KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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Research of rapid prototyping technologies for production of new parts

Final project for Master degree

Supervisor
Assoc. Prof. Dr. Marius Rimašauskas

Kaunas, 2015

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FACULTY OF MECHANICAL ENGINEERING AND DESIGN

RESEARCH OF RAPID PROTOTYPING TECHNOLOGIES FOR PRODUCTION OF NEW PARTS

Final project for Master degree

Industrial engineering and management (621H77003)

Supervisor

__________ Assoc. Prof. Dr. Marius Rimašauskas

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Reviewer

__________ Assoc. Prof. Dr. Paulius Griškevičius

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Project made by

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KAUNAS, 2015

KAUNAS UNIVERSITY OF TECHNOLOGY

Mechanical engineering and design

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Industrial engineering and management (621H77003)

(Title and code of study programme)

Research of rapid prototyping technologies for production of new parts

DECLARATION OF ACADEMIC HONESTY

3 June 2015

Kaunas

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Mockus, L. Research of rapid prototyping technologies for production of new parts. *Master's* final project / supervisor Assoc. Prof. Dr. Marius Rimašauskas; Kaunas University of Technology, Faculty of mechanical engineering and design, Department of production engineering
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SUMMARY

In Master's final work was made research of rapid prototyping technologies for production of new parts. Was designed 3D model and using 3D printing and vacuum casting process manufactured prototypes. Designed and manufactured electric air ionizer part. Was calculated time and material consumption and material cost after manufacture prototypes. Was manufactured final product – air ionizer. Was compared prototypes dimensions with designed dimensions. At the end of work was calculated air ionizer price, made marketing elements analysis.

The modelling work was done using "SolidWorks 2015" software package. 3D printing was carried out using "Objet30" printer.

Keywords

Rapid prototyping, 3D printing, vacuum casting, air ionizer

Mockus, L. Naujų gaminių gamybai naudojamų sparčių prototipų gamybos technologijų tyrimas. *Magistro* baigiamasis projektas / vadovas Doc. Dr. Marius Rimašauskas; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas, Gamybos inžinerijos katedra
Kaunas, 2015. 71 p.

SANTRAUKA

Magistro baigiąjame darbe atliktas sparčios prototipų gamybos technologijų tyrimas naujų gaminių gamybai. Buvo suprojektuotas gaminio dizainas ir pagaminti prototipai naudojantis 3D spausdinimo ir liejimo vakuume naudojant silikono formą būdais. Sukurtas galutinis produktas – oro jonizatorius. Suprojektuota ir pagaminta elektrinė oro jonizatoriaus dalis. Apskaičiuotos laiko ir medžiagų sąnaudos gaminant prototipus. Palyginti prototipų matmenys su projektiniais matmenimis. Darbo pabaigoje suskaičiuota oro jonizatoriaus kaina, atlikta marketingo elementų analizė.

Modeliavimo darbai atlikti naudojantis “SolidWorks 2015” programos paketu. 3D spausdinimas atliktas naudojantis “Objet30” spausdintuvu.

Reikšminiai žodžiai

Sparti prototipų gamyba, 3D spausdinimas, liejimas vakuume, oro jonizatorius.

KAUNO TECHNOLOGIJOS UNIVERSITETAS
MECHANIKOS INŽINERIJOS IR DIZAINO FAKULTETAS

Tvirtinu: ______________________________
Gamybos inžinerijos (parašas, data)
katedros vedėjas ______________________________
(vardas, pavardė)

MAGISTRANTŪROS STUDIJŲ BAIGIAMOJO DARBO UŽDUOTIS
STUDIJŲ PROGRAMA PRAMONĖS INŽINERIJA IR VADYBA

Magistrantūros studijų, kurias baigus įgyjamas magistro kvalifikacinis laipsnis, baigiamasis darbas yra mokslinio tiriamojo ar taikomojo pobūdžio darbas (projektas), kuriam atlikti ir apginti skiriama 30 kreditų. Šiuo darbu studentas turi parodyti, kad yra pagilinęs ir papildęs pagrindinėse studijose įgytas žinias, yra įgijęs pakankamai gebėjimų formuluoti ir spręsti aktualią problemą, turėdamas ribotą ir (arba) prieštaringą informaciją, savarankiškai atlikti mokslinius ar taikomuosius tyrimus ir tinkamai interpretuoti duomenis. Baigiamuoju darbu bei jo gynimu studentas turi parodyti savo kūrybingumą, gebėjimą taikyti fundamentines mokslo žinias, socialinės bei komercinės aplinkos, teisės aktų ir finansinių galimybių išmanymą, informacijos šaltinių paieškos ir kvalifikuotos jų analizės įgūdžius, skaičiuojamųjų metodų ir specializuotos programinės įrangos bei bendrosios paskirties informacinių technologijų naudojimo įgūdžius, taisyklingos kalbos vartosenos įgūdžius, gebėjimą tinkamai formuluoti išvadas.

1. Darbo tema

Research of rapid prototyping technologies for production of new parts
Naujų gaminių gamybai naudojamų sparčių prototipų gamybos technologijų tyrimas.

Patvirtinta 2015 m. gegužės mėn. 11 d. dekano įsakymu Nr. ST17-F-11-2

2. Darbo tikslas

Palyginti 3D spausdinimo ir liejimo vakuume technologijas, nustatyti jų tinkamumą naujų produktų gamybai.

3. Darbo struktūra

*Įvadas. **Naujų produktų gamybos analizė**. Naujo produkto kūrimo koncepcija. Sparti prototipų gamyba. **Naujo gaminio projektavimas**. Oro jonizatoriaus veikimo principas. Oro jonizatorių tipai. Oro jonizatoriaus elektroninės plokštės gamyba ir jos testavimas. Oro jonizatoriaus korpuso projektavimas. **Naujo gaminio gamybos tyrimas.** 3D spausdinimo procesas. Liejimo vakuume procesas. Naudojamos medžiagos ir įrankiai. Laiko sąnaudų skaičiavimas.Kainos skaičiavimas.Kokybės tikrinimas. **Oro jonizatoriaus verlo idėjos pristatymas.** Oro jonizatoriaus kaina. Marketingo elementų analizė. **Išvados. Literatūros šaltiniai. Priedai***

4. Reikalavimai ir sąlygos_

Oro jonizatorius turi būti visiškai saugus, neturi būti atvirų kontaktų ir laidų. Oro jonizatorius maitinamas iš 230V elektros lizdo. Korpuso gamybai naudojamas plastikas. Gabaritiniai matmenys nedidesni, negu: ilgis – 180mm, plotis – 80mm, aukštis – 60mm.

5. Darbo pateikimo terminas 2015m. Birželio mėn. 10 d.

6. Ši užduotis yra neatskiriama baigiamojo darbo dalis

Išduota studentui Laimonui Mockui

Užduotį gavau Laimonas Mockus ______________________
(studento vardas, pavardė) (parašas, data)

Vadovas Doc.dr. Marius Rimašauskas ______________________
(pareigos, vardas, pavardė) (parašas, data)

INTRODUCTION

The design of new products is the key combat zone that all companies must master to remain in business-to compete at a basic level. Product designers are the front-line congregates who lead and execute the battle. Product design is a set of activities that involves more than engineering. It is complex with risks and prospects, and requires effective decision over technology, market and time. To avoid drawbacks, today's design engineers must understand and use many tools of modern product development practice. For almost all products, it is no longer acceptable to develop major improvements without first consulting customers to forecast the market acceptance of the enhancements: the risk is too high to just accept one product manager's belief in their "feel" for the market. Nowadays designers often use rapid prototyping technology to improve design or to test detail.

Rapid prototyping methods are broadly used in product development process. They let for fast and low-cost manufacturing a small batches of components directly from the part geometry parameterization kept in a 3-dimensional CAD model. The prototype used for calculation of many aspects of how well corresponding to its purpose of the prototyped component in the developed product. There are different rapid prototyping methods, but 3D printing is one of the most commonly used, because the product variety and customers needs change all the time, so 3D printing is fastest choice to create product prototype. Also there are other choices like vacuum casting process which is suitable for small-batch production.

The main aim of master thesis is to compare 3D printing and vacuum casting technologies and determine the suitability for manufacturing new products.

There are 4 main objectives:

1. Make theoretical analysis of technological suitability for manufacture a new products.
2. Choose a product, design and analyse construction.
3. Manufacture prototypes using 3D printing and vacuum casting methods.
   - calculate time consumption
   - calculate material consumption
   - check prototypes quality
4. Make analysis of marketing elements and calculate air ionizer price.

1. NEW PRODUC MANUFACTURING ANALYSIS

1.1.New product development concept

Very quick changes in technology, the emergence of worldwide industrial and consumer markets, increasing market demolition and product differentiation, and the increasing options for developing and manufacturing products have improved the pressure on all firms to more successfully develop new products. In many open-minded firms, the design of new products is conducted by a team representing a number of functional areas. Marketing, design engineering ,product planning, reliability engineering, manufacturing engineering, supply management, quality, finance, field support, and, frequently, carefully selected suppliers and customers are involved, as appropriate. If successfully done, new product development (NPD) can be a basis of competitive advantage for a company and a competitive strategy for the inside and outside partnerships of the supply chain.

That concept consist of 3 phases: 1. Design phase, 2. Development phase 3. Production phase.

Design phase. A design process is the set of technical actions within a product development process that work to meet the marketing and business case visualization. This set includes improvement of the product vision into technical specifications, new concept development, and personification engineering of the new product.

Development phase. A product development phase is the entire set of activities required to bring a new concept to a state of market preparation. This set includes everything from the personalize inspiring new product vision, to business case analysis activities, development of manufacturing plans, marketing efforts, technical engineering design activities, and the validation of the product design to conform to these plans. Often it even take in development of the distribution channels for strategically marketing and introducing the new product.

Production phase. Neither the product development phase nor the design phase encompasses the subsequent production process, when the products are physically made. The design of the manufacturing process, however, is usually considered part of the product development process. Often the product design phase and the design of its production system must be carried out simultaneously. Effectively performing this integration is part of the study of simultaneous engineering. [1]

1.2.Rapid prototyping

Rapid prototyping (RP) is a class of computer-aided technologies for building 3-D prototypes from a range of materials based on data obtained from computer-aided design (CAD) drawings. The dimensional data in digital form taken from CAD drawings is converted into build directions for the 3-D model on various RP machines or systems. Typically these call for the construction of the model one layer at a time. The objective of all RP systems is the fabrication of prototypes, molds, and even functional parts or tools faster and more economically than they could be made by skilled persons using hand tools or conventional machine tools. Even the fastest RP fabrication process takes from 3 to 72 hours, depending on the size and difficulty of the prototype. Nevertheless, all of these methods are faster than the weeks or even months required to make a prototype by traditional handcrafted methods. [2]

1.2.1. Silicone rubber molding process

Silicone rubber molding for investment casting. Silicone elastomers are used since the early 80s in medical, auto industry, electronics, in construction, industrial applications. These elastomers today a success due to their exclusive characteristics, such as enlarged compressive strength, flexibility in a huge range of temperatures, a wide range of hardness. Silicone gum is a synthetic polymer with a molecular structure consisting of a huge cable formed by two atoms of silicon and oxygen in other way. The dominant link of silicon-oxygen gives silicone rubber its own performance and characteristics concerning in increased resistance to various chemical agents and variations in temperature, excellent mechanical properties, transparency and natural clearness. [3]

The technological advantages of silicone rubber are: light mixing and processing, very short processing time, easy disassembly from mold, not adhesive, practical in the wide range of temperatures, very good resistance.

Model preparation. The original element of the production process - it is a model that can be made from any material, for example; wood, plaster, metal, synthetic materials, wax, ceramics.

Porous structure of the models, such as; plaster, must be protected from sticking to liquid silicone - the surface must be coated with varnish (acrylic, epoxy, polyester). As well as glass and ceramic models of surface should be protected from sticking vaseline or liquid wax. [4]

Silicone mass preparation. Prior to discharge from the silicone mass air to be removed because of the mix of silicone and reagent, the mass gets a lot of air, which can be put on the surface of the model and appear in the form of defects, which should then be removed.

Forms manufacturing. Silicone molds can be produced in several ways. It depends on the model form, in economic terms (the consumption of silicon), the form of the production speed. Prior to the production of a form to be prepared for the frames, the best of wooden planks. Closes forms and large products are often used in the manufacture of frames and glass polyester laminate.

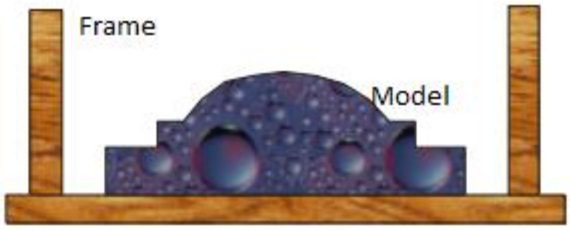


Fig.1.1. Open forms [4]

Model is mounted on a stable base wedges, gluing vaseline, modeling clay or modeling clays. Patterns of hollow should be filled with plaster or modeling ground. The model frame can be various types of boxes and cardboard, glue tape. In practice, the use of easy to produce, and the scrapping of the adjustable frame boards.

One part form. Wall thickness, depending on the model and the product, 20-50mm

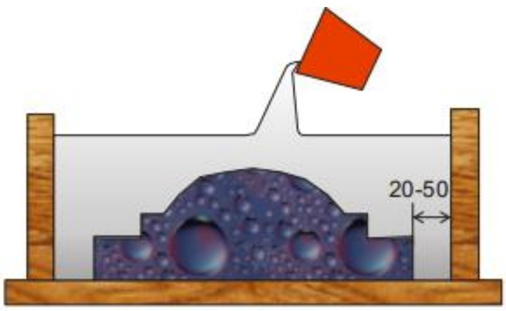


Fig. 1.2. Fill with silicone [4]

Through the x time, depending on the chosen silicon features ranging from rubber filler in the form of ready to use.

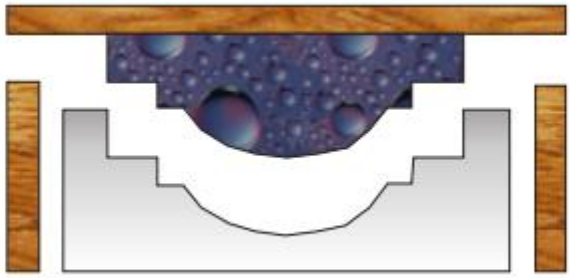


Fig. 1.3. Disbanding [4]

Plaster or resin to be poured in a thin stream (so that the product no air) to the lowest form of location.

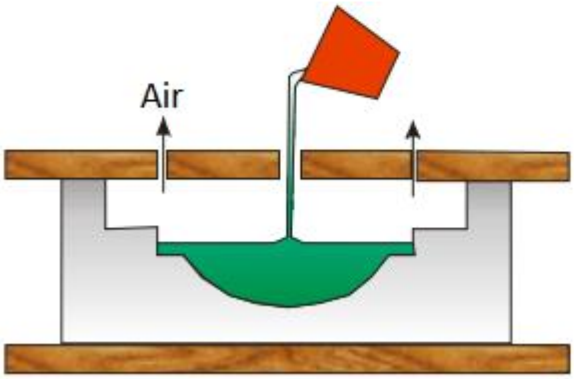
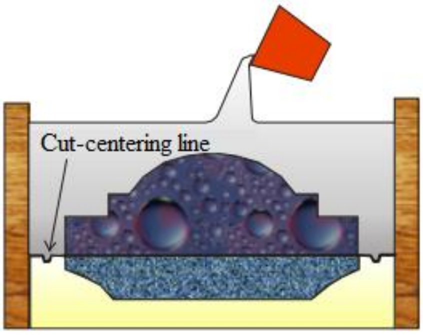


Fig. 1.4. Model production [4]

Multiple parts form. Model punched in the dough to form the division line. Necessary for both form part of the cut-centering occasioned dough



.Fig. 1.5. Cut – centering line [4]

After hardening silicone rubber, shaped collapsible frame of the model is separated and immobilized dough layer. Rubber surfaces lubricated with petroleum jelly or other Sequestrate and prepared for another form of half filling. Small patterns with dimensions 50 x 50 x 50 can be completely pour rubber and then cut with a razor blade.

