MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

Kazakh National Research Technical University named after K.I.Satbayev

A.Burkitbaev Institute of Industrial Automation and Digitalization

Department of Industrial Engineering

Junusbekova Y.Y

# Research of materials for manufacturing elements of an unmanned aerial vehicle by 3D printing

**DIPLOMA WORK**

5B071200-Mechanical Engineering

Almaty 2020

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**APPROVED FOR DEFENSE**

Head of the Industrial

Engineering Department, PhD

Arymbekov B.S.

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Topic: " Research of materials for manufacturing elements of an unmanned aerial vehicle by 3D printing "

5B071200-Mechanical Engineering

Performed by Junusbekova Y.Y

Reviewer

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_____

"_____" _____2020

Scientific adviser

Candidate of Technical Sciences,

Associate Professor

_____Isametova M.E

"_____" _____2020

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**TASK**

**for completing the diploma work**

For student:*Junusbekova Yerkenaz Yerlankyzy*
Topic: " *Research of materials for manufacturing elements of an unmanned aerial vehicle by 3D printing* "
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: 3D printer characteristics,list of materials.
Summary of the diploma work:

a) *Construction description;*
b) *Information about printer and technology;*
c) *Selected material properties.*

List of graphic material: tables of mechanical and physical properties
Recommended main literature:


1. Practical 3D Printers: The Science and Art of 3D Printing,Brian.E-«Apress»,2012.-p 20.
2. A review of additive manufacturing**,** Wong, K. V. and Hernandez, A-Springer,2012.-p 5.
3. www.3dglobatek.com

## 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 the creating | 1.03.2020 | |
| Printer choice | 10.03.2020 | |
| Preparation of materials list | 17.03.2020 | |
| Comparing and analyzing all properties | 15.04.2020 | |

## 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 | 28.04.2020 | |
| Normcontrol | Candidate of Technical Sciences,Isametova M.E | 12.05.2020 | |

Scientific adviser _____ Candidate of Technical Sciences,Isametova M.E

Signature

The task was completed by student: _____ Junusbekova Y.Y

Signature

Date: “13” May 2020

## ANNOTATION

In this diploma work the kinds of materials depending on the type of printer were considered.

The purpose of this diploma work is to propose and evaluate the selection of materials for the prototype of unmanned aerial vehicle produced by 3D printer. Examining starts from the parts of construction in general. Print of the model will carry out by FlashForge Guider II. Fused Deposition Modeling`s specifications and process description were considered. In consonance with this the materials were chosen and observation were made. Survey contains information about fabric`s physical and mechanical properties, printing aspects and review of made products.

# АННОТАЦИЯ

В данной дипломной работе были рассмотрены виды материалов для выбранного типа принтера.

Целью данной дипломной работы является сравнение и оценка выбора различных материалов для изготовления прототипа беспилотного летательного аппарата на 3D-принтере. Анализ начинается с частей конструкции в целом. Печать макета будет выполнена на Flash Forge Guider II.

Была произведена оценка спецификации и описания процесса fused deposition (моделирование путём декомпозиции плавящегося материала). В соответствии с этим были выбраны материалы и проведены наблюдения. Работа содержит информацию о физических и механических свойствах материалов.

# АҢДАТПА

Бұл дипломдық жобада пилотсыз әуе аппаратының прототипін 3D принтермен басып шығару үшін арналған материалдар қарастырылған.

Дипломдық жобаның мақсаты модельді 3D принтер арқылы басып шығаруға арналған әртүрлі материалдарды сынау және бағалау болып табылады.Алдымен анализ конструкцияның бөліктері туралы шағын информациядан басталады.3D басу Flash Forge Guider II принтерінде жүзеге асырылады.

FDM (материалды еріту) технологиясының ерекшеліктері және жалпы процесстің қалай жүргізілетіні сипатталған.Принтердің түрі және баспа технологиясына қарай отырып материалдардың түрлері таңдалынды.

**CONTENTS**

# INTRODUCTION

Modern 3D systems allows to quickly and efficiently solve tasks in mechanical engineering by using prototype of future products before the mass production. The use of it at the development stage allows to create high quality products cheaper and faster. It is an exact opposite of traditional methods based on the layer by layer synthesis of any construction. It used at every stage of production starting from the creation of the concept and ending with final manufacture. Work of engineers are getting simplified by 3D installations. Because by inspecting the entire product range gives confidence that each detail is made in accordance with requirements and quality standards.

Every year this method gets popular because it reduces waste and increases production reliability. This phenomenon is a reliable foundation for the business competitiveness in any engineering field. In the lot of processes and in a number of areas, additive technologies have begun to quickly supplant traditional production methods. With this prospect in industry in economic component is growing every day. Thanks to replacements of traditional methods the risk of design errors and a layout test cost are reduced. In addition, the pricing policy is available and fair enough to enterprises.

## 1 Brief construction description

The drones or UAV (Unmanned aerial vehicles)-an aircraft which is controlled remotely or autonomously with predetermined route. Usually used for military purposes because they don’t put human`s life in a danger and flight can done as much as fuel is enough. Types of them are differ in their purposes. The first large category is military or combat drones. They have complex design and are able to perform more functions like patrolling large areas, tracking a target, providing attacks for missions and etc. Second group is civil drones for transporting, scientific researches, mapping and monitoring. And the last group is consumer drones like for advertising business, taking photos or videos and preparation of promotional materials.Figure 1 shows the drone.

