

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF
KAZAKHSTAN



School of Industrial Automation and Digitalization

Department of Industrial Engineering

Bekmuratov N. B.

3D PRINTING OF DRONE PARTS

DIPLOMA PROJECT

5B071200 – Mechanical Engineering

Almaty 2020

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF
KAZAKHSTAN



School of Industrial Automation and Digitalization

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APPROVED FOR DEFENSE

Head of the Industrial

Engineering Department, PhD

Arymbekov B.S.

DIPLOMA PROJECT

Topic: “**3D Printing of drone parts**”

5B071200 – Mechanical Engineering

Performed by:

Bekmuratov N. B.

Candidate of Sciences
Docent, associate professor
_____Isametova M.E
_____2020

Almaty 2020

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CONFIRM

Head of the Industrial

Engineering Department, PhD

Arymbekov B.S.

TASK

for completing the diploma project

For student: Bekmuratov N. B.

Topic: “**3D Printing of drone parts**”

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

Deadline for completion the work "24" May 2020

Initial data for the diploma project: computer modelling of ball mill drive

Summary of the diploma project:

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

List of graphic material: *presented 20 slides of presentation of the diploma project*

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.

THE SCHEDULE

For the diploma work preparation

Name of sections, list of issues being developed	Submission deadlines to the scientific adviser	Notes
Theoretical part	10.03.2020	Task completed
Technical part	23.03.2020	Task completed
Calculation part	8.04.2020	Task completed
Modeling part	15.04.2020	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
Theoretical part	Docent, Isametova M.E	10.03.2020	
Technical part	Docent, Isametova M.E	23.03.2020	
Calculation part	Docent, Isametova M.E	8.04.2020	
Modeling part	Docent, Isametova M.E	15.04.2020	
Normcontrol	Docent, Isametova M.E	22.05.2020	

Scientific adviser

Docent, Isametova M.E
Signature

The task was completed by student:

Signature

Bekmuratov N. B.

Date:

“22” May 2020

Аңдатпа

Қазіргі уақытта адам өміріне 3Д принтерлер үлкен қарқынмен енуде. Медицина саласынан бастап, тамақ әзірлеу, құрылыс, әртүрлі объектілерді басып шығару және т.б. Біздің дипломдық жұмыс ең керек салалардың бірін қамтып алуда – өрттен адам өмірі мен олардың персоналдық заттарын қорғау. Дронның ең алғашқы тесттік үлгісін өз қолымызбен жинап, Сатпаев Университетінде орналасқан 3Д принтерді пайдаланып керек бөліктерін басып шығарған болатынбыз.

Аннотация

В наше время 3D принтеры начали брать очень широкий оборот применения в разных сферах человеческой жизни, начиная: медициной, приготовление пиццей, строительством, проектированием разных объектов и т.д. Данная дипломная работа включает в себя одну из важнейших сфер – защита от пожаров в малых помещениях персональных вещей и жизни людей. Была разработана начальная стадия продукта, где мы собрали полностью летающий дрон, полностью спроектированный своими руками и детали, которые были напечатанны на 3D принтере находящийся в стенах Сатпаев Университет.

Annotation

Nowadays, 3D printers have a wide angle of using in spheres as: medicine, cooking, construction, designing products, etc. This diploma work consists of the main part of social life – protection of personal property and people life from fire threat. We designed minimum valuable product of our work, where drone was designed with own hands and parts were printed with the 3D printer of Satpayev University.

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Introduction

First 3D printer was announced about 30 years ago, in 1984 year. Inventor of first printer was Chak Hall and he was the founder of a biggest company in the world named «3-D Systems». Company at this time took a first place in creating of 3D printers. Since printers have changed in a lot of aspects as in technology, producing, design, etc. Today engineers have an opportunity for creating any kind of constructions from needed materials. Size of creating objects just limited only with the size of printing surface of printer and sometimes details of whole constructions can be joint with the special super glues.

1 3D Printer overview in Flash Forge Guider II

3D Printing is a technology of creating volume physical object with the 3D digital model, which was prepared from scanning or drawing a model in 3D programs as AutoCad, KOMPAS, Inventor, etc.

