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Design and Statistical Analysis of the Cockpit for the Flight Simulator

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The subject of the study is the cockpit of a dynamic flight simulator. The flight simulator has been used for a long time for training pilots of any type of aircraft. This type of training is more economical. A flight simulator improves control skills in extreme situations with minimum risks for the future pilot. Training on the flight simulator makes it possible to reproduce unfavorable weather conditions at any time. The pilot is on the ground in a special cockpit that is mounted on a movable platform. This system is necessary to provide as close to real flight conditions as possible. The subject of the research in the article is an aviation simulator on the Stewart platform. The aim is to create and analyze the cockpit for the flight simulator with the help of software. The paper presents an already simulated platform and its characteristics. Considering its overall dimensions and weight the cabin is modeled in SolidWorks. The developed 3D model is a cockpit of an airplane with the selected overall dimensions for convenient use. The balsa material from which the cabin is projected, as they are not important aerodynamic characteristics. What matters is the ability of the cabin to withstand the planned loads, the weight of the cabin and its appearance. A static analysis of the loaded cabin was conducted. A loaded cab means that inside the cab the loads are applied in two places. These loads are equal to the weight of the pilot's seat with a person and the weight of the entire electronic part by means of which the movement of the cockpit and visualization of the flight takes place. For the analysis, the cockpit was fixed at the attachment points to the platform. The attachment will be done by welding. The analysis includes the following shear and bending moment diagrams: loads to assess the structure withstand a given weight, displacement, deformation, safety margin to understand what the maximum possible loads the model can withstand without deformation. The research was conducted using SolidWorks Simulation software. Based on the data obtained from the epectra, conclusions were made about the operability and safety of the developed structure.

***Key words**:* flight simulator, cockpit, structure, model, load, static analysis, shear and bending moment diagrams, SolidWorks.

Introduction

The use of flight simulators is an important part of pilot training. There are many varieties of dynamic flight simulators on the Stewart platform, but their cost is very high. Therefore, the question of building a simulator, directly on a moving Stewart platform arises. The main problem is the choice of platform and cockpit design, considering the place of their installation and the loads they have to withstand. To solve this problem, let's simulate the cab and platform with SolidWorks software and analyze the loaded structure.

Analysis of recent research and publications

Despite the new results in the creation of air simulators, the relevance of their design will remain unchanged not only because of the complexity of the design, but also because of the very high price. Therefore, the possibility of performing calculations using software (ANSYS, SolidWorks) by the finite element method[1] is also necessary.

In the article [2], different designs of Stewart platforms were investigated by finite element analysis using ANSYS software.

In the articles [3-6] several varieties of the platform were considered and mathematical calculations were performed for each of them. For a platform with six degrees of freedom, direct and inverse problems of platform dynamics (loaded and unloaded) and equilibrium positions were calculated.

The articles [7, 12] describe the process of modeling, development and control of the Stewart platform using SolidWorks and Matlab-Simulink software and the use of PID controllers.

The articles [14, 15] describe various options for improving the simulators by improving optimization methods and using a transmission drone, which takes place in the sky in real time.

1 The main part

A flight simulator is a simulator that provides ground training for pilots by making the conditions as close to the real ones as possible. Training pilots not only on a real aircraft, but with the help of simulators significantly improves results [8].

Training on a flight simulator can prepare a pilot for difficult and unpredictable cases. They are related to system malfunction, engine failure or dangerous meteorological conditions. When flying a real aircraft, it is not possible to deliberately obtain such conditions, and it is too dangerous for the aircraft crew [9].

To reproduce the flight as much as possible, flight simulators are mounted on a moving platform and replicate the cockpit of a real aircraft. Such a cockpit is equipped with advanced technology to use virtual and augmented reality. The mobility of the platform and the presence of VR and AR allows you to feel the authenticity of flight [16].

The platform for which the cabin is modeled and calculated is shown in Fig. 1.

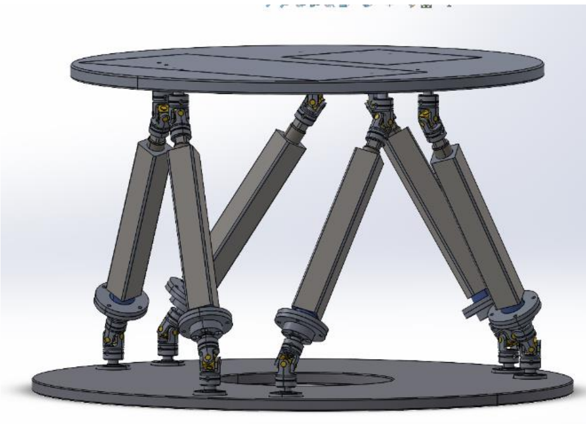

Figure 1 - Stewart platform for the flight simulator

The presented platform was modeled taking into account the theoretical data of the cabin, so the diameter of the upper movable platform is 2.8 meters.

The Stewart platform is a mechanism with one moving platform and six degrees of freedom. The platform is able to move in three linear and three angular directions thanks to the so-called legs, in which the length is automatically changed, they can move separately from each other or in any combination. Each leg is connected by a hinge to the ground [10].

The cabin of the flight simulator was designed for small rooms, but with the ability to install all the necessary instruments. The cockpit layout is shown in Figure 2.

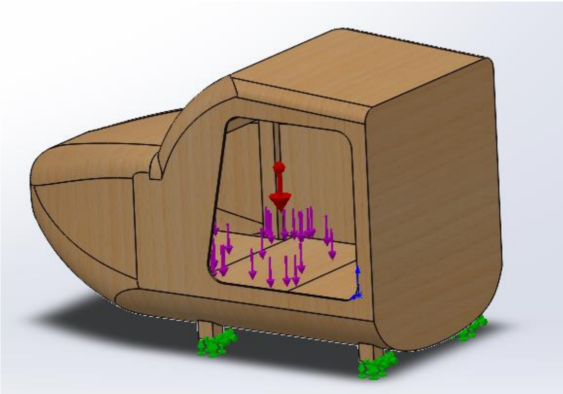

Figure 2 - Layout of the cabin

Based on the data about the location of the simulator and the dimensions of the moving platform, it was accepted that the height of the cabin cannot exceed 1.9 m and the length of 2.5 m, the cabin was modeled using SolidWorks.

Material - balsa was chosen for the cabin. Since the cabin is not designed for real flights, we do not need the aerodynamic characteristics.

These data are needed for a static analysis in SolidWorks Simulation. The 3D model of the loaded cabin and the SE (finite element) mesh is shown in Figure 3.

The high coefficient of curvature-based SE mesh was used for the reliability of the calculation. The maximum mesh element size is 11.2407 mm, the minimum is 3.74688 mm, the minimum number of elements in a circle is 15, with a total of 3804666 elements. Thanks to such grid parameters, we provide calculation accuracy.

The external loads on the interior of the cab were specified in two locations of 2000N and 3000N. The first is the place of equipment installation, which corresponds to the size and approximate weight of the necessary equipment. The second is the "pilot" seat, taking into account the weight of the seat and the approximate weight of the person.

The model is completely fixed by the bottom for analysis, because in real life the cockpit will be fixed on the platform in this way.

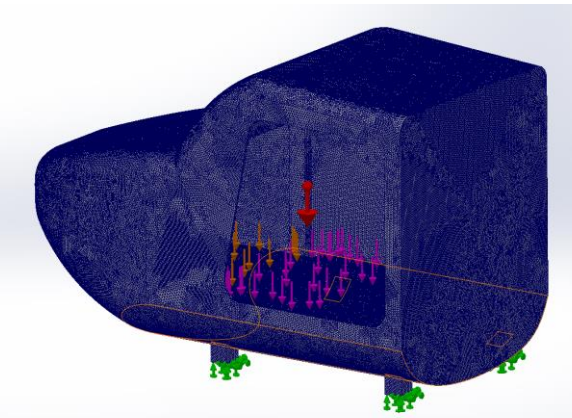

Figure 3 - 3D model of the loaded cabin and grid

For statistical analysis, not only the forces exerted from the equipment and the pilot, but also the force of gravity were taken into account.

The results of the static analysis are shown in Figures 4, 5, 6.

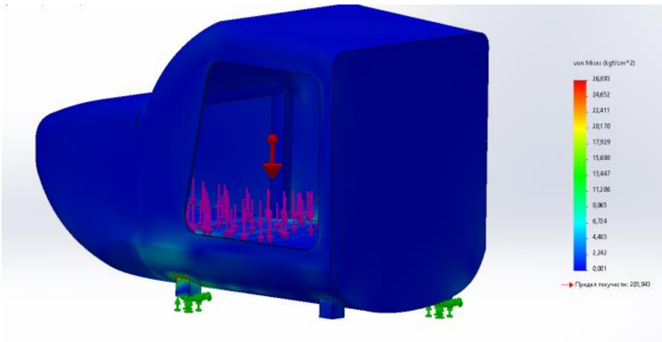

Figure 4 - Static analysis (stress diagram)

The stress, at the load we need, is formed at the attachment points of the legs to the moving platform. The maximum stress value is less than the yield strength and has a numerical value of 26893 kg/cm2.

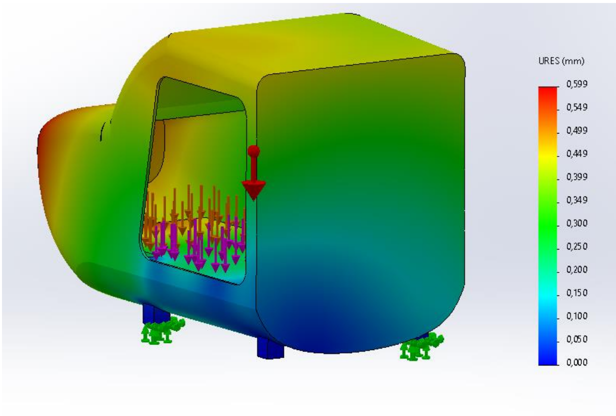

Figure 5 - Static analysis (displacement diagram)

From the displacement diagram we see that the maximum displacement occurs in the forward part of the cabin, but does not deform it. The largest displacement is 0.589 mm in the area with the red color.

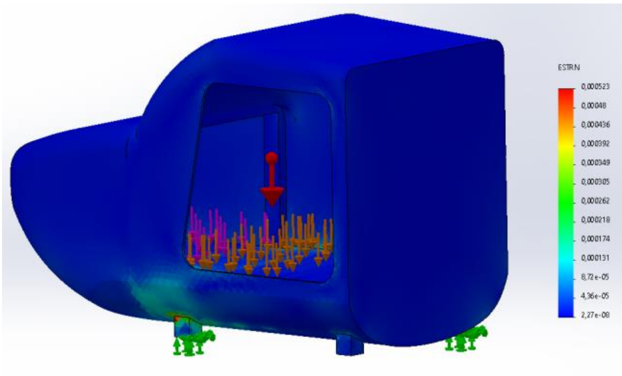

Figure 6 - Static analysis (strain diagram)

The deformation diagram shows that the largest deformation occurred at the attachment points of the cab to the upper platform. In the deformed state, the cabin remains suitable for use, because there were no significant changes in the structure. Based on the data obtained, we can see that the weakest place is the attachment areas, so if the platform is constantly used, regular checks of the condition of the attachments are necessary to prevent accidents and life-threatening situations.

In order to obtain a holistic picture, shear and bending moment diagram of the safety margin was constructed (Figure 7).

The safety margin check was based on the Von Mises (VM) fracture criterion. This criterion is based on the Mises-Hencki theory, the so-called energy theory of forms of change. According to this theory, the plastic material begins to fail where the Von Mises stress equals the ultimate stress. In our case, we take the yield stress as the limiting stress.

Safety margin (FOS) = $\frac{\sigma_{\text{Limit}}}{\sigma_{\text{VM}}}$

$$\sigma_{\text{VM}} = \sqrt{(\sigma_1 - \sigma_{2)})^2 + (\sigma_2 - \sigma_{3)})^2 + (\sigma_1 - \sigma_{3)})^2 \cdot 0.5} \qquad (1)$$

where: $\sigma_1,\ \sigma_2,\ \sigma_3$ – main stresses[11].

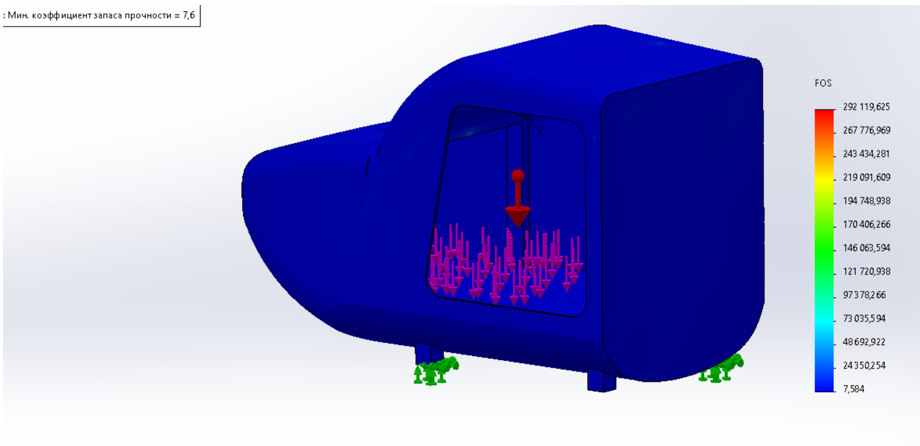

Figure 7 - Safety margin

The minimum safety margin is 7.6, so that the structural integrity will not be compromised. Therefore, the use of this cab is quite safe.

Conclusions

In this article the cabin for dynamic flight simulators is investigated.

In the course of the work the design of the moving platform was demonstrated, a 3D model of the cabin was developed, based on which the analysis was carried out using SolidWorks Simulation, for this model was fixed to the lower part, and the load of 3000N and 2000N was applied to the inside of the cabin in two places, a grid was created and the following shear and bending moment diagrams were built: stress, movement, deformation and safety margin. Based on the data obtained from the shear and bending moment diagrams, it can be concluded that this model can withstand the specified loads, and the resulting stresses and strains do not affect the integrity of the structure.

The results of the work performed will help in creating and calculating not only the cabin in question, but any mechanism or part to be manufactured to avoid problems during operation.

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Проєктування та статистичний аналіз кабіни пілота для авіатренажеру

Предметом вивчення є кабіна динамічного авіатеранжера. Авіатренажери вже великий проміжок часу використовують для підготовки пілотів будь-якого типу літаків. Такий вид тренувань більш економічний. Авіасимулятор покращує навички керування в екстремальних ситуаціях з мінімальними ризиками для майбутнього пілота. Навчання на авіасимуляторі дає змогу відтворити несприятливі погодні умови в будь-який період часу. Пілот знаходиться на землі в спеціальній кабіні, яка встановлюється на рухому платформу. Дана система потрібна для забезпечення максимально наближених до реальних умов польоту. Предметом дослідження в статті є авіаційний симулятор на платформі Стюарта. Мета полягає в створенні та аналізу кабіни для авіасимулятору за допомогою програмного забезпечення. В роботі представлено вже змодельована платформа та її характеристики. Враховуючи її габаритні розміри та масу змодельовано кабіну в системі SolidWorks. Розроблена 3D модель представляє собою кабіну літака з підібраними габаритними розмірами для зручного використання. Підібрано матеріал бальса з якого проєктується кабіна, так як нам не важливі аеродинамічні характеристики. Важлива можливість кабіни витримувати заплановані навантаження, вага кабіни та її зовнішній вигляд. Проведено статичний аналіз навантаженої кабіни. Під навантаженою кабіною мається на увазі, що в середині кабіни прикладені навантаження в двох місцях. Ці навантаження рівні вазі крісла пілота разом з людиною та вага всієї електронної частини за допомогою якої відбувається рух кабіни та візуалізація польоту. Для проведення аналізу кабіна була зафіксована за місця кріплення до платформи. Кріплення буде відбуватись за допомогою зварювання. Аналіз включає в себе такі епюри: навантажень, щоб оцінити витримає конструкція задану вагу, переміщення, деформації, запасу міцності, щоб зрозуміти які максимальні можливі навантаження може витримати модель без деформацій. Дослідження проводились за допомогою програмного забезпечення SolidWorks Simulation. На основі даних отриманих з епюр зроблені висновки про працездатність та безпечність розробленої конструкції.

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