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Log Unloading at Logging Enterprise Berths – Experimental Studies

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Abstract – *Nacrtak*

In the development of market economy in Russia, the main trend in the log processing industry is the implementation of the cutting edge technology and effective innovation in order to boost the labor productivity and reduce the production cost on the basis of environmentally friendly and rational use of timber resources. Taking into account the important role of water log transport used for timber rafting, the problem of efficiency of loading and unloading of flat rafts at log unloading berths is quite urgent. The current research considers the ways of increasing unloading efficiency of multi-row flat rafts at logging enterprise berths. The aim of this research is to present the results of the experiments of unloading multi-row flat rafts at logging enterprise berth. In these experiments, a load lifting crane equipped with special load grippers was used for unloading multi-row flat rafts at log unloading berth. During the experiments, the duration of unloading sequence from water to the unloading berth was defined and applied to multi-row flat rafts calculated by Northern (Arctic) Federal University named after M.V. Lomonosov and Volga State University of Technology based on the results of the laboratory experiments and statistical processing of the obtained data. We also carried out a strength test of the crane load gripper used for transposition of lengthy flat rafts in timber onshore yards and log unloading berths. The research was carried out on lifting force fluctuation amplitude and oscillation period of the load gripper during the process of flat raft unloading from water on log unloading berth. The fluctuation amplitude of the lifting force of the load-gripper from the ground is higher by 11–33% than from the water, facilitated by the water damping capacity. Based on the laboratory research, the durability of load grippers, patented in the Russian Federation under No. 2476366 and No. 2526767, was experimentally tested. The hypothesis of theoretical calculations of the special load gripper based on the equitability of gross load distribution on the gripper applicable to general purpose lifting apparatus for four choker grapples was experimentally confirmed. The certainty assumption amounted to 97.6%.

Keywords: log unloading berth, crane tower, flat raft, duration of uploading sequence, lift rope capacity

1. Introduction – *Uvod*

The main task of the development of market relations in Russia is to develop productivity of the timber processing complex, introduce promising technological processes into production and use effective technical solutions increasing labor productivity and reducing the cost of products based on environmentally friendly and rational use of timber resources (Kamusin 1997, Vojtko and Gajsin 2013).

Taking into account the role and importance of timber water transport for the delivery of timber to consumers, the problem of improving the unloading operations of flat rafts from water at enterprises with log unloading berth is very relevant (Korpachev 1997, Afonichev et al. 2009).

2. Materials and methods – *Materijal i metode*

The aim of the present research is to increase the efficiency of unloading multi-row flat rafts from water to the log unloading berth at log processing enterprises.

The task set during the study was to develop a methodology and to conduct experimental studies of the cycle duration of unloading various flat rafts with load-grabbing devices from water to log unloading berth in laboratory conditions.

Experimental technique – the analysis of theoretical and experimental studies (Mitrofanov 2000, Mitrofanov 2007, Vasil'ev and Paponov 2013), as well as expert assessments, screening and production experiment (Vojtko and Gajsin 2013) allowed us to establish that the duration of the cycle and the magnitude of the random load on the crane from overloading the weight of the load when unloading flat rafts from the water to log unloading berths of the of timber processing enterprises depends on: the weight of the forest load, m; speed of its movement, υ; dimensions of the load: length, L; width, B; height, H; average diameter of round timber, d_{avg}; density of timber, ρ_t; acceleration of free fall, g; coefficient of kinematic viscosity of water, v.

In accordance with the similarity theory (Sedov 1966), out of nine significant factors, among which three parameters m, υ, L are chosen as the main ones, six dimensionless complexes can be made, which are the similarity criteria for the process of unloading flat rafts from water to shore:

$$t = f\left(\frac{\upsilon^2}{gL};\frac{mg}{BH\beta\rho_t\upsilon^2};\frac{\upsilon d_{avg}}{v};\frac{L}{B};\frac{B}{H};\frac{d_{avg}}{H}\right) \quad (1)$$

Where:

υ speed of vertical movement of forest load, m/s

g acceleration of gravity, m/s^2

L, B, H length, width, height of load, m

m mass of forest load, kg

ρ_t density of wood, kg/m^3.

β coefficient of full wood

d_{avg} average diameter of round wood materials, m

v coefficient of kinematic viscosity of water, m^2/s

To compare the results of studies of the duration of the cycle of unloading three-row flat rafts from water to the berth in the laboratory and production conditions of VSUT, the Froude criterion is used:

$$t_p = t_m\sqrt{\lambda} \quad (2)$$

Where:

t_m cycle duration of unloading flat rafts from water by a tower crane on the model, s

λ scale of simulation, 1:10.

Experimental studies of the duration of the unloading cycle and the hydro-mechanical loads on lifting equipment when unloading the flat rafts from the water were carried out on a physical model