Figure 1 − The drone

UAV for entertainment intentions may have simple design and may also contain complex constituent parts allowing a device to turn into professional one. Each drone`s construction is unique in its way but several basic elements are present at any device`s design. They are frame, flight and speed controllers, engines, propellers and batteries.

Frame-foundation on which all the elements are attached. Working hours and total life of the drone depends on how the frame is strong and reliable. In manufacturing of frame the focus should be on turning the drone into lightweight, long-lasting and shock-resistant. Should be made from featherlight and everlasting materials like polymers, alloys of light metals or carbon. Figure 2 demonstrates the frame.

Figure 2 − The frame

The flight controller is the base of the drone. It is programmed to process various signals coming from the operator's remote control and the sensors installed on it. The more signals the controller can process, the more versatile the drone is. Using a loop, the flight controller is connected to each of the four engines, which allows you to send control signals to them (programmed commands).The flight controller is shown in the Figure 3.

Figure 3 – The flight controller

Since the firmness of the whole flight depends on the operation of the flight controller, when making drones, designers effectively apply different strategies that permit these components to be vibrationally protects as much as conceivable. During the flight, the superior the vibration-isolated controller, the more steady the drone will fly. As of late, high-class flight controllers are accessible with built-in vibration isolation.

Engines, propellers and speed controllers. Auxiliary components dependable for the flight of the drone. The speed controllers set the speed of the air ship based on information gotten from the flight controller. The UAV`s engines are shown in Figure 4.

Figure 4 – Engines of the drone

It is worth noticing that propellers and motors are the foremost wearing parts of the drone, since during its flight the most burden lies with them. In this case, within the occasion of different crisis circumstances, counting the drop of drones, the uncovered parts of the structure, to which the propellers have a place, break to begin. UAV engineers suggest buying gadgets prepared with uncommon propeller assurance. It can be circular segments or casings, safe to impacts and securing propellers from breakdowns.

Another critical component of the drone as in guideline of any independent gadget, is the battery. Its capacity (communicated in milliamps per hour) decides the greatest stature that the drone can fly, as well as extend and flight time. Based on this, drone engineers moreover pay very a part of consideration to the battery. All batteries are moderately overwhelming, so the plan for joining them must be solid sufficient (another reason why the outline must be made of solid and solid materials). Due to the little capacity and little estimate of the battery, scaled down drones can remain working for no more than 3-5 minutes. Novice models are able to remain for approximately 12-15 minutes. The flight length of proficient devices in standalone mode is no more than half an hour. As you'll be able see, drone flight time, depending on the size and capacity of the batteries, is presently one of the foremost problematic factors within the improvement of the industry, be that as it may, drone engineers and producers guarantee that tackling this issue may be a matter for the close future.

## 2 Chosen printer characteristics

Our choice fell on a new model FlashForge Guider II which have received a large work area and upgrades.

The case of the device is made of high-quality metal, due to which, when printing, unnecessary play is completely removed. The closed design of the model ensures the maintenance of the required internal temperature, and this in turn guarantees minimal shrinkage of the print. The printer is equipped with a control panel in the form of a touch screen. On it you can select the desired model for printing, while, in the same place, the model's layout is displayed. The printer also has a special security system that will allow you to continue printing after switching on if there was a power failure or you turned off the printer in the middle of printing. In expansion, the gadget encompasses a finder that identifies the nearness of plastic and stops the work when it is missing. All characteristics are presented in the Figure 5.

| | |
|---|---|
| **Operation systems** | Linux, MAC OSX, Vista, Windows7, Windows8, Windows XP |
| **Power Supply** | 100-230 V |
| **Dimensions, mm** | 549x490x561 |
| **Weight, kg** | 11 |
| **Software** | Flash print |
| **Country of origin** | China |
| **File format** | STL, OBJ, G, GX |
| **Working camera** | 280x250x300 |
| **Z-axis positioning allowance** | 2.5mkm |
| **X and Y-axis positioning allowance** | 11mkm |
| **Specialization** | Design, Architecture, Manufacturing, Education, Building |
| **Temperature of printing table** | <120°C |
| **Temperature of extruder** | 180-240°C |
| **Printing technology** | FDM |
| **Layer thickness** | 100mkm |
| **Printing accuracy** | 0,1-0,2 mm |
| **Noise level** | <50 dB |
| **Supporting materials** | ABS, PLA, PVA |
| **Thread diameter** | 1,75 |
| **Nozzle diameter, mm** | 0,4 |
| **Display** | 5`` sensor screen |
| **Amount of printing knobs** | 1 |
| **Speed of printing** | 40-200 mm/s |

Figure 5 – Characteristics of FlashForge Guider II

The working size of the printer is 280x250x300 mm, it is warmed, which permits you to utilize a assortment of materials for 3D printing, such as: PLA, PBT, ABS, PET, ABS +, Dad, Elastan, Hips, PVA, Nylon, coPET, Plastan and numerous others . The printer is featured with special functions as USB, Ethernet and Wi-Fi module, and is additionally able to put through to a computer. The device has a peculiar

properties like large volumes, high quality workmanship, works with numerous print materials ,convenient display, failure assurance and plastic detector and being able to connect to the computer. A several number of FDM systems allow you to set up several parameters of the printing process. Such as nozzle temperature, working surface, print speed, layer height, and cooling fan speed. To not interrupt modeler`s operation sometimes the parameters can be installed by the printer operator

Presently the choice will be made from the sort of printer and on which strategy it'll work. The normal layer stature utilized in FDM shifts from 50 to 400 microns and can be decided at the program cutting organize. A lower layer tallness will give a smoother portion and more precisely reflect complex geometry, whereas a bigger layer tallness permits the portion to print speedier and at a lower taken a toll.

