DOM TECHNIKY ČSVTS

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XIII. OCELIARSKA KONFERENCIA

OCEĽOVÉ KONŠTRUKCIE SÚČASNOSTI

BRATISLAVA 1982

Литература

[1] В е л е н я , Е.И. - Н е ж д а н о в , К.К.: "Экспериментальное изучение выносливости сжатой зоны стенки стальных подкрановых балок" Издательство словацкой академии наук, Братислава,"Stavebnícky časopis", 1979, № 7

[2] Н е ж д а н о в , К.К.: "Стенд для испытания балок на выносливость" Авторское свидетельство № 840679, 1981

[3] Ш к о л ь н и к , Л.М.: "Методика усталостных испытаний", Справочник, Металлургия, М. 1978

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COMPUTERIZED OPTIMAL DESIGN OF METAL STRUCTURES

The goal of optimal design is the determination of those values of design variables, subject to relevant constraints, that minimize the cost or weight function. The main research theme of the group "Metal structures" in our department is the optimal design of metal structures. In our research work several mathematical programming methods were adopted and applied to various optimal design problems (see. e.g. [1,2] . The aim of the present contribution is to give a short description of the complex method of Box [3] and its application to the optimal design of a welded portal frame.

1. The Complex Algorithm

The algorithm minimizes the nonlinear objective function

$$y = f\,(x_1, x_2, \ldots, x_n)$$

subjected to inequality explicit constraints and nonlinear inequality implicit constraints of the n independent and $m-n$ dependent variables

$$x_i^U \leqq x_i \leqq x_i^L\ ; \quad i=1,\ldots,n; \quad i=n+1,\ldots,m$$

In the first iteration cycle an original "complex" is generated. The complex contains $k \geqq n+1$ feasible points or vertices in an n - dimensional design space. It is assumed that an initial feasible point exists.

$$x_{ij} = x_i^L + r_{ij}\left(x_i^U - x_i^L\right)\ ;\ i=1,\dots,n\ ;\quad j=2,\dots,k$$

where x_{ij} the ith coordinate of the jth point, r_{ij} random numbers between $0 \div 1$.

Each point is examined to see whether it satisfies the explicit and the implicit constraints. If not the trial point is moved halfway towards the centroid of the remaining points as follows:

$$x_{ij}^{New} = \frac{x_{ic} + x_{ij}^{Old}}{2}$$

$$x_{ic} = \frac{1}{k-1}\sum_{j=1}^{k}\left(x_{ij} - x_{ij}^{W}\right) \qquad i=1,\dots,n$$

Once x_{ij}^{New} is obtained it must then be examined for feasibility. The function values are evaluated at each of points. The points with the worst and the best function values are determined. The convergence criterion is checked:

$$\left|f_{max} - f_{min}\right| < \beta$$

If it is not fulfilled the worst point x_{ij}^{W} for which $f\left(x_{ij}^{W}\right) = f_{max}$, is rejected and replaced with a new one

$$x_{ij}^{New} = \alpha\left(x_{ic} - x_{ij}^{W}\right) + x_{ic} \qquad i=1,\dots,n$$

where α is the reflexion coefficient.

This procedure - reflexion and contraction - is repeated, until the convergence criterion is fulfilled or the iteration number reaches its ultimate value.
Some modifications were implemented at the complex algo-

rithm [4] related to the expansion and halving steps, to the variability of complex 's size (k), convergence and reflexion coefficients (β, α). The main modification was the adoption of discrete member sizes, which made the search more practicable.

2. Minimum Weight Design of Welded Plane Frames

We illustrate the application of the above described method by the numerical example of a plane frame, made of welded I-section bars as shown in Fig. 1. We consider the dimension of columns and rafters to be different. So the number of variables is eight.

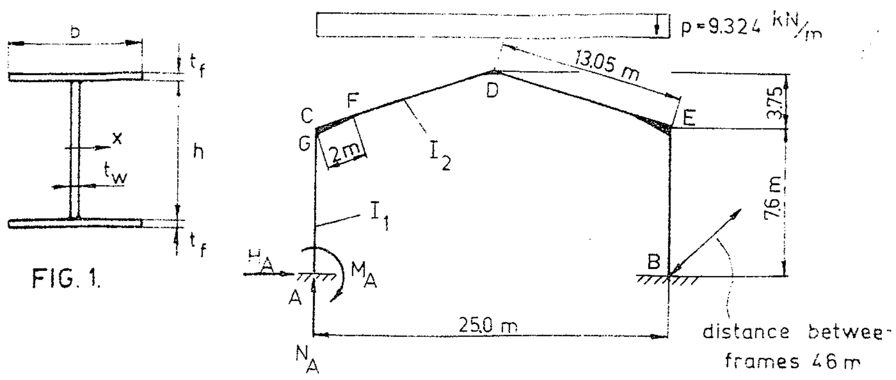

Fig. 1

The volume of the frame made of welded I-sections subjected to bending and compression should be minimized. The objective function is

$$V = 2\sum_i A_i\ \ell_i\ ; \qquad i=1,2$$

where $A_i = h_i t_{wi} + 2\, b_i t_{fi}$, and ℓ_i are the area and of the ith member, respectively. The <u>constraints of maximum stresses</u> in the columns and rafters are

$$\sigma_{Mi} + \sigma_{Ni} \leqq R_u$$

where $\sigma_{Mi} = {}^{Mi}/{}_{W_{xi}}$; the section modulus $W_{xi} \cong h_i \, (b_i t_{fi} + h_i t_{wi}/6$

and

$$\sigma_{Ni} = N_i/A_i \qquad i=1,2$$

Mi and N_i the bending moment and compressive force, respectively, R_u the limit stress.

The <u>constraints of web and flange buckling</u> for steels of tensile strength 370 MPa may be expressed as [3]

$$\frac{h_i}{t_{wi}} = 145 \sqrt[4]{\frac{\left(1 + \frac{\sigma_{N_i}}{\sigma_{M_i}}\right)^2}{1+173\left(\sigma_{N_i}/\sigma_{M_i}\right)^2}} \; ; \; \frac{b_i}{t_{fi}} = 30; \quad i=1,2$$

The computer program was written in Fortran IV and run on computer CDC 3300 and ODRA 1304, respectively. Concerning the effectiveness of the computation it was found, that the best values of k are around 2.n [16], the best values of α are from 1,3 to 1,7 and the best values of β are around 600 (0,5 %). Parameters and final values are shown in Table 1 for three runs.

Table 1. Dimensions in mm and sec

k	α β	k_1	t_{w1}	b_1	t_{f1}	h_2	t_{w2}	b_2	t_{f2}	$V.10^{-8}$ mm^3	CPU time
14	1,3 600	540	4,5	280	10	620	6	110	9	2,7082	111,6
16	1,3 1200	600	5	200	13	560	5,5	170	8	2,7602	106,8
18	1,3 600	620	5,5	200	13	580	5,5	170	7	2,7625	114,6

<u>References</u>

[1] F a r k a s , J.: 11th Congress of IABSE, Vienna 1980, Final Report, 597-602

[2] F a r k a s , J.: Acta Techn. Acad. Sci. Hung. 87, 1978, 295-306

[3] B o x , M.J.: Computer Journal, 8, 1965, 42-52

[4] J á r m a i , K.: Publ. Techn. Univ. Heavy Industry, Miskolc Ser. C. Machinery, Vol. 37, 1982