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ИССЛЕДОВАНИЕ ВОЗДЕЙСТВИЯ СНЕГОВОЙ НАГРУЗКИ НА КАРКАС ТЕПЛИЦЫ ДЛЯ ВЫРАЩИВАНИЯ СЕЯНЦЕВ С ЗКС В SOLIDWORKS*

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Развитие компьютерных технологий оказывает значительное влияние на все сферы деятельности человека, упрощая его жизнь. При этом совершенствуется не только аппаратная составляющая, но и программное обеспечение, в том числе и системы автоматизированного проектирования, способные облегчить труд инженера не только по разработке проектной документации, но и по выполнению трудоемких прочностных расчетов любой сложности. Программа SolidWorks предназначена для решения подобных задач. Кроме того, использование специализированных инструментов структурного анализа SolidWorks Simulation, SolidWorks Motion и других позволит значительно разгрузить умственный труд инженера, исключив монотонные арифметические вычисления.

Объектом исследования данной научной работы является каркас теплицы для выращивания сеянцев с закрытой корневой системой. Предмет исследования – напряжения, возникающие в конструкции теплицы под воздействием снеговой нагрузки и собственной силы тяжести. Цель работы – обоснование параметров конструкции каркаса теплицы для выращивания сеянцев с закрытой корневой системой (ЗКС) на основе анализа нагрузок и напряжений, возникающих в ее элементах под действием веса элементов конструкции и снеговых воздействий для обеспечения необходимой и достаточной прочности методом твердотельного моделирования.

В процессе работы проводилось исследование модели каркаса теплицы для выращивания сеянцев с ЗКС с целью оптимизации конструкции. В результате исследования определены: максимальные напряжения, возникающие на каркасе теплицы под действием снеговой нагрузки; наиболее нагруженные места конструкции. Даны рекомендации по оптимизации конструкции.

Ключевые слова: *лесовосстановление, теплица, твердотельное моделирование, анализ нагрузок.*

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STUDY OF THE IMPACT OF SNOW LOAD ON THE GREENHOUSE FRAME FOR GROWING SEEDLINGS WITH CRS IN SOLIDWORKS*

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The development of computer technology has a significant impact on all spheres of human activity, making his life easier. At the same time, not only the hardware component is being improved, but also the software, including computer-aided design systems that can facilitate the engineer's work not only in developing design documentation, but also in performing time-consuming strength calculations of any complexity. SolidWorks is designed to solve such problems. In addition, the use of specialized structural analysis tools SolidWorks Simulation, SolidWorks Motion and others will significantly lighten the engineer's mental work by eliminating monotonous arithmetic calculations.

The object of study of this scientific work is the frame of a greenhouse for growing seedlings with a closed root system. The subject of the study is the stresses arising in the structure of the greenhouse under the influence of snow load and gravity. The purpose of the study is to substantiate the design parameters of the greenhouse frame for growing seedlings with the closed system based on the analysis of loads and stresses arising in its elements under the influence of the weight of structural elements and snow impacts to ensure the necessary and sufficient strength by the method of solid modeling.

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In the process of work, a study of the model of the greenhouse frame for growing seedlings with the closed root system is carried out in order to optimize the design. As a result of the study, the following are determined: maximum stresses arising on the greenhouse framework under the influence of snow load; the most loaded places of the structure. Recommendations for design optimization are given.

Keywords: *reforestation, greenhouse, solid-state modeling, load analysis.*

INTRODUCTION

The basics of state policy in the field of use, protection and reproduction of forests in the Russian Federation for the period up to 2030 and the Forest Code of the Russian Federation provide for the further development of forest reproduction. The law specifies that reforestation is carried out to restore cut down, dead, damaged forests and should ensure the restoration of forest plantations, the conservation of the forests biological diversity and useful functions of the forests. Methods of forest restoration are defined by part 1 of Article 62 of the Forest Code: natural, artificial and combined. Artificial reforestation is carried out by planting seedlings or sowing seeds of forest plants. Planting of seedlings and saplings is carried out with an open and closed root system (CRS) [1].

Studies on growing pine with a closed root system have shown that despite the lag in growth at the first stages compared with the open root system, crops with a closed root system already in the fourth year of cultivation give a gap in height growth compared with the open root system. This factor shows that crops with the CRS grow in height faster and in the coming years will surpass crops with the open root system in diameter [2].

Repeated buildings collapses, including greenhouses, due to the snow loads have led to the fact that the task of regulating snow loads on the coatings has become very actual. This problem is difficult and extensive, and its solution, for a number of reasons, turns out to be insufficient and still far from being completed. The snow formation on the coating depends on the geometric characteristics of the greenhouse and its position relative to the wind direction. Snow loads on the coatings of heated and unheated greenhouses differ by 3–4 times [3]. Proceed from this, optimization of the greenhouse frame design based on analysis of the impact of snow load using high-precision intelligent computer-aided design systems is an actrual topic.

