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MEASUREMENT OF ICE LOADS ONBOARD ICEBREAKER «KAPITAN DRANITSYN» DURING ARCDEV - EXPEDITION

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ABSTRACT

The full scale measurement of parameters of ice loads is one of the important direction of investigations of interaction of ships and offshore structures with ice. The presentation contains the description of measuring equipment used for the measure of the response of the ice belt grillage of icebreaker «Kapitan Dranitsyn» during ARCDEV-expedition, the method of data processing and samples of results. The method of data processing is based on using finite element approach and allows us to obtain ice pressure, the contact area position, the shape of contact area and pressure pattern. The described approach was used for the development of the statistical model of ice load.

1. INTRODUCTION

The measuring of parameters of ice loads in the frame of Work Package 8 of project ARCDEV was carried out by two groups of scientists: on the tanker UIKKU and on the icebreaker «Kapitan Dranitzyn». The level of loading under interaction of ship and ice was estimated trough the strength parameters of the ice belt structures in both cases. There is some difference in ways of processing of preliminary data. This article is dedicated to description of measuring onboard of icebreaker «Kapitan Dranitzyn» which were carried out by scientific group from AARI (Russia).

Up to the early 80th AARI was the leading organization in Russia in the field of full scale testing of ice belt structures of ice going ships and icebreakers. The ARCDEV expedition allowed AARI to recapture the similar measuring on modern techniques. The measurements were carried out using 4-channels system. There was involved the new method of processing of signal records which allow to obtain the ice pressure

2. DESCRIPTION OF THE MEASURING SYSTEM

The measuring equipment used on board of icebreaker «Kapitan Dranitzyn» during expedition ARCDEV allowed to record the local strains of hull structure member in the set of points. The measured area arranged on the ice belt grillage between framing 118 and 130 and between double bottom and second deck (Figure 1 and Figure 5).

The equipment consisted on gauges, the digital converter and the recorder. The gauges are the wire sensors with base 20 mm. The configuration of measuring system used for every informational channel four wire gauges connected as a bridge. The total number of informational channels is 4 (table 1).

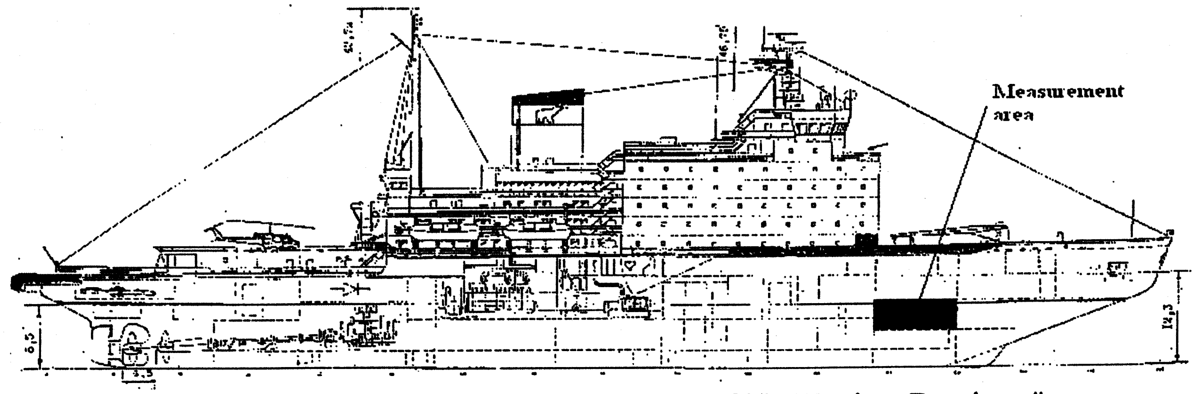


Figure 1. Measurement area in bow region of i/b "Kapitan Dranitsyn"

The calibration of wire gauges was carried out using steel calibration plate that fixed as a cantilever beam and was loaded by the force on the free end. The values of strains along the plate were used for the calibration. The signal that was recorded is a value of misbalance of the wire gauges bridge. The total account of the processed records is 113 with duration from 100 to 2000 sec (most 600 sec). The total duration is approximately 85000 sec.

