MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

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 taking into account aerodynamic loads"

5B071200-Mechanical Engineering

Performed by Akzhigitova A.Z

Reviewer
____
____

"_____" _________2020

Scientific adviser
Candidate of Technical Sciences,
Associate Professor
______Isametova M.E
"_____" _________2020

Almaty 2020

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TASK
for completing the diploma work

For student: Akzhigitova Aruzhan Zhanserikovna
Topic: "CAD/CAE design of unnamed aerial vehicle design taking into account aerodynamic loads"
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) *Construction of unmanned aerial vehicle;*
b) *CAD/CAE systems;*
c) *Aerodynamic specifications of unmanned aerial vehicle.*

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
General information about unmanned aerial vehicle	15.03.2020	Task completed
Construction of aerial vehicle	30.03.2020	Task completed
Usage of CAD/CAE systems	14.04.2020	Task completed
Aerodynamic specifications	25.04.2020	Task completed

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 ________________ Candidate of Technical Sciences,Isametova M.E

Signature

The task was completed by student: ___________ Akzhigitova A.Z

Signature

Date: “15” May 2020

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CAD/CAE design of unnamed aerial vehicle taking into account aerodynamic loads

EXPLANATORY NOTE

for diploma work

5B071200- Mechanical Engineering

Almaty 2020

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EXPLANATORY NOTE

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5B071200-Mechanical Engineering

Performed by Akzhigitova A.Z
Reviewer
____
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"_____" _________2020

Scientific adviser
Candidate of Technical Sciences,
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ANNOTATION

In a modern world where unmanned aerial vehicles became regular part of human life, there are many ways of using them. One of the purposes can be extinguishing fire with this type of machines.

This diploma work is a study of an unmanned aerial vehicle taking into account aerodynamic loads, for use in fire extinguishing processes, using CAD / CAE systems. This work provides a structure, the field for which a mechanism is developed, as well as the results of computer modeling of this unit. Some of the CAD/CAE systems software as COMPAS and ANSYS were used to achieve drawings of the plates, landing gears, shell of the machine, alongside with the modeling results. From all of the results derived information from the programs this unmanned aerial vehicle was developed, considering problems such as stability, endurance, and weight.

АҢДАТПА

Пилотсыз ұшу аппараттары адам өмірінің ажырамас бөлігіне айналған қазіргі әлемде оларды қолданудың көптеген жолдары бар. Бір мақсат осы машинаның көмегімен өртті сөндіру болуы мүмкін.

Бұл тезис CAD / CAE жүйелерін қолдана отырып өртке қарсы процестерде қолдануға арналған аэродинамикалық жүктемелерді ескере отырып, ұшқышсыз ұшу аппаратын зерттеу болып табылады. Бұл жұмыс құрылымды, механизм әзірленетін аймақты, сондай-ақ осы құрылғыны компьютерлік модельдеудің нәтижелерін ұсынады. Компас және ANSYS сияқты кейбір CAD / CAE бағдарламалық жасақтамалары тақталардың сызбаларын, шассиді, машина корпусын және модельдеу нәтижелерін алу үшін пайдаланылды. Бағдарламалардан алынған барлық нәтижелердің ішінде бұл пилотсыз ұшақ тұрақтылық, төзімділік және салмақ сияқты проблемаларды ескере отырып жасалған.

АННОТАЦИЯ

В современном мире, где беспилотные летательные аппараты стали неотъемлемой частью человеческой жизни, существует множество способов их использования. Одной из целей может быть тушение пожара с помощью этого типа машин.

Данная дипломная работа представляет собой исследование беспилотного летательного аппарата с учетом аэродинамических нагрузок для использования в процессах пожаротушения с использованием систем CAD / CAE. Эта работа предоставляет структуру, область, для которой разработан механизм, а также результаты компьютерного моделирования этого устройства. Некоторые из систем программного обеспечения CAD / CAE, такие как COMPAS и ANSYS, использовались для получения чертежей плит, шасси, корпуса машины, а также результатов моделирования. Из всех результатов, полученных из программ, был разработан этот беспилотный летательный аппарат с учетом таких проблем, как стабильность, выносливость и вес.

CONTENT

INTRODUCTION

The main goal of this project is to build an unmanned aerial vehicle (from further on UAV) that can be used in firefighting. The indicated type of vehicles can be very helpful in many types of situations and also no human risks provided. Good example of possible usage of this vehicle was on the 11th of August 2019, when hills near Kok-Tobe TV Tower (1 hectare of territory) were caught on fire. No firefighter was harmed during aforementioned operation, but still it took a lot of effort, equipment (like helicopter) and people to stop the fire from additional destruction. In this sort of areas (hills, mountains, and other difficult to approach places), UAV can be the best solution, for troubles caused during inability of getting to the center of ignition.

This work presents general information about construction of UAV, how it works, main data of aerodynamics, how necessary calculations were made, drawings of mentioned machine, and what capabilities it has.

2 Basic information about aerial vehicle

This unmanned aerial vehicle (or it is called drone sometimes) is developed to be used for firefighting purposes, but mostly it is just like any other ordinary drone that is used for everyday variety of purpose uses, like for taking videos or photos, (or sometimes it is used just like a toy) and they can be controlled by anyone nowadays. By meaning that the structure of this machine is simple, it is meant that it has motors, propellers, batteries, and etc., like any other machine that can be called drone. Of course there are some modifications (which are described in the next chapters of this work) that were made, since not every UAV can be used in firefighting. Next chapters describe construction (what type of components it has and what kind of modifications were made for its firefighting purposes) and the aim of this vehicle.

2.1 Construction of aerial vehicle

To function fully UAV needs motors, propellers, battery, flight controller, frame etc. First of all this machine needs frame on which all of the electronics and landing gears are fastened. The following Figure 1 and Figure 2 represent lower and upper parts of frame.

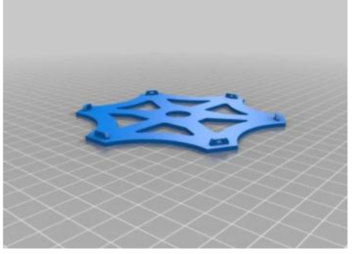

Figure 1.Lower frame of the UAV

Figure 2. Upper frame of the UAV

There are some holes in it made by purpose that is making this vehicle lighter, since it needs to carry on other details aside from the main details. Alongside with other special purpose for this holes, is to connect the details with each other.