## 3 FDM technology specifications

There are a large number of 3D printing technologies. Appearing in the late 80s of the last century thanks to S. Scott Trump, today it has reached unprecedented heights. This is confirmed by the figures: in 2014 around 125 thousand units of 3D printers were sold worldwide. The most common and accessible technology is FDM. This technology is used both in cheap home printers and in industrial highly accurate 3D printing.

The principle of operation of this technology consists in layer-by-layer deposition of a product from molten plastic. 3D model of STL format is loading in G-code reader 3D printer software. STL (stereolithography) is a file format which contains three dimensional models applied to additive technologies. The program automatically hosts a virtual product model is located in the working chamber. The application mechanically generates spare system components and produces selection of the required volume of material used, and also the duration of the product. Prior to printing, the product is mechanically divided into layers and starts the deduction of the movement of the extruder. The working process is shown in Figure 6.

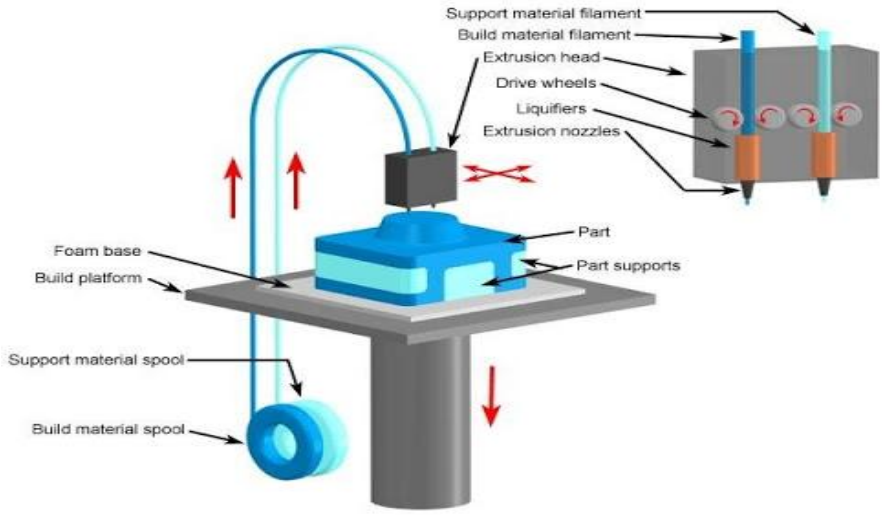


Figure 6 – The process of FDM

Following this, the action of a specific 3D printing is activated: at high temperatures, the extruder slowly melts the filament and layer by layer has the specified G-code parameters. After the build process is completed, auxiliary support is removed.

Finished products can be used in printed form or subjected to any post-processing method. The efficiency of product construction using FDM technology is more dependent on size of the printed layer. This accuracy varies from 0.127 to1 mm. The outer layer of the manufactured parts is often a little ribbed (roughness within the

boundaries is 0.1-1 mm). The advantages of this technology are durable parts, high wear resistance of the product, low cost of materials used, a wide range of post processing. Products after printing is ready to use and they don't any post processing. Devices functioning with this technique use materials such as polymers, different types of plastic based composites and metal mixtures. However printing with metals is connected with technical difficulties and requires specialized equipment.

FDM works with thermoplastics such as ABS, Polycarbonate and Polyphenylsulfone, Elastomers. Maximum part size os 36x24x36 in. Surface finish is rough and build is slow. Applied in rapid tooling patterns, small detailed parts, presentation models, patient and food applications, high heat applications.

Before start analyzing some properties of materials should be considered. Strength of a material is a property of resistance to fracture under the influence of stress, which is caused by external loads. The greatest strength of finished products today is provided by one of the most popular plastics - ABS and its modification ABS-plus, in which carbon fibers are added. By the way, a car was even printed from the latter.

Next is the ability of a material to maintain integrity when bent over a cylindrical surface. There are a number of rubber-like polymers such as NinjaFlex or RubberPlast. Of these, you can print phone cases, bracelets and even slippers.

A melting temperature is one of the important parameters, the ease of working with the material and the need to have a heated platform in a 3D printer depend on it. The melting point is the temperature at which a substance undergoes a transition from a solid to a liquid state. For example PLA melts already at a temperature of 170-180°C and does not need additional heating.

Water solubility. An important property for printers that can print with two plastics at once. The second polymer is used to build supports for overhanging structures, which are needed in almost all complex products.

## 4 Materials review

Selection of appropriate material to print a given object or any construction is getting to be progressively troublesome as the modern industry suggests a new type of fabric and you can notice a rise of drastically modern materials.

