EXPERIMENTAL METHOD FOR DETERMINING FORCES AT BENDING OF PERFORATED PLATES

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Abstract: This paper describes the method of calculating the forces which appear at the bending of perforated plates with holes of different shapes and placed in different patterns, by means of a dynamometric table which uses resistive tensometric transducers (strain gauges). It also describes an instrument for the recording of data from the dynamometric table, a tool created with the aid of the “TestPoint” software which, beneath the data recording, ensures the filtering and statistic processing of data. The obtained results are displayed in comparative graphs for six types of perforated plates, as well as for an unperforated plate.

Keywords: perforated plate, V-bending, transducer, strain gauges

1. Introduction

The resistive tensometric transducer (Figure 1) consists of base plate 1 and upper plate 2, between which two elastic members 3 are fitted. The base plate has wedges designed for alignment on the compound table, and the upper plate has T-shaped keyways devised for the alignment and fixation of the experimental mold.

The elastic member has been configured so as to allow:

- highlighting the forces studied, with good reproducibility;
- fitting the number of transducers required to build a complete bridge in order to achieve maximum sensitivity, temperature compensation, as well as nonlinearity and hysteresis errors;
- the maximum reduction of the area where voltage distribution is uneven

Figure 1 Resistive tensometric transducer

Figure 2 Tensometric transducer layouts

The tensometric transducers have been bonded at the points where the flexural torques created by the vertical and horizontal forces are cancelled, thus avoiding the mutual influences of the measuring bridges.

For data analysis, we have used an assembly consisting of three sub-modules (Figure 3):

- the experimental facility, which in fact directly processes the parts and converts certain mechanical magnitudes into electrical signal via the dynamometric table;
- the data acquisition system;
- the software package that controls the data acquisition and processing system.

The resistive tensometric transducers, which are part of the experimental facility, are connected via the patch panel to the ACjr-12 analogue-to-digital conversion board. They are powered by stabilized electric current. The panel has an eight-channel acquisition capability with a cumulative sampling frequency of up to 10 kHz. In low-noise mode, the panel is used with an 18-bit resolution, which means 0.024% at a sampling frequency of 12 Hz and a signal level of 50 mV. The measurement accuracy ensured in this way is of 0.08%. Data is retrieved via the Signalys 3.01 software package.

In addition to archiving and storing the data collected on magnetic storage media, this software allows signal conditioning (filtering, scaling), data analysis (statistical processing, highlighting of minimum and maximum values, elimination of the time variable) and data preparation for the graphical presentation on the monitor, graphics printer or plotter. This data acquisition system has also been used to calibrate the dynamometric table.

The signal acquired from the KPCI 3108 analogue-to-digital board is processed, filtered and saved via a virtual tool created by the author in the TestPoint program, a software package that accompanies the acquisition card and that is dedicated to data acquisition (Figure 4). The tool contains blocks made available to the user by the program, which allow changing the number of channels along which the acquisition is made, the acquisition rate, the total acquisition time, as well as filtering data to eliminate the “noise” inherent to any acquisition and saving data as text files.

The tool is designed to have four distinct modules: a data acquisition and viewing module, a filtering module, a module for converting electrical magnitudes into mechanical ones, and a module for saving data as text files (ASCII).

3. Determining the Forces Occurring at the Bending of the Perforated Plates

After the calibration of the dynamometric table, a V-bending mold has been mounted on it (Figure 5), and the assembly thus obtained has in turn been mounted on the 450 [N] hydraulic press located at the Faculty of Engineering in Sibiu.

Figure 5 V-bending mould used at the bending of the perforated plates

Figure 6 Perforated plate specimens required at bending points

The specimens used for these tests have been made from plate of 1.2 mm thickness and perforated in various shapes (Figure 6), in order to determine the forces occurring therein depending on the type of perforation. Moreover, the forces have been determined on a direction perpendicular to the plane of the dynamometric table (hereinafter referred to as vertical direction) and on a direction parallel to the long side of the specimens (hereinafter referred to as the horizontal direction) as well as for a plate of the same thickness, but not perforated.

Figures 7 to 20 show the variation graphs of forces on the horizontal and vertical directions that occur during the bending process for each type of perforated plate studied. Table 1 also shows the maximum values in the two-force mode.

