

A System for Determining the Rheological Characteristics of Marine Technical Liquids

Vitalii Nikolskyi

National University "Odessa maritime academy"
dept. of Theory of automatic control and
computer technology
Odessa, Ukraine
prof.Nikolskyi@ukr.net

Mark Nikolskyi

National University "Odessa maritime academy"
dept. of of Automation of Vessel Gas Turbines
and Diesel Installations
Odessa, Ukraine
markdezert@ukr.net

KyryloBerezhnyi

National University "Odessa maritime academy"
dept. of Theory of automatic control and
computer technology
Odessa, Ukraine
90demon777@ukr.net

Oleg Bloshenko

National University "Odessa maritime academy"
dept. of Theory of automatic control and
computer technology
Odessa, Ukraine
prtfnx@gmail.com

Abstract—Ship's technical fluids (heavy fuel oil and lubricating oil) when operating diesel engines are considered as "Newtonian" and when operating on nominal revolutions are guided by kinematic viscosity. When bunkering the vessel, a technical passport with one value of kinematic viscosity and density is provided on them. In recent years, cases of operation of the main engines at the turning points, which are half the par value, have become more frequent.

When located in the gaps of tribotechnical units of diesel engines, ship's technical fluids manifest themselves as "non-Newtonian" with the effect of thixotropy. Not taking into account these properties increases the wear of elements of fuel equipment and bearings. This leads to an increase in accidents and operating costs. The negative effect is amplified in the maneuverable mode of the diesel engine with a sharp variation in the load characteristics and, consequently, a sharp change in the viscosity coefficients.

We have created a computer system that includes a submersible probe rheometer with a piezoelectric drive. The novelty of the system is the possibility of its use in the complex analysis of "non-Newtonian" liquids and the study of the effect of thixotropy in real time. Existing ship's stationary laboratories do not allow for detailed analyzes.

Keywords—"non-Newtonian" thixotropic fluid; tribotechnical unit; computer system; rheological characteristics; viscosensor with piezoelectric drive

I. INTRODUCTION

In recent years there are two trends in the operation of ship diesel engines: the use of two kinds of fuel - fuel and heavy gas; continuous operation at partial loads.

Ship technical liquid (cylinder and lubrication oils, heavy fuel oil) arrive in the clearances of diesel engines movable parts and the fuel injection equipment, which gaps constitute

10-25 microns and experience deformation leading to change in their properties [1, 2, 3]. They behave like thixotropic liquids [3]. At the same time, when bunkering a vessel for oil and fuel, a passport is issued, which indicates a number of parameters and, in particular, one kinematic viscosity value corresponding to the nominal operating mode of the internal combustion engine.

"Viscosensor" viscosity regulators are widely used on vessels, the work of which is based on the vibrational method. They consist of two parts: on one controller a viscometer is made; on the second - the viscosity regulator.

However, the operation of the ICE is not limited to the nominal mode (clear passage). A significant part is the maneuvering regimes (mooring operations, narrow passage, drift). In such modes reverses alternate with start, acceleration and braking of ICE. Changing the load on the motor during the excitement also leads to a change in the shear strains that the liquids experience. The failure statistics of the ICE elements and nodes indicate that most of the failures in operation occur precisely in the maneuvering operating modes. Measuring probes of ship viscometers [4] do not allow covering the entire range of shear deformations.

In [5] a computer system for determining the rheological characteristics of marine technical fluids in laboratory conditions is presented, which includes: measuring probe, the operation of which is based on the method of coaxial cylinders, with a drive on a linear piezoelectric actuator (LPA) [6]; programmable logic controller (PLC) from the company Phoenix Contact series ILC 151 [7] from the TATU SmartLab [8]; software based on functional blocks from the standard library of the integrated project development environment [9, 10].

The computer system tests revealed deficiencies in the use of accessories made on a 3-D printer and software that allows

measurements at 4 speeds at the same temperature.

In order to use such a system on the ship, it is necessary to synchronize with the operation of the internal combustion engine and to connect to the steam supply actuator for heating the heavy fuel oil.

II. PURPOSE OF WORK

The purpose of the study is to modernize the computer system that takes into account the operational features of technical marine fluids in diesel: the temperature range; needle nozzle speed; thickness of the gap in the tribotechnical unit.