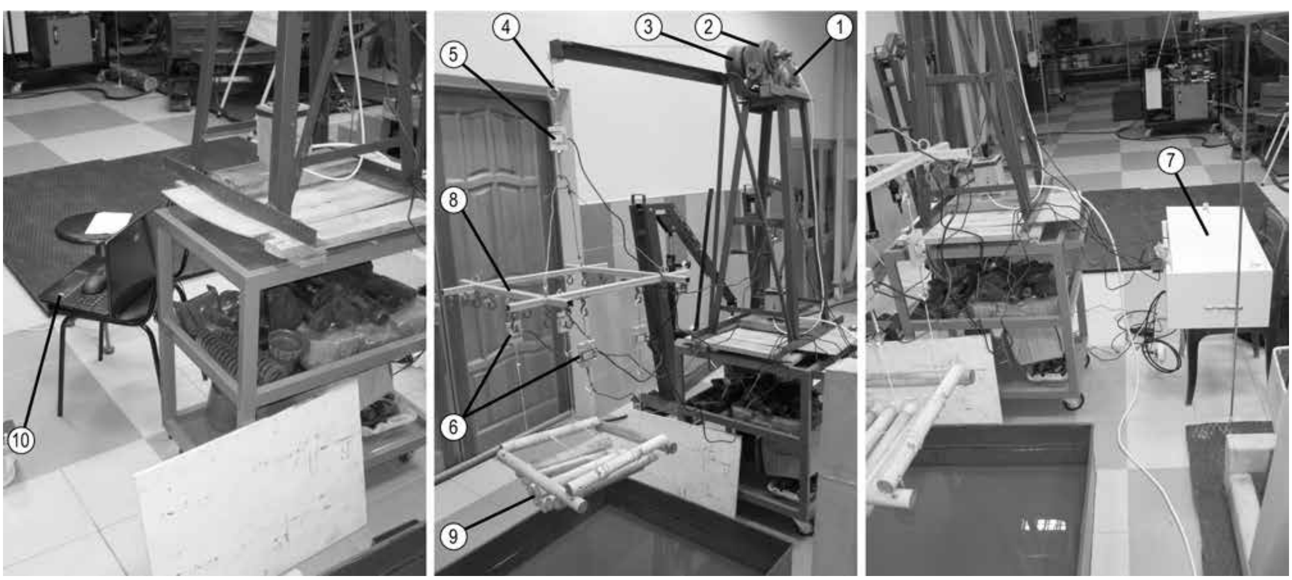

Fig. 1 Experimental setup to study the process of unloading flat rafts from water: 1 – AC electric motor; 2 – worm gear; 3 – welded drum; 4 – cable-block system; 5 – force sensor UU–K50; 6 – force sensor UU–K10; 7 – module for converting analog signal NI 9219; 8 – load-bearing frame; 9 – model of a flat unit; 10 – HP 550 personal computer

Slika 1. *Eksperimentalni postav za istraživanje procesa istovara splavi s vode: 1 – elektromotor izmjenične struje; 2 – pužni prijenosnik; 3 – zavareni bubanj; 4 – sustav kabel-blok; 5 – senzor sile UU–K50; 6 – senzor sile UU–K10; 7 – modul za pretvorbu analognoga signala NI 9219; 8 – nosivi okvir; 9 – model plošne jedinice; 10 – osobno računalo HP 550* of the lifting mechanism of a tower crane on a scale of 1:10, equipped with a collapsible lifting device.

Experimental studies were carried out in the laboratory conditions of the Department of Forestry and Chemical Technologies of the Volga State University of Technology in a hydraulic tray with dimensions of 1.5×1.0×0.3 m. The experimental setup included: 1) a tower-type lifting mechanism with variable lifting capacity from 49 to 490 N, depending on the weight and volume of the load, lifting speed of 0.3 m/min; 2) models of flat rafts of various parameters (one-, two-, three-, four-row) and weighing from 5 to 30 kg; 3) a physical model of a new load-lifting frame with load-lifting slings and hooks; 4) a hydraulic tray of 1.5×1.0×0.3 m with variable dimensions of the depth and unloading yard; 5) a set of measuring instruments registering and lighting equipment; 6) remote control of the lifting mechanism, measuring and lighting equipment (Fig. 1).

To study the process of unloading flat rafts from the water to the shore, multi-row flat rafts of the NArFU and VSUT design were used (Fig. 2–4, Table 1–4). Six variants of flat rafts were formed: one-, two-, three-row ones with a length and width of 4, 5, 6 m; the number of logs 15, 16, 32, 45 pieces; the average diameter of the sortings 0.25; 0.3; 0.4 m; volume 3.14; 5.65; 11.3; 22.61; 33.91 m^3; weight 1978, 3561, 6545, 7122, 14 243 kg. A layer-by-layer method of loading and unloading operations with flat rafts was developed (Fig. 5) at riverine forest warehouses and raids of the melt, protected by patent RF No. 2476366. To expand the technological capabilities of crane unloading of flat rafts of various designs and sizes, three lifting devices are proposed and justified: special (Fig. 6) (patent RF, No. 2476366), folding (patent RF, No. 2526767), collapsible.

Experimental studies of the unloading process of flat rafts were carried out in two stages (Vojtko and Gajsin 2013, 2014). In the first stage, the duration of the unloading cycle of one-, two-, three-row PS of the NArFU and VSUT construction from water and from land was checked (Fig. 2–4). The experiments were carried out in the following sequence. The investigated model of a flat raft was placed in a hydraulic tray of specific dimensions of the unloading yard. The weight, volume, and load draft were measured, after which it was lifted from the water by a crane to a height of 1 m at a given speed. The duration of the unloading cycle of the flat raft was measured using a mechanical stopwatch. The repeatability of the experiments to determine the duration of the discharge of the flat raft from the water consisted of 15 observations.

