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COMPUTER MODELING OF THE STRESSES IN WELDED TRUSS

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Resume. *The stresses localization in the construction elements of welded roof truss that is 18000x3600 mm and is made of 100x100x10 mm steel rolled L-bar is studied. The nodes are designed without adapters. Computer modeling of the studied construction loading process was applied in the program complex ANSYS Workbench 14.5, which is algorithmically based on the finite elements method. The values of external loads on the top chord nodes were discretely prescribed to be from 10 kN to 650 kN. The maximum load is limited by the arising of edge state in welded truss. The study obtained numerical and graphical information base on the stress-strain state parameters along the bottom chord of the truss at different levels of external force action. The level of stresses, localized in truss nodes, was identified. According to the research results it was concluded that local strengthening of the bottom chord central part is appropriate. This will increase the level of allowable loads on the structure and improve the reliability of building exploitation.*

Keywords*: welded roof truss, stress-strain state, computer simulating experiment.*

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Formulation of the problem. The use of welded truss structures in modern construction is caused by a number of advantages in comparison with other designs of similar functionality (high bearing capacity, lower consumption of materials, high technology manufacturing and installation). However, structural and technological features of welded truss complicate engineering calculations, which would take into account the complex influence of many factors on the formation of the stress-strain state (SSS) in the construction elements.

The geometric characteristics of construction, operational load and own weight of the structure is taken into account in classical engineering calculations. The complex impact of constructive features (construction of nodes), technological factors (stress from welding) and operational loads (wind, snow, seismic, etc.) are taken into account through the system of the coefficients. This approach in some cases leads to excess of ultimate strength, and therefore, to the cost of material and its design, in other cases –it leads to the reduction of reliability of the truss during exploitation because of the stresses localization in some parts of the construction.

Approved operating constructions that are calculated on the average, but not on the actual load, continue to be exploited without paying attention to the discrepancy between the design and the actual load. In the study of accidents of such constructions the cause of damage of the truss as a result of the coincidence of a number of adverse factors is commonly found.

Analysis of recent research and publications. The method of calculating according to the method of boundary conditions is standardized for truss constructions. This method is used in European standards [1], and in the ISO standard [2].

In modern science, a large number of calculation software systems is widely used each of which has its key advantages and disadvantages. An important advantage of such researches is the possibility to perform multivariate computer modeling experiment that is to take into account many factors that affect the behavior of welded truss, lead to their deformation, damage and destruction.

Calculation of metal structures, in particular welded truss, using software systems are demonstrated in the works of Drokin A.V. [3], Alpatov V.Y. (PC POFSC- Myrazh-PSMC, «Lira-W», SCAD, Cosmos Works, Design Space) [4], Aldushkin R.V. (PC SCAD and Mathcad) [5], Dubenets V.H., Savchenko O.V. (PC APM WinTruss) [6], Shynher N.Y. (PC ANSYS) [7] and others.

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In the analysis of these studies the following drawbacks have been revealed. During the transition from real construction to the actual design scheme using the method of boundary conditions:

the joint-core moment free design scheme has been introduced;

stability of compressed design elements excluding torsion-flexible forms of loss of stability has been considered;

the calculated resistance of materials smaller than normative has been accepted (in order to improve the reliability of calculation, actual strong characteristics of materials are artificially reduced by the designer);

in assessing the stability of compressed core elements the condition of their installation has been regarded very approximately.

Many of these simplifications could lead to a substantial deviation of the design characteristics of SSS from real, especially for core systems, the elements of which have spatial geometric imperfections.

As a result of these drawbacks some designs may have excessive ultimate strength, while others – insufficient ultimate strength.

The aim of the work is to reveal the values of the local loads in the construction elements of welded roof truss in particular along its bottom chord under conditions of focused static loading of the construction on the upper chord opposite the nodes. Maximum stresses have been formed particularly in the bottom chord and cause the limiting state of the structures, its damage and destruction.

Setting of the objectives (problem). To achieve this goal it is necessary to develop a full-scale design of welded roof truss, its loading scheme, to adapt algorithm of program complex ANSYS Workbench 14.5 to study the local stresses in the elements of the construction, to create an information base about the level of stresses depending on the level of external force influence and to analyze received results.

