PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
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RANGE ACTION AND POSSIBILITIES OF ITS FORECAST AND PREVENTION

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Abstract

Range action in ports and its signs are considered. The effect of long waves (surf beats and meteorological vibrations) is the possible cause of oscillations of port aquatories. The method of range action forecast based on the results of comparison of facts about the position of barometrical fields, pressure gradients and the duration of a certain synoptical situation with the extent to which the range action has developed is interesting too. Different hypotheses about the way the energy of long period oscillations of the water mass in port is converted into periodic motions of moored ships are discussed. Authors believe that to forecast and prevent range action main efforts must be directed to the study of long waves in the coastal zone of the sea. The succession in investigations of the connection between individual processes when forecasting the range action is suggested.

Periodical horizontal drifts of ships moored in ports are called the range action. The first signs of range action are weak rhythmical stretchings and slackenings of moorings and inconspicuous periodical displacements of the ship. In case of a weak range action periodical stretches of the moorings become stronger and one should increase the number of moorings to continue handling operations. During heavy range action it is not possible to keep the ship moored, it cannot even be kept in position by strong anchor chains. Great displacements of ships can lead to serious accidents such as wrecking of berth structures, great damages to the ship's hull and even total wrecking of the ship. Cases of destructive range action are known in the Soviet ports Tuapse, Sochi, Batumi a.o.(1)

Numerous observations showed, that during ship's motions there can always be registered oscillations in the port water area with periods from 30 sec. to 7,5 min and a mean height of about 20-30 cm. Information about flows in the port during range action is more scarce. The measurements of flows in the Tuapse port aquatory during range action showed, that while ships performed considerable cyclic horizontal motions a sparbuoy did not make any visible similar displacements. This makes evident that flows in the port waters during range action are not strong. Special instrumental measurements performed in the port of San Nicolas (Peru) showed, that there are flows with the speed 15-25 cm/sec in the case of considerable motions of ships (2). But in that case no registration of wave oscillations was conducted, so it is impossible to arrive at a conclusion as to the part played by the flows observed in the creation of range action.

Now the majority of scientists believe that range action in ports are caused by long waves of open sea: surf beats and meteorological vibrations. Surf beats are sea waves with mean periods of about 1-3 min. and a height from I cm to several dm. The first to discover and describe them was W.H.Munk (3). Meteorological vibrations fall on the frequency scale between surf beats and tides. Their periods vary from 7,5 to 100 min and the height - from 5 to 100 cm. First attempts to register and to explain them were made at the end of XIX th century in well known works of Ferrel, Chrystall, Airy and others.

Long waves of both types pass through protective structures of the port and transform on its aquatory into a system of oscillations with one or several periods and heights. Any port can be considered as an almost closed system, which is exposed to continuous spectrum of oscillations penetrating through the entrance. The port system selects from that spectrum and resonantly amplifies oscillations with frequencies, close to the seiche-like frequencies of the port waters, with the surf beats causing own oscillations of smaller port aquatories and meteorological vibrations those of big ones. Thus, according to Joosting (4), seiches in Capetown are the result of joint influence of surf beats and meteorological vibrations; the first causing dangerous ship motions in some isolated regions of the port, the second - all over the aquatory. In Japanese ports, which are situated in natural bays and harbours and have large aquatories, meteorological vibrations and tsunamis are the real causes of port oscillations. Study of meteorological vibrations and tsunamis therefore is more interesting there.

The effect of long waves on port aquatories may appear in two ways. Firstly, after the long waves entered the port, they can be reflected over and over again and subjected to interference. If there is no intense damping of wave conditions, a stable long period "crowdness" is created in the port, which leads to range action. Secondly, if there is resonance between port aquatory and long waves from the sea of open, seiches are amplified and cause ships motions both due to the periodical change of slope surface and due to oscillating opposite currents in the seiches nodes. One process does not exclude the other, but are rather complementary. The result is a rather complicated system of different wave oscillations. The following is noteworthy: dangerous ships motions in ports have periods close to those of own port aquatory oscillations.

Up to now there is no agreement about the way the energy of long period oscillations of the water mass in port is converted into periodic motions of moored ships. According to Wilson's hypothesis (5, 6) the cause of the ships motions is ships acceleration by alternate changes in directions of water currents; these currents occur in case of long waves and seiches. Joosting (4), believes that the cause of range actions is the tangential component of the gravity, which has effect on the ship when she is on the inclined slope of the long wave. To verify these hypotheses the authors calculated speeds of flows in the seiches nodes of Tuapse port (by Defants method). Results of flow speed calculations for two-nodes and four-nodes seiches (see Fig. 1) are shown on table 1.