3D Printer is device for layered creation of layout by using computer's 3D model:

Advantages of 3D printing:

- Creating exact model of desired object in the screen
- Fast speed of printing (1.2cm/sec)
- Economical consumptions of materials
- Opportunity of creating needed sum of exact copy of objects
- Longtime and convenient storage of used materials
- A large assortment of using materials
- Autonomic process of creating volume object



Figure – 1 3D Printer Flash Forge Guider II

Firstly, for using 3D printer user have to add created digital 3D model into the special program named “Flash Print”. Flash Print is a software program where user can make a connection between 3D printer and computer. Operating systems supports: Windows, IOS, Linux. After downloading digital model creator can find specialized functions and can change some of aspects in the process of 3D printing as the size, speed of printing, etc. After, engineer can add auto supporter or create by own. In the final stage before how we print a model printer has to be connected to computer or laptop. There is 3 types of connection: by wire, by Wi-Fi or by flashcard. Then we have to choose a needed printer, in our case it is Flash Forge Guider II. Last step includes window, where user can change some configurations as: Machine Type, Material type of extruder, Supports, Raft, and Resolution. Also, there is some

additional options: Layers, Shells, Infill, Speed, Temperature and Others. Users only need to set up the nozzle temperature according to the material. The nozzle temperature for PLA is recommended to be 220⁰C, Conductive PLA and flexible material temperature is recommended to set at 230⁰C. By the way, the main practical options can be different than in manual. So, we have to use it: temperature of the table has to be 100⁰C -110⁰C and extruder 230⁰C -240⁰C if we use ABS material. If using material is PLA, then options also changes as table 50⁰C -55⁰C, extruder 200⁰C -210⁰C. Next step is preparing a box, where printing will be. In options of 3D Printer we can find “Stabilizing mode”. User needs it for making high accuracy printing. After, user has to make accuracy work with extruder for being sure that all system work in exact accuracy. Before how we turn on table and heat it, we have to use glue for making right contact between table and printing type at the time of printing. In case of not using glue, model can change own coordinates and whole operation of printing will fail. Extruder also has to be heated. On the screen user chooses extruder and the touch a “Heating”. Engineer has to wait until extruder will extrude a filament.

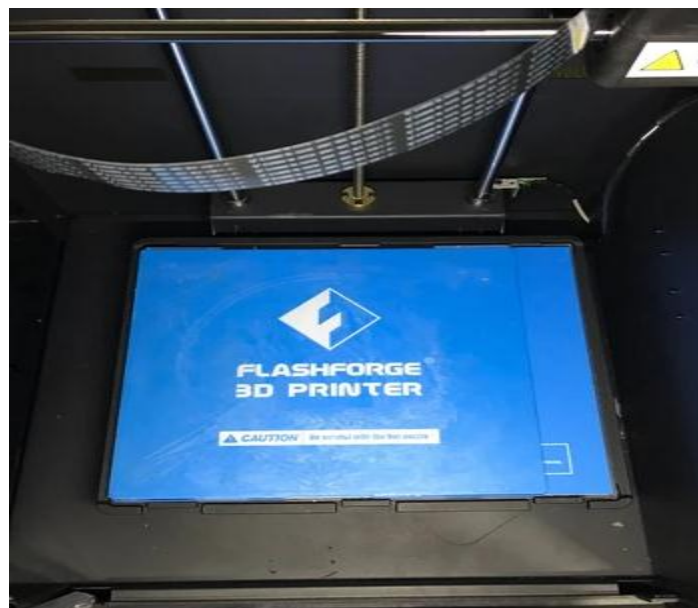


Figure – 2 Printing table of 3D Printer

If 3D printer and source is connected, by Flash Print our 3D model changed in GCode, where file converts in STL format, which is used in 3D printers. After that work on the screen of the printer you can watch a time when your object will be finished. After printing we use abrasive for cleaning a surface of object. Also, by using special knives user have to cut all supporters.

2 3D printing methods

2.1 SLA technology - laser stereolithographic

The principle of operation of this technology is the action of a laser, UV or IR on a photopolymer (liquid). As a result, the liquid is converted into a fairly hard plastic. From above, the polymer is drilled on a given platform, then the beam passes through a layer of liquid under the platform, which leads to hardening and adhesion to the platform, thus creating one layer. As a result of repeating such a procedure, the necessary layout is formed many times.

The main advantages of such a print include:

- accuracy
- print speed
- the minimum percentage of technical failures, such as overheating, peeling, head malfunction, sticking, peeling corners.

The disadvantages include:

- high price
- small color palette
- low physical strength of the finished product.