Results of the research. To research the stresses localization in welded roof truss under static load using the method of computer modelling the configuration of the truss and the scheme of its loading has been selected (fig.1). Constructively the truss with the size of 18000x3600 mm is made of 100x100x10 mm steel rolled L-bar. The nodes are designed without adapters.

Characteristics of mechanical properties of steel in the condition of stretching were obtained in previous studies by the authors due to a series of natural experiments for statistical sampling[5], that is ultimate strength (optional average value) for basic material $\overline{\sigma_{в}}$ = 380 MPa, for welding joint $\overline{\sigma_{в}}$ = 283 MPa, the optional average values of yield strength $\overline{\sigma_{T}}$ = 273 MPa, ultimate strength $\overline{\delta}$ =0,36. These figures actually were used as input information database in the computer modeling experiment.

The loading scheme of welded roof truss has been proposed and it identifies the operational mode to the studied design.

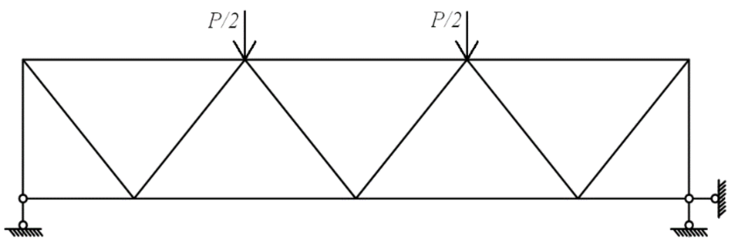


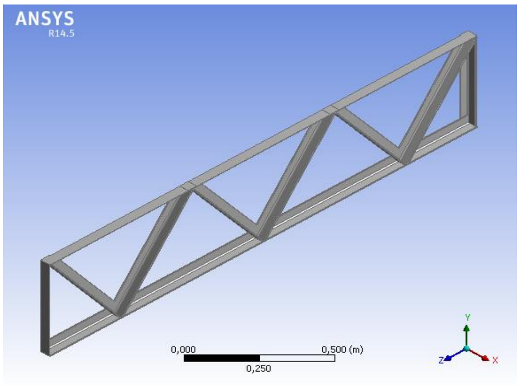
Figure 1. Structural design of welded truss and the scheme of its loading

Research of the stresses localization in the construction elements of welded roof truss under static loading is done by computer modeling experiment using the applied program complex ANSYS Workbench 14.5, which is algorithmically based on the finite elements method. The aim of the finite elements method is to find the response of the system for a given external influence. The mathematical model is used for the solution:

geometric model CAD together with a given loading is a formalized physical model (figure 2,a);

complete-element net model CEA is a mathematical representation of geometric model CAD; this is a calculation model (figure 2, b);

accuracy of calculations is determined by physical model assumptions and density of the net.



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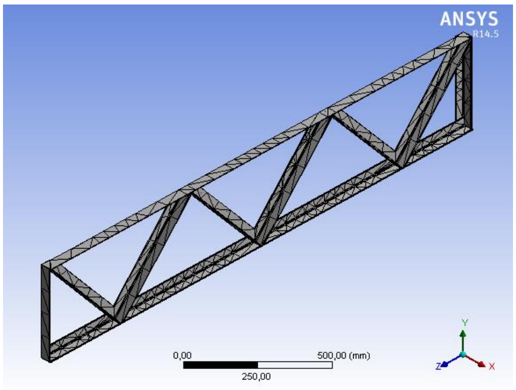

б

Figure 2. Truss with dimensions of 18000 × 3600 mm:
a) CAD is a geometrical model of the truss; б) CAE is a complete-element net model of the truss

Solution of the problem runs through 4 stages.

Main assumptions:

selection of the type of analysis (static, dynamic, modal) the relevant configuration of the program is performed;

choice of contact model;

selection of the type of components (thecal or solid).

Preprocessing:

building of a geometric model. It can also be exported from any CAD-system;

the choice of the material of the object and identification of its all necessary properties (can be set from the keyboard or can be imported from the library materials of ANSYS);

generation of the net. Geometric model is divided into finite elements. During the division various parameters of the net can be set;

loading and fastening of the construction;

choice of calculation parameters.

Calculation.

Post processing:

revision of the results. As a result of the solution a file of results is formed;

validation of the solution. All physical quantities are presented in graphical window ANSYS in the form of images, tables, graphs, animations.

