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# PROPOSAL OF SOLUTION FOR HYDRAULIC CONTROL OF OUTBOARD ENGINE ON "RIB-720 CANDO"

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***Abstract:*** *The subject of this paper is analysis of the existing mechanical control system of outboard four-cylinder gasoline engine, model Yamaha F150FET 6 BMX, from the aspect of reliability and sustainability of the existing system. Followed with a detailed description of failure, the impact on maneuverability and problems faced by crew with reference to the material and the existing solution for making the sides of the boat (tube), resulted in finding a proposal for a solution to this problem. The following problems were observed in the work: inaccuracy and failure of the control system, poor response and poor sensitivity of the control system, frequent cracking of the existing PVC tube due to minimal mechanical damage. Therefore, in order to eliminate the identified deficiencies and engineering solutions for outboard management engine followed with replacement of the sides of the boat with a more durable material will result in fully meeting the requirements for the operation of the boat. Looking at the advantages and disadvantages of hydraulic and mechanical control systems, it was decided to approach the installation of a hydraulic control system, which characteristics (response, precision, ergonomics, reliability in operation) completely surpassed the existing mechanical control system. Also, considering the conditions of exploitation, which derive primarily from the specifics of the user (military unit), and following the poor characteristics of the PVC material along with the frequent bursting of the boat's tubes, market research was undertaken with the aim of rebuilding the old tubes and replacing them with a new tube made of the most modern, very durable material (Hypalon-Neopren).*

***Keywords:*** *control system, worm gears, hydraulic gears, outboard engine, tube.*

## 1. INTRODUCTION

Rubber boat with a solid hull - RIB is a multi-purpose vessel with exceptional maneuverability, characterized by high speed, ease of handling, comfort, excellent navigational characteristics and stability.

The RIB-720 CANDO type boat (picture 1) definitely belongs to the group of vessels that can have all the features of a modern rubber boat with a solid hull, whose basic technical and nautical characteristics ensure efficient and effective execution of tasks on the water.

**Figure 1.** RIB 720 rigid hull inflatable boat – CANDO

It is primarily intended for the execution of a wide range of combat and non-combat activities, such as: search and rescue of victims, longitudinal and transverse transportation, patrolling in the area of ports and anchorages, reconnaissance of rivers, canals and lakes, support for diving activities, evacuation of the population by waterways and distribution of vital foodstuffs in case of natural disasters.

The basic parts of the boat are: flexible rubber tube, underwater part-hull, control panel and drive part.

The flexible rubber tube is made of five independent sections. It represents a part of the boat whose main purpose is to provide additional buoyancy, unsinkability and stability. Considering the purpose and important meaning, the tube is most often made of several sections, which increases the toughness of the boat in the event of a possible puncture or burst. In this case, the other, undamaged sections retain their function and ensure the boat's buoyancy, and all sections separately have valves for injecting or expelling air from the tube. The tube of the boat RIB-720 is made of PVC material, and it can be made of different types of materials: hypalon combined with neoprene, polyurethane or polyamide and the like.

The underwater part of the boat-hull is made of fiberglass in the so-called "V" profile in order to provide the necessary hydrodynamic form necessary for achieving high speeds and overcoming large waves while driving.

In case of water penetration, the boat is equipped with a drainage pump, which is located in the stern part.

The control panel is intended for remote control of the boat, monitoring driving parameters such as speed, distance traveled, boat position, fuel level and other information required for nautical driving. Commands are transmitted to the boat's drive through the control panel and in this way the desired action is realized (driving on the course, speed control, various maneuvers, etc.).


**Figure 2.** Outboard engine Yamaha type F150FET 6 BMX

The boat is powered by an installed outboard four-stroke engine manufactured by Yamaha type F150FET 6 BMX. The engine has a supporting electro-hydraulic system that, in addition to changing the trim while driving, also ensures bringing the engine into the transport position during transport by trailer.

In order to protect against corrosion, it has zinc protectors installed (on the outside of the engine and in the cooling system). The engine has a so-called "Trim & Tilt" system intended for adjusting the angle of the engine or propeller while driving, which results in better performance of the boat as a whole (start, acceleration, speed, economy).

**Table 1**. Basic technical data of the outboard engine

| BASIC TECHNICAL DATA | | | |
|---|---|---|---|
| Basic information about the boat CANDO | | Basic information about the engine Yamaha type F150FET 6 BMX | |
| type | RIB | outboard type | four-stroke gasoline |
| length over all | 7.20 m | volume | 2670 $cm^3$ |
| width over all | 2.85 m | number of cylinders | 16 |
| internal length | 5.35 m | diameter of cylinder | 94 mm |
| max. internal width | 1.75 m | power on the propeller | 110.3 kW (150HP) |
| tube diameter | 0.54 m | maximum number of revolutions | 4500–5500 min |
| number of chambers | 5 | dry engine weight | 223 kg |
| weight, without engine | 815 kg | transmission ratio | 2.0 (28/14) |
| the maximum number of persons allowed | 15 | / | / |
| maximum load capacity | 3600 kg | / | / |

The advantages that RIBs have over vessels of similar size are primarily the result of excellent nautical characteristics. For example, one of the positive nautical features of this boat is its excellent stability. Through testing, it was established that thanks to the given constructive solutions, the boat can successfully resist the force that causes tilting, due to the unevenly distributed load, and thus prevent unwanted overturning.

