Development of a Computer System of Technical Condition for the Electric Podded Azimuth Thrusters

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

Sergii Khniunin
dept. of Theory of automatic control and computer technology
National University "Odessa Maritime Academy"
Odessa, Ukraine
reg-post@ukr.net

Vitalii Budashko
dept. of Electrical Engineering and Radio Electronics Faculty
National University "Odessa Maritime Academy"
Odessa, Ukraine
bvv@te.net.ua

Mark Nikolskyi
dept. of Automation of Vessel Gas Turbines and Diesel Installations
National University "Odessa Maritime Academy"
Odessa, Ukraine
markdezert@ukr.net

***Abstract*—The results of studies of the influence of the emerging a Coandă effect when using the boundary modes of operation of the propulsion complex as part of the creation of a computer system for the technical condition of the electric podded azimuth thrusters for improving the safety of operation of marine facilities are presented.**

Keywords—safety of navigation, the Coandă effect, an electric podded azimuth thrusters, propulsion complex, piezo transducers

I. INTRODUCTION

Recently, with stricter requirements for the safety of operation of marine facilities, manufacturers are using new technologies to create more sophisticated systems. In the case of using azimuthal propeller units, when the aircraft moves slowly at a given rate (when laying the cable on cable-laying vessels) and when the position is held (on scientific vessels and semi-submerged floating drilling platforms), a situation arises when the flow of water is directed under the bottom and "sticks" to it under the action of the Coanda effect (Fig. 1).

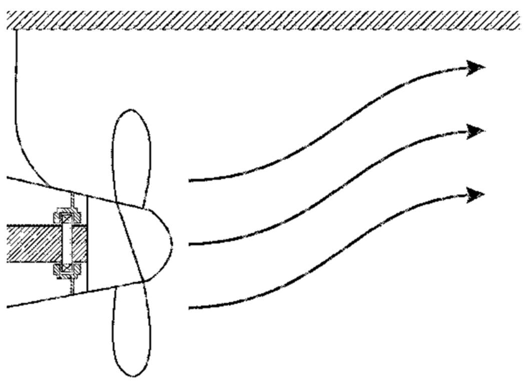

Fig. 1. Manifestation of the Coanda effect

The appearance of this effect leads to the following negative consequences:

- there is an uneven and unplanned premature wear of components of the azimuth screwdriver column, namely: deadwood, thrust and bearing bearings,
- the action of the external force results in the loss of the screw stop to 15%.

II. PURPOSE OF WORK

Creation and improvement of the theoretical and software-technical base of the ship's azimuth screwdriver column monitoring system for ensuring the safety of commercial and naval vessels.

III. CONTENTS AND RESULTS OF THE RESEARCH

This problem is known to the manufacturers of azimuth screwdriver columns [1], but at the moment the countermeasures are reduced to a mechanical counteraction to the effect of this effect by entering the mounting angle of the entire structure. This measure does not completely eliminate the effect of this effect, but only shifts the moment of its appearance to higher speeds, and also leads to a decrease in the efficiency of the entire propulsion complex due to the non-optimal direction of the water flow at an angle to the horizontal.

In order to detect this effect, we proposed and patented a ship monitoring system for the appearance of the Coanda effect [2] for monitoring the technical condition of the azimuth helical column shown in Fig. 2.

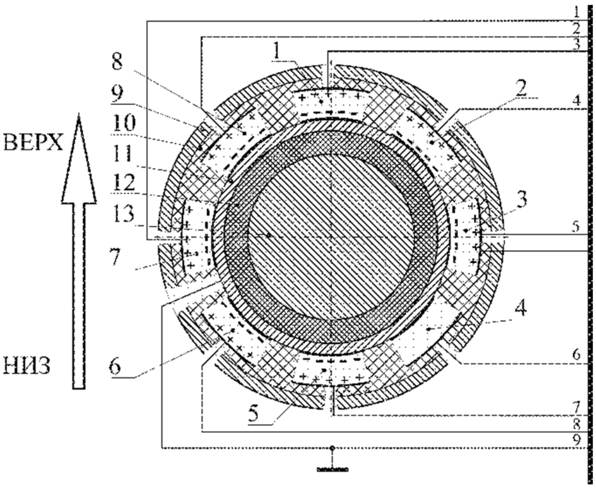

Fig. 2. Coanda effect monitoring system with sensor installation in a stern bearing

