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WELDED TRUSS DEFORMATION UNDER THERMAL INFLUENCE

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Summary. *The article studies some deformation features of the full-scale physical model test of the 2000x400 mm rectangular welded truss at thermal influence ranging from 20 to 160°C. Numerical information based on the values of deformations at seven control points of the truss for chords and nodes was obtained as a result. A computer simulation experiment using SolidWorks software for similar impact parameters on truss was performed. Results comparison of full-scale physical model deformation and computer simulation experiments revealed its similarity. Experimental results can be used in determining the parameters of the stress-strain state of the elements of the trusses under simultaneous force and temperature effects.*
Key words: *welded truss, thermal influence, temperature deformations.*

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Problem statement. Welded trusses can be subjected to an action of load and heat within their operation. Such conditions are caused either by the action of the technological environment (metallurgical plants, rolling machines, foundries, powder spray booths, etc.) or by emergencies (fire accidents). A truss heating results in some temperature deformations in the truss structural parts. Taking into account that all these elements are fixed with each other into a rigid system, there is no doubt that some extra internal stress is likely to appear in them. Such temperature stresses overlay with the stress caused by external load and reduce the calculated bearing capacity of the truss.

Different software packages have been used in welded trusses design having both advantages and disadvantages, providing different levels of coincidence of the simulation results with performance figures of the trusses designs. It is undoubtful, that to guarantee the safe operation of the truss under load and thermal impact conditions, one should know the expected calculated characteristics provided by the software package chosen for the design. For the best validity check of the obtained design results, one should use the full-scale specimen. Nevertheless, tests with the full-scale specimen of the welded trusses are made in rare cases due to their high cost. Thus, the decision was made to study the above-mentioned characteristics using a physical model of a 2000x400 mm welded truss.

Analysis of the latest research and publications. To determine the stress and strain state parameters (SSS) in the welded trusses components a great number of applied software complexes have been used in modern science and engineering practice (SC POFSC-Mirazh-PCMK, «Lira-W», SCAD, Cosmos Works, Design Space, SC SCAD and Mathcad, SC ANSYS Workbench 14.5, SolidWorks Simulation and others [1…4]).

As a rule, these software complexes are based on the systems of finite-element analysis and make possible the stress and strain state parameters to be calculated in the welded trusses design elements on the design stage. Taking into account this information, the most efficient size of the cross-section of key elements and welded joints for their joining so that to provide the design strength, rigidity, reliability and durability of the trusses in general.

According to the results of the study done review dealing with welded trusses due to the use of the above-mentioned software packages, there is no available information on the obtained results reliability at the simultaneous impact of force and thermal action.

The software package SolidWorks Simulation has been used for the above-mentioned study of the welded truss. This software complex enables us to take into account the multi-parameter impact of design, technological and operation factors on the design behavior within its operation.

The aim of the paper is to prove the reliability of the results of a computer-aided simulating experiment dealing with the calculation of a rectangular welded truss under thermal influence conditions.

Problem (task) setting. To achieve the goal set in the paper under consideration one had to make a force full-scale and computer-aided simulating experiment using the applied software complex SolidWorks Simulation for a physical model of 2000x400 mm welded rectangular truss made of a steel rolled 40x40x4 mm angle profile under thermal influence conditions.

The task of the study is to prove the reliability of the computer-aided simulating experiment results using the applied software complex SolidWorks Simulation under the welded truss thermal influence conditions.

Study outcomes. A physical model design of a 2000x400 mm welded truss, which was studied, is shown in fig. 1.

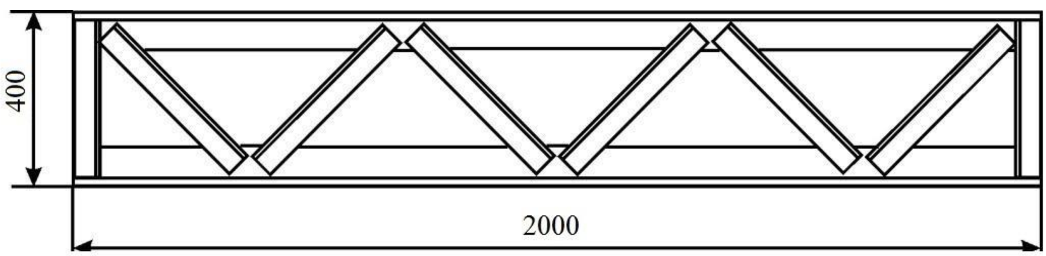

Figure 1. A physical model design of a 2000x400 mm welded truss

The physical model of the truss is made of a hot rolled 40x40x4 mm angle profile of standard quality steel ВСт3пс. All welded joints are made by semi-automatic arc welding by a wire electrode of 1.2 mm diameter Св-08Г2С in the CO_2 environment.

