

FAILURE MODE AND EFFECT ANALYSE IN HIGH SPEED CRAFTS.

Capt. Merayo, Pedro. Capt. Martín, Agustí

Abstract

The aim of this report is to identify the correct procedures when facing anomalies which could put the vessel at risk. In so doing, the basic workings of this type of ship, in terms of its propulsion and evolution, will be explained.

Keywords

Safety, high speed crafts, failure mode.

1. LOGITUDINAL AND TRANSVERSAL MOTION

In this type of vessel, a bow thruster is not required because appropriate handling of the jets, orientating them correctly and with adequate control over the opening or closing of the buckets¹, is enough to make the vessel stop, go ahead or astern, move laterally to the port or starboard, or to make her rotate around her own geometrical centre.

Fig.1. Catamaran with water jets in navigation



www.greekislands.gr

Basically, the handling of a vessel during a manoeuvre is limited to two situations: one relating to longitudinal or lateral motion, ahead or astern and port or starboard, and the other to rotation around a point.

¹ Water jet elements used to change the direction of the propulsion from ahead to forward and vice versa

A longitudinal motion can be achieved without any difficulty by holding the nozzles parallel to the centre line of the vessel and opening the buckets to go ahead, or closing them (to reverse the water flow) to go astern.

To move the vessel transversally it is necessary to combine the strength of the four jets² and make them act on the rotation or transfer point we are most interested in, depending on the situation. To do so, it is necessary to know how the rotation point (on which the forces produced by the jets will act) works, and how its position can be controlled.

High speed vessels have their rotation point afore when they travel at their cruising speed, and even more forward in single hull vessels. However, when the vessel is stopped or manoeuvring at slow speed, it is possible to control the rotation/transfer point through the vessel's centre line by opening or closing the nozzles on each side.

The vessel will always move and rotate to the side where the buckets are closed, or in other words, to the side that is going astern. As a general rule, if we want to achieve a pure lateral movement, we should have in mind that the nozzles which go ahead generate more thrust than the ones that go astern. For this reason, we must compensate for this effect by fully closing the nozzle astern buckets and opening the other side to only 70% ahead.

To manoeuvre the vessel with a lateral movement parallel to the jetty, the steering nozzles must be opened 20° outward, with the buckets situated on the side we would like to move to 100% closed (astern), and the buckets on the opposite side 70% open (ahead). With this jet arrangement the vessel can be made to move sideways.

Fig. 2. Steering nozzle- water jet



www.liveyachting.com

If we want to make a slight turn to the side we are moving to, the nozzles must be opened 10° outward with the buckets kept in the same position as before. If the nozzles are kept at 10°, the rotation point of the vessel moves afore and the vessel is made to move transversally with a slight shift ahead and a smooth turn to the side where the buckets are closed.

² Water jets

If during the movement the buckets are maintained in the previous position, and the nozzles are opened to the maximum of 30° outwards, the rotation point moves to aft, making it move faster than the fore. This is to say that the vessel is moving while the fore turns slightly towards the opposite side of the main movement.

The turn manoeuvre when the vessel is stopped or moving at slow speed is obtained by steering the nozzles from both sides 30° inwards, closing the buckets 100% (astern) on the side you want to turn to and opening them 70% on the other side, with the object of compensating for the difference in strength between the ahead and astern jets. With this, two equal forces in opposite directions to those created by the jets will act on the natural rotation point of the vessel, situated approximately a third of the length from afore, creating a torque which will make the fore of the vessel turn to the side where the buckets are closed.

These manoeuvres are performed via the manoeuvre console, normally situated in each wing, although catamarans are now being produced without them. This makes it necessary to manoeuvre from the console bridge without having a direct view of the jetty when the vessel is less than 50 metres from it, with only the images of the video monitors and the indications of the fore and aft officers as a guide.

There are two ways to perform the manoeuvre from the console: the normal or automatic mode, and the manual or backup mode. In the former, two controllers situated in the lower part of the console are used: the master, a large joystick which moves in all directions and has a system which can lock the it in any position, and with which all the vessel movement commands are made; and the "moment potentiometer", which is used only to turn. The position of these two controllers is interpreted by a PC which sends an electronic signal through a feedback cable and executes the command received, steering the nozzle and opening and closing the buckets. If the master controller is being used and maintained in a particular position (e.g. for a lateral movement), and at the same time the moment potentiometer is turned, the nozzle position indicator will close, showing the transition from a transversal movement to a turn in the same direction. As soon as we stop the activation of the "moment potentiometer", the nozzles will return to their previous transversal movement position.