1.2.2. Silicone vacuum casting

Possibilities of use rapid prototyping methods could be significantly extended by taking advantages of devices for vacuum casting. It enables to produce models from different resins (with properties very similar to finished plastic or rubber products) and wax models for die casting process. Vacuum casting system consists of: vacuum chamber and heat chambers. Vacuum chamber herself gives possibilities for manufacturing silicon rubber molds and resin free of air bubbles generated during mixing. Main use of vacuum chamber is casting of resins, waxes and other plastics in silicon molds - prepared in the first step from the rapid prototyping models. It is easy to reach wide range of resins, which gives possibilities to accomplish variety properties of produced products. It is possible to produce objects which are similar in hardness and elasticity to rubber, and also to significantly harder and less elastic like ABS plastic. [5]

Silicone vacuum casting workflow: (Fig. 1.6)

1. Preparing of master model/pattern with Rapid Prototyping (RP) method
2. Preparing of mold design
3. Preparing of mold casing. The mold casing should ensure tightness and have suitable overall dimensions
4. Mold filling with silicon
5. Heat treatment of the mold – soaking at 70^0C for 12 hours
6. Separate the mold
7. Removing of model system

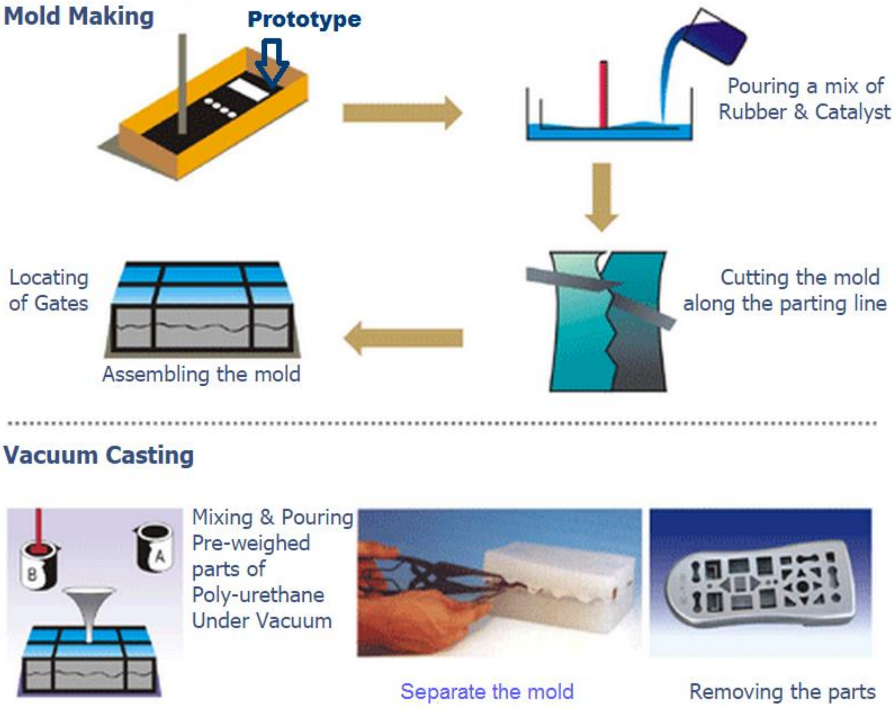


Fig. 1.6 Vacuum casting workflow [5]

Vacuum casting has become a widely accepted method of soft tooling, replacing traditional methods such as investment casting. Vacuum casting is a new version of investment casting with changes to the process of creating the mold. Several needs are addressed by vacuum casting which makes it extremely popular. Most importantly, vacuum casting reduces the time for part production when compared to tradition methods. This, in sequence, significantly reduces costs. The additional following characteristics offered by vacuum casting justify the choice of this technology for the efficient process: precise castings, consistent quality, up to 90% saving in time, fit and function testing, material choices, cost saving.

1.2.3. 3D printing

3D printing technology is almost automatic, additive manufacturing process for producing 3D solid objects from 3D CAD model. There are a lot of different technological variants, but almost every existing, 3D printing machine functions in a similar way: a 3D CAD file is sliced into a series of 2D plane sections and these are deposited by the printer, one above the other, to make the part. [6]

All commercial rapid prototyping process depend on computers, but four of them require lasers either to cut or fuse each lamination or provide adequate heat to sinter or melt metal powders or plastic resins. The four processes that depend on lasers are stereo lithography (SL), selective laser sintering (SLS), laminated object manufacturing (LOM), and directed light fabrication (DLF). The four processes that do not require lasers are fused deposition modeling (FDM), three dimensional printing (3DP), direct shell production casting (DSPC), and solid ground curing (SGC).[7]

Stereolithography. A stereo lithography apparatus (SLA) (fig. 1.7) is a rapid prototyping device used to create 3D plastic parts from CAE/CAD data. A stereo lithography apparatus combines four different technologies: lasers, optical scanning, and photopolymer chemistry and computer software.

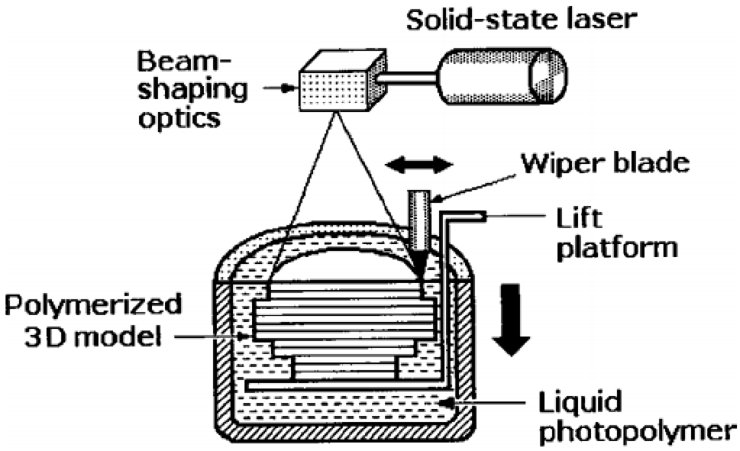


Fig.1.7. Stereo-lithography (SL) [7]

The part and supports STL files are “sliced” into a series layers variable in thickness from 0.13 mm to 0.51 mm. Computer controlled optical scanning system moves a laser beam in the Y and X directions while drawing a layer of the part. The photopolymer hardens wherever the laser beam strikes it. Software has been developed which allows for a second pass of the laser on the layer perpendicular to the first pass. This results in a relatively high degree of solidification of the part.

Vertical elevator lovers the newly formed layer into the container of liquid resin. Successive layers are built on top of another to form a completed “green” part. Typically, part build time ranges from one to two hours for small and simple parts, to up words of 50 hours to large complex parts. Part size is limited by the volume of the container-the smallest 190x190x230 and the largest 510x510x610 mm.

***Fused Deposition Modeling (FDM*)**. Fuse deposition modeling is a rapid prototyping technologiem that mixes CAD, polymer science, CNC, and extrusion technologies to produce 3D objects directly from CAD model. The process begins with the creation of a detail on a CAD system as a solid model. The model changed into an STL file using a specific translator on the CAD system. The STL file is sent to the FDM slicing and pre-processing software, where the engineer spends much time in selecting proper positioning, creating supports and slicing and other dimensions to prepare the model for sending to the fused deposition modeling machine (Fig.1.8). A correct orientation of the STL model is necessary to minimize or eliminate supports. The STL file is then sliced into thin cross sections at a selected resolution, creating an SLC file. Every slice must be a closed curve; any unclosed curves are corrected and closed. Supports are then created if required, and sliced. Supports could also be created as piece of the CAD model and imported as fragment of the STL file. The sliced model and supports are then converted into modelling language (SML) file which covers actual instructions code for the fuse deposition modeling machine tip to follow defined tool paths, called roads, to deposit the extruded material to create each layer section. The engineer selects many sets and road parameters to make sure a good SML file is created. The SML file is then sent to the FDM machine, where the FDM head creates each straight layer by depositing heated extruded material on a foam basis until the part is completed. The part is then taken out, supports are carefully separate, and it is complete for use.[8]

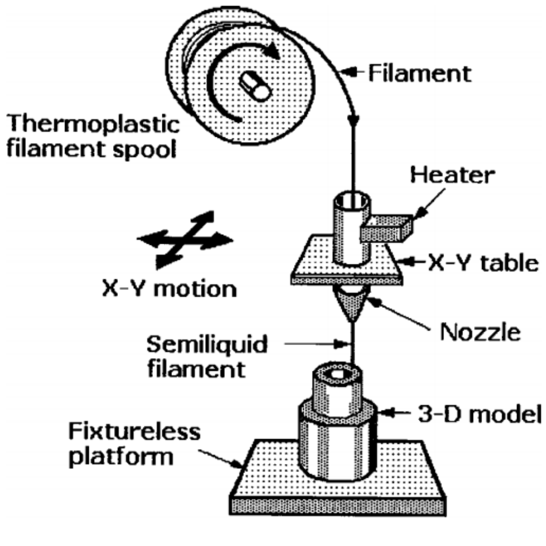


Fig.1.8. Fused Deposition Modeling (FDM) [7]

PolyJet. PolyJet is a variant of SLA, in that it uses a photopolymer cured with ultraviolet light, as it is being dispensed through the print head. The unique feature of this method is that it employs the highest layer resolution among other 3D print methods (at around 16μ) which results in highly accurate, smooth and very detailed models. In terms of the resolution capabilities, it comes nearer than other 3D print systems to matching the resolutions requirements of a typical microelectromechanical systems device. A variety of rigid and elastomeric, shining and opaque materials are available with this technique. On the downside, temperature stability of the materials used in this method tends to be lower than in other 3D methods. However, properties of the materials used in this method may be restrictive its use for various devices built for handling fluids, chemicals and mechanical loads. PolyJet process offers a special ability to the end user to create its own materials based on the design requirements and the final application, by mixing current materials into a new compound. [9].

Table 1. Process capabilities of the main 3D printing methods discussed in this review

Process parameter	**SLA**	**FDM**	**PolyJet**
Layer thickness, µm	50-100 (high resolution) 120-150 (standard resolution)	180 (high resolution) 250 (low resolution)	16 (high resolution) 30 (low resolution)
Min feature size, µm	250-380 (high resolution) 630-890 (standard resolution)	630	600 (high resolution. 1100 (low resolution)
Material selection	Various ABS-like; rigid and clear polycarbonate; semi-flexible polyethylene	ABS, polycarbonate, polyphenylsulfone	Rigid, elastomeric, translucent, opaque, ABS, polypropylene-like
Max model size, mm	~600x700x500	~600 x 700 x 500	~ 500 x 400 x 200
Comments	ABS can be ultrasonically welded	Available in various colors. Soluble support materials	Allows custom creation of materials from the library of materials Meltable support

2. NEW PRODUCT DESIGN

The quality of the air we inhale and the consequent worries for human health are influenced by a variety of factors. These include hazardous material discharges inside and outside, climatological and airing conditions, and toxin decay and removal processes. Over 78% of time for most people is generally spent in inside environments so that the influence of building structures, surfaces, and ventilation are significant considerations when evaluating air pollution experiences. For this reason now are very popular air ionizer.

An air ionizer is a useful item to have in the house. Ionizer or air purifiers remove allergens and dust particles from the air, as well as act as an air freshener, neutralizing odors and improving air quality. Ionizers can give indoor air the same number of negatively charged ions as fresh outdoor air, making ionic air cleaners a popular choice for treating Seasonal Affective Disorder.

2.1.Air ionizer working principle

Negative ions can be produced by copying any of the ways that nature uses - UV (lamps), radioactive sources. But it most cases it is also too dangerous, too luxurious or just unreasonable. For this reason most producers use the method called "corona discharge" which is similar to lightning. A high voltage (but at extremely limited current, for safety) is applied to one needle (fig.2.1). Electricity is a movement of individual electrons. And these electrons, supplied by the internal circuit, are pressed down the needle near the point. The closer they get to the point, the closer they become forced together. Electrons naturally repel each other, so as they reach the needle end, the density becomes too much and they "jump" off, onto the nearest air molecule (positively charged), turning it into an ion. By adjusting the voltage level, the needle profile and the various materials used, this process can be made very efficient. Negative ions again repel each other, so they are driven from the needles as a gentle breeze, forming a dense "cloud" opposite the ionizer, which disperses in all directions into the room.

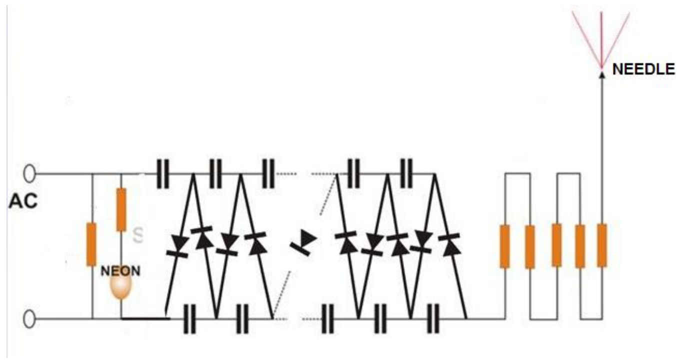


Fig.2.1 Air ionizer circuit schematic [10]

The ions leaving the ionizer are small, high speed ones. These are found to be most helpful to health. If they encounter with particles of smoke or smog near the ionizer, they pass on their "static" charge. This particle is then strongly attracted to the nearest "earthed" surface. Out to the room the ions indeed begin to slacken. As they drift, poisons such as dust, pollen, and cigarette smudge and even evaporated substances like spray propellants and machine fumes are attracted to and cluster around the ions. This has the consequence of making the ion grow in size. There comes a point where it is too weighty to be carried in the air, so it drops to the ground. The capability of an ionizer to remove very fine particles from the air makes it very valuable for health. Recent studies indicate that the smaller the particle, the harder it is for our immune systems to manage with. So ionizers have a "dual action" effect. They surpass at removing microscopic particles - the most harmful - and at the same time they return a "strength" to the air - which our bodies seem to need for their everyday active.

2.2.Types of air ionizers

Domestic "home and office" room ionizers (Fig.2.2)

These are the type what will be manufacturing. They manufacture negative air ions to revitalize and cleanse stale inside air and are designed to maintain negative ion levels equivalent or higher that is possible to find in the most refreshing and freshness places - in the mountains, near waterfalls.

Commercial premises ionizers (Fig.2.)

These are almost like the home / office ionizers, but on a bigger scale and usually incorporate a big filter, either mechanical or electrostatic, also they have additional accessories like: air purifier with HEPA filters.

Fig.2.2 Commercial air ionizer [11]

Personal Ionizers (Fig.2.3. a, b)

There are two elementary versions of personal ionizers. First one is like the room models but lower power, intended to create a individual breathing space for someone in the indoor or travelling. These can be powered by AC or battery. The other one is small and hangs around the neckline to produce ions just in front of the body.

a) [12] b) [13]

Fig.2.3 Personal air ionizers: a) room model b) hang neck air ionizer.

Vehicle ionizers (Fig.2.4.)

These are similar to the home ones, designed to operate in a vehicle from its battery, to keep the driver alert and stress free.

Fig.2.4 Vehicle air ionizer [14]

2.3. Air ionizer circuit board manufacture

City modernization has resulted in a huge defalcation of naturally created ions that are good for health. The simple air ionizer circuit (Fig.2.5.) presented here will insincerely restore appropriate strength to make the interior air clean and usable.

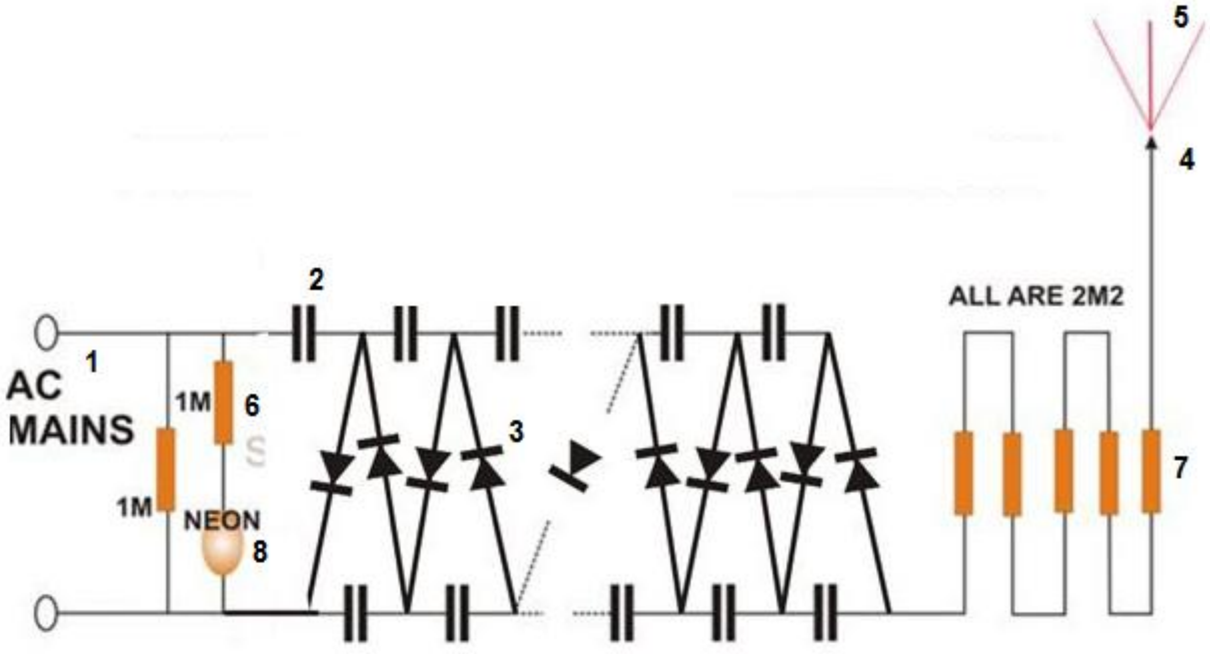


Fig.2.5 Air ionizer circuit scheme

During each set of the input AC (1), the charge is stirred back and forth across each row of capacitors (2), but always keeping a forward direction in the network, due to effect of the screed diodes (3).