Figure – 4 SLS technology

2.2 SLS - selective laser sintering

The technological process of model formation is very close according to the principle of work with the previous one. The main difference is the lack of possible

self-distribution of the powder. Therefore, this task is performed by a special roller, which evenly distributes the powder on the surface of the object. The basic principle of operation is to spray a multi-colored hardener onto a thin layer of fine powder in predetermined areas. This procedure is repeated many times, and as a result the necessary element is formed. It should be noted that the layers are so thin that the previous ones are visible under them. As a result of the increase in the number of layers, the bottom of the tank gradually drops down. The time to receive the finished product directly depends on the complexity of the execution of the object itself. At the end of the working process, the finished model is carefully removed from the composite and moved to a booth for cleaning powder through brushes and air flow from the compressor. After cleaning, it is necessary to impregnate the item with special superglue. It should be noted that the residual powder will be reused to create a subsequent model. As a result, we can draw conclusions about non-waste material production.

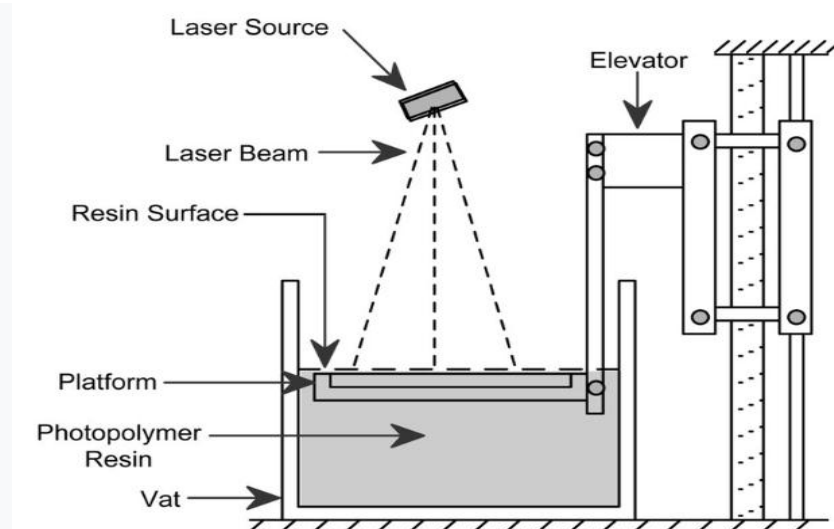


Figure – 5 Graphic how works 3DP

2.3 3DP – Three Dimensional Printing

Technology was created by MIT student Paul Williams and was bought by zCorp. To the material from powder form glue is applied which binds granules and then a fresh layer of powder is applied over the bonded layer. Then engineers got a material which calls sandstone. Advantages: users can use dyes with the different types of color, technology is cheap and highly effective, it can be used in office and at home, can be printed from the materials such as powder of glass, powder of bones, recycled rubber, bronze and wood chips. Also, 3DP can be used in the cooking of meals. Powder is glued by the eaten glue and adds colorant and favor. Disadvantages: finished model can has a high accuracy on the surface, 100 micron, material has to be processed for giving need characteristics.



Figure – 6 Printed 3D object

2.4 MJM - deposition method

In this method, the light curing of the polymer is carried out through the influence of an ultraviolet flash. The molten acrylic photopolymer (plastic) is applied to the printing platform using the head. On this platform, plastic can be illuminated with a halogen lamp, as a result of which the material hardens. The procedure is repeated many times to achieve the desired result. An important detail is the maintenance of protruding or overhanging parts, which is carried out using household wax. This material is applied simultaneously with the polymer and is removed as a result of heating in the furnace, without leaving any residue.

B. Multi Jet Modeling

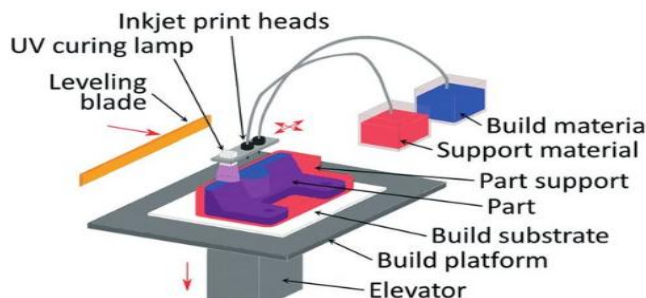


Figure – 7 Graphic how works MJM

2.5 DLP — Fusion Technology

DLP is quite similar in its technological process to MJM. A clear difference is the impact of the projector with the usual light flux on the model to obtain curing of the polymer. The photopolymer is added to the cuvette as it is consumed. During the printing process, the machine closes to prevent the model from flashing. The protruding parts are also supported by the use of wax. Which removal technology is the same.