The manual or backup mode is used as a separate system from the automatic. In this case the PC does not send the manoeuvre signals to the nozzle. Instead the small joysticks situated in the lower part of the manoeuvre console are used. Each joystick steers the pair of nozzles on its side with two movements: port and starboard to steer the nozzles and fore and aft to open or close the buckets. The system operator must have a very clear idea of this, being aware at every moment of where and how the forces of the jets are acting, because any uncertainty during manoeuvre can cause an incident.

The manual manoeuvre mode therefore demands concentration and requires that the basic procedures are followed in order to avoid any mistakes. As a general rule, the first step to keep in mind when preparing any manoeuvre is to orientate the steering nozzles by opening or closing them to prepare a transfer or a turn manoeuvre respectively. Following this, the buckets can be operated on, closing the ones on the side to which we want to turn or move towards and opening those on the other side. An inverse procedure is used to pass from one situation to another, firstly putting the buckets in the neutral (or 0%) position, thereby eliminating the forces produced by the transfer or turn, and then reorientating the steering nozzles to the position we require.

2. POSSIBLE FAILURES DURING THE MANOEUVRE

We will now consider the possible failures which may occur during a manoeuvre and how to address them.

2.1. MAIN ENGINE FAILURE

Depending on the number of engines affected, this could lead to the vessel becoming inoperable. Factors such as oil mist in the sump, an overheating bearing, starter motor failure etc. can stop the engine or make it impossible to start.

Vessel berthed, one engine failing to start:

- A. Buckets indicator to neutral.
- B. Steering nozzle indicator to 0 (rudder amidships position).
- C. Trim tabs³ stowed
- D. Main engine indicator showing around 390 rpm (except for the failed engine at 0 rpm).

Solution:

Couple the corresponding engines of each hull, SIME-PIME or SOME-POME, thereby avoiding overloading the working engine if both engines on the opposite side are coupled.

When the vessel has left the berth and is going ahead, the other operational engine should be coupled.

When the vessel starts to gain speed, set the inoperative engine to backup or manual mode, which uses a system independent of the automatic one. In this case the PC does not send the manoeuvre signals to the nozzle, but rather two small joysticks situated in the lower part of the manoeuvre console are used. Each joystick steers the two nozzles of each side with two movements, port and starboard to orientate the nozzles, and fore and stern to open and close the buckets. By using the corresponding handle, activate opening mode and the tiller of each hull will open.

At the same time, adjust the trim tabs, leaving the side where the engines are operative in normal mode while backup mode is set for the side where the inoperative engine is. Fix the trim tab on this side to 50% using the switch. An initial cavitation is noticeable in the ramp-up if the trim tabs have not been activated. This will increase with speed, indicating that the tabs must be activated without delay.

Repeat this process in reverse when the vessel approaches harbour. Reduce the rpm, in turn reducing speed and power. The engines should be idling when the buckets arrive at the fully open position.

To transfer control from the navigation to the manoeuvre console, follow these steps:

³ Flaps situated in the lower part of a water jet

- A. Put the four opening handles for the buckets, along with the motor revolution handles, in neutral position. The bucket indicator needles will be at 0 except for that of the inoperative engine. Put this at 0 by using the corresponding tiller.
- B. Stow the trim tabs on the side of the operative engines and use the corresponding controller to stow the buckets on the other side.
- C. Set Normal mode for the trim tabs as well as for the inoperative engine.
- D. Rudder amidships.
- E. Transfer control by pressing the button situated in the navigation console, which indicates whether it is in navigation or manoeuvre mode.
- F. Take control of the manoeuvre console and decouple the inoperative engine.

The inoperative engine becomes operative while the vessel is sailing.

Procedure to be followed to couple the engine.

- A. Put the bucket of the inoperative engine in neutral position with the tiller.
- B. Couple the engine and use the controller to open the buckets.
- C. Set the engine control (in backup mode) to normal.
- D. Set the trim tab on the side that was in backup mode to normal.
- E. Gradually increase the revolution of the engine until it matches the others.

Fig. 3. High speed vessel operation control console





2.2 TRIM-TAB STOWAGE FAILURE

The trim-tab is a considerably large piece of metal which is essential both for navigation and manoeuvre. If a trim tab failure occurs during navigation, it will be immediately noticeable due to the considerable cavitation produced by the water stream hitting the flap.