When all capacitors reach their full load, the voltage across each of them becomes equivalent to the peak AC input mains voltage and the multiplied value of all the capacitors results to the required voltage.

But basically it is found that the maximum voltage at the output of circuit never reaches more than minus 4,5 kV due to voltage drop through the component leads. But, coincidentally that's the exact voltage perfectly suited for ionizing air. Voltages higher than this will start making ozone rather than ions.

This voltage is finally fed to the pointed end terminal (4) (needle shaped) of the circuit where the voltage (electrons) gets intense to a level difficult to accommodate. Also, since the electrons when too close, reject each other, tend to fly out in the ambient air in the form of shooting ions (5).

2.3.1. Air ionizer parameter calculation

First of all, using “CW / BRM Online Java Calculator” [15] measured how many stages (2 diodes and 2 capacitors) will be and calculated output voltage at full load. In required specification table (Fig.2.6) input multiplier type, which is CW (Cockcroft Walton Multiplier) also input wave form (Sine wave), AC input voltage, which is 230V, Target output voltage – 4500V, output current – 0,0001A, stage capacitance (two capacitors with 10nF capacity) – 20nF and tweak number of stages from optimal left 0.

Required specifications

Select Multiplier type :	CW type ▼
Select input waveform :	Sine wave ▼
Peak ac input voltage E_{pk} from driver stage in Volts:	230
Target dc output voltage V_{OUT} in Volts:	4500
Required output current I_{Load} in Amps:	0,0001
Enter stage capacitance or driver frequency:	20 nF ▼
Tweak number of stages from optimal:	0 ▼

Calculate Reset

Fig. 2.6 Specification table

Then press calculate and get results, which are show in table (Fig.2.7.)

Results

Parameter Description	Half wave	Full wave
Theoretical optimum number of stages:	14.9 stages	10.84 stages
Optimum integer number of stages :	15 stages	11 stages
Driver stage frequency :	NaN kHz	NaN kHz
Minimum Driver stage output power :	NaN Watts	NaN Watts
Output Ripple voltage :	NaN Volts	NaN Volts
Output Ripple factor :	NaN %	NaN %
Open circuit output voltage :	6796 Volts	4984 Volts
Voltage drop in multiplier :	2265.24 Volts	415.29 Volts
Calculated output voltage at full load :	4530 Volts	4568 Volts
CW Output Power :	NaN Watts	NaN Watts
Stage capacitance value :	20 nF	20 nF
Capacitors minimum working voltage rating :	453.05 Volts	453.05 Volts
Total stored energy in capacitors under no-load :	61.58 mJ	67.73 mJ
Total stored energy in capacitors under full-load :	27.37 mJ	56.91 mJ
Capacitor count :	30	33
Diode count :	30	44
Component count :	60	77
Effective BRM capacitance :	Not Applicable	Not Applicable
BRM resonant inductor :	Not Applicable	Not Applicable

Fig. 2.7 Result of the CW multiplier calculations

From get results clearly that it will be necessary 15 stages with 30 capacitors and 30 diodes, calculated output voltage at full load is 4530Volts, open circuit output voltage is 6796 Volts, voltage decrease is due to the diodes and resistors resistivity. According to the data obtained, it is possible to design the scheme

2.3.2. Air ionizer circuit simulation

Secondly with program *"Circuit simulator v1.6i"* was done a circuit simulation (Fig. 2.8) to check or circuit was done correctly and or generated voltage will reached the determined limit, which is –little more than 4kV.

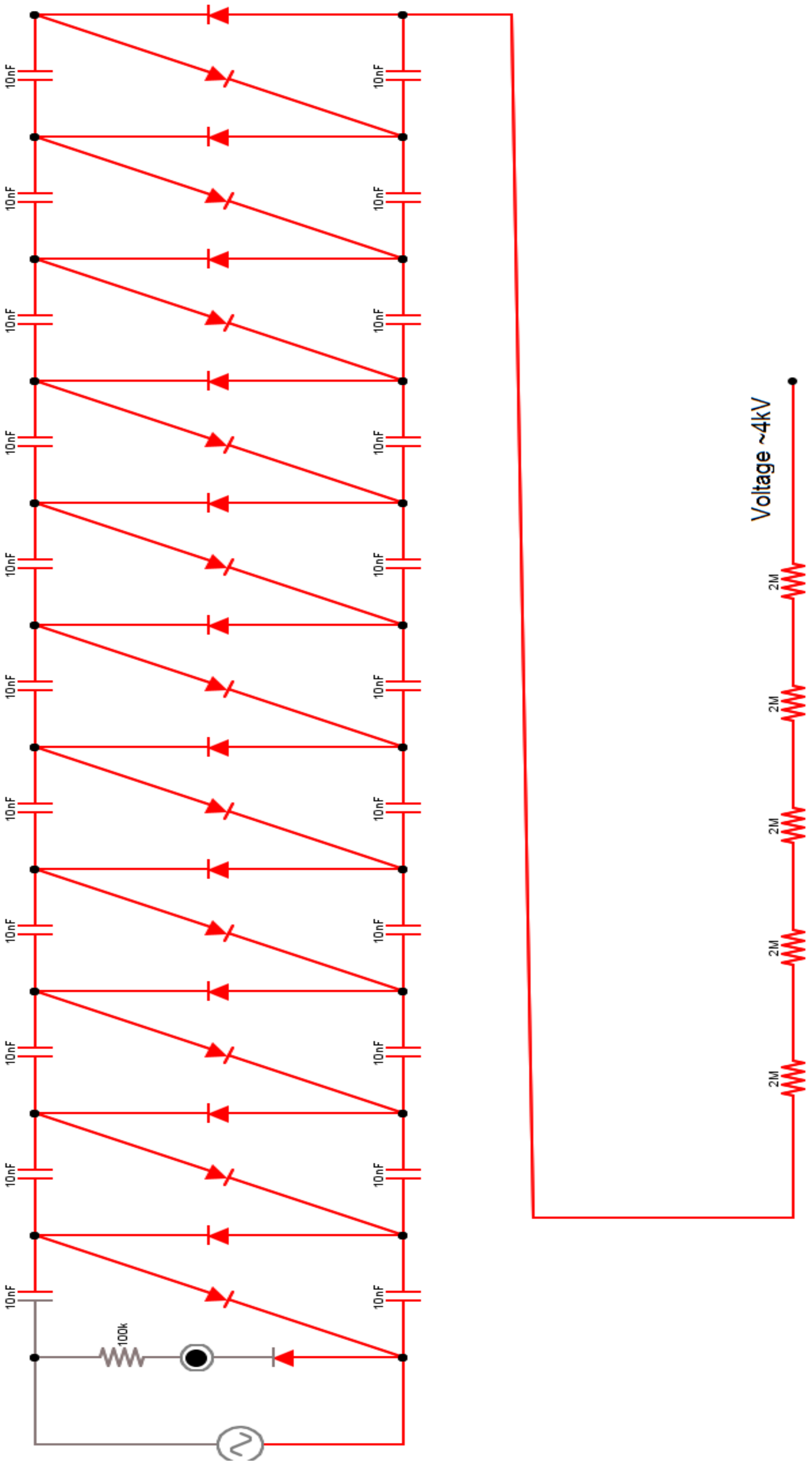


Fig. 2.8 Air ionizer circuit

Approximately after 8 seconds circuit in the end of the circuit, reached negative voltage peak was 4,37kV (Fig. 2.9.)

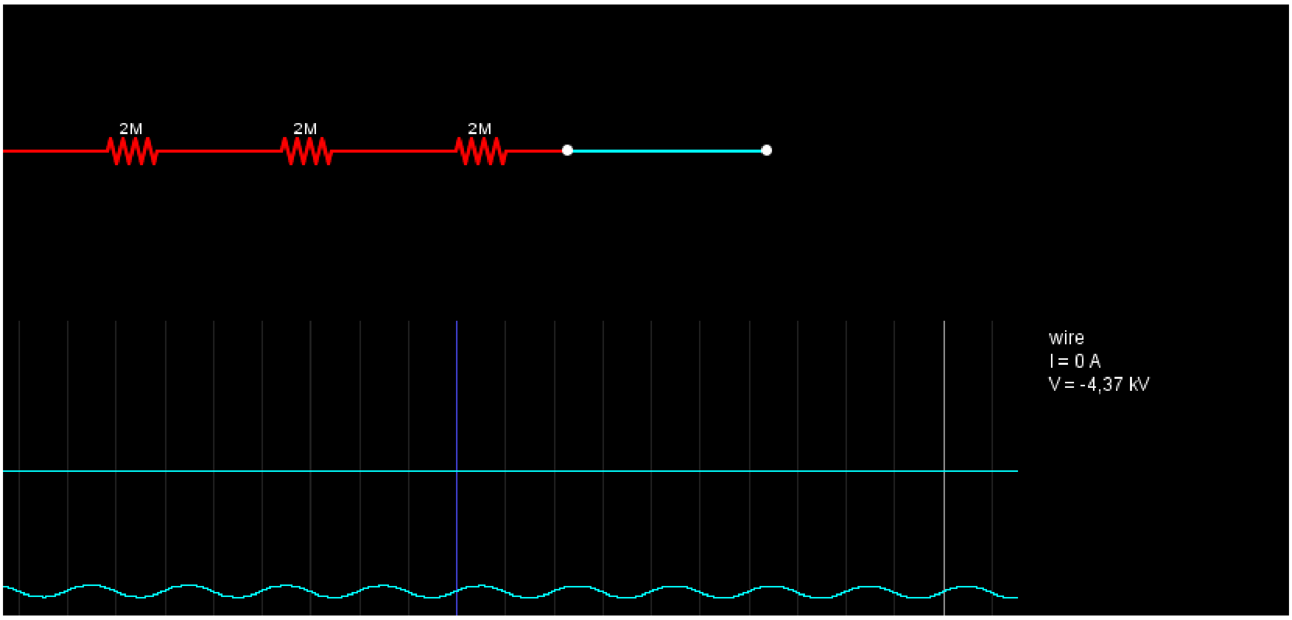


Fig.2.9 Reached the highest negative voltage

2.3.3. Manufacturing circuit scheme

The next step is to buy all necessary items for manufacturing air ionizer circuit, which are show in fig.11.

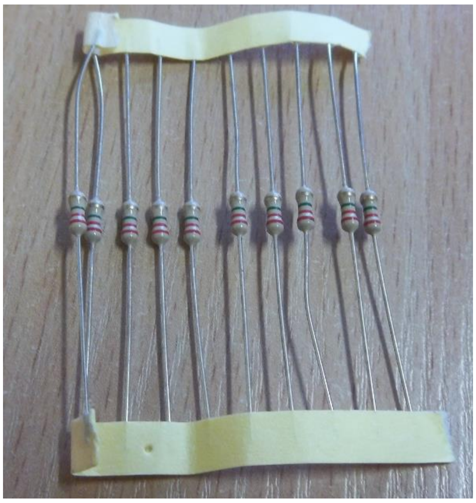
Necessary part list for air ionizer:

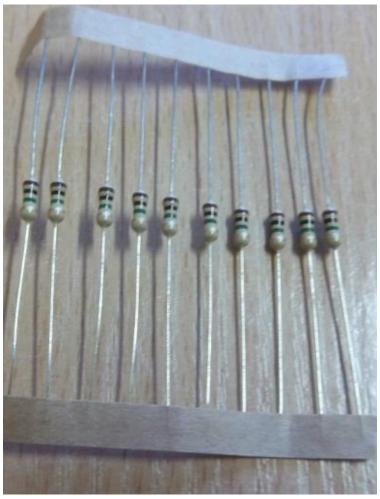
1. Capacitor 10nF 630 volts, Polyester = 30 units. (Fig.2.10 a)
2. Diode 1N4007 = 31 units. (Fig.2.10 b)
3. Resistor 2M2, ¼ W = 5 units. (Fig.2.10 c)
4. Resistor 100k, ¼ W = 1 units (Fig.2.10 d)
5. LED = 1 unit (Fig.2.10 e)
6. General Purpose PCB 1 unit (Fig.2.10 f)

Necessary tools: (Fig.2.11.)

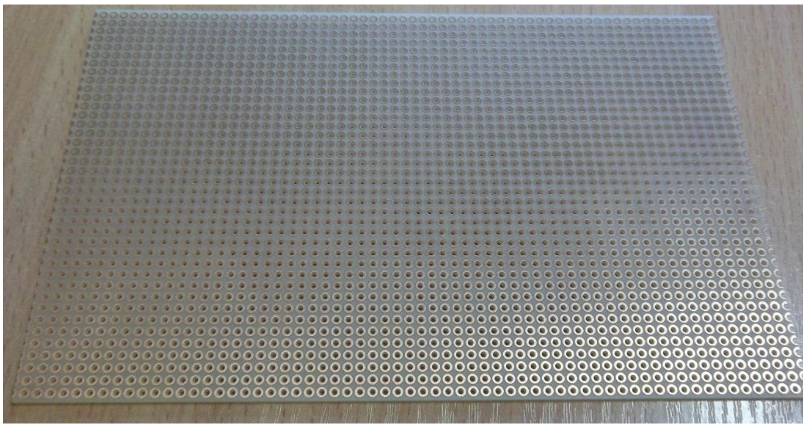
1. Soldering-iron (Fig.2.11 a)
2. Soldering flux (Fig.2.11 b)
3. Solder (Fig.2.11 c)

a) b)



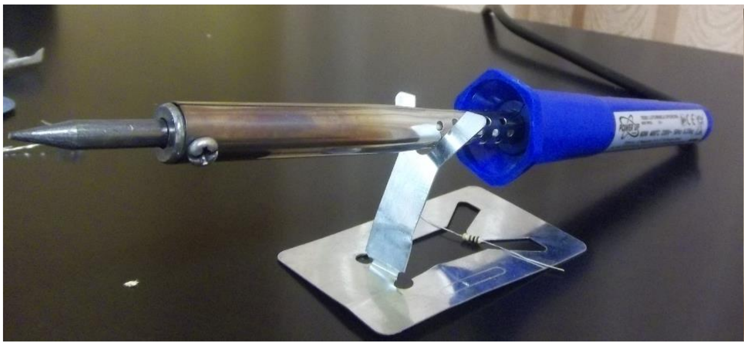


c) d) e)



f)

Fig. 2.10 Necessary parts: a) – Capacitor, b) – Diode, c) Resistor, d) – Resistor, e) LED, f) PCB plate.



a)

b)

c)

Fig. 2.11. Necessary tools: a) Soldering-iron, b) Soldering flux, c) Solder

To create air ionizer circuit scheme it is not necessary have very good electronics specialist knowledge, there is some basics rule: 1.Know diode construction (Fig.2.12) and know, that electric current flows from the anode to the cathode. 2. Different stages contacts cannot touch.

