Rational Structure of Panel with Curved Plywood Ribs

Jānis Šliseris, Kārlis Rocēns

Abstract—Optimization of rational geometrical and mechanical parameters of panel with curved plywood ribs is considered in this paper. The panel consists of cylindrical plywood ribs manufactured from Finish plywood, upper and bottom plywood flange, stiffness diaphragms. Panel is filled with foam. Minimal ratio of structure self weight and load that could be applied to structure is considered as rationality criteria. Optimization is done, by using classical beam theory without nonlinearities. Optimization of discreet design variables is done by Genetic algorithm.

Keywords—Curved plywood ribs, genetic algorithm, rational parameters of ribbed panel, structure optimization.

I. INTRODUCTION

MINIMAL material consumption, structure weight, new rational large span structures and use of environmentally friendly materials in structures are the main directions of research in today's structural engineering science. Wood is one of the renewable natural resources and plywood sheets provide a rational use of wood. Traditionally used flat plywood sheets are not rational in many cases because of their slenderness and insufficient load bearing capacity. The load bearing capacity of plywood sheets could be increased significantly by using sheets with curved shape. Therefore, in this paper a new panel structure is proposed, witch is based on cylindrical plywood ribs in combination with other plywood elements – top and bottom flange, shear stiffness diaphragms, plywood stiffeners, and inside filled with foams. The structure becomes more efficient if it's geometrical and mechanical parameters (technologically changeable) are optimized. In this paper optimization of the proposed panel structure is elaborated.

II. STRUCTURE OF PANEL AND PARAMETERS TO BE OPTIMIZED

In this paper way of optimization of geometrical and mechanical parameters of panel with curved plywood ribs is shown. Cross section, longitudinal section and structural analysis scheme of provided structure are showed in fig 1.

The curved plywood shell could be manufactured by using hot pressing, cold pressing, vacuum pressing or making structure with special nonsymmetrical structure, curved with moisture difference [1]-[3]. In this work it is assumed that curved plywood shells are made with symmetrical structure with respect to its mid surface and curved by hot pressing.

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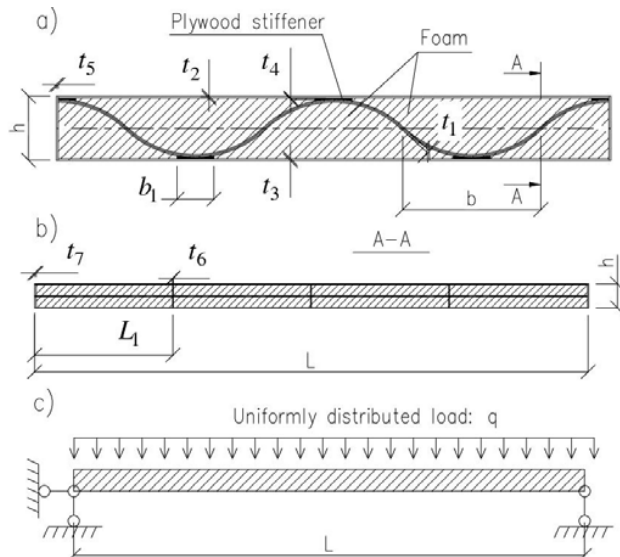
Fig. 1 The panel with curved plywood ribs: a – cross section, b – longitudinal section, c – structural analysis scheme

The most important geometrical and mechanical parameters of panel are:

t_1- thickness of cylindrical shell ribs,

t_2- thickness of top plywood flange,

t_3- thickness of bottom plywood flange,

t_4- average thickness of plywood stiffener,

t_5-thickness of side element, during optimization it is constant t_5=6.5 mm,

t_6- thickness of shear stiffness diaphragms, during optimization it is constant t_6=9 mm,

t_7- thickness of support stiffness diaphragms, during optimization it is constant t_6=12 mm,

b- width of cylindrical shell,

h- total height of panel,

b_1- width of plywood stiffener,

L_1- distance between shear stiffness diaphragms (count of shear stiffness diaphragms is $n = \dfrac{L}{L_1} - 1$) ,

L- span of panel,

ρ_p - density of foam.

The panel thickness h depends on heat and sound insulation requirements and load bearing capacity requirements [4]. Therefore this parameter is not included in design vector. The design vector parameters are optimized for each discrete values of thickness of panel h=200,250,300,350 mm.