Predominantly, ABS and PLA are the two primary polymers utilized in FDM 3D printing, but there ought to not to be a main reason to play a key part within the future of FDM. In addition to PLA and ABS, printing is possible with nylon, polycarbonate, polyethylene and many other thermoplastics, which are widespread in modern industry. It is possible to use a material such as PVA plastic. This material is soluble in water, which makes it very useful when printing models of complex geometric shapes. It is also possible to use composite materials that simulate wood, metals, stone. Such materials use all the same thermoplastics, but with impurities of non-plastic materials. So, Laywoo-D3 is 40% natural wood dust, which allows you to print "wooden" products, including furniture. A material called BronzeFill has a real bronze filler, and the models made from it can be polished and polished, achieving high similarity to products made of pure bronze. Thermoplastics serve as a connecting element in composite materials - they determine the thresholds of strength, thermal stability and other physical and chemical properties of finished models.

Now lets consider the conditions of manufacturing with different types of materials. With ABS or PLA - does not cause any big difficulties. One of the most common plastics. The only peculiarity is that the ABS plastic gives a sufficiently large shrinkage (about 3 percent), and high-quality 3d printing requires warming up the entire printer camera. Do not forget that you should not work with ABS plastic indoors. Vapors can cause migraines and poor health.

All observed fabric will be graded by three categories: quality status, mechanical presentation and procedure. Taking into account what client wants to print some criterias are recorded. A simplicity of print-bed grip,speed, stream exactness, ease to nourish into printer is a vital factor of estimation. Finished object`s looks assessing, maximum level and length of stretching, a grip between layers, required vitality to break a product with unanticipated affect are ranked.

### 4.1 ABS plastic

ABS plastic is a present yellow synthetic polymer with a high degree of impact resistance and elasticity. In 1954 was launched by Borg-Warner company. Due to its

technical properties, it has been widely used as an engineering and structural material. For convenience, the word was reduced to the first three letters of the names of the monomers included in the ABS (acrylonitrile, butadiene, styrene), which in combination with a thermoplastic resin form a stable polymer. In addition, in the domestic market you can find such names as “acrylonitrile copolymer”, “ABS copolymer” or just ABS. Proportions are: 15–35% acrylonitrile, 5–30% butadiene and 40–60% styrene.

In order to produce one kilogram of such a polymer, it takes about 2 kg of oil (as a material and an energy source). In addition, the ABS can be recycled. Some of its species are stable to ultraviolet radiation, which led to one of the most extensive exemptions from car sales in the history of the United States.

Due to the combination of three elements, ABS plastic has excellent features: acrylonitrile gives chemical stability, a certain rigidity and hardness, butadiene increases strength, toughness and frost resistance; styrene gives good dielectric properties and improves manufacturability. Thanks to outstanding mechanical and physical properties it is deliberated for making objects that have feasible worth. The fabric could be a light, yellowish hue that can be freely tinted within the desired color amid the generation of sheets. By including uncommon components to the composition, it is conceivable to attain total straightforwardness of the fabric.

When printing with this type of material, a barely perceptible smell of heated plastic is captured. Although some complain that this plastic "stinks", but the majority of users believe that when working with it it does not emit any smell at all. In any case, if you are working in a small room, it is necessary to equip it with an appropriate ventilation system and make sure that the ABS plastic you are using does not have any impurities, and the printer does not exceed the permissible temperature for heating it.

Regular ABS plastic can withstand short-term heating up to 90-100° C and heat-resistant ABS - up to +110-130°C. Maximum temperature for continuous operation: 75-80 °C, for heat-resistant grades: up to 90-100 ° C. Parts made from standard ABS can be operated at sub-zero temperatures up to -40 ° C. It has a higher impact resistance compared to high impact polystyrene and other styrene copolymers.At 204-238°C items can be effortlessly done with injection molding or extrusion.Ignites only when it heated to 395° C.

A density is changes consistently from 900-1530 kg/m^3 which can be less or more dense than water (1000 kg/m^3).Thus it has a neutral buoyancy.It shows status of how well molecules are connected.

Chemical structure ((C8H8)x(C4H6)y(C3H3N)z)) has a tensile strength of 22MPa-the greatest stress or strain on which it can hold and will not transform by

deformation. Even with a high mechanical load (let's say simpler - when struck with a sledgehammer), an ABS plastic product is deformed, but does not crack or break. And, in general, the deformed area is easily and quickly restored. It will not work with any other plastic - it will simply collapse.

Unaffected to acids, alkalis, inorganic salts, fats, hydrocarbons, lubricating oils. But it is worth remembering that this type of plastic does not hostile to ultraviolet and weathering, it is well soluble in acetone, benzene, ether, and some other solvents. However, many of these disadvantages are addressed by modifying the source. It is not harmful if used in accordance with all the rules and in normal conditions. When heated, the plastic begins to release toxic acrylonitrin fumes, which can cause allergies in humans. As for the volume of vapors, it is small, since the material is consumed very slowly during printing. A appropriately prepared room must have a hood and ventilation. To guarantee the security of human can be ascribed to the reality that putting away nourishment or drinks in such utensils is entirely disallowed, due to unsafe vapor.