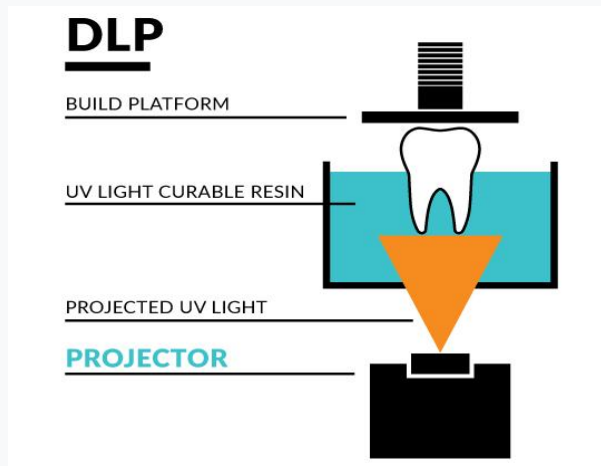


Figure – 8 Graphic how works DLD

2.6 Polyjet Technology

This technology was created by the company Objet in 2000 and in 2012 Stratsys bought them. The essence of the technology: tiny nozzles shoot out photopolymer with a little doses and then instantly polymerizes on the lay of device by the Ultra Violet radiation. The main difference between PolyJet and stereo lithography is an opportunity of printing with different materials. Advantages of technology: layer thickness up to 16 micron, fast printing, because liquid material can be transfer in a short time. Disadvantages of the technology: printing only by using photopolymer – highly specialized, expensive plastic which to sensitive to Ultra Violet and because of fragile enough.

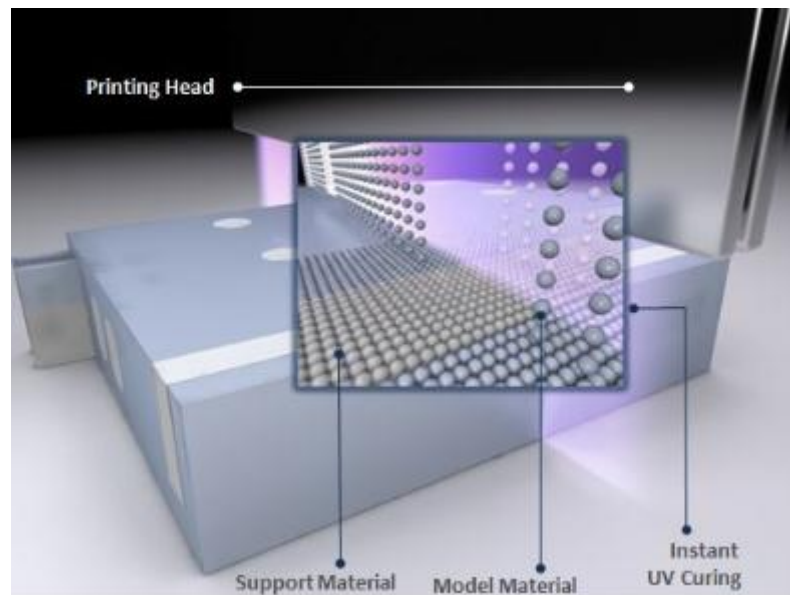


Figure – 9 Molecular structure of the material

2.7 LENS – Laser Engineered Net Shaping

Material from the nozzle blows out in the powder form to the focused laser beam. Sure, some amount of powder blows out to incorrect direction, but other doze instantly sinter and layer by layer forms correct needed 3D shape. By using this technology engineers prints models from the steel and titan. Before, how this type was not created users were not so seriously, because the only used objects from plastic. But, this method changed the game and by using powders engineers make alloys instantly.



Figure – 10 Process of LENS method

2.8 LOM – Laminated Object Manufacturing

Thin laminated parts of the materials cut with the knife or with the laser and then are sinter and stick together to 3D object i.e. tiny layer of material lays and it

will be cut. After, next layer go through previous process. All layers are sintered or pressed. With this type of technology users can make 3D models from plastic, aluminum and paper. To the printing of models from aluminum are used tiny aluminum layers and then sintered by the ultrasound vibration.