The span of panel depends on building's overall structure of the building, therefore it is not considered as an optimized parameter. According to classical knowledge of this type of

structure the material consumption is smaller for smaller span [5]. For each value of span L=4000, 6000, 8000, 10000 mm are found optimal values of design vector components.

Other mentioned parameters can be optimized therefore the design vector consists of eight parameters:

$$x = \{t_1, t_2, t_3, t_4, b, b_1, n, \rho_p\} \qquad (1)$$

Each component of design vector takes one value from eight discrete values. These values are shown in table 1.

TABLE I
PARAMETERS TO BE OPTIMIZED AND ITS DISCRETE VALUES

t_1, t_2, t_3, t_4,* mm	b, mm	b_1, mm	n	ρ_p, kg/m³
6.5	400	80	1	9.9
9	450	90	3	13.7
12	500	100	5	17.5
15	550	110	7	21.4
18	600	120	9	25.2
21	650	130	11	29.0
24	700	140	13	32.8
27	750	150	15	36.6

* Each design variable could be different from each other.

The thickness of plywood elements is taken according to Finnish birch plywood standards. For each thickness of Finnish birch plywood its appropriate characteristic strength and mean stiffness properties are used in the analysis. The minimized objective function is the ratio of structure's weight- W and maximum value of load- Q that could be applied to structure:

$$f(x) = \frac{W}{Q} \qquad (2)$$

where W- total weight of panel, Q- maximal value of load that is uniformly distributed and satisfies ULS (ultimate limit state) and SLS (serviceability limit state) criteria.

III. DISCREAT PARAMETER OPTIMIZATION WITH GENETIC ALGORITHM

A. Overview of optimization algorithms

There are many methods that provide optimization of the structures. The classical methods are based on calculus and use of function derivatives. Serious problems arise in the cases if there are local extremes, discrete design variables, discontinuous objective function or nonconvex design space [6]. These properties of objective function are difficult to identify for large and relatively novel systems. In this case a new structure is provided and there is no preliminary knowledge of its behavior depending of its parameters, therefore use of nontraditional optimization technique is more rationally. There are several nontraditional optimization techniques- Genetic algorithms [7]-[8], Simulated annealing [9], Particle swarm optimization, Ant colony optimization, Fuzzy optimization, Neural-network-based methods. For this type of problem according to [6]-[10] the most convenient is Genetic algorithm, therefore it will be used in further structure optimization.

B. Genetic algorithm (GA)

A general constrained minimization problem can be stated as

$$\begin{cases} Minimize(f(x)) \\ g_i(x) \le 0, i = 1..m \\ h_j(x) = 0, j = 1..p \end{cases} \qquad (3)$$

where x − vector of design variables, $f(x)$ − objective function, $g_i(x), h_j(x)$ - constrains that in form of inequalities and equalities.

GA can be used only for unconstrained problems. Therefore problem (3) is converted into an equal unconstrained minimization problem by using concept of penalty functions as

$$Minimize(\Phi(x))$$

$$\Phi(x) = f(x) + \sum_{i=1}^{m} r_i \left(G_i(x) \right)^2 + \sum_{j=1}^{p} R_j \left(h_j(x) \right)^2 \qquad (4)$$

where r_i, R_j − penalty parameters, its values are constant during optimization, $G_i(x)$ is defined as

$$G_i(x) = \begin{cases} g_i(x), g_i(x) > 0 \\ 0, g_i(x) \le 0 \end{cases} \qquad (5)$$

GA is based on the principles of natural genetics and natural selection (Darwin's theory of survival of the fittest). The basic operators of natural genetics are reproduction, crossover and mutation. Simplified flowchart of GA is shown in fig 2.
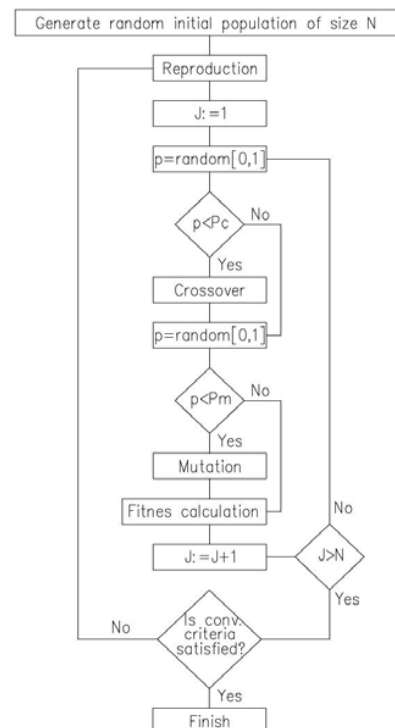

Fig 2. Flowchart of Genetic algorithm.