The most impediment of ABS plastic can be considered generally weak resistance to coordinate presentation to daylight. In expansion, the potential poisonous quality of the fabric somewhat limits the utilize within the make of toys, nourishment bundling and restorative disobedient.

ABS is produced by emulsion copolymerization of individual elements. The process is considered quite energy intensive. For the manufacture of 1 ton of raw plastic, about 2 tons of oil is spent in equivalent energy and materials. The annual growth in global ABS production is estimated at 5.5%.Accessible within the frame of granules and single sheets. Granular plastic serves as a crude fabric for assist accuracy casting of different items. Sheet ABS can be utilized as a wrapped up item or semi-finished item for insides enrichment, sticking different models and shapes. Plastic sheets are moreover utilized as crude materials for the fabricate of complex parts by vacuum molding.

A large number of automotive parts are made from ABS plastic, such as the inner lining of cabs, instrument panels, shift knobs, hand brakes. The polymer is widely used for the production of housings for home appliances: vacuum cleaners, food processors, telephones, computer and office equipment. Cases of industrial units, high pressure washers, compressor equipment, sanitary products, electrical devices are made of ABS plastic. Almost all types of stationery are made from plastic: pens, stippers, markers, pencil stands, document holders and more. There is a food grade of plastic, from which all kinds of containers for storing products, containers, and containers of drinking water are made. A huge number of children's goods (designers, toys, educational games) are produced from ABS. Also, the material is used to create

sports, trade and advertising equipment, tools and weapons. For this, high-quality brand-name modifications of the material supplied on special coils are used. Parts imprinted from this polymer are characterized by high strength and resistance to mechanical stress. A case of printing on a 3D printer of a firearm Liberator is known.

Using a 3D printer, printing with ABS plastic is simple. The substance has certain characteristics that increment its propensity to shrivel, that's , cooling incites a misfortune of volume. As a result, the wrapped up ABS string is distorted and delaminated. It is conceivable to dodge all this when printing on a 3D printer, you ought to as it were studied the specialized writing. Can be broken up in acetone and other fluids, which contributes to the generation of expansive parts. In the event that you treat the surface of the wrapped up item with acetone, at that point you may accomplish a superbly smooth surface, snugness.

They have supplanted polystyrene in numerous applications since of its predominant quality and durability, and way better wrap up - indeed in spite of the fact that it is twice the taken a toll at about $1.50 per kg. Since ABS polymers are thermoplastic they can moderately effortlessly be recycled. Anticipated to stay the driving designing plastic 7 with a showcase measure of $22.3 billion for 2015, which is anticipated to develop at 6% per year.

Today, Taiwan, Japan and South Korea are the world leaders in the production of ABS plastic. These countries control about 74% of the production and sales of the material. Among the largest companies involved in the production of plastic, it can be noted: Korean LG Chemicals, Basf and Samsung Industries, Taiwanese Chi Mei Corp., Dow and Formosa, as well as Thechno Polimer (Japan). Of the European manufacturers known Polimeri Europe, Ineos.

### 4.2 PLA

One of the extensively applied thermoplastics which is caused by several aspects at once. PLA or polylactic acid is a thermoplastic polyester that is created from inexhaustible sources such as corn containing a lot of starch, graminaceous plant, tapioca radical, cellulose, soy protein and cassava tuber. These ingredients allow to operate without threat to human health. Carbon dioxide emissions to the atmosphere are significantly reduced compared to the manufacture of "petroleum" polymers. The use of fossil resources is reduced by a third, the use of solvents is not required at all. Regarded as more eco-friendly than ABS based on oil and biodegradable. Sugarcone and cone are the foundation of polylactide production. Most clients of PLA plastic appreciate it for natural neighborliness and security for people. With appropriate

utilize, the speed of printing plastic can be very fast. When working, the fabric gives tall precision within the improvement of points of interest.

Becomes rotten at open environment. Reaction to the moisture at high temperatures is quite different. It starts to bubble and flow from extruder nozzle. Output object may change its color and deviation from initial technical program parameters can vary. Decomposition time in water will be six months to two years while ordinary plastic`s time takes from 500-1000 years. According to all these facts it is safe to print children toys, even printer parts and food implements.

Synthesis parts are renewed every year and it is very promising. Agreeing to numerous specialists, polylactide-printed bundling will before long be able to supplant routine biodegradable analogs. Within the generation of PLA plastic, half as much is radiated into the environment as compared to the generation of petroleum-based polymers, carbon dioxide. At the same time, the use of fossil is additionally decreased by 35%.Under the impact of sunlight and dampness the structure completely will ruin in two months to three years. In this case a functional parts can not be printed. Nevertheless details from PLA have superior sliding and plain bearings can be made of them.

Natural transparency smoothly can change into any level of non-transparency. Long-lasting and solidified objects have more glossed finish than ABS. Therefore it is harder to grind and modify. Has a large number of colors and is commodious to use in household. PLA got own natural, plant drawning and gratifying smell. This fact make it desired for home printers, designers and educational institutions.

PLA has low shrinkage, that is, loss of volume during cooling, which helps to prevent deformation. However, shrinkage has a cumulative effect with increasing dimensions of printed models. In the latter case, it may be necessary to heat the working platform to uniformly cool the printed objects. This permits you to print with tall determination, make geometrically complex models, which is strenuous to do, for illustration, when printing ABS plastic. In expansion, polylactide items for all intents and purposes don't require extra preparing, and they are instantly prepared for operation. Objects printed from PLA can be painted with acrylics.