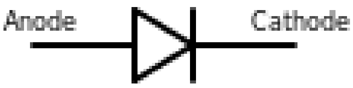
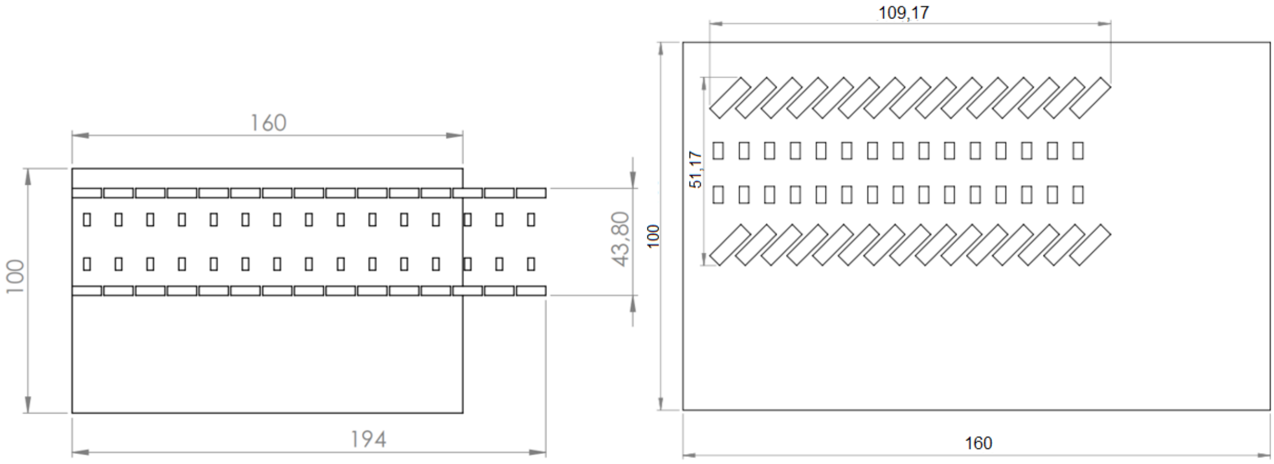


Fig.2.12 Diode

Here are a few possibilities lay out the components on the circuit board. In the first template (Fig.2.13. a) capacitors and resistors are displayed along the circuit board, this template are not so good, because capacitors and resistors does not fit in the circuit board, because circuit board are 160mm length, and arranged capacitors occupy 194mm length.



a) b)

Fig. 2.13 Component layout: a) Layout 1; b) Layout 2

The second template (Fig.2.14 b) will be good, but capacitors position are not so good, because in another circuit board side it is very hard to solder contacts that they do not touch each other. Best option is in third template (Fig.2.14) there is quite good possibility solder contacts, and all circuit fit very well on the circuit board, there is only ~103mm length and ~37mm width. Selected third option set out components.

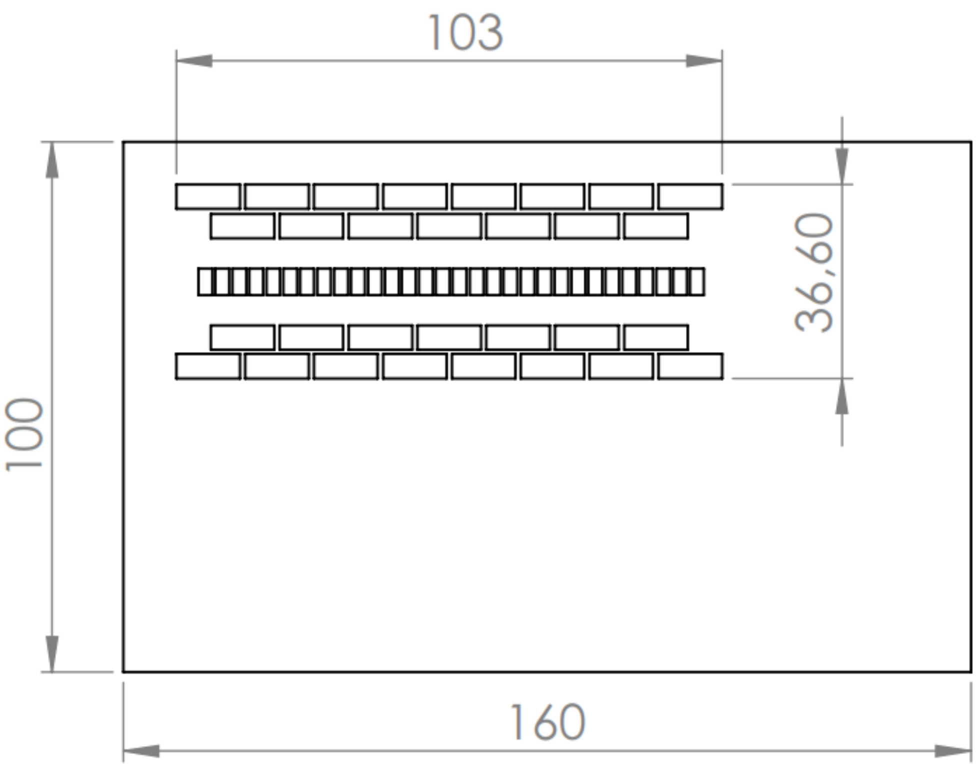


Fig. 2.14 Component layout 3

First get a components and arrange on the circuit board, and put contact with each other with hands only, to see or it fits, and to see or we not doing mistakes.

When we have collected all the plate we can solder. Before wiping contacts with flux, so that the solder will stick better to contact. And we have all circuit board done. (Fig. 2.15) (Fig.2.16). To the end of circuit we soldering needle. Plug circuit to the AC source and take finger or lips near the tip and literally feeling a flow of cool fresh air. Later in the circuit board will be made some changes that it fit in plastic case: circumcised edges, cut unnecessary contacts, soldered resistor in different position.

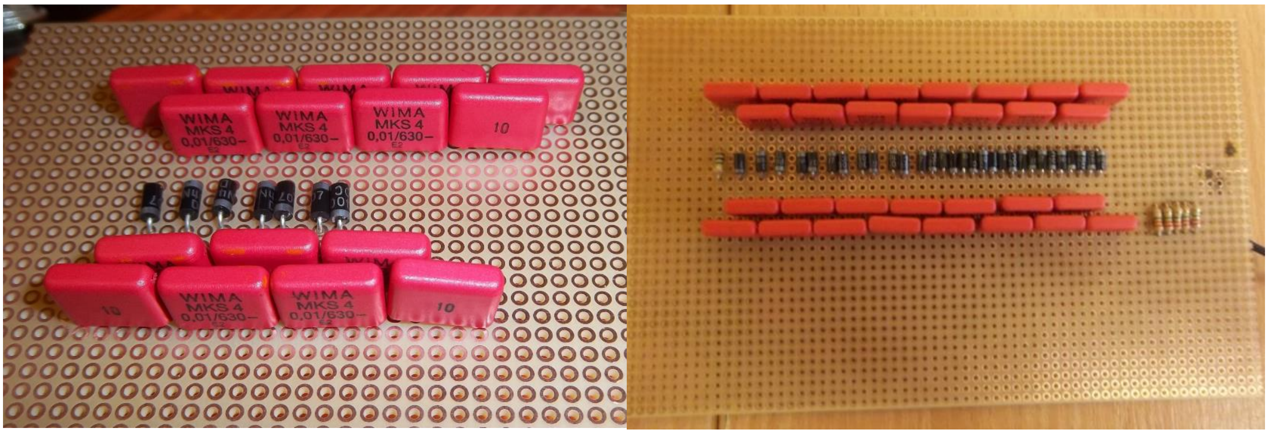


Fig. 2.15 Top of the circuit board

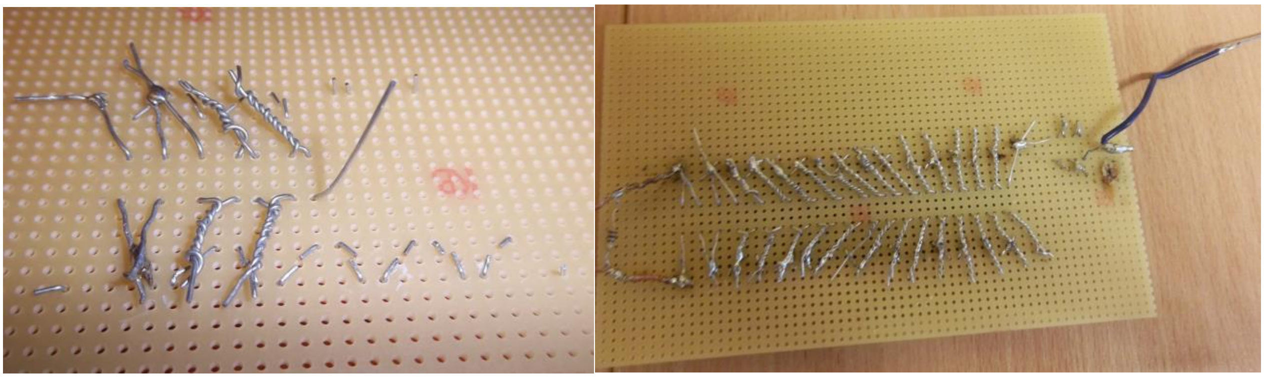


Fig.2.16 Bottom of the circuit board

2.3.4. Air ionizer circuit board test.

To detect whether the manufactured circuit board works well, was made box of Plexiglas, which was divided into two equal parts. Using heating elements box was allowed on the same amount of tobacco smoke. On each of the heating element was sift to 0.13g of tobacco.

One box was inserted in the air ionizer needle, another side of the box, was empty. Refilled smoke was set time and turned on the air ionizer. After two minutes of box parts which were inserted air ionizer needle was transparent. (Fig.2.17)

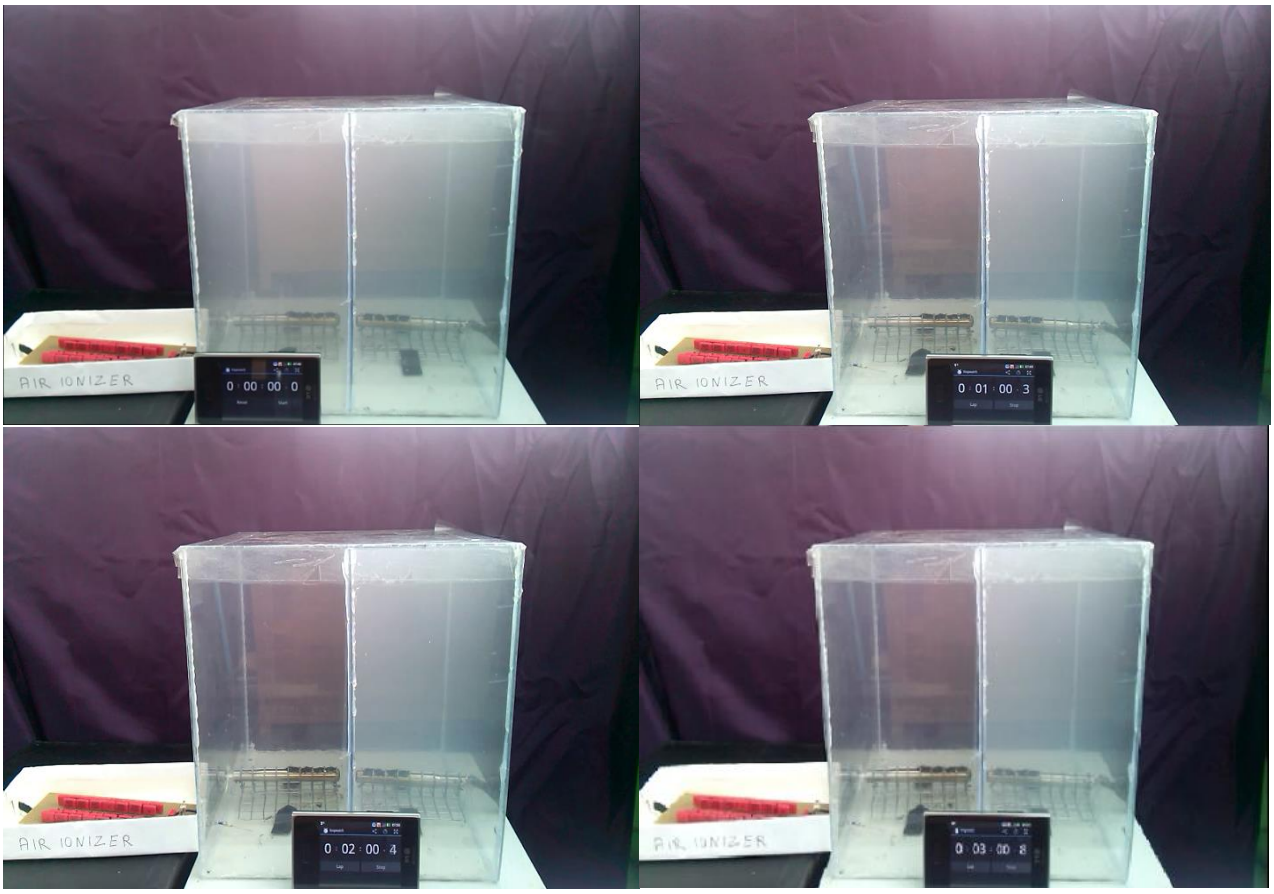
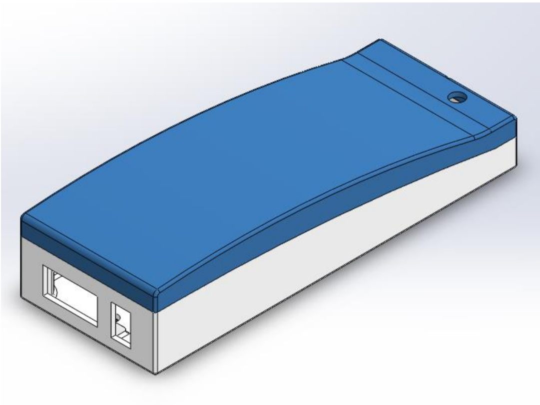


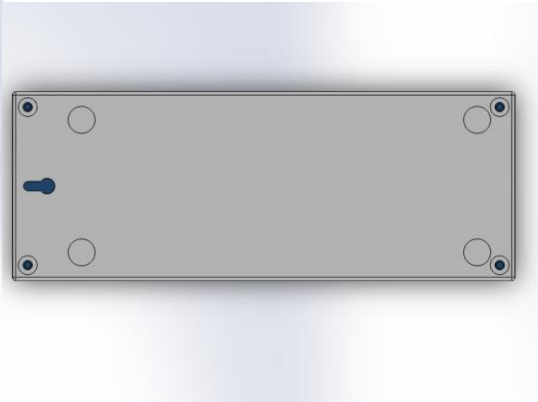
Fig. 2.17 Test box

After the test it can be concluded that manufactured circuit board works well. No suspicious noise, smell or sparking were not observed.

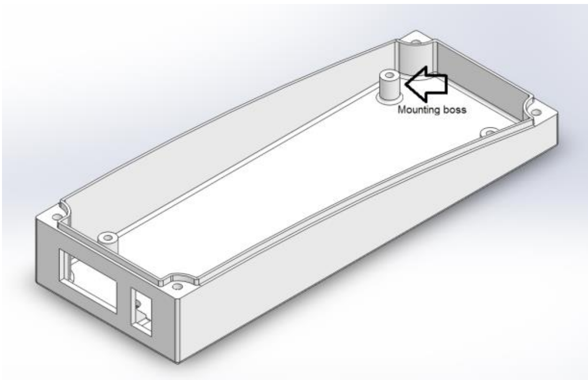
2.4.Air ionizer plastic case design

When the dimensions are known of the circuit board with components, is possible to design the plastic case. To design plastic case must provide that the plastic case will be easy to manufacture, there are no will be sharp edges and small parts. It would be better that plastic case consist of two parts. Case wall thicknesses will be 2mm. Details of dimensions: 160mmx60mm, the height can be varied, but cannot exceed 50mm. It must be made cavity for power socket and rocker switch as well as hole for the needle and LED. It was designed two models of air ionizer plastic case: the first model, where the top part is blue and the bottom part is white (Fig.2.18 a) is connected with 4 screws from the bottom.(Fig. 2.18 b) Circuit board is screwed onto the four mounting boss with screws. (Fig. 2.18 c)





a) b)



c)