Reproduction is the first operator applied to the population to select "good" design vectors that gives a minimal value to objective function.

Crossover is second operator applied to the population with initially defined probability Pc. The Crossover operator randomly selects two design vectors (called parents) from population and by changing its binary codes obtains two new design vectors although there are also methods that use only real numbers [11].

The crossover operator generate random integer number in interval from 1 to n, where n- length of binary code. By changing binary numbers of parents from i-th place, where i is generated as random number, obtains two new binary codes (called child). The crossover operation is done only in case if child gives better value of fitness function.

For example if two components of design vector has values $x_1 = 105(mm)$ and $x_2 = 110(mm)$, n=8, i=6, the crossover modify components of design vector following obtaining a new values of components of design vector $x_1^` = 106(mm)$ , $x_2^` = 109(mm)$:

$$\begin{cases} x_1 = \{011010 \,|\, 01\} \\ x_2 = \{011011 \,|\, 10\} \end{cases} \xrightarrow{crossover} \begin{cases} x_1^` = \{01101010\} \\ x_2^` = \{01101101\} \end{cases}$$

The *Mutation* operator is applied to the new binary codes with a specific small probability Pm. This operator changes each number in binary code from value 1 to 0 or 0 to 1 with probability Pm, that is very small, usually Pc<0.01. In previously given example the Mutation operator gives following result:

$$x_1 = \{0110(1)001\} \xrightarrow{Mutation} x_1^` = \; 0110(0)001 \; .$$

III. OPTIMIZATION

The value of maximal total load Q is calculated using following criteria's:

1. Compressions stress in top flange of panel is less than compression strength of plywood (in direction of mostly orientated veneer fibers):

$$g_1 = \frac{\left|\sigma_{max}^-\right|}{f_{c,0,k} \cdot \left(\dfrac{k_{mod} k_{sys}}{\gamma_m}\right)} - 1 \le 0 \tag{6}$$

2. Tension stress in bottom flange of panel is less than tension strength of plywood (in direction of mostly orientated veneer fibers);

$$g_2 = \frac{\left|\sigma_{max}^+\right|}{f_{t,0,k} \cdot \left(\dfrac{k_{mod} k_{sys}}{\gamma_m}\right)} - 1 \le 0 \tag{7}$$

3. Deflection of panel is less than 1/200 of span. Deflection is calculated using Timoshenko beam theory that takes into account shear deformations. The problem is solved using Ritz method, approximating deflection function of simply supported beam by forth order polynomial. Obtained following equation for deflection in middle of span:

$$\Delta(0.5L) = \frac{0.013 \cdot qL^6 GI + 0.167 \cdot qL^4 E \cdot t \cdot h^5}{EGL^2 I^2 + 16E^2 I \cdot t \cdot h^5} \tag{8}$$

$$g_3 = \frac{\left|\Delta(0.5L)\right|}{\dfrac{1}{200}L} - 1 \le 0 \tag{9}$$

4. Shear stress in curved plywood shell and foams are less than shear strength. In numerical analysis foam material are Extended polystyrene (EPS). The EPS is reduced to equal thickness plywood rib by using radio of Shear modulus of EPS and plywood.

$$g_4 = \frac{\left|\tau_{max}\right|}{f_{v,k} \cdot \left(\dfrac{k_{mod} k_{sys}}{\gamma_m}\right)} - 1 \le 0 \tag{10}$$

5. Compression stress in top flange should not exceed buckling stress that is calculated using linear Euler analysis of buckling. Top flange is considered as a simply supported beam under axial load with span equal to distance between shear stiffness diaphragms.

