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ACCURACY ANALYSIS OF THE MODEL EXPERIMENTS ON DIPPING PURSE SEINE MODELS AT SIDE STREAM[1]

Abstract. The research aim is to analyze accuracy of the experimental data obtained during the experiments in the hydraulic channel of "MariNPO", LLC (Kaliningrad) in 2014. During the experiments, three purse seine models were immersed under different loading of a leadline (0 kg, 0.248 kg, 0.338 kg) and different speed of the current (0.2 m/s, 0.3 m/s, 0.4 m/s). Seven experiments were carried out for each model (0 kg and 0.2 m/s; 0.248 kg and 0.2, 0.3, 0.4 m/s; 0.338 kg and 0.2, 0.3, 0.4 m/s). To confirm reliability of the data there was carried out the analysis of the total error which included: instrumental error, cargo error, measurement error of the net the models were made of, inaccuracy of immersion, displacement of the seine along *OY* axis, approximation error. To approximate the pilot data there was chosen the method of ordinary least squares. Approximation was conducted with a straight line (linear regression), polynomial *n* (polynomial regression), and a combination of arbitrary functions. The least error (6.82%) was obtained in the experiment 0 kg and 0.3 m/s, maximum (14.76%) – in the experiment 0.338 kg and 0.2 m/s. When the error doesn't exceed 15%, subject to the adequate precision of measurement, the results of the experiments should be considered satisfactory.

Key words: purse seine, approximation, mathematical model.

Introduction

The experiments of submerging purse seine models in the hydraulic channel of "MariNPO", LLC were conducted in 2014; the experimental results have been earlier introduced [1]. Three models of a purse seine were built with different leadline loading: 0 kg, 0.248 kg, 0.338 kg. The characteristics of the experimental purse seines are given in Table 1.

Table 1

Characteristics of the purse seine models*

Model	$L_ж$, m	$H_ж$, m	$L_{вп}$, m	$H_п$, m	*a*, mm	*d*, mm	u_x	u_y	F_0
1	10	2.1	7	1.5	10.0	1.16	0.7	0.714	0.210
2					6.0	0.4			0.133
3					10.0	0.95			0.190

* $L_ж$ - length of top selection in harness; $H_ж$ - height of seine in harness; $L_{вп}$ - length of top selection; $H_п$ - height of seine in landing; u_x – horizontal landing coefficient; u_y – vertical landing coefficient.

Experimental measurements were done in still water, as well as in a flow having velocity 0.2 m/s, 0.3 m/s, 0.4 m/s. Iimmersion time, immersion depth, displacement of the leadline along *OY* axis, approximation error were being measured during the experiments. The purpose of the research was to justify the reliability of the data obtained.

Error calculation

In order to confirm the reliability of the data, it is necessary to calculate the error. The error consists of instrumental error (stopwatch, ruler, hydrometric flowmeter C-31), cargo error, error of the net the models were made of (mesh size, thread diameter), immersion error, displacement of the seine along *OY* axis, and approximation error.

The following formula is used to estimate the overall error:

$$\delta_{tot} = \sqrt{\left(\frac{\delta_{instr}}{100\%}\right)^2 + \left(\frac{\delta_c}{100\%}\right)^2 + \left(\frac{\delta_n}{100\%}\right)^2 + \left(\frac{\delta_{imm}}{100\%}\right)^2 + \left(\frac{\delta_{disp}}{100\%}\right)^2 + \left(\frac{\delta_{appr}}{100\%}\right)^2},$$

where δ_{tot} - overall error of the experiment; δ_{instr} - relative instrumental error; δ_c - relative cargo error;

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δ_n - relative net webbing error; δ_{imm} - relative error of purse seine immersion; δ_{disp} - relative error of purse seine displacement; δ_{appr} - relative approximation error.

The relative error was calculated using the formula:

$$\delta_x = \frac{\varepsilon_1}{\overline{x}} 100\%,$$

where δ_x - relative deviation of the value; $\overline{x}$ - arithmetic mean value; ε_1 - absolute error of the value.

Absolute error ε1 is calculated using the formula:

$$\varepsilon_1 = \sigma_{\overline{x}} \times t_{\beta\alpha},$$

$$\varepsilon_1 = \sigma_{\overline{x}} \times t_{\beta},$$

where $\sigma_{\overline{x}}$ – mean square deviation of the values; $t_{\beta\alpha}$ – Student's coefficient, which depends on the number of degrees of freedom (n – 1) and confidence probability β.