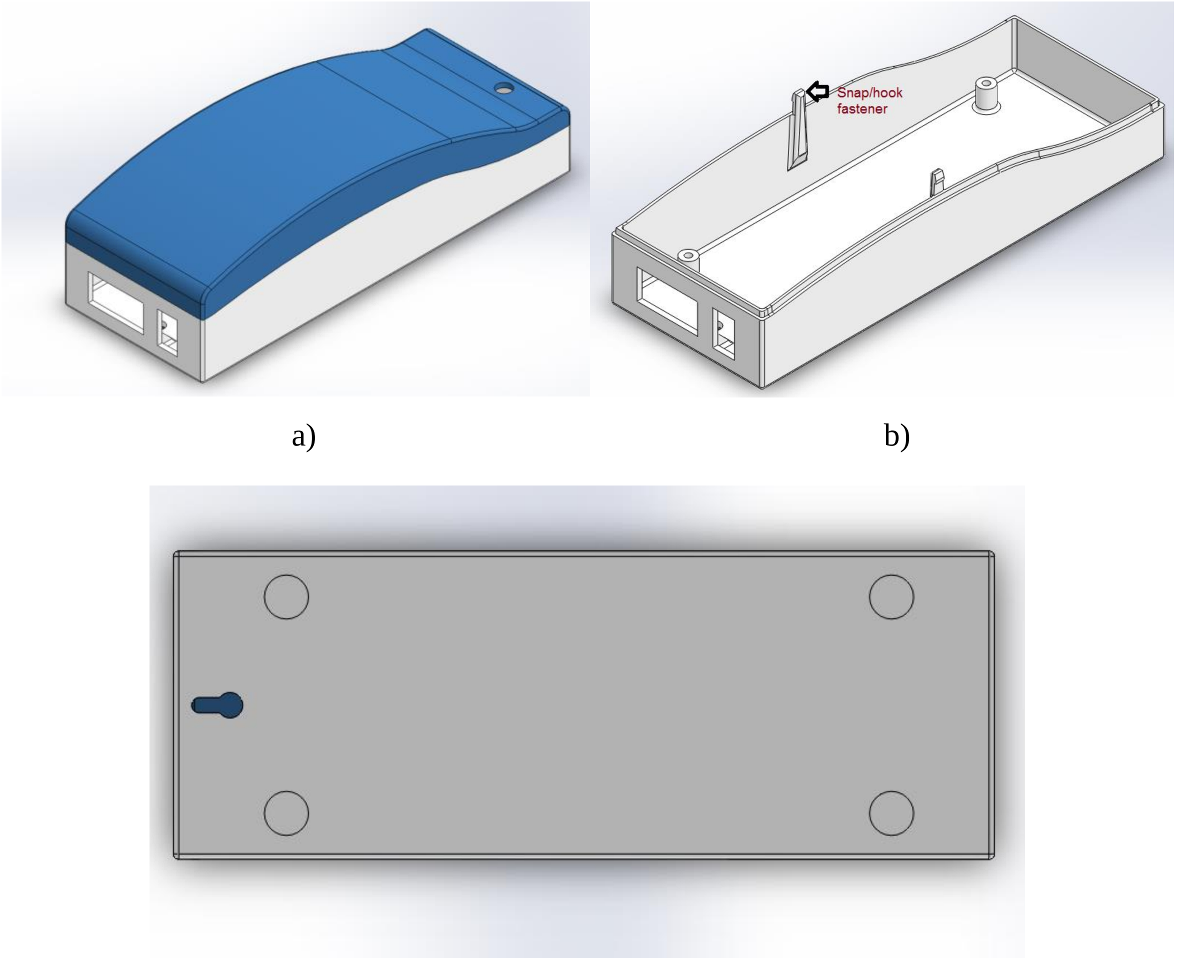
Fig. 2.18 First model. a – top and bottom part, b – model bottom, c- mounting boss

The first model overall dimensions are: 160mm x 60mm x 33,4mm

Mass – 71,83g. Material mass density is 1160kg/m^3

First model drawing are presented in **appendix 1.**

Another plastic case model (Fig. 2.19 a) are the same like first one, but there is no screw mounting, instead of bolts are used snap/hook mounting (Fig. 2.19 b), so the model height increase. The top part has holes for the light - emitting diode (LED) and air ionizer needle. Bottom part has two holes for the power socket and rocker switch. In this model isn't holes from the bottom. (Fig. 2.19 c)



a) b)

c)

Fig. 2.19 Second model. a – top and bottom part, b – snap/hook fastener, c – model bottom

The second model overall dimensions are: 160mm x 60mm x 44mm
Mass – 76,54g. Material mass density is 1160kg/m^3
Second model drawing are presented in **appendix 1.**

Model selection. First model is lighter 4,71g, that's mean that it is possible to save money, if will be manufactured first model. Second model snap/hook fasteners will be hard to cast, because it is small detail, furthermore it can break by casting or assembling/disassembling model. First model is 10,6mm lower than second model.

Summarizing selected the first model for further production. The model will be printed with a 3D printer and molded by vacuum casting.

3. RESEARCH ON NEW PRODUCT MANUFACTURE

3.1.Printing 3D printer

3D printing is a way to create solid objects directly from 3D files. While numerical design is nothing new, manufacturing has usually depend on technologies that cut objects from a bigger blocks or sheets of material; or forming methods that depend on expensive molds. In compare, 3D printing is an additive process that builds parts one layer at a time from the bottom up.

Used over industries, it supplement traditional technologies to improve product design, rationalize manufacturing, and even create entirely new business models. And as its benefit and accessibility increase, so does its potential to unlock innovation in countless inventors, engineers and designers and whose ideas were previously too difficult to manufacture

PolyJet 3D printing is similar to inkjet printing, but instead of jetting drops of ink onto paper, PolyJet 3D Printers jet layers of curable liquid photopolymer onto a build tray.

3.1.1. Equipment and materials

Used equipment provided in the picture below (Fig. 3.1). Provided below – Objet 30 rapid prototyping and manufacturing apparatus and WaterJet cabinet. Main characteristics of equipment are provided in (Table 2) and (Table 3). The WaterJet provides easy and fast cleaning of support material from models printed with PolyJet technology. WaterJet comes equipped with two types of nozzles, enabling you to choose the flow pressure suitable for cleaning, both delicate and robust models.

a) b)

Fig. 3.1 Equipment: a) Objet 30, b) Water Jet cabinet

Table 2. Objet30 technical specification

Model materials	Support material	Material cartridges	Net build size
• Rigid Opaque white (VeroWhitePlus) • Rigid Opaque blue (VeroBlue) • Rigid Opaque black (VeroBlack) • Rigid Opaque gray (VeroGray) • Polypropylene-like (DurusWhite)	FullCure 705 non-toxic gel-like photopolymer support	Sealed four 1 kg cartridges	294 x 192 x 148.6 mm
Layer sickness	**Build resolution**	**Accuracy**	**Size and weight**
28 microns	X-axis: 600 dpi; Y-axis: 600 dpi; Z-axis: 900 dpi	0,1mm	Machine: 82.5 × 62 × 59 cm; 93 kg Tray size: 300 × 200 × 150 mm

Table 3. Water Jet technical specification

Operating pressure	Maximum model size	Maximum pressure	Minimum intake water pressure
~90 bar	300x200x200 mm	~110 bar	1 bar

Water consumption	Maximum intake water temperature	Noise level
<10l/min	40°C	85-88 dB

Used photo-polymer “Vero Gray” whose main characteristics are provided in **appendix 2.**

3.1.2. Printing process

1. Create own 3D CAD model with SolidWorks (Fig. 3.2)

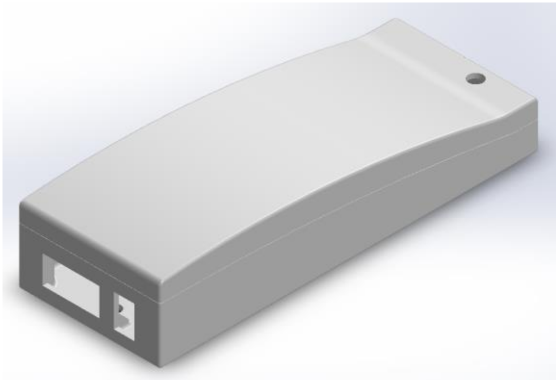


Fig. 3.2 3D model

2. The native CAD file is exported to a STL file which is a rendered surface model used by 3D printing software “Alaris 30”.(Fig. 3.3)

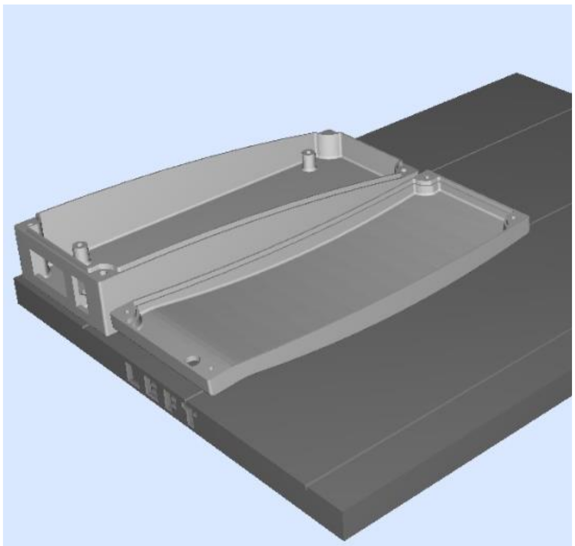


Fig. 3.3 Placed model

3. 3D printer software automatically calculates model consumption – 138g, support consumption 133g and duration of the process 7 hours 36 minutes (Fig. 3.4)

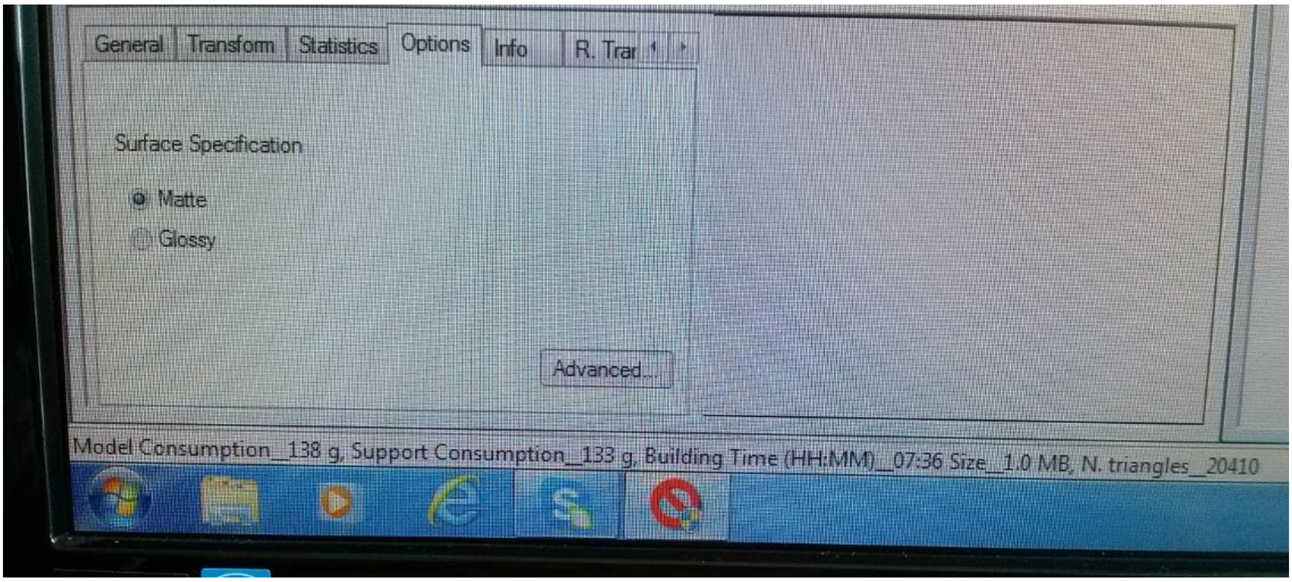


Fig. 3.4 Calculated model material consumption and build time

4. The STL file is then processed through the printer software for orientation on the build plate, layer slicing (as thin as 28 microns), and placement of the support structure (Fig. 3.5). Program automatically recalculate the required amount of material which is 139g and support material 133g. It is also shown how many slices was made, in this case that is 978 slices, material left in cartridges, print history .

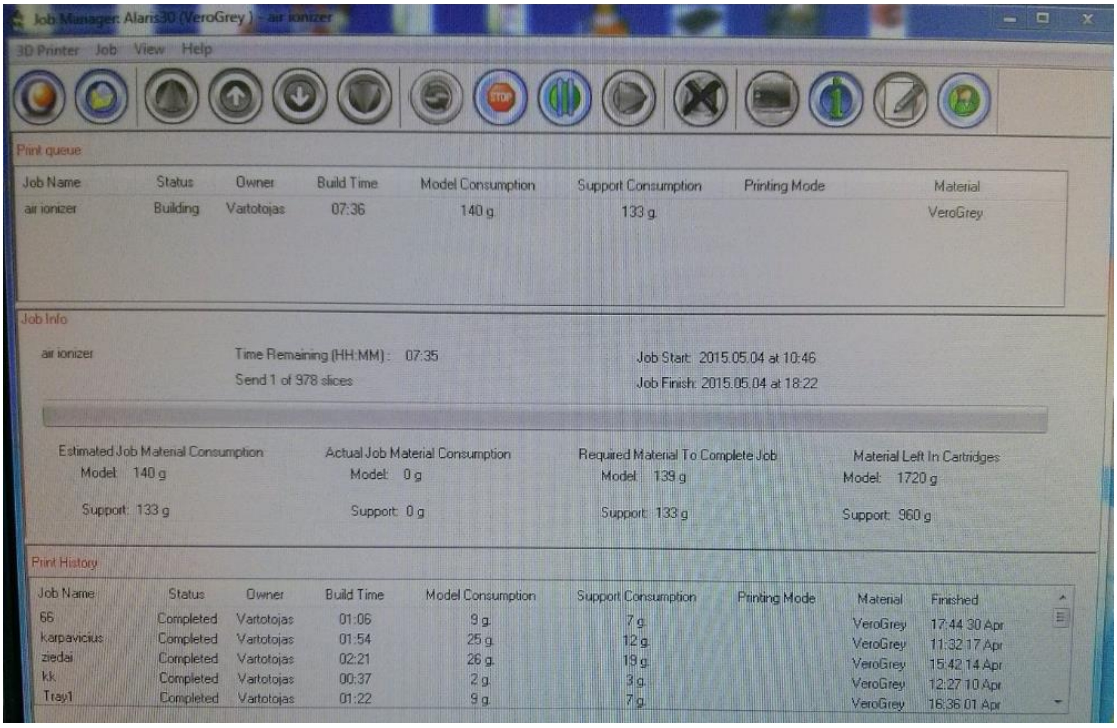


Fig. 3.5 Software page

5. Run print. In objet 30 software window (Fig. 3.6) you can see printing head temperature, sensor parameters and how many material left in cartridges.

Fig. 3.6 Printing parameters

6. When the printing is finished the program shows how long the process took and what was the real material consumption (Fig. 3.7)

Duration of the process: 7 hours 20 minutes

Actual job material consumption: model – 140g ; support – 80g

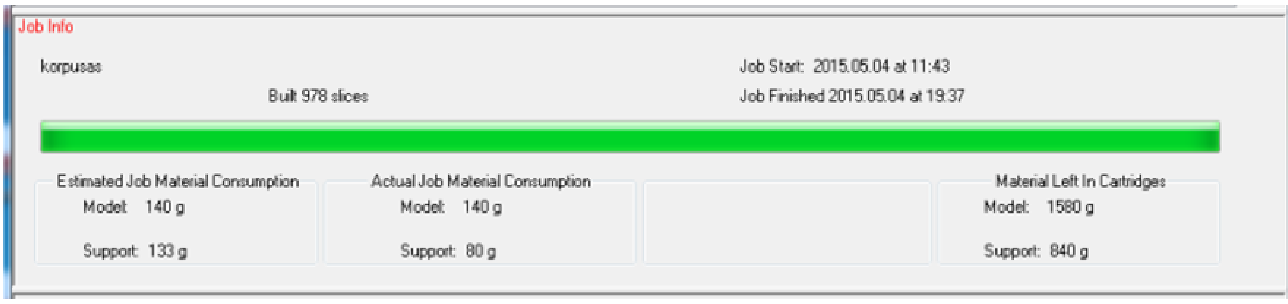


Fig. 3.7 Real material consumption and process duration

7. Model take out from Objet 30. (Fig. 3.8). The model is thicker wall, because it consists support material, in the model is visible grid on the walls, it consists of a basic material to ensure that the wall would be stiffened.