Figure – 11 LOM 3D printer

2.9 FDM - Fused Deposition Modeling

The technology of 3D printing, where creating of object based on heating filament from plastic and by the extruder partly liquid material used the construct 3D object. This method created in 1988 by the American company named Stratasys. After how extruder heated filament material will take a liquid form and layer by layer it will create model horizontally and vertically. Usually, filament is a spool of a plastic thread. Microprocessor turns on or off material feed and controls movement of the head in coordinates. After printing users deletes excess materials by using special chemical liquids or abrasive. In this method usually used manufactural thermoplastics, which can hold high temperatures and mechanical forces. But, as universal material basically can be used ABS plastic. Because, it is a cheap material and it has high temperature resistance.

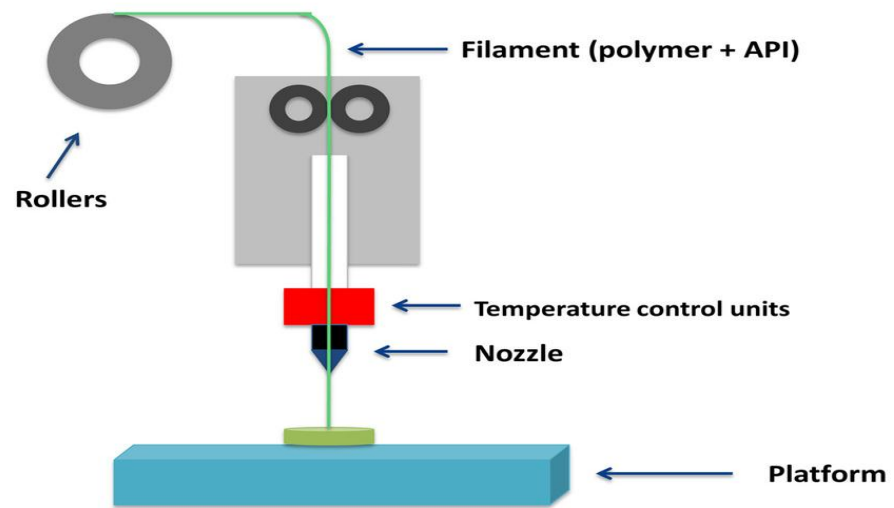


Figure – 12 Principle of working FDM method

3 Choosing right material for work

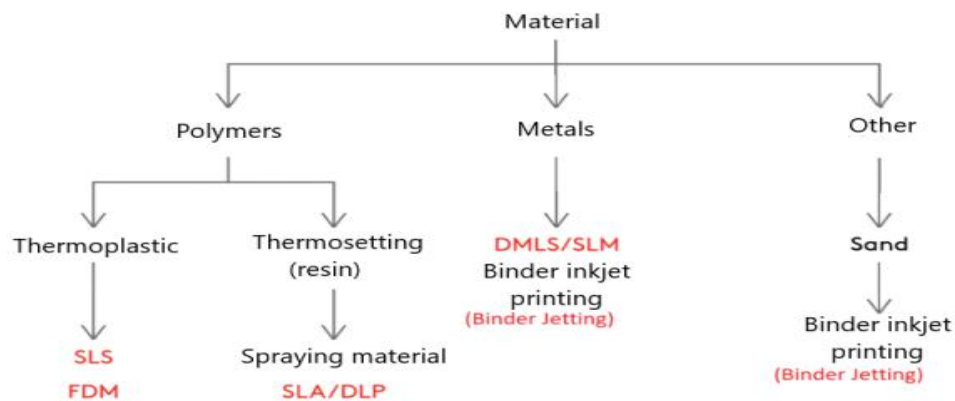


Figure – 13 Types of 3D printing materials

For 3D Printing a device we have a lot of types of materials. But, let us to divide into types of material we get 3 sections: Polymers, Metals and Other (sand). Polymers divided to 2 parts: Thermoplastic and Thermosetting. Here for our tasks we need to use Thermoplastic and SLS method of printing. Because, Thermosetting materials do not have a needed structure of the construction. Structure was created by Ultra Violet curing (polymerization). It means that it is as ceramic materials, which cannot give us absorb characteristics for vibrations of motor. High value of vibration could be a cause of low degree of manipulation with copter and mechanical damage after long time of affecting vibration waves. FDM method also cannot be used in printing of copter. Structure as you can see was printed by molten filament extrusion. Firstly, it does not have high strength characteristics until 30MPa and it depends on thickness of printing. Secondly, in FDM printing usually uses materials as PLA, ABS, etc. types of plastic. Thermal resistance of these plastic materials for PLA 180°C and for ABS 220°C. Metals cannot be useful because of 2 reasons: price of material and 3D printers also, molecular structure. There is steel can be changed by carbon steel. But, price is too high, even if weight is low. Molecules accommodation of other metals also close and it gives high weight. For productivity of our drone we need to minimize weight of construction and maximize traction force.