According to the results of the computer simulation experiment the value of the stresses along the truss bottom chord at different levels of external force influence by means of static loads has been received (figure 3).

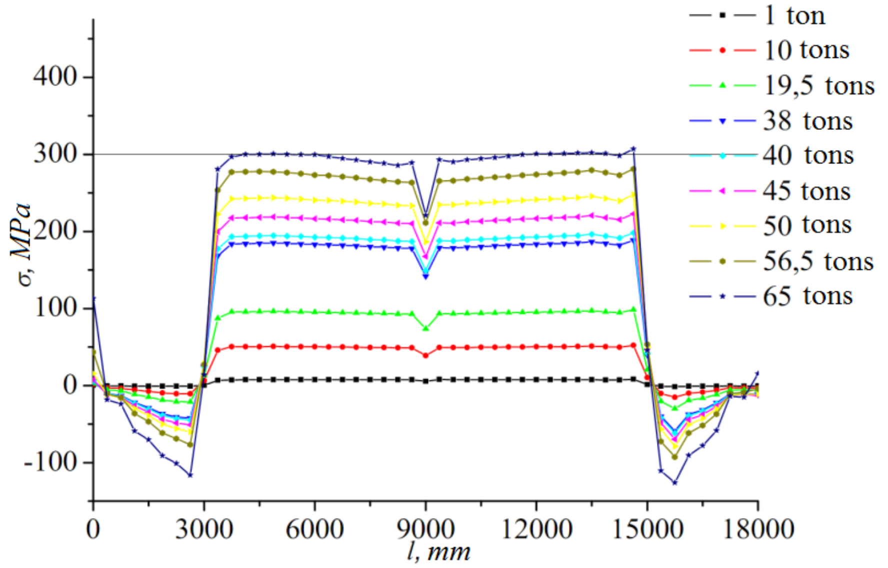

Figure 3. The stress along the truss bottom chord at different loading levels

The received values of maximum stresses***σ*,** (MPa) along the truss bottom chord at different loading levels *P,* (kN) are summarized in table 1.

Table № 1.
Maximum stresses in the truss bottom chord, received due to the computer simulation experiment

№	1	2	3	4	5	6	7	8	9
P, (kN)	10	100	195	380	400	450	500	565	650
***σ*,** (MPa)	8,3	52,1	98,4	188,5	198,2	222,7	247,7	288,1	307,0

Thus, according to the results of the computer simulation experiment the value of the stresses along the bottom chord of a full-scaled truss under the influence of static loads of different levels has been revealed.

The loss of truss durability according to the computer simulation experiment occurred at the loading P_{max}= 565 kN, plastic deformation of the construction occurred due to the stress of 380 kN.

According to the fig.3 it is obvious that maximum stresses are localized in the central part of the bottom chord of the truss. Therefore, to increase the bearing capacity of the studied construction of the roof truss, to improve its reliability it is necessary to strengthen particularly this part of the bottom chord. Constructive solutions and technology of strengthening performance can be viewed in the following studies.

Conclusions. To prevent accidents and damage of welded roof truss that are projected or exploited it is necessary to have information about the level of their bearing capacity. The research using the computer simulation experiment in the program complex ANSYS Workbench 14.5. has been completed. The values of stresses along the bottom chord of welded roof truss and the places of formation of its peak values have been revealed.

The ways of truss durability have been proposed. The represented computer simulation experiment should be done during the projecting of welded constructional truss. Due to the calculation results the bearing capacity of the projected construction can be increased by means of the local strengthening of its elements. The described method can be used for verification calculations of the constructional trusses, that are exploited, and to prevent the ultimate state under the action of possible force impacts.

References

1. Eurocode 1. Basis of Design and Action on Structures. Part 1: Basis of Design, ENV 1991 CEN-1, 1994.
2. General Principles on Reliability for Structures: ISO/TC98.5723-94, 1994.
3. Drokyn A.V. Optymyzatsyia stroytelnykh konstruktsyi, podverzhennykh sylovym y termycheskym vozdeistvyiam. Diss. dokt. tek. nauk. Belhorod, 2003, 20 p. [In Russian].
4. Alpatov V.Yu. Optymalnoe proektyrovanye metallycheskykh struktur. Diss. dokt. tek. nauk. Samara, 2002, 23 p. [In Russian].
5. Aldushkyn R.V. Razvytye y sovershenstvovanye ratsyonalnykh metodov usylenyia y rehulyrovanyia usylyi v metallycheskykh konstruktsyiakh balochnoho typa y fermakh. Diss. dokt. tek. nauk. Orel, 2008, 20 p. [In Russian].
6. Dubenets V.H., Savchenko O.V. Praktykum z obchysliuvalnoi mekhaniky. Rozrakhunok i proektuvannia konstruktsii ferm na APM WinTruss. Kyiv, Znannia Publ., 2007. 172 p. [In Ukrainian].
7. Shynhera N.Ya. Statystychna model dlia vyznachennia zalyshkovoho resursu typovoi zvarnoi fermy pry tsyklichnykh navantazhenniakh. Diss. dokt. tek. nauk. Ternopil, 2012, 166 p. [In Ukrainian].

Список використаної літератури

1. Eurocode 1. Basis of Design and Action on Structures. Part 1: Basis of Design, ENV 1991 CEN – 1, 1994.
2. General Principles on Reliability for Structures: ISO/TC98.5723 – 94, 1994.
3. Дрокин, А.В. Оптимизация строительных конструкций, подверженных силовым и термическим воздействиям: автореф. дисс. на соискание научн. степени канд. техн. наук: специальность ВАК 05.23.01 «Строительные конструкции, здания и сооружения» [Текст] / А.В. Дрокин. – Белгород, 2003. – 20 с.
4. Алпатов, В.Ю. Оптимальное проектирование металлических структур: автореф. дисс. на соискание науч. степени канд. техн. наук: специальность ВАК 05.23.01 «Строительные конструкции, здания и сооружения» [Текст] / А.В. Дрокин. – Самара, 2002. – 23 с.
5. Алдушкин, Р.В. Развитие и совершенствование рациональных методов усиления и регулирования усилий в металлических конструкциях балочного типа и фермах: автореф. дисс. на соискание научн. степени канд. техн. наук: специальность ВАК 05.23.01 «Строительные конструкции, здания и сооружения» [Текст] / Р.В. Алдушкин, – Орел, 2008. – 20 с.
6. Дубенець, В.Г. Практикум з обчислювальної механіки [Текст] / В.Г. Дубенець, О.В. Савченко // Розрахунок і проектування конструкцій ферм на APM WinTruss. – К.: Знання, 2007. – 172 с.
7. Шингера, Н.Я. Статистична модель для визначення залишкового ресурсу типової зварної ферми при циклічних навантаженнях: дис. на здобуття наук. ступеня канд. техн. наук: 01.05.02 – математичне моделювання та обчислювальні методи [Текст] / Шингера Наталія Ярославівна. – Тернопіль, 2012. – 166 с.

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КОМП’ЮТЕРНЕ МОДЕЛЮВАННЯ НАПРУЖЕНЬ У ЗВАРНІЙ ФЕРМІ

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Резюме*. Досліджено локалізацію напружень в елементах зварної підкроквяної ферми 18000 x 3600 мм, виготовленої зі стального вальцьованого кутника 100x100x10 мм. Конструкцію вузлів виконано без косинок. Використано комп’ютерне моделювання процесу навантажування досліджуваної конструкції в середовищі програмного комплексу ANSYS Workbench 14.5, який алгоритмічно базується на методі скінченних елементів. Значення зовнішніх навантажень на вузли верхнього пояса задано дискретно від 10 кН до 650 кН. Максимальне навантаження обмежено настанням граничного стану в зварній фермі. За результатами дослідження отримано чисельну і графічну інформаційні бази про параметри НДС уздовж нижнього пояса ферми при різних рівнях зовнішнього силового впливу. Виявлено рівень напружень, локалізованих у вузлах ферми. За результатами досліджень зроблено висновок про доцільність зміцнення нижнього пояса ферми в центральній його частині. Це дасть можливість збільшити рівень допустимих навантажень на конструкцію та підвищити надійність експлуатації будівлі в цілому.*

Ключові слова: *зварна підкроквяна ферма, напружено-деформівний стан, комп’ютерний моделюючий експеримент.*

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