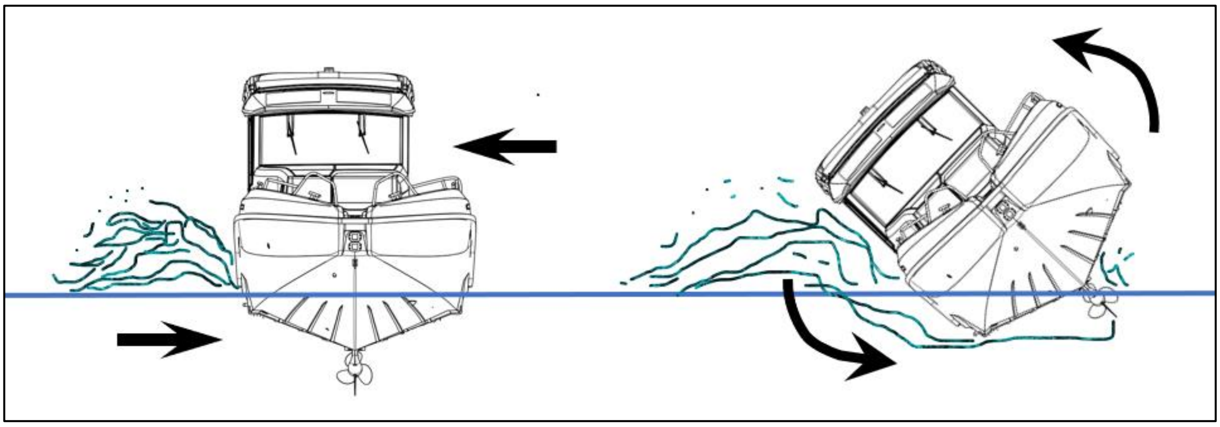

Figure 22: Illustration of a schematic drawing seen from ahead showing a vessel out of balance that capsizes.

2.5 The craft’s design and stability

The NSIA compared the stability of models X-27 SUV and X-26 S, as their hulls are identical. The result shows that the X-27 SUV has significantly poorer stability characteristics than the X-26 S, which is primarily due to the higher centre of gravity caused by the pilothouse. The higher centre of gravity reduced the area under the GZ curve, which reduces the margins in terms of resisting dynamic forces.

The calculations do not take into account the dynamic forces that affected the craft, but show how capable it could have been of resisting the heeling moment caused by the sudden stop and the dynamic forces. Good static stability is an indicator of whether the craft will capsize or be capable of righting itself after heeling, but the stability characteristics are less important to the spinout itself.

The poor stability was a contributing factor to the craft capsizing. This is a safety problem for the craft type Hydrolift X-27 SUV. The manufacturer has subsequently distributed information that existing craft are not to be used and no new ones are to be sold until the boat type has undergone a safety upgrade. The NSIA nevertheless submits a safety recommendation addressed to the manufacturer to implement measures to ensure good stability characteristics for the craft type X-27 SUV, in addition to a safety recommendation to the NMA to carry out an audit of the manufacturer.

2.6 CE marking of the craft

NS-EN ISO 12217-1:2017 requires either stability calculations or a practical inclining test to be carried out before a boat can be CE marked. The manufacturer chose a practical inclining test. The investigation has shown that the test carried out did not conform to the procedure described in the standard. The NSIA is of the opinion that if the tests had been correctly done, the result would have provided a clear indication of the craft's poor stability.

According to ISO 11592-2:2019, the craft should have undergone a manoeuvring test. The test is intended to verify circumstances relating to the craft’s dynamic stability characteristics, see 1.9.3. The manufacturer’s test was based on inadequate validation and verification. Such tests must be meticulously documented. As a minimum, there should be chart plotter transcripts, information about loading conditions, and angles of heel and trim should be measured throughout the manoeuvres.

The CE marking was based on the manufacturer’s internal control and documentation. Had the manufacturer chosen a different design module, one that required third-party control of the craft in connection with CE marking, then factors relating to the stability would probably have been identified at an earlier stage. They could also have been identified through an audit by the NMA.

The NMA audits manufacturers, but does not apply a systematic approach to audits, as no comprehensive overview of the industry exists. Manufacturer audits have been limited to about one a year over the past five years, depending on capacity. In practice, this means that the chance of a certain manufacturer being audited is slim, unless the NMA is notified of circumstances that suggest that an audit is required.

The NSIA submits a safety recommendation to the Norwegian Maritime Authority on this point.

2.7 Application and interpretation of standards in connection with CE marking

The investigation has shown that the pleasure craft's CE marking was based on an incorrect interpretation of NS-EN ISO 12217-1:2017 during its initial testing. Consequently, the conditions for the CE marking were not met.