MATERIALS AND METHODS STUDIES

Before analyzing the loads and stresses that arise in the structural elements of a greenhouse under the influence of internal and external forces using solid-state modeling tools, it is necessary to calculate the snow load, which, in turn, depends on the territorial location of the greenhouse (see the table).

The standard value of the snow load on the horizontal projection of the coating should be determined by the formula [4]

$$S_0 = c_e c_t \mu S_g , \qquad (1)$$

where c_e is a coefficient that takes into account the removal of snow from building coatings under the influence of wind or other factors; c_t – a thermal coefficient; μ – a coefficient of transition from the weight of the snow cover of the ground to the snow load on the coating; S_g is the standard value of the weight of snow cover per 1 m^2 of horizontal surface of the earth, kPa.

Algorithm for performing analysis in SolidWorks [5]:

1) creating a new static study;

2) determining the material of the greenhouse structural elements using material editing tools;

3) imposing external connections that limit the movement of the greenhouse model in space;

4) imposing external loads and gravity on the greenhouse frame according to the above calculations for snow and wind loads;

5) creating a model mesh;

6) launching study analysis;

7) assessment of the strength of the greenhouse frame structure based on the results obtained.

RESULTS AND THEIR DISCUSSION

Based on the initial data, a three-dimensional model of the greenhouse to study and justify the design parameters was developed (Fig. 1).

To analyze the resulting greenhouse frame model in a computer-aided design system, we create a new static study and set the characteristics of steel St3 [6].

We apply external links on the greenhouse model that limit the movement of the greenhouse model in space. It is planned to install reinforced concrete piles as the foundation of the greenhouse; we fix the plane of each pile at the level of the supporting surface.

Initial data for conducting research work

№	Parameter	Meaning
1	Territorial location of the greenhouse	Krasnoyarsk region
2	Snow area	V
3	Dimensions of the area for the greenhouse, m	30×17,3
4	The shape of the end and row structures of the greenhouse	arched
5	Number of end structures	2
6	Number of row structures	14
7	Step between arches, m	2
8	Maximum distance between the axes of the upper and lower belts of the arch, mm	465
9	Steel grade of greenhouse structural elements	St3

Having previously determined the snow load and the equivalent forces corresponding to this load, we apply them to the greenhouse frame together with the force of gravity (Fig. 2). The equivalent forces of the asymmetric snow load are 442.5 kN and 737.5 kN [4; 7].

Creation of a model grid. To automatically adapt the element size to the local curvature of the geometry and to create a smooth grid array, we will use a grid density set based on mixed curvature, with the grid density set to the maximum, which ensures maximum calculation accuracy.

Analysis of the study: based on the calculation results, a load diagram was obtained in the form of a ribbon with a color indication, where red is the maximum voltage, blue is the minimum (Fig. 3).

The maximum stresses arising on the greenhouse frame under snow load are 1038 MPa, which is 4.15 times higher than the permissible stresses (250 MPa). The spot of maximum stresses concentration is located at the bend of the inner belt on the side of the seventh arch (Fig. 4). This is due to the fact that the arches, located closer to the center of the greenhouse structure, experience the greatest stresses, since they do not have additional supports inside the structure.