$$g_5 = \frac{\left|\sigma_{max}^-\right|}{\sigma_{crit}} - 1 \le 0 \tag{11}$$

6. Stress of top flange should be less than bending strength of plywood(in orthogonal direction of mostly orientated wood fibers). The top flange is considered as a beam on elastic foundation. The elastic foundation is EPS and it is assumed that it satisfies Vinklers hypothesis. The modulus of elasticity of EPS is calculated depending on density of EPS. In case if relative deformations are less than 10% density of EPS could be approximated by following linear relationship [12]:

$$E_p = \frac{\rho_p - 6.096}{12.724} \tag{12}$$

$$g_6 = \frac{\left|\sigma_{max}\right|}{f_{m,90,k} \cdot \left(\dfrac{k_{mod} k_{sys}}{\gamma_m}\right)} - 1 \le 0 \tag{13}$$

where $k_{mod} = 0.55$ modification factor for long term load [13]-[14], $k_{sys} = 1$, $\gamma_m = 1.2$ - material safety factor, $f_{c,o,k}$, $f_{t,o,k}$, $f_{v,k}$, $f_{m,90,k}$ - characteristic strength of Finnish birch plywood, $G = \dfrac{G_{v,mean}}{1 + k_{def}}$, $E = \dfrac{E_{t/c,0,mean}}{1 + k_{def}}$, $k_{def} = 0.8$ - safety factor, that takes into account creep for services class 2 [13]-[14], I- second moment of area- calculated taking into account reduced width of compressed and tensioned flange according to [13]-[14], t- reduced thickness of plywood shell-

sum of thickness of plywood shell and EPS thickness that is reduced to equal plywood thickness, ρ_p – density of EPS, $\frac{kg}{m^3}$, E_p – modulus of elasticity of EPS, MPa.

The weight of structure W is calculated assuming that plywood average density is 700 kg/m³.

Probability of crossover, probability of mutation was used 0.7 and 0.001. In the reproduction operator the only 3% of design vectors with highest fitness ratio was kept. Numerical results showed that fast result convergence is obtained if the probability of crossover and mutation are in interval 0.65...0.75 and 0.0005…0.0015, respectively. The behavior of objective function in design space showed that global optimum could be found with high probability if reproduction operator keeps less than 3% of design vectors with highest fitness ratio. In case if it was 5%...7% there is a big probability to identify local extremes.

The analysis showed that objective function f(x) is strong nonlinear with many local extremes. Results approved that classical optimization methods are difficult to use in this case. It could be done only in case if the design space is divided in many smaller subspaces.

The rational parameters of panel is obtained for the case if the span varies form 4000 to 10000mm, height of panel varies form 200 to 350 mm and uniformly distributed load varies from 2 to 7.5 KPa. The values of rational parameters and reserve of strength and stiffness for each criterion are showed in table II.