III. CONTENTS AND RESULTS OF THE RESEARCH

We suggest upgrading the system, which includes a temperature control unit and software for reading data in real "hard" time and transferring data to an array followed by processing and transmission to the human machine interface (HMI) (Fig. 1), where 1 is a container with a heating element to create conditions testing of technical fluid, close to the temperature conditions of ICE; 2 - immersion nozzle; 3 - test liquid; 4 - measuring probe; 5 - reversible linear piezoelectric engine LPE-5; 6 - sensors for fixing the movement of the motor guide; 7 - ILC 150 GSM / GPRS controller (PLC) and WP 04T touch screen WEB-panel [11] with a user-friendly interface that is used as a real-time monitor; 8 - single-phase full-wave thyristor voltage converter for regulating the actual voltage on the heating element; 9 is a rotary piezoelectric actuator (RPA) [12], which rotates the coupled resistor and performs two functions.

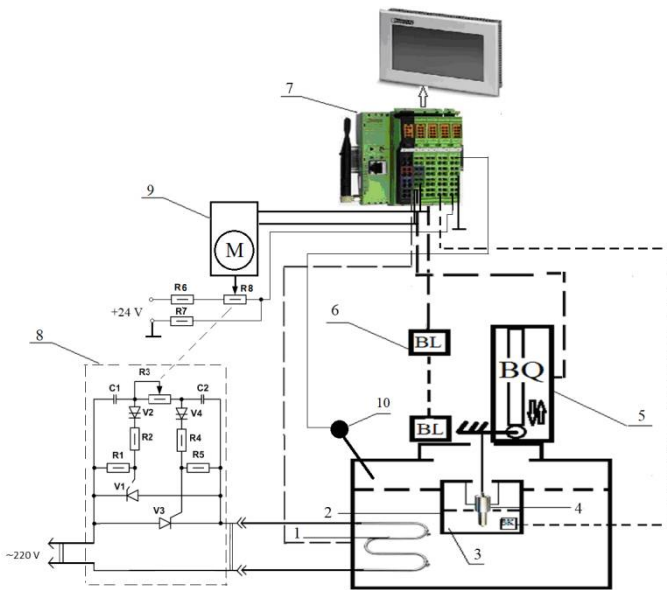


Fig. 1. Functional scheme of computer system

First, set the moving speed of the movable part of the measuring probe and measure the time intervals between two points. The second is the temperature control of the liquid to be tested. 10 - temperature sensor. R3, R8 - paired resistor, which, on the one hand, sets the control angle of the thyristor converter, and, on the other hand, it performs the function of the rotor angle sensor of the LPE.

Software for the controller is developed with the help of PC Worx. For the subsequent processing and visualization of the data, the programs Visu +, Microsoft Excel using MS ACCESS database were used.

When programming, it was taken into account that the controller operates in the "real hard time" mode. He performs a consecutively infinite cycle of performing all the specified operations. To prevent collisions of data processing, a "semaphore" system was used, described below.

The task of the controller software is to control the piezoelectric motor and measure the time of the cylinder passing through the liquid. The engine moves the cylinder in the fluid at speeds corresponding to the nozzle segment speeds. Measuring the travel time of a cylinder of a given segment at different engine speeds and fluid temperatures, it is possible to construct a rheological characteristic.

The project was carried out from the calculation of the engine speed change in 6 modes. The cylinder has two moves - from top dead center (TDC) to bottom dead center (BDC) and from BDC to TDC. And these movements can occur at different speeds due to the structural features of the cylinder. To take this condition into account, the time is measured in 12 modes (2 per speed mode). The temperature varies in 13 modes. As a result, you need to get 156 values.

To structure the received data, the type of variables "array" was used. It is declared in the data types in the "Arrays" file (Fig. 2). A total of 12 arrays have been created to record 12 speed modes. Each array contains 13 integer values, for each temperature mode.