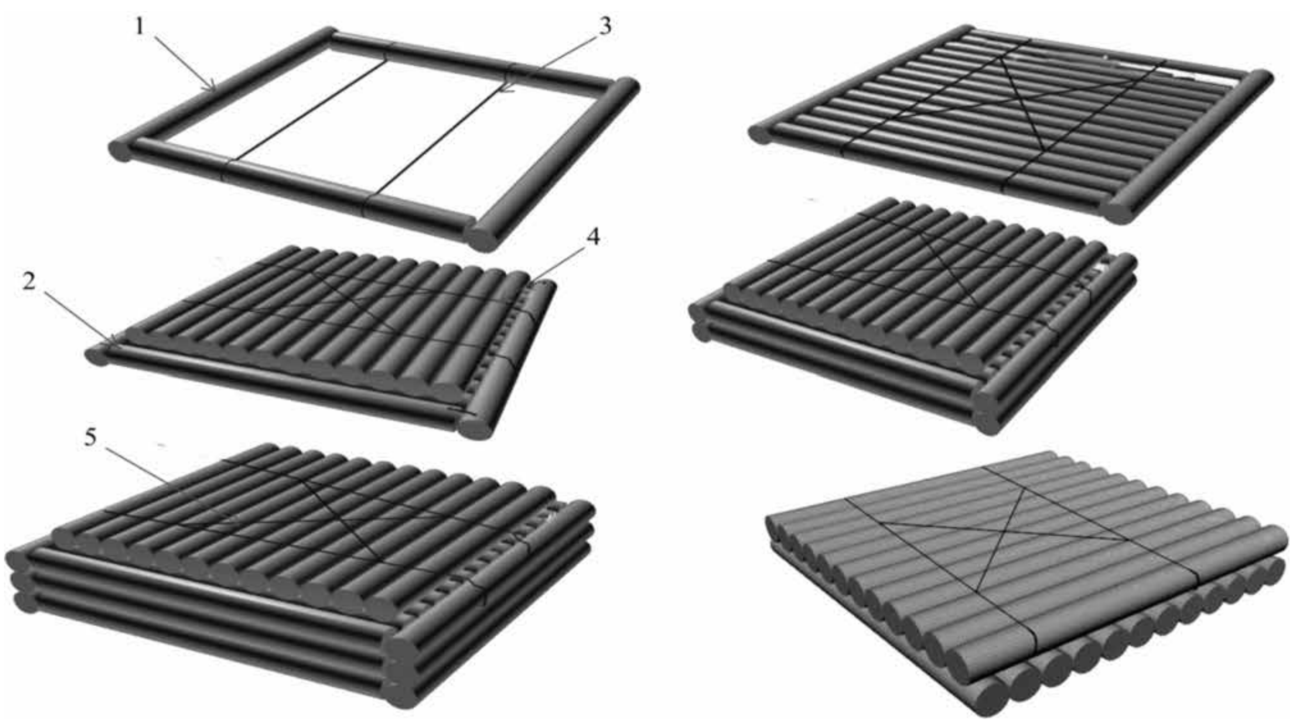

Fig. 2 Models of flat rafts of NArFU structure connected by forming rigging: 1 – solid log; 2 – wire or chain tie; 3 – lower binding; 4 – upper binding; 5 – vertical connection

***Slika 2**. Modeli ravnih splavi NArFU konstrukcije spojenih formirajućom oputom: 1 – čvrsti trupac; 2 – vezica od žice ili lanca; 3 – donji vez; 4 – gornji vez; 5 – vertikalni spoj*

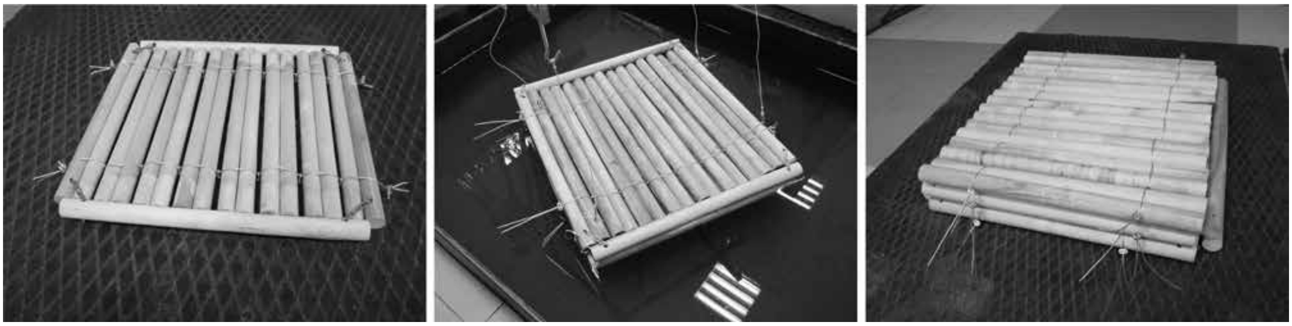

Fig. 3 Models of flat rafts of construction 2 VSUT

***Slika 3**. Modeli ravnih splavi konstrukcije 2 VSUT*

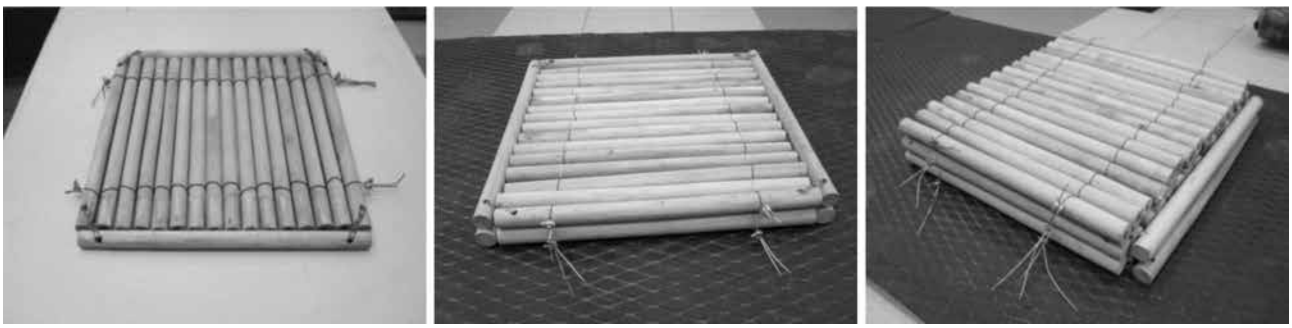

Fig. 4 Models of flat raft of construction 3 VSUT

***Slika 4**. Modeli ravnih splavi konstrukcije 3 VSUT*

In the second stage, the forces arising in the main load rope of the tower crane and in choker grips when unloading the flat raft from the water were investigated (Fig. 5, 6). The experiments were carried out in the following sequence. The investigated model of a flat raft was placed in a hydraulic tray of specific dimensions of the unloading yard. The weight, volume, and draft of the load were measured, after which it gradually rises from the water with a crane to a height of 1.0 m at a given speed. The resulting forces in the main load rope when unloading the flat raft from the water were measured using a UU-K50 force sensor having a measurement limit of 0.5 kN. The resulting forces in choker ropes when unloading the flat raft from the water were measured using UU-K10 force sensors with a measurement limit of 0.1 kN. The repeatability of the experiments was established by calculation and consisted of 15 observations.