In this scheme, the following is reflected: the sensor system 1–8, 9 – the motor nacelle body, 10 - the dielectric gasket, 11 – the negative pole, 12 – the deadwood bearing, 13 – the shaft line. Piezoelectric sensors in the form of plates and disks were used as sensors. Let us analyze the properties of PE of this physical form.

Variants of piezoelectric converters in the form of plates are shown in Fig. 3.

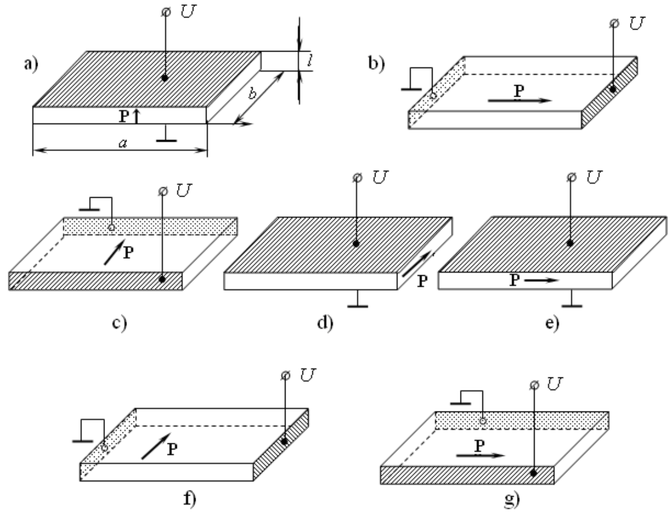

Fig. 3. Piezoceramic transducers in the form of plates: a, b, c – traditional; d, e, f, g – domain-dissipative transducers

In Fig. 3, a, b, c show the traditional piezoelectric transducers, in which the electrodes are printed on the faces perpendicular to the polarization vector P. Fig. 3, d, e, f, g show the domain-dissipative transducers [3, 4], in which the electrodes are placed on the faces parallel to the polarization vector P (the polarization vector is perpendicular to the field strength vector between the output electrodes).

Consider, for example, piezoelements in the form of a plate with linear dimensions: length – a = 5 cm; width – b = 5 cm and thickness l << a, b.

A schematic model of such a converter is shown in Fig. 4.

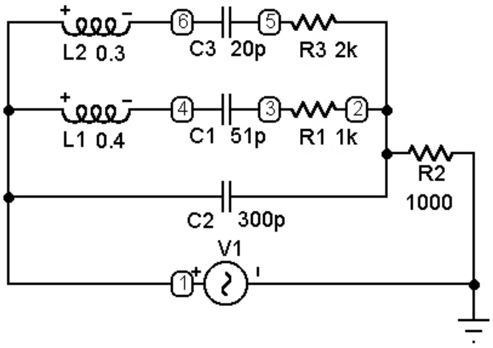

Fig. 4. Schematic model of a piezoelectric transducer in the form of a plate

A characteristic feature of such a piezoelectric element is the presence of two circuits with a series (mechanical) resonance. The resonance in each of the circuits corresponds to the mechanical resonance of the sample along the length or the width.

AFC and PFC for the circuitry of the traditional piezoelement in the form of plates (in Fig. 3, a – c) are shown in Fig. 5.

