In the figure the result of load influence on the earth surface is shown, where the curves of motion changes $u^{\circ}_x=u_x\mu/p$ (m), $u^{\circ}_y=u_y\mu/p$ (m) and normal stresses $\sigma^{\circ}_{yy}=\sigma_{yy}/p$ in transverse plane (η=0) are presented.

It follows from the analysis of curve behavior that extreme deflexions u_x of the earth surface and extreme normal stress σ_{yy} take place at y=–0,4R, but maximum horizontal displacement u_y is at y=0,8R (here σ_{yy} is equal to zero). Increasing $|y|$ displacements and stresses damp quickly, and at $|y|$=3,2R dynamic influence of load on the earth surface is virtually imperceptible.

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OPTIMIZATION OF BUILDING CONSTRUCTIONS ON THE BASIS OF GENETIC ALGORITHM

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The technique of optimal design of bearing structures on the basis of genetic algorithm has been suggested. A design of steel frame with varying 9 parameters using the method of finite elements is considered as an example. The best variant corresponding to the volume minimum of the frame material is revealed.

In the last few decades in the spheres of engineering, economics and planning there is a trend of transition from the admissible technical and managing solutions to optimal ones. However, the modern optimization theory has not met the requirements of a design engineer because of the fact that its strict mathematical methods do not take into account real conditions of design problems. Besides, modern complicating design practice needs in efficient mathematical means of solving such problems.

A distinguishing feature of the new approach is a complex development making possible to design a whole system, but not its separate parts. Therefore, one of the most important scientific and applied problems is to develop methodology of optimal design of complex technical systems – the system design.

A construction is characterised by a number of criteria: cost, reliability, weight, size, engineering time and etc, that can came in mutual contradiction. The difficulty of the problem solution consists in the lack of a priori information necessary for searching for optimal variant of construction. Therefore, the design procedure is worthwhile to arrange in such a way that the volume of information on construction would increase at every subsequent stage. At the same time it is necessary to exclude inadequate variants revealed in the course of design. Thus, the two tendencies are to combine: generation of variety of modifications and truncation of the obtained variety [1]. A suggested design procedure is consistent with evolution optimization strategy and genetic algorithm (GA) in particular [3].

Construction design is presented in the form of some sequence of its development levels which are characterised by the degree of its element detail elaboration. Such design technique can be connected with some hierarchical model possessing peculiarity of another class of evolution model i.e. a sequential decision tree.

Genetic algorithms received a wide acceptance in the middle of the 1960's owing to J. Holland's works. They simulate evolutionary process with the stress on genetic mechanisms, i.e. gene inheritance and recombination. It is made by some number (population) of artificial chromosome (individuals). Each chromosome contains n genes that correspond to n desired variables of optimization problem.

Genetic algorithms like evolution algorithm in general are applied to search for the function global extremum of many variables. The principle of their operation is based on modelling some mechanisms of population genetics, manipulation of chromosome set at forming genotype of a new biological individual by means of inheritance of parents' chromosome parts, accidental variations of genotype known as mutation.

In fig. 1 genetic algorithm is shown. The main idea of evolution consists in improving the individual fitness of the first population generation until cease criteria are achieved.