Table 1
The arrangement of gauges for the second configuration of measuring system

Channel number	Arrangement of sensors
1	Bridge on web of stringer IV between frames 127 and 130
2	Bridge on web of stringer V between frames 127 and 130
3	Bridge on web of frame 128S middle of span between stringers IV and V
4	Bridge on web of frame 127 between stringers IV and V

3. MEASUREMENT RESULTS PROCESSING
3.1. Method of processing

The method for measurement results processing developed in AARI was used. The method assumes that the ice load on ice belt structure can be represented as a set of region with uniform distributed pressure on outside plating (Fig. 3) $(p_1,\ldots,p_n)$.

Let there are installed $\boldsymbol{m}$ sensors in the measuring area of ice belt. The finite element strength analysis allows to set correspondence between strains in the points with gauges $(\varepsilon_1,\ldots,\varepsilon_m)$ and load parameters $(p_1,\ldots,p_n)$. The strains ε_i can be calculated through signal value on sensor V_i and calibration coefficient α : $\varepsilon_i = \alpha \cdot V_i$.

Thus,

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_m \end{bmatrix} = \begin{bmatrix} k_{11} & \cdot & \cdot & \cdot & k_{1n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ k_{m1} & \cdot & \cdot & \cdot & k_{mn} \end{bmatrix} \cdot \begin{bmatrix} p_1 \\ p_2 \\ \cdot \\ \cdot \\ \cdot \\ p_n \end{bmatrix}$$

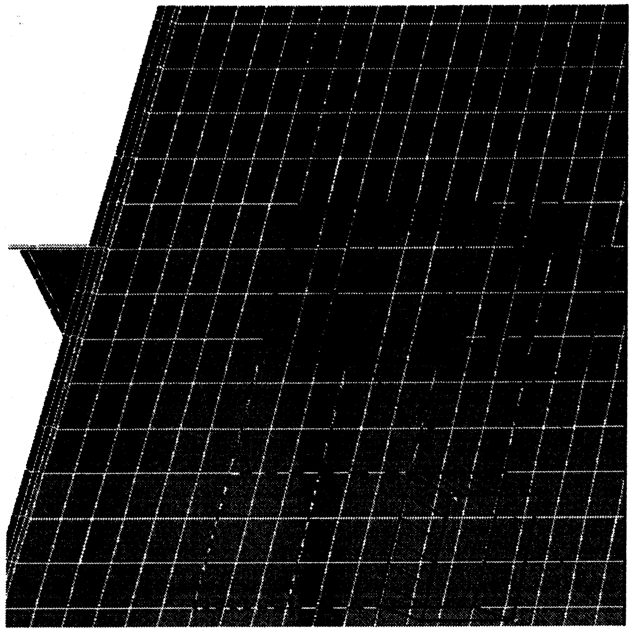


Figure 3. The general representation of ice loads as a set of regions with uniform distributed pressure.

The influence coefficients k_{ij} are results of finite element analysis. The strains ε_i are calculated from the components of strain tensor in the point of gauge installation

$$\begin{bmatrix} \varepsilon_x & \gamma_{xy} & \gamma_{xz} \\ \gamma_{xy} & \varepsilon_y & \gamma_{yz} \\ \gamma_{xz} & \gamma_{yz} & \varepsilon_z \end{bmatrix}$$

with help of transformation of strain tensor to the coordinate system of gauge.