3.1 Choosing by functionality of 3D Printing methods

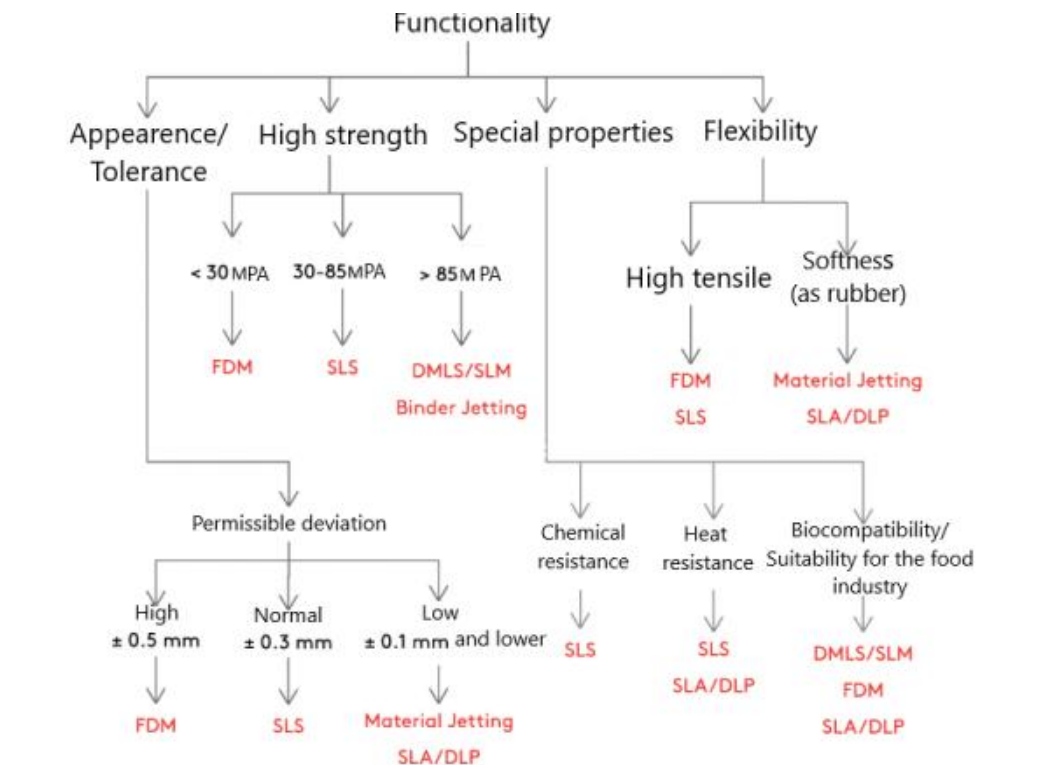


Figure – 14 List of functionalities of 3D printing methods

As we can observe permissible deviation of SLS is normal $\pm 0.3\text{mm}$. It gives to us high accuracy of printing details of copter. Strength is also in normal range. We do not need too high strength of material because case is not planning affect copter to mechanical experiments. As special properties could be added Chemical and Heat resistance. Flexibility is good characteristic for our drone and the reason is absorbing of vibration without any kind of other helpers as foam rubbers or other dampers. Accuracy of details size $\pm 0,3\text{mm}$ gives an opportunity of printing high quality of details with high accuracy. Sizes of platforms also comfortable to creating detail. Because, long range details in drone are frame and arm claw. Last criteria need for supports and SLS printers do not require supports.