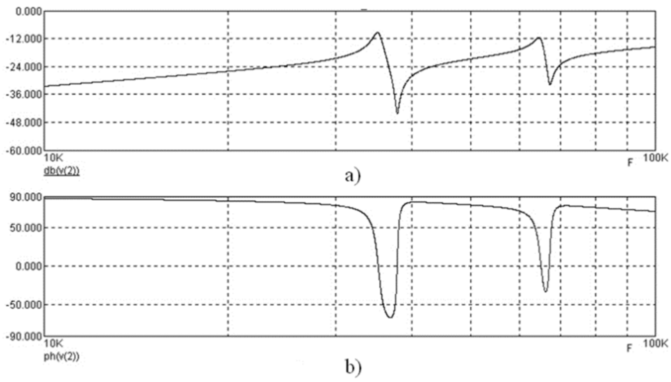

Fig. 5. AFC (a) and PFC (b) of the circuit design of the traditional PCE in the form of a plate

AFC and PFC for the schematic model of the domain-dissipative SCE in the form of plates (from Fig. 3, d - g) are shown in Fig. 6.

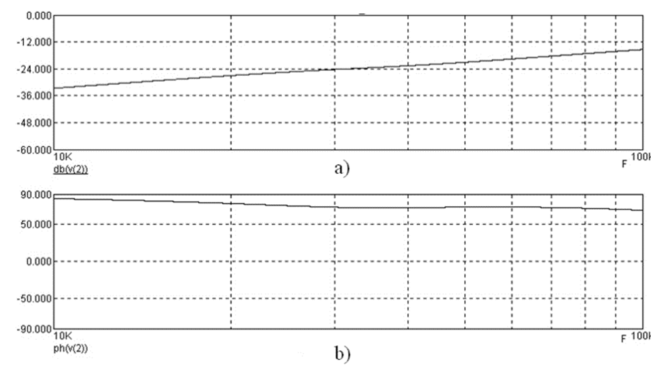

Fig. 6. AFC (a) and PFC (b) schematic model of domain-dissipative piezoelements

As can be seen from Fig. 5 and 6, for traditional PCE in the form of plates in the investigated frequency range there are two resonances. In the domain-dissipative piezoelectric cell, these resonances are suppressed, i.e. extended operating frequency range.

Transient characteristics for circuitry models of traditional piezoelements and domain-dissipative piezoelectric elements are shown in Fig. 7 and 8 respectively.

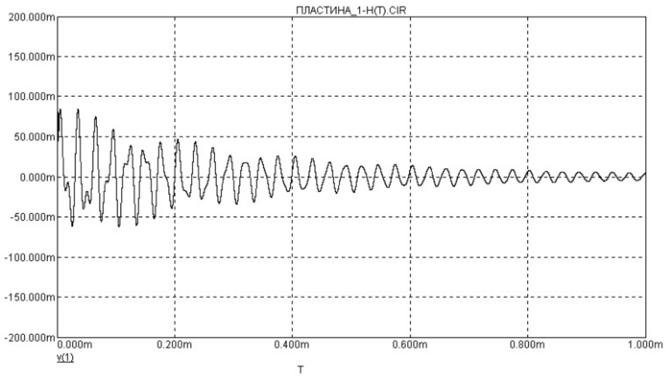

Fig. 7. The transient characteristic of the circuitry model of a traditional piezoelement in the form of a plate

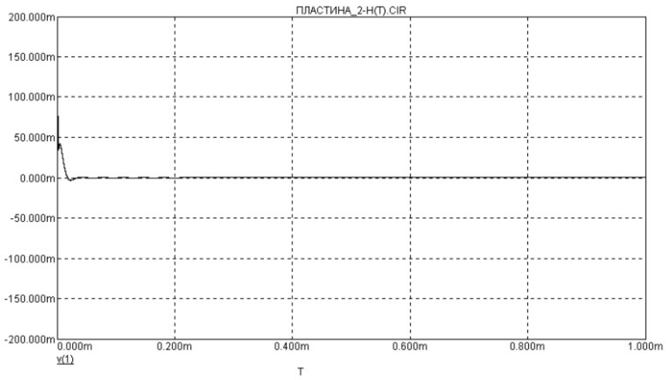

Fig. 8. Transient characteristic of the circuit-model of the domain-dissipative piezoelectric element

For cases where it is not possible to mount a sensor system in a stern bearing, we have designed and patented the Coanda Effect Monitoring System [5] shown in Fig. 9.