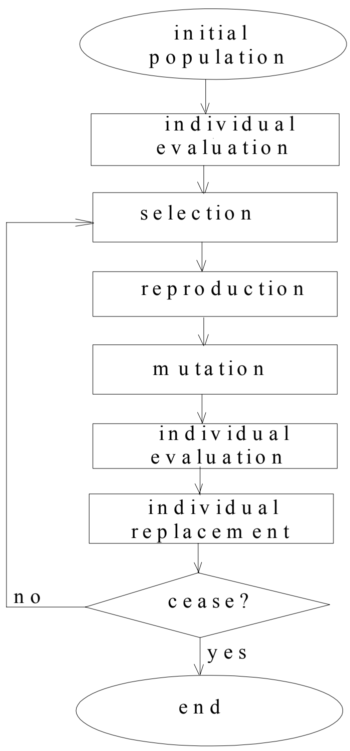

Fig. 1. *The genetic algorithm*

1. *Initial population.* At first it is necessary to create the initial population of individuals. As nothing is known about objective function, let us take the individual genes in the earlier stated area as accidental and uniformly distributed.
2. *Individual evaluation.* It is necessary to determine fitness for each of newborn individuals on the basis of objective function. Then one can start generation loop to improve individual fitness.
3. *Selection* is the first step to this improvement at which individuals are selected by chance or on the basis of their previous fitness according to the strategy. This selection serves as either genus prolongation or elite status transfer. Individual with an elite status can be neither excluded from real generation nor changed.
4. *Reproduction* means genus prolongation of individuals selected for this purpose. The simplest way of reproduction is coping individuals. Besides, GA strategy tries to generate the best individuals by gene recombination in chromosome. As a rule, in this case parent individuals form couples that exchange genes with each other by chance and form in this way two newborns.
5. *Mutation* changes separate genes of gene pool. Owing to it at GA gene pool should be renewed because at reproduction there would be loss gene pool variety usually after a few number of generations.
6. *Individual evaluation.* After changing individual chromosomes by recombination and mutation it is necessary for every newborn to determine the fitness.
7. *Individual replacement.* At the end of generation loop it is necessary to find out what individuals should be excluded from the population. Otherwise without replacement the population would grow longer. GA is usually replaced with the majority of parents by newborns.
8. *Cease criteria* define duration of optimization process and play a decisive role in evaluation of results. The two variants of forming cease criteria are used: 1) fitness control, as a result of which the process is ceased if the maximum fitness value in population is not fundamentally improved in the range of specified generation number; 2) determination of generation number.

Both variants have disadvantages. In the first variant it can happen that the maximum fitness value in the population does not change for a long time, but then, e.g. due to successful mutation there is an improvement. Therefore in the case of early cease only suboptimum is achieved.

In the second variant optimum criteria are not the main one at all. Often the solution maintaining enough the tolerance set up for varied parameters is chosen. In this case it is still necessary to carry out optimization processes with different numbers of generations to estimate the results.

By means of selection and exclusion of individuals with relatively poor fitness the population is also revalued. It is clear that in this case the gene pool can lose some good genes. GA tries to reduce these losses as much as possible [1, 2].

Let us consider the design of steel frame as an example. The volume is minimized along with weight and material consumption. The additional conditions connected with stress and stability conditions, general and local are specified. As a material steel S345 with the following characteristics is used: density ρ=78,5 kN/m^3; the module of longitudinal elasticity E=2,1·10^5 MPa, lateral deformation coefficient ν=0,3, yield stress $R_{уп}$=360 MPa, design resistance R_y=300 MPa.

The frame sizes are specified: l_c=4,8 m, l_p=4 m and load intensity on horizontal projection of the beam is 8 kH/m. 9 parameters of the system are optimized (fig. 2): b is a half of the width of the flange beam; $h_{рл}$ is the cross-sectional height of the beam from the left; $h_{рп}$ the cross-sectional height of the beam from the right; $h_{св}$ the cross-sectional height of the support upwardly; $h_{сн}$ – the cross-sectional height of the support below; $t_{рп}$ and $t_{рс}$, $t_{сп}$ and $t_{сс}$ – the thickness of flange and the beam wall and the support correspondingly.

From the conditions of observing the local stability of flange beam cross-section elements the admissible relations of their sizes are stated: for the flange it is 10, for the support it is 110. The upper and lower bound of the desired variables are stated in the following way (in sm): $5\le b\le 15$; $10\le h_{рл}\le 30$; $10\le h_{рп}\le 30$; $0,5\le t_{рп}\le 1,5$; $0,5\le t_{рс}\le 1,5$; $10\le h_{св}\le 30$; $10\le h_{сн}\le 30$; $0,5\le t_{сп}\le 1,5$; $0,5\le t_{сс}\le 1,5$.

Objective function, expressing the volume of the frame material has the following form:

$$V = 2,4\,t_{\text{сс}}(h_{\text{св}} + h_{\text{сн}} - 2\,t_{\text{сп}}) +$$
$$+2\,t_{\text{рс}}(h_{\text{рл}} + h_{\text{рп}} - 2\,t_{\text{рп}}) + b(19,2\,t_{\text{сп}} + 16\,t_{\text{рп}}).$$

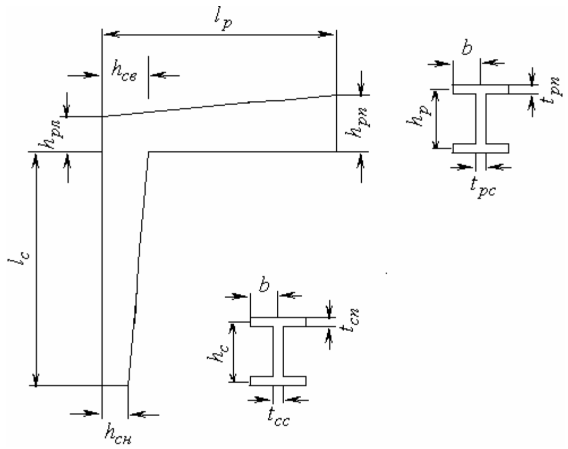

Fig. 2. *Frame profile and cross-sections of the beam and support*

The same expression with the opposite sign defines the fitness function.