Fig. 3.8 Printed model: Shown above - bottom part, b) Shown below - top part

8. Using Water jet cabinet washed out support material for both parts. (Fig. 3.9)

Fig. 3.9 Washed out model without support material

9. Model assembled, check that everything is fine (Fig. 3.10)

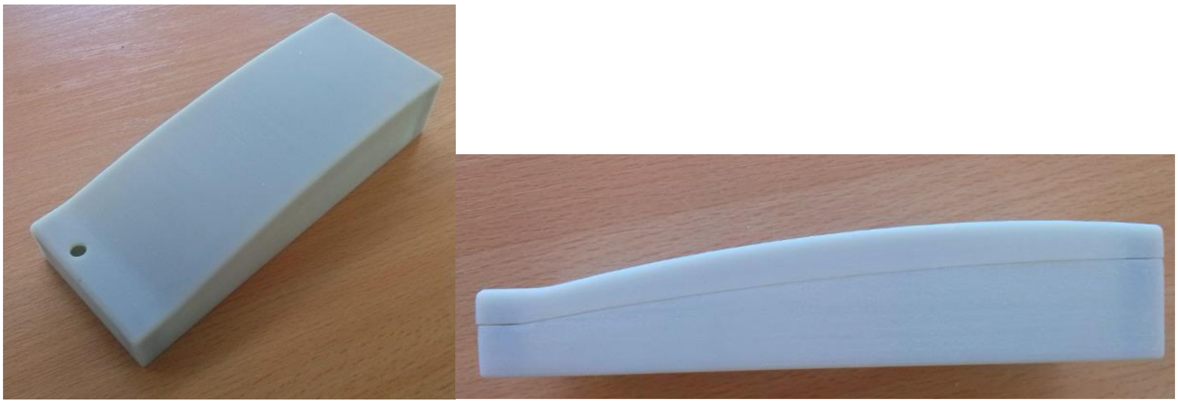


Fig. 3.10 Assembly

3.2. Vacuum casting

3.2.1. Equipment and material

Silicone. The BLUESIL RTV 3428 A&B is a two component silicone elastomer which cures at room temperature by a polyaddition reaction. Characteristics are shown in Table 5 and Table 6.

Table 4. Characteristics of the non-cured product. [16]

Properties	**BLUESIL RTV 3428 A**	**BLUESIL RTV 3428 B**
Appearance	Viscous liquid	
Color	Colorless	Pink, White, Colorless
Specific gravity *(at 23°C, g/cm³)*	1,1	1,1
Viscosity *(at 23°C, mPa.s)*	25000	8000

Table 5. Characteristics of the cross linked product. [16]

Properties	**BLUESIL RTV 3428 A&B**
Hardness *(Shore A, on a 6mm thick specimen)*	28
Tensile strength at break *(MPa)*	7,5
Elongation at break *(%)*	600
Tear strength *(KN/m)*	20
Linear shrinkage *(%, 7 days after curing at 23°C)*	0,1

Vacuum casting polyurethane. Used by vacuum casting in silicon molds for making prototype parts and mock-ups with mechanical properties similar to thermoplastics like polystyrene and filled ABS.

Polyurethane consist of two materials: Isocyanate PX 226 and Polylol PX 226-245 (Fig.3.11). Physical properties, mechanical and thermal properties presented in **appendix 3**

a) b)

Fig. 3.11 Polyurethane material: a) Isocyanate PX 226; b) Polylol PX 226-245

Preheat the materials, tools and form of the silicone used two heating ovens: UFB 400 and UFB 500 (Fig.3.12), technical characteristics presented in table 7.

a) b)

Fig. 3.12 Heating oven: a) UFB 400; b) UFB 500

Table 7. Technical characteristics

	UFB 500	UFB 400
Exterior w x h x d, mm	710 x 760 x 550	550 x 680 x 480
Interior w x h x d, mm	560 x 480 x 400	400 x 400 x 330
Power, W	2000	1400
Temperature range, ^{o}C	+30 up to +220	+30 up to +250

Vacuum casting machine. Silicones with a viscosity above 14,000 should be vacuumed to escape air accumulations and bubbles in the finished mold. Mixed and pour silicone that has not been vacuumed, air may be stuck in the mixture as it turns from liquid to solid and these bubbles may show up on the mold surface. These bubbles will be transferred to your finished model which is unattractive and unwanted. In order to avoid this is used vacuum casting machine (Fig. 3.13) characteristics shown in table 8.

Fig. 3.13 Vacuum casting machine

Table 8. Vacuum casting machine characteristics

Vacuum power of pump:	m^3/h	25
Max. pressure absolute:	hPa	<0,8
Power input:	kVA	0,8
Outside size:	h x w x d, mm	745 x 800 x 565
Size of chamber inside:	h x w x d, mm	660 x 400 x 455
Max. mould size theoretical:	h x w x d, mm	405 x 400 x 455
Capacity cup 1:	ml	400
Capacity cup 2:	ml	600

3.2.2. Vacuum casting process

Before making silicone mold is needed prototype. For this reason will be used prototype, which was made with 3D printer. (Fig. 3.14) Because the prototype consist of two parts, so every vacuum casting process should be done for every part.

Fig. 3.14 Prototype

1. Set parting line, casting rod and air tubes. Setting parting line means tapping the edge of the seperation face of the part, because the silicone mold would be easy to split. Because the part edge is very small 1mm tape adhesive on the flat parts part. With the tape stick the holes where were power socket and rocker switch, because another way it will be impossible to remove part from silicone mold. Later the holes will be made mechanically. Mark tape edges in red colour, because it would be better to see part in silicone mould, when will have to split the mould. Set air tubes is very important, because later, when polyurethane was filled the air will be pushed through the holes and will be easier to see when the mold will be completely filled with polyurethane. Another important step is set casting rod. The rod will be set at the unseen surface of the part that means the face can not be seen after assembling the whole model. Casting rod would be set in the center as possible, thus the liquid resin running similarly in the mold when casting, and the bubbles can be easily under controlled. In addition casting rod takes the responsibility of holding the pattern in the box as well, so it must be stuck pattern steadily. In figure 3.15 shows bottom and top part construction with parting line, casting rod and air tubes.

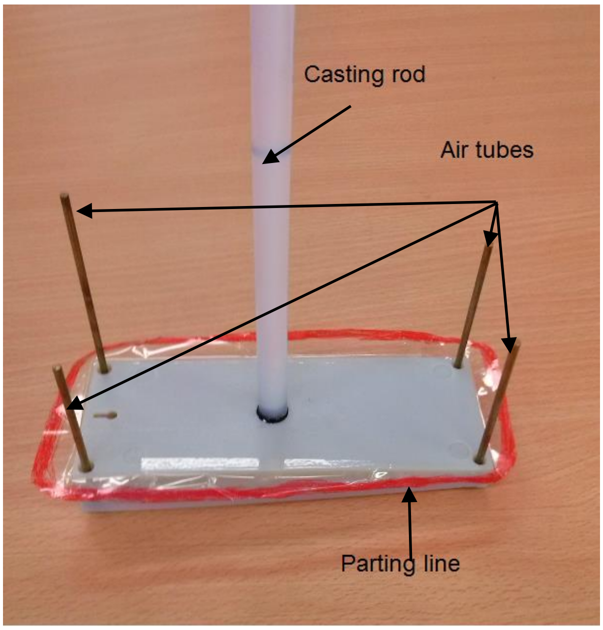


Fig. 3.15 Part with set casting rod, air tubes and parting line

2. ***Build up silicone mold box.*** Box could be made from any material, but it must be steadily and strong. For the walls were used the plastic window sills profiles, the walls of the box was connected with bolts and hot glue. According to the part dimensions which is 160 x 60 x 25 mm. and other part 160 x 60 x 15 mm., box dimension was 230 x 110 x > 60 mm, that is because the distance between the edge of part and inside wall of the box is about 20-25mm. In wooden plate drill the hole, to shove casting rod and stick it with hot glue. (Fig. 3.16)

Fig. 3.16 Made box

3. ***Pour silicone.*** According to box dimension 230 x 110 x >60 mm, calculate the needed weight of silicone, that silicone fully cover the bottom part the height must be 70 mm. Calculated required volume of silicone

$$V_1=L \cdot H \cdot D = 230 \cdot 110 \cdot 70 = 1771000mm^3 = 1771cm^3 = 0{,}001771m^3$$

Where: V_1 – Required volume of silicone for the bottom part

L – Box length

H – Box height

D – Necessary depth

Specific gravity of silicone is 1,1 g/cm^3 it is mean, that needed weight of silicone for bottom part will be:

$$m_1=1771cm^3 \cdot 1{,}1g/cm^3=1948{,}1g=1{,}948kg$$

Do the same calculations to another top part:

$$V_2=L \cdot H \cdot D = 230 \cdot 110 \cdot 60 = 1518000mm^3 = 1518cm^3 = 0{,}001518m^3$$

Where: V_2 – Required volume of silicone

L – Box length

H – Box height

D – Necessary depth

Specific gravity of silicone is 1,1 g/cm^3 it is mean, that needed weight of silicone for top part will be:

$$m_2=1518cm^3 \cdot 1{,}1g/cm^3=1669{,}8g=1{,}670kg$$

Add 100 parts of BLUESIL RTV 3428 A to 10 parts of BLUESIL RTV 3428 B. The two components may be intimately mixed either using a low-speed electric mixer to minimize the introduction of air into the mixture.

Necessary weight of components (table 9)

Table 9. Required weight of components.

	Bottom part	**Top part**
BLUESIL RTV 3428 A (kg)	1,771	1,518
BLUESIL RTV 3428 B (kg)	0,177	0,152

Fill both components into the bucket and mix it. After mixing bucket was put into the vacuum casting machine. BLUESIL RTV 3428 A&B is degassed under a vacuum of 30 to 50 mbar. The degassing of the mixed product or of the two separated parts occurs under a vacuum of 30 to 50 mbar. Under vacuum, the product expands 3 to 4 times its initial volume and forms bubbles on its surface. These bubbles will disappear gradually and the mixture will sink back down to its initial volume within 5 minutes (Fig. 3.17). Vacuum was released and the operation was repeat a few minutes later.

a) b)

Fig. 3.17 Degassing process: a) - Under the vacuum; b) – Released vacuum

After degassing the liquid of silicone was pour slowly into the box with which the pattern structure in. Fill very slowly should not let the silicone fall on the pattern, because it may break off mold structure. Afterwards, move the box into the vacuum machine and vacuum it (Fig. 3.18 a).

a) b)

Fig. 3.18 Silicone mold box: a) under vacuum; b) placed in the oven.

When vacuuming was finished, move the box into the oven and cure it under 23^{o}C degree about 16 hours (Fig. 3.18 b).

4. ***Split the mold***. Once the curing is finished, the frame was removed, and using knife and special tweezer (Fig. 3.19) the mold was split along with the tape connected to the part. The split face from outside wall to the edge of the tape should be like a wave, to prevent the refraction when assembling the mold (Fig. 3.20)

a) b)

Fig. 3.19 Splitting mold: a) – Special tweezer; b) – knife

Fig. 3.20 Split mold

5. ***Pour the mold.*** Sprayed a little bit release agent on both side of mold. Assembled the mold, place boards on both sides and fix them securely into place using insulating tape and mold was putted into the oven and preheated it under 70°C. (Fig. 3.2). In another was putted Isocyanate PX 226 and Polylol PX 226-245 and preheated it under 23°C.

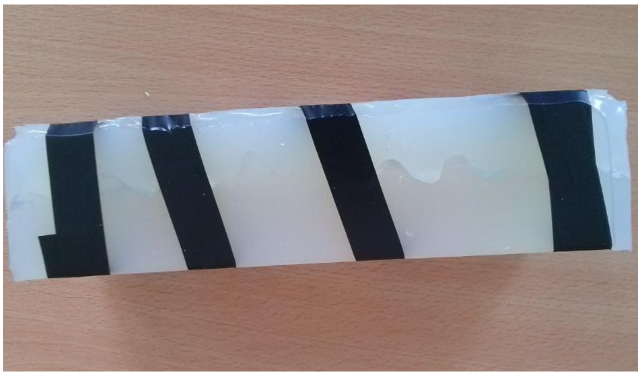


Fig. 3.21 Taped mold

To calculate how much Isocyanate PX 226 and Polylol PX 226-245 was needed, use bottom and top part 3D CAD model. (Fig. 3.22)

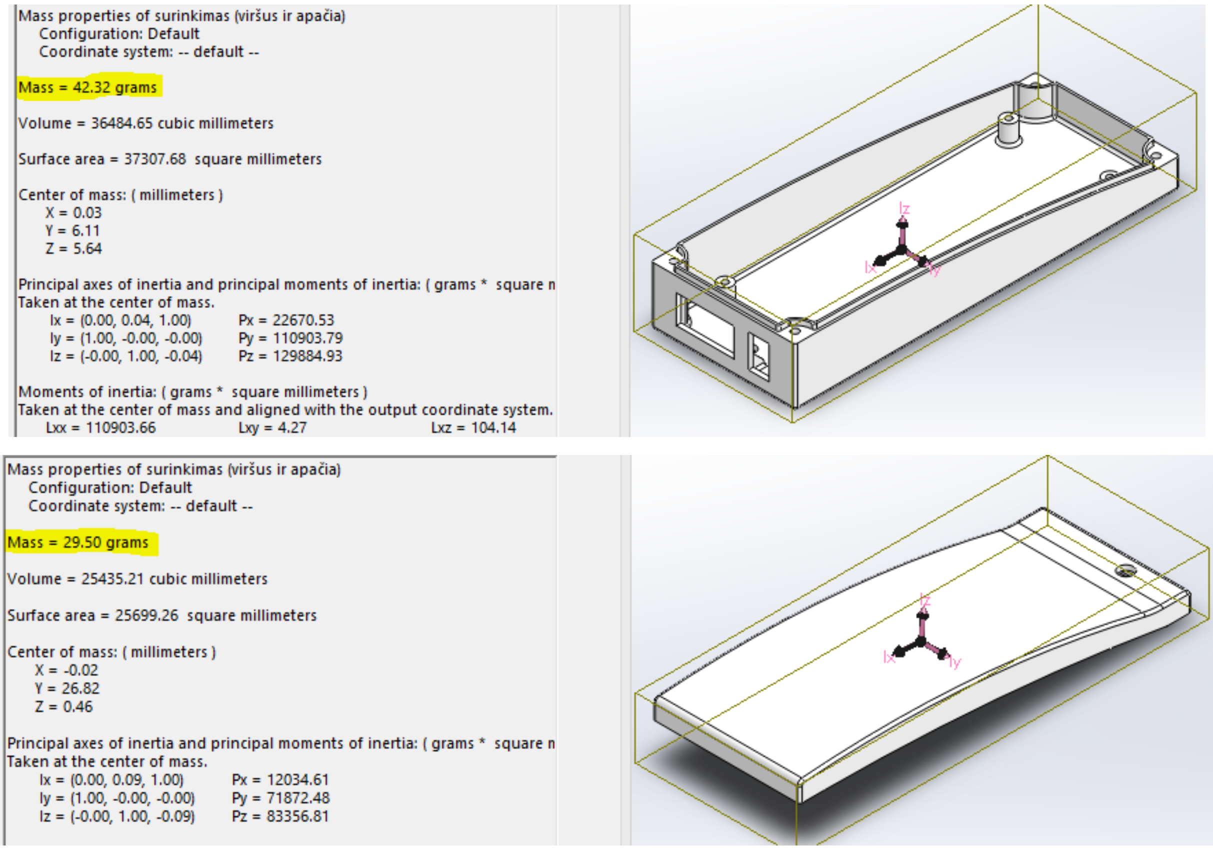


Fig. 3.22 Model parts mass

Isocynate and polyol mix ratio by weight are 2:1.

For the bottom part: mass – 42,32g Isocyanate need 28,21g, polyol – 14,1g. Because the part are small the big part of the material will remain on the bowl wall and casting feed edges. To avoid failure to fill form, the amount of material was used: .Isocyanate - 50g, polyol – 25g. For the top part: Isocynate - 34g, polyol – 17g. After degasing for 10 minutes under vacuum, poured isocyanate into polylol and mixed about 30 seconds. Take out the mold from the oven put down into vacuum casting machine and fill the mold with polyurethane (Fig.3.23). Cure at 70^{o}C for 60 minutes.

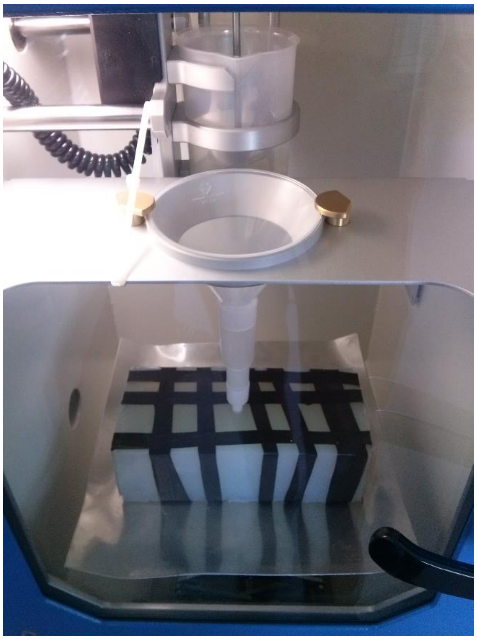


Fig. 3.23 Cast under vacuum in silicone mold

After one hour the mold was took out from the oven and opened. First time there was made mistake to use much power to tape mold with insulating tape, so result was that bottom part edges were not filled correctly (Fig. 3.24). Second time mold was taped using not so much strength, and the result was better (Fig. 3.25).