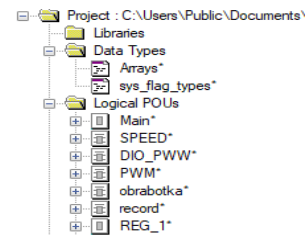


Fig. 2. Project tree

The main function block Main consists of blocks in the language FDB and separate blocks in the language ST (Fig. 3). The SPEED unit generates a piezoelectric motor control signal at a predetermined rate. The DIO_PWW block locks the cylinder's travel time from one end position to the other. The PWM unit generates a digital pulse width modulation signal. The record block forms and fills the array. The obrabotka block processes arrays to construct a rheological characteristic.

Variables I_0_1_1_1 and I_0_1_1_2_1 indicate the position of the cylinder, TDC and BDC, respectively. When you start work (translating the value of the variable Start to 1) and the cylinder reaches one of the boundary positions, a signal is generated to one of the CTU_1 or CTU_2 counters. Each of them sends a signal to control the engine in one of the speed modes, from 1 to the value of the variable SET_01, which is equal to 6 in this study (Fig. 4).

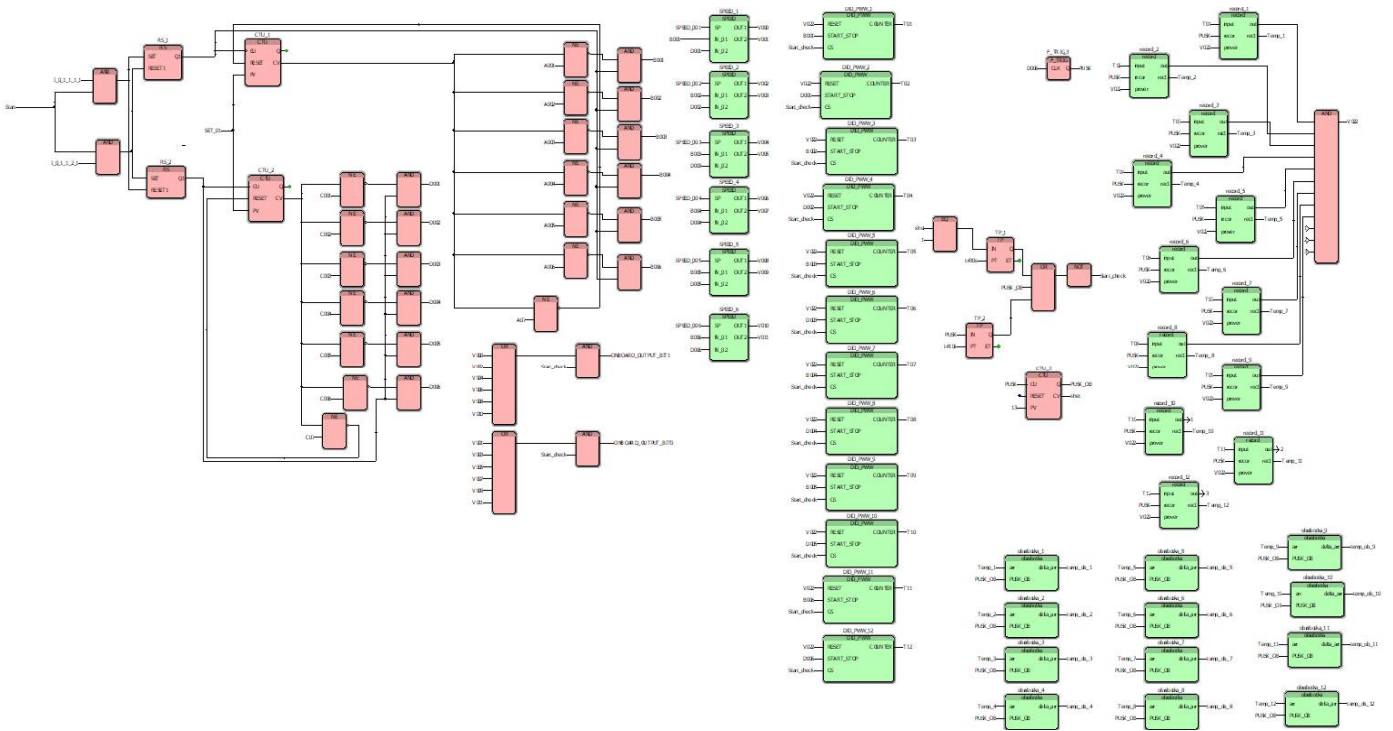


Fig. 3. Function block diagram Main

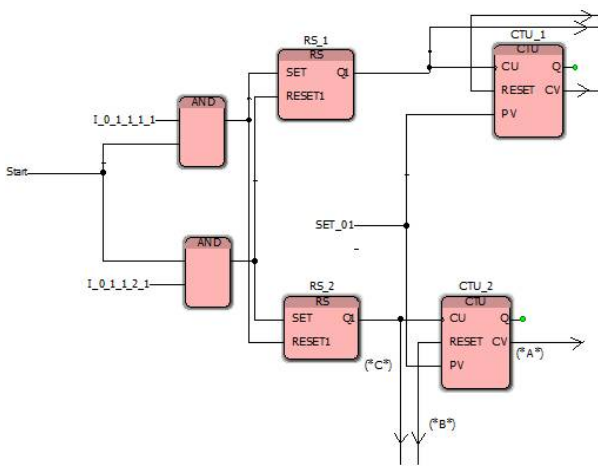


Fig. 4. Running and determining the position of the cylinder

