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Magnetic course measurement system using inductive sensor

SUMMARY

The paper presents problems related to the navigation system of a prototype of unmanned underwater apparatus designed for sea exploration.

The author took part in the tests of the navigation and propulsion systems and describes the applied magnetic course measuring method and system in which an inductive transmitter of inductive gyrocompass produced in series has been used.

INTRODUCTION

A prototype of unmanned underwater apparatus has been built at the Technical University of Szczecin.

The apparatus is designed for sea bottom exploration, underwater inspections of hydraulic engineering structures, installations and mineral resources as well as for collecting samples without danger for the personnel. The apparatus is supplied and controlled from a surface mother craft by means of a cable. The control is aided by a main 16 - bit computer carried by the surface craft working together with a 16 - bit computer installed in the underwater apparatus. All measurements, regulation and control of processes taking place during operation of the apparatus are carried out using these two computers. This way it is possible to control :

a/ the movement of the apparatus in the given direction (manually),
b/ the movement of the apparatus along a given trajectory,
c/ the approach of the apparatus to a given point,
d/ the movement at a constant depth,
e/ the movement at a constant distance from sea bottom,
f/ the dynamic stabilization of the apparatus in the water depth.

The author took part in research work related to the development of the apparatus, especially focussed on navigation and propulsion systems. The paper presents the magnetic course measurement method and system using inductive transmitter of an inductive gyro-compass. The standard inductive gyro-compass is used as course indicator on board planes and helicopters of different types and destination. Unfortunately because of its relatively high weight, substantial power consumption and of lack of appropriate analog signal carrying information on the current course it was impossible to apply it fully in the underwater apparatus. Thus only the inductive transmitter of the inductive gyro-compass determining the direction of the terrestrial magnetic field forces has been used in the system. The sensor supplies signals about the current course which after initial processing are transmitted to the deck computer. The final processing is carried out there and the information on the current course is delivered to the course indicator and to the course recorder. This enabled to diminish the weight of the equipment more than ten times and to obtain analog signals carrying information on the current course possible to be processed by a computer. It also allowed to diminish the course measuring error using all the twelve impulses of phase voltages.

MAGNETIC SOUNDER AND ITS FUNCTIONING PRINCIPLE

The magnetic sounder (Fig. 1) consisting of two identical and arranged in parallel cores made of molybdenum permalloy is used as the measuring element of inductive transmitter. Two windings are coiled on the cores - the primary submagnetizing biwinding and the secondary for measuring purpose. The primary windings consisting of two parallel wires coiled on each core separately are connected in series. The secondary winding is coiled on both cores.

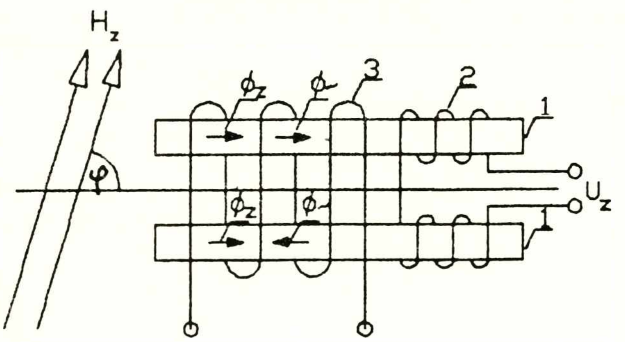

Fig. 1. Magnetic sounder : 1 - core, 2 - submagnetizing winding, 3 - measurment winding

When the sounder is placed in the terrestrial magnetic field having the horizontal component of intensity H_Z then the terrestrial field lines are focused in the cores 1. This in turn results in the creation of the magnetic flux Φ_Z proportional to the magnetic permeability of the core material. The alternating current having f frequency, passing through the magnetizing winding 2 is periodically dismagnetizing the cores, changing their magnetic permeability. Cores are saturated at the maximum submagnetizing current values. Their magnetic permeability is changing quickly. The magnetic flux Φ_Z in cores is changing accordingly. When diminishing the submagnetizing current the magnetic permeability of cores is increasing and passing through zero it reaches its maximum value.The magnetic flux is also reaches its maximum value.

