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The use of an optical system for bending and torsional analyses of open cold-formed profiles

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ABSTRACT:
The paper presents the application of the Aramis optical system for determining the bending and torsional rigidity of cold-formed C profiles. Cold-formed thin-walled beams have many advantages that are technically important. The subject of the experimental research were thin-walled cold-formed beams loaded with a concentrated force in 1/3 of the beam span. The paper presents an example of using this system as an auxiliary tool for testing the free torsion of unstiffened and stiffened C-elements. The presented results are part of the research on the impact and effectiveness of the use of longitudinal bracing made in 3D printing technology.

KEYWORDS:
Aramis; light steel skeleton; thin-walled elements

1. Introduction

In experimental design studies, optical measuring systems DIC - Digital Image Correlation are being increasingly used. Digital image correlation is intended for contact-free measurements of the state of displacement in both two and three-dimensional coordinate systems [1]. Conducting this type of research involves taking a series of photos of the analysed structure at various loads. Then, the photos taken at individual stages are subjected to analysis aimed at calculating the displacements of the tested element. An example of an optical image correlation system is the Aramis system developed by the German company GOM. The article presents an example of the use of this system as a tool supporting the research of free twisting of cold-formed elements.

2. Description of the tested object

The subject of the study was a thin-walled C-beam, made cold using Am-Tech (Fig. 1). The material from which the profile is made is a galvanized steel sheet with a yield strength of fyb = 235 MPa, tensile strength fu = 360 MPa, Young's modulus E = 2.05 · 105 MPa, Poisson's number ν = 0.3 [2].

The proposed method of stiffening to increase the flexural and torsional rigidity of the profile was made using 3D printing technology (Fig. 2). Technical parameters of the stiffener: density 1050 kg / m3, tensile strength 44 MPa, Young's modulus 2000 MPa and Poisson's ratio 0.3. The length of the stiffening insert is 140 mm, the height and width are adapted to the cross-section of the cold-formed profile.

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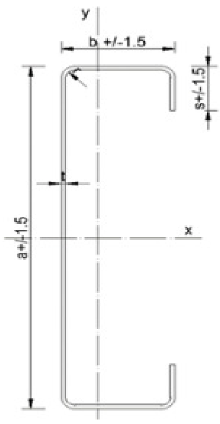


Fig. 1. Cross-section of a C-profile C140: a = 140 mm, b = 38 mm, s = 18 mm, t = 1,5 mm, r = 3 mm

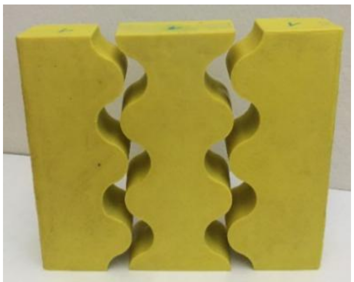


Fig. 2. Proprietary solution for thin-walled profiles

The beam loading diagrams are illustrated in Figure 3. The total length of tested profiles was 2500 mm, and the distance between supports 2350 mm. The load Q = 54.94 N was applied diagonally on the opposite shelves in 1/3 of the beam length between the supports (Fig. 3). First, the P1 shelf was loaded, followed by the P2 shelf. The next stage was loading the profile in reverse order to the load.

a) b)

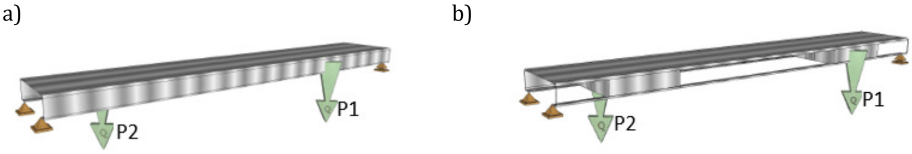


Fig. 3. Load diagrams of tested profiles: a) model without stiffener, b) model with stiffener**.**

Stiffening ribs were placed in the cross-sections of application of concentrated forces. Each stiffener was connected to the profile using a M8 threaded rod.