In Fig. 5, depending on the pass number (compare the value of the variable C00 (1-7) and the counter value), a control signal is applied to the variable D00 (1-6) corresponding to the specific speed mode. Similarly for the counter CTU_1, giving the control signal to the variable B00 (1-6).

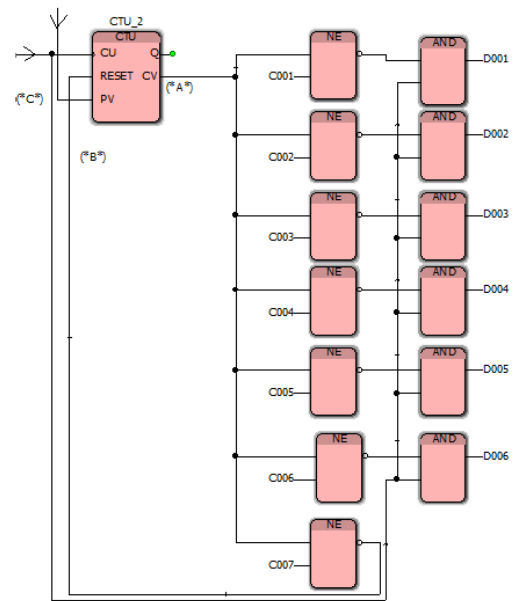


Fig. 5. Control of cylinder strokes at different speeds

In the variables SPEED_00 (1-6), the speed of the linear motor is set. The output of V000 (Fig. 6) corresponds to the movement of the cylinder down, and V001 to the movement of the cylinder upward. Similarly for the remaining blocks SPEED_ (2-6)

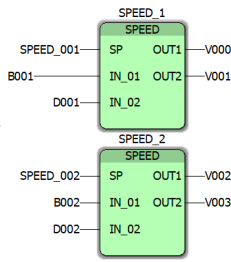


Fig. 6. Control and setting the cylinder speed

The PWM is made in the structural language of ST and generates a signal using the Pulse Width Modulation, which in the FB Speed (Fig. 7) generates the final signal to the piezoelectric motor, depending on the control signal. The controller performs one cycle of its work in 1 ms. Hence, at a frequency of 100 Hz, the speed can be changed in 10 modes.

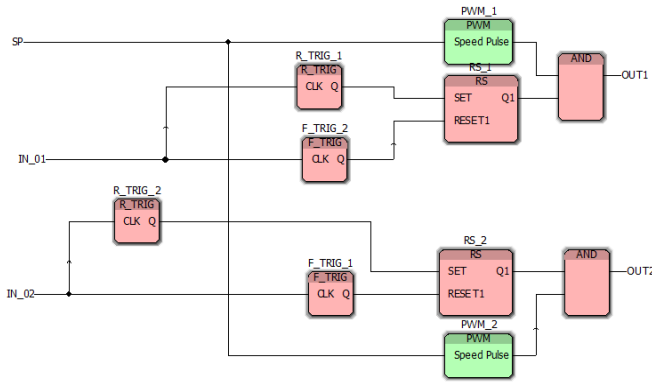


Fig. 7. FB(functional block) Speed

The variable ONBOARD_OUTPUT_BIT1 and ONBOARD_OUTPUT_BIT0 (Fig. 8) controls the motion of the piezo motor down and up respectively. The variable Start_check sets the engine to "pause".