The impediment of PLA plastic is its expanded delicacy and inflexibility, hence, not at all like ABS, evacuating underpins from PLA when printing on single-extruder 3D printers is an amazingly time-consuming method.

Another positive feature of PLA plastic is its relatively low melting point, approximately equal to 170-180 ° C. Thanks to this, the energy efficiency of 3D printing is markedly increased, and it is also possible to use inexpensive aluminum or brass nozzles for printing. Extrusion of PLA is carried out at a slightly lower

temperature - 150-160 ° C. For better adhesion of a PLA plastic product to the work table, use a heat-resistant masking tape or polyimide film.

The disbenefit of polylactide is unhurried solidification- glass transition eventuates at a temperature of roughly50 ° C. This should be contemplated when picking a 3D compositor for printing with PLA plastic. A mechanism with an unlatched sort of housing, supplied with auxiliary air chilling for faster glass passage, is best suited. It is prudent that the employing platform is heated from below, otherwise when printing enormous objects there is a peril of model contortion. However, unlike ABS plastic, heating the exertion platform is not necessary, compact items can be printed on a cold table.

PLA is the most proper solution when the shape is censorious than purpose. With amounts as tensile strength of 37MPa,strength ratio of 40 and can sustain 129 kg. It can be wield to form objects to resist weights and loads.

The first layer in printing with FDM technology is very vital and it must be protected. Regarding to this PLA doesn't have particular requirements. Another main point for the PLA print out-turn to be the pre-eminent is to wield blowing at full power. So the plastic will cool in time and not misshape. Plastic thread is hard, solicitation of next layer will be slower and products will be smoother. It imposes on the details of settings, the alternatives are guided by the material. The obstacle of PLA plastic is its extended delicacy and resoluteness, consequently, not at all like ABS, emptying supports from PLA when printing on single-extruder 3D printers is an incredibly time-consuming. But for a few supplications of its status and opposion to temperature extremes makes it essential for totally combined parts of any question. Really, the primary test could be a carefully commanded handle for the generation of high-quality, first-class plastic yarn from plastic gums. The causation of such plastic could be a complex prepare for the initation of plastic granules - strings, circular cross-section with the same estimate and uniform thickness. Most thermoplastics can easily pass this test. But the next step is much more difficult to pass, because the thread should melt evenly and apply even layers when printing.

PLA-plastic is consummate for producing all kinds of souvenirs and one-time products (food packaging, disposable tableware, bags). In medicine, polylactide is used in the creation of pins and surgical sutures. PLA items look more qualitative with a glossy reflection. Among the few practical industrial implementations, it is possible to designate the inventation of packaging for food, containers for pharmaceutical substances and surgical threads. It is uneasy to grind ready models. PLA is soluble in methylene chloride (dichloromethane). Processing of printouts with dichloromethane.

### 4.3 Other consumables

Admired plastic at present that take a part in a number of industries is polyethylene terephthalate which formed on polyester PET. Translucent sheet PET has eminent light transmittance. Owing to swift ignition and self-extinguishing, it is cut only by a laser and under the sway of heating, it is contorted, which will decide the value of the complited result. Printing is laborious because melting occurs at peak temperatures(250° C), and when cooling (67-81°C)the material gives remarkable shrinkage. That is why the printing process called for reinforcement by underpinning structures, which are plainly removed after originating the model. With an increase in intrinsic viscosity, the crystallization rate decreases. Strong, wear-resistant, good dielectric. The use of PET is also explicated by its convenience, chemical resistance to alkalis, acids, organic solvents, hostility to high wear, facility to oppose various temperatures, insoluble in water, the probability of defended contact with food, low coefficient of friction, high pliability and toughness, clarity of varnish processing. From the impediments, it is worth noticing as it were the propensity to unconstrained crystallization, which can lead to misshapening of items, penetrability to gas particles. It is essential that after hardening, PET is able to resist temperatures of 220 ° C.

The density is 20% higher than ABS.Chemically resistant, so acetone treatment will not work. This material can be machined by drilling, sawing, milling.Superfluous all its characteristics both at low temperatures, up to -40° C, and at high, up to +75° C degrees. Desmolition transpires statistically along the polymer chain.The key vaporous products are terephthalic acid, acetic aldehyde and carbon monoxide. At 900 ° C, a wide-reaching number of diverse hydrocarbons are made,predominantly explosive products are arranged of carbon dioxide, carbon monoxide and methane.

A fully pick of antioxidants can be used to intercept PET oxidation thrpughout processing.With amount of tensile strength of 75 MPa and yield robustness 40 MPa tremendously against to wear and possesses a high flexural modulus.

The use of PET is advisable in the FDM technique, when printing is carried out in layers but it has some complications. Firstly, the work is too slow-going.Secondly, the out-turn does not diverge in high resolution, so the surface of the model will stand out.Thirdly,there may be problems with fixing on the desktop, since it can stick to it. To keep away from this, desktop heating is applied when certain coatings are on them.Fourth, if there are overhanging elements, the use of support structureswhich are afterwords removed. PETT is used incisively for these aim. Unlike PLA or ABS, PETG tends to leak out of the extruder in avoidable places and may leave futile plastic threads on the printout.You need to experiment with the settings of the

extruder or expand retraction, and the printout itself can be speedily heated with a hot air gun.