The second stage of processing is the calculation of pressures p_j. This stage was realized as a solution of the following linear programming problem:

$$F = \sum_{i=1}^{n} a_i \cdot p_i \rightarrow \min$$

$$p_i \geq 0$$

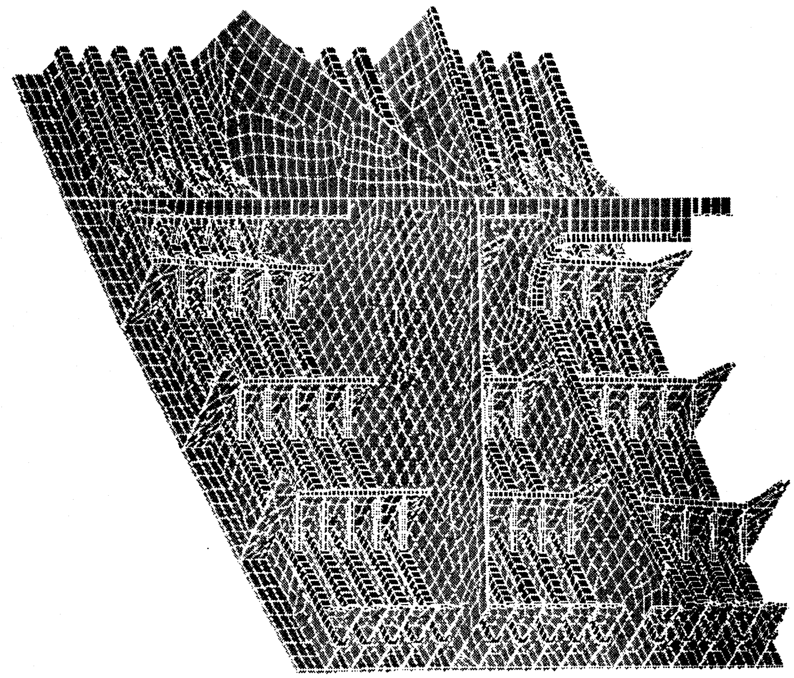
$$\sum_{i=1}^{n} k_{ij} \cdot p_i = \alpha \cdot V_j, \; j = 1, \ldots, m$$

a_i is an area of region i;
F is a total force of interaction.

3.2. Calculation of influence coefficients

The calculation of influence coefficient required the development of the finite element model of ice belt structure in the measurement area. The finite element model was carried out for the grillage along the hull from framing 124 to framing 133 and on vertical direction from double bottom level to the level 1.5 m above water line. The outside plating, webs of framing and brackets were approximated by the 8-nodes shell elements, the flanges of framing and brackets were approximated by the bar finite elements. The general and detailed views of model are shown on the Fig. 4.

a)



b)

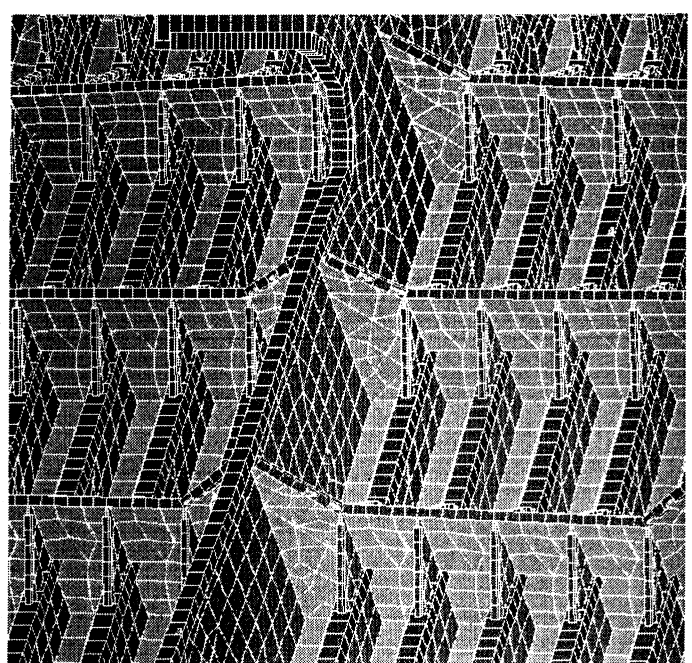


Figure 4. The general view of the finite element model (a) and detailed view (b)

The regions with uniform distributed pressure were chosen as three levels area between frames 124 $^{1}/_{2}$ and 132 $^{1}/_{2}$ along the grillage and between second deck and stringer V on vertical direction. The total number of regions is 24 (Fig. 5). The average value of the region area is 0.83 m^2 (maximal area is 1.05 m^2, minimal area is 0.77 m^2).