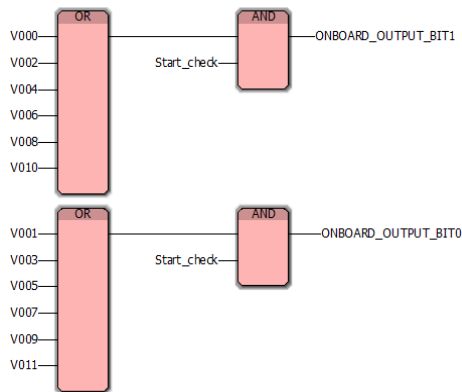


Fig. 8. Control of signal supply to engine movement

The variable V022 (Fig. 9) clears the variables T0 (1-12). B00 (1-6) and D00 (1-6) are the control signals that determine the movement of the cylinder. The variable Start_check stops the movement of the cylinder, and, accordingly, the counter is placed on the "pause". The time of motion of the cylinder is recorded in the variable T0 (1-12). Similarly for the remaining

DIO_PWW_ (3-12).

TP_4 generates a periodic sequence of pulses with a period of the specified variable V005, which are counted by the counter CTU_1. The control is performed by the control signal of variable START_STOP and CS.

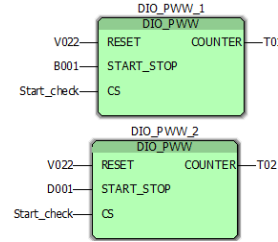


Fig. 9. Record the time of movement of the cylinder from the extreme positions

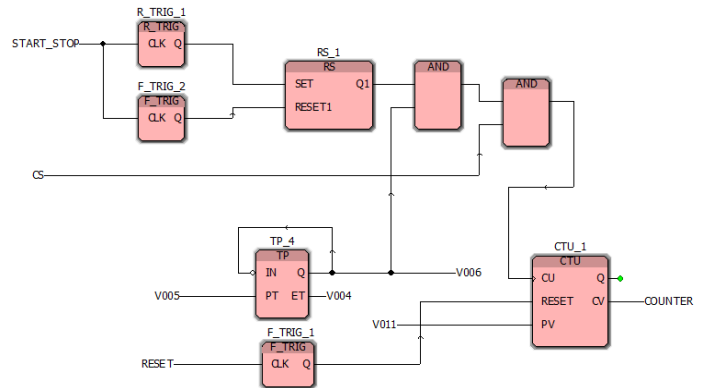


Fig. 10. FB DIO_PWW

After the 6-speed cylinder passes the CTU_1 and CTU_2 counters are reset and the values of T0 (1-12) are written into arrays (Fig. 11)

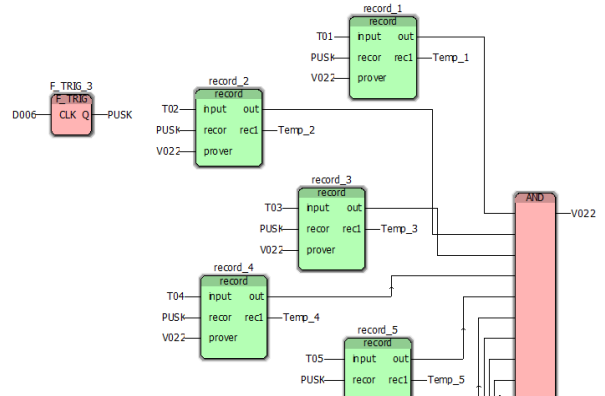


Fig. 11. Recording information in an array and managing synchronization

The F_TRIG_3 block translates the value of the PUSK variable to 1 when the cylinder completes the movement up in the sixth speed mode.

When translating the PUSK variable to 1, a control signal is applied to the blocks record_ (1-12). The program has input variables: Input - the time to be written; recor - control signal; prover is a semaphore. With its value 1, the work stops.

Output:out is a variable that takes the value 1 when the time recording ends. When out of all the blocks record_ (1-12) takes the value 1, the semaphore V022 takes the value 1, blocking the operation of the block. This is necessary to synchronize the recording of values;rec1 is an array containing time values for one speed mode.