Mean square deviation $\sigma_{\overline{x}}$

$$\sigma_{\overline{x}} = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}{n(n-1)}},$$

where n - number of measurements; x_i - i-st element of measurement.

Table 2 shows the results of calculating the relative error of the measurement values.

Table 2

Error results

Error	Relative error, δ								
	Model 1			Model 2			Model 3		
	V = 0.2 m/s	V = 0.3 m/s	V = 0.4 m/s	V = 0.2 m/s	V = 0.3 m/s	V = 0.4 m/s	V = 0.2 m/s	V = 0.3 m/s	V = 0.4 m/s
Thread diameter, d	0.58%			1.19%			0.71%		
Mesh size, a	0.47%			0.64%			0.39%		
Cargo weight, P	0,01%								
Flowmeter C-31	0.4% - for 0.2 m/s; 0.6% - for 0.3 m/s; 0.8% - for 0.4 m/s								
Ruler	5%								
Stopwatch	0.01%								

Table 3 shows the results of calculating the relative error of the immersion of the seine.

Table 3

Error of immersion and error of displacement of purse seine in immersion, %

Load; flow velocity	Model 1		Model 2		Model 3	
	Immersion of purse seine	Displacement of purse seine	Immersion of purse seine	Displacement of purse seine	Immersion of purse seine	Displacement of purse seine
0 kg; 0.2 m/s	4.96	3.37	3.32	4.49	2.75	2.41
0.248 kg; 0.2 m/s	3.79	2.20	2.41	4.17	6.30	4.49
0.248 kg; 0.3 m/s	2.75	1.27	2.45	5.31	4.82	4.49
0.248 kg; 0.4 m/s	3.21	4.71	3.84	2.92	3.31	4.50
0.338 kg; 0.2 m/s	3.28	2.52	4.95	2.34	5.03	4.50
0.338 kg; 0.3 m/s	3.58	1.92	6.08	2.54	4.39	4.49
0.338 kg; 0.4 m/s	3.59	6.53	4.21	3.86	4.81	2.92

For representation of the obtained experimental data as a function $y = f(x)$ we use approximation [2].

For our approximation, let us choose the least squares method - this is the most common way of approximating the data [3]. The method provides the minimum sum of deviation squares from the approximating function to the experimental points, and it also does not require passage of the approximating function through all the experimental points. Using the least squares method, the most common is straight line approximation (linear regression), n-degree polynomial approximation (polynomial regression), and the approximation by a combination of arbitrary functions ("linfit" function).

As a calculation example let us take model 2 under 0 kg loading and flow velocity equal to 0.2 m/s. The input data for calculation of approximation were estimated on the basis of the work theory [4].

The input data:

$$\tau = \begin{pmatrix} 0.2 \\ 0.4 \\ 0.6 \\ 0.8 \\ 1 \end{pmatrix} \quad \nu = \begin{pmatrix} 0.858 \\ 0.707 \\ 0.783 \\ 0.8 \\ 0.858 \end{pmatrix} \quad \omega = \begin{pmatrix} 0.448 \\ 0.426 \\ 0.448 \\ 0.435 \\ 0.458 \end{pmatrix},$$

where τ – relative immersion time of the purse seine; ν – relative immersion rate of the purse seine; ω – relative displacement of the purse seine along the OY axis in immersion.

To calculate the linear regression, integrated in MathCAD functions such as slope (evaluate slope coefficient of a straight line) and intercept (finds the point of intersection with the y-axis) are used.

The linear regression is given by:

$$f_{\text{lin}}(\tau) = A + B \times \tau,$$

where

$$A = \text{intercept}(\tau, v),$$

$$B = \text{slope}(\tau, v).$$

To calculate the polynomial regression, regress and interp functions are used.

The polynomial regression of the 2$^{\text{nd}}$ degree is given by:

$$f_2(\tau) = a_1 \times \tau^2 + a_2 \times \tau + a_3.$$

To calculate approximation by a combination of functions, built-in "linfit" function is used.

Approximating function is given by:

$$f_{\text{lin}}(\tau) = a \frac{1}{\tau + 1} + b \sin(\tau).$$

Let us plot on a graph and compare approximation results (Fig. 1, 2).