Table I

Height of long waves (seiches), m	0,10	0,20	0,40	0,80
Speed of flows in nodes of two-nodes seiches on axis OO, m/s	0,03	0,06	0,12	0,24
Speed of flows in nodes of four-nodes seiches on axis AA, m/s	0,04	0,08	0,15	0,30

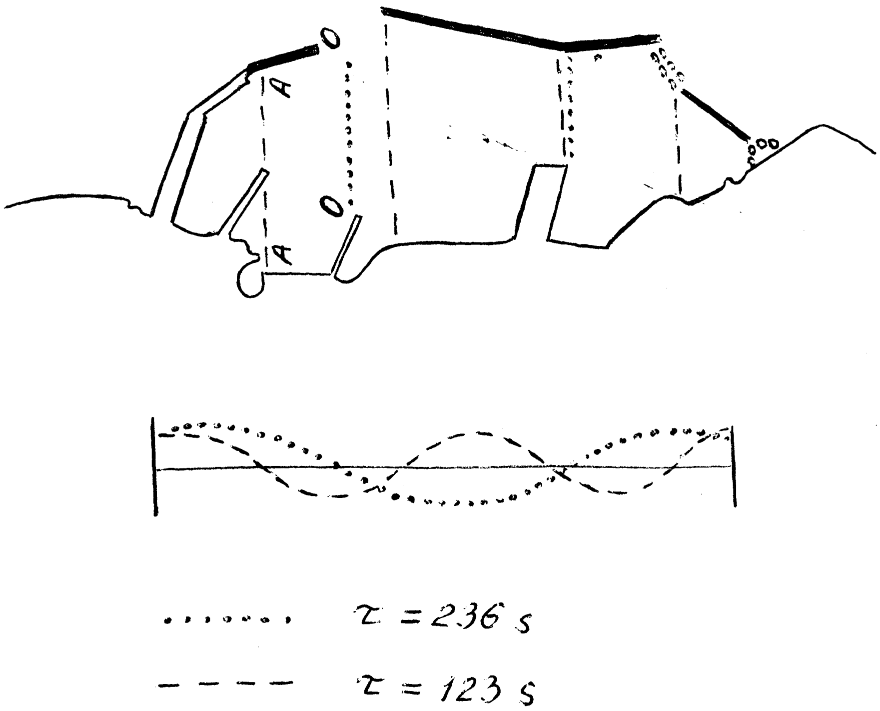

Fig. 1. Two-nodes (τ =236 s) and four-nodes (τ = 123 s) seiches in Tuapse port. Node-lines are shown on plan of port.

In Tuapse port long waves very seldom have a height of more than 30 cm. Long waves with height about 80-100 cm were observed only once from 1958 to 1970. So we shall consider that the mean speed does not exceed 10-12 cm/sec. Loads on ship plotted against flow parameters (speed and direction) for ships with tonnage 20000 and 133000 tons are shown in fig. 2. These plots are taken from (7).