The NSIA is of the opinion that the standard was also misinterpreted during the supplementary inclining test. The manufacturer placed weights representing luggage near the bottom of the craft, at the centre of the boat, which had a favourable effect on the stability before the weight of passengers was added. This gave the craft a better initial stability than it would have had without luggage weights on board.

Although NS-EN ISO 12217-1:2017 did not describe precisely where luggage weights should be placed during practical inclining tests, there are other indications in the standards that the weights should be placed where they are unfavourable to the stability. The purpose of the standard for practical inclining tests is to assess how much the boat will heel by placing all persons on board to one side in the most unfavourable way possible. Pleasure craft are often used without people bringing luggage, and the loading condition tested would not reflect these conditions, which would then be less favourable. As section 3.4.4 of the standard specifies that the weights representing luggage and personal belongings should not total *less than* 20 kg, this implicitly means that they should not be placed in a favourable position in terms of stability.

In cases where luggage weights are placed where they benefit stability, this allows manufacturers to fictitiously improve stability by placing weights below the boat's centre of gravity. The luggage weights then become a prerequisite for CE marking, and individual journeys without luggage weights could put the boat in a loading condition for which it has not been tested or approved.

The NSIA submits a safety recommendation to the Norwegian Maritime Authority on this point.

2.8 Stability requirements in the ISO standard

The investigation has shown that the CE marking is based on ISO standards that do not adequately address stability requirements for this craft group. This concerns requirements for both static and hydrodynamic stability. Hydrodynamic forces affect the boat as it moves through the water. These forces can affect the boat's stability in different ways, particularly high-speed craft.

It will be up to the manufacturers' knowledge and experience of boat-building to take account of the fundamental principles to ensure that the hull design has inherent stability as regards both static and dynamic states. If a vessel is designed with a low centre of gravity, that provides a good basis for hydrodynamic stability. The CE marking is based on ISO standards, which are not particularly well suited to evaluating the effect of dynamic stability factors on craft with a high potential speed, such as the X-27 SUV.

It is possible to meet the heeling requirements set out in the standard through the practical test while still having fundamentally inadequate stability. The NSIA carried out a practical inclining test with only six people, which is two fewer than the craft was CE marked for. It is possible to place the persons on board and achieve a permissible angle of heel, but minor changes to the positioning of weights in accordance with the test requirements made a great difference.

Figure 23 shows a calculation of six persons placed to starboard where the resulting angle of heel will be within the requirement for CE marking. The GZ curve shows a list of 14.6 degrees, which is within the requirement, but nevertheless shows that, although positive, the stability is very poor between this angle and 60 degrees. In this case, a minor shift of the weights during the practical stability test will have a great effect on the angle of heel.

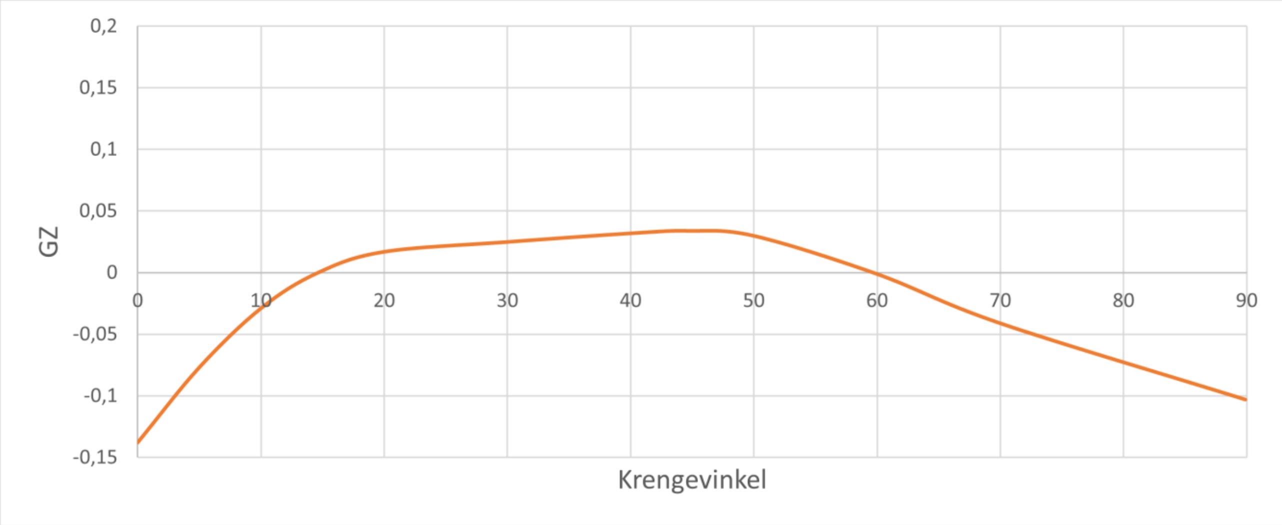

Figure 23: GZ curve illustrating the loading condition based on 50% fuel, a full freshwater tank and six persons on the starboard side simulating the practical implementation of testing in accordance with NS-EN ISO 12217-1:2017. Source: NSIA