During one period of the submagnetizing current oscillation the magnetic permeability of cores and in consequence the flux Φ_Z are changing two times. This way, if the magnetizing current changes with frequency f, the magnetic flux Φ_Z in cores changes with doubled frequency 2f, inducing in the measurement winding 3 , encircling both cores, an electromotive force of 2f frequency. The value of this force depends on angle ϕ (angle between the longitudinal direction of sounder core axes and the direction of the horizontal force component of the terrestrial magnetic field). If the core axes coincide with the direction of terrestrial field forces then the induced electromotive force has the maximum value. On the other hand if the axes of cores are perpendicular to the direction of terrestrial field forces then the electromotive force is equal to zero. The primary windings are connected so that, when supplying them with alternating current having frequency f, magnetic fluxes Φ_Z are created in cores. Acting in opposite direction the fluxes are neutralizing each other. They induce no electromotive force in the measurement winding coiled on both cores. The primary winding is needed only for converting the constant terrestrial magnetic field in the core into pulsating fields through the change of magnetic permeability of cores. In result an electromotive force dependent only on the terrestrial magnetic field is induced in the measurement winding of the sounder. With the same position of cores in relation to the field force direction the value of electromotive force depends also on the degree of permeability modulation, i.e. on the ratio between the maximum and minimum values of the magnetic permeability. This is why molybdenum permalloy is applied as the material for cores. The material is characterized by very high magnetic permeability in non-saturated condition. It has the ability to saturate already under the influence of weak magnetic fields and has a relatively low permeability.

TRANSMITTER MEASUREMENT SYSTEM WITH SYNCHRONOUS FILTER

The measurement system of the inductive transmitter sensor consists of three sounders placed in one plane on the sides of an equilateral triangle (Fig. 2). The submagnetizing windings are connected in series and

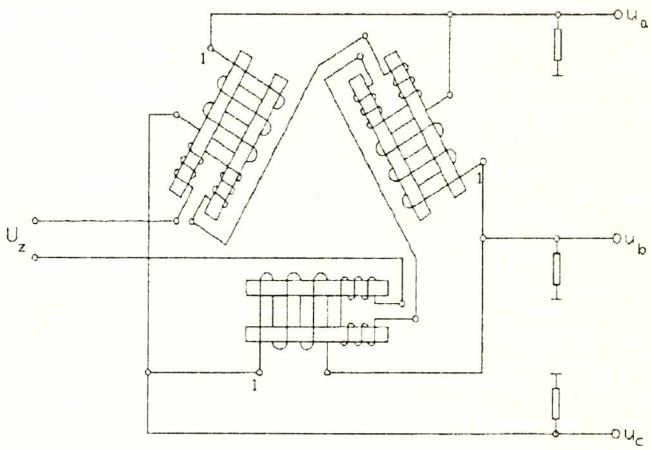

Fig. 2. Inductive sensor

supplied from an alternating current source with 400 Hz frequency and 1.7 V voltage. The triangle connected measurement windings are loaded with star connected three resistors R.

Fig. 3 shows the real changes of phase voltage obtained from the inductive transmitter for different course angles ϕ together with the sinusoidal supply voltage as the carrying voltage.

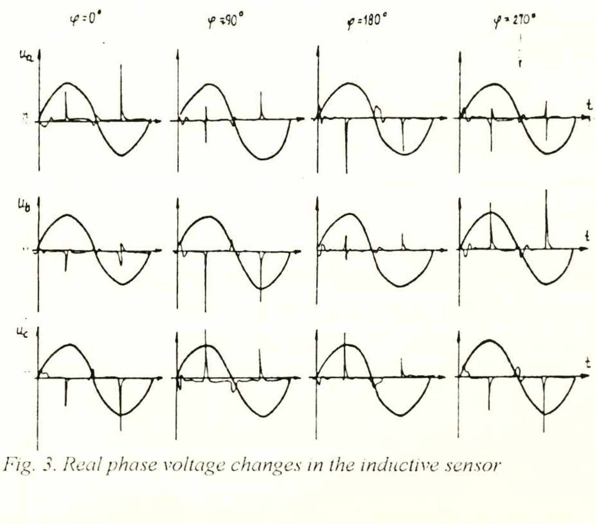

Fig. 3. Real phase voltage changes in the inductive sensor

The information about the course angle is given in the amplitude of short voltage impulses occuring close to the extremes of the supply voltage. Amplitudes of particular phase voltages can change from negative, through zero to positive values depending on the course angle. In result the information on the course is given in the amplitude of twelve impulses. The question is whether all twelve impulses are indispensable to obtain the given course angle accuracy. The problem has been analyzed and it resulted that to obtain the same accuracy as for the compass (abt. 3°) it is enough to use six impulses emerging close to the positive (or negative) extremum of supply voltage half-waves. The accuracy is absolutely sufficient in case of steering the underwater apparatus. This simplifies to a great extent the electronic system. Phase voltages u_a, u_b, u_c are taken for further processing. Analyzing the real changes of these voltages (Fig. 3) it has been found that they contain a large number of disturbances. Because the information on the course is given exclusively by the amplitudes of impulses it has been assumed that all other changes constitute disturbances which diminish the measurement accuracy.