Internal:step - initial value 1, determines the index of the array in which the time is written, is equal to the iteration number of the measurements.

The engine may overheat during operation. For this, pauses are introduced between the full passages of the cylinder for all 6 speeds (Fig. 12).

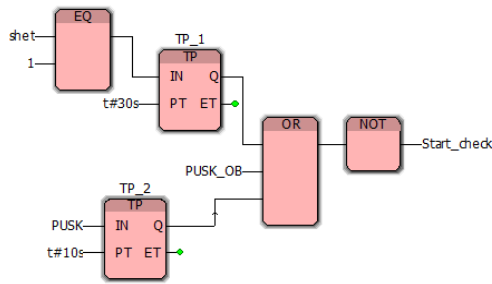


Fig. 12. Organization of a pause of the engine between the passages of the cylinder

TP_1 and TP_2 form a time pulse translating the variable Start_check to the value FALSE. The engine stops for 30 seconds after the first pass and 10 seconds after each next. The variable PUSK_OB signals the shutdown.

Counter CTU_3 (Fig. 13) counts the number of changes in the PUSK variable. That is, the number of passes of the cylinder for all 6 speeds is counted. The pass number is written to the variable shet, and when 13 is reached, the PUSK_OB variable takes the value 1, passing the control signal to the obrabotka_block (1-12) (Fig. 14).

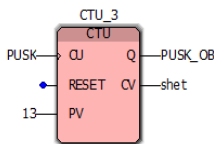


Fig. 13. Calculation of the passage phases of the cylinder at different speeds

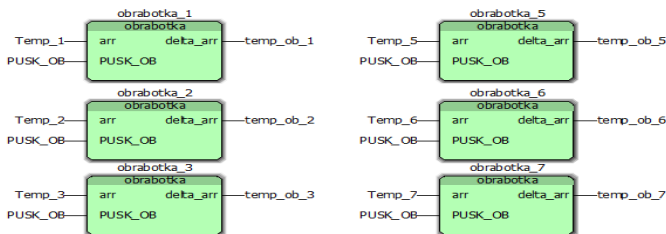


Fig. 14. Processing of received arrays

The program has such input variables:arr - an array with the duration of the piston motion at the same speed level;PUSK_OB is the control signal.Output:delta_arr -

processed array.Internal:i - counter of iterations of the inner loop.

For the construction of a rheological characteristic, a difference between the value at idle and "under load" is necessary, which is calculated by the obrabotka block. The array temp_ob_ (1-12) (Fig. 15) is the result. Each array corresponds to the speed mode, and contains measurements at a nominal value (1 index), and the difference between the mode under load and nominal (2-13 indices).

Variable	Value	Default value	Type	Instance
temp_ob_1			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_1
temp_ob_2			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_2
temp_ob_3			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_3
temp_ob_4			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_4
temp_ob_5			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_5
temp_ob_6			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_6
temp_ob_7			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_7
temp_ob_8			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_8
temp_ob_9			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_9
temp_ob_10			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_10
temp_ob_11			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_11
temp_ob_12			rec	STD_CNF.STD_RES.STD_TSK.Main.temp_ob_12

Fig. 15. Resulting arrays

The temp_ob_ (1-12) arrays are marked with an OPC check mark in the Variables Worksheet. This makes them available for transfer to the OPC server.

Fig. 16 shows a program for controlling the temperature of a test fluid in FBD language in the range of 30 to 100 ° C. To implement this function, an AI2ME module was added to the Interbus bus. The analog voltage inputs receive information from the temperature sensor (10) (Fig. 1) and the resistor R7, which is paired with the resistor R3 and sets the angle of the thyristor unlocking.

The piezoelectric actuator (9) (Fig. 1) executes the PLC commands to change the angle of rotation R3.