TABLE II
NUMERICAL RESULTS OF OPTIMIZATION WITH GA

				Geometrical parameters, mm					ρ_p, kg/m3	f(x), kg/kN	Reserve of strength and stiffness for each criteria (see eq. (6)-(13)), %					
L	h	t_1	t_2	t_3	t_4	b	b_1	n			g_1	g_2	g_3	g_4	g_5	g_6
								q=2 KPa								
4000	200	6.5	6.5	6.5	6.5	450	80	3	9.9	9.4	62.9	69.2	44.9	16.1	99.6	97.6
4000	250	6.5	6.5	6.5	6.5	550	90	3	9.9	10.0	66.6	73.2	60.1	10.7	60.4	99.4
4000	300	6.5	6.5	6.5	6.5	650	100	3	9.9	10.5	69.6	76.1	69.7	6.3	98.0	99.7
4000	350	6.5	6.5	6.5	6.5	750	90	3	9.9	11.0	71.4	77.9	75.6	0.9	99.7	99.3
6000	200	6.5	6.5	6.5	24	400	80	5	9.9	10.1	54.8	57.8	6.2	20.4	89.4	96.1
6000	250	6.5	6.5	6.5	9	450	90	5	9.9	9.7	49.4	52.8	2.5	8.7	89.4	97.5
6000	300	6.5	6.5	6.5	6.5	500	100	5	9.9	10.0	52.8	57.1	22.8	9.0	99.4	98.5
6000	350	6.5	6.5	6.5	9	600	80	5	9.9	10.5	54.5	60.4	37.9	0.5	92.8	98.0
8000	200	6.5	24	6.5	27	400	80	5	9.9	15.1	47.8	74.2	0.5	14.3	99.7	92.5
8000	250	6.5	9	6.5	27	400	150	5	9.9	12.6	56.9	61.9	3.0	21.2	99.4	91.0
8000	300	6.5	6.5	6.5	27	450	90	5	9.9	11.1	51.9	52.1	1.1	18.5	96.4	97.5
8000	350	6.5	6.5	6.5	12	400	80	5	9.9	10.8	53.4	49.9	5.0	28.8	47.5	96.1
10000	200	24	27	27	27	400	130	7	9.9	25.2	68.4	73.9	0.2	75.6	99.5	93.4
10000	250	6.5	27	12	27	400	130	7	9.9	18.0	55.2	74.1	0.3	22.3	94.7	93.9
10000	300	6.5	21	6.5	27	400	150	7	9.9	16.0	48.9	71.2	2.5	20.7	58.4	91.9
10000	350	6.5	18	6.5	27	400	80	7	9.9	14.5	47.0	67.1	5.7	23.0	95.5	90.2
								q=3 KPa								
4000	200	6.5	6.5	6.5	9	400	80	3	9.9	6.7	53.4	60.8	31.7	1.3	25.1	94.4
4000	250	6.5	6.5	6.5	6.5	450	90	3	9.9	7.0	58.2	65.5	49.3	3.0	99.8	96.4
4000	300	6.5	6.5	6.5	6.5	500	90	3	9.9	7.4	62.9	69.9	62.4	5.7	98.7	98.0
4000	350	6.5	6.5	6.5	9	600	100	3	9.9	7.9	66.6	73.6	71.6	0.0	99.5	99.9
6000	200	6.5	6.5	6.5	27	400	150	5	9.9	8.1	51.3	56.8	3.9	1.4	97.7	92.3
6000	250	6.5	6.5	6.5	15	400	130	5	9.9	7.4	46.8	50.6	1.7	2.5	99.2	93.0
6000	300	6.5	6.5	6.5	6.5	400	90	5	9.9	7.1	42.6	44.8	3.0	2.6	59.0	94.1
6000	350	6.5	6.5	6.5	6.5	450	110	5	9.9	7.5	47.8	51.7	25.4	3.2	66.7	95.9
8000	200	6.5	27	18	27	400	80	7	9.9	13.0	59.6	71.5	8.2	0.2	99.8	90.6
8000	250	6.5	24	9	24	400	80	7	9.9	11.2	46.1	69.7	3.0	0.4	94.8	89.2
8000	300	6.5	12	6.5	27	400	140	7	9.9	9.6	47.7	58.9	4.3	0.1	93.6	84.7
8000	350	6.5	6.5	6.5	21	400	120	7	9.9	8.3	47.1	46.4	0.4	12.1	98.6	93.2
10000	200					Maximal deflection criteria is not satisfied										
10000	250	21	27	27	27	400	150	7	9.9	18.4	63.9	70.1	0.5	67.2	98.6	91.2
10000	300	6.5	24	21	27	400	90	7	9.9	13.7	58.3	64.2	0.9	2.4	99.8	89.0

