STIFFNESS ESTIMATION METHOD FOR THE DISCRETIZED DYNAMIC MODEL OF RAILWAY CAR BODIES

TRAN QUOC KHANH and P. MICHELBERGER

Department of Transport Engineering Mechanics,
Technical University of Budapest, H-1521

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Abstract

A method has been presented for the algorithmized estimation of equivalent second-order moments involved in the discretized model of railway car bodies. Assuming the deflection function of the continuum model to be known, the objective function to be minimized as well as the method of numerical solution are described. Application of the method is illustrated on hand of a test problem.

Introduction

This scope is strictly related to the algorithmic, rather than a heuristic modelling for the strength analysis of railway car bodies exposed to vertical, symmetric, dynamic loads [2, 3]. The continuum model will be substituted by a discretized model relying on continuous model data, and the algorithm is expected to suit; computation of mass and stiffness matrices. A method suitable to estimate equivalent stiffnesses for the discretized dynamic model of railway-car bodies will be presented.

Stating the conditional extremum problem, and theoretical solution

Assumptions made in estimating the equivalent stiffness are:

a) The car body is beam hinged both ends, with N bar sections of constant cross section and specific weight, with a permanent elasticity constant and second-order inertia moment.

b) Real beam deflection f_i at x_i ($i = 1, 2, \ldots, p$) and characteristic A_i, ϱ_i, E_i, H_i ($i = 1, 2, \ldots, N$) are known, where:
   - A_i — cross-sectional area of bar section i;
   - ϱ_i — specific density of bar section i;
   - E_i — elasticity constant of bar section i;
   - H_i — length of bar section i.

Applying these conditions and symbols, the problem of estimating second-order moments of inertia becomes:

Let us find $I_1, I_2, \ldots, I_N$ so that function

$$H(I_1, I_2, \ldots, I_N) = \sum_{i=1}^{P} \chi_i \left| f(x, I_1, I_2, \ldots, I_N) - f_i \right| \tag{1}$$

is minimized under conditions

$$I_i < 0 \qquad (i = 1, 2, \ldots, N) \tag{2}$$

$$|f(x_i, I_1, I_2, \ldots, I_N) - f_i| \leq \varepsilon(\forall i \in I^*) \tag{3}$$

where ε and χ_i $(i = 1, 2, \ldots, p)$ are given positive constants;
$I^* = \{ i \in \{1, 2, \ldots, p\} \mid f_i$ is sufficiently high; $\}$
$f(x_i, I_1, I_2, \ldots, I_N)$ — static deflection of the cross-sectional centroid at x_i of the continuum model beam, if I_i is a second-order inertia moment of the cross section of bar section i $(i = 1, 2, \ldots, N)$.

This static deflection is expressed by:

$$f(x_i, I_1, I_2, \ldots, I_N) = \sum_{1=1}^{N} \gamma_{il} \frac{1}{I_1} (i = 1, 2, \ldots, p) \tag{4}$$

where γ_{il} $(i = 1, 2, \ldots, p; l = 1, 2, \ldots, N)$ are constant, to be calculated if characteristics A_i, ϱ_i, E_i and H_i $(i = 1, 2, \ldots, N)$ are known.

Problem (1) to (3) may be reduced to problem (5) to (7) below:

Let us find $\tilde{I}_1, \tilde{I}_2, \ldots, \tilde{I}_N$ so as to minimize function

$$\mathbf{K}(\tilde{I}_1, \tilde{I}_2, \ldots, \tilde{I}_N) = \sum_{i=1}^{P} \chi_i \mid \Sigma \gamma_{ie} \tilde{I} - f_i \mid \tag{5}$$

under conditions:

$$\tilde{I}_i > 0 \qquad (i = 1, 2, \ldots, N) \tag{6}$$

$$\left| \sum_{e=1}^{N} \gamma_{ie} \tilde{I}_e - f_i \right| \leq \varepsilon \qquad (i \in I^*) \tag{7}$$

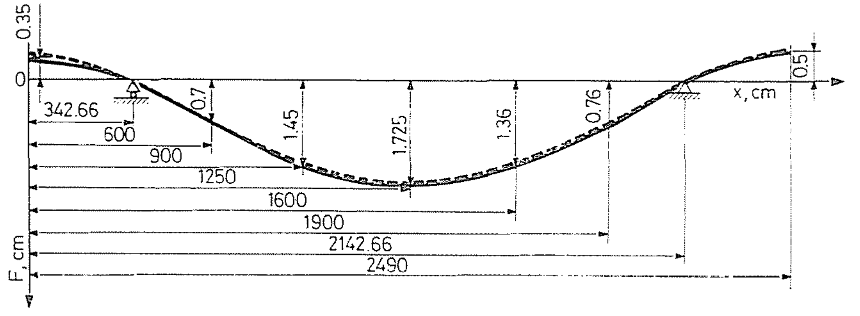
In fact, problems (5) to (7) are convex programming problems to be solved by the SUMT method [1]. Since the local optimum point of the problem is at the same time the global optimum point, the solution accuracy may be increased at will.

Practical computation results

Practical computations concerned a railway luggage truck body that has been divided to seven bar sections, with geometrical and physical characteristics according to Table 1:

Table 1

Bar section No.	Ai (cm²)	Hi (cm)	ϱi (dN/cm³)	Ei (dN/cm²)
1	229.43	150.33	1.19483×10^{-2}	2.1×10^6
2	331	192.33	3.4151×10^{-2}	2.1×10^6
3	219.22	163.54	7.85044×10^{-2}	2.1×10^6
4	176.28	1533.5	12.10546×10^{-2}	2.1×10^6
5	118.03	102.96	1.4536×10^{-2}	2.1×10^6
6	145.83	99.34	3.6163×10^{-2}	2.1×10^6
7	258.11	252.4	1.19483×10^{-2}	2.1×10^6



The real static deflection diagram of the beam is seen in Fig. 1. The calculated optimum vector of the second-order inertia moment is:

$$I_{opt} = \begin{bmatrix} 0.6845\times10^6 \\ 0.7465\times10^6 \\ 0.1920\times10^6 \\ 0.8247\times10^6 \\ 0.8247\times10^6 \\ 0.1907\times10^6 \\ 0.7477\times10^6 \\ 0.6714\times10^6 \end{bmatrix} (\mathrm{cm}^4)$$

To check the result, obtained let us compare the deviations between real and computed static deflections of the beam, as plotted in Fig. 1.

References

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Tran Quoc Khanh
Prof. Dr. Pál Michelberger } H-1521 Budapest