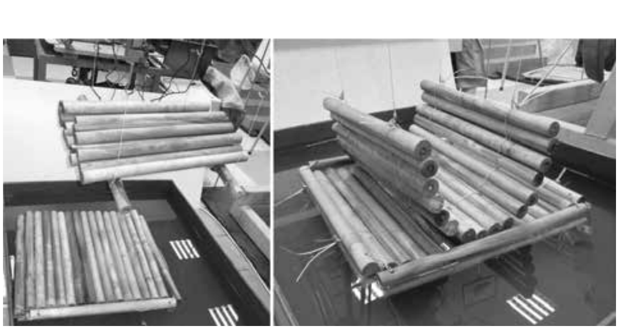

Fig. 5 Lifting of the first row of a flat raft: on left – NArFU construction; on right – VSUT construction

***Slika 5.** Podizanje prvoga reda ravne splavi: lijevo – konstrukcija NArFU; desno – konstrukcija VSUT*

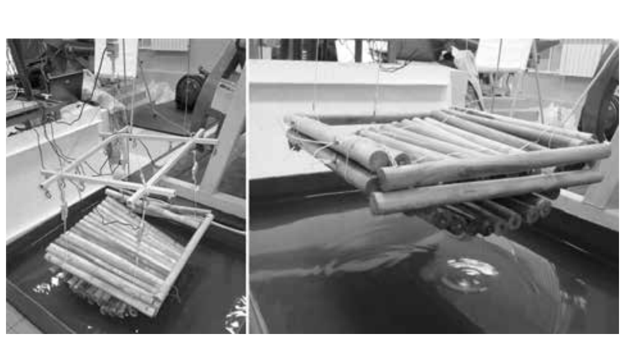

Fig. 6 Lifting of two rows of a flat raft: on left – NArFU construction; on right – VSUT construction

***Slika 6**. Podizanje dva reda ravne splavi: lijevo – konstrukcija NArFU; desno – konstrukcija VSUT*

3. Results – *Rezultati*

Based on the performed laboratory experiments and statistical processing of the data obtained, the duration of the unloading cycle of multi-row flat rafts of the NArFU and VSUT design from the water to the shore was determined (Table 1, 2).

Table 1 Duration of unloading cycle of flat rafts of NArFU construction from water by a tower crane

Tablica 1. *Trajanje ciklusa istovara ravnih splavi konstrukcije NArFU iz vode toranjskom dizalicom*

Name of operation – *Naziv operacije*	Time, s – *Vrijeme, s*					
Type of flat raft (overall size, cm) *Vrsta ravne splavi (ukupna veličina, cm)*	Single row (400×400×25) *Jedan red (400×400×25)*		Double row (500×500×60) *Dva reda (500×500×60)*		Three row (600×600×**x120)** *Tri reda (600×600×120)*	
Type of experiment – *Vrsta pokusa*	Model *Model*	Nature *Priroda*	Model *Model*	Nature *Priroda*	Model *Model*	Nature *Priroda*
1. Removing upper bindings of flat raft *1. Uklanjanje gornjih vezova ravnoga splava*					22	71
2. Rolling side logs of the first row to the center of flat raft *2. Kotrljanje bočnih trupaca prvoga reda do središta ravne splavi*					6	20
3. Lowering the lifting device in the center of flat raft *3. Spuštanje uređaja za podizanje u središte ravne splavi*	3	9.5	3	9.5	6	19
4. Capturing the first row of logs of flat raft *4. Hvatanje prvoga reda trupaca ravne splavi*	13	41.1	15	47.4	52	163
5. Lifting the first row of logs of flat raft *5. Podizanje prvoga reda trupaca ravne splavi*	3	9.5	3	9.5	7	21
6. Turning a tower crane with a load *6. Okretanje toranjske dizalice s teretom*	15	47.4	15	47.4	28	89
7. Lowering the first row of logs of flat raft to the overpass *7. Spuštanje prvoga reda trupaca ravne splavi do nadvožnjaka*	2	6.3	2	6.3	3	10
8. Removing chokers from forest load *8. Uklanjanje čokera sa šumskoga tovara*	6	19	7	22.1	6	20
9. Raising the lifting device by a crane at idle 9. *Podizanje uređaja za dizanje u praznom hodu dizalice*	2	6.3	2	6.3	3	10
10. Turning the tower crane *10. Okretanje toranjske dizalice*	15	47.4	15	47.4	29	91
11. Lowering the lifting device in the center of flat raft *11. Spuštanje uređaja za podizanje u središte ravne splavi*					7	21
12. Capturing the remaining rows of flat raft by load-grabbing device *12. Hvatanje preostalih redova ravne splavi uređajem za hvatanje tereta*					37	117
13. Lifting the remaining rows of flat raft by crane *13. Podizanje preostalih redova ravne splavi dizalicom*					6	20
14. Turning the tower crane in loading position *14. Okretanje toranjskoga krana u položaj za utovar*					28	89
15. Lowering of forest load onto the overpass *15. Spuštanje šumskoga tovara na nadvožnjak*					3	10
16. Removing chokers from forest load 16. *Uklanjanje čokera sa šumskoga tovara*					13	40
17. Raising the lifting device by a crane at idle *17. Podizanje uređaja za dizanje u praznom hodu dizalice*					6	20
18. Turning the tower crane *18. Okretanje toranjske dizalice*					29	92
Total – *Ukupno:*	59	186.6	62	195.9	292	923