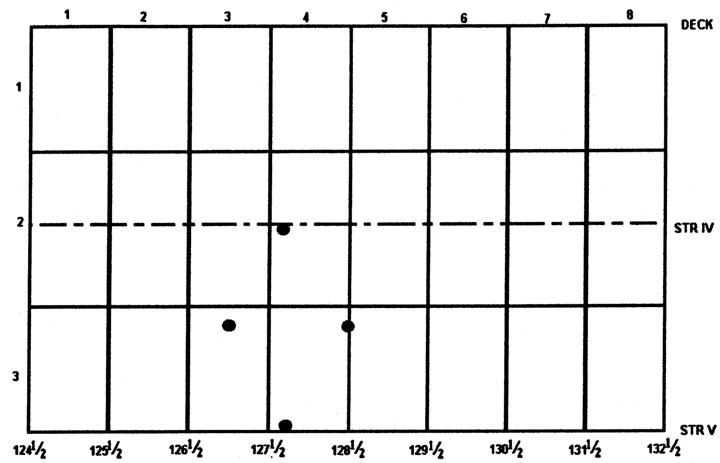


Figure 5. The arrangement of regions with uniform distributed pressure. The lower edge is a set of corresponding framing numbers. DECK is the level of second deck. STR IV is the level of forth stringer. STR V is the level of fifth stringer. • - the gauge positon.

3.3. Calculation of the ice load parameters

The main parameter of ice load for the further analysis is the maximal ice pressure on the one of regions for the time t.

$$p_{\max} = \max(p_i),\ i = 1,\dots,m$$

The sample stochastic process $p_{\max}(t)$ is on Fig. 6.

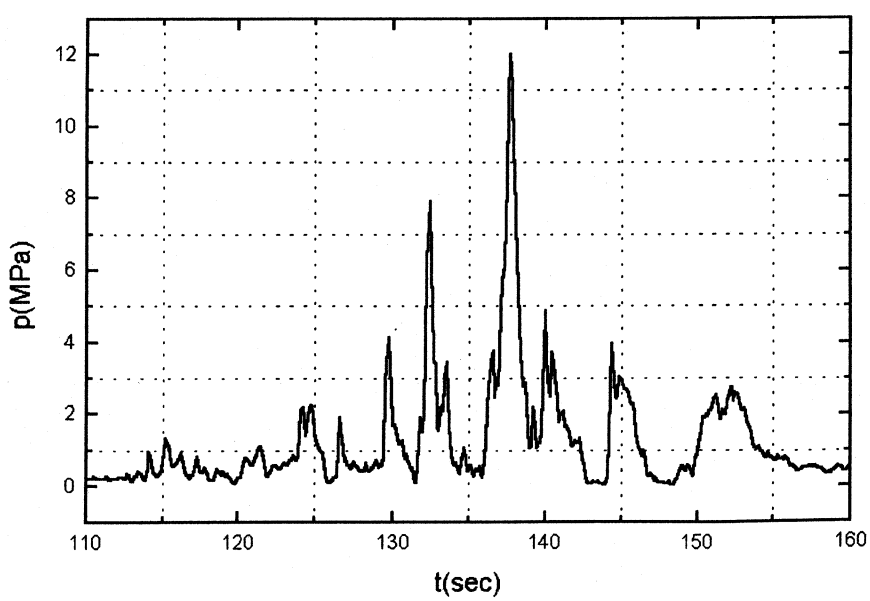


Figure 6. The sample of function $p_{\max}(t)$ (ramming before ice station #4)

4. RESULTS

The resulting information was obtained as the parameters of stochastic processes $p_{max}(t)$, corresponding parameters of ice cover and average motion speed in zones with homogeneous ice condition. The zones with homogeneous ice condition correspond to time of record of ice belt structure response on the ice action.