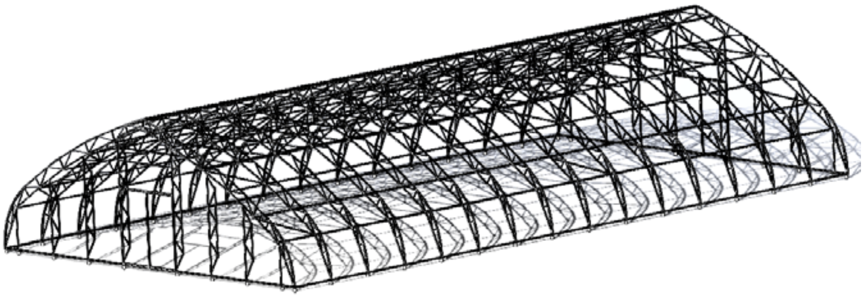

Fig. 1. Three-dimensional model of a greenhouse

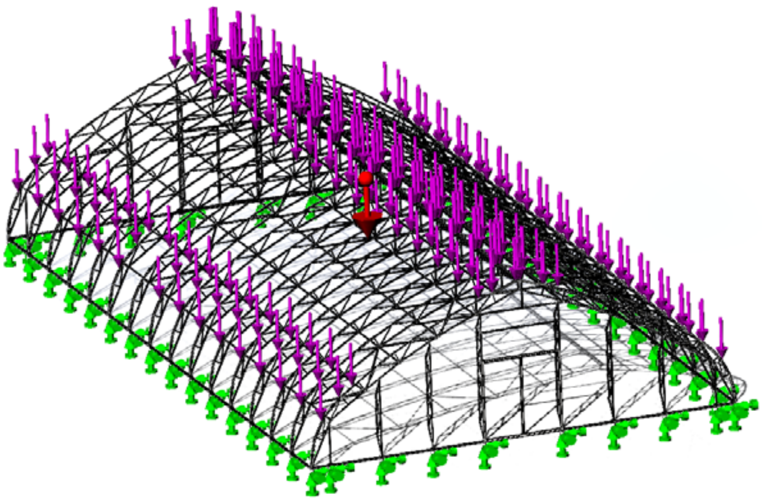

Fig. 2. Application of equivalent snow load forces to the greenhouse frame

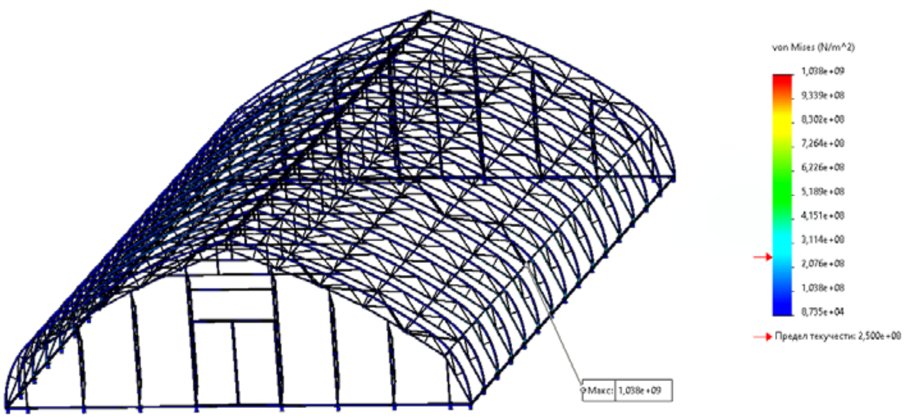

Fig. 3. Stress diagram on the greenhouse frame from snow load

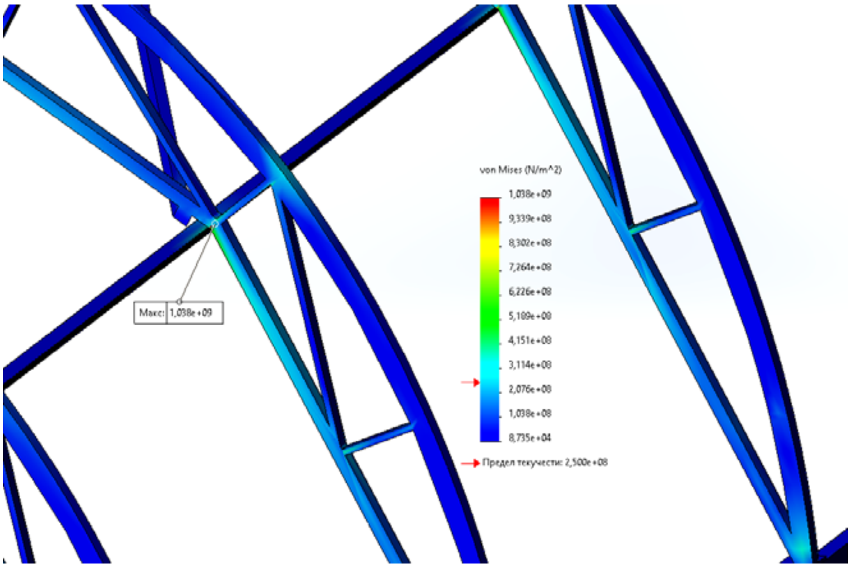

Fig. 4. Spot of maximum stress concentration from snow load

The data obtained make it possible to conclude that it is necessary to increase the distance between the inner and outer belts of the arch by 1.5-2 times, which will increase the load capacity of the loaded nodes.

CONCLUSION

Based on the results of the stress analysis of the construction of the greenhouse frame for growing seedlings with a closed root system under the influence of a snow load, the following conclusions are made:

– the maximum stresses arising on the greenhouse frame under the influence of a snow load exceed the permissible stresses by 4.15 times;

– the most loaded place is the node on the inner belt of the arch, where the small and large radii of the belts of ordinary greenhouse structures meet;

– to significantly increase the strength of the greenhouse frame structure, it is necessary to increase the distance between the inner and outerbelts of the arch by 1.5–2 times;

– it is recommended to replace the steel of the greenhouse frame structure with steel of a higher strength class S345 [8].

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