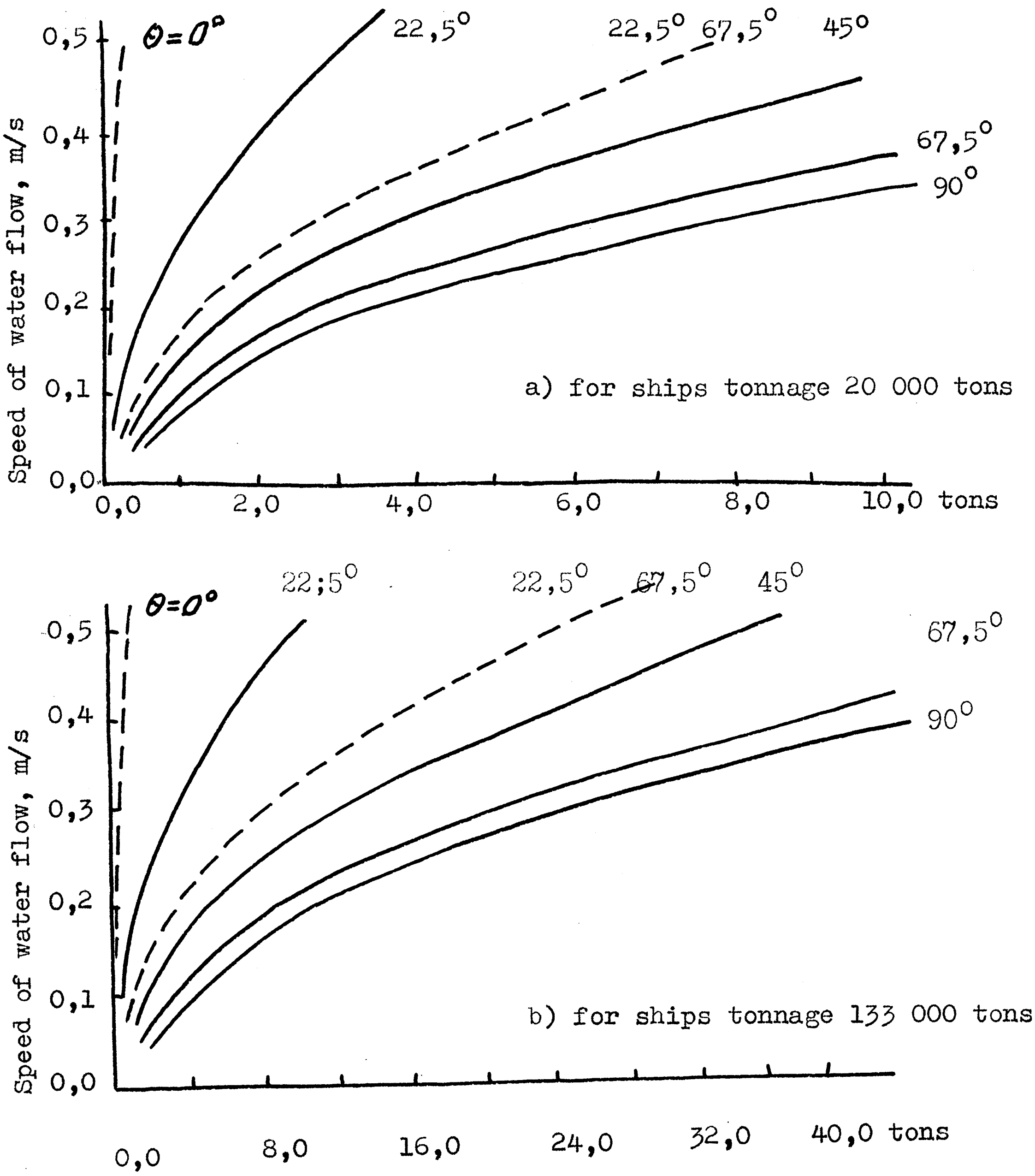

Fig.2. Loads on ship in tons:

— — — load on ship along its longitudinal axis

———— side load on ship

θ - the angle between the speed direction and longitudinal axis of ship

In fig. 2 we see, that for ships with tonnage 20000 and 133000 tons, for flow velocities of about 0,15 m/sec the loads on ship will be small (about 0,05-0,1 tons), if the angle between the direction of current and longitudinal axis of ship is near 0^{o}. But velocities will be greater (about 2-8 tons), if the angle is near 90^{o}. The ship experiences much bigger loads if the tangent component is considered being the driving force. For example: let a ship be on the inclined side surface of a wave. Moreover it is known that its length is considerably smaller than the wave length and the wave period is considerably greater than the period of ships own vertical oscillations (Fig.3).

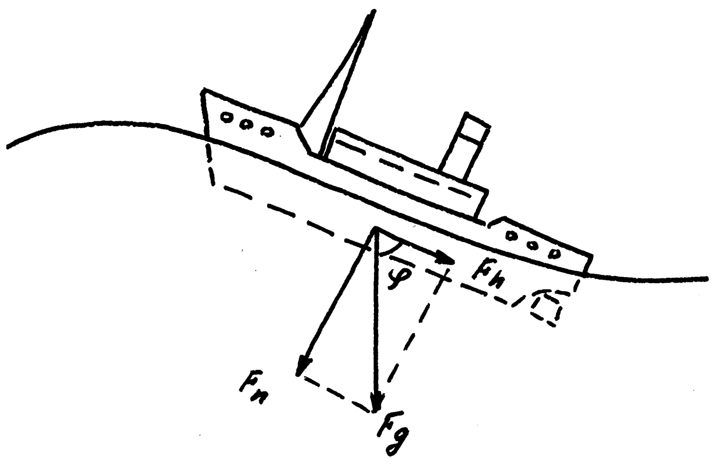

Fig.3. A ship on the inclined side surface of a wave: F_g - the ship gravity and its tangential F_h and normal F_n components.

Now we can divide ships gravity Fg on components: the first F_n is perpendicular to the wave surface or to the horizontal plane of the ship(assuming these surfaces are equivalent to one another); the second F_h is tangential component. The last can be considered horizontal with a high degree of accuracy. If we know the wave parameters and the ship gravity, we can calculate the horizontal component of the gravity in the following way:

$$F_h = F_g \cos \varphi \qquad /1/$$

Maximum values of horizontal components of ships gravity were calculated for ships with tonnage 20000 and 133000 tons. Results of calculation correspond to two-nodes and four-nodes seiches of Tuapse port with τ =123 and 236 sec and wave length λ = 900 and 1300 m. These results are shown in table 2.