The deformation behavior of a welded building truss under temperature variations has been studied by means of the tests with the full-scale specimen in a special work tool to determine any temperature deformations of flat trusses [5] (fig. 2).

The tool under discussion to determine any temperature deformations of flat trusses operates in the following way.

At the beginning of the experiment, a test specimen of the truss is heated in the technological furnace up to 180°C and some fixtures are installed on the base elements (fig. 2). The values of instant temperature are read by the video filming method according to the indices of an infra-red thermometer and the indices of 7 linear deformation indicating devices (dial indicators) (fig. 3).

Figure 2. A fixture to determine any temperature deformations of flat trusses and a test model during the experiment

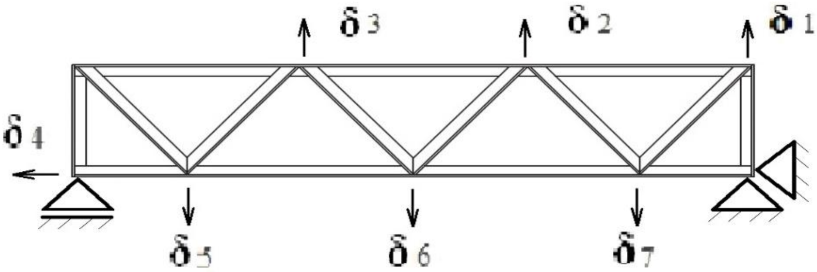

Figure 3. A scheme of measured temperature deformations for the truss joints and the bottom chord

The video filming of the temperature and deformations values takes place until the truss temperature equals the room temperature. While the truss was being cooled, it was determined:

- δ_1, δ_2, δ_3, δ_5, δ_6, δ_7 – lateral deformations measured in the truss upper and bottom chords opposite the joints (arrows specify the direction of deformation);
- δ_4 – horizontal temperature deformations measured in the truss butt end (bottom chord deformation).

According to the results of the experiment, some information arrays have been obtained for each indicating device (table 1). To create adequate conditions of comparison with the results of the computer-aided simulating experiment, the results were reformatted to the form from t = 20°C to 160°C, unlike those obtained from t = 160°C to 20°C.

Table 1

Deformation of a physical model of a 2000x400 mm welded truss under temperature influence conditions according to the results of the full-scale experiment

t, °C	δ_1, mm	δ_2, mm	δ_3, mm	δ_4, mm	δ_5, mm	δ_6, mm	δ_7, mm
20	0	0	0	0	0	0	0
40	0.12	0.06	0.05	0.32	-0.01	-0.08	-0.01
60	0.20	0.12	0.13	0.72	-0.02	-0.14	-0.02
80	0.27	0.18	0.22	1.12	-0.035	-0.20	-0.03
100	0.33	0.25	0.30	1.41	-0.05	-0.25	-0.045
120	0.39	0.35	0.40	1.80	-0.07	-0.32	-0.06
140	0.48	0.46	0.51	2.35	-0.09	-0.40	-0.08
160	0.60	0.63	0.63	3.23	-0.115	-0.58	-0.10

According to the range of temperature accepted for the full-scale experiment, a computer-aided simulating experiment was made using the applied software complex SolidWorks Simulation and the proper deformations of the truss elements were determined. The superimposed curves of temperature deformations of the truss bottom chord are shown in fig. 4, and on fig. 5 – of the welded truss joints according to the results of a full-scale (curve A) and a computer-aided simulating (curve B) experiments. Numeric character 1 means the coordinates of the points obtained due to the experiments and numeric character 2 means the lines obtained after the linear approximation of the experimental data.