Next piece is landing gear, on which this vehicle lands, that is demonstrated on the Figure 3. It is connected to the main frame by pins, for this particular reason there are some holes designed in the main frames of this UAV. Another function that this gear provides is that it secures motor and propellers. This detail have to be strong enough to be able to last during some potential emergency landings, and have to light enough to not overweight the whole mechanism. During designing this landing gears motor, propeller sizes were taking into account.

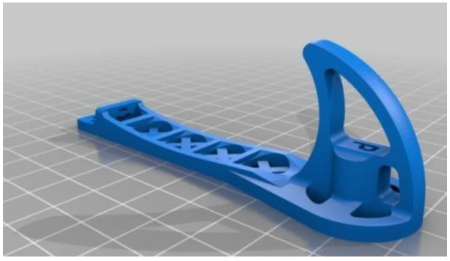

Figure 3.Landing gear of the UAV

To ensure recurrence of attachment, there are also some plastic cables can be used to tie frames with landing gear.

When there is a body now it comes to the parts that move this machine. Motor is the part which that causes propellers into motion. For this vehicle the further showed on Figure 4 is Turnigy 2900kv motor that is suitable for this particular UAV. Also this motor is only 19 grams, and easy to attach to the landing gear with screws.

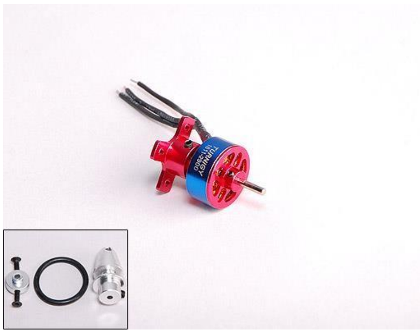

Figure 4.Turnigy motor for the UAV

There are also some clamps for mounting the motor into the landing gear, alongside with some screws.

Since there will be some vibrations in this machine there have to be some Dampeners to prevent it from falling apart, because of the vibrations. These details are made from rubber, to be able to decrease possible damage.

Alongside with motors there are propellers that are installed to them. The operation that is done by the propellers is lifting force that they initiate with the power of the motors. For each motor there is its own propeller, and for this case since there are 6 motors, there are also 6 propellers for each of them.

This type of propellers, (Figure 5 represents them) are more stable for turbulence, rather than the normal two winged propellers.

Figure 5.Propelers 5030 R for the UAV

Another part is battery (exposed in the Figure 6) made from polymer lithium that is small in size and charges faster which is relevant in this case. It is important to be able to charge it fast and easy, because this vehicle will be used for probable lifesaving situation, when time is very precious.

Figure 6. Battery Turnigy 2200 mAh Lipo pack

After that is Electronic Speed Controller (ESC) which is connected to the batteries, motors and flight controller. The function of these devices is to regulate rotation speed of the motor to ensure proper working of the UAV. Just like motors and batteries this type of controller has to be attached to each of the motors, so there should be 6 of them for their respective motor and batteries. Additionally all of them connect to the Flight Controller that is pictured on Figure 7 and like so the whole system is related.

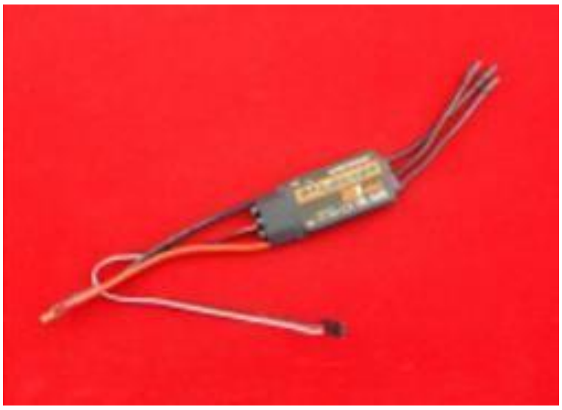

Figure 7. Electronic Speed Controller 60 A

Since there is body and main enforcement, it comes for the controlling the flight itself. Like any kind of mechanism there has to be some sort of “brains”, in this case the main part of this system is Flight controller. This “brains” supervise all of the received data, makes calculations and then spreads signals all over the system. It also may contain some sort of the transducers (like accelerometer in this type of UAV). This detail maybe done specially by using programming (it is meant that some coding may be used), to add some additional modifications for this drone, or it can be chosen from many already existing types (that is represented further on the Figure 8).

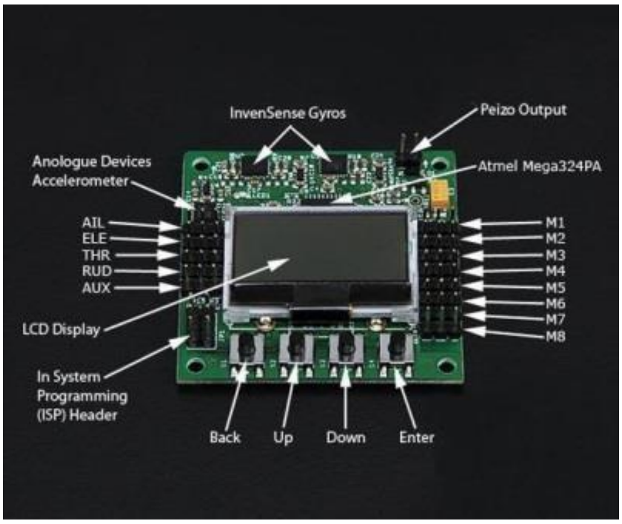

Figure 8. Flight controller KK2

Some of the electronic devices can be joined by some sort of the wires, for example flight controller can be connected with receiver through harness, which is used as the conductor of signal.

Some other detail which also is responsible for flight control is the Receiver that can be seen on Figure 9. As its name says it receives the signal and conducts all of the data.

Figure 9. Receiver of the UAV

Of course all of the elements are connected with each other in correct order by harnesses and binders, all over the frame.