The information divided on three groups for the further analysis:

1. The motion of icebreaker «Kapitan Dranitzin» and tanker UIKKU in old channel in Ob Bay. The caravan was moved in ice cover with practically constant ice thickness .
2. The of icebreaker «Kapitan Dranitzin» and tanker UIKKU followed icebreaker «Russia» in Ob Bay and Kara Sea. The ice conditions for this group of records are less homogenous. The records of the structure response shows that the icebreaker periodically moves on open water contrastingly routinely interaction with ice in old channel.
3. Ramming of icebreaker «Kapitan Dranitzin». Analysis of this regime requires accurate synchronization of the structural response with data on motion speeds (for example, one second discretisation). The data on ramming will analyze in future as one of cases of design loads.

There were obtained the following parameters of stochastic process per every record:

p_a – mean value of pressure;

σ - standard derivation of pressure;

α, β - parameters of shape and scale of Γ-distribution;

λ- parameter of exponential distribution if Γ-distribution has worth χ^2-estimation.

The samples of histograms for the maximal ice pressure during certain record are on the Fig. 7 taking into account the discretisation frequency for the most records 10 Hz. Thus, the number of events for every record are in the range from 1000 to 20000.

In additional, the correlation coefficients between random values describing ice loads and environmental condition were calculated for first and second groups of ice conditions. There is essential correlation between p_a and σ for the both groups of information. The satisfactory regression can be obtained between parameter of exponential low and motion speed v for the first type of ice condition:

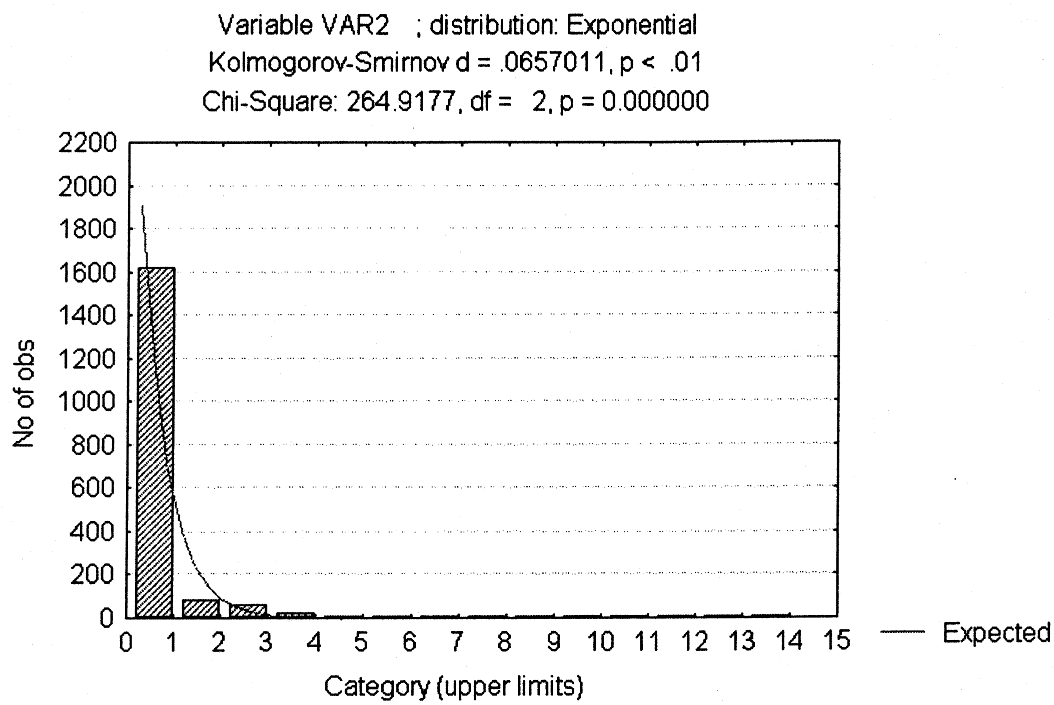
$$\lambda=2.15+\exp(0.16\cdot v-1.49)$$

The suitable for practical purposes can be accepted the regressions of Γ-distribution parameters on the motion speed for the second group of data (Fig. 8):