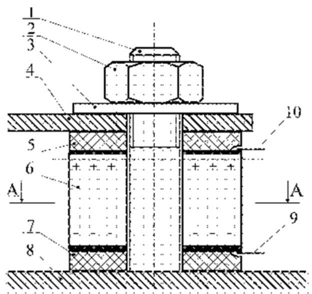

Fig. 9. Monitoring system of the Coanda effect with the sensor system in the place where the azimuth screw column

In the given scheme it is reflected: 1 - a bolt of fastening of an azimuthal screw-column column to the vessel hull, 2 - a nut, 3 - a washer, 4 - fastening of an azimuth screw-column column, 5 and 7 - gaskets from an insulating material, 6 - a piezoelectric sensor, 8 - a ship hull, 9 and 10 - positive and negative contacts of the piezoelectric sensor.

Its difference from the proposed earlier is that the installation of this system on the ship can be made without interference in the design of the azimuth screwdriver column. During installation, piezoelectric sensors are used, installed in places most susceptible to mechanical stress when this effect occurs [6] - for bolts in the form of rings.

Let us analyze the functional properties of piezoelectric converters in the form of rings. The versions of piezoelements in the form of rings are shown in Fig. 10.

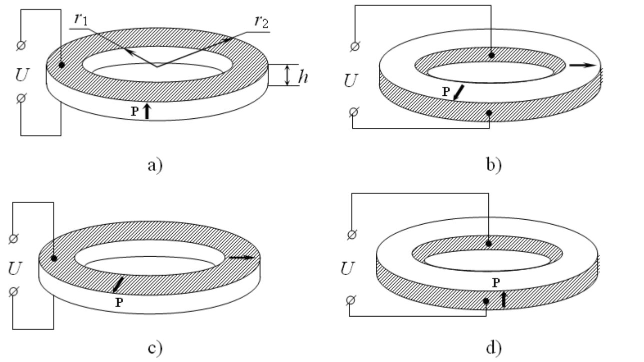

Fig. 10. Piezoceramic transducers in the form of rings: a, b - traditional; c, d - domain-dissipative

In Fig. 10, a, b shows the traditional piezoelectric elements, in which the electrodes are printed on the faces perpendicular to the polarization vector P. Fig. 10, c, d show the domain-dissipative piezoelements in which the electrodes are applied on the faces parallel to the polarization vector P (ie, the polarization vector is perpendicular to the field strength vector between the output electrodes).

Consider, for example, piezoelements in the form of rings with radii r_2 = 4 cm, r_1 = 3 cm and thickness $h \ll r_2$. A schematic model of such a converter is shown in Fig. 11.

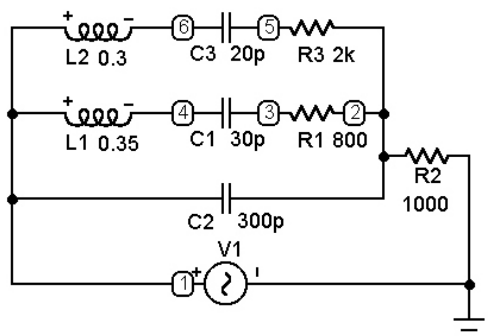

Fig. 11. Schematic model of piezoelectric transducer in the form of rings

As for piezo elements in the form of plates (Figure 3), the piezoelement model in the form of rings also has two circuits with a series (mechanical) resonance. The difference is the values of dynamic capacitances and inductances. AFC and PFC for the circuitry of the traditional piezoelement in the form of rings (according to Fig. 10, a, b) are shown in Fig. 12.