And the last part is the transmitter, sometimes called remote controller, which generates the signal that is then received and handled by receiver. Thanks to modern technical achievements, sometimes drones can be controlled from smartphones or other electronic devices. To be able to do so, there have to be some program coding involved. Also by making individual program code for this UAV increases any chance of hacking which means that the drone will be fully controlled without any possible interception from unwanted faces. Or again it can be chosen from any other existing transmitters (see the Figure 10), by adding some necessary changes to it.

Figure 10. Transmitter (or remote controller) of the UAV

For this particular UAV since it is designed for firefighting another important pieces are camera and the firefighting liquid that will be attached to the bottom of the drone for better results. The function of the camera is to be able to see environment in which the vehicle flies, and it is important that it can work during being enveloped with high temperatures. Now it is time to explain the liquid SAT119. This liquid was developed in Japan and principle of it is simple. The bottle or capsule (depending on the area and difficulty of fire) with SAT119 is thrown to the fire and during high temperatures of the fire this liquid produces water, carbon dioxide and ammonia gases. As a result the water will evaporate and help with lowering the temperature and ammonia gas will stop fire from further on spreading through the area.

SAT119 (which is shown on Figure 11) is commercial worldwide name, but the original name was FIRE117,

Figure 11. SAT119- firefighting liquid

There also can be other components like any type of barometers, compass, gyroscope or transducers for example the GPS that can be seen from Figure 11, to be able to locate the device.

Figure 11. GPS of the UAV

2.2 How aerial vehicle works

So basically signal from transmitter (Figure 10) is received by the Receiver (Figure 9) and then goes to the flight controller (Figure 8), where all of the signals are handled and after that all of the data is sent through binders to motors (Figure 4), furthermore that leads propellers to make desired action. When it comes to flight itself, propellers have to rotate in opposite directions (that is demonstrated on Figure 12, where CW standing for clockwise and CCW standing for contra clockwise), moreover speed of rotation manipulates direction.

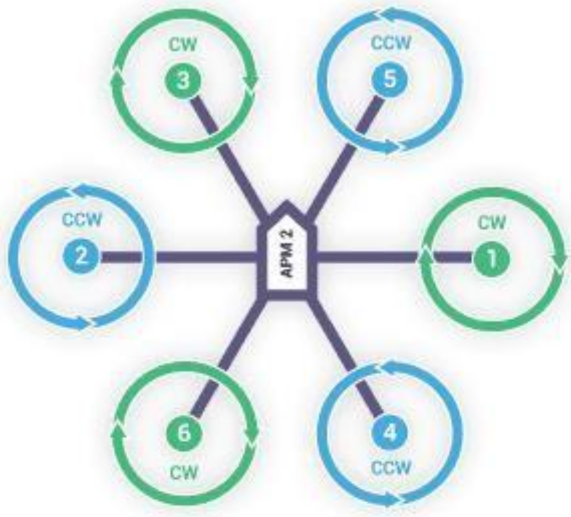

Figure 12. Schematic representation of propellers rotation direction

Also at the bottom there will be manipulator (or may be known as mechanical hand), that will hold the SAT119 (mentioned before firefighting liquid), that can be thrown when needed, which will be controlled by the same transmitter. How it works is uncomplicated, just like the UAV flies. Meaning that the signal sent from the transmitter will be received by receiver and after that the specialized bucket (same method as firefighting helicopter bucket that is able to open from the bottom to throw the liquid) will do the action that was commanded, which is throw the bottle (or ampule) to any direction that was chosen by the human that controls this vehicle.

Or another type of this bucket that will be able to sprinkle this liquid, to the direction that was ordered by operator (human controlling the UAV)

Obviously to be able to work efficiently, the aerial vehicle must have a camera, that can rotate through 360 degrees and will be protected from high temperatures. This will allow easier control if the machine will be out of the sight, for example where people won’t be able to get there.

2.3 Aim of the aerial vehicle

The main goal for this vehicle is firefighting in areas which are hard to approach on foot. There are many cases of fire in which it was hard to reach the fire and it took longer time to get rid of fire. The UAV can work just like a firefighter except, there is no risks for human and also it approaches desired places quicker. For example, suppose there is fire on the 10th floor of some building, instead of wasting time for the firefighters to go up, mentioned vehicle can reach hazardous area agile. Or another scenario were there some people trapped in the room with fire blocking their only way out, this machine can just fly to the needed place fast and using the camera on it the human controlling the UAV can analyze the situation and throw the SAT119 (Japanese liquid that can reduce fire) mentioned before, to save people by opening up their way out.

Also one of the useful functions of the drone is that it is small, so if there is any pace that human firefighter can reach for example the building may be crushed and there is some barriers on the way, instead of wasting time on cleaning the way through this machine can easily fly through any holes or even get to the main fire point by any other way where human firefighter cannot fit in.

Furthermore, one more operation that can be done with this vehicle and that is work from the distance. Imagine there is fire somewhere far away from the firefighting station it will come in handy if firefighters will activate the drone while they are on their way to the needed point. So this will save some time, while the UAV will be able to get to the point faster and also the firefighters can see and analyze the situation before they reach the place.

One more thing is that depending on the bucket, it may sprinkle the liquid again if area with fire is hard to get, or to open up exit for the victims of fire from far away.

3 Usage of the cad/cae systems

Since this works is concentrated on developing unmanned aerial vehicle for firefighting, there are some programs that are involved in this process. For example there are some certain programs used for drawing, or calculation, all of these operations can be done by hand but these systems make it easier and faster, also they are very convenient, further on explained about these systems.

3.1 What is CAD/CAE?

CAD Systems (Computer Aided Design Systems) - are the systems of the software that help to design any project easier and faster. Another function of CAD systems is to decorate ready work by the standards. Many systems are made so that 2D and 3D modeling was as simple as possible, also to apply formalization in uncomplicated way. Examples of CAD Systems are: Autodesk AutoCAD, SolidWorks, KOMPAS, CYCAS, DraftSight, LibreCAD, etc.

CAE Systems (Computer Aided Engineering Systems) – are the type of systems that make calculations of any type, from basic strength calculation to different processes of casting. Sometimes it is called engineering analyze systems. It also uses 3D models from the CAD systems to make calculations. Examples of CAE Systems are: MATLAB, Fusion 360, Simscale, Inventor, ANSYS, Scilab, Simio, Hyperworks, etc.