$$\alpha=0.76\cdot v-2.48$$

$$\beta=0.06\cdot v+1.07$$

a)



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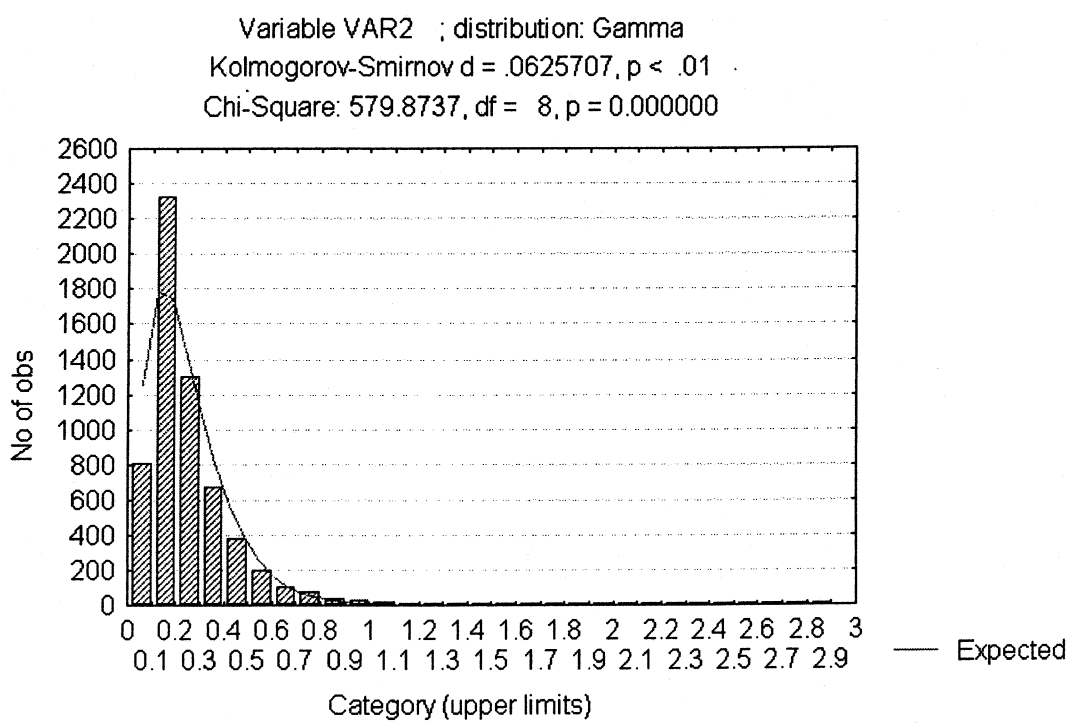

Figure 7. The samples of corresponding histograms and the distribution low for the maximal ice pressure for the two records: exponential (a) and Γ-distribution (b)