10000	350	6.5	24	6.5	27	400	140	7	9.9	12.0	37.3	68.8	0.3	5.8	90.7	90.1
q=4 KPa																
4000	200	9	6.5	6.5	6.5	400	100	3	9.9	5.5	44.2	54.1	15.5	9.0	94.1	91.9
4000	250	6.5	6.5	6.5	9	400	120	3	9.9	5.6	55.8	63.2	47.0	0.9	99.7	91.2
4000	300	6.5	6.5	6.5	6.5	400	90	3	9.9	5.8	59.2	65.9	58.0	10.6	86.4	92.2
4000	350	6.5	6.5	6.5	6.5	450	90	3	9.9	6.1	62.4	69.2	67.0	9.4	45.9	95.2
6000	200	9	18	6.5	24	400	140	5	9.9	8.1	42.1	65.3	2.2	0.1	99.3	82.4
6000	250	9	6.5	6.5	27	450	130	5	9.9	6.6	42.3	50.5	3.0	7.7	99.2	94.1
6000	300	9	6.5	6.5	12	400	130	5	9.9	6.3	43.2	48.9	8.0	21.0	94.5	90.7
6000	350	6.5	6.5	6.5	12	400	110	5	9.9	6.1	45.4	49.2	23.7	0.9	98.6	91.5
8000	200	9	27	27	27	400	120	7	9.9	12.1	61.6	66.8	1.6	9.7	97.0	88.5
8000	250	9	27	12	24	400	120	7	9.9	10.2	47.1	69.2	0.4	15.9	99.5	88.7
8000	300	9	24	6.5	21	400	120	7	9.9	9.1	36.1	67.9	1.9	15.3	98.0	86.7
8000	350	9	12	6.5	27	400	110	7	9.9	7.9	39.7	53.2	0.3	15.5	98.5	80.8
10000	200						Maximal deflection criteria is not satisfied									
10000	250						Maximal deflection criteria is not satisfied									
10000	300	18	27	27	27	400	120	7	9.9	14.2	59.5	66.0	0.7	57.4	99.7	88.2
10000	350	9	24	21	27	400	90	7	9.9	11.4	54.1	61.1	0.1	19.2	99.8	85.8
q=5 KPa																
4000	200	9	6.5	6.5	12	400	130	3	9.9	4.8	43.1	53.8	18.2	0.5	98.8	88.6
4000	250	9	6.5	6.5	6.5	400	90	3	9.9	4.8	45.3	55.1	32.3	8.9	81.8	90.4
4000	300	9	6.5	6.5	6.5	450	120	3	9.9	5.1	53.5	62.7	51.9	12.6	99.1	93.1
4000	350	6.5	6.5	6.5	6.5	400	100	3	9.9	5.1	58.4	65.5	63.3	6.5	33.2	89.9
6000	200	12	24	6.5	24	400	120	5	9.9	7.6	35.2	67.9	0.5	17.2	99.8	83.7
6000	250	12	12	6.5	27	450	150	5	9.9	6.6	38.2	56.0	3.6	8.4	99.2	78.5
6000	300	9	6.5	6.5	21	400	100	5	9.9	5.3	35.8	42.9	1.7	8.6	98.4	89.9
6000	350	9	6.5	6.5	12	450	120	5	9.9	5.3	33.5	41.6	7.5	0.5	97.2	93.0
8000	200						Maximal deflection criteria is not satisfied									
8000	250	9	27	24	24	400	80	7	9.9	9.4	55.8	63.7	2.7	3.3	98.9	84.9
8000	300	9	24	9	27	400	150	7	9.9	8.2	39.8	65.1	2.5	4.8	94.1	84.5
8000	350	9	21	6.5	27	400	80	7	9.9	7.3	29.4	60.6	1.9	4.1	58.2	80.0
10000	200						Maximal deflection criteria is not satisfied									
10000	250						Maximal deflection criteria is not satisfied									
10000	300						Maximal deflection criteria is not satisfied									
10000	350	9	27	27	27	400	120	7	9.9	10.6	54.9	61.0	1.9	9.6	99.7	85.8
q=7.5 KPa																
4000	200	12	6.5	6.5	27	400	80	3	9.9	3.7	14.2	56.2	24.7	28.3	85.6	63.9
4000	250	12	6.5	6.5	6.5	400	100	3	9.9	3.6	97.8	36.1	34.6	44.7	25.4	51.4
4000	300	9	6.5	6.5	18	400	90	3	9.9	3.7	67.3	71.0	82.0	22.2	88.8	57.6
4000	350	9	6.5	6.5	6.5	400	90	3	9.9	3.8	55.8	57.9	13.4	44.9	96.4	57.6
6000	200	12	27	18	27	400	100	7	9.9	6.3	16.0	35.0	18.5	21.9	91.9	88.8
6000	250	12	24	6.5	27	400	100	7	9.9	5.5	21.8	20.7	6.8	3.1	94.4	53.6
6000	300	12	6.5	9	27	400	150	7	9.9	4.8	74.1	18.8	25.9	54.0	90.6	24.1
6000	350	18	6.5	6.5	27	600	100	7	9.9	4.5	93.4	63.7	0.5	97.9	72.7	98.1
8000	200						Maximal deflection criteria is not satisfied									
8000	200						Maximal deflection criteria is not satisfied									
8000	250	12	27	21	27	400	150	7	9.9	7.2	66.0	97.7	9.8	93.9	97.4	7.7
8000	350	12	27	12	24	400	110	7	9.9	6.4	25.7	6.6	0.9	35.4	48.1	92.7
10000	200						Maximal deflection criteria is not satisfied									
10000	250						Maximal deflection criteria is not satisfied									
10000	300						Maximal deflection criteria is not satisfied									
10000	350						Maximal deflection criteria is not satisfied									