The history of this systems started 30 years ago with basic software to draw the sketches of the details in the late 70s (some of them are still used nowadays). After that there were systems that were able to make 3D drawings of the object and to solve modeling problems of the object.

3.2 Implying CAD/CAE Systems

After developing the idea about drone that will be embedded in firefighting, it comes to calculations and drawings of this machine. Since it is not the regular UAV, all of the focus was on the Japanese firefighting liquid. It was important that this UAV will be able to fly with this kind of extra weight in the form of specialized bucket that carries the mentioned before liquid, alongside with the camera. Since 4 motors won’t be enough to lift this kind of weight, it was decided to make a 6 motor drone (or can be called as hexacopter sometimes). And to make it too complicated the design of this vehicle’s frame was simplified to a hexagon shape that can be easily connected with basic landing gear.

The drawings were made by using one of the CAD Systems program called KOMPAS. It allows to design 2D and 3D model of this UAV, alongside with the drawings, also this program was chosen because it is accessible for students (on their website it can be downloaded for free specially for students for educational purposes only with all of the functions included).

First of all, 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.

Another part of the design is small holes to be able to connect the frame with landing gear. The frame and landing gears connect with each other by pins for more security of the whole machine.

It is suggested to use carbon fiber to construct this aerial vehicle’s body, including frames, landing gears and shell if needed

All of the drawing are issued according to standards by the program COMPAS and included at the end of this work in the form of Attachments.

The result of the work done on the COMPAS program regarding the frames is represented on Figure 13.

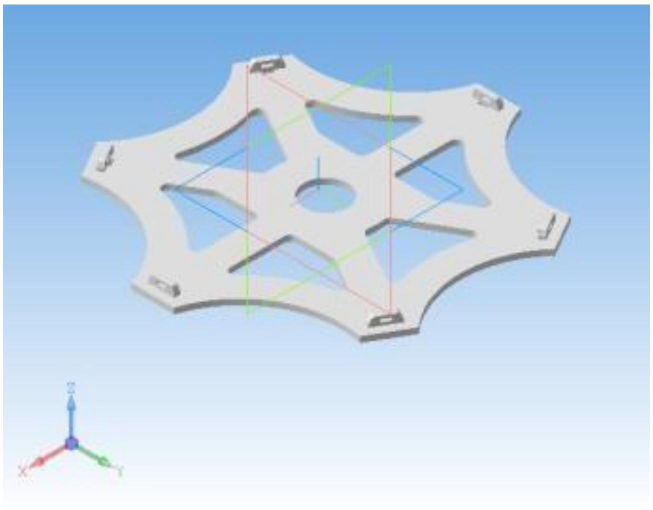

Figure 13. 3D model of the lower frame of the UAV done with COMPAS program

The frames are thin but they are stiff enough to be able to hold all of the devices on it and to be able function properly without falling apart.

There are special points at which both of the frames (lower and upper) can be connected to each other and can be connected to the landing gear securely by the straps and screws.

The following Figure 14 shows the view of the upper frame of the UAV.

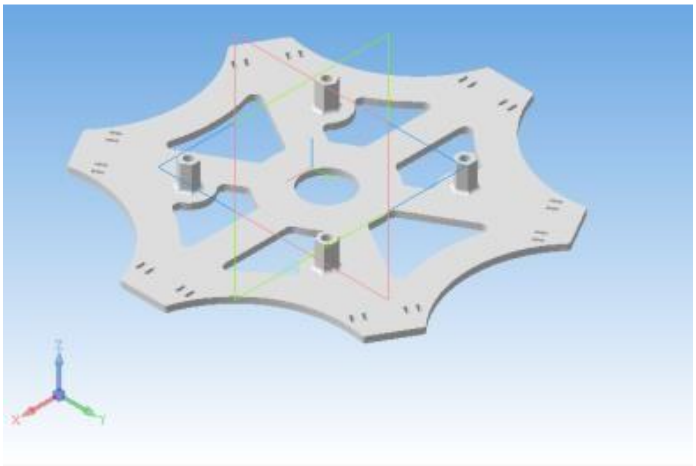

Figure 14. 3D model of the upper frame of the UAV done with COMPAS program

See at the end of the work Attachment A and Attachment B to see drawings (that were decorated according to standards) of lower and upper frames of the UAV respectively.

Then it was time to draw the landing gears, during designing them the main point was to make sure that they will be stable, but also again light in weight because of the problem mentioned before. One more thing about this landing gear is that motors will be mounted in them including propellers that will be adjusted on the top of the motor. So it is important to keep in my mind motor's and propeller's dimensions. And some other thing to have in view is that these gears will be connected with frames.

Final product that was made by the help of the program COMPAS is showed in Figure 15 further below.

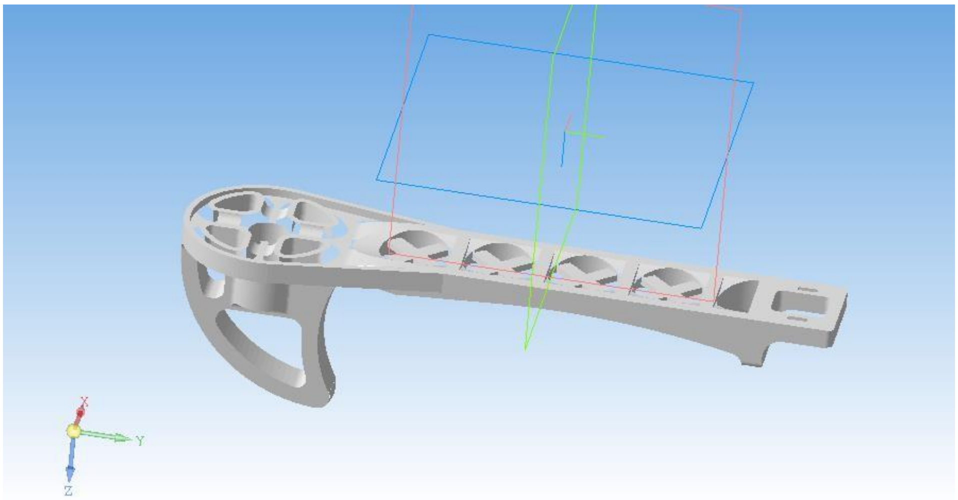

Figure 15. Landing gear of the UAV done with COMPAS program

Formalization of this landing gear drawing can be seen in Attachment C, at the end of the work.