The standard describes that weights should be moved around during the test to ensure that they are in the most unfavourable location. As the standards are currently designed, tests will not identify residual stability because they stop within the requirement without mapping the overall static stability. For craft with a high potential speed, such as the X-27 SUV model, there should be requirements in place for e.g. calculations of GZ curves and use of the criteria for area under the GZ curve. A more thorough mapping of static stability is important to evaluate sufficient area to withstand dynamic forces.

The NSIA considers NS-EN ISO 12217-1:2017 inadequate as a safety standard for the stability of craft such as X-27 SUV. This represents a safety problem, and the NSIA submits a safety recommendation to the NMA on this point.

2.9 The training situation

The purpose of the practical part of the course was to make the operators aware of how to handle the craft in different situations and at different speeds. When the operator made an unexpectedly tight turn, it was impossible for the instructor to intervene by physically taking over control until it was too late and the consequence had already become a reality. It is important in a training situation that the instructor has the situation under control, as the situation can quickly change at high speed, and has the possibility to correct errors. The interaction between the instructor and operator had not given them a sufficient shared situational awareness and understanding of what was to be done.

The course participant was an experienced boat operator, but did not have experience of stepped hulls. This is probably the reason why what he himself saw as a sensible manoeuvre triggered this incident. When a craft is improperly operated at high speeds, large quantities of energy are released that could cause significant personal injury and material damage. The NSIA is of the opinion that a high-speed course must entail a particular focus on the conditions for operational limits for certain hull designs.

The course framework did not plan for the training to take place at speeds in excess of 30 knots, but on this course, the participants could drive faster if they mastered it. Generally speaking, increased speed increases the risk of energy released in the event of an incident, but also the risk of spinout in cases where the operator is unfamiliar with the characteristics of the craft.

2.10 Survival aspects

When the craft suddenly capsized, the instructor and course participants found themselves inside the pilothouse of a craft that was upside-down in the water. The inflated life jackets were counterproductive to begin with, as the buoyancy and use of crotch straps made it more difficult to evacuate from the craft. The NSIA would like to point out that it is essential to use life jackets in boats where required and will not argue against their use. In cases where floatation devices are used inside enclosed spaces and covered areas on board boats, their use should be subject to a risk assessment of the advantages and disadvantages.

3. Conclusion

3. Conclusion

The incident happened in connection with the practical part of a high-speed licence course. The combination of high speed entering a turn and a reduction in speed caused a spinout and subsequent capsizing.

The investigation has shown that the X-27 SUV model has significantly poorer stability characteristics than the X-26 S model, primarily due to the higher centre of gravity caused by the pilothouse. The poor stability was a contributing factor to the craft capsizing. This constitutes a safety problem for the craft type Hydrolift X-27 SUV, and the manufacturer is recommended to implement measures to ensure good stability characteristics for this type of craft, and the NMA is advised to carry out an audit of the manufacturer.

The practice used by the manufacturer in connection with the tests conducted for the original CE marking of this pleasure craft was based on the incorrect location of persons on board, among other things, and thus on an incorrect interpretation of the applicable standard. Consequently, the conditions for the CE marking were not met. The NSIA is of the opinion that if the testing had been correctly done, the result would have provided a clear indication of the craft's poor stability. This is a safety problem, and the NMA is recommended to carry out more frequent controls of CE marking of pleasure craft.

The investigation has also shown that the incorrect interpretation of NS-EN ISO 12217-1:2017, on which practical testing is based, contributes to making it possible to fictitiously improve the stability by using weights representing luggage placed below the craft’s centre of gravity as permanent ballast. The weights then become a prerequisite for meeting the stability requirements stipulated in the standard. The NMA is recommended to implement measures to ensure that craft provided with CE marking have been correctly tested.

The CE marking is based on ISO standards, which are not particularly well suited to evaluating the effect of dynamic stability factors on craft with a high potential speed, such as the X-27 SUV. Moreover, the standard is inadequate because it does not require an overall mapping of static stability, particularly as regards requirements for residual stability under different loading conditions. It is possible to meet the requirements stipulated in the standards and still have poor stability. This represents a safety problem, and the Norwegian Maritime Authority is recommended to implement measures to ensure that the regulatory framework for CE marked recreational craft contain the requirements necessary to ensure good fundamental stability.