Type of 3D printing	Accuracy of details size	Maximum size of platform of 3D printers	Need for support in 3D printing
FDM	$\pm 0.5\%$ (lower limit: $\pm 0.5\text{mm}$) – working table: $\pm 0.15\%$ (lower: $\pm 0.2\text{mm}$ limit) - manufactural	300 x 300 x 400 mm for desktop 3D printers Until 1000 x 1000x 1000 mm	Not always required

		for manufactural 3D printers	
SLA/DLP	$\pm 0.5\%$ (lower limit : $\pm 0.10\text{mm}$) – working table: $\pm 0.15\%$ (lower: $\pm 0.05\text{mm}$ limit) - manufactural	200 x 200 x 200mm for desktop 3D printers Until 500 x 550 x 500 mm for manufactural 3D printers	Always required
SLS	$\pm 0.3\%$ (lower limit: $\pm 0,3\text{mm}$)	Until 750 x 550 x 550 mm	Not required
DMSL/SLM	$\pm 0.1\text{mm}$	Until 500 x 280 x 360 mm	Always required

Figure – 15 3D printers characteristics

4 SLM as 2-nd option

As was written before SLM method of 3D printing has a several minuses for practical using. First aspect is a price of materials for creating parts of copter. There usually used powder from metals as carbon, titan, chrome, etc. A kilogram of 316 stainless steel powder costs about 350-450 U.S. dollars and SLM printers starts from 150.000 U.S. dollars. Secondly, vibration waves can affect to construction and after that controlling of drone will not be easy and this problem can be solved by adding a weight for drone or dampers to absorbing vibration cycles. On the other hand it gives to us more spending of energy and we need to install more powerful motors. Motors directly influence to the price of device and if we change this part, we have to change whole construction. Alternatively, it gives high mechanical and thermal properties. In conclusion we can be sure that if project financing allows for giving more opportunity, then copter can be created with SLM method or in other case it is good enough with SLS 3D printing

4.1 Why not SLA?

Stereolithography method was the 1-st method in the world which started 3D printing direction. It uses now in such a different ways as a prototyping, making models, décor parts of houses, concept-designs and etc. In this method, instead of powder always uses liquid polymer resin which cures by laser beam. Hardened polymer cannot be used as a carcass of copter because of its fragility.

4.2 Whole plan of using

There is first scenario – fire in the building, on 7-th floor. After how firefighters will come they have to prepare hose with the water, stairs and sure whole actions take a lot of time. As we know time will not play in our side. But, what if one of the firefighters will use a firefighter drone while other team members are doing previous operation. Drone user is controlling machine and trying to stop a big distribution of fire or in other words taking a control with the minimum damage of person's property.

4.3 How drone will work?

Drone with an opportunity of lifting heavy mass will care with special fire extinguisher grenade “SAT 119”.



Figure – 16 Fire extinguisher grenade “SAT 119”

Drone will have 3 types of using grenade: 1-st – dropping as cargo helicopters, 2-nd – shooting from pneumatic automat, 3-rd – spraying. First type will be used in open locality with a little fire area, but places where hard to reach. Second type can be used in skyfall or places which have a big altitude and where source of fire big and device needs a long trajectory. Third mechanism can be useful when fire source is not big and it is under control.

4.4 Minimum valuable product

After designing parts of drone we printed in 3D printer and made work with electronic part of copter. Then team members checked all need characteristics in CAE and CAM systems. After taking needed results we started to check our hypothesis in real action. Firstly for this real life situation fire was lighted and a part of liquid from SAT 119 was poured to the plastic tiny pocket. Copter gets close to the fire and with the help of high temperature pocket was melted and liquid of grenade drops to the fire and started chemical reaction and as a result fire was extinguished.

4.5 Working model

MVP was not good enough for manufacturing. Reasons: does not having special software for high accuracy of shooting grenade, low payload, carcass from little temperature resistance.

But, after research works I found good alternative. Material should not be from ABS plastic or from other types of this material. For high temperature resistance and mechanical properties we have to use Sinterit PA12 Fresh Powder. PA12 – polyamide powder with granulation of 20-100 microns and here has to be used SLS printing.

5 Economic Part: Pricing and comparison with other drones

5.1 Price of drone which will be made SLS and SLM methods

Electronic equipment = 85.000 tg

Sinterit PA11 Onyx Print Ready = 27.265 rub/2kg

Fire extinguisher grenade “SAT 119” = 90\$

Software = 2000\$

3D Printer Sinterit Lisa Pro = 2 192 715 rub

32,534\$=grenade+drone+2kg of powder+3D printer

661\$= grenade+drone+2kg of powder



Figure – 17 3D Printer Sinterit Lisa Pro

3D Printer Sinterit Lisa Pro is a second generation SLS 3D desktop printers. One of the main advantages of this device is a laser with high quality and power. Using SLS technology gives to user high module of stretch in compression. During printing construction does not need in add forms for making it sustainable, which gives an opportunity invisible transaction from one layer to another. In this version, PRO version, print camera is much bigger than in other printers, which gives advantage of printing detail with 32cm .