3. Description of the research

The presented experimental studies were research studies that allowed the assessment of the application of the Aramis optical system for profiles subjected to free twisting. The Aramis optical-measuring system is intended for contact-free measurements of displacements in elements subjected to load. It consists of a set of cameras recording changes in the shape of the tested object and software.

To perform the experiment, the Aramis system was used, equipped with a system of two 12 MPx digital cameras with a speed of 25 Hz photos and a resolution of 4096 x3000 pixels-seli (Fig. 4a) [3].

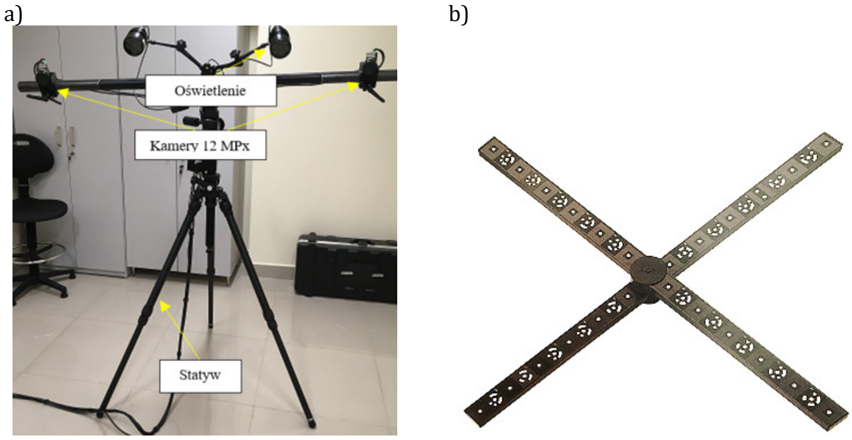


Fig. 4. Aramis system and its components: a) main measuring module, b) calibration cross.

The test was preceded by calibration of the device using a calibration cross, Fig. 4b. The whole process is based on the correlation principle and the method of searching for points with the same coordinate values. Calibration takes place in 24 steps, in variable positions.

The next step is to create a "pattern" or layer area with a black and white background applied (Fig. 5). Using this irregular pattern, the area analysing program creates a grid of analysed points (Fig. 5). The points created are means of so-called "Facets", that is, the means of small areas into which the entire analysed area was divided. The program then records the coordinates of these points so as to use its position to determine the displacement. The selection of the size of the facets depends on the person developing the test results and is carried out after the experiment is complete with regard to the purpose and accuracy of the measurement.

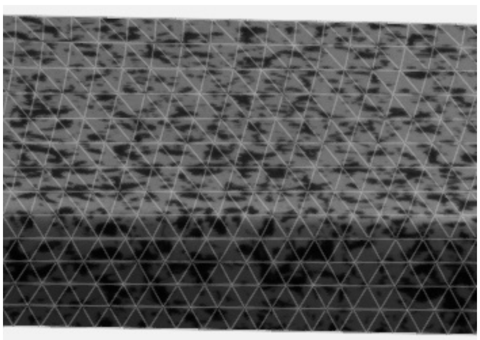


Fig. 5. Pattern applied to the tested sample and generated grid of points by the Aramis system.

The measurements consists of taking pictures, with the help of which, the spatial coordinates of selected points are determined. Depending on the test, the measurement process takes place in several stages. The first stage is taking a photo of the element in an undeformed state. reference photo (stage 0), followed by a series of photos corresponding to the subsequent stages of loading the tested object - stages 1, 2, 3, etc. Then each photo is compared with a reference photo and a set of displacement values of selected points on the surface of the object is created.