The results showed that in almost all cases the leading criteria is maximal deflection –g_3. For the spans less than 6000 mm and total thickness of panel greater than 300 mm in some cases leading factor is maximal shear stress- g_4. For loads grater than 5 KPa, in some cases the leading factor is maximal compression stress in top flange – g_1. The criteria of maximal local bending stress in top flange are satisfied in all cases with reserve more than 50%. The compressed flange buckling criteria is satisfied in all cases with reserve more than 80 % when load is less than 5 KPa. In the case when span is 10000 mm and total thickness of panel h=200 mm, then deflection criteria is satisfied only in case when q= 2KPa.

The contour plot of objective function that is approximated by second order polynomial depending on span L and total thickness h when q=2KPa is shown in Fig 3. The plot shows that there are minimum point when h=225mm and L=6500mm.
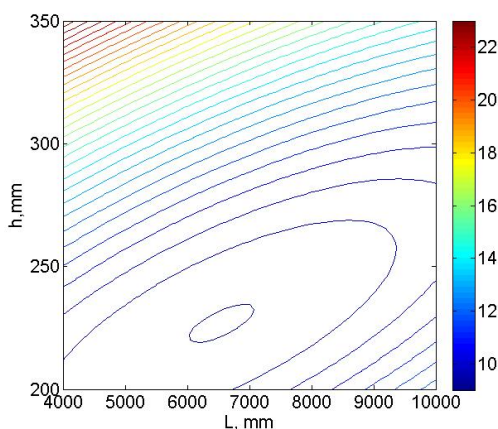

Fig. 3 Contour plot of objective function f(x) (kg/KN) depending on h and L, when q=2KPa.

The contour plot of objective function f(x) when L=6000 mm depending on total thickness of panel h and load q is shown in Fig 4. Minimal value of objective function f(x)=5..6 kg/kN is obtained when the load are maximal- grater than 5 KPa.
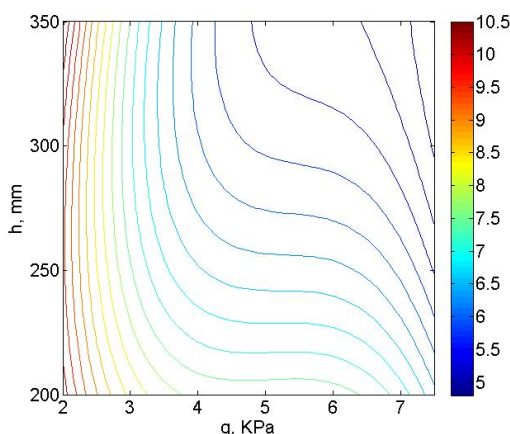

Fig. 4 Contour plot of objective function f(x) (kg/KN) depending on q and h, when L=6000 mm

During the process of optimization was discovered that the optimization procedure becomes more effective if used as two step optimization procedure. The first step is discrete parameter optimization with GA to identify the behavior of objective function in large design space. In the second step continuous parameter optimizations in the small design subspace that is identifier from the results of first step are done.

IV. CONCLUSION

Proposed a novel panel with curved plywood ribs structure and analysis method of its rational discrete geometrical and mechanical parameters by using Genetic algorithm optimization method.

Rational thickness of plywood elements, shape parameters of curved ribs with stiffening elements and density of foam of novel panel structure is obtained by using proposed method for the case if span varies form 4 to 10 m, total thickness of panel from 200 to 350 mm and uniformly distributed load on panel varies from 2 to 7.5 KPa. In the case if span is 8 m total thickness of panel is 250 mm and load is 3 KPa the rational parameters of panel are: thickness of curved plywood rib is 6.5 mm, thickness of compressed flange is 24 mm, thickness of tensioned flange is 9mm, thickness and width of plywood stiffener are 24 mm and 80mm, distance between shear stiffness diaphragms is 1000 mm, width of cylindrical shell is 400 mm and density of EPS foam is 9.9 kg/m^3.

The proposed analysis method of rational discrete parameters of novel panel structure that is based on Genetic algorithm becomes more effective if it is combined with classical optimization methods for continuous design variables obtaining two step optimization method.

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