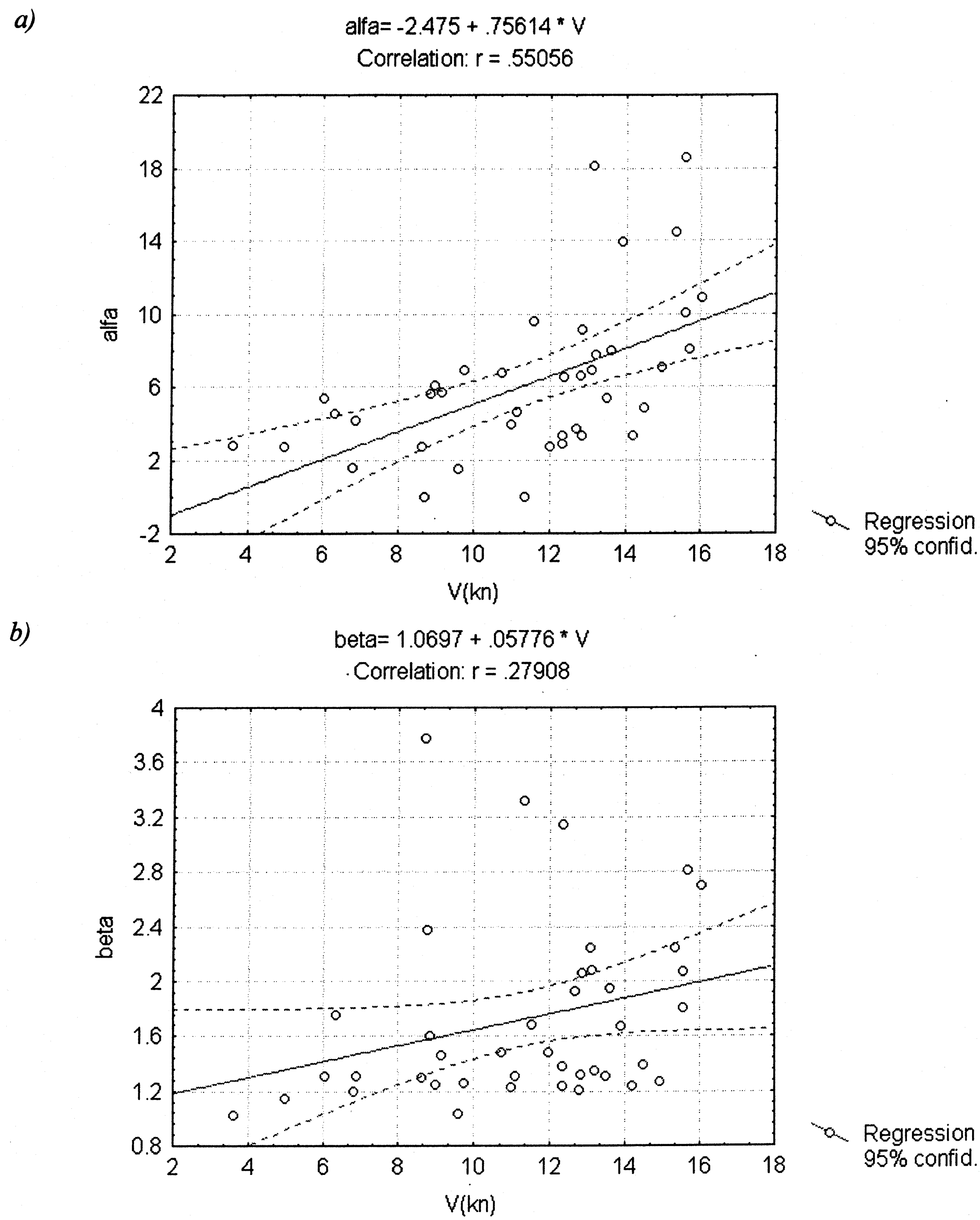

Figure 8 Regression between motion speed and parameters of Γ-distribution for ice pressure: a) shape parameter α, b) scale parameter β.

Such approach of data processing allow us to predict the return period for the ice pressure. As a parameter of dependence of ice pressure on time was chosen the average number N of overlap of pressure p the prescribed level p_0 per time unit. Omitting the details

$$N = \lambda \cdot \exp(-\lambda p_0) \cdot \sqrt{\frac{D}{2\pi}}$$

D – the variance of the speed of increasing of pressure ***dp/dt*** that can be calculated by the additional numerical processing of preliminary data.

The processing of stochastic processes ***p(t)*** for every record gives the average function ***N(p₀)*** not only for every motion regime but for the total period of records taking into consideration the relative partial duration of every motion regime (Figure 9).

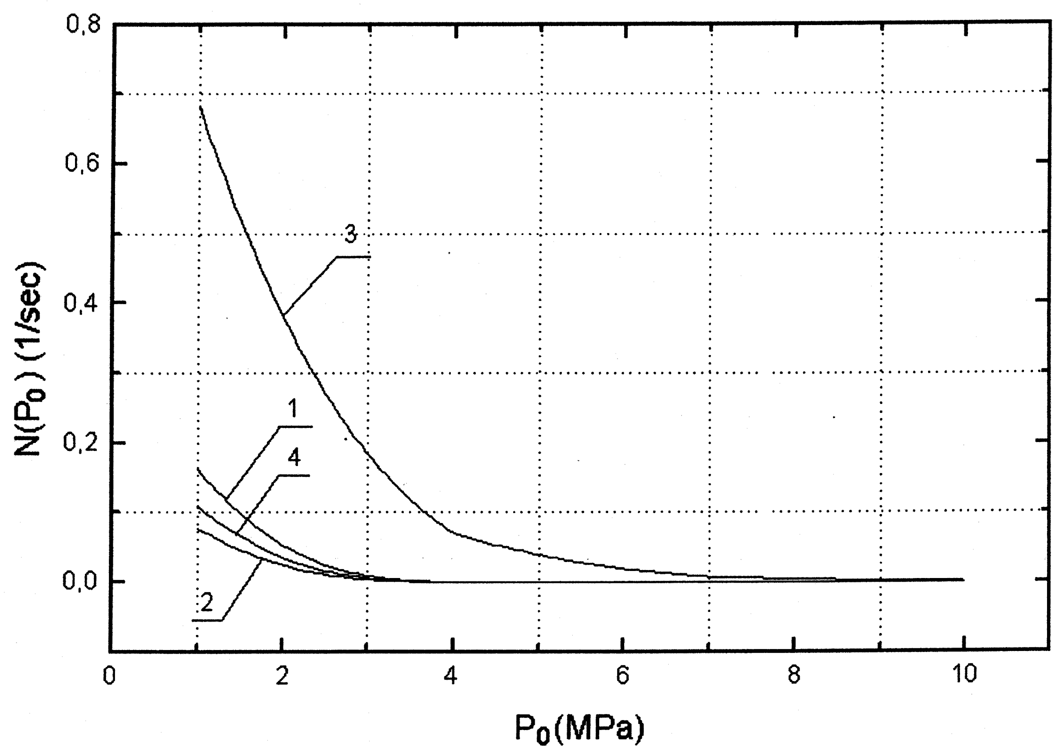

Figure 8. The average number of overlap of ice pressure the level p0 per unit time (1/sec): 1 – motion in old channel, 2 – following leading icebreaker, 3 – ramming, 4 – total for measuring time.

5. RECOMMENDATIONS

The recommendation are concerned mainly technical aspects of using equipment and method of measuring:

1. To increase the number of sensors up to 30 – 50 arranging in the similar measuring area of a structure to have the good approximation of the contact area shape and pressure pattern.
2. To carry out the calibration of measuring system by inner controlling loading for the whole measuring area of structure.
3. To develop software for uninterrupted recording of signals from sensors in synchronism with GPS-data.

6. CONCLUSIONS

The results of work allow to make following conclusions:

1. The suggested method of signals processing will allow to obtain more accurate shape of contact area and pressure distribution on contact area if more number of sensors are in use.
2. The results of processing of data can be used for prediction of ice loads for the purposes of the ice belt structure reliability estimation for two mentioned regimes of motion.
3. The value of average number $\boldsymbol{N}$ of overlap of pressure $\boldsymbol{p}$ the prescribed level $\boldsymbol{p_0}$ per time unit can be used for the life time of ice belt structures and a determination of design load in terms of reliability.