Figure – 18 Sinterit PA11 Onyx Print Ready and printed materials

Sinterit PA11 Onyx Print Ready is a new type of material for desktop 3D SLS printers. Main mechanical difference – high mechanical strength and resistance to various influences as thermal, chemical, mechanical etc. Material is produced as a powder to sintering. Products from this powder are shockproof and wear-resistant and they can be used in the most severe conditions. For instance, an army eyeglass case was printed from this type of material, which successfully withstood harsh weather conditions and an open-close test without wear.

Price of drone which will be made SLM method:

Electronic equipment = 100.000 tg

Stainless steel 316 powder= 500\$/1kg

Fire extinguisher grenade “SAT 119” = 90\$

Software = 2000\$

3D SLM Printer = 150.000\$

152.840\$=grenade+drone+1kg of powder+3D printer

840\$= grenade+drone+1kg of powder

Fire extinguisher grenade “SAT 119” = 90\$

Software = 2000\$

5.2 Prices of manufactural drones



DESIGN	RANGE (MILES)	FLIGHT TIME	SPEED (MPH)	ALTITUDE (FT)	PAYLOAD (LBS)	DIMENSIONS	PRICE (\$)	STOCKIST
TIBURON JUNIOR 	300	40 hr	92	18,000	20	9 x 5ft	POA	LINK
EDGE UAS 	60	2 hr	58	-	0.3	4.3 x 2.7ft	7500	LINK
MD4-3000 	30	45 min	45	13,000	11	7 x 7ft	POA	LINK
M600 	26	60 min	50	-	4	3 x 3ft	14,000	LINK
VANGUARD 	22	94 min	40	15,000	4.4	2.7 x 2.7ft	45,000	LINK
MCFLY-HELIOS 	9	60 min	31	1,600	13	4.5 x 4.5ft	POA	LINK
CHAOS HL48 	8	45 min	30	-	15	5.2 x 5.2ft	20,000	LINK
MAVIC PRO 	4.3	27 min	40	16,000	0	0.7 x 0.3ft	1,000	AMAZON

Figure – 19 Prices of manufactural drones

We have to use own software because ready software of drones cannot be useful in our case works, because they were coded for delivering. Also, we need to change some of construction. Because, shooting or holding and dropping grenade takes another type of adding and surely it will take additional weight for drone what can be not useful in our work. With another word we can say that ready manufactural drones cannot be used in our sphere of the work.

Difference between SLS and SLM printed drones

Economic analysis for 1 unit drone:

Equipment	SLS	SLM
Price of printer	29.900\$	150.000\$
Price of powder 1kg	185\$	250\$
Software for drone	2.000\$	2.000\$
Fire extinguisher grenade	90\$	90\$
Electronic equipment	200\$	250\$
Total	32.375\$	152.590\$
Variable cost for production		
Price of printer	29.900\$	150.000\$
Software for drone	2.000\$	2.000\$

Total	31.900\$	152.000\$
Fixed cost for 1 unit drone		
Price of powder 1kg	185\$	500\$
Fire extinguisher grenade	90\$	90\$
Electronic equipment	200\$	250\$
Total	475\$	840\$

.

Conclusion

The direction of diploma work was dedicated to the one of the main aspects of human life – 3D printing which we connected with fire security. Our work contains a lot of other parts of the whole plan as CAD, CAE, CAM systems, aerodynamic of flying objects, software and hardware parts which you can read in others diploma works.

3D printers have a wide angle of using and it can be also add another spheres. We just tried to start new one. Diploma contains all types of 3D printing which can be used in engineering, partly in Mechanical Engineering. Also, was explained how user can use FDM 3D Printer Gefogre Guider II and how was created details of copter with images. After that were shown MVP (Minimum Valuable Product) and the ways of construction. Added old and new types of firefighting scenarios. Next step was how to improve MVP into working model with the new kind of researches.

In the end was showed why ready manufactural drones cannot be used in our case models and their unacceptable price. Also, was added economic data of the price all process.

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