Another detail is the shell of the UAV. It is not necessary for this type of machines, but for firefighting drone it is important that electronics devices in it works properly, that is why for this case shell will be suitable option.

It is important for this shell, to be able to resist high temperatures, apace from being light that is why it can be seen very thin from the Figure 16.

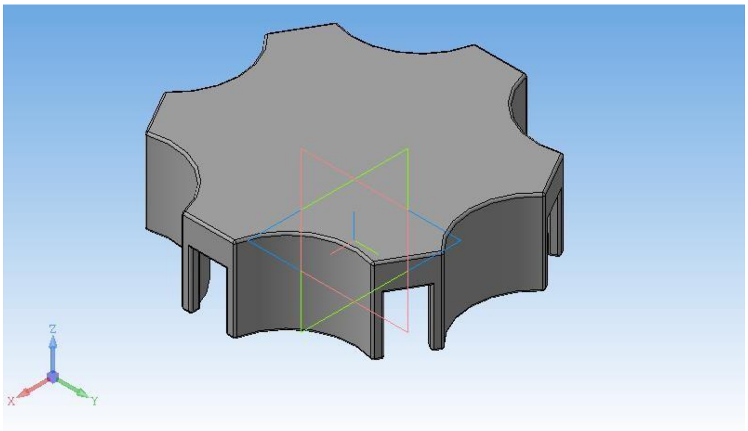
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Figure 16. Shell of the UAV done with COMPAS program

The shell is also simple, just covering the whole frame with removable bottom.

To complete working on CAD Systems with adding up some of the electronics, motors, propellers, and bucket, and achieved outcome product (without shell since it is not indispensible detail of this vehicle) that is illustrated in Figure 17 further down below.

Figure 17. Graphical representation of the designed UAV

Moving on to the next step of calculation using one of the CAE Systems programs, which is eCalc. This program was designed to calculate some of the characteristics of the UAV like thrust, estimated flight time and etc., since there is already included some of the aerodynamic specifications and geometrical data of some types of the propeller.

Concluding calculations for this machine with payload mass of 3 kilograms, it needs 6 N of thrust to function for each propeller. Following Table 1 represents outcome data from the calculations.

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. Data from the eCalc

There are other CAE systems that were used during designing this aerial vehicle that will be discussed in the next chapter.

4 Aerodynamics of the aerial vehicle

Aerodynamics is a part of mechanics which is dedicated on regularity of motions of liquids and gases (especially of the air). It also studies bodies and their motions in liquids and gases. Laws of aerodynamics describe how and why all of the planes and other types of aerial vehicles fly.

4.1 Principle of the aerodynamics

There are 4 basic forces acting on the UAV during flight, which are: lift, weight, thrust and drag. Lift and weight are opposite, as well as, thrust is opposite to drag. Since this machine has a certain weight and there is gravity acting on it, here comes first force, which is weight (basically it pulls body, in our case the drone, down). Contradictory to weight, there is lift. This force acts on pulling body upwards, in case when it overcomes the weight force. So these forces respond for the movement of this UAV down and up, there are also forces that act during movements to the right and left. When drone receives command to shift side to the given direction, during flight towards that orientation, there is force called thrust that acts on the body. While towards is thrust, on the other side there is drag force that pulls machine other contrary way. All of this 4 forces act on any aircraft, but principles by which plane and this unmanned aerial vehicle works, is a little different. And also how they fly differs too.

To be able to lift this drone, there have to be three components, which are: solid, fluid and motion. In this case propeller acts as a solid, air as the fluid, and then when motor impels the propeller to work, it is considered as a motion. But principle of how propeller can pull up the machine is similar to principle of the airplanes wing ability to move through air, since their profile sides are look alike.

Another difference from the airplane, is that this type of vehicle achieves lift rapidly, unlike the airplane which needs driving force instead.

Here is the description of how this aircraft moves to the sideways. When there is a command to shift to the left direction, propellers from that side start to slow down on their rotation speed, while propellers on the other side start to pick up their rotation speed, and that’s how the thrust to the left side appears, and vice versa is the movement to the right side. Also since there is thrust, there is also drag force which will pull to the opposite direction. And during motions to the sides, lift and weight forces are in equilibrium state, so that depending on which force is overpowering the other, machine will be moving towards that side direction only.

The UAV can be rotated too. There are 3 propellers that rotate along clockwise and other 3 that rotate counterclockwise. Principal is similar to how thrust and drag forces developed. Meaning depending on the desired orientation, 3 propellers from that direction will rotate faster, while the other 3 will slow down a little. Again in this situation, lift and weight forces are equal to each other, and this machine won't move in vertical direction, since it is focused on other movement.

4.2 Aerodynamic specifications of aerial vehicle

To be able to get accurate calculation results about aerodynamic loads of the UAV, once again CAE systems were used. Most of them use finite element method to derive the data. This means that from the geometrical information's of the object alongside with the material science of it and physics of the modeling process, program can give results according to aerodynamic specifications of the reproduction modeling. One of these programs is ANSYS.

Calculations begin with inputting data like geometries of the object (which can be done in the program itself, or by adding ready drawings from CAD systems using DXF format), also material science of the object.

To determine aerodynamic specifications of this UAV following equations are used:

- Direct numerical simulations
- Reynolds averaged Navier- Stocks equations
- Three dimensional steady state vortex solution

First of all to be able to calculate all of the coefficients, there have to be mesh (shown in Figure 18) that was divided using finite elements method for precise results.

