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COMPUTER MODELING OF DEFORMATION OF WELDED TRUSS WITH GUSSET PLATES IN ITS NODS

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Summary. *The aim of the study is to detect welded constructive truss deformation patterns with regard to constructive and technological features of the nodes. Merely performing of multifactor computer simulation experiment using application software systems and modern computational base makes it possible to perform such design calculation with a high reliability of the results. The study of welded secondary truss model behavior under the influence of external static loads was performed. The 2000x400 mm prototype was made of 40x40x4 mm double steel roll angle profile. Nodes gusset plates were designed as rectangular and made of steel plate 6 mm thick. The diagram of truss bottom chord load-extension and deflection for different external load values was obtained according to the results of computer simulation experiment in ANSYS Workbench 14.5 framework. The obtained results are of theoretical and practical interest both for the designing of new trusses and inspecting of operated ones.*

Key words: *secondary truss, gusset plates in nodes, chord deformation.*

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Problem setting In modern construction industry load bearing welded rod metal structures (bridge span truss, trussed rafters, trestle and bridge superstructure technological equipment supports, conveyor passage truss etc.) are used with ever increasing frequency. Subjective aspects do influence design and production of welded truss, so the planner cannot assert with certainty the concordance of estimated and actual parameters of structure's deflected mode (DM). Classical design calculation of welded truss does not make it possible to fully take these characteristics into account.

Present state of computer engineering and calculation methods makes it possible to solve this issue and assess welded truss DM parameters in conditions of multiple factor influence by means of computer simulation experiment.

Analysis of latest research and publications

Calculations of metal structures and welded truss in particular were done in the works of Drokin A.V. [1], Alpatov V.Yu. (PC POFSK-Mirage-PSMK, "Lira-W", SCAD, Cosmos Works, Design Space) [2], Aldushkin R.V. (PC SCAD and Mathcad) [3], Dubenets V.H., Savchenko O.V. (PC ARM WinTruss) [4], Shynhera N.Ya. (PC ANSYS) [5] and others.

Analysis of the results of conducted earlier experimental and theoretical research for different structural forms and technological factors that influence the deformation of welded truss shows the following:

– empirical dependencies, graphs and nomograms for characterization of uniform node truss bearing capacity were proposed;
– truss bearing capacity with static load was calculated by means of computer simulation experiment without further verification of the results obtained.

Meanwhile during DM tests of the nodes the influence of their structural and technological features on the welded truss rigidity was not taken into account.

Work objective is to find deformation patterns of bottom chord and welded construction truss in whole at different levels of static load taking into account structural and technological characteristics of nodes.

Problem statement Truss structural elements are usually joined by manual arc welding.

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In view of their strength and durability welded joints in truss nodes have the following characteristics:

- residual thermal stress appears after welding;
- high concentration of stress due to structural features or technological defects (undercutting, lack of fusion, spills, cold and hot cracks etc.);
- inhomogeneity of physical and mechanical properties of the material in the area of welded joint, caused by the difference of chemical composition of the main metal, weld seam metal, and thermally affected area.

The above-mentioned characteristics of welded joints significantly complicate estimation of truss behavior mode using classical calculating methods. Such calculations are bound to result in a structure having either overrated criteria of strength, materials consumption and cost, or being an accident-prone one in other cases.

Research task is to detect with high accuracy and reliability deformation level of welded truss with orthogonal gusset plates in its nodes and diagonals with butts perpendicular to their axes under static operational loads of different rate.

Research results A physical model of an orthogonal truss with triangular grid (fig. 1) is used for the research. The choice is made due to the structure versatility and wide variety of its applications. Such truss configuration can be used as a rafter truss in buildings, as well as a load-bearing structure in bridges, crane girders and towers, and power transmission poles. Such truss configuration only without gussets has undergone semi-natural power experiment, which showed high matching level of structure stress-strain behavior data with that of computer simulation [6].

Chords and diagonals of the truss are made of paired standard rolled angular sectional shape 40x40mm with 4mm width, and the gussets are made of 6mm wide plate. The truss is made of regular quality ВСт3пс steel. All welding seams are done by semiautomatic arc welding with direct current using 1,2mm Св-08Г2С wire electrode in CO_2 environment in accordance with standardized technologies. Welding current was 110 Amps.

Structure loading pattern which complies with truss operational mode was applied (fig. 2).