PET like PLA is dissolvable in acetone, which complicates the post-processing. PET prints can be straigthfully scratched.Polyethylene terephthalate is refinned by injection molding, extrusion, molding. Fibers and attenuated films made of PET are extruded by freezing at room temperature. The point of crystallinity can be regulated by tempering at a definite temperature within the glass transition temperatures Tc and melting Tm,the paramount crystallization rate is achieved at -170° C.

The leading utilization is accompined with the manufacture of PET containers, in particular bottles for carbonated drinks, since PET has remarkable barrier peculiarities.In this case, amorphous PET undergoes biaxial elongating above Tc to fabricate crystallinity.Other exertions cover textile fibers, electrical insulation, and blow molded products.An example of this are: car parts,cases of sewing machines, handles of electric and gas stoves, details of engines, compressors,electrical components,various connectors,medical devices.

Next one is incredibly strong,persistent,adaptable and thermoplastic polymer Nylon,excellent option for pulling gears,transportable joints,detachable parts and mechanism.Flexible when thin,with interlayer adhesion,transculent or white rod,acquiscent to coloring with particular dyes. The material has high ductility, wear and distortion resistance, stability, managing temperatures from -40 to + 150 ° C, repellent of most organic solvents. Cold nylon does not twig to anything (the only exception is molten nylon), so if you are preparing a part from several ones,apprise ways of mechanical connection.More fluid than ABS, reverse retraction with an extruder works very imperfectly, often resulting in printing errors.At 150°C it loses brightness and turns to yellow and not used for upraised temperatures on account of low melting point 214°C.The tensile strength may be diversified by adaptation of the construct circumstances. The more prominent the degree of extend amid drawing, the higher the tirelessness and the under the prolongation.

The high hygroscopicity of nylon (the propensity to captivate moisture) indespensible drying of the nylon threads promtly before printing. Water vapor can be released from the nozzle, which is not harmful for the extruder. Nylon should be supplied in a vacuum package or at least in a water-absorbed container. The fused nylon exudes toxic bits in small abundances, hardens for a extended time. At the paired time, no hazes or odors are voited, it is advocated to print in well-ventilated rooms or using an overtired snood.

Printing machinery using nylon is alike to printing with ABS with some dissimilarities. Like ABS plastic, nylon is susceptable to crumpling and disfiguration through uneven cooling, which requisites the wield of a heated platform. Low

coefficient of abrasion of nylon, extruders with scattered pulling mechanisms should be serviced. Nylon does not pole to glass and other flatten top, so when printing, you can use masking tape with wax impregnation (masking tape).

Nylon is virtually not glued, which makes it strenouos to building large-sized parts from pieces, if the part consists of several units, then it is imperative to review the mechanical link. Realizible to tie nylon by softening the veneers to be combined. Nylon is viable with acid-based dyes. However, professional nylon beneficial have lately emerged. An example is Taulman3D nylon (Taulman3D 618 Nylon, Taulman3D 645 Nylon). How to print with nylon and get the best upshot.The extrusion temperature of nylon should be 240-260 ° C and above. Endorsed observing with temperature by hoisting it step by step until it seems unsurpassed.The active side must be heated to 80 °C-100 ° C and more, because nylon is delicate to cooling too briskly, from which it curves.To help grip on a metal or glass desktop, use PVA glue (clerical glue stick).Substantiated that the layer cooling fans are turned off and the printing process itself is not in a draft.

The expanse of nylon is very spacious: from household office utensils to automated machines. These are medicine (bone regeneration and replacement, individual prostheses), foundry (the two-section molds), CNC plants (prototyping and a limited number of products), invigorate batteries (like a battery separator), music (nylon strings). The use of this fabric exploitation abets to resolve many varigated problems in the national economy. Nylon is engaging as a material for printing ascribed to its attainable and befitting slip coefficient, which lets the apply of nylon in bearings and other alike mechanisms, continually in the absence of lubricant.

Ensuing supple and unsusceptible to abrasion thermoplastic polyurethane (TPU).Very frequent form of elastic polymer or thermoplastic elastomer (TPE).The premier factors for the fabrication of substances are aliphatic isocyanate, basic and complex polyesters. The previous diminish brittleness in cold climate and increment UV resistance. The last mentioned provide the items frost resistance and assurance against organisms. Still others supplement the coefficient of extending and recuperation after distortion. Things from this polymer do not lose plasticity in the cold of 60 degrees, do not withstand 80 degrees in the heat, do not respond to fats and oils, are impervious to wear and friction. It participates in a number of assembly processes for both domestic and industrial usage. In certain mixtures, it can become very mushy.

TPU has many superiorities. When it comes to 3D printing, TPU details are durable. Able to oppose ambient temperatures up to 80° C. Its thread is hold out against to abrasion, shock and to many chemicals. It is convertible and takes a part in many industries. TPU carries burdens greater than rubber, twice as elastic, twice as

powerful and with no bother recuperates after deformation. Does not react to oils, does not adhere to dirt and wears out three times slower. Polyurethane is lighter than metal, more stretchy, not electrically conductive, and don't resist to abrasive. The ratio of cost to permanence is in favor of TPU. The low polymer density of 1,280 g /cm^3 collated to rubber 1,500 g /cm^3 and steel 7,800 g /cm^3 brings down the weight of the accomplished product. Ascribed to additives, it is attainable to turn out a polymer material with a programmable coefficient of abrasion and products with a tensile property of 6 times(20.7-96MPa).The substance allows heating up to 190-220° C.