During a manoeuvre, the incorrect stowage of trim tabs can produce a very high risk of accident. It is essential to verify the LED indicators which show the correct stowage of the flap; otherwise, if we want to go astern and close the buckets, the water stream will impact on a part of the flap, projecting the vessel ahead with a force proportional to the power given to the engines.

Solution:

If the failure occurs during navigation, initiate backup mode and regulate to 50%. However, if local control is not possible, the flap can be isolated and left in floating position.

Before the manoeuvre starts, verify that the trim tabs are stowed when the buckets are put in neutral position. If not, use the protected buttons marked “emergency flaps-up”. If this emergency system fails, manual emergency stowage can be performed by hoisting the trim tabs via a winch or pulley which pulls a rope tied fast to the shaft. This will only be possible if the hydraulic system has previously been depressurised.

2.3. FAILURE CAUSED BY FEEDBACK CABLE BREAK.

The mechanical Morse cable is used to produce feedback signals. It moves two transducers installed in each water jet, the main one situated in the outer jet and the other, which remains at standby, in the inner.

The transducers send separate direct and indirect signals through an interface to the LMP and the MIM; these signals are compared in the LMN/MIM which produces an output signal and sets off an alarm when the normal limits are exceeded.

If one of these cables breaks, an alarm is activated because a limit in one of the indication signals has been exceeded.

Solution:

In the case of failure of the input signal to the main transducer, the alarm (mechanical steering feedback) is set off, and the standby transducer in the inner jet automatically becomes the main one, thus avoiding steering control failure.

If both signals fail, the rudder will remain immobile in the alarm position, which will force the manoeuvre to stop in order to proceed to system repair.

2.4. PROPORTIONAL STEERING VALVE (PTO) FAILURE.

This anomaly appears when the steering stops working in Normal mode, remaining stationary and failing to show the position of the steering nozzles or buckets.

The steering does not follow the control signal and the indicator alarm signal shows that there has been an error, since there is no correspondence between the order given and the response.

Solution:

Set the steering to Backup mode and situate it amidships while the vessel is sailing. Transfer control from the navigation to the manoeuvre console, bearing in mind that the former has an independent transfer switch for each jet and the latter only has one switch per side. For this reason the manoeuvre console can only be used in backup because each steering commands a pair of jets.

2.5. JET HYDRAULIC HOSE BREAK

Given that the control systems are hydraulic, the failure of one of them will first cause an oil spill and consequently a loss of jet control.

A low level in the hydraulic oil tank will be conclusive proof that a significant failure has taken place.

Solution:

As soon as possible, and with great care, isolate the tank by activating the solenoid valve of the PTO (situated in the internal engines of each side, PIME and SIME, as we have previously said), and stopping the hydraulic jet pumps. Next, decouple the main engines on the side where the failure was detected. When this happens during navigation, speed should be reduced, and during manoeuvre stopped completely, in order to proceed immediately to repair.

The manoeuvre console has the indicator or alarm set to Normal mode, transferring control to the Lipsstick combined system.

1. Test mode system.
2. Lipsstick failure alarm.
3. Control selection failure in the navigation or manoeuvre console.
4. Mechanism failure in Normal or Backup mode.

5. In Normal mode, discrepancy between the angle set for the rudder and its actual position.
6. Cable break in inputs X, Y, M or rpm in Normal mode.
7. Insufficient operative services to activate Normal mode.

REFERENCES

- [1] D. M. Carrillo, J.A. Lopez-Orozco, J. M. Giron-Sierra “*Simulation environment for the investigation of automatized cooperation of marine crafts*” 2006 - 6th Vienna International Conference on Mathematical Modelling (MATHMOD 2006) v. 30
- [2] “*International Code of Safety for High-Speed Craft (HSC Code)*” (resolution MSC.36 (63), which was developed following a revision of the Code of Safety of Dynamically Supported Craft (resolution A.373(X)).
- [3] Owen, Paul “*High Speed Craft: A Practical Guide for Deck Officers*” 1995 Nautical Institute
- [4] Du Cane, Peter “*High-speed small craft*” 1964 Edition, 3. Publisher, Temple Press Books,
- [5] Odd M. Faltinsen “*Hydrodynamics of High-Speed Marine Vehicles*” New York 2005 Cambridge University Press