The turn maneuver with full deflection of the engine to one side and the other is performed with about 85% of the maximum power of the engine, whereby the boat successfully performs the turn without feeling a loss of stability or an excessive heeling angle. Also, at small deflections of the rudder and at maximum speed, the vessel has excellent maneuverability and stability. Finally, at low speeds it is possible to successfully maintain the set course, and the stopping manoeuver after reducing the maximum engine throttle to zero is realized in a short time and over a short distance (the stopping distance is 3-4 boat lengths).

## 2. ENGINE MANAGEMENT SYSTEM ON RIB-720 CANDO BEFORE REPLACEMENT

Control of the Yamaha F150FET 6 BMX outboard engine, changing the direction of the vessel, was done through the steering head (a mechanical steering system consisting of a worm gear system and a toothed cable).

The mechanical control system in the previous examples proved to be very unreliable in operation. Given that the RIB-720 "CANDO" as a vessel is used in dynamic conditions that require sudden changes in the direction and direction of navigation, the mechanical steering system was not able to keep up with the required work dynamics, precision in management and system response. During sudden changes in the sailing direction, due to the small pitch of the thread on the toothed cable of the mechanical system, as well as the poor characteristics of the material of the worm gears, the cable "skipped" and the control system failed.

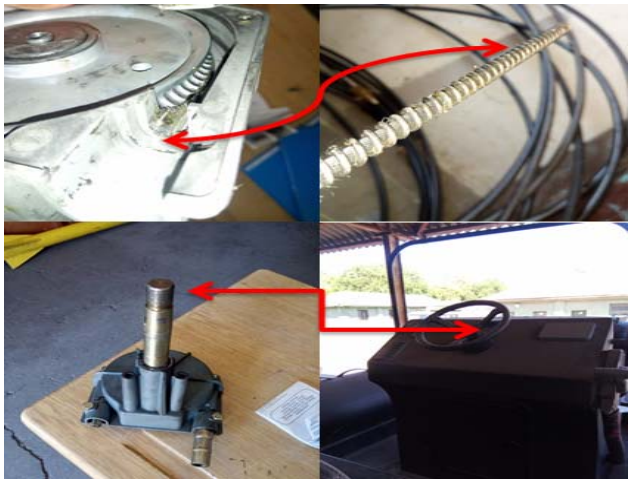

**Figure 3.** Previous mechanical control system

The failure of the mechanical control system was manifested by inaccuracy and the impossibility of controlling the RIB-720 CANDO, poor (late) response of the control system, the impossibility of positioning the RIB in the desired direction as well as the turn and greatly affected the ergonomic working conditions of the crew.

Given that the current mechanical control system has proven to be very unreliable in operation, considering the advantages and disadvantages of hydraulic systems, experts from the flotilla proposed replacing the existing mechanical control system with a new hydraulic control system.

## 3. NEW HYDRAULIC STEERING SYSTEM ON RIB 720 CANDO

### 3.1. Advantages and disadvantages of hydraulic systems

Hydraulic system is a technical system, which in general, represents set of devices capable of transferring energy and information using hydraulic fluid.

The hydraulic system converts the mechanical energy into hydraulic one and vice versa.

A medium for converting and transferring energy to hydraulic systems is fluid in which the volume must not significantly change by the action of an external force (incompressible fluids).

The main advantages of hydraulic drives are:

- very low weight, dimensions and moments of inertia,
- simple overload protection,
- the possibility of obtaining large transmission ratios without use of reducers,
- possibility of continuous change of speed and direction,
- very simple conversion of rotary to translational getting around,
- high speed of response, due to practical incompressibility hydraulic oil.

Basic disadvantages of hydraulic systems:

- sensitivity to dirt,
- loss of energy, which turns into heat, especially in throttle control,
- occurrence of internal and external losses,
- the possibility of air penetration into the system,
- the influence of temperature changes on the operation of the system.

### 3.2. Description of the newly installed hydraulic control system

Due to the previously mentioned malfunctions, the existing mechanical control system was replaced by a new ULTRAFLEX hydraulic system.