4. Safety recommendations

4. Safety recommendations

The Norwegian Safety Investigation Authority submits the following recommendations[12] for the purpose of improving safety at sea:

Safety recommendation MARINE No 2023/02T

On 25 October 2022, the pleasure craft Malmhella was carrying a group of course participants who were taking the practical part of the high-speed course when the craft capsized.

The poor stability was a contributing factor to the craft capsizing, and the investigation has shown that the craft did not meet the relevant requirements for CE marking. This represents a safety problem for this type of craft.

The Norwegian Safety Investigation Authority recommends that the manufacturer, Hydrolift AS, implement measures to ensure that the craft type X-27 SUV has good stability characteristics.

Safety recommendation MARINE No 2023/03T

On 25 October 2022, the pleasure craft Malmhella was carrying a group of course participants who were taking the practical part of the high-speed course when the craft capsized.

The poor stability was a contributing factor to the craft of the type X-27 SUV capsizing, and the investigation has shown that the craft did not meet the relevant requirements for CE marking. This problem was not identified by the manufacturer's own quality control, and Hydrolift AS has not previously been audited by the supervisory authority. This represents a safety problem.

The Norwegian Safety Investigation Authority recommends that the Norwegian Maritime Authority carry out an audit of Hydrolift AS to ensure sufficient production control.

[12] The investigation report is submitted to the Ministry of Trade, Industry and Fisheries, which will take the necessary steps to ensure that due consideration is given to the safety recommendations.

Safety recommendation MARINE No 2023/04T

On 25 October 2022, the pleasure craft Malmhella was carrying a group of course participants who were taking the practical part of the high-speed course when the craft capsized.

The CE marking of the craft was based on the manufacturer's internal control and documentation, which were inadequate. The Norwegian Safety Investigation Authority considers it a safety problem that manufacturers are not subject to frequent controls by the supervisory authority. In particular, this applies to audits of manufacturers that make use of internal control.

The Norwegian Safety Investigation Authority recommends that the Norwegian Maritime Authority increase the frequency of audits targeting manufacturers, with a particular focus on stability.

Safety recommendation MARINE No 2023/05T

On 25 October 2022, the pleasure craft Malmhella was carrying a group of course participants who were taking the practical part of the high-speed course when the craft capsized.

The Norwegian Safety Investigation Authority is of the opinion that the standard NS-EN ISO 12217-1:2017 was misinterpreted during the supplementary inclining test. This meant that luggage weights were placed in locations advantageous to stability. This makes it possible for manufacturers to fictitiously improve the stability by using permanent ballast. The luggage weights thus become a prerequisite for CE marking. Individual journeys without luggage weights could put the boat in a loading condition for which it has not been tested or approved.

The Norwegian Safety Investigation Authority recommends that the Norwegian Maritime Authority implement measures to ensure that recreational craft provided with CE marking have been correctly tested.

Safety recommendation MARINE No 2023/06T

On 25 October 2022, the pleasure craft Malmhella was carrying a group of course participants who were taking the practical part of the high-speed course when the craft capsized.

The NSIA is of the opinion that poor stability was a contributing factor to the craft of the type X-27 SUV capsizing. Standard ISO 12217-1:2017, which forms the basis for the CE marking, is not well suited to assess the effect of dynamic stability factors on craft with potential speeds as high as the X-27 SUV. Moreover, the standard is inadequate because it does not require an overall mapping of static stability, particularly as regards requirements for residual stability under different loading conditions.

The Norwegian Safety Investigation Authority recommends that the Norwegian Maritime Authority implement measures to ensure that the regulatory framework for CE marked recreational craft contain the requirements necessary to ensure good fundamental stability.

Norwegian Safety Investigation Authority
Lillestrøm, 28 June 2023

References

References

BLOUNT, D.L., CODEGA, L.T. (1992). Dynamic Stability of Planing Boats. Marine Technology, Vol. 29, No 1, Jan. 1992, pp. 4–12.

ELIASSON, R., LARSSON, L. and ORYCH, M. (2014). Principles of Yacht Design. Bloomsbury Publishing.

FALTINSEN, O.M. (2005). Hydrodynamics of High-Speed Marine Vehicles. Cambridge University Press.

KOKKONEN, T. (2018). CFD Analysis of Stepped Planing Vessels. Master's Thesis, Chalmers University of Technology.

LEWANDOWSKI, E.M. (2004). The Dynamics of Marine Craft. Maneuvering and Seakeeping. Advanced Series on Ocean Engineering – Volume 22. World Scientific.

PIKE, D. (2004). Fast Powerboat Seamanship. The complete Guide to Boat Handling, Navigation, and Safety. International Marine/McGraw-Hill

WINES, C., HAMSTAD, T.S. (2017). Experimental Exploration of Spinout Incidents with a Remote Controlled High-Speed RHIB. 14th International Conference on Fast Sea Transportation – FAST 2017, Nantes, France.