Comparing the duration of the unloading cycle of flat rafts of the NArFU design (Table 1) and VSUT design (Table 2) from the water to the overpass, it can be seen that for full-scale conditions it is lower for the VSUT construction: 1) single-row of flat raft by 22.3 seconds, or 14%; 2) two-row of flat raft by 38 seconds, or 24%; 3) three-row of flat raft by 173.7 seconds, or 54%. The most effective method of unloading three-row flat rafts of the VSUT construction from the water to the overpass is the fourth method (option II), when the timber load is lifted in two stages: in the first stage, 1 row of round timber is lifted; in the second stage, 2 and 3 rows of logs (flat rafts) are lifted. The use of a special load-grabbing device and load-grabbing bindings of flat rafts of the VSUT design contributes to reducing the cycle duration.

An experimental test of the strength of the load-grabbing device for the transportation of long-strip flat raft coastal timber warehouses and log unloading berths was performed. Comparing the maximum lifting efforts of multi-row flat raft from the water (Table 3) in chokers of the lifting device of the tower crane T_2 = 57291.4 N (experiment $GV4_2$, lifting of the 2nd and 3rd rows three-row flat raft, size 6×6×0.8 m, volume 22.6 m^3, weight 14.2 t) with breaking force in choker grips R_2=146952.7 N (rope diameter d_o=16.5 mm double twisting type TK construction 6×19(1+6+12)+1+19(1+6+12), marked in the full-time group of 1670 N/mm^2), it is clear that the margin of safety of anchor grips exceeds 2.57 times the operational loads of the timber processing process on the log unloading berths.

Table 2 Duration of unloading cycle of flat rafts of VSUT construction from water by a tower crane

Tablica 2. *Trajanje ciklusa istovara ravnih splavi konstrukcije VSUT iz vode toranjskom dizalicom*

Name of the operation – *Naziv operacije*	Time, s – *Vrijeme, s*									
Type of flat raft (overall size, cm) *Vrsta ravne splavi (ukupna veličina, cm)*	Single row *Jedan red* (400×400×25)		Double row 1 *Dva reda 1* (500×500×60)		Double row 2 *Dva reda 2* (500×500×60)		Three row 1 *Tri reda 1* (600×600×120)		Three row 2 *Tri reda 2* (600×600×120)	
Type of experiment – *Vrsta pokusa*	Model *Model*	Nature *Priroda*	Model *Model*	Nature *Priroda*	Model *Model*	Nature *Priroda*	Model *Model*	Nature *Priroda*	Model *Model*	Nature *Priroda*
1. Lowering the lifting device in the center of flat raft *1. Spuštanje uređaja za podizanje u središte ravne splavi*	3	9.5	3	9.5	3	9.5	3	9.5	3	9.5
2. Capturing the first row of logs of flat raft *2. Hvatanje prvoga reda trupaca ravne splavi*	7	22.1	6	19	5	15.8	6	19	4	12.6
3. Lifting the first row of logs of flat raft *3. Podizanje prvoga reda trupaca ravne splavi*	3	9.5	3	9.5	3	9.5	3	9.5	3	9.5
4. Turning a tower crane with a load *4. Okretanje toranjske dizalice s teretom*	15	47.4	15	47.4	15	47.4	15	47.4	15	47.4
5. Lowering the first row of logs of flat raft to the overpass *5. Spuštanje prvoga reda trupaca ravne splavi do nadvožnjaka*	2	6.3	2	6.3	2	6.3	2	6.3	2	6.3
6. Removing chokers from forest load *6. Uklanjanje čokera sa šumskoga tovara*	5	15.8	4	12.6	5	15.8	6	19	3	9.5
7. Raising the lifting device by a crane at idle *7. Podizanje uređaja za dizanje u praznom hodu dizalice*	2	6.3	2	6.3	2	6.3	2	6.3	2	6.3
8. Turning the tower crane *8. Okretanje toranjske dizalice*	15	47.4	15	47.4	15	47.4	15	47.4	15	47.4
9. Lowering the lifting device in the center of flat raft *9. Spuštanje uređaja za podizanje u središte ravne splavi*					3	9.5	3	9.5	3	9.5
10. Capturing the second row of logs of flat raft *10. Hvatanje drugoga reda trupaca ravne splavi*					7	22.1	6	19	5	15.8
11. Lifting the second row of logs of flat raft *11. Podizanje drugoga reda trupaca ravne splavi*					3	9.5	3	9.5	3	9.5
12. Turning a tower crane with a load *12. Okretanje toranjske dizalice s teretom*					15	47.4	15	47.4	15	47.4
13. Lowering the second row of logs of flat raft to the overpass *13. Spuštanje drugoga reda trupaca ravne splavi do nadvožnjaka*					2	6.3	2	6.3	2	6.3
14. Removing chokers from forest load *14. Uklanjanje čokera sa šumskoga tovara*					5	15.8	3	9.5	3	9.5
15. Raising the lifting device by a crane at idle *15. Podizanje uređaja za dizanje u praznom hodu dizalice*					2	6.3	2	6.3	2	6.3
16. Turning the tower crane *16. Okretanje toranjske dizalice*					15	47.4	15	47.4	15	47.4
17. Lowering the lifting device in the center of flat raft *17. Spuštanje uređaja za podizanje u središte ravne splavi*									3	9.5
18. Capturing the third row of logs of flat raft *18. Hvatanje trećega reda trupaca ravne splavi*									5	15.8
19. Lifting the third row of logs of flat raft *19. Podizanje trećega reda trupaca ravne splavi*									3	9.5
20. Turning a tower crane with a load *20. Okretanje toranjske dizalice s teretom*									15	47.4
21. Lowering the third row of logs of flat raft to the overpass *21. Spuštanje trećega reda trupaca ravne splavi do nadvožnjaka*									2	6.3
22. Removing chokers from forest load *22. Uklanjanje čokera sa šumskoga tovara*									3	9.5
23. Raising the lifting device by a crane at idle *23. Podizanje uređaja za dizanje u praznom hodu dizalice*									2	6.3
24. Turning a tower crane *24. Okretanje toranjske dizalice*									15	47.4
Total – *Ukupno:*	52	164.3	50	158.0	102	322.3	101	319.3	143	451.9

