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PHOTOELASTIC INVESTIGATIONS OF THIN-WALLED STRUCTURE MODELS

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In the paper applications of the photoelastic reflected light technique for thin-walled structure models investigations are presented. Casting of the epoxy resin models and procedure of the stress concentration testing, for example in the coachwork truss joint, are described. Experimental design method for models of the stress concentration factor determining were applied.

Keywords: thin-walled structures, photoelasticity, experiment design.

The modern designing of the supporting machine structures is aimed at making maximal use of the load-carrying capacity of materials and at minimizing their weight with limitations to constructional, technological and functional nature being retained. This can be achieved by applying thin-walled structures.

One of the basic problems connected with the use of photoelastic measuring techniques for thin-walled structure investigations is making a model of the construction being tested. The use of the simple similarity criteria makes it necessary to perform models with very thin walls. In this connection it is common practice to use the so-called affine modelling (e.g. [1]) for which the scale of the thickness of walls is different from that of other linear dimensions ($k_t = k_d$). This combined with the recording of photoelastic images by means of the reflected light technique makes it possible to test models of thin-walled constructions.

The technology of making the above models depends, first and foremost, on their configuration. The relatively simplest technology is constructing a model consist of elements cut out of thin cast plates joint by means of gluing. In the case of constructions made of profiles with non-flat surfaces, the following techniques are used: gravitational casting, pressure casting, or forming a thin plate before polimerization of the composition used is completed. In the first case, however, the occurrence of a substantial limitation to the thickness of the walls of the element being cast (t > 2 - 2.5 mm) can be observed. The use of pressure casting technology offers far greather possibilities. By way of example, a schematic diagram of the system for pressure casting of pipes with a square cross-section (40 x 40 x 1.0 (1.5)) and being about 500 mm long is given in Fig. 1.

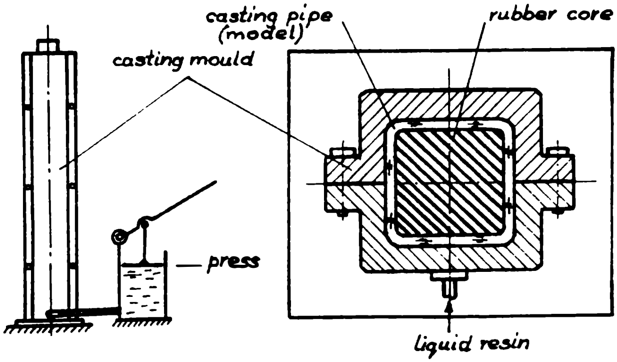

Fig. 1.

In order to carry out an experimental analysis of the phenomena of stress concentration in the coachwork truss joint, their models have been made. The pipes cast with the use of the pressure technique were connected by means of gluing. In the experiment, an analysis was being made of stress concentration in the joint presented in Fig. 2, while the stress concentration coefficient was defined as the relation of maximum stresses in the given joint with reference to the "basic" joint (T type, i.e. $\gamma = 0^o$). Tested joints were loaded by the torque moment applied to the cross-bars where as the two cases of conditions for fixing the longitudinal member of framework, i.e. $\beta = 0^o$ and $\beta \neq 0^o$ (free turn) were being considered. As the criterion of the optimization of the experiment the minimization was accepted of the number of experiments being indispensable for determining the mathematical model of the stress concentration coefficient. It has been assumed that the model is approximated by the non-linear function whose general form is as follows:

$$\alpha_k = b_o + \sum_{S=1}^{S} b_S x_S + \sum_{S=1}^{S} b_{SS} x_S^2 + \sum_{S \neq R}^{S} b_{SR} x_S x_R \qquad (1)$$

where: $x_S = x_S/x_0$ - dimensionless relation of physical variables (in this case - geometrical parameters),

S - number of variables x_S.

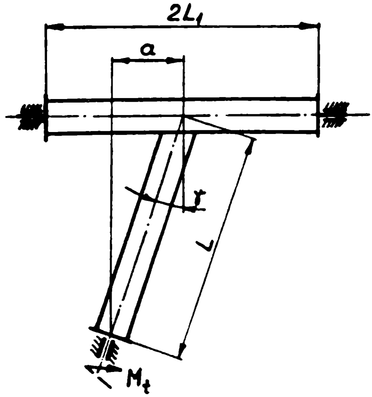

Fig. 2.

As parameters affecting the value α_k the angle γ was assumed as well as the dimensions L_1 and L:

$$\alpha_k = f\ (\gamma,\ L_1,\ L) = f_1\ (a,\ L_1,\ L) \tag{2}$$

By using the orthogonal experiment design N = 9 experiments (for S = 2) were obtained. In order to carry them out it was enough to make 5 physical models of the joint being tested. Based on the analysis of photoelastic images recorded with the use of the reflected-light technique the values α_k were calculated in the particular experiments and next, the values of the model coefficients (1) were determined. The following forms of the functions approximating the values α_k were obtained:

- for $\beta = 0$

$$\alpha_k^f = 3.46 + 1.02 \frac{a}{L} - 9.34 \frac{L_1}{L} - 2.46 \left(\frac{a^2}{L^2}\right) + 8.0 \left(\frac{L_1^2}{L^2}\right) + 5.4 \frac{aL_1}{L^2} \tag{3}$$

- for $\beta = 0$

$$\alpha_k^n = 2.46 + 1.41\,\frac{a}{L} - 4.85\,\frac{L_1}{L} - 1.86\,\left(\frac{a^2}{L^2}\right) + 3.18\,\left(\frac{L_1^2}{L^2}\right) + 2.62\,\frac{aL_1}{L^2} \qquad (3)$$

The distributions of α_k^f (L_1/L) given as examples are shown in Fig. 3. The analysis of the experimental results indicates a more significant effect of the parameter L_1/L than a/L as well as the occurrence of the essential interaction between L_1/L and a/L parameters.

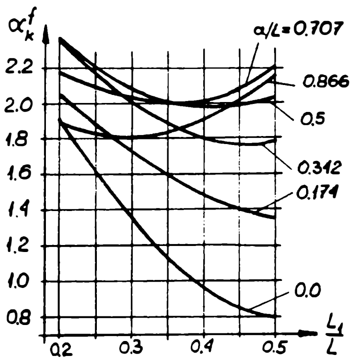

Fig. 3.

The example of the experiment presented above has shown the suitability of the research methodology accepted. This has also been confirmed by other research studies carried out by the author (e.g. [2]).

References

[1] Method fotouprugosti, ed. by G.L.Chesin, Strojizdat, Moskva, 1975.
[2] Jankowski L.J., Romanów F., Investigations of stress concentration in thin-walled elements of chassis frames, Proc. of the International Conference on Vehicle Structures, I.Mech. E.Conference Publications, London, 1984.

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