In the tests of thin-walled beams, five stages were made for a non-stiffened beam and a stiffened beam. The first stage 0 served as a reference photo. The next stages were taking pictures under load and unloading of the tested element. And so in the experiment, stage 1 was the application of load on one of the P1 profile shelves, and stage 2 was the load on the second shelf of the P2 profile in accordance with the diagram presented in Fig. 3a. Then there was the process of unloading the shelf P2 and then P1 which corresponded to the stages of taking pictures 3 and 4. The same loading and unloading process was performed for a stiffened beam. The designations of stages for the stiffened beam have been marked from 5 to 8.

After the examination, the photos taken were analysed using the software. For vertical displacements, a displacement map with designated points is shown. The points were determined on the web of the C-profile in the cross-section of the load application and in the middle of the analysed area.

4. Experimental research results

The results of vertical displacement tests are shown in Table 1. The columns correspond to profiles without stiffeners and with stiffeners, and the rows represent loads and unloadings. Each photo at selected points show the displacement values. It is worth mentioning that in the conducted research, the system allows the determination of displacements at any selected point located in the measuring area. From the results of vertical displacements presented, improvement of deflections in stiffened models is visible.

Table 1
Map of vertical displacement results

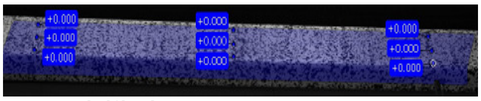
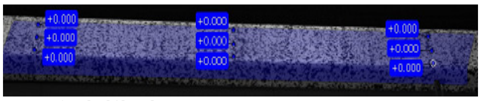
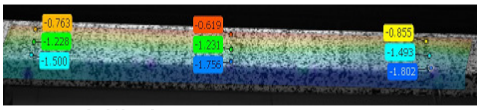
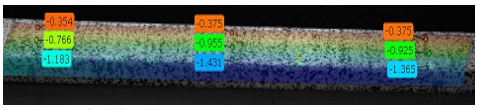
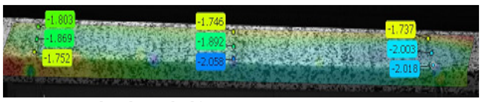
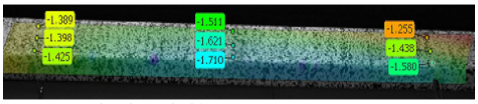
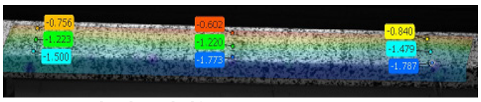
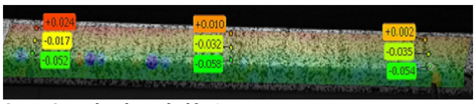
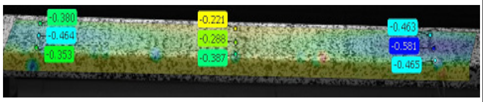
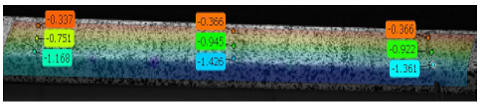
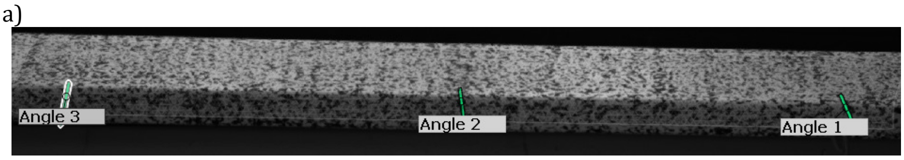
Non-stiffened profile	**Stiffened profile**
Stage 0 - reference sample 	Stage 0 - reference sample 
Stage 1 - shelf loading P1 	Stage 5 - shelf loading P1 
Stage 2 - shelf loading P2 	Stage 6 - shelf loading P2 
Stage 3 - unloading shelf P2 	Stage 7 - unloading shelf P2 
Stage 4 - unloading shelf P1 	Stage 8 - unloading shelf P1 