Newly installed hydraulic steering system (ULTRAFLEX) consists of a hydraulic steering pump located on instrument panel, cylinder which is connected to the outboard engine and connecting hoses. In normal working conditions and initiated by turning the steering wheel, the pump will pump the oil flowing through the engine and hose to the cylinder, in the desired direction of deflection. As a result, there is the movement of a cylinder which instantly moves the engine connected to the cylinder. The pump is equipped non-return valve, which prevents the return of outgoing liquid along the same hose, and therefore system operation and engine management with two or more control stations is enabled.

The system consists of:

1. Hydraulic pump UP28 T (It can only be used with the tilt X52 mechanism). Working volume per revolution - 28 cc. Number of clips - 5 pieces. Pressure 70 bar. Weight - 5 kg. Maximum supported steering wheel diameter - 710mm.
2. Steering wheel tilt mechanism X52. It allows a maximum tilt of 48°.
3. Hydraulic hoses Length - 6.5 m (Number - 2 pieces).
4. Hydraulic cylinder UC-128-OBF/1. Cylinder volume - cc 120. Thrust - 450 kg. Diameter Extensions - 3/8".

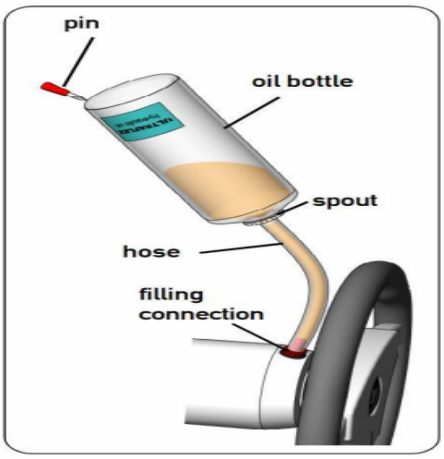


**Figure 4.** New hydraulic steering system (ULTRAFLEX)

The new hydraulic control system is designed in accordance with UNI-EN-ISO 10592 and A.B.I.C. P21 regulations, and can operate at temperatures between -18°C (0°F) and +77°C (+ 170 °F). All components are made using materials i work processes that offer system safety and reliability in the most extreme conditions.

## 4. REPLACING THE TUBE ON THE RIB-720 CANDO

### 4.1. Description and characteristics of the tube before replacement

The flexible rubber tube of the boat RIB-720 was made of PVC material, where it was transversely divided into five independent sections.

As a part of the boat whose basic purpose is to provide additional buoyancy, unsinkability and stability, the characteristics of the material from which it was made (PVC), did not fully meet the strict requirements of the user (military unit), and above all in the domain of reliability and durability of the tube.

In the conditions of dynamic driving, during the realization of regular and training tasks, violent landings on untidy shores of water surfaces, there were bursts of existing tubes and due to small mechanical damages, which greatly affected the navigation of the boat, the performance of tasks as well as demotivating the boat's crew.

**Figure 5.** Damaged tube on the bow part

Due to the poor characteristics of the PVC material and the frequent bursting of the boat's tubes, market research was undertaken with the aim of rebuilding the old tubes and replacing them with a new tube made of the most modern, very durable material (Hypalon-Neopren).

### 4.2. Description and characteristics of the newly installed tube

After market research, the replacement of the existing (PVC) tubes with new tubes was carried out at the plant of ADVANCE, which also replaced the control system with a new hydraulic control system. The newly installed tubes are made of the most modern Hypalon-Neoprene (CSM) material.

The French company Pennel & Flipo is the world's most famous company specializing in production Hypalon-Neoprene material for special purposes, under the brand name "Orca". Tradition in this company has been producing materials for over 50 years. Premium Hypalon-Neoprene canvas is the highest quality material for making tubes in the world.

This is supported by the fact that all military and special purpose boats are made from of this material. Durability, elasticity, resistance to wear, damage and UV rays, the simplicity of maintenance, and the tightness of the chambers on the seams of the boats, are fundamental characteristics that set this material apart from all others. It is safe to say that the tubes produced from this material are in the category the best in the world.

## 5. CONCLUSION

The newly installed hydraulic control system has completely surpassed the existing mechanical control system in terms of its characteristics (responsiveness, control precision, ergonomics, operational reliability).

The first replacement of this control system was carried out in 2020, after which no malfunctions were observed in the operation of the new control system during a regular operation. The new outboard motor management system ensured the reliability of the RIB-720 CANDO, providing reliable maneuverability and precision. The improvement of these characteristics was especially noticed by the boat's crew during practice tasks in more extreme conditions and dynamic driving with sudden changes in manoeuvers. By replacing the mechanical control system with a new hydraulic system, as well as replacing the tube from PVC with a new tube made of durable Hypalon-Neoprene material, it fully met the expectations of the user. Lastly, based on empirical conclusions after two years of exploitation, RIB 720 CANDO can safely conclude that the new solution in fully responded to the strict demands of the user, and made the RIB 720 Cando more reliable and tougher.

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