

Effective and environmental friendly propulsion system for small fishing cutter

Dymarski Czesław¹

¹ Faculty of Ocean Engineering and Ship Technology, Gdansk University of Technology, Gdańsk, Poland.

Abstract—The paper presents the description of the propulsion system of the small fishing vessel and hydraulic drive and control system of its essential equipment. The presented systems are modern, effective and ecological friendly and were installed on small fishing cutter. The cutter has been designed at the Faculty of Ocean Engineering and Ship Technology of Gdansk University of Technology. In September 2002 the vessel started regular fishing at the Baltic Sea. The up to now completed sea trials and operation results are very promising.

Keywords—*shipbuilding, propulsion systems, hydraulic drive and control systems, controllable pitch propeller, ship equipment, fishing vessels*

I. INTRODUCTION

About ten years ago, when Poland was preparing to join the European Union one of the many essential problems waiting for solving was modernization of Polish fishing fleet especially for many not rich fishermen. For this reason at the Faculty of Ocean Engineering and Ship Technology of Gdansk University of Technology it was decided to design a modern cutter which would serve as an example of effective small fishing vessel and would be available for mentioned above fishermen.

It was assumed that the vessel has to be environmental friendly and fulfil each and every current requirement of classification societies and European Union regulation. Moreover she ought to ensure the effective and safe fishing with the use of the most modern methods and equipment. It must work in various sea conditions operated by small crew and she has to withstand competition with Danish and German cutters. The length of the cutter was assumed 10 m, because such small boats are not covered by fishing limits in the European Union.

The paper presents the description of the main propulsion and other basic ship systems designed at the Faculty and applied on the fishing cutter.

II. PRE-CONDITIONS AND TECHNICAL ASSUMPTIONS

One of the most important tasks of the mentioned undertaking was to work out an appropriate propulsion and steering system of the cutter. Also the drive system of other ship equipment had to be analysed and designed. It was assumed that the mentioned systems should be fuel-efficient simultaneously with relatively high reliability and low price. Fulfilment of these assumptions was carried out by:

- ◆ Application of high-speed traction diesel engine type SW 680 adopted for marine conditions. That type of engines has 155 KW of power at 2000 rpm and is produced by PZL Mielec in Poland in big quantity, which makes them relatively cheap and reliable.
- ◆ Application of controllable pitch propeller, which gives possibility to use full engine power in different sea operations. It increases effectiveness of whole propulsion system and also, in some way, safety of sailing in difficult sea conditions.
- ◆ Application of reducing gear box with fixed gear ratio. An originally reversible gear produced by PZM AMEX in Poland was adopted into irreversible gear. This became possible due to the application of CP propeller. Such a propeller enables backward motion of the vessel without the necessity of alteration of shaft rotation direction. Instead of reverse gear the driving shaft of the oil pump was assembled. The existing coupling was used for switching the pump on and off. The lack of space and the quantity of the transmitted power determined the application of the single-stage pump with constant discharge, characterized with relatively limited dimensions. This pump supplied deck machinery such as trawl and net winches.

- ◆ Using, already existing (on engine) pump of steering system for supply CP propeller, steering gear, and hydraulic motors of bilge and fire pumps.
- ◆ Application of polymer water lubricated bearing of propeller shaft. It eliminated risk of lubrication oil leakage into the sea.