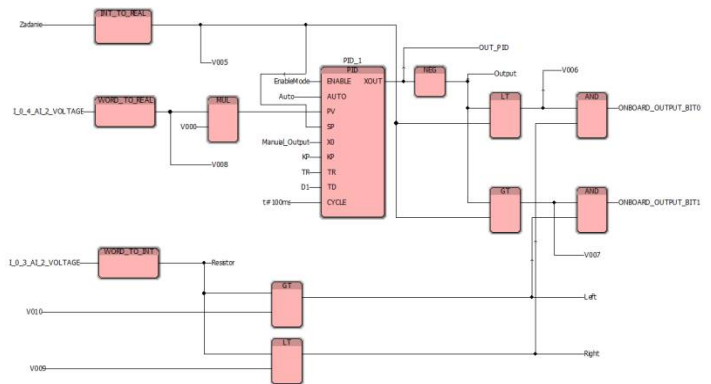


Fig. 16. Temperature controller program

To process and visualize the received data, a connection was established between the controller and the PC through the OPC server "AX OPC-server", the client on the PC for which SCADA is the VISU + system. Through the "ODBC DSN" protocol, the SCADA system supports a real-time database in "MS ACCES". Information from the database gets "Microsoft Excel", in which dependency charts are already being built. The information exchange is shown on Fig. 17.

The upgraded system is universal, it allows you to quickly rebuild from the version for laboratory studies to the viscosity

regulator of heavy fuel. The connection of the rotary piezoelectric motor allows testing of the cylinder oil.

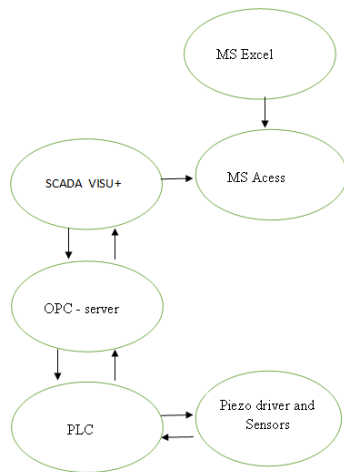


Fig. 17. Scheme of information transfer

During the tests, the data provided in Temp_(1-12) was obtained. This graph (Fig. 18) represents the dependence of the time of passage of the cylinder on the number of the experiment, at different speeds before processing the data and calculating the difference. This is done for clarity. As can be seen from the graphs, at low speeds, deviations reach 10%. At high speeds, graphics are almost linear. This is due to the fact that the software implementation of the pulse width modulation was chosen. To reduce the deviation, it is necessary to use hardware modules, for example the Phoenix Contact IB IL PWM / 2-PAC module, which will significantly increase the accuracy.

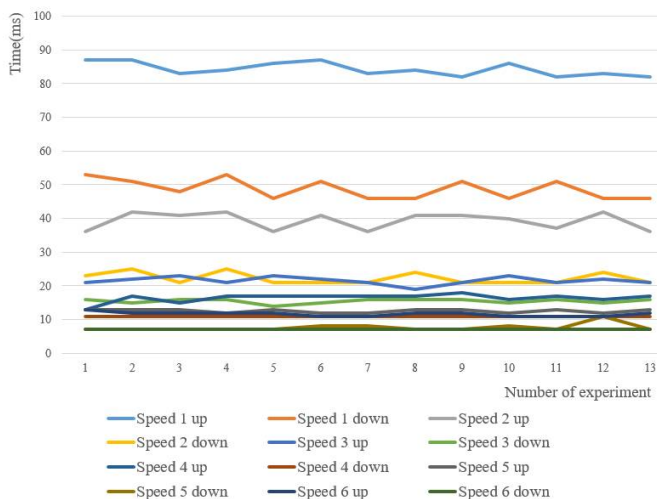


Fig. 18. Chart of the time of passage of the cylinder at different speeds

IV. CONCLUSION

Thus, the task of modernizing the system for determining the rheological characteristics of marine technical fluid has been fulfilled. The processes occurring in the measuring probe

correspond to the actual processes in the fuel equipment of the low-speed diesel. However, the nonlinearity of the linear piezoelectric motor is due to the low carrier frequency of the pulse-width modulation of engine control by software. At ILC 150 GSM/GPRS controllers, the cycle time is at least 1 msec. It has been experimentally established that the carrier frequency of 100 Hz allows for sufficient smoothness of speed change. At a frequency of 100 Hz, one period is 10 ms, and this is 10 cycles to the controller. Therefore, at a discreteness of 1 ms, 10 values of the speed of a linear piezoelectric motor can be provided. But at these speeds, the moving part of the engine at certain speeds does not reach the extreme points, which leads to an increase in the measuring time.

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