Table 3 Results of experimental verification of grappling device strength for transshipment of flat rafts from water on log unloading berths

***Tablica 3**. Rezultati pokusa provjere čvrstoće hvataljke za prekrcaj splavi s vode na vezovima za istovar trupaca*

Experiment *Pokus*	Scale λ=10 *Razmjer λ=10*	Flat raft – *Ravna splav*		Lifting force – *Sila dizanja*						$\frac{(\Sigma T_i - T) \times 100\ \%}{T}$
		Type *Vrsta*	Overall size L×B×H, m *Ukupna veličina L×B×H, m*	In the rope T, N *U užetu T, N*	In chokers of load-grabbing device, N *U čokerima uređaja za hvatanje tereta, N*				ΣT_i	
					T_1	T_2	T_3	T_4		
GV1	Model *Model*	1-row *1 red*	0.4×0.4×0.025	27.4	6.4	8.0	6.2	7.5	28.1	
	Nature *Priroda*		4×4×0.25	27,409.6	6443.0	7963.0	6227.2	7453.1	28,086.3	2.46
GV2	Model *Model*	2-row *2 reda*	0.5×0.5×0.06	98.0	24.2	21.7	27.0	26.0	98.9	
	Nature *Priroda*		5×5×0.60	97,870.4	24,183.2	21,672.7	26,997.7	26,026.8	98,880.4	1.03
GV3	Model *Model*	2-row (1st row) *2 reda (1. red)*	0.5×0.5×0.03	47.6	12.4	12.0	12.0	12.5	48.9	
	Nature *Priroda*		5×5×0.30	47,622.1	12,448,6	11,994.5	12,004.3	12,472.1	48,919.5	2.72
	Model *Model*	2-row (2nd row) *2 reda (2. red)*	0.5×0.5×0.03	52.2	12.9	13.7	12.8	13.7	53.1	
	Nature *Priroda*		5×5×0.30	52,168.4	12,877.1	13,663.6	12,840.8	13,729.3	53,110.8	1.80
GV4	Model *Model*	3-row (1 st row) *3 reda (1. red)*	0.6×0.6×0.04	94.4	22.6	24.4	23.5	25.6	96.1	
	Nature *Priroda*		6×6×0.4	94,438.0	22,555.3	24,418.6	23,536.0	25,595.4	96,105.3	3.84
	Model *Model*	3-row (2nd and 3rd row) *3 reda (2. i 3. red)*	0.6×0.6×0.08	199.4	44.9	57.3	44.0	54.1	200.3	
	Nature *Priroda*		6×6×0.8	199,424.1	44,944.9	57,291.4	43,983.8	54,067.0	200,287.1	0.43
GV5	Model *Model*	3-row (1 st row) *3 reda (1. red)*	0.6×0.6×0.04	94.6	22.9	24.2	24.0	25.6	96.7	
	Nature *Priroda*		6×6×.,4	94,634.2	22,947.6	24,222.4	24,026.3	25,595.4	96,791.7	2.28
	Model *Model*	3-row (2nd row) *3 reda (2. red)*	0.6×0.6×0.04	105.3	26.5	27.3	26.4	25.8	106	
	Nature *Priroda*		6×6×0,4	105,349.9	26,453.4	27,308.6	26,379.9	25,806.2	105,948.1	0.57
	Model *Model*	3-row (3 rd row) *3 reda (3. red)*	0.6×0.6×0.04	104.4	23.6	28.8	23.7	29.4	105.5	
	Nature *Priroda*		6×6×0.4	104,351.6	23,558.5	28,758.0	23,674.2	29,417.0	105,407.7	1.01

Table 4 Results of experimental studies of load fluctuation amplitude in load-grabbing device when unloading flat rafts from water by a crane

***Tablica 4**. Rezultati eksperimentalnih istraživanja amplitude fluktuacija opterećenja u uređaju za hvatanje tereta pri istovaru ravnih splavi iz vode dizalicom*