III. DESCRIPTION OF THE SYSTEM AND ITS COMPONENTS

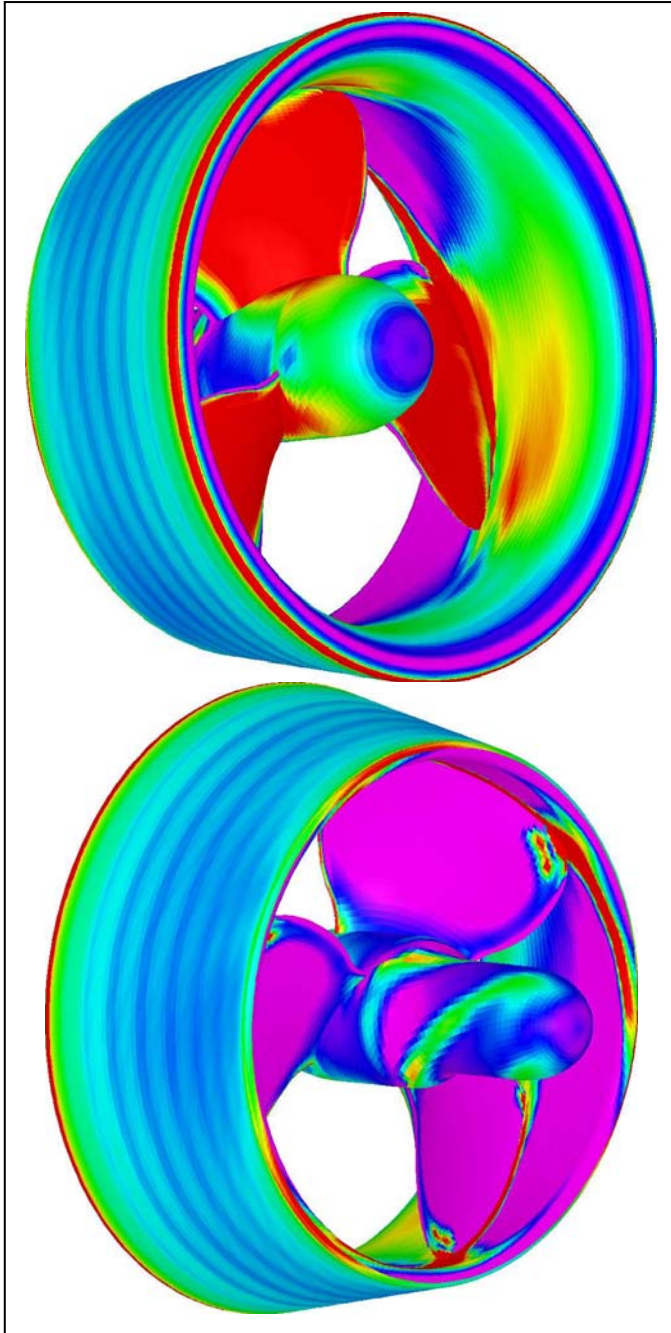


Figure 1. Pressure coefficient distribution on screw propeller and nozzle for $J = 0.6$ shown from both sides.

The most difficult problem in designing the propulsion system arose due to the lack of suitable modern CP propeller of such small power. It became essential to design a new modern and effective CP propeller to fulfil assumed expectations. The Faculty has experience in design and research of that type of devices. It was an advantage in designing as well as in numerical calculation and laboratory testing. Results of this works were published [1] – [5]. It should be mentioned that in the servomotor located inside the shaft, the cartridge pilot-operated check valve was applied. It enables cutting off chamber of hydraulic cylinder and keeping adjusted pitch without constant oil supplying, what increases efficiency of the control system.