In order to eliminate the diturbances a very reliable and simple synchronous filter has been designed. Its diagram is shown in Fig. 4 and the changes of voltage in the filter system in Fig. 5.

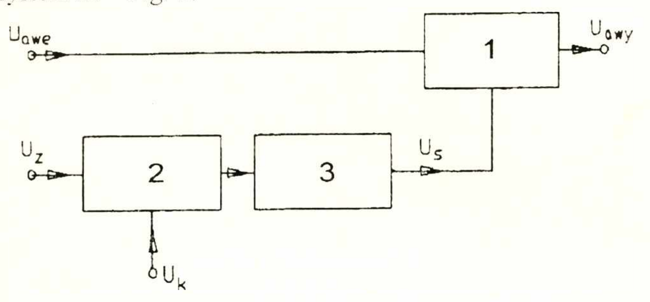

Fig.4. Block diagram of synchronous filter: 1 - analog key, 2 - comparator, 3 - univibrator

The real changing voltage, which is to be filtered constitutes the input to the analog key. The key is controlled by rectangular auxiliary voltage. The sinusoidal voltage U_Z (1.7 V, 400 Hz) supplying the submagnetizing winding of the inductive transmitter is simultaneously compared in the comparator with the set voltage U_k . The output voltage from the comparator is high when U_Z is higher than U_k and low when U_Z is lower than U_k. The passage from high to low voltage levels results in triggering a univibrator and generation of rectangular impulse with duration time τ. The voltage opens analog keys. The key opening for time τ causes that the output voltage from analog keys contains only the information on the value of angle φ and that all disturbances occuring in time when the keys are opened are eliminated. The main advantage of this filtration method is its simplicity and practically lack of amplitude and phase deformations of the filtered signal. The second advantage is the possibility to regulate the filtering time of the filtered signal (through regulation of the time constant τ of the multivibrator), and to regulate the beginning of filtering of the set changing voltage U_k (through the regulation of the voltage input to the

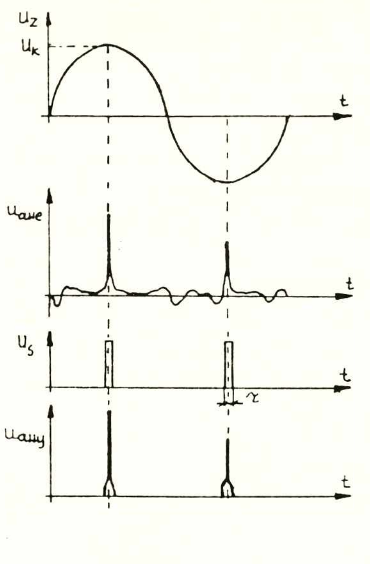

Fig. 5. Voltage changes in synchronous filter: U_{awe} - input voltage, U_{awy} - output voltage, U_s - signal voltage

computer) obtaining this way the possibility to optimize the filtration parameters. Basing on the hitherto made analysis an electronic system has been developed (block diagram in Fig. 6.). The analog output signals from this system include information on the course angle.

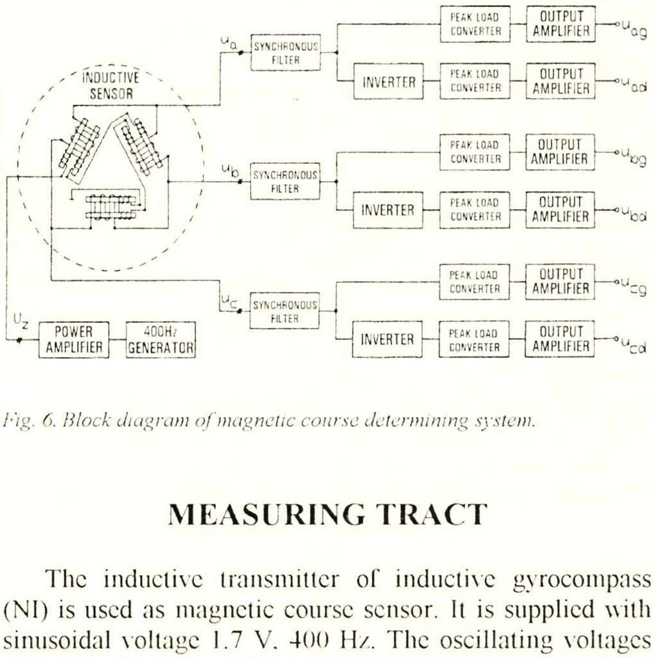

Fig. 6. Block diagram of magnetic course determining system.