Experiment *Pokus*	Scale λ=10 *Razmjer λ=10*	Flat raft – *Ravna splav*			Oscillation amplitude of lifting force *Amplituda osciliranja sile dizanja*					Load rise time, s *Vrijeme podizanja tereta, s*				
		Type *Vrsta*	Weight m, kg *Težina m, kg*	Overall size L×B×H, m *Ukupna veličina L×B×H, m*	In chokers T, kgf *U čokerima T, kgf*	In chokers of load-grabbing device, kgf *U čokerima uređaja za hvatanje tereta, kgf*				t	t_1	t_2	t_3	t_4
						T_1	T_2	T_3	T_4					
AV1	Model *Model*	1-row *1 red*	1.978	0.4×0.4×0.025	2.0	0.3	0.3	0.3	0.3	1,0	1,0	1,0	1,0	1,0
	Nature *Priroda*		1978	4×4×0.25										
AV2	Model *Model*	2-row *2 reda*	7.122	0.5×0.5×0.06	3.1	0.2	1.3	0.2	1.2	0.6	0.6	0.6	0.6	0.6
	Nature *Priroda*		7122	5×5×0.60										
AV3	Model *Model*	2-row (1st row) *2 reda (1. red)*	3.561	0.5×0.5×0.03	1.7	1.4	0.2	1.2	0.2	1.0	1.0	0.6	1.0	0.6
	Nature *Priroda*		3561	5×5×0.30										
	Model *Model*	2-row (2nd row) *2 reda (2. red)*	3.561	0.5×0.5×0.03	2.4	0.9	0.2	0.7	0.2	1.0	1.0	0.6	0.6	0.6
	Nature *Priroda*		3561	5×5×0.30										
AV4	Model *Model*	3-row (1st row) *3 reda (1. red)*	6.545	0.6×0.6×0.04	0.3	0.3	0.3	0.2	0.1	0.6	0.6	0.6	0.6	0.6
	Nature *Priroda*		6545	6×6×0.4										
	Model *Model*	3-row (2nd and 3rd row) *3 reda (2. i 3. red)*	14.243	0.6×0.6×0.08	7.6	2.2	1.7	1.5	1.7	1.0	1.0	0.6	0.6	0.6
	Nature *Priroda*		14.243	6×6×0.8										
AV5	Model *Model*	3-row (1st row) *3 reda (1. red)*	6.544	0.6×0.6×0.04	1.8	0.6	0.4	0.3	0.6	0.6	0.6	0.6	0.6	0.6
	Nature *Priroda*		6544	6×6×0.4										
	Model *Model*	3-row (2nd row) *3 reda (2. red)*	7.122	0.6×0.6×0.04	5.1	0.8	0.1	0.7	0.3	1.0	1.0	1.0	1.0	1.0
	Nature *Priroda*		7122	6×6×0.4										
	Model *Model*	3-row (3rd row) *3 reda (3. red)*	7.122	0.6×0.6×0.04	5.0	1.4	1.4	1.0	1.3	1.0	1.0	1.0	1.0	1.0
	Nature *Priroda*		7122	6×6×0.4										

The validity of the accepted assumption in theoretical calculations (Vojtko and Gajsin 2013) of a special lifting device has been experimentally confirmed, when the total load on the lifting traverse of a tower crane is evenly distributed over four choker grips (Table 3). The reliability of the accepted assumption is $(\Sigma T_i - T) \cdot 100\% \ / \ T = 97.57\%$.

The oscillation amplitude of the lifting forces and the period of oscillation of the lifting device when unloading flat rafts with a crane from water on the log unloading berths were studied (Table 4). The oscillation amplitude of the lifting forces by the lifting device of forest goods from land is 11–33% greater than from water, which is facilitated by the damping properties of the liquid (Fig. 7, 8).

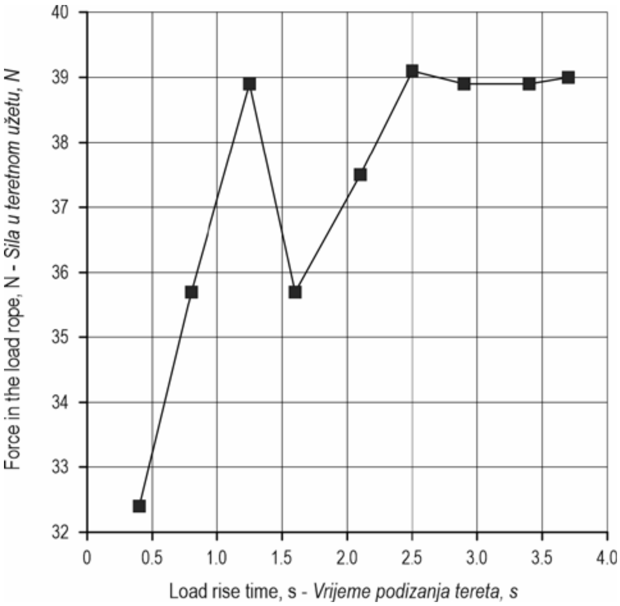

Fig. 7 Amplitude of force fluctuations in load rope of grappling device when unloading a two-row flat raft from the land

Slika 7*. Amplituda kolebanja sile u teretnom užetu hvataljke pri istovaru dvoredne ravne splavi s kopna*

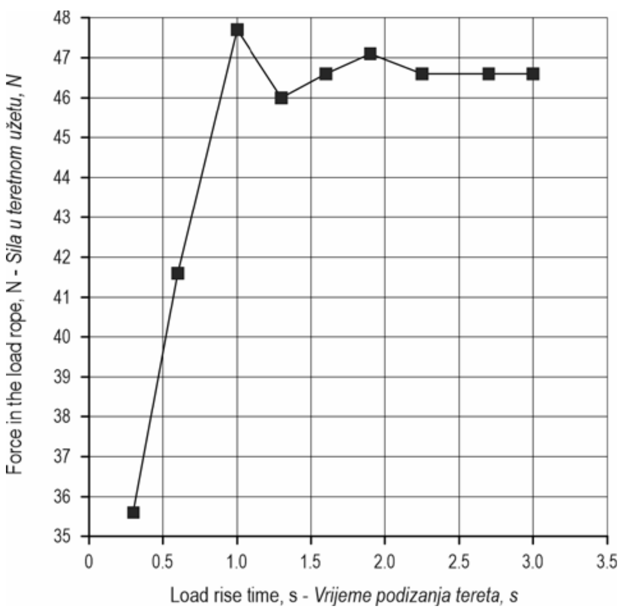

Fig. 8 Amplitude of force fluctuations in load rope of grappling device when unloading a two-row flat raft from water

Slika 8*. Amplituda kolebanja sile u teretnom užetu hvataljke pri istovaru dvoredne ravne splavi iz vode*

4. Discussion – *Rasprava*

The obtained results of laboratory studies of the amplitude and period of oscillation of the lifting forces by the lifting device of forest load from land (Fig. 7) and water (Fig. 8) are consistent with the oscillogram of the lifting forces of bundles of logs from water and land (Fig. 9) by the lifting mechanism of the KM-3076 electric crane on the log unloading berths of the JSC »Solikamskbumprom« (Vojtko 2006).

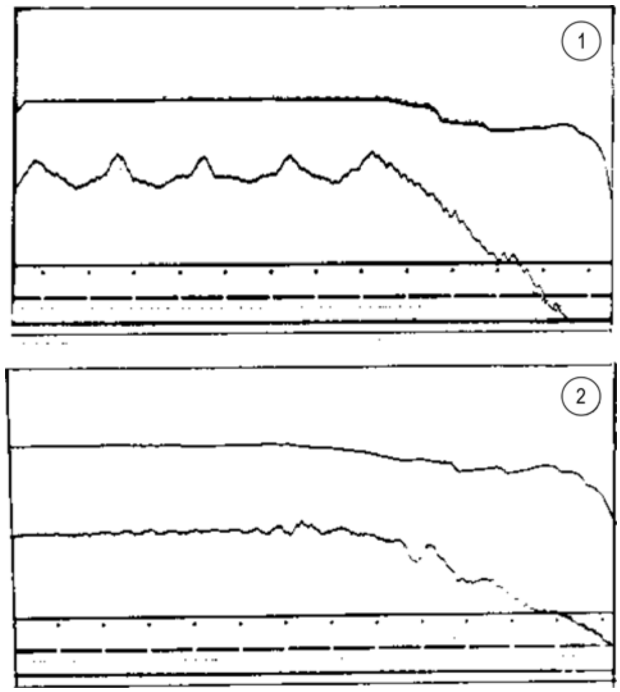

Fig. 9 Oscillogram of lifting forces of bundles of logs from water and land (Fig. 9) by lifting mechanism of KM-3076 electric crane: 1 – from water; 2 - from land (*according to Vojtko 2006)*

Slika 9*. Oscilogram sila podizanja zavežljaja trupaca iz vode i kopna (slika 9) mehanizmom za podizanje električne dizalice KM-3076: 1 – iz vode; 2 – sa zemlje (prema Vojtko 2006.)*

The performed studies of the oscillation amplitude of the lifting forces and the oscillation period of the lifting device during unloading by a crane from the water on the raids of the float are consistent with the production studies of the KM-3076 crane on the log unloading berths of the float of the JSC »Solikamskbumprom« (Vojtko 2006).

5. Conclusion – *Zaključak*

On the basis of laboratory studies, an experimental test of the strength of the load-grabbing devices, protected by patents of the Russian Federation No. 2476366 and No. 2526767, was carried out (Vojtko and Gajsin 2013). The duration of the cycle of unloading flat raft of the NArFU and VSUT structures from water to shore (Table 1, 2) by a tower crane equipped with a special load-grabbing device (Fig. 1) for transshipment of long-length flat rafts at coastal timber warehouses and raids of timber industry enterprises was defined. The hypothesis made on the basis of theoretical calculations of a special load-grabbing device regarding the uniformity of the distribution of the total load on the load-grabbing device into four choker grips (Table 3, 4) was experimentally confirmed. The reliability of the accepted assumption was 97.6%.

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Sažetak

Istovar trupaca na vezovima poduzeća za sječu – eksperimentalna istraživanja

Tijekom razvoja tržišne ekonomije u Rusiji glavni je trend u industriji prerade trupaca uvođenje najnovijih tehnologija i učinkovitih inovacija koje povećavaju produktivnost rada i smanjuju troškove proizvodnje na temelju okolišno prihvatljivoga i racionalnoga korištenja drvnih resursa. Uzimajući u obzir važnu ulogu transporta trupaca vodom, koji služi za splavarenje drva, problem učinkovitosti utovara i istovara ravnih splavi na vezovima za istovar trupaca vrlo je hitan. Prikazano istraživanje promatra načine povećanja učinkovitosti istovara višerednih ravnih splavi na vezovima šumarskih poduzeća. Predmet su ovoga istraživanja rezultati pokusa istovara višerednih ravnih splavi provedenih u laboratorijskim uvjetima. U tim je pokusima dizalica za podizanje tereta, koja je opremljena posebnim hvataljkama tereta, korištena za istovar višerednih ravnih splavi na vezu za istovar trupaca. Tijekom pokusa definirano trajanje slijeda istovara od vode do mjesta za istovar primijenjeno je na višeredne ravne splavi koje je sračunalo Sjeverno (Arktičko) federalno sveučilište nazvano po M. V. Lomonosovu (NArFU) i Volga, državno tehnološko sveučilište (VSUT), na osnovi rezultata laboratorijskih pokusa i statističke obrade dobivenih podataka. Također je provedeno ispitivanje čvrstoće hvataljke tereta dizalice koja služi za prijenos dugačkih ravnih splavi u kopnenim skladištima drva i vezovima za istovar trupaca. Provedeno je istraživanje amplitude kolebanja sile dizanja i razdoblja osciliranja hvataljke tereta tijekom procesa istovara ravne splavi iz vode na vez za istovar trupaca. Amplituda kolebanja sile podizanja hvataljke tereta s tla veća je za 11–33 % nego iz vode zahvaljujući sposobnosti prigušenja vode. Na temelju laboratorijskih istraživanja eksperimentalno je ispitana trajnost hvataljki tereta patentiranih u Ruskoj Federaciji pod br. 2476366 i br. 2526767. Eksperimentalno je potvrđena hipoteza teoretskoga proračuna hvataljke specijalnoga tereta o ravnomjernosti raspodjele bruto opterećenja na hvataljku primjenjivo na aparate za podizanje opće namjene za četiri čokerske hvataljke. Pretpostavka sigurnosti iznosila je 97,6 %.

Ključne riječi: vez za istovar trupaca, kranski toranj, ravna splav, trajanje slijeda istovara, nosivost užeta za podizanje

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