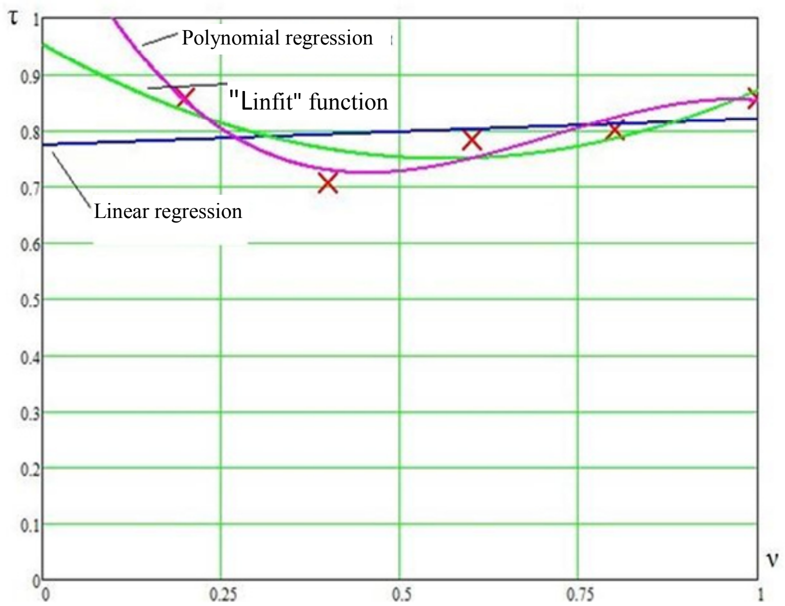

Fig. 1. Approximation results of the experimental data of the relative immersion rate

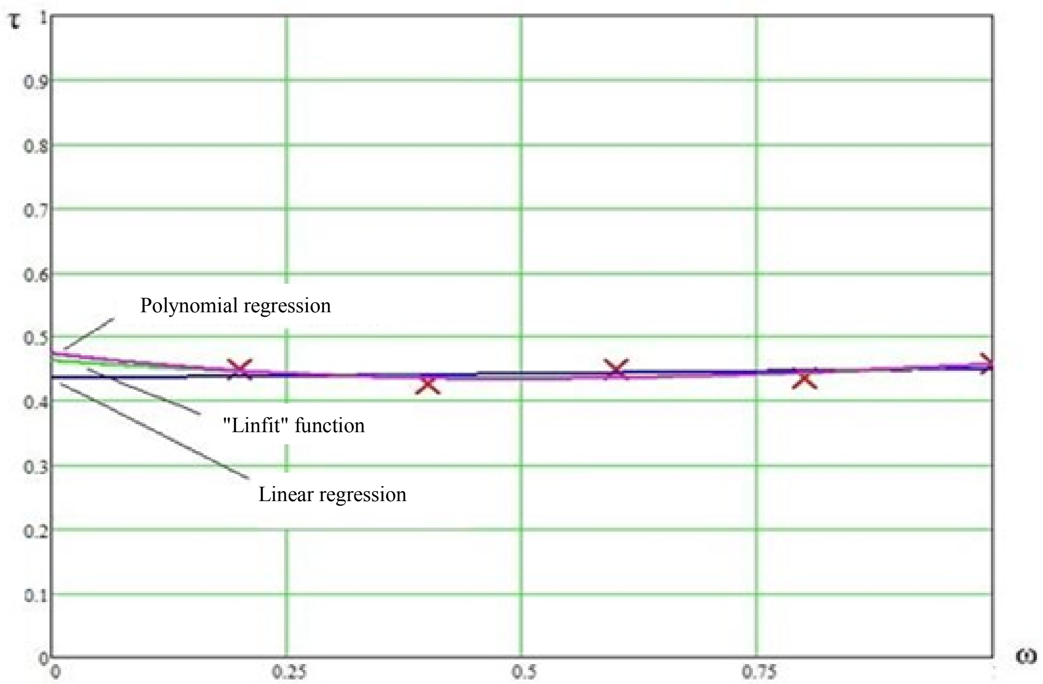

Fig. 2. Approximation results of the experimental data of the relative displacement of purse seine

Approximation error can be calculated using the following formula:

$$\delta_A = \frac{v - v_A}{v_A},$$

where δ_A - approximation error; v_A - relative immersion rate of the purse seine in approximation.

Table 4 shows approximation error results of the relative immersion rate of the purse seine.