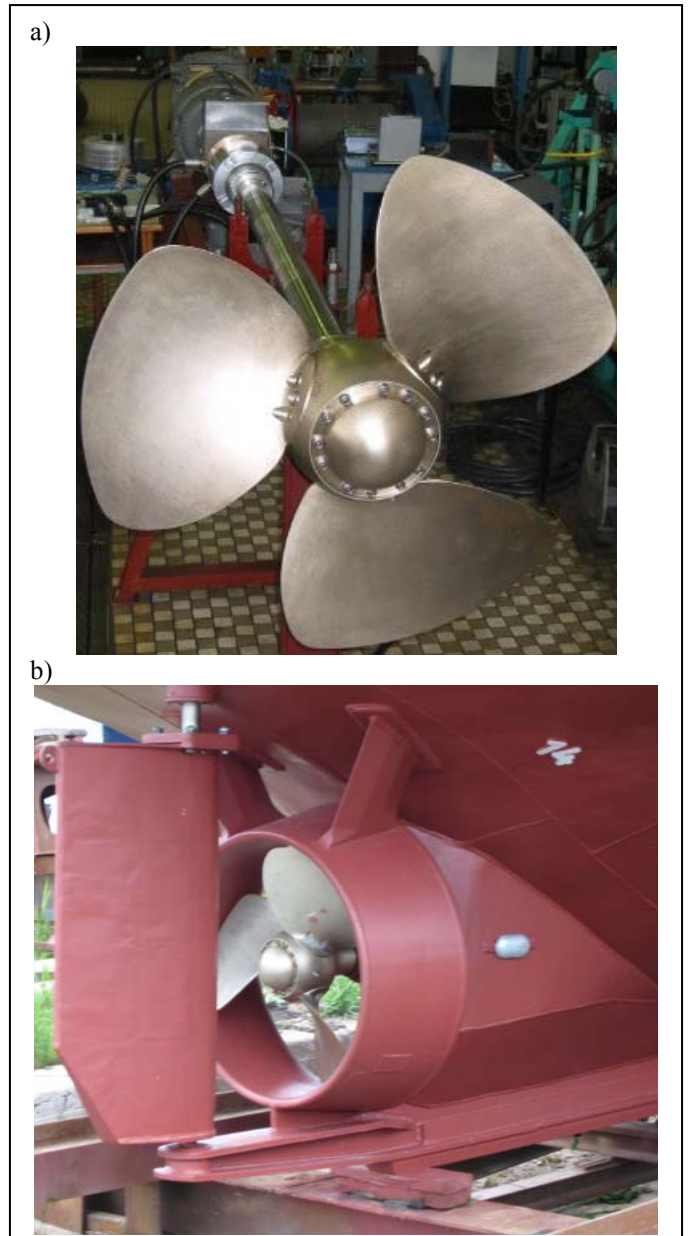


Figure 2. Photo of the CP propeller: a) on the laboratory testing stand; b) on the cutter before launching.