Using the method of finite elements for calculation, let us break the half of the frame volume into 108 elements – 48 in the beam and 60 in the support, in this case in the cross-section there are 6 elements (2 per the flange and the wall).

According to the number of optimized parameters we introduce the chromosome model

b	$h_{\text{рп}}$	$h_{\text{рп}}$	$t_{\text{рп}}$	$t_{\text{рс}}$	$h_{\text{сн}}$	$h_{\text{св}}$	$t_{\text{сп}}$	$t_{\text{сс}}$

The elements are classified in 4 groups – flange and beam wall, flange and support wall. Junctions are classified into 26 groups, motion of which corresponds to chromosome genes.

Table 1. *Sizes of profile elements*

	b	$h_{\text{рп}}$	$h_{\text{рп}}$	$t_{\text{рп}}$	$t_{\text{рс}}$	$h_{\text{сн}}$	$h_{\text{св}}$	$t_{\text{сп}}$	$t_{\text{сс}}$
1	55	138	143	6,4	5,0	100	105	5,0	5,0
2	69	209	231	5,7	5,1	298	281	6,6	5,0
3	50	120	157	5,6	5,0	102	158	5,0	5,0
4	50	120	194	5,6	5,0	101	108	5,0	5,0
5	63	191	252	5,2	5,0	191	300	5,8	5,0
6	50	115	123	7,0	5,0	102	119	5,0	5,0
7	50	161	162	5,5	5,0	101	121	5,0	5,0
8	51	128	169	5,6	5,0	103	116	5,0	5,1
9	51	131	154	6,1	5,1	102	120	5,0	5,0
10	50	126	161	5,8	5,0	110	117	5,1	5,1

To calculate the frame the following parameters are used: 20 individuals; 300 generations; 0,1 selection pressure; 0,05 mutation standard; 15 replacement number.

Mutation deviations have linear character and amount 0,001...0, 0001 for flange and wall thickness, but for the other elements 0,01...0,001.

The obtained results (sizes are in mm) are presented in the table 1. In the table 2 the frame volume V, m^3, the largest normal stresss σ, MPa, and the relation $b/t_{\text{рп}}$ and $b/t_{\text{сп}}$ are presented.

From the Table 2 it is evident that the relations of $b/t_{\text{рп}}$ and $b/t_{\text{сп}}$ are exceeded in the second and fifth lines. In the fifth and sixth lines the calculated stress is exceeded. Thus, the three variants of solution should be ignored.

Table 2. *Geometric characteristics of frame and stress*

	V	σ	$b/t_{\text{рп}}$	$b/t_{\text{сп}}$
1	0,0150	161	7,4	9,4
2	0,0265	160	11,7	10,1
3	0,0150	161	8,5	9,5
4	0,0147	160	8,4	9,5
5	0,0224	388	11,5	10,4
6	0,0153	338	6,8	9,5
7	0,0149	162	8,6	9,5
8	0,0149	162	8,7	9,7
9	0,0152	162	7,9	9,7
10	0,0149	161	8,2	9,3

The wall thicknesses correspond to specified lower bound. The other parameters are in the range of specified bounds. In the rest seven variants of solution the volume is not sufficiently different (in the range of 3,4 %). The minimal volume corresponds to the fourth variant of solution.

Conclusion

1. Genetic algorithms are powerful finding means. The solution obtained on their basis is suboptimal, but it does not prevent from application of algorithms to search for global extremums at building construction optimization.
2. Genetic algorithms are acceptable for solution of multiparametric nonconvex problems in comparison with the known analytical methods of optimization.
3. The solution can be made more accurate having increased the grid density of the finite elements. Increasing the number of optimized parameters results in increase of the number of individuals and generations. Besides, machine time consumption increases, that sometimes may serve as an evaluation parameter of using genetic algorithms.

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