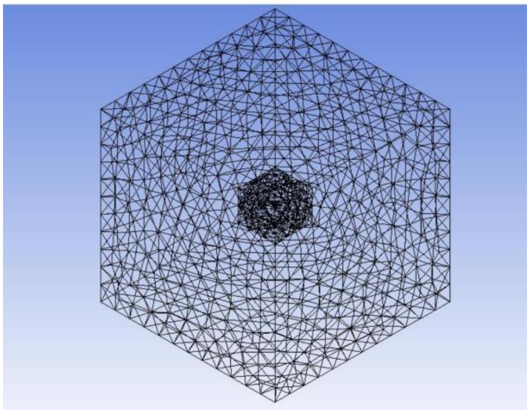

Figure 18. Estimated mesh of the reproduction modeling using ANSYS

After adding velocities to modeling, further illustrations (Figure 19, Figure 20, and Figure 21) were received.

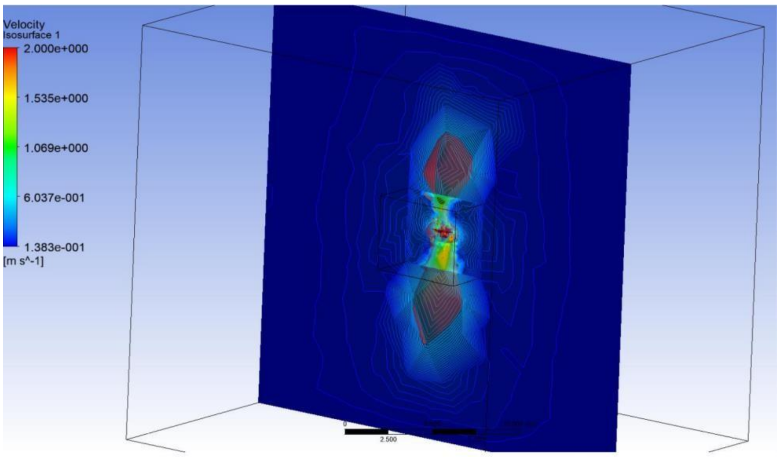

Figure 19. ANSYS aerodynamic loads calculation results during 0 km/h

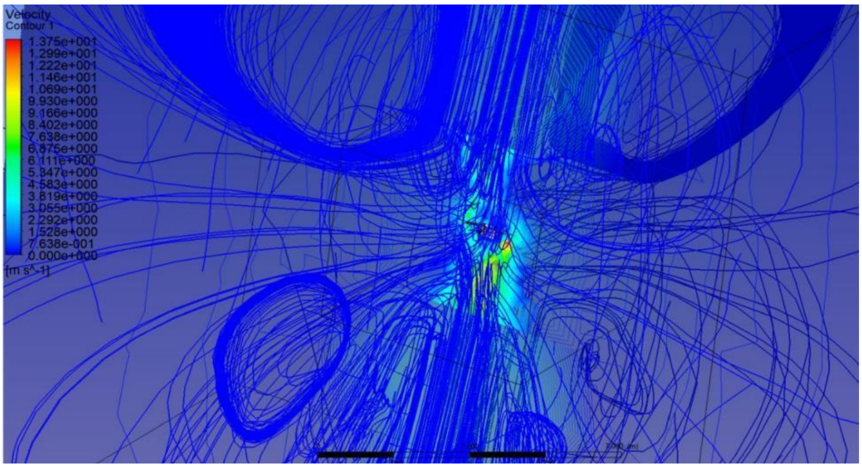

Figure 20. ANSYS aerodynamic loads calculation results during 0 km/h vortex state

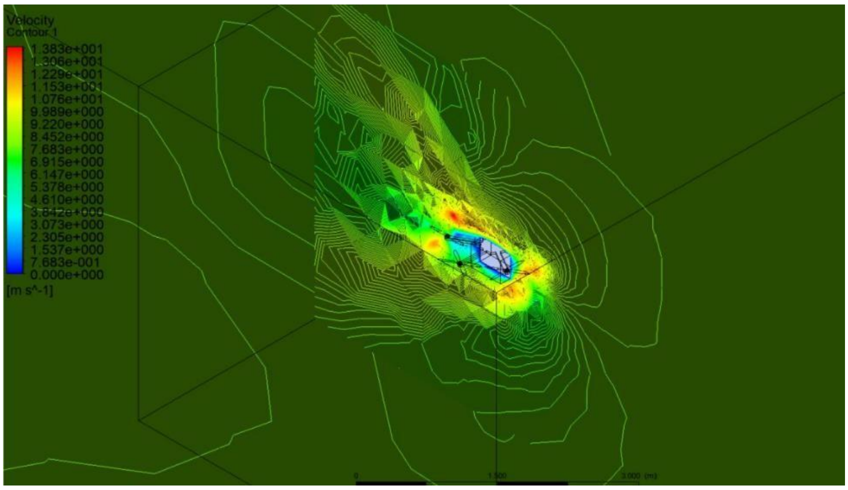

Figure 21. ANSYS aerodynamic loads calculation results during 15 km/h

Another data derived during 15 kilometers per hour with vortex state represented in Figure 21.

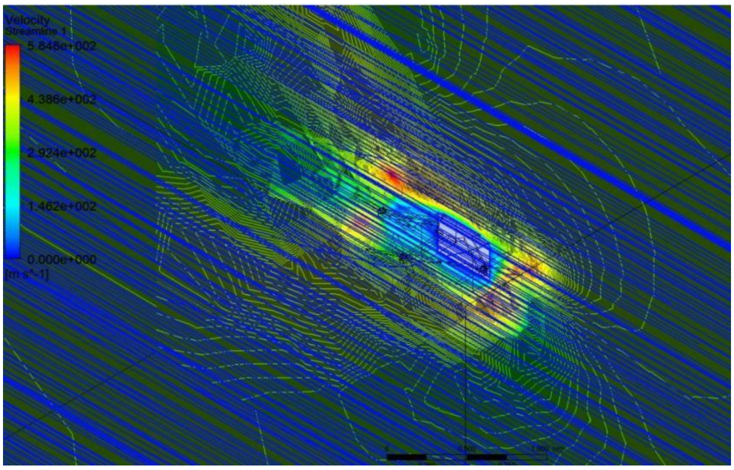

Figure 21. ANSYS aerodynamic loads calculation results during 15 km/h vortex state.

All of the derived material from ANSYS shows how real machine will perform during calculated environment.

By using ANSYS program during design process, acquired information's are important for further improvements for aerodynamics, strength, etc. which then can be applied aftermath.