Table 2

a) for ships tonnage 20 000 tons

Height of long waves, m		0,10	0,20	0,40	0,80
Horizontal component of ships gravity, tons	for λ = 900 m	7,0	14,0	28,0	56,0
	for λ =1300 m	4,8	9,6	19,2	38,0

b) for ships tonnage 133 000 tons

Height of long waves, m		0,10	0,20	0,40	0,80
Horizontal component of ships gravity, tons	for λ=900 m	46,5	93,0	186	372
	for λ=1300m	32,0	64,0	128	256

Comparing tables 1 and 2, and fig. 2 it is noted that horizontal component of gravity affects over the ship stronger than orbital water flows of long wave in 20 - 100 times by different angles between longitudinal axis of ship and flows direction.

Thus, the influence of horizontal component of gravity over the ship being on the inclined water surface, is the possible mechanism of ship motions by presence of long wave crowdness or seiches oscillations of water mass in the port. In accordance with this, the long waves height is the most correct index of the force of the range action in the port. This index permits us to consider the range action even in the absence of moored ships.

Authors believe that in order to forecast and prevent range action in ports main efforts must be directed towards the study of long waves in the littoral zone of the sea. In this respect surf beats are most dangerous for port aquatories of the USSR. But taking into consideration that ship tonnage increases continuously by and port structures go farther and deeper into the sea thereby increasing the areas of port aquatories, it is necessary to study meteorological vibrations too.

V.Bychkow, J.Darbyshire and Strekalov /8/ have determined dependence of elements of surf beats on the parameters of wind waves in open port roadstead. The height of surf beats is expressed as:

$$\bar{h}_n = \frac{k}{\sqrt{gH}} \frac{\bar{h}^2_{\beta z}}{\bar{\tau}_{\beta z}} \qquad /2/$$

where k = 32, $\bar{h}_{\beta z}$ - mean height of wind wave, $\bar{\tau}_{\beta z}$ - mean period of wind wave, H - depth, g - acceleration of gravity.

Correlation between periods of surf beats $\bar{\tau}_n$ and wind waves $\bar{\tau}_{\beta z}$ can be well approximated by the equation:

$$\bar{\tau}_n = 20\ \bar{\tau}_{\beta z} - 50 \qquad /3/$$

Empirical equations /2/ and /3/ were received for depth H=11 m. Calculations by Gluchovski /9/ make it possible to determine the parameters of wind waves on the surface if they are known on some depth. Parameters of long waves almost do not change on that depth. Surf beats usually occur simultaneously with wind waves. The authors assume that it is quite possible to use equations /2/ and /3/ for forecasting surf beats parameters on open roadsteads of ports.

When forecasting the range action the connection between individual processes should be determined in the following order:

a) wind waves parameters in the open sea; b) expected parameters of wind waves in the coastal (near the port) zone; c) calculated values of own oscillations of port aquatory and some of its parts, at least to the fifth or sixth nodes; d) effect of surf beats on the port aquatory or some of its parts; e) motions of moored ships as the result of long wave crowdness or seiche oscillations on the port aquatory.

The method of range action forecast for Tuapse port by Mitina /10/ is interesting too. This method is based on the results of comparison of facts about the position of barometrical fields, pressure gradients and the duration of a certain synoptical situation with the extent to which the range action has developed. The method was also applied for forecasting range actions in the ports of Novorossijsk, Sochi and Batumi;

We shall not touch here the possibility of constructive changes of aquatory and port structures to prevent the range action because these changes are difficult to realize. However we suggest a rather simple, but reliable way to forecast this phenomenon in the existing and projected ports. As is known, observations of wind waves and swell in the littoral zone have been conducted everywhere and more or less regularly during last decades. On this basis we can construct regime functions for distribution of wind waves elements, proceeding from which we can get a rather complete idea about surf beats in the regions of interest by means of empirical equations /2/ and /3/. The data obtained should be compared with the calculated values of port aquatories own oscillations which will make it possible to foresee the cases of coincidence periods. One may make use of one of the methods by Defant, Proudman J. as well as calculations by A. Koch to calculate the own oscillations of port aquatories. Disregard of long waves when designing new ports may result in ports being idle several months a year, as is the case in some ports on the Caspian, the Black and the Baltic seas.

Range action is widespread on the earth. With the navigation intensification range action brings ever more increasing damages. The investigation of this phenomenon will make it possible to solve such a problem of practical significance as forecasting the range action and taking measures to decrease it in existing and projected future ports.

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