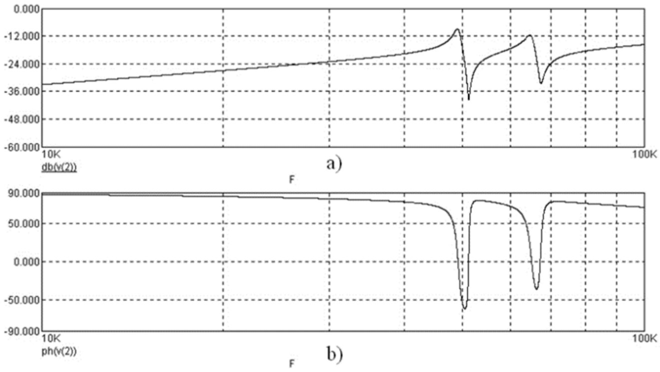

Fig. 12. AFC (a) and PFC (b) circuitry of a traditional piezoelement in the form of rings

AFC and PFC for the circuit model of the domain-dissipative piezoelectric element in the form of rings (according to Fig. 10, c, d) are linear, as in Fig. 6.

In Fig. 13 shows the frequency response and PFC of the circuit model of piezoelectric elements in the form of rings for different values of the internal radius r_1.

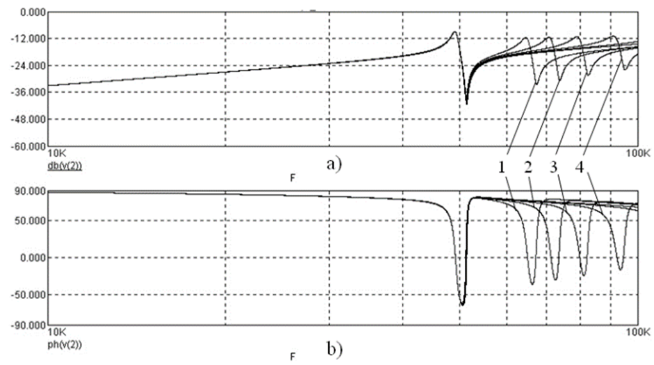

Fig. 13. AFC (a) and PFC (b) of the circuit model of piezoelements in the form of rings for different values of the internal radius r_1: 1 - r_1 = 3 cm; 2 - r_1 = 2.6 cm; 3 - r_1 = 2.3 cm; 4 - r_1 = 2 cm

The transient response for the circuitry model of a traditional piezoelectric element in the form of rings is shown in Fig. 14.

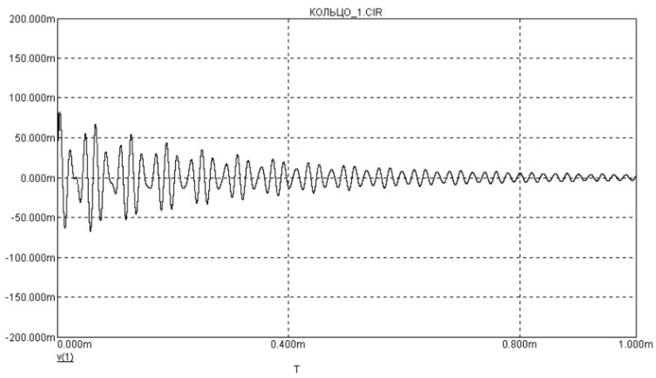

Fig. 14. The transient characteristic of the circuitry model of the traditional PCE in the form of rings

Conclusions and Recommendations

As a result of the studies, the following results were obtained.

For the first time, a method for determining the Coanda effect was developed on the basis of fixing the deflections of the ship shafting under the influence of external force carried out by sensors located at control points.

Models of bimorph piezo transducers have been improved, which made it possible to determine the physical parameters (characteristics) of the primary converters included in the computer system for determining the Coanda effect.

Functional and circuit simulation of piezoelectric converters was developed further by taking into account the polymorphism of the primary converter, which made it possible to select the optimal types, shapes, types and sizes of piezoelectric converters.

The created computer system for determining the appearance of the Coanda effect in the operation of the electric podded azimuth thrusters, which allows to reduce the accident rate and improve the work of the dynamic positioning system of semi-submersible floating drilling rigs. The difference between the proposed system and the existing mechanical systems lies in the possibility of abandoning cumbersome mechanical structures that reduce the efficiency of the propulsion complex and reduce the accident rate of their operation.

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