Fig. 3.24 Poorly casted detail

Fig. 3.25 Finish casting bottom and top part

Fig. 3.26 Finish casting model

3.3.Time consumption

Manufacture time is one of the main indicator of production, sometimes longer manufacturing time is worth more to save money and otherwise. In this work was calculated time for printing 3D printer and vacuum casting. At first, calculated 3D printing manufacturing time (Table 10)

Table 10. 3D printing manufacturing time

Operation		**Time, min**
1. Preparation (Cleaning 3D printer, 3D CAD file processing)		5
2. Printing		440
3. Model cleaning		10
	Total	**455**

Printing with 3D printer, all model are printed in one time. Total manufacturing time is 455 minutes. Casting model in vacuum casting, must made silicone mold for both parts, so time consumption will double. Time consumption of vacuum casting process are shown in table 11.

Table 11. Vacuum casting process manufacturing time for one part

Operation		**Time, min**
1. Preparation (Set parting line, casting rod, air tube, building box)		30
2. Pour silicone (Mixing, degassing, filling and curing)		973
3. Split the mold		10
4. Pour the mold (Preheating, mixing, degassing, curing, cooling)		113
5. Finishing (Disassembling, drilling, grinding)		11
	Total for one part	**1137**
	Total for model	**2274**

When the silicone mold was made, time consumption for model was even more less (Table 12).

Table 12. Time consumption without silicone mold manufacture

Operation	Time, min
1. Preparation (Clearing, tape wrapping)	8
2. Pure mold (Preheat, mixing, degassing, curing, cooling)	113
3. Finishing (Disassembling, drilling, grinding)	11
Total for one part	**132**
Total for model	**264**

Make a model with 3D printer take 455 minutes, make silicone mold an model take 2274 minutes, but when is have silicone mold for both parts, manufacture time consumption was 264 minutes it is 191 minutes shorter than printing with 3D printer.

3.4. Cost calculation

To calculate the cost of manufacture air ionizer plastic model, must have material price and needed material quantity. Required amount of material are calculated in previous chapters. For the 3D printing program automatically calculated material consumption. 3D printing cost calculation. (Table 13), Vacuum casting cost calculation are shown in table 14.

Table 13. 3D printing cost

Material	Material cost	Quantity	Cost,
Model material	0,33€/g	140 g	46,2€
Support material	0,13€/g	80 g	10,4€
		Total cost	**56,6€**

Table 14. Vacuum casting cost

Material	Material cost	Quantity	Cost,
Silicone (BLUESIL RTV 3428 A&B)	16,5€/kg	3,62 kg	59,73€
Polyurethane (Isocyanate PX 226 and Polylol PX 226-245)	0,22€/g	126 g	27,72€
		Total cost	**87,45€**

Model cost, which are printed 3D printer is 56,6€, model which made using vacuum casting process is 87,45€, but when are silicone mold, other model will cost 27,72€, because do not need make mold for the model.

3.5.Dimensional analysis

There are no manufacture method where was manufactured part or detail, that there would not be dimensions difference between 3D CAD model and finished part. This is due to: equipment and tools quality, material, workers experience, weather conditions and so on. 3D printing accuracy as high as 0.1 mm. Vacuum casting accuracy depends on many factors: using material, degasing quality, curing temperature and other. Accuracy is lower than 3D printing and is approximately 0.2-1 mm. In figure below show 3D CAD model where dimensions marked with letters (Fig.3.27). In table 15 was shown design dimensions, 3d printed model and vacuum casting model dimensions.

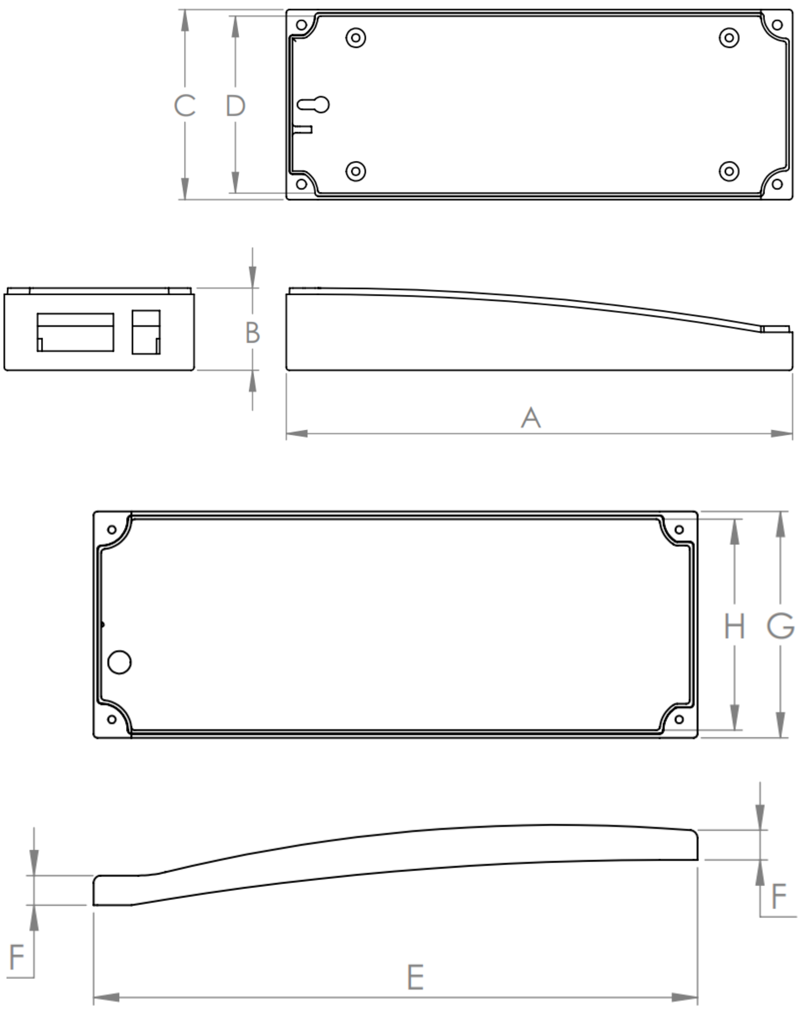


Fig. 3.27 Marked design model dimension

Table 15. Dimension analysis

Dimension	Design model	3D printing model	Difference +/- mm	Vacuum casting model	Difference +/- mm
A	160mm	160,1 mm	+0,1	160,3 mm	+0,3
B	26 mm	26 mm	0	25,6 mm	-0,4
C	60 mm	60 mm	0	60,3 mm	+0,3
D	56 mm	56,1 mm	+0,1	56,3 mm	+0,3
E	160 mm	160 mm	0	160,9 mm	+0,9
F	7,89 mm	7,9 mm	+0,01	7,9 mm	+0,01
G	60 mm	60,1 mm	+0,1	60,3 mm	+0,3
H	56 mm	55,9 mm	-0,1	56,6 mm	+0,6

According to the table 15 data, can be seen that when printing 3D printer dimensional tolerances not exceeding 0,1 mm. Vacuum casting model dimensions are all bigger, but not exceeding 1 millimetre, that is because silicone mold before pouring polyurethane is heated and expands slightly.

4. AIR IONIZER BUSINESS IDEA PRESENTATION

The quality of the air we breathe and the attendant consequences for human health are influenced by a diversity of factors. These include hazardous material discharges inside and outside, meteorological and ventilation conditions, and pollutant decay and removal processes. Over 75% of time for most people is generally spent in indoor environments so that the influence of building structures, surfaces, and ventilation are important considerations when evaluating air pollution exposures. For this reason now are very popular air ionizer.

An air ionizer is a useful item to have in the house. Ionizer or air purifiers remove allergens and dust particles from the air, as well as act as an air freshener, neutralizing odors and improving air quality. Ionizers can give indoor air the same number of negatively charged ions as fresh outdoor air, making ionic air cleaners a popular choice for treating Seasonal Affective Disorder.

4.1.Air ionizer price

Pricing is the most complex commodity market conjuncture mechanism, its barometer. Price reflects the pricing system of factors: cost dynamics, performance indicators, inflation, supply and demand, market monopolization and so on. Furthermore, the particular price at a given moment is dependent on the productive forces market development, from the intermediate and end-use; depending on how much and what kind of agents operating in the market.

First of all calculated all elements cost (Table 16). Elements purchased from “Lemona”. “Lemona” is one of the largest companies in the Baltic States selling electronic parts and components.

Table 16. Elements cost

Element	Quantity	Cost per piece, €/pcs	Cost, €
Diode 1N4007	31	0,03	0,93
Capacitor 10nF 630V	30	0,20	6,00
Soldering wire	1	1,07	1,07
Board with dots (PCB)	1	2,61	2,61
Resistor 0,25w 10K	1	0,03	0,03
Resistor 0,25w 10M	5	0,03	0,15
LED 5mm	1	0,29	0,29
Rocker switch ON-OFF	1	0,58	0,58
Power socket	1	1,16	1,16
Power cable	1	1,45	1,45
Clip for LED	1	0,04	0,04
Flux	1	1,74	1,74
		Total cost	**16,05**

Second calculate employee cost. Vacuum casting process takes 5,7h, without silicone mold making it takes 3h; 3D printing takes 0,33h. Hourly rate is 6€/h. Salary for employee: vacuum casting process: 5,7h·6€/h=34,2€, without silicone mold manufacture: 3h·6€/h=18€; 3D printing process: 0,33h·6€/h=1,98€

From the 3.4 chapter are known air ionizer plastic model cost for both manufacturing methods: 3D printing and vacuum casting process, using these calculations, calculated the final price of air ionizer. (Table 17)

Table 17. Air ionizer price

3D printing		Vacuum casting		Vacuum casting (without silicone mold)	
Material cost	56,60€	Material cost	87,45€	Material cost	27,72€
Employee cost	1,98€	Employee cost	34,20€	Employee cost	18,00€
Elements cost	16,05€	Elements cost	16,05€	Elements cost	16,05€
Total	**74,63€**	**Total**	**137,70€**	**Total**	**61,77€**

Total air ionizer price using 3D printing method is 74,63€, using vacuum casting process first piece of air ionizer price would be 137,70€, the second, third and other price would be 61,77€, that it is because it would be not necessary make silicone mold, therefore the seven model produced by vacuum casting method would be cheaper than produced by 3D printing method (Fig. 4.1).

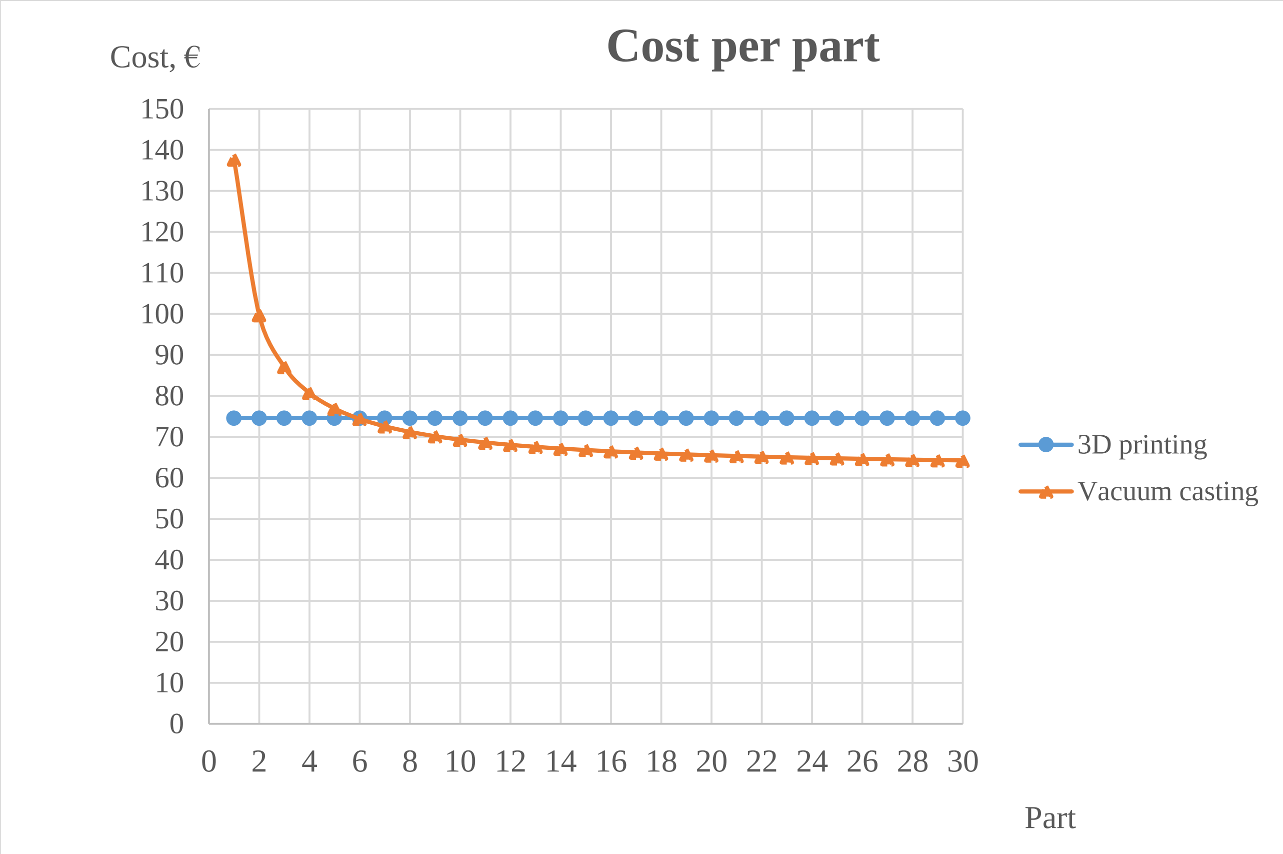


Fig. 4.1 Price comparison

According to figure 4.1 can be seen that manufacturing prototypes using 3D printing method worthwhile when is not more than 6 prototypes, otherwise cheaper would be manufacture silicone mold and manufacture prototypes using vacuum casting process.

4.2.Analysis of marketing elements

Macro environment analysis is analysis of all the factors that a company is unable to control. Companies guide this analysis to stay abreast of the issue in the current business environment. A common tool for conducting a macro environment analysis is the PEST framework, which consist of factors from the political, economic, social, technological aspects in the business environment. The ultimate purpose of this analysis is to create a strategy that will leverage as many of these external factors as possible to the company's favor.

4.2.1. Macro environment analysis

Political – legal environment

- Documentation and quality assurance

Product do not have all certification according to ISO 9001, product and processes certification (EN standards, verification of technical conditions), CE marking.

Influence → Without that documentation there are no possibility to sell product in Lithuania or other country.

- Government stability

Lithuanian government changes every four years.

Influence → It is very difficult to predict what type of government will manage country the next four years, it may be inconvenient to take by law.

- The level of freedom of the media

In Lithuania are not large restrictions on: the press, advertising on television.

Influence → It is possible to advertise on the Internet or in the press

Economic – competitive environment

- Number of new residential building completed

According to Lithuanian Department of Statistics [17] the number of new building completed in 2014 compared with 2013 year number, this number is bigger. (Fig.4.2)

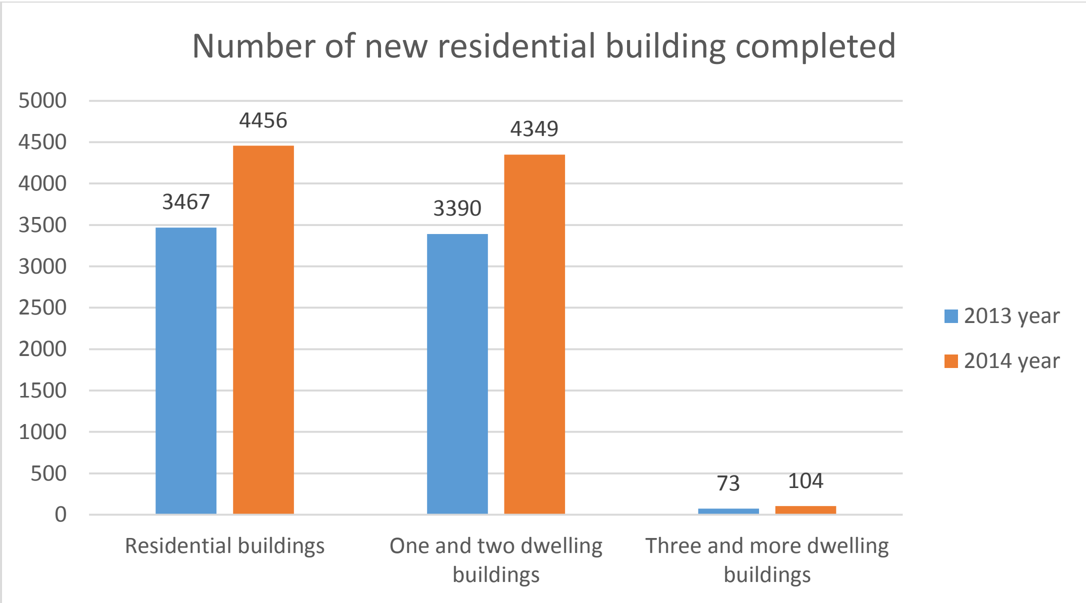


Fig. 4.2 Number of new residential building completed

Influence → More new residential building are completed, more people live in apartments, where are possibility, that people wants to be in apartments where is fresh air and they will want buy air ionizer.