It is made up from a number of polymers, its state may determined by a mixture of polymers. The temperature at which the thread will be forced out is 230–255 degrees. A hot gathering platform is inessential. But the temperature must not exceed 60 degrees. The extruder system must stand up to elastic and reduced volume by a pressure materials to a ceaseless temperature of 250 degrees.

Things made of TPU are designated by a high degree of solidity, they neutralize the impact of strapping mechanical loads, hard-wearing and protected from damages, do not split upon collision.

In those zones in which such toughness is condemnatory, in definite the origination of parts for car insides fittings, sports merchandise, specialized parts and extraordinary cables, TPUs can accomplish high results (compared to utilizing other materials).Polyurethane items are safe to rough substances of a strong state, with the assistance of which they clean and pound surfaces. Thermoplastic polyurethane is exploited for the forge of undemanding and sophisticated shapes, and thick products. Mold and germs do not settle on them. With elongation 5-8 times, tensile strength 5.5 MPa, can handle tensile loads in the range of 21-55 MPa. Due to the Shore hardness coefficient of 85-90, they are used as a precautionary sheath of a cable with dynamic load, where there are vibration and forces act.

After detailed look to every material they have been ranked among these criterias from low to high in Figure 7.

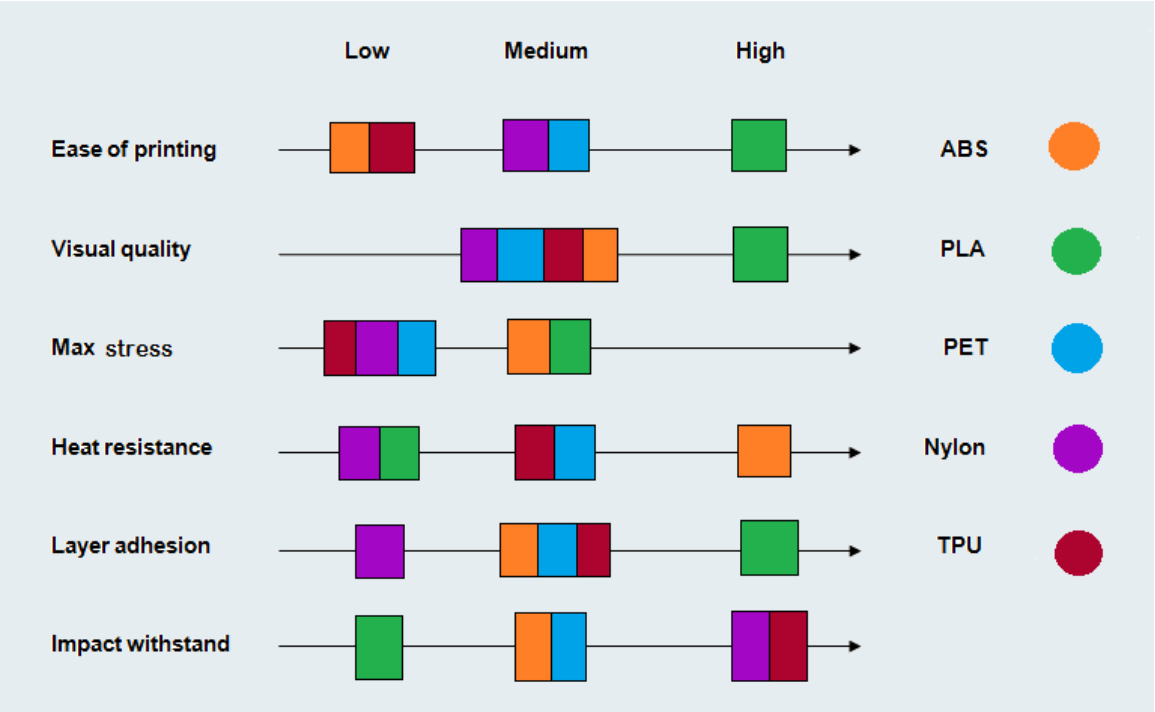


Figure 7 – Evaluation of materials

Here ease of printing was rated by some factors like smell during the process, temperature of printing, toxicity and need for fulfillment of additional tasks like if material is not so easy to come off the base, heated table should be installed. Visual assessment was done by checking the printing parameters, quality of finished surface and strength of it. Max stress was determined by common hook and loading weighted hook until it breaks. Heat resistance shows how material will remain unaffected to the heat related operations. Layer adhesion measures a conduct of molecular networks of materials between them or between different type of substances.

# CONCLUSION

This work is intended to choose appropriate material for printing the prototype of unmanned aerial vehicle. In the course of work the method of printing, complete description of various materials by presenting the advantages and disadvantages, mechanical and printing characteristics of each one.

By checking materials one by one and upon completion of the work done the results are shown in one graph. Taking into consideration every criteria led to our choice settle on ABS.

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