CONCLUSION

This work represents all of the basic information about firefighting unmanned aerial vehicle. It can be built in real life and be used for its main purpose which is extinguishing the fire. All of the details that were mentioned in this work were chosen as the best suitable details for this machine, but it can be changed for further improvements, or some changes in its purpose.

All of the data shown from modeling process serve as portrayal of the capabilities of this machine to suppress fire.

Fire represents thread not only for humankind but also to animals (approximately over 1.25 billion of them were vanished because of the Australian bushfire in January 2020), and to nature. It is our responsibility to be able to prevent further damage from fire, and this vehicle can be used for this purpose.

Drones are wildly used nowadays for different purposes, and this work shows one of the ways that it can be used, to make life easier and safer.

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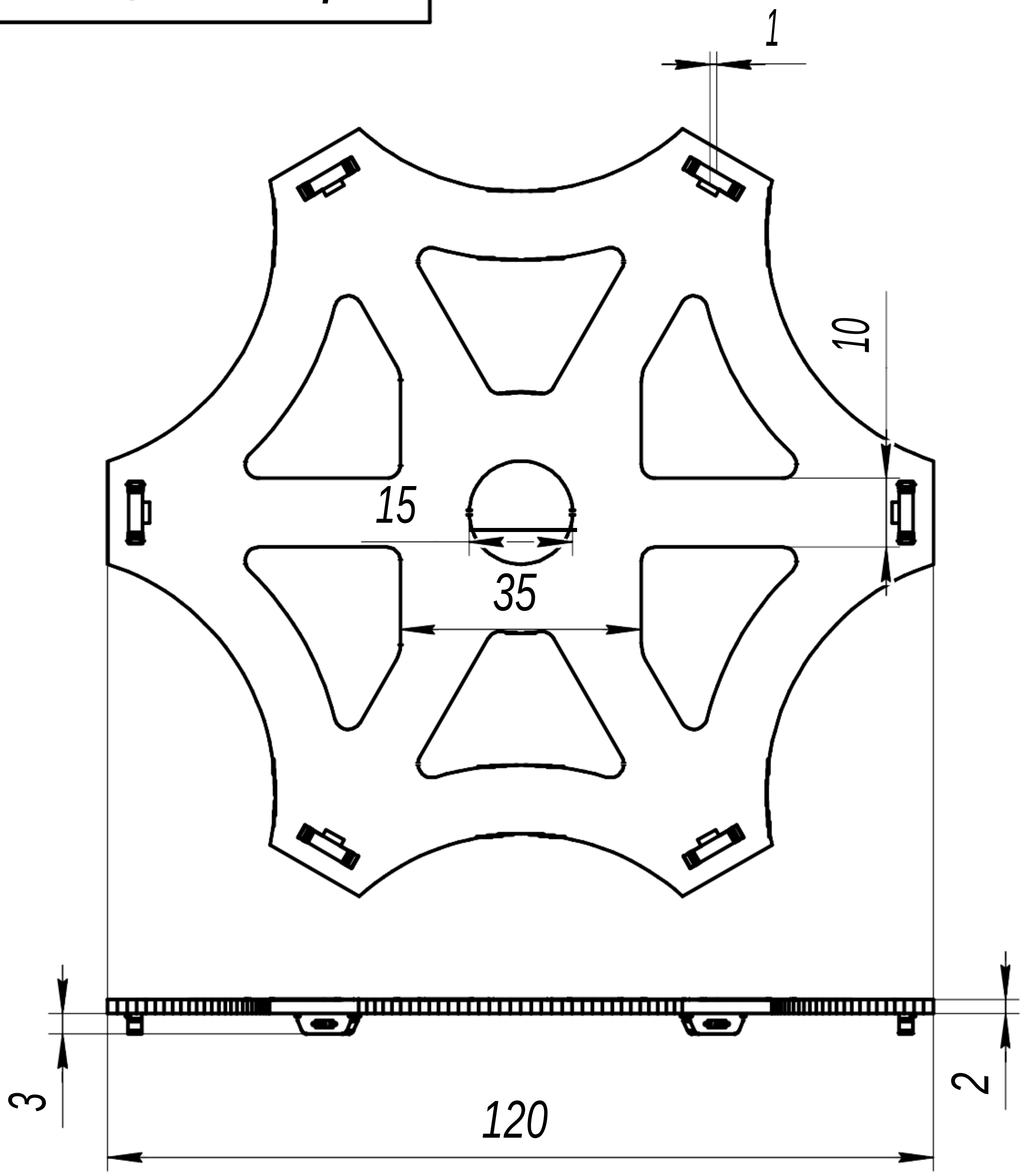

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Т.контр.				
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Lower plate