- Number of private cars

According to Lithuanian Department of Statistics [17] the number of private cars is growing steadily. (Fig. 4.3)

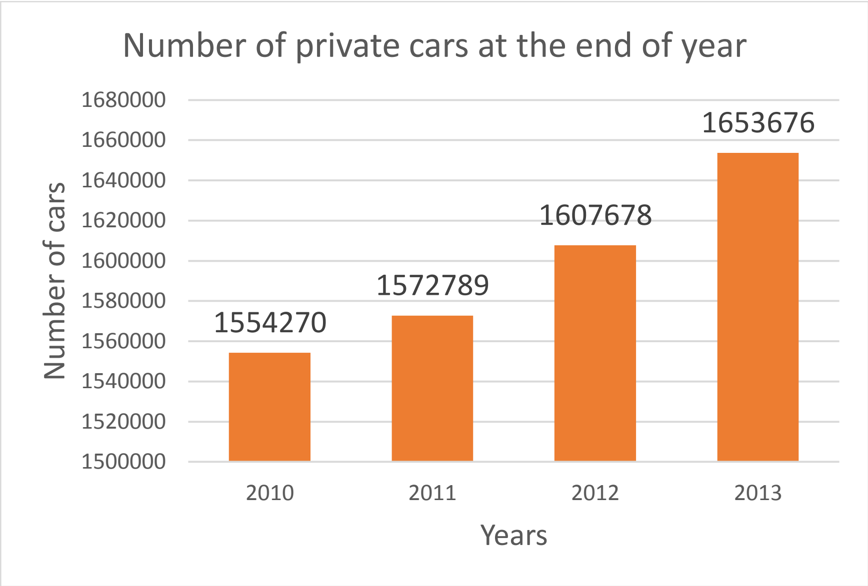


Fig. 4.3 Number of private cars

Influence → The number of private cars is growing steadily year by year. In future it will be a possibility to make air ionizer, which could use in car, so bigger number of cars is bigger possibility sell air ionizer in future,

- Minimum monthly wage

According to Lithuanian Department of Statistics [17] the minimum monthly wage are growing steadily, show in (Fig. 4.4)

Fig. 4.4 Minimum monthly wage (2010-2014 second quarter)

Influence → increasing the average earnings would increase a fair amount of personal income, it would allow the purchase of goods that are not necessities. Decline in real wages, declining purchasing power of money, bought fewer goods, almost all the attention paid to the necessities of the goods.

Social – cultural environment

- Population

According to Lithuanian Department of Statistics [17] the number of Lithuania inhabitants are decrease (Fig. 4.4)

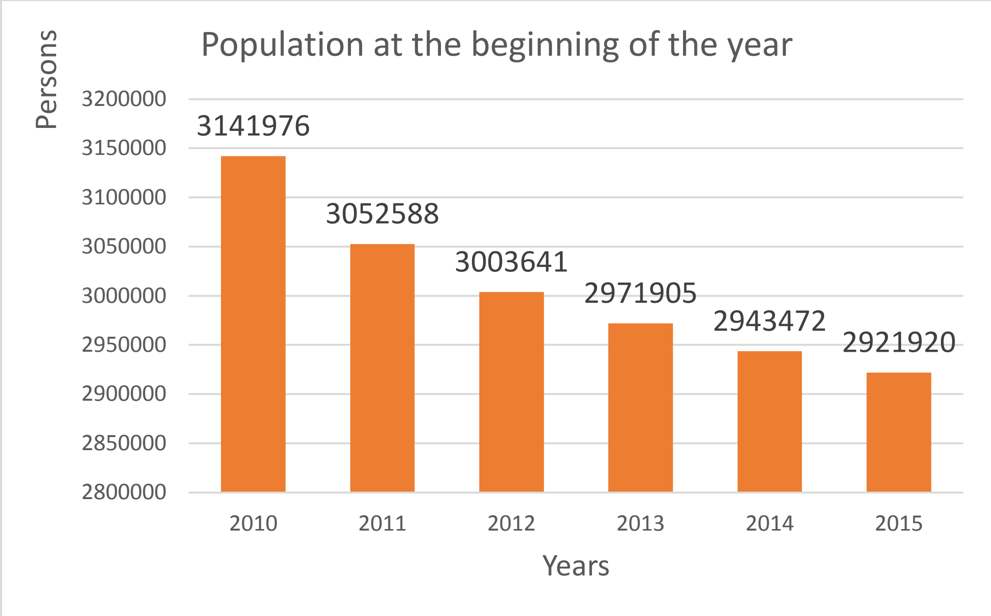


Fig. 4.5 Population in Lithuania

Influence → Decreasing the number of people due to the decreasing potential buyers

- Internal migration

According to Lithuanian Department of Statistics [17] the number of internal migration is steadily growing all the time (Fig. 4.6)

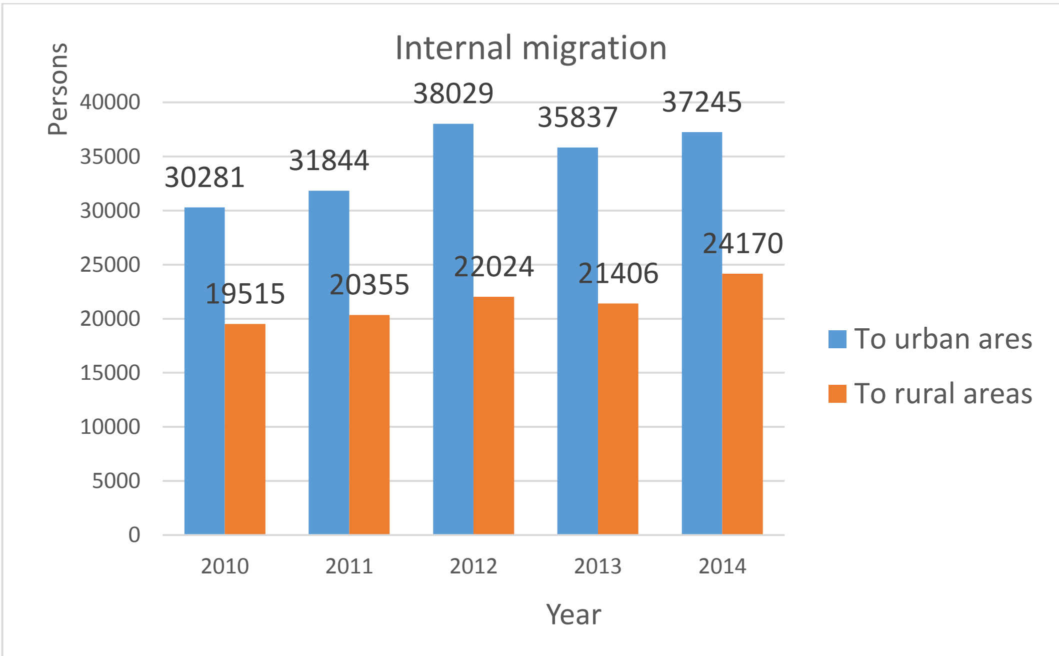


Fig. 4.6 Internal migration in Lithuania

Influence → As more people migrate to the city, the more people live in apartments, where air is not as clean as in rural areas, so people will be interested in taking care of the cleanliness of the air in your house and therefore there will be more people who will buy air ionizer.

- Unemployment rate

According to Lithuanian Department of Statistics [17] unemployment rate in Lithuania in 2010 was 17,8%, 2011- 15,4%, 2012 – 13,4%, 2013 – 11,8%, 2014 – 10,7%. (Fig. 4.7)

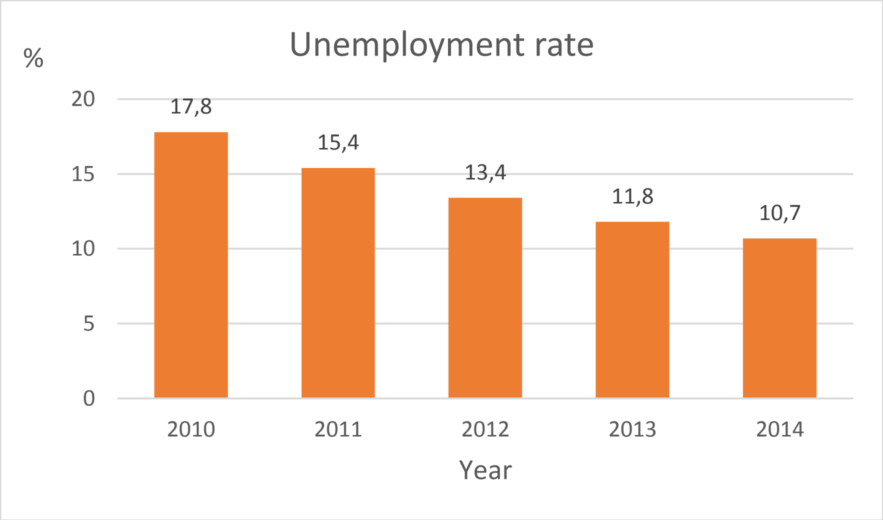


Fig. 4.7 Unemployment rate

Influence → Compared with previous years, this figure dropped further projected decline rate, but the unemployment rate remains quite high and this will reduce the number of potential buyers

Technological – scientific environment

- Technical progress acceleration

Influence →

Positive: technical progress will reduce the cost of production for the product will be sold at a lower price.

Negative: the emergence of new technologies is often associated with the collapse of the old, and in the future it could pose a threat to our product. Scientists in the future can create an even better and more modern product, which will be driven out of our product from the market.

- Products sale online.

Influence →Since online marketing is very popular and developed, it will be able to offer items purchased online.

- Patent and license

Influence → When you have a patent the product is protected, that competitors did not produce the same.

4.2.2. Market segmentation and selection of the target segment

Segmentation is the process of dividing a market into distinct groups of buyers with different needs, characteristics, or behavior who might require separate products of marketing programs.

The company determined and analyzed segments can choose which of them will serve it. This company sets its target market, which directs the marketing mix.

Air ionizer target market segmentation and the performance based on geographic, demographic, psychographic and consumer behavior characteristics.

- ***Geographic characteristics***

Each market segmentation criteria have certain characteristics by which users can be divided. Geographic criteria to outline the analysis of the population density.

Population density - The larger the population and density, the higher you can expect the product demand and sales, so the product more focused on people living in larger cities or towns or areas where the air is polluted

- ***Demographic characteristics***

Each market segmentation criteria have certain characteristics, which users can be divided. Demographic criteria need to split the analysis by income, age and gender

Income - product-oriented to upper middle-income people and families. Since underage cannot get revenue to pay attention to their family income

Age – There is no age limit, but people who wants to buy this product probably must have own home or apartment or rent apartment so age could be from 23 years and older.

Gender - Air ionizer is designed for both male and female representatives.

- ***Psychographic characteristics***

Psychographic market segmentation can be carried out in accordance with such features as social class, attitudes to the particular brands or goods and lifestyle.

Social class – That type of product are for people whom social grade is D or higher that is semi and unskilled manual workers.

Attitudes to the particular brands or goods – that are people who always want to try something new, that people always goes hand in hand with technology.

Lifestyle – These are the people who take care of their own and others' health.

- ***Behaviour characteristics***

This segmentation is performed according to the user's behavior and market segmentation discussing such features as benefits sought, people who likes flaunt (swagger)

Benefits sought - buyers looking for high-quality, long-serving products that are consistent in their home environment, and to distinguish from other products

People who likes flaunt (swagger) – for that people type aren't difference for product quality or long – serving, that people just want to have a product which is better than other people or just not have that type of product.

After segmentation analysis, target market segment composed:

Male and female who are 23 years old or more, who take care of their own and others health, living in urban places and whose families or they themselves receive medium and higher income and evaluate the innovations.

4.2.3. Analysis of competitors

Competitors - market players, offering prospective buyers the same or similar products that satisfy the needs. Product choice in the market only very rarely. Actions of competitor's activities of the company can have a major impact, and competitive analysis is an integral part of other brand marketing solutions.

Air ionizer competitors - it all manufacturers of air purifier, ozone generators and air purifier - ionizer. For air ionizer competitors use the data for analysis of competitors' strengths and weaknesses (Table 18). This analysis to identify and describe direct air ionizer competitors, analyze them or serve the same customer and meet the same needs.

Table 18. Air ionizer competitor analysis

Competitor	Advantages	Disadvantages	Market size
Air purifier	• Clean the air from dust, animal hair, pollen. • Use air filters	• not kill bacteria • no remove odors	In Lithuania it is not popular at this time. There is about 10 air cleaning products seller.
Ozone generator	• remove odors • kill bacteria • Produce low level of ozone.	• No air filters • Possibility produce too many ozone.	
Air purifier - ionizer	• Clean the air from dust, animal hair, pollen. • Kill bacteria	• Very expensive	

Air purifier does not take up extra space, but because of its content filters and fan it is much higher than the air ionizer, air ionizer also practically do not emit sound and kills bacteria. Competing products are destined for the same user - people who care about the cleanliness of the home and household and his health, so they will be among direct competitors.

4.2.4. SWOT analysis

SWOT analysis is organized planning method to evaluate the strengths, weaknesses, opportunities and threats involved in a project or business venture. SWOT analysis can be performed product, location, industry or person. It means showing business or project targets and on internal and external factors that are favorable and unfavorable to achieving this goal.

Goal Determination should be done after the SWOT analysis was performed. This would allow achievable goals and objectives must be established organizations.

- Strengths: characteristics of the business or project that give it an advantage over others.
- Weaknesses: characteristics that place the business or project at a disadvantage relative to others
- Opportunities: elements that the project could exploit to its advantage

- Threats: elements in the environment that could cause trouble for the business or project

Table 19. SWOT analysis

Strengths	**Weaknesses**
✓ New, innovative product ✓ Location and geography ✓ Price ✓ Oriented to one product ✓ Rapid prototyping manufacture	✓ Lack of work experience ✓ Lack of job knowledge ✓ Not first priority product ✓ No documentation and quality assurance ✓ Lack of marketing experience
Opportunities	**Threats**
✓ Growing economy ✓ Increasing air pollution ✓ Decreasing unemployment rate ✓ Online sell ✓ Improve design and capabilities	✓ Decreasing population ✓ Tax increases ✓ New competitors/online competitors ✓ Government stability ✓ Economic recession

Strengths and Opportunities (SO)

- Due to low commodity prices can increase online sales.
- For orientation in one product can fully concentrate on product design and improvement of features.

Strengths and Threats (ST)

- Thanks to the low prices could win the competitive battle against competitors.

Weaknesses and Opportunities (WO)

- Improving design and capabilities might get necessary documentation and quality assurance.
- Selling over the internet can improve marketing skills.

Weaknesses and Threats (WT)

- Working on the product could reduce lack of work experience, lack of job knowledge, lack of marketing experience.
- Making the right marketing decisions: advertise on television, online, in the media, could help to defeat competitors.

CONCLUSIONS

1. Rapid prototyping techniques is often used for prototyping, because it is cheaper than other manufacture methods. Using prototype is possibility to check assembly quality, measure it and perform tests.
2. Two plastic case models was designed: screw model and snap/hook model. To manufacture was selected screw model, because it is 4,71g lighter, so it is possible to save 3-6 € depending on the chosen method of manufacture and it is 10,6mm lower than snap/hook model.
3. Manufacture prototypes using rapid prototyping methods: 3D printing and vacuum casting.
   a) Printing prototype using 3D printer took 455 minutes, using vacuum casting process – 2274 minutes, majority of time (2010) minutes took silicon mold manufacturing.
   b) When printing with 3D printer model material cost 56,6€, vacuum casting – 87,45€, but second model cost 27,72€, because do not need make silicone mold
   c) More precise are 3D printer printed model, dimension tolerances nor exceeding 0,1mm. Vacuum casting dimension tolerances not exceeding 1mm.

   According to calculations manufacturing models using 3D printing method worthwhile when making no more than 6 models, otherwise it is cheaper to manufacture model using vacuum casting process.
4. Air ionizer price (material, elements, