ANALYSIS OF TWO CONTACT SHAPE OPTIMIZATION PROBLEMS

I. Páczelt[1], Z. Mróz[2] and A. Baksa[1]

[1]*Institute of Applied Mechanics, University of Miskolc, Miskolc, Hungary*
[2]*Institute of Fundamental Technological Research, Warsaw, Poland*

e-mail: paczelt@freemail.hu

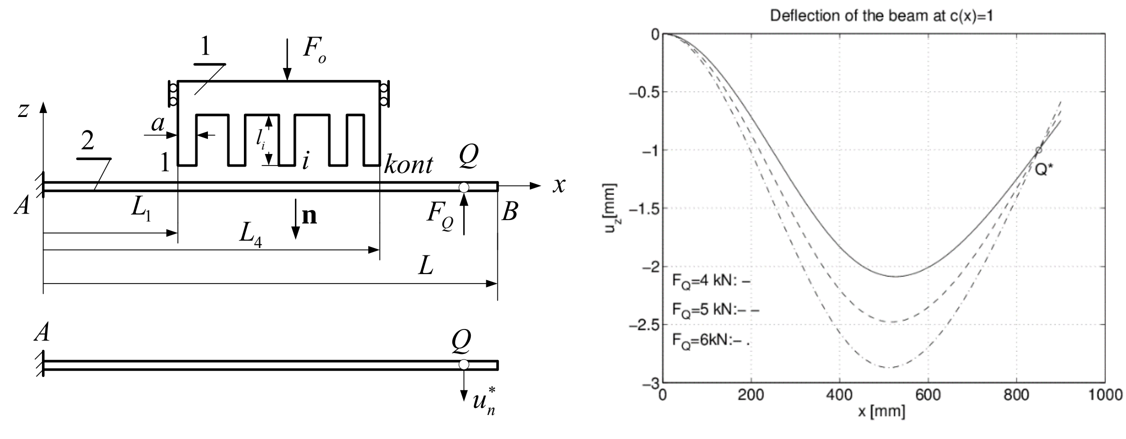
1. Introduction

The first problem relates to control of a point displacement of a loaded structure by applying the interacting punch loading. As at the same point both the displacement and the force are prescribed, a new type of optimization problem is formulated. The solution method of this problem can be used for design of robot clippers and gardening or plantation tools for mechanical processing.

In the second problem the steady wear state of the drum brake is analysed. Minimizing the wear dissipation power, the contact pressure distributions of the leading and trailing shoes are determined. The maximal pressure value is usually higher on the leading shoe. Next, the optimization problem is considered by maximizing the braking torque in the steady wear state and determining the optimal pin position.

2. First problem: displacement control of a loaded structure

2.1 Consider a cantilever beam clamped at its end *A* and loaded at point *Q* by the force F_Q, Fig.1. To control the deflection at *Q*, the lateral stamp action is applied by inducing the resultant load F_0 by a set of grippers or by a continuous contact interaction. The stamp form is defined by a given distribution of contact stresses between the stamp and beam with constraints that the displacement u_n^* and force F_Q at the point *Q* of the beam are prescribed.



a) b)

Fig. 1a. Beam system for transmission of the stamp load F_0 the vertical displacement u_n^*.
1b) numerical results for different values of F_Q.

Assume first that the stamp action is executed by a set of grippers of the cross section area $A = ab$ and varying length l_i, cf. Fig. 1a. The forces between the stamp and beam are prescribed by the control function $c(\mathbf{x})$

(1) $$P_j = Ac(x_j)p_{\max} \quad ,j=1,...,kont$$

where $p_{\max}$ is the maximum of the contact pressure.

Using the Green function for the beam $H^{(2)}(x,s)$, the vertical displacement (in the direction *–z, in the* direction ***n***) at the point Q is expressed as follows

(2) $$u_n^* = \sum_{j=1}^{kont} H^{(2)}(x_Q, x_j)P_J + u_{n,load}^{(2)}$$

where $u_{n,load}^{(2)} < 0$ is the vertical displacement at point Q resulting from the specified force F_Q.
Using (1) and (2) we have

(3) $$p_{\max} = \frac{u_n^* - u_{n,load}^{(2)}}{\sum_{j=1}^{kont} H^{(2)}(x_Q, x_j)c(x_j)\,A}$$

After calculation of $p_{\max}$, from geometrical contact conditions we can determinate the shape of the stamp [1,2] The results in Fig.1b correspond to the beam cross section area $A_b = bh = 20 \cdot 50\,mm^2$, Young modulus $E = 2 \cdot 10^5\ MPa$, and other geometrical parameters $L_1 = 350, L_4 = 550, x_Q = 850, L = 900\,mm$, $kont = 5$.

2.2 A mechanical system has also been analysed when the beam is allowed to execute the rigid body vertical displacement $\lambda_F^{(2)}$. In this case, the large displacement u_n^* at Q can be assumed. In the solution of the optimization problem, first the value of $\lambda_F^{(2)}$ is calculated and from contact conditions between the punch and beam the rigid body displacement $\lambda_F^{(1)}$ is specified for punch, which may used in the mechanical technological process. The prescribed displacement u_n^* can be reached only by the vertical motion of the punch at the calculated rigid body displacement $\lambda_F^{(1)}$.
In the example of variant 2.2 the beam cross section area was different: $A_b = bh = 20 \cdot 75\,mm^2$, because the original area corresponds to a flexible beam with too large displacement.

3. Second problem: maximizing the torque of drum brake

In the previous paper [3] the formulae of the contact pressure distribution in the steady wear state for drum brake system were derived. The contact pressure distributions on the leading and trailing shoes were found to be different and larger on the leading shoe. Using these contact pressure distributions, it is easy way to calculate the braking torque. Assuming the varying position of the shoe pin, the optimization problem can be formulated by requiring the optimal pin position corresponding to maximal braking torque. The steady wear states and optimal designs were specified for both shoes. The elastic displacements of the drum brake at the optimal contact pressure distribution is calculated by the finite element system ABAQUS.

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