Figure 7 Variation of horizontal force for three specimens with circular holes of diameter $d = 1$ mm

Figure 8 Variation of vertical force for three specimens with circular holes of diameter $d = 1$ mm

Figure 9 Variation of horizontal force for three specimens with circular holes of diameter $d = 3.5\text{mm}$

Figure 10 Variation of vertical force for three specimens with circular holes of diameter $d = 3.5\text{mm}$

Figure 11 Variation of horizontal force for three specimens with square holes of side $\ell = 10\text{ mm}$

Figure 12 Variation of vertical force for three specimens with square holes of side $\ell = 10\text{ mm}$

Figure 13 Variation of horizontal force for three specimens with 24.2×2 wedge keyway holes (Z-shaped perforation) arranged longitudinally

Figure 14 Variation of vertical force for three specimens with 24.2×2 wedge keyway holes (Z-shaped perforation) arranged longitudinally

Figure 15 Variation of horizontal force for three specimens with 24.2 x 2 wedge keyway holes (Ap-shaped perforation) arranged longitudinally

Figure 16 Variation of vertical force for three specimens with 24.2 x 2 wedge keyway holes (Ap-shaped perforation) arranged longitudinally

Figure 17 Variation of horizontal force for three specimens with 24.2 x 2 wedge keyway holes (Ap-shaped perforation) arranged transversely

Figure 18 Variation of vertical force for three specimens with 24.2 x 2 wedge keyway holes (Ap-shaped perforation) arranged transversely

Figure 19 Variation of horizontal force for three plate specimens of thickness $g = 1.2$ with no perforations

Figure 20 Variation of vertical force for three plate specimens of thickness $g = 1.2$ with no perforations

4. Conclusions

After analyzing the graphs above, we have noticed the following:

Along the horizontal direction, the force is approximately 10% of the force along the vertical direction, in all 7 cases studied;

The force along the horizontal direction slightly decreases at first, then increases quite rapidly during the stroke of the punch, following which, at the time of the withdrawal of the punch, it again has a slight tendency to decrease; at the same time, we have noticed that the horizontal force has values that are very close for all the specimens, which is why we can state that it is influenced neither by the perforation type nor by the hole size, and what is more, it is sensitively equal to the horizontal force of the non-perforated plate; The vertical force also has a slight tendency to decrease at the beginning of the bending process, following which its value increases much faster and to a higher value than the horizontal force, then decreases just as fast, and, towards the end of the bending process, it again has a very slight upward trend. As regards a comparison between the value of this force on perforated plates and the value of the same force on a non-perforated plate, we have noticed an increase of about 50% in this force in the latter case provided that the perforated surface is of 25%.

Table 1 Results of experimental tests

Current no.	Perforation type	Plate thickness g [mm]	Hole diameter d [mm]	Maximum force along horizontal direction F _{Hmax} [kN]	Maximum force along vertical direction F _{Vmax} [kN]
1.	circular “Z”	1.2	1	0.34363	3.48938
2.				0.33203	4.05243
3.				0.31586	3.15796
Arithmetic mean				0.33051	3.56659
4.	circular “Z”	1.2	3.5	0.33997	3.84460
5.				0.34424	3.17841
6.				0.31403	3.16650
Arithmetic mean				0.33275	3.39650
7.	square “Ap”	1.2	10	0.33722	7.82776
8.				0.31433	3.28552
9.				0.31616	3.26691
Arithmetic mean				0.32257	4.79339
10.	longitudinal Z-shaped keyway	1.2	24.2 x 2	0.31586	7.46765
11.				0.32227	4.45770
12.				0.34302	7.85522
Arithmetic mean				0.32705	6.59352
13.	transversal Ap-shaped keyway	1.2	24.2 x 2	0.35248	3.33832
14.				0.33295	7.79694
15.				0.32745	3.87573
Arithmetic mean				0.33946	4.93581
16.	longitudinal Ap-shaped keyway	1.2	24.2 x 2	0.35797	3.13477
17.				0.33295	7.79694
18.				0.32745	3.87573
Arithmetic mean				0.33945	4.93581
19.	Non-perforated plate	1.2	---	0.34088	4.30328
20.				0.29388	3.26324
21.				0.33813	7.66724
Arithmetic mean				0.32429	5.07792

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