Table 4

Approximation error results of the relative immersion rate of the purse seine

Load; flow velocity	Model 1			Model 2			Model 3		
	Linear regression	Polynomial regression	"linfit" function	Linear regression	Polynomial regression	linfit" function	Linear regression	Polynomial regression	"linfit" function
0 kg; 0.2 m/s	9.45	9.05	8.09	15.25	7.89	12.77	15.25	5.79	12.77
0.248 kg; 0.2 m/s	4.86	1.76	4.34	10.73	7.7	10.16	10.74	4.85	8.76
0.248 kg; 0.3 m/s	3.41	3.35	4.34	4.59	0.64	4.66	12.1	5.48	11.73
0.248 kg; 0.4 m/s	2.60	0.91	2.30	2.59	0	4.03	7.92	0.64	7.73
0.338 kg; 0.2 m/s	4.86	1.76	4.34	17.9	8.59	16.11	9.61	8.46	8.08
0.338 kg; 0.3 m/s	3.41	3.35	4.34	8.77	3.48	7.3	12.1	5.48	11.73
0.338 kg; 0.4 m/s	3.25	3.07	3.48	5.97	1.14	5.33	6.47	0	7.62

Table 5 shows approximation error results of the relative displacement of the purse seine in immersion.

Table 5

Approximation error results of the relative displacement of the purse seine in immersion

Load; flow velocity	Model 1			Model 2			Model 3		
	Linear regression	Polynomial regression	"linfit" function	Linear regression	Polynomial regression	"linfit" function	Linear regression	Polynomial regression	"linfit" function
0 kg; 0.2 m/s	5.94	6.65	5.99	7.21	3.12	7.58	7.21	3.12	7.58
0.248 kg; 0.2 m/s	13.67	6.41	9.23	3.18	2.99	2.29	10.46	6.6	9.84
0.248 kg; 0.3 m/s	5.79	0.39	5.41	5.69	1.09	6.14	2	1.73	2.28
0.248 kg; 0.4 m/s	0.53	0.32	1.52	1.08	0	1.30	0.42	0.21	1.16
0.338 kg; 0.2 m/s	5.33	3.55	4.25	15.47	9.34	14.14	6.77	5.99	5.81
0.338 kg; 0.3 m/s	2.86	1.18	3.38	6.06	4.06	5.52	1.84	1.44	1.97
0.338 kg; 0.4 m/s	1.08	0.43	1.62	1.11	0.11	2.01	1.37	0	2.01

Table 6 shows overall error of the experiments with the purse seine models.

Table 6

Overall error of the experiments with the purse seine models, %

Load; flow velocity	Model 1	Model 2	Model 3
0 kg; 0.2 m/s	13.70	11.41	9.08
0.248 kg; 0.2 m/s	9.13	10.88	12.36
0.248 kg; 0.3 m/s	6.82	7.94	10.12
0.248 kg; 0.4 m/s	7.72	7.66	7.61
0.338 kg; 0.2 m/s	7.65	14.76	13.37
0.338 kg; 0.3 m/s	7.42	9.96	9.88
0.338 kg; 0.4 m/s	9.53	7.84	10.08

Measurement accuracy is considered adequate when the error does not go beyond 15%.

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В. В. Макаров. А. А. Недоступ

АНАЛИЗ ТОЧНОСТИ МОДЕЛЬНЫХ ЭКСПЕРИМЕНТОВ ПО ПОГРУЖЕНИЮ МОДЕЛЕЙ КОШЕЛЬКОВОГО НЕВОДА ПРИ УСЛОВИИ БОКОВОГО ТЕЧЕНИЯ

Цель исследования – анализ точности данных, полученных экспериментальным путем в 2014 г. в гидроканале ОАО «МариНПО» (Калининград). В ходе экспериментов осуществлялось погружение трех специально построенных моделей кошелькового невода с различной загрузкой нижней подборы (0; 0,248 и 0,338 кг) и при различной скорости течения (0,2; 0,3 и 0,4 м/с) – по 7 экспериментов для каждой модели (0 кг и 0,2 м/с; 0,248 кг и 0,2; 0,3 и 0,4 м/с; 0,338 кг и 0,2; 0,3 и 0,4 м/с). Для подтверждения достоверности полученных данных был проведен расчет общей погрешности, включающей в себя инструментальную погрешность; погрешность веса грузов; погрешность измерений дели, из которой были сделаны модели; погрешность погружения невода; погрешность смещения невода оси *OY*; погрешность аппроксимации. Для аппроксимации экспериментальных данных был выбран метод наименьших квадратов. Аппроксимация была проведена прямой линией (линейная регрессия), полиномом *n*-й степени (полиномиальная регрессия) и комбинацией произвольных функций. Наименьшая погрешность (6,82 %) была получена в эксперименте 0 кг и 0,3 м/с, наибольшая (14,76%) – в эксперименте 0,338 кг и 0,2 м/с. Учитывая, что точность измерений считается достаточной, когда погрешность не выходит за рамки 15 %, результаты экспериментов следует признать удовлетворительными.

Ключевые слова: кошельковый невод, аппроксимация, математическая модель.

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