Figure 6b shows the torsion angle in selected section planes (Fig. 6a). On the horizontal axis of Figure 6b, the successive stages of loading - unloading the beam are marked. For a non-stiffened profile, step 1 means an unloaded sample. Next step 2 is loading the shelf P1 according to the markings in the diagram shown in Figure 3. In step 3, the profile is located while loading the shelves P1 and P2. The next step was to relieve the shelves, then remove the load from the shelf P2 position 4 to completely unload the beam position 5. For the stiffened beam, the same procedure (steps 6-10) was performed as for the stiffened beam. An increase in torsional stiffness is visible in the planes of the Angle 1 and Angle 3 cross-sections, i.e. in places where the profile is stiffened. On the other hand, in the plane of torsion angle measurement Angle 2, there is no significant effect of stiffening on the torsion angle reduction. It follows that the stiffener ensures that the contour is not deformable in cross-sections of the profile, but as it moves away from the stiffener, its effect on the torsion angle decreases.

a)



b)

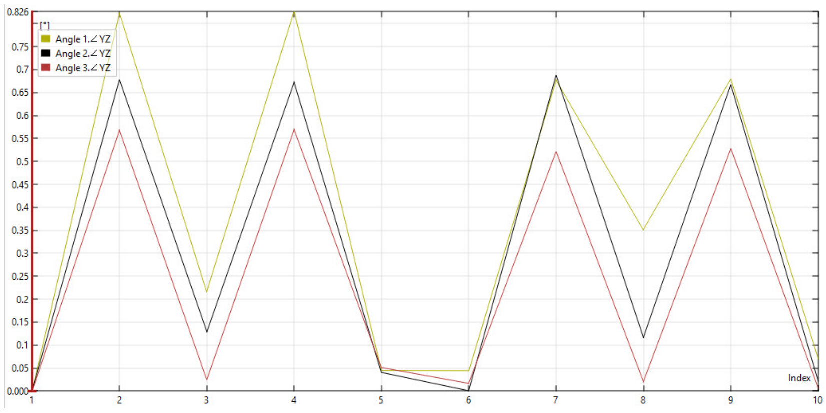


Fig. 6. Measuring sections of the torsion angle in the plane of the cross-section of the profile.

3. Summary

The use of the Aramis optical measuring system allows detailed observation of deformation of the cold-bent profile subjected to loading and unloading. At the same time, the example shows the effectiveness of using stiffening inserts. The results presented in the paper are a part of research on the impact and effectiveness of the use of 3D printing in models subjected to free twisting.

Literature

[1] Kowalewski Z., Dietrich L., Kopeć M., Szymczak T., Grzywna P., Nowoczesne systemy optyczne w badaniach mechanicznych – budowa, działanie, zastosowania, XXII Seminarium „Nieniszczące badania materiałów" Zakopane, 16-18 marca 2016.

[2] Katalog ocynkowanych profili stalowych SundeySystem, PPUH AmTech Sp. z o.o.

[3] ARAMIS User Manual, GOM mbH, Mittelweg 7-8 D-38106 Braunschweig.

Zastosowanie systemu optycznego do analizy giętno-skrętnej otwartych profili zimnogiętych

ABSTRAKT:
W pracy przedstawiono zastosowanie systemu optycznego Aramis w celu określenia sztywności giętno - skrętnej zimnogiętych profili ceowych. Belki cienkościenne kształtowane na zimno charakteryzują się wieloma zaletami ważnymi z inżynierskiego punktu widzenia. Przedmiotem badań doświadczalnych były belki cienkościenne kształtowane na zimno obciążone siłą skupioną w 1/3 rozpiętości belki. W pracy przedstawiono przykład wykorzystania tego systemu jako narzędzia pomocniczego do badań nieswobodnego skręcania nieusztywnionych i usztywnionych elementów ceowych. Prezentowane wyniki stanowią część badań nad wpływem i skutecznością zastosowania usztywnienia podłużnego wykonanego w technologii druku 3D.

SŁOWA KLUCZOWE:
Aramis; lekki szkielet stalowy; elementy cienkościenne