MEASURING TRACT

The inductive transmitter of inductive gyrocompass (NI) is used as magnetic course sensor. It is supplied with sinusoidal voltage 1.7 V, 400 Hz. The oscillating voltages carrying the information on course angles, obtained from the sensor, are supplied to three identical processing blocks. This is why the functioning of only one measuring tract will be described. The oscillating phase voltage, e.g. u_a, is supplied to the filter system. This system filters out all the disturbances and separates from the whole oscillation the impulses carrying information on the course angle. Only six impulses occuring close to the positive maxima of the positive voltage half-waves supplying the sensor are taken.The output impulses from the filter are separated and changed into impulses having the same sign and amplified to the appropriate level. The separated and amplified impulses are directed to the converter changing their amplitude to proportional constant values.Six constant voltage are obtained at the output from the electronic system. Their value determines explicitly the course angle. Fig. 7 shows the changes of these voltage values depending on course angle ϕ. The voltages are supplied through multiplexer to the analog-to-digital converter and further to the microprocessor system. The aim of this system is to determine the course angle, to show it on the digital display and to feed it to the course recorder.

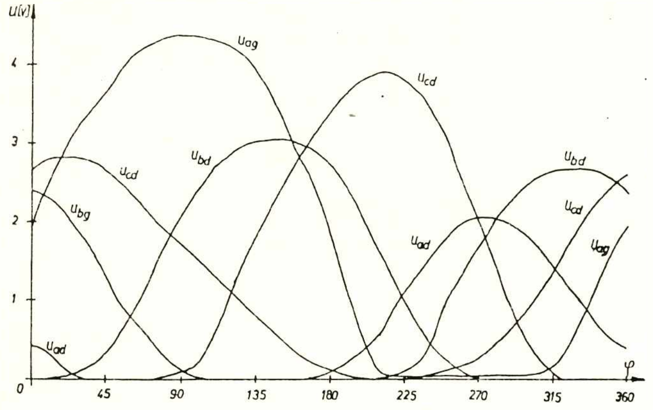

Fig. 7. Dependence of output voltages on course angle

The system has been mounted in the underwater apparatus. The apparatus was subject to thorough investigations and service tests in real conditions (deep water tests on a lake). The results confirm that the assumed technical and operating parameters have been met.

RECAPITULATION

- Due to its low weight ,volume, and power consumption the described course measuring system is specially applicable for small gabarite apparatuses.
-The measuring sytem is easy to couple with a microprocessor system because the input information on the course angle is in the form of only six standard analog voltages.
-The accuracy of the measuring system can be increased through the introduction of all twelve voltages.
-Tests carried out in real conditions have confirmed the assumed parameters and full usefullness of the prototype.

BIBLIOGRAPHY

1. Badźmirowski K., Pieńkos J. et al. :" Uklady i systemy mikroprocesorowe . " WKŁ, Warszawa 1990 .
2. Gajewski P. , Turczyński J. :" Cyfrowe uklady scalone CMOS ." WKŁ, Warszawa 1990.
3. Kulka Z. ,.Libura A. , Nadachowski M. :"Przetworniki a/c i c/a ." WKŁ, Warszawa 1987.
4. Kulka Z. , Nadachowski M.:" Liniowe uklady scalone." WKŁ, Warszawa 1987.
5. " Opis techniczny busoli giroindukcyjnej typu GIK-1." Wydawnictwa Przemysłu Lotniczego, Warszawa 1976.

Conferences

Technical-Scientific Conference on New Trends in Refrigeration

The Conference was held on 23-24 June 1994 in Szczecin, organized by Refrigeration Dept., Marine Technology Faculty of the Technical University of Szczecin together with Refrigeration and Air-conditioning Section of the Polish Society of Mechanical Engineers as well as Ship Machinery and Installations Dept. of the Merchant Marine Academy in Szczecin.

Some new achievements in design, research, and operation of refrigeration machinery and installations were presented in 16 papers.

Conference participants were also given an opportunity to acquaint themselves with the results of 14 projects dealing with:

- chemical cooling media;
- recent ecological problems connected with exploitation of the refrigerating, air conditioning and ventilation installations;
- ecological construction of machinery and installations;
- automation and appliances for refrigerating units.

One of the papers was devoted to 30th anniversary of education of ship refrigeration in Poland, which underlined a jubilee nature of the conference.