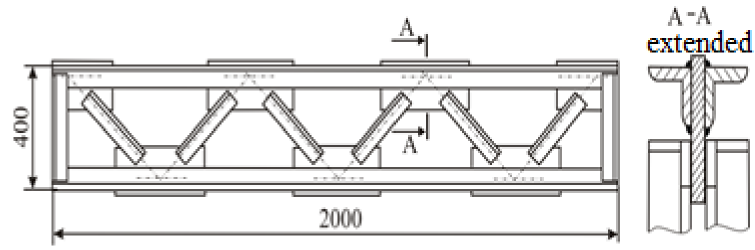


Figure 1. Physical model of welded secondary truss with gusset plates

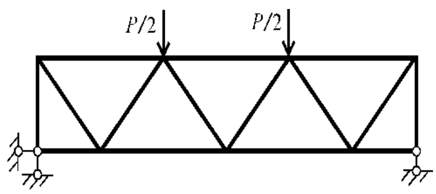


Figure 2. Loading scheme of welded truss

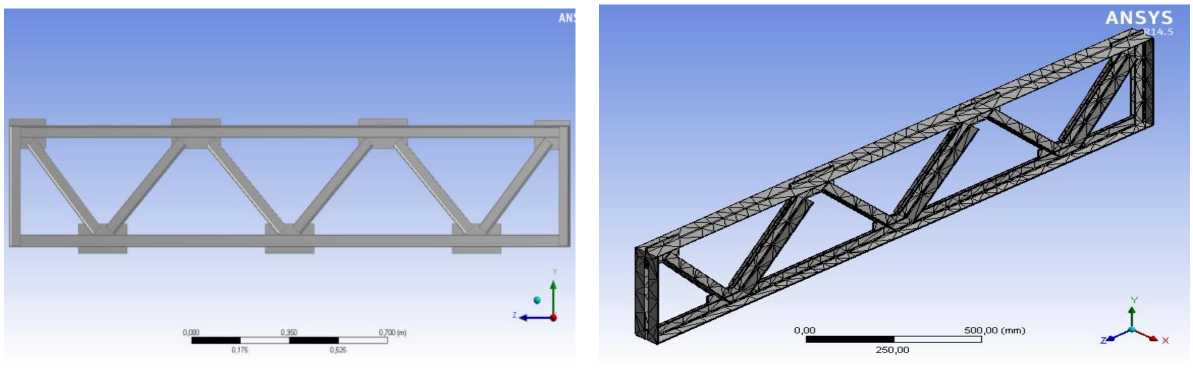
The task set in the research was accomplished by means of computer simulation experiment using numerical methods in ANSYS Workbench 14.5 application environment, based on finite element method.

This software application has the following advantages:

- possibility to create calculated model of a structure or its import from CAD systems (namely SolidWorks, AutoCAD, Inventor, etc.);
- possibility to test structure's reaction to different physical influences (different kinds of loads, temperature, etc.);
- ability to perform structure optimization;

– possibility to carry out users' calculated data exchange and management (ANSYS EKM);
– high research productivity.

To simulate rafter truss behavior mode in ANSYS Workbench 14.5 software application its geometric model (fig. 3) and finite element grid model (fig. 3b) were developed.



a) *b)*

Figure 3. 2000x400 mm truss: a) CAD – geometric model; b) CAE – finite-element grid model

Results of computer simulation experiment in ANSYS Workbench 14.5 environment are shown in the graph of truss bottom chord extension at different values of external load (fig. 4)

Linearity between external load and load-extension of the bottom chord breaks within 200 and 215 kN force range.

The graph of bending deflection along the truss bottom chord at different values of external load is also worth considering (fig. 5).

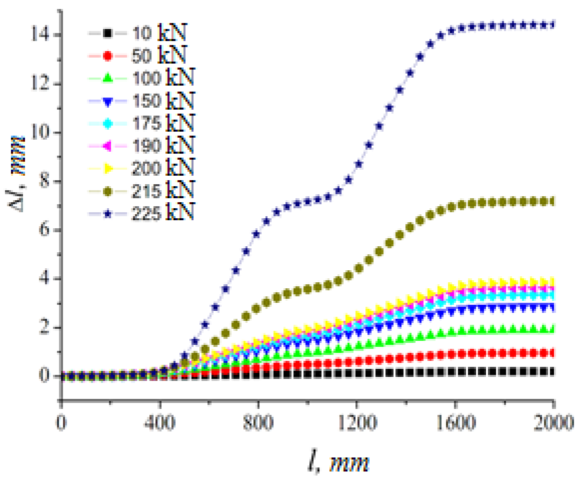


Figure 4. Diagram of load-extension along the truss bottom chord at different loading levels

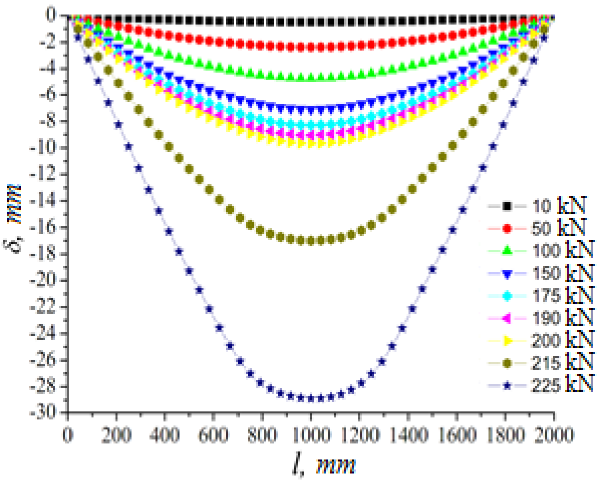


Figure 5. Diagram of deflection along the truss bottom chord at different loading levels

Safe power range, as in case of longitudinal deformation of the bottom chord, is limited with external load of 200 kN. Linearity violation occurs with load increase, hence significant plastic deformation of the structure. Such loads are especially dangerous with cyclic constituent of the force spectrum as they lead to creation and expansion of low-cycle fatigue cracks.

Numerical values of maximal elongations and bending deflection of truss bottom chord depending on the amount of load have been obtained. The results are shown in the table.

Table № 1

Welded truss loading and deformation results received with a computer simulation experiment

№	Load P, H	Bottom chord extension Δl, mm	Bottom chord deflection $\delta_{розр}$, mm
1	10000	0,20	-0,48
2	50000	0,96	-2,37
3	100000	1,92	-4,74
4	150000	2,88	-7,10
5	175000	3,36	-8,29
6	190000	3,65	-9,04
7	200000	3,86	-9,67
8	215000	7,20	-16,99
9	225000	14,42	-28,89

Obtained numerical calculation results are shown in the graphs of welded truss bottom chord deformations of both load-extension type (fig. 6a) and bending deflection type (fig.6b), clearly presenting loads leading to loss of truss resilience and transition of deformation into plastic phase.

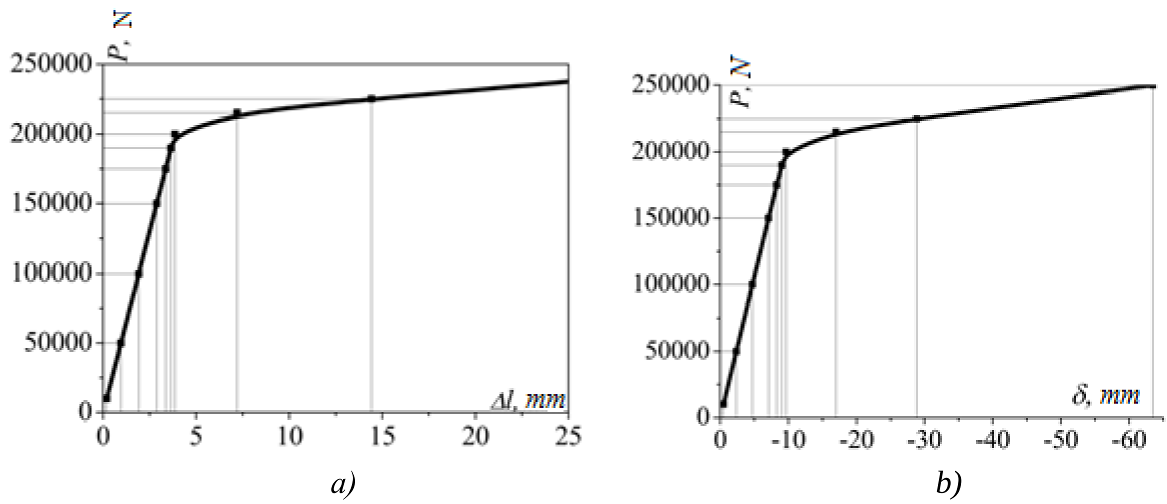


Figure 6. Welded truss deformation diagrams obtained with computer simulation experiment: a) maximum load-extensions of the bottom chord; b) maximum deflections of the bottom chord

Visual presenting of truss configuration change with load values at marginal state have been carried out (fig. 7). Color picture explicitly shows the bottom chord area with maximal tensile stress. This area is localized in the central part of the chord between truss side nodes.

Fig. 7 lets us find out tension level not only in the bottom chord, which is given the most attention in the previous graphs, but also in all truss components. Such information is useful for choosing welded truss reinforcement methods.

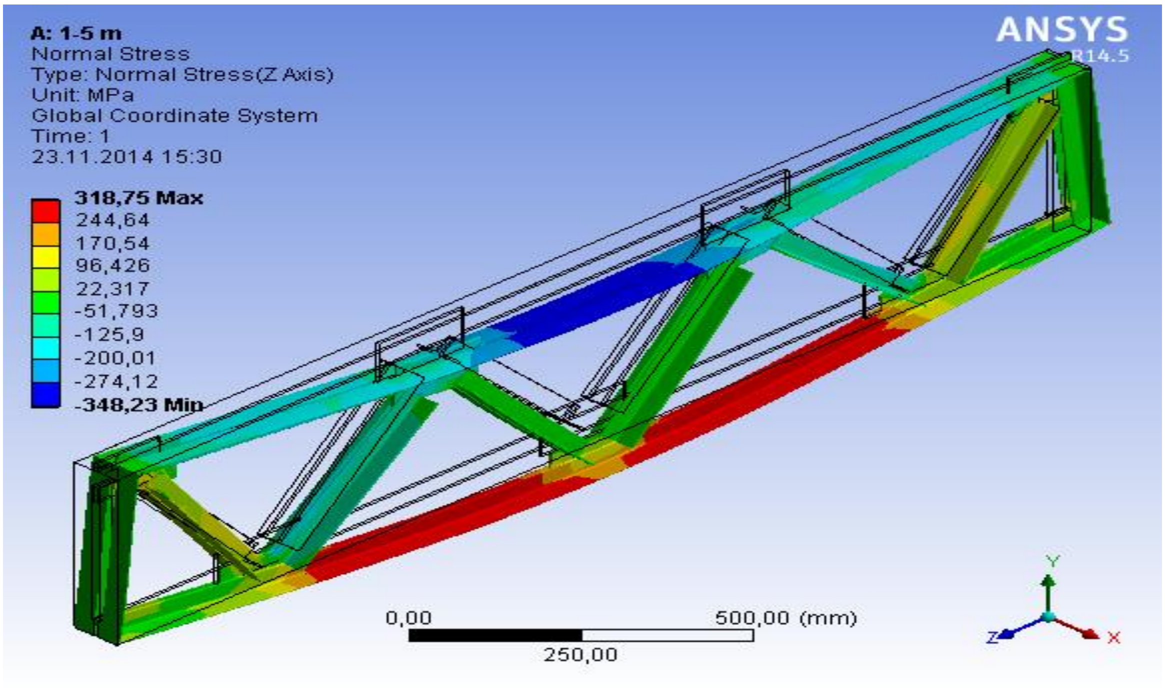


Figure 7. Welded truss deformation diagram, obtained with computer simulation experiment, at a limit state of the construction

Loss of load-bearing capacity of a welded truss with dimensions 2000x400mm made of paired rolled metal ribs measuring 40x40x4mm with gusset plates and orthogonally cut diagonals occurred at load of P_{max}= 215 kN, whereas plastic deformation of the structure according to performed calculation results took place at external load of 190 kN.

Conclusions According to the results of a multifactor computer simulation experiment a diagram of longitudinal and lateral (transversal) deformation of bottom chord of a 2000x400mm welded truss made of 40x40x4mm paired rolled metal ribs with gusset plates in its nodes at different values of external load was obtained. Research results show that plastic deformation of the structure occurred at external load of 190 kN, and loss of its load-bearing capacity happened at the load P_{max}= 215 kN. Methodical approaches used in the research are worth considering both in calculations of welded truss rated capacity and in checking load-carrying capacity as well as safety coefficient of welded truss currently in use in order to prevent their emergency breakdown.

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КОМП'ЮТЕРНЕ МОДЕЛЮВАННЯ ДЕФОРМАЦІЇ ЗВАРНОЇ ФЕРМИ З КОСИНКАМИ У ВУЗЛАХ

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***Резюме**. Виконано дослідження поведінки фізичної моделі зварної підкроквяної ферми при дії зовнішніх статичних навантажень. Дослідний зразок 2000×400 мм виготовлено зі спареного стального вальцьованого кутникового профілю 40×40×4 мм. Вузлові косинки для ферми виконано прямокутними зі стальної пластини товщиною 6 мм. Вибрано схему навантажування, яка ідентифікує експлуатаційний режим для конструкції такого типу. За результатами виконання комп'ютерного моделюючого експерименту в середовищі ANSYS Workbench 14.5 отримано діаграми видовження та прогину нижнього пояса ферми при різних значеннях зовнішнього навантаження. Отримані результати становлять теоретичний і практичний інтерес як для проектування нових ферм, так і для перевірки ферм, які експлуатуються.*

***Ключові слова:** підкроквяна ферма, косинки у вузлах, деформування пояса*

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