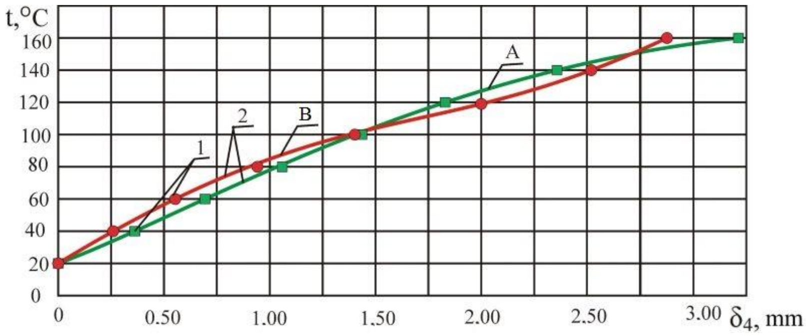

Figure 4. Superimposed curves of temperature deformations of the truss bottom chord δ_4 according to the results of a full-scale (curve A) and a computer-aided simulating experiments (curve B)

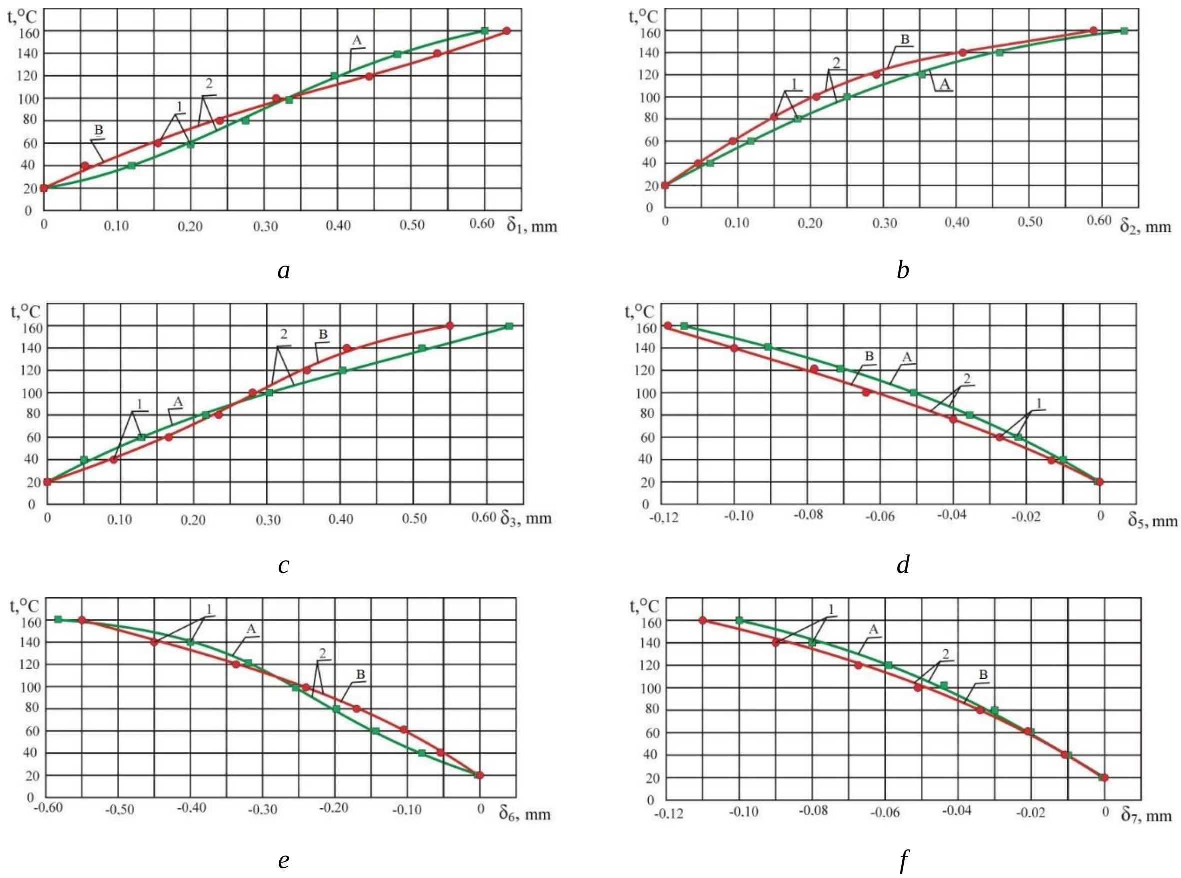

Figure 5. Superimposed curves of temperature deformations of the truss joints (fig. 3) according to the results of a full-scale experiment (curve A) and a computer-aided simulating experiment (curve B)
a – for δ_1; *b* – for δ_2; *c* – for δ_3; *d* – for δ_5; *e* – for δ_6; *f* – for δ_7

While making the computer-aided simulating experiment the parameters of a finite element model and other methodical aspects of calculations were accepted taking into account the experience of the authors studying the load impact on the trusses' designs [4 and 6], where high indices of the simulation results reliability were obtained.

The satisfactory coincidence of the indices is quite predictable according to the results of a full-scale experiment and a computer-aided simulating experiment at the visual comparison of the superimposed curves of temperature deformations (fig. 4, 5). While comparing the numerical bases of the results of the above-mentioned full-scale experiment and the computer-aided simulating experiment by analytical method, it was found, that the coincidence of the temperature deformations values equals 95.8…98.7%.

Thus, the software package SolidWorks used for computer-aided simulating experiments can also be used for simulation of similar structures behavior with a high degree of obtained results reliability.

Conclusions. A complex study of a physical model of a 2000x400 mm welded truss has been done by both a full-scale experiment and a computer-aided one as well to define the influence of temperature on the change of parameters of welded trusses' stress-and-strain state and, as a result, their load-bearing capacity reduction under simultaneous thermal and load influences. The technological range from 20 to 160°C has been studied which is typical for metallurgical plants, rolling machines, foundries, etc.

According to the results of the study, some thermal deformations taking place in the welded truss components were found within the range of technological temperatures, which have caused some extra internal stresses under the truss closed and rigid design conditions. Such stresses together with the stresses caused by the load impact result in the truss bearing capacity loss. Taking into account the fact, that under the above-mentioned temperatures the mechanical properties of structural steels change very little (durability limit and yield limit), a great number of scientists and engineers have neglected the thermal impact. Due to such approach, the truss damage can occur under the prelimit design load action conditions.

The study of thermal impact has been done using the computer-aided simulation in the software complex SolidWorks according to the directions similar to the full-scale experiment. Some information basis was obtained and superimposed curves of temperature deformations were built. The 95.8…98.7% coincidence of temperature deformations values was calculated according to the results of information bases comparison of a full-scale and a computer-aided experiments.

The obtained results of the research can be used in welded trusses design under simultaneous load and temperature impact conditions. The software SolidWorks providing the high reliability of the calculated results should be applied.

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ДЕФОРМУВАННЯ ЗВАРНОЇ ФЕРМИ ПРИ ТЕПЛОВИХ ВПЛИВАХ

Ярослав Швед; Ярослав Ковальчук; Наталія Шингера

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Резюме. *Зварні фермові конструкції зазнають комплексного впливу експлуатаційних, технологічних та аварійних чинників. Це ускладнює визначення конструктивних проектних показників, які б забезпечили безаварійне функціонування таких ферм упродовж планового періоду експлуатації. При сумісному силовому й температурному впливах на фермову конструкцію пошкодження в конструктивних елементах і місцях їх з'єднання виникають унаслідок зміни механічних властивостей матеріалу, поєднанні внутрішніх напружень від температурних деформацій з напруженнями від зовнішніх навантажень. Існуючі розрахункові методики не дають можливості врахувати такий комплексний вплив з високим ступенем достовірності. Для виявлення особливостей деформування й руйнування зварної прямокутної ферми виконано натурні експериментальні дослідження для фізичної моделі 2000х400 мм при температурному впливі від 20 до 160^{O}С. Отримано чисельну інформаційну базу про значення деформацій у 7 контрольних точках ферми для поясів і вузлів. Виконано комп'ютерний моделюючий експеримент програмним пакетом SolidWorks для аналогічних параметрів впливу на ферму. Побудовано суміщені графіки відповідних деформацій за результатами натурного і комп'ютерного моделюючого експериментів, які дають можливість візуально якісно порівняти ступінь співпадання отриманих показників. При чисельному порівнянні результатів натурного і комп'ютерного моделюючого експериментів виявлено їх співпадання на рівні 95,8…98,7%. Це свідчить про раціональний вибір програмного пакета для комп'ютерного моделювання та оптимальні параметри скінчено-елементної моделі. Отримані результати роботи і використані при дослідженнях методичні підходи доцільно застосовувати при визначенні параметрів напружено-деформівного стану елементів ферм при одночасних силових і температурних впливах.*

Ключові слова*: зварна ферма, тепловий вплив, температурні деформації.*

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