

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF
KAZAKHSTAN



School of Industrial Automation and Digitalization
Department of Industrial Engineering

Made by: MasheyevaRamina

CAD/CAE design of unnamed aerial vehicle design

DIPLOMA WORK

Specialty 5B071200 – Mechanical Engineering

Almaty 2020

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF
KAZAKHSTAN

Kazakh National Research Technical University named after K.I.Satbayev
Institute of Industrial Automation and Digitalization
Department of Industrial Engineering

APPROVED FOR DEFENSE

Head of the Industrial
Engineering Department, PhD
Arymbekov B.S.

“ ” _____ 2020

DIPLOMA WORK

Topic: "CAD/CAE design of unnamed aerial vehicle design"

5B071200-Mechanical Engineering

Performed by

Masheyeva R.K.

Reviewer

Scientific adviser

Candidate of Technical Sciences,
Associate Professor

_____ Isametova M.E

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TASK

for completing the diploma work

For student: Masheyeva Ramina Kanyshkyzy

Topic: "CAD/CAE design of unnamed aerial vehicle design"

Approved by the order of university rector №762-b from "27" January 2020

Deadline for completion the work "24" May 2020

Initial data for the diploma project: Basic information about unmanned aerial vehicle

Summary of the diploma work:

- a) *Description of UAV;*
- b) *CAD/CAE systems;*
- c) *CAE ANSYS Workbench calculations.*

List of graphic material: Graphical representations of details of unmanned aerial vehicle

Recommended main literature:

1. Encyclopedia of Physics (2nd Edition), R.G. Lerner, G.L. Trigg, VHC publishers, 1991
2. Svishev. G, "Aviation: Encyclopedia" Russian Encyclopedia, 1994
3. McClamroch, N. Harris. "Steady Aircraft Flight and Performance." Princeton University Press, 2011

THE SCHEDULE

For the diploma work preparation

Name of sections, list of issues being developed	Submission deadlines to the scientific adviser	Notes
Main features of unmanned aerial vehicles	20.03.2020	
Construction of aerial vehicle in KOMPAS-3D	30.03.2020	
General introduction and acknowledgement of ANSYS	10.04.2020	
Calculations results	25.04.2020	

Signatures

Of consultants and standard controller for the completed diploma work, indicating the relevant sections of the work (project).

The section titles	Consultant name (academic degree, title)	Date	Signature
Main part	Candidate of Technical Sciences, Isametova M.E	25.04.2020	
Normcontrol	Candidate of Technical Sciences, Isametova M.E	15.05.2020	

Scientific adviser

Signature

Candidate of Technical Sciences, Isametova M.E

The task was completed by student:

Signature

Masheyeva R.K

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Signature

Candidate of Technical Sciences, Isametova M.E

The task was completed by student:

Signature

Masheyeva R.K

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Department of Industrial Engineering

GRADUATE WORK

CAD/CAE design of unnamed aerial vehicle

5B071200- Mechanical Engineering

Made by

Masheyeva R.K.

Scientific director Isametova M.E associate
professor

Almaty 2020

ANNOTATION

The main purpose of the group project is creating of unmanned aerial vehicle using modern technologies of designing, modeling and construction. First of all, we have to understand primary activities that given vehicle has to perform. Basically, the given unmanned aerial vehicle is going to be used by fire safety facilities. In case of large fire in city environment when firefighters do not have an access to hard to reach premises. Designing and construction of such vehicle has to include specific features like sufficient materials, simplicity and sustainability to fire.

Till nowadays there are lots of different existing method for modeling and construction that include various programs and software. The given diploma work will include CAD/CAE designing of unmanned aerial vehicle. These programs are the most available and simple in usage. Design includes drawing of working schemes of the body parts of UAV.

The vehicle itself consists of some complicated spare parts and joints. In order to simplify the process of further construction and mass-production, 3D printing CAM systems are going to be used. So the primary idea is to simplify designs and drawings as much as it possible. Excluding unnecessary complicated schemes and emphasizing the work on the case of the UAV, theoretical research work has been made in order to suit and increase easiness of applying finished drawings in 3D printing machine.

The relevance of given diploma work could be best described by explanation of the role of UAV in modern human life. This information is also going to be present in the paper.

АННОТАЦИЯ

Основная цель группового проекта - создание беспилотного летательного аппарата с использованием современных технологий проектирования, моделирования и строительства. Прежде всего, мы должны понять основные действия, которые должен выполнить данный аппарат. По сути, данный беспилотный летательный аппарат будет использоваться средствами пожарной безопасности. В случае сильного пожара в городской среде, когда пожарные не имеют доступа в труднодоступные помещения. Проектирование и конструкция такого транспортного средства должны включать в себя определенные особенности, такие как достаточное количество и бюджетность материалов, простота и устойчивость к пожару.

До настоящего времени существует множество различных существующих методов моделирования и конструирования, которые включают в себя различные программы и программное обеспечение. Данная дипломная работа будет включать проектирование CAD / CAE беспилотного летательного аппарата. Эти программы являются наиболее доступными и простыми в использовании. Конструкция включает в себя чертеж рабочих схем кузовных частей БПЛА.

Само транспортное средство состоит из некоторых сложных запасных частей и соединений. Чтобы упростить процесс дальнейшего строительства и массового производства, будут использоваться системы 3D-печати САМ. Поэтому основная идея заключается в том, чтобы максимально упростить дизайн и чертежи. Исключая ненужные сложные схемы и делая упор на корпусе БПЛА, были проведены теоретические исследовательские работы с целью подбора и повышения простоты применения готовых чертежей в 3D-печатной машине.

Актуальность данной дипломной работы лучше всего можно объяснить объяснением роли БПЛА в жизни современного человека. Эта информация также будет присутствовать в статье.

АННОТАЦИЯ

Топтық жобаның негізгі мақсаты заманауи дизайн, модельдеу және құрылыс технологияларын қолдана отырып, ұшқышсыз ұшу аппаратын жасау болып табылады. Біріншіден, біз осы аппараттың негізгі орындайтын әрекеттерін түсінуіміз керек. Шын мәнінде, бұл ұшқышсыз ұшу аппараты өрт қауіпсіздігі жабдығы ретінде пайдаланады. Қалалық ортада, қатты өрт болған кезде, өрт сөндірушілер қол жетімді емес жерлерге кіре алмайтын кезде. Мұндай құрал жобалау мен салу белгілі бір ерекшеліктерді қамтуы керек, мысалы, материалдардың жеткілікті саны мен бюджетті болуы, қарапайымдылық және отқа төзімділік.

Бүгінгі күні модельдеу мен дизайнның әртүрлі әдістері бар, олардың құрамына әртүрлі программалар мен бағдарламалық қамтамасыздандыру программалары кіреді. Бұл дипломдық жұмыста CAD / CAE программалары арқылы ұшқышсыз ұшу аппараттарының дизайнын жобалау кіреді. Бұл бағдарламалар ең қол жетімді және пайдалануға оңай болып саналады. Құрылыс ҰҰА дене бөліктерінің жұмыс сызбаларын қамтиды.

Аппарат өзі күрделі бөлшектер мен қосылыстардан тұрады. Әрі қарай салу және жаппай өндіріс процесін жеңілдету үшін CAM 3D басып шығару жүйелері қолданылады. Сондықтан басты идея – мүмкіндігінше дизайн және сызбаларды жеңілдету. Қажетсіз күрделі сызбаларды жойып, ҰҰА корпусына басты назар аудара отырып, 3D баспа машинасында дайын сызбаларды таңдау және көбейту мақсатында теориялық зерттеулер жүргізілді.

Бұл дипломдық жұмыстың өзектілігін қазіргі заманғы адамның өміріндегі ҰҰА-ның рөлін көрсетумен түсіндіруге болады. Бұл ақпарат мақалада болады.

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1. Introduction

1.1 Definition of unmanned aerial vehicle

Thanks to the development of electronics in recent years, it has become possible to create an automatic control system and design for multi-rotor UAVs.

An unmanned aerial vehicle (shortly UAV) is an aircraft piloted remotely or flying autonomously, without the assistance of a human. UAVs are equipped with electronics, special equipment, and powerful shielding of case. They are usually quite compact in size for less noticeability, but can also have large sizes comparable to full-size aircraft. Small sizes of the vehicle are obtained due to the absence of a human, human's life support systems, control and information output systems.

Even now, manned aircraft are much more expensive than drones both in terms of service and in terms of production. While a conventional aircraft requires pilots' protection and life support systems, an unmanned aerial vehicle is extremely compact and convenient. Not including the costs of training specialists and operators, drones are already highly necessary alternative aerial vehicle.

1.2 Relevance of the topic from a large-scale view

Using of unmanned devices are most relevant for those industries where both mobility and high quality information are required. In particular, industries that needs to regulate and control features on distant territories are very keen on using drones. The integration of such devices in the daily operational process will help to create great benefits in the implementation of any kinds of projects.

It should be noted that due to the high speed of development of modern technologies, all devices in such industries are rapidly aging. One of the key features of the designing described in this paper is the use of the most convenient systems available today. The simplicity will play a big role in further manufacturing and mass-production.

2. UAV classification

2.2 Some principles of division of the types of UAV

There are three basic principles for controlling an unmanned aerial vehicle

- automatic control;
- remotely piloted control
- mixed type of management.

A particular component of the main sort of UAV control is the finished computerization of the undertaking. This kind of control requires the high caliber of the created framework to comprehend the errand, for instance, following the way dependent on sensors on board the UAV. A component of the second sort of UAV control is that the steering of the gadget is done utilizing some transmitting gadget in manual control mode. The third sort of control consolidates the highlights of the first and second kind of control.

When playing out the assignment in disconnected mode, flight conditions may change that require a choice from the pilot of the gadget, because of which the UAV can be changed to manual control mode, to maintain a strategic distance from a basic circumstance and afterward come back to the robotized flight mode

Three main types of UAV should always be considered:

1. unmanned uncontrolled; (balloons, free balloons)
2. unmanned automatic;
3. unmanned remotely piloted aircraft (UAVs). UAVs are usually divided according to such interrelated parameters as mass, time, range and flight altitude.

Fundamental points of interest of using UAV:

1. arrangement speed (on planned flights, setting up a model for activity takes from 20 to 30 minutes, which is advantageous)
2. the capacity to be overhauled by a couple of administrators
3. high versatility, the utilization of portable and portable control stations
4. present day video frameworks and continuous data transmission frameworks that are not sub-par compared to, and some of the time outperform in their qualities, the frameworks utilized in helicopters and airplane (scope of up to 150 km)
5. varying media least perceivability, the capacity to lead incognito reconnaissance
6. lack of strict requirements for the launch pad
7. strong economic performance

2.2 Multicopters

Multicopters have an even (from 4 to 12) number of consistent pitch propellers (there is no automatic swashplate, unlike single- and twin-screw machines). Each screw is driven by its own motor. Half of the screws turn clockwise, half - against, so the multicopter needn't bother with a tail rotor. Multicopter move by changing the speed of turn of the screws. For instance, accelerate all the screws - lift; accelerate the screws on one side and delayed down on the other - sideways development; accelerate the clockwise turning screws and hinder the counterclockwise pivot. In this work 6-motor UAV is considered, shown in Pic.1.



Pic.1. Graphical representation of the designed UAV

The microchip framework makes an interpretation of radio control orders into orders for motors. To guarantee stable floating, multicopter as a matter of course give three gyroscopes that fix the move of the gadget. As a helper instrument, in some cases an accelerometer is likewise utilized, the information from which permits the processor to set a completely level position, and a barosensor that permits you to fix the gadget at the ideal stature.

The following is an explanation of gyroscope and accelerometer terms. A gyroscope is a quickly pivoting strong, the hub of revolution of which can alter its course in space, the least difficult is a top (spinning top). The accelerometer is a gadget fit for estimating the increasing speed of an article, which it procures when moved comparative with its zero position. The accelerometer is utilized both for estimating the speeding up toward the path to which the uprooting happened, and for estimating the increasing speed brought about by the gravity of the Earth.

3. CAD systems

3.1 CAD systems definitions and basics

Computer-aided design (CAD) is a computer technology that designs a product and documents the design's process. CAD may facilitate the manufacturing process by transferring detailed diagrams of a product's materials, processes, tolerances and dimensions with specific conventions for the product in question. It can be used to produce three-dimensional diagrams, which can then when rotated to be viewed from any angle, even from the inside looking out.

CAD is used as follows:

- To produce detailed engineering designs through 3-D and 2-D drawings of the physical components of manufactured products.
- To create conceptual design, product layout, strength and dynamic analysis of assembly and the manufacturing processes themselves.
- To prepare environmental impact reports, in which computer-aided designs are used in photographs to produce a rendering of the appearance when the new structures are built.

CAD systems exist today for all of the major computer platforms.

Most universities no longer require classes for producing hand drawings. Instead, there are many classes on different types of CAD software. Because hardware and software costs are decreasing, people at universities and manufactures learn how to use these high-level tools. These tools have also modified design work flows to make them more efficient, lowering these training costs even further.

3.2 KOMPAS-3D modeling system

The main tasks of the KOMPAS-3D system are solving the formation of a three-dimensional model of the part in order to transfer the geometry to various calculation packages. Also it is aimed to development packages of control programs for Computer Numerical Control equipment, as well as the creation of design documentation for the modeled parts.

Parts designed in KOMPAS-3D can be transferred to create assembly units in other three-dimensional modeling systems.

Data can be transferred from KOMPAS-3D to other systems through standard exchange formats - IGES and SAT. To transfer the geometry of a part to stereolithographic equipment, the STL format is used. Some functions of KOMPAS-3D are designed specifically for the quick implementation of standard design techniques.

A convenient technique for modeling products that differ only in some structural elements is the use of a previously workpiece part as the base. A

workpiece part can be inserted into the model by saving the link to the file containing it. In this case, any changes to the model in the source file will be transferred to all models containing this workpiece. The use of a workpiece in some cases can significantly speed up the system when parts of high complexity are designed

To repeat operations, KOMPAS-3D provides various options for copying commands: copying along a parallelogram and concentric grid, along a curve, mirror copying. It should also be noted the possibility of copying not only individual elements, but also sets of elements and arrays of copies, as well as the ability to delete individual instances from an array of copies.

KOMPAS-3D provides the user with various means of obtaining flat images of the model. In this drawing, all the commands for editing the image, setting dimensions and technological designations are available.

When creating flat images of a part, you can select not only its standard projections, but also any custom orientation of the part. This allows you to quickly get high-quality images of parts for catalogs, text documents, etc.

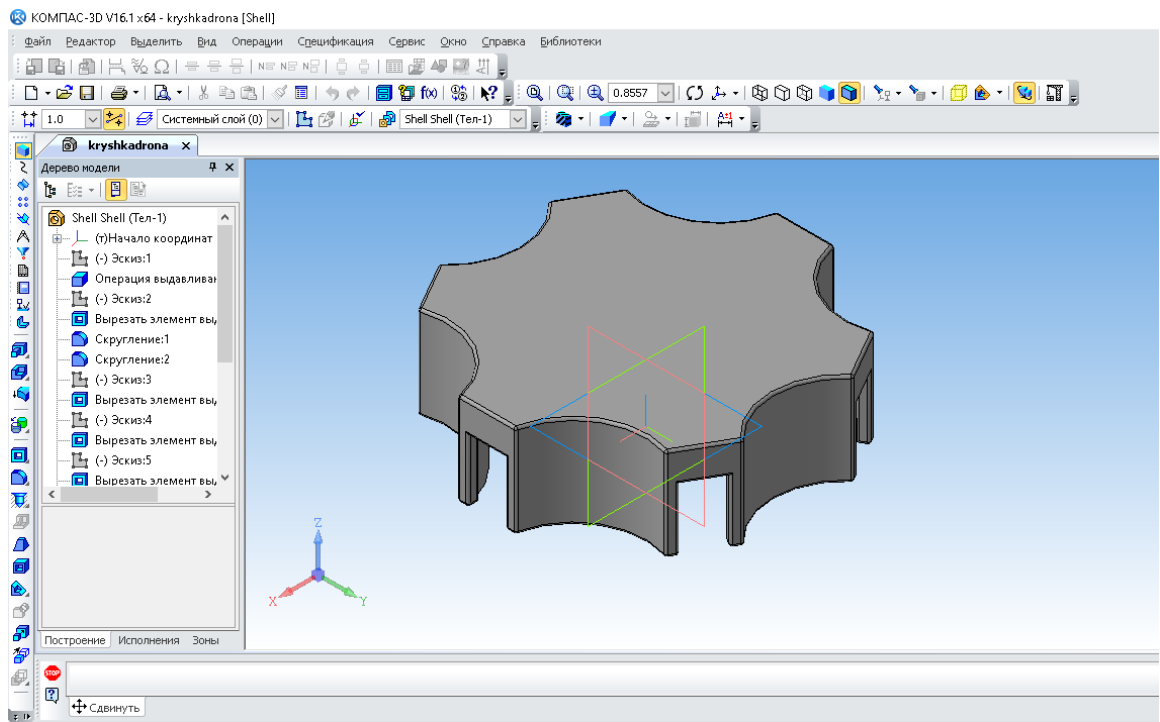
It is also allowed to create cross-sections of the parts. Usually, when using a three-dimensional modeling system, a product model is first created, and after its flat images are created.

However, sometimes it is necessary to build a three-dimensional model of a part, the scheme for which has already been released. And here is the complete integration of the components of the KOMPAS - KOMPAS-3D and KOMPAS-GRAPHIC system appears.

3.2 UAV designing in KOMPAS-3D

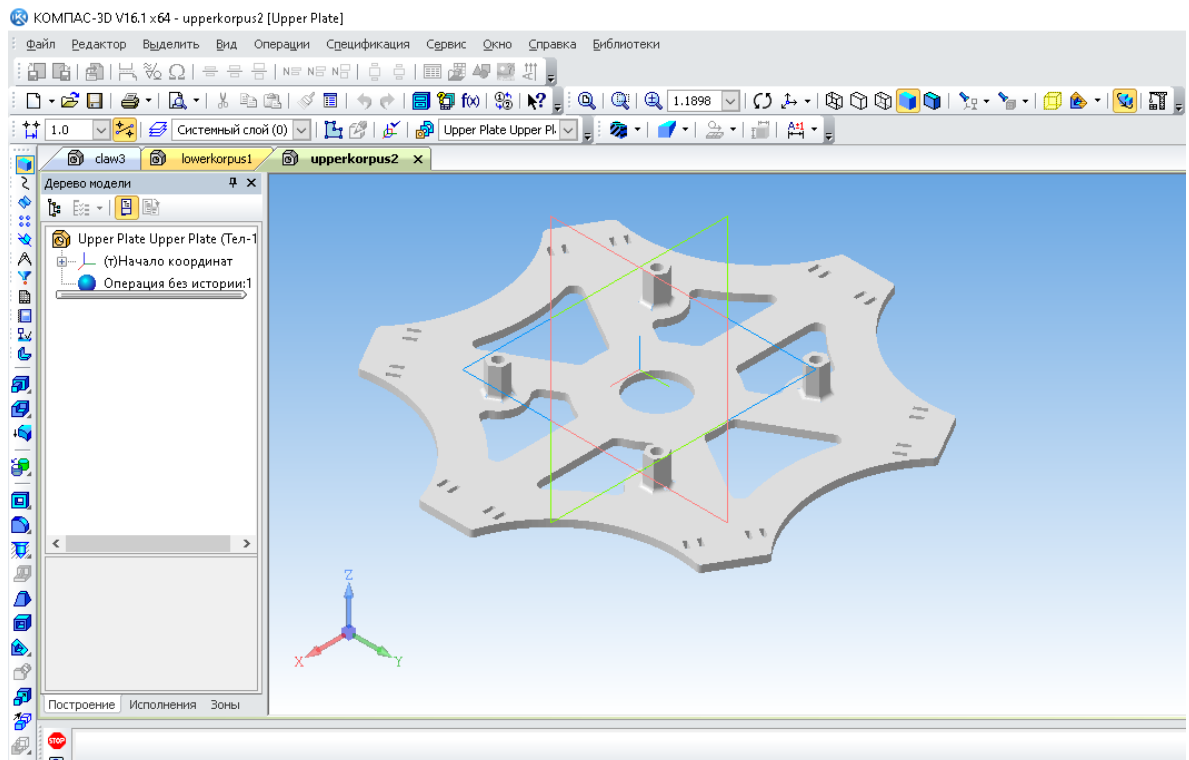
In given diploma work 4 details of the UAV were constructed: shell, upper and lower plates, claw. Each of them were constructed with consideration of specific shapes and application features. All the dimensions and proportions were chosen accordingly to final expected model. Drawings began from the frame taking into account all of the electronic parts, and one of the goals was to make it as light in weight as possible because of the excrescent weight of the specialized bucket that holds the firefighting liquid. Short review on main details is going to be presented.

The shell was made of plates, using curvy and straight lines. Mirroring of objects was also necessary when creating the figure. Piece is shown in Pic.2.

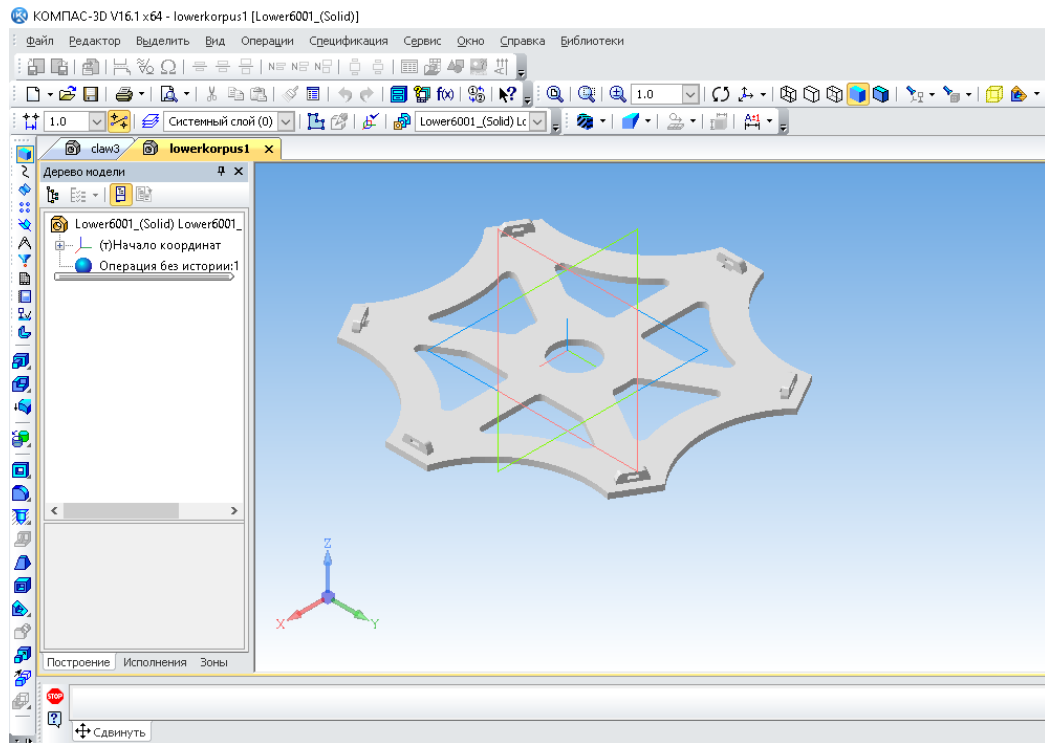


Pic.2. 3D model of a Shell of UAV

The upper plate (see Attachment A) and the lower plate (see Attachment B) were designed firstly in the way to perfectly fit to each other. Moreover, dimensions were chosen proportionally to the shell. Pieces are shown in Pic.3. and Pic.4. respectively.

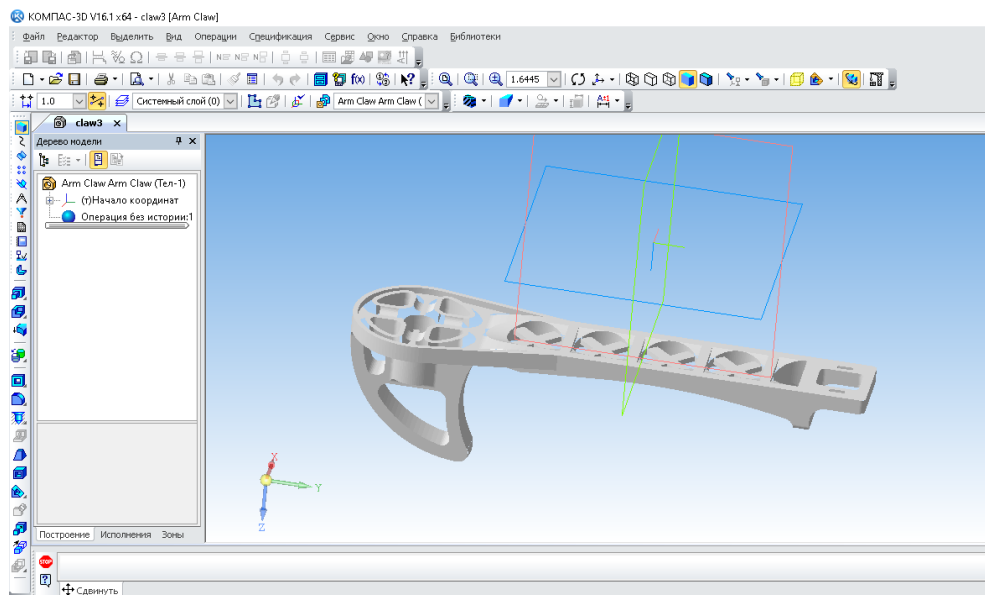


Pic.3. 3D model of an Upper plate of UAV



Pic.4. 3D model of a Lower plate of UAV

Designing of the claw (see Attachment C) was more complicated due to the range of different shapes and necessity to connect separated details. The other tricky feature is that lots of different holes are required to be made in order to be able to connect details in the future. The advantage of virtual modeling is the ability to identify weaknesses in the structures of the tested objects and determine the specific characteristics of the tested objects without using real models. Piece is shown in Pic.5.



Pic.5. 3D model of a Claw of UAV

The final 3D model of our UAV that was obtained by connecting details and including some construction features is shown in Pic.7.



Pic.6. Solid 3D model of UAV hexocopter.

4 CAE systems

4.1 CAE systems definitions and basics

CAE is a framework applied for computerization of designing computations, investigation and recreation of physical procedures, complete powerful demonstrating, check and streamlining of items. Building examination frameworks are intended to consider the conduct of an item utilizing its geometric model - when in doubt, such a model is made in the CAD framework. On account of the created CAE-frameworks, the main items gathered in a genuine workshop show all the attributes set somewhere around its creators and can be promptly delivered to the customer.

The most widely recognized are SAE frameworks that utilization the arrangement of frameworks of fractional differential conditions utilizing the finite element method (FEM).

The elements of building examination frameworks (CAE) have wide decent variety, as they are related with structure strategies for investigation, demonstrating, and enhancement of plan choices. The organization of building CAE frameworks fundamentally incorporates programs for the accompanying methodology:

- analysis of the kinematics and dynamics of the product with the determination of the trajectories of moving parts and active forces in the process of work;
- modeling of elastic-stressed, deformed, thermal state, structural vibrations, determination of critical loads. Most often performed in accordance with the finite element method;
- simulation of complex production systems based on models of mass service.

4.2. Finite element method

FEM cuts a structure into several elements (pieces of the structure). Then reconnects elements at “nodes” as if nodes were pins or drops of glue that hold elements together. This process results in a set of simultaneous algebraic equations. Positive sides of FEM:

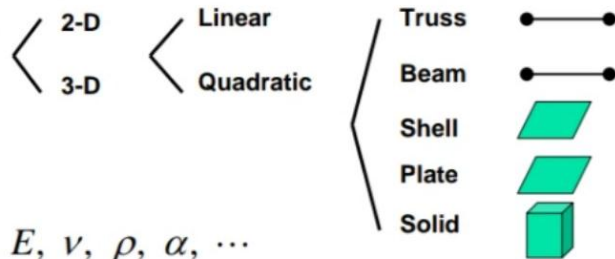
- Can promptly deal with exceptionally complex geometry.
- Can deal with a wide assortment of designing issue
- Can deal with complex limitations. Indeterminate structures can be solved.
- Can deal with complex loading: Nodal load, Distributed element loads, Time or frequency dependent loading.

For all CAE systems application of finite element method is performed in the same way as shown in Pic.7.

[1] Select analysis type

- Structural Static Analysis
- Modal Analysis
- Transient Dynamic Analysis
- Buckling Analysis
- Contact
- Steady-state Thermal Analysis
- Transient Thermal Analysis

[2] Select element type



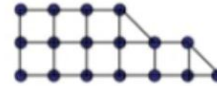
[3] Material properties

$E, \nu, \rho, \alpha, \dots$

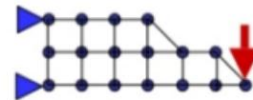
[4] Make nodes



[5] Build elements by assigning connectivity



[6] Apply boundary conditions and loads



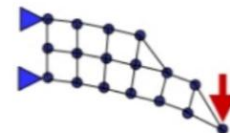
[7] Process

- Solve the boundary value problem

[8] Postprocess

- See the results

- Displacement
- Stress
- Strain
- Natural frequency
- Temperature
- Time history



Pic.7. The working principle of FEM

4.3. Introduction to ANSYS

ANSYS - a widespread programming arrangement of finite element method (FEM), existing and creating in the course of recent years, is very well known among masters in the field of computerized building estimations (CAD, or CAE) and FE for unraveling straight and nonlinear, fixed and non-fixed spatial issues mechanics of a deformable strong and basic mechanics (counting non-fixed geometrically and truly nonlinear issues of contact connection of auxiliary components), issues of liquid mechanics and for heat move and warmth move, electrostatics, acoustics, and mechanics-related fields.

ANSYS is an adaptable, solid structure and examination instrument. It works in the earth of the working frameworks of the most widely recognized PCs - from PC to workstations and supercomputers. An element of the program is the record similarity of all individuals from the ANSYS family for all stages utilized. The multi-reason direction of the program (i.e., the execution of apparatuses for depicting it framework reaction to impacts of different physical nature) permits you to utilize a similar model for taking care of related issues, for example, warm quality stacking, the impact of attractive fields on auxiliary quality, warmth and mass exchange in an electromagnetic field. A model made on a PC can be utilized on supercomputer. This furnishes all clients with advantageous highlights to understand a wide scope of building issues.

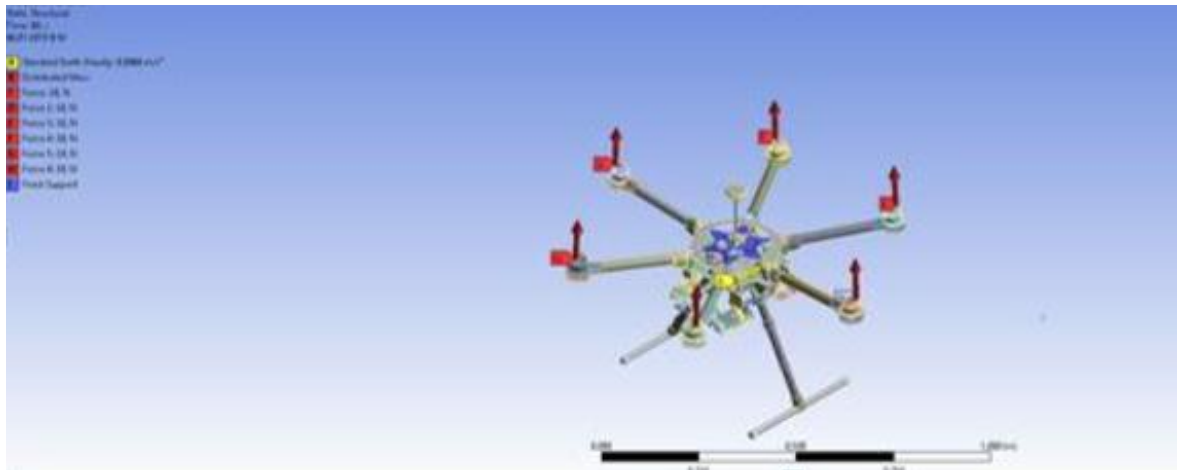
4.4. CAE Calculations of UAV in ANSYS Workbench.

For this machine with payload mass of 3 kilograms, it needs 6 N of thrust to function for each propeller. Following Table 1 shows values of set loads to the construction.

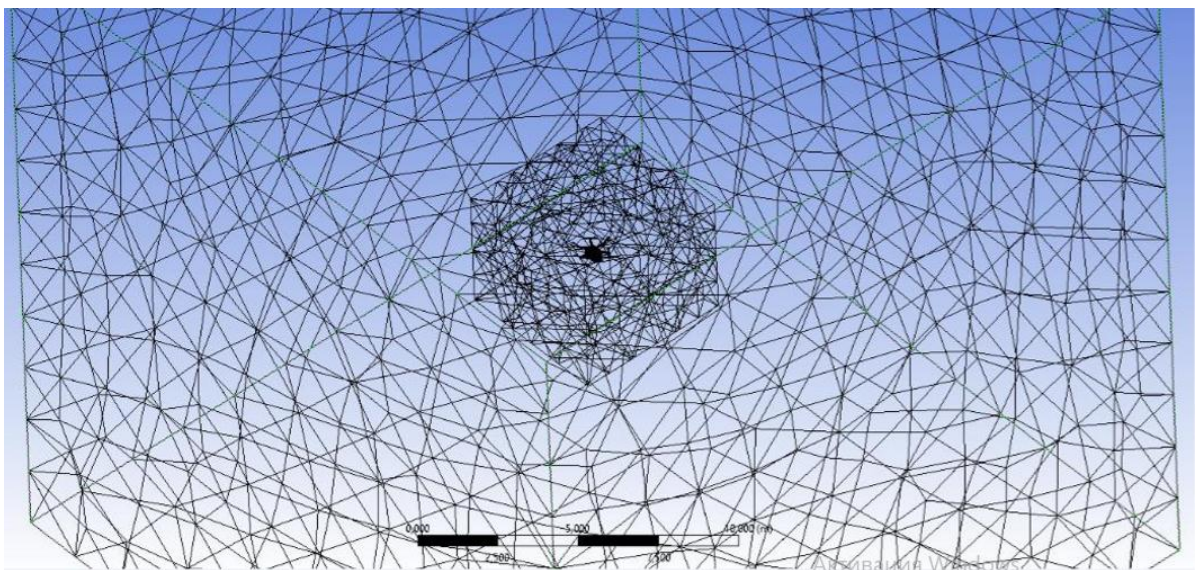
Type of the load	Value
Standard gravitational force	29.4 N
Thrust propeller 1	6 N
Thrust propeller 2	6 N
Thrust propeller 3	6 N
Thrust propeller 4	6 N
Thrust propeller 5	6 N
Thrust propeller 6	6 N
Payload	2 N

Table 1. Income data for calculations in ANSYS.

First of all, we imply 3D model of hexacopter that was constructed into the program and determine the loads to the parts of the construction that is illustrated in Pic.8. The program itself sets the finite element method for calculations. The net is constructed from three and four-sided elements. The Pic.9. shows the estimated surface mesh of FEM that was built considering future aerodynamic calculation.

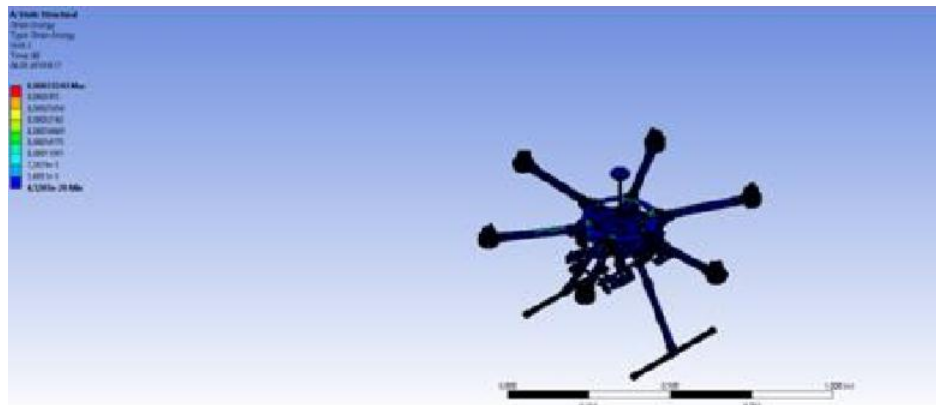


Pic.8. Set loads on 3D model of hexacopter.

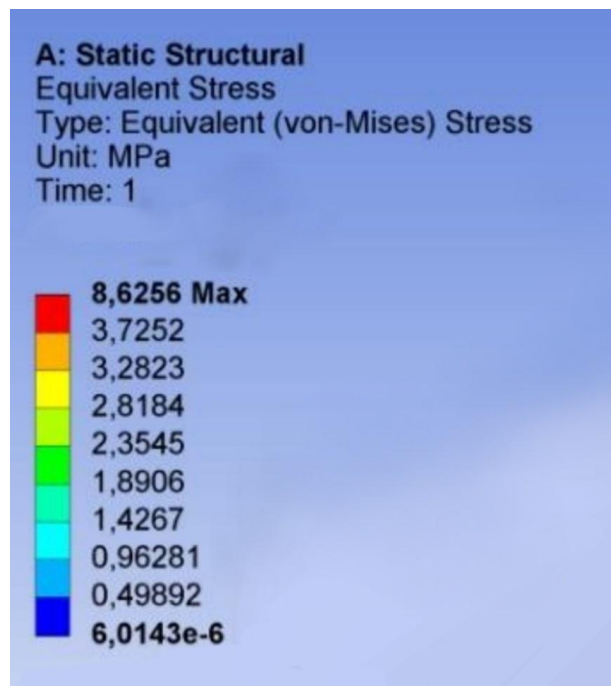


Pic.9. Finite element surface mesh of hexacopter.

Making calculations in the ANSYS program we obtain the results of stress distribution on our 3D model of UAV. The graphical representation of results is shown in Pic.10., the close look to the numerical results are given in Pic.11.

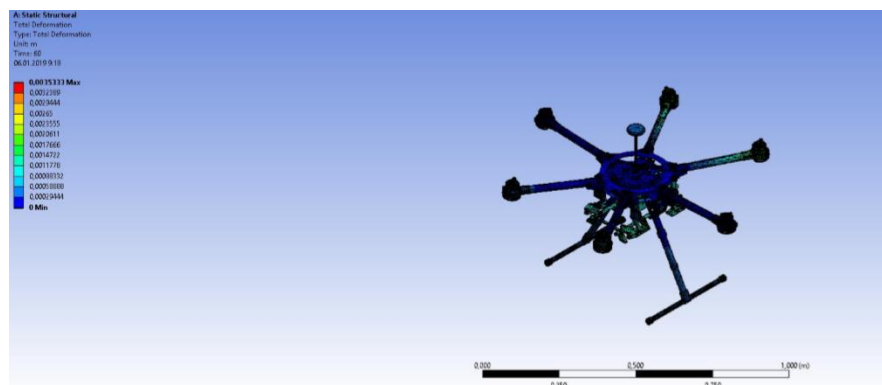


Pic.10. The results of the stress in the nodes of the construction



Pic.11. Close look to the numerical results of stress

Pic.12. shows the result of determining the deformation of the isometric hexacopter design. The following Pic.13. shows the close look to numerical results of deformation.



Pic.12. The result of determining of deformation of the hexacopter shown in isometry



Pic.13. Close look to the numerical results of deformation

As can be seen from the solution, the developed hexacopter design will provide the necessary strength, and will not collapse, being, all the time, within the elasticity range.

Until this point in time, the best method to evaluate the any kind of properties of a mechanism is to use automated analysis systems (CAE). Among the current CAE devices, an uncommon job is played by edifices of the limited component strategy. These complexes allow simulation of the work of the investigated physical phenomenon. This is why ANSYS Workbench system was chosen in CAE analysis and stress and deformation calculations.

CONCLUSION

The given diploma work represents the features of modeling and designing of unmanned aerial vehicle aimed to fight big-scale fires in hard-to-reach places. Considering all the basics and features learnt in a bachelor course, the paper includes theoretical and schematic description of the process of designing UAV. Designing was conducted in CAD KOMPAS 3D and CAE ANSYS Workbench systems. Moreover, introduction to the UAV definitions and descriptions included. From the designed point of view, working drawings and 3D models clearly show the ability of implementing of the work to practical uses. Making the designing process plain and using accessible resources gives an opportunity for planning mass production of the machine.

Future perspectives are expected to be valuable in a modern world, where life is mostly automatized. Also positive environmental changes are highly expected due to the primary purpose of the usage of UAV.

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Лев. лист

Стр. №

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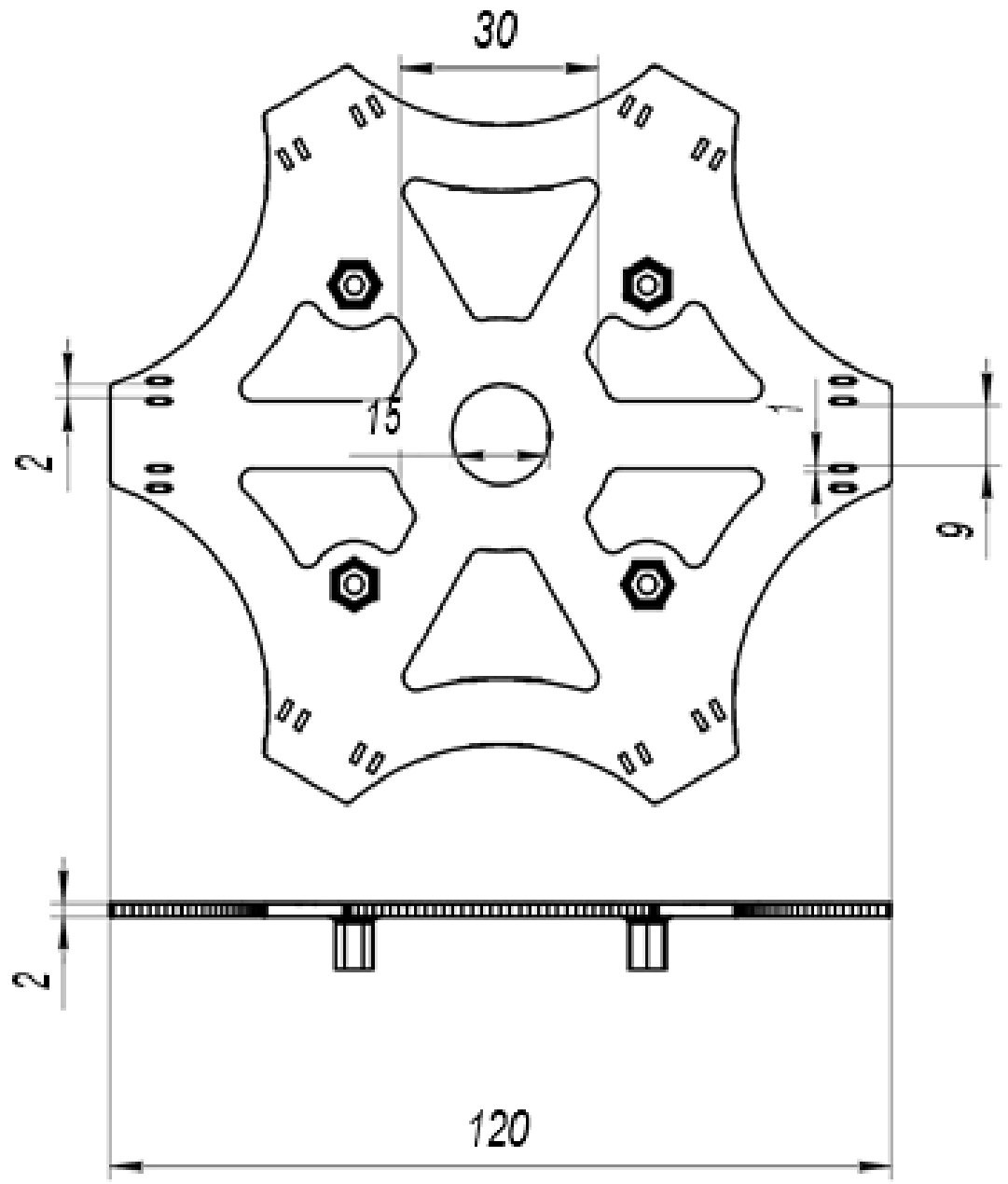
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Upper Plate

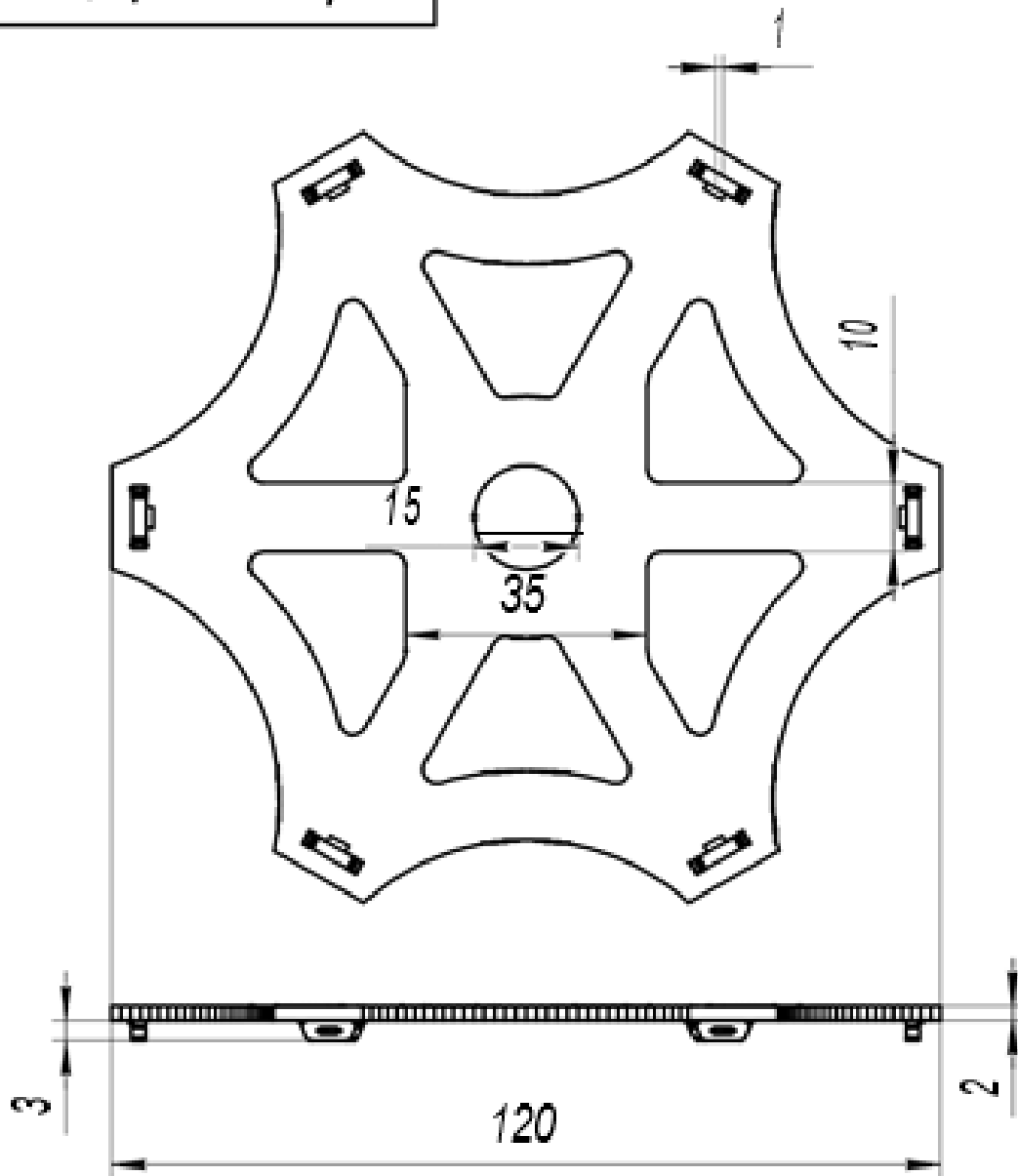


Разраб.	Машчэнева Н.
Прое.	Замецова М.
Т. кант.	
Н. кант.	
Уме.	

Upper Plate		
Ліст.	Маса	Масштаб
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Ліст	Лістаў	1
Abs Plastic		

Attachment A

Lower plate



Листовой

Слой №

Подкладка

Имя файла

Взам. инв. №

Подкладка

Имя файла

Разраб.	Masheveva R.		
Проект.	Sametova M.		
Уточн.			
Исполн.			
Утв.			

Lower plate

Lower plate

ABS Plastic

Кол.	Масса	Масштаб
1	0,1	1:1
Лист	Листов	

Активация Wind
Чтобы активировать раздел "Параметры".

Landing Gear

Листов. кол-во

Строч. №

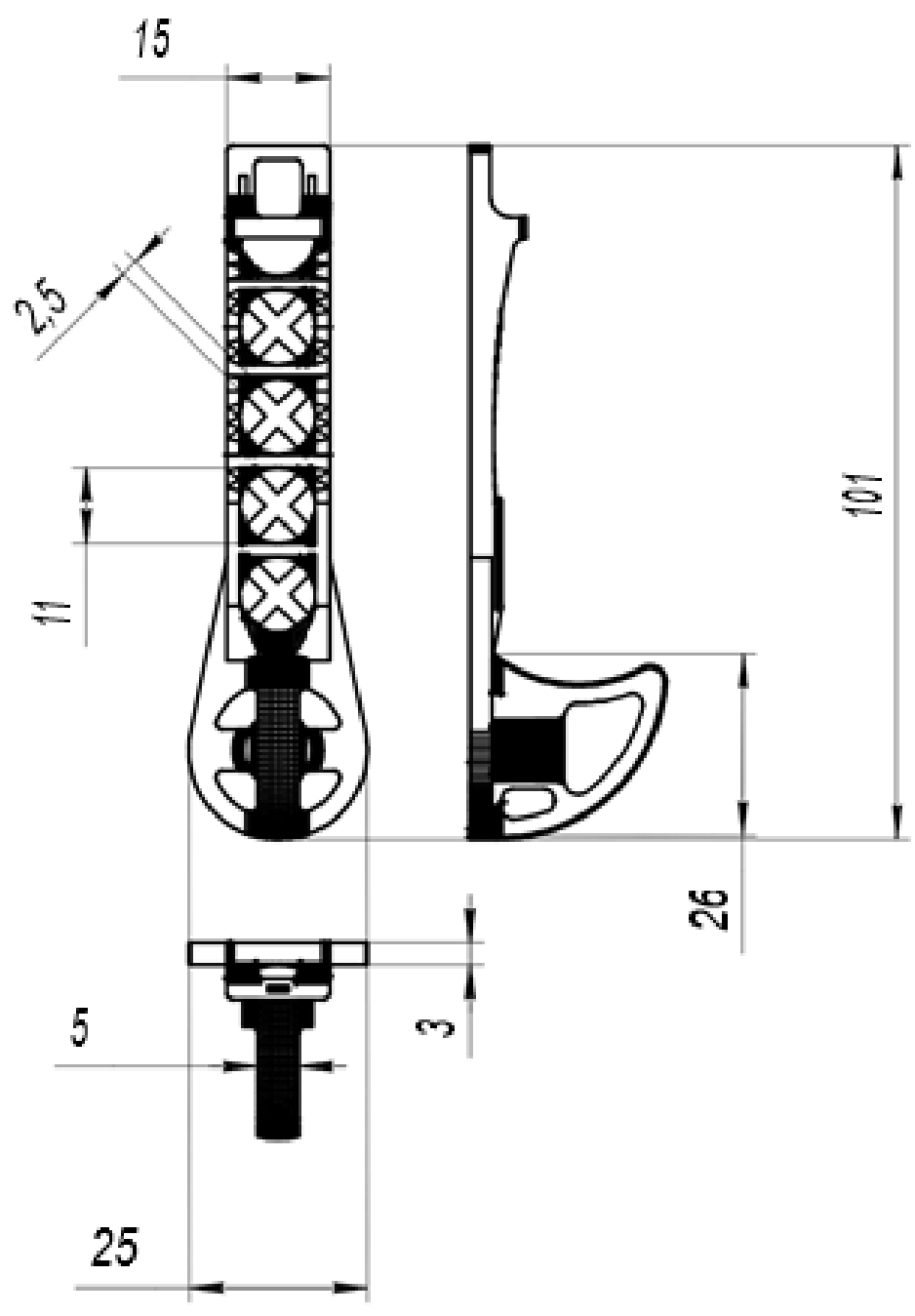
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Взам. лис. №

Подл. дата

Имя. Инициал.



Разработчик	Машерова Н.		
Проектировщик	Саметова М.		
Утвердил			
Имя. Инициал.			

Landing Gear		
Landing Gear	Лист	Масса
Abs Plastic	Листов	Максшк
		0,05
		1:1
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