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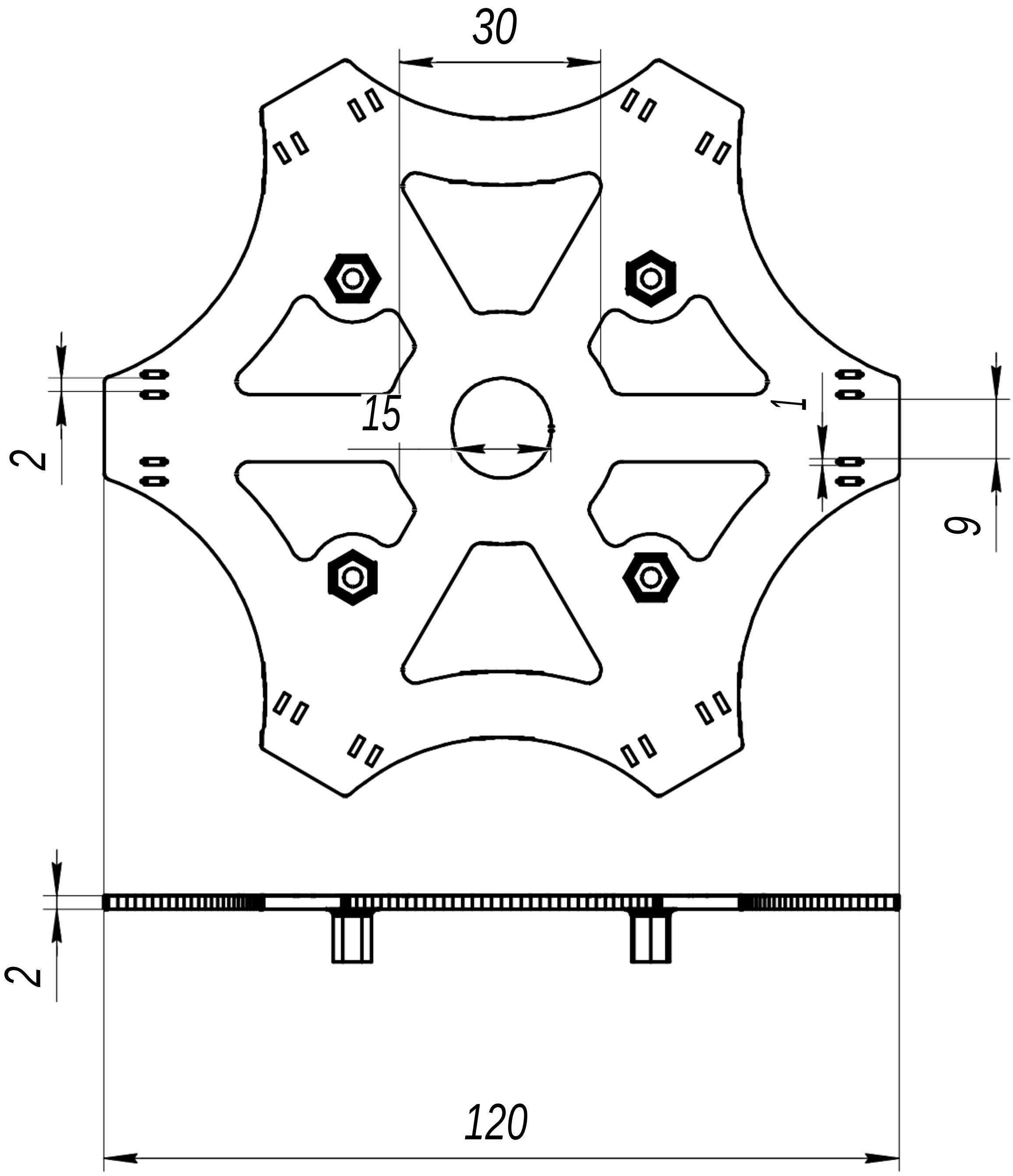

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Landing Gear

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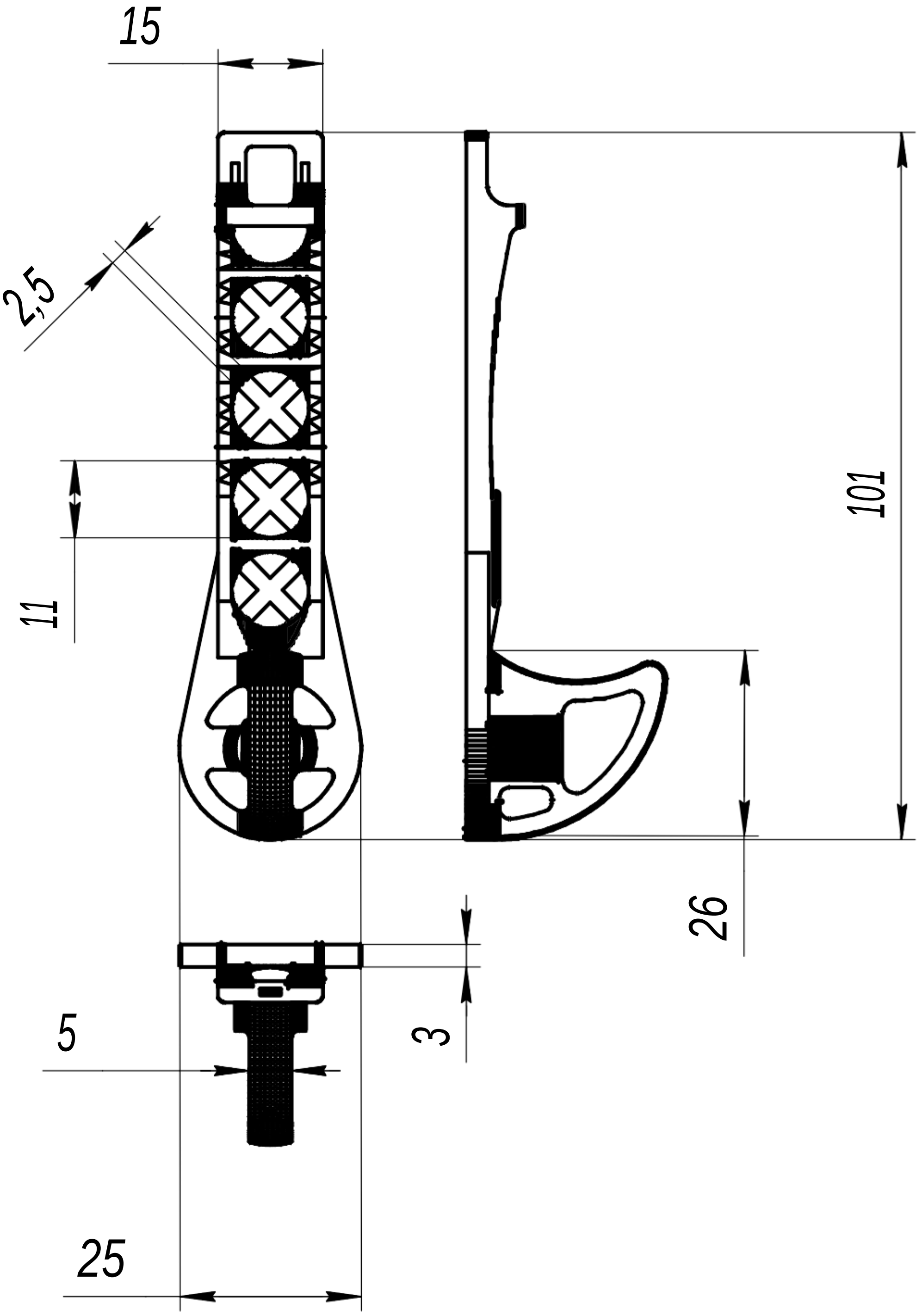

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