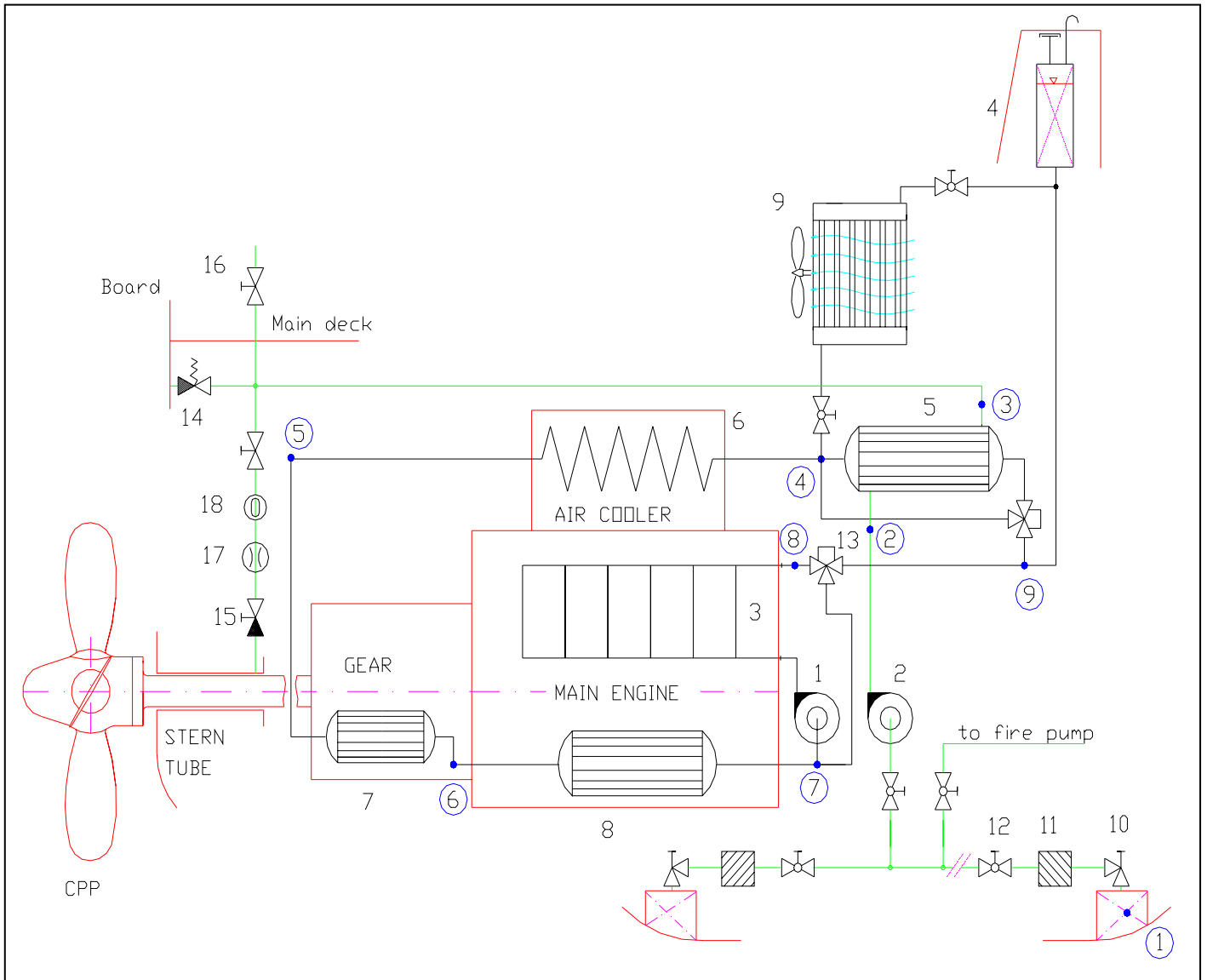


Figure 3. Scheme of the cooling system. Nomenclature: 1 – fresh water pump, 2 – sea water pump, 3 – main engine cooling circulation, 4 – fresh water tank, 5 – fresh water cooler, 6 – air supercharging cooler, 7 – gear oil cooler, 8 – main engine oil cooler, 9 – radiator inside crew cabin, 10 – Kingston, 11 – sea water filter, 12 – cut-off ball valve, 13 – thermostat valve, 14 – non-return overflow valve, 15 – cut-off non-return valve, 16 – cut-off valve, 17 – water flow-meter, 18 – water flow-indicator.

Laboratory tests of the main engine and its basic systems especially cooling system were carried on simultaneously with above mentioned works. Because of the lack of free space and additional requirements of heating of the cabin and of the water supplying to the stern tube bearings, the cooling system had to be designed specially for this cutter. The system is presented schematically on Fig. 3.

The size and the application of the vessel had the most crucial influence on all essential machinery driving systems. As it was mentioned before, because of the lack of space in the machinery room a current generator could not be applied. This

brought the necessity of application of the hydraulic drive system which has many advantages. The most essential of them are as follows:

- considerably high forces and moments obtained at relatively low operational velocity,
- relatively low mass and dimensions compare with electric systems and, as result of it, low dynamic loading from forces and moments of inertia,
- good protection of mechanisms' and devices' construction against overload,
- smooth control of devices' operational velocity,
- possibility of automation of devices' control and monitoring.

Taking into account the above conditions and requirements the drive system has been developed and is presented schematically on Fig. 4.

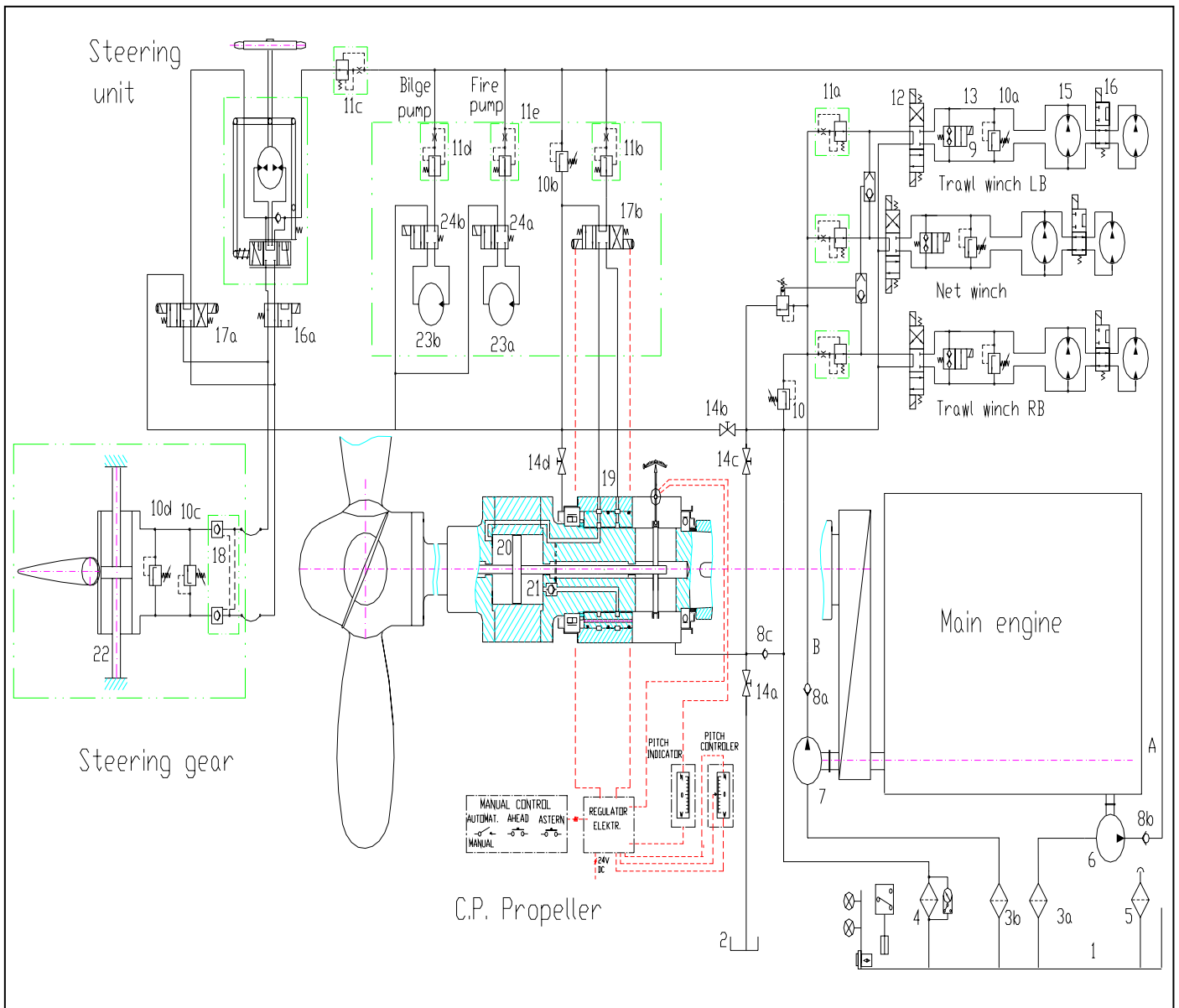


Figure 4. Scheme of the hydraulic drive and control of the equipment of the fishing cutter KR10 and the remote control system of the CP propeller.
 Nomenclature: 1 – main tank, 2 – drain tank, 3- suction filters, 4 – return filter, 5 - reservoir oil filter, 6, 7 – pumps, 8 – check valves, 9 – pressure relief valve pilot operated, 10 - pressure relief valves, 11 – 2-way flow control valve, 12 – manual operation 4/3-way directional control valve, 13 - shut-off valves, 14 – manual operated shut-off valves (a, e – standard closed, b, c, d – standard open) 15 – 2-directional fixed displacement motors, 16 - 4/2-way directional control valves, 17 - 4/3-way directional control valves, 18 – pilot operated check valves, 19 – radial sliding seal, 20 – hydraulic cylinder of the CP propeller, 21 – cartridge pilot operated check valve, 22 - hydraulic cylinder of the steering gear, 23 - fixed displacement motors, 24 - 4/2-way directional control valves, 25 – shuttle change-over valve

The system consists of two major lines:

- A – supplied by the pump (6) attached to the main engine and
- B – supplied by the pump (7), attached to the gear.

Both pumps suck the oil in through the suction filters (3) from the single, common, main tank (1). There is also another, smaller drain tank (2). It enables emptying the case of the mechanism for the propeller pitch change during repair. The case is located below the level of the oil in the main tank. The oil from the drain tank is not pumped into the main reservoir.

The equipment absorbing less power, but very important from the vessel safety point of view is connected to the line A. These are: steering gear, propeller pitch regulation mechanism, bilge pump and fire pump. Because of the application of the fixed displacement oil pump the mentioned above power receivers have to be fitted with flow control valves (11) assuring that each of them is supplied independently with appropriate oil flow.

This results in the continuous running of the pump at the pressure of the opening of the pressure relief valve. From the

efficiency point of view such solution is not advantageous but, as far as the presumed vessel drive system is concerned, it is technically reasonable.

According to the assumptions, for the elementary control of the rudder blade a turning valve was deployed. Usually such a valve is used in trucks' power steering systems. The valve is connected with the steering wheel in the wheelhouse. The oil gets into one of the chambers of the servo-motor of the steering gear through the four-ways two-stage (4/2-way) directional control valves (16a) and the twin, pilot operated check valve (18). The steering gear is protected against the overload by the pressure relief valves (10c) and (10d). The turn of the steering wheel results in the flow of the exact amount of the oil forcing the appropriate turn of the rudder blade. The position of the rudder blade is displayed in the wheelhouse.

In case of damage of the valve or when difficult maneuvers have to be performed, the additional 4/3-way directional control valve is deployed (17a). It enables button control of the rudder blade after shutting the connection with the valve off.

The regulation of the pitch of the CPP is completed with the 4/3-way directional control valve (17b), which is connected by the oil conduits with radial sliding seal (19) and then with the hydraulic cylinder (20) located in the rotational system between the propeller and tunnel shafts.

There is a pilot-operated check valve (21) assembled in the channel supplying the oil to the front chamber of the hydraulic cylinder (20). Its aim is to shut-off tightly the loaded cylinder chamber and keep the propeller pitch unchanged in case of the accidental depressurization. The detailed description of the applied CPP mechanism together with the discussion of its grounds is presented in [6].

The control of the CPP is a follow-up type. The set-up value of the pitch is maintained by the regulator, which compares it with the actual propeller pitch value. When the difference between those two values exceeds the presumed accuracy, the voltage is supplied to the appropriate coil of the directional control valve (17b) and the valve is switched in order to decrease this difference. It is possible to make use of the button-control after switching the system into manual mode.

The control of bilge and fire pumps is very simple. In order to start any of them, the appropriate button should be pressed. This results in voltage supply to the coil of 4/2-way directional control valve (24a) or (24b) and then oil supply to the hydraulic motor (23a) or (23b) driving the pumps

The high power demand deck equipment is connected with the line B. The equipment consists of two trawl winches and fishing net winch. In order to maintain their constant operation speed they are supplied by 2-way flow control valves (11). Each of the winches is driven by two hydraulic motors (15) connected with each other by the 4/2-way directional control valve (16). This enables double-gear operation of each winch. The direction of the winches' rotation is controlled by the 4/3-

way directional control valve (12). Shifting of the valve slider up results in hauling of the rope while shifting the slider down runs the rope out. In order to improve the control of the winch the shut-off valve (13) has been deployed. It enables connection of both conduits before engines. Such a solution enables the automatic pulling the rope out of the winding drum, caused only by the drag of hauled trawl net, while the valve (12) is set to the middle position. The speed of such forced laying out of the rope depends on the speed of the cutter and on the number of operating motors. Similarly when the slider of the valve (12) remains at its bottom position, the slow, with low-moment laying out of the unloaded rope is possible, for example during the auxiliary works with the trawl-net on the deck or when the cutter stops.

The overflow valve (10a) limits the maximum towing power of the winch and the valve (10) determines the maximum forcing pressure of the pump. In order to minimize the energy consumption and improve the efficiency of the system the additional pilot operated pressure relief valves (9) is applied, controlled by the instantaneous maximum working pressure. The pressure signal from the most loaded winch gets at the valve through the system of two shuttle change-over valves (25).

The pressure conduits of both lines are connected with the shut-off valve (14e), standard-closed. In case of failure it enables supplying the equipment from another line.

IV. EXPLOITATION EXPERIENCE

In July 2002 the cutter passed successfully the trials at sea and then headed for the port of Darłowo, where after additional trials and exhibition organized by the owners in the presence of the warranty engineer and many local fishermen, started regular fishing.

Until the moment of submission of the paper for publication the news from the cutter were good. The maximum speed of the vessel equals 9.4 kn. The maneuverability of the cutter is better than sufficient. The system keeps the pitch of the CPP constant, without any noticeable traces of drift. The same applies to the rudder.

After the sea trials, on the owner request the periods necessary for CPP pitch and rudder position change have been significantly decreased. This was possible thanks to the application of the flow control valves (11a) and (11b) in the line A (see Fig. 4). They make possible controlling the distribution of the oil flow from the pump (6) to particular equipment units. This increased the maneuverability of the cutter during fishing with limited speed. According to the owner report the fishing was conducted during the stormy weather, at the wind 7°B and sailing at 9°B₁ when even bigger cutters equipped in fixed pitch propellers had to take shelter at the harbor.

V. CONCLUDING REMARKS

The solution of the cutter propulsion and control systems is a prototype and includes some features of originality.

The current, advantageous results of cutter operation resulted in significant interest of small ship-owners in such type of vessel. Many questions concerning the price and terms of delivery are raised. This brings hope that the solution is successful although the more general conclusions have to be postponed.

Laboratory research on dynamic of the trawl winches and numerical calculations of trawl systems, especially pelagic fishing [9], [11] are being continued at our Faculty.

REFERENCES

- [1] Dymarski Cz.: Empirical Research on the Sliding Radial Seals Applicable to C P Propellers. Polish Maritime Research No 4, Vol. 3, Gdansk, December 1996.
- [2] Dymarski Cz.: Controllable pitch propeller of low-power with screw-toothed gear in the pitch control mechanism (in Polish). Marine Technology Transaction, Technika Morska, Vol. 8, Gdańsk, 1997.
- [3] Dymarski Cz.: Laboratory tests of a hydraulic servomechanism of low-power controllable pitch propeller (in Polish). Marine Technology Transaction, Technika Morska, Vol. 8, Gdansk, 1997.
- [4] Dymarski Cz.: Laboratory investigations of the stern tube bearings and pitch control mechanism of the low – power CP propeller with screw-toothed gear. Polish Maritime Research, No 3, Vol. 5, 1998.
- [5] Dymarski Cz.: Theoretical Research on Sliding Radial Seals Applicable to C P Propellers. Polish Maritime Research No 1 March 1998, Vol. 5.
- [6] Dymarski Cz.: Pitch Control Servomechanism for a Low Power Rate CP Propeller. Marine Technology Transaction, Technika Morska, Vol. 12, Gdańsk, 2001.
- [7] Dymarski P.: Paraboloidal Panels and Higher Order Dipole Distribution for Propeller and Foil Flow Calculations, HYDRONAV' 2001, pp.19-29, Szczecin – Międzyzdroje 2001.
- [8] Dymarski P., Dymarski Cz.: Curvilinear Panels and Higher Order Dipole Distribution Method for Ducted Propeller Flow Calculations. Marine Technology Transaction, Technika Morska, Vol. 12, Gdańsk, 2001.
- [9] Dymarski Cz. Nakielski J.: Calculation of motion trajectory and geometric parameters of the trawl during pelagic fishing. Polish Maritime Research No 4 October 2009.
- [10] Krepa J.: General preliminary design of the small fishing cutter. Gdansk University of Technology, Faculty of Ocean Engineering and Ship Technology. Gdansk, 1998.
- [11] Nakielski J.: Kinematic forces effect on the towing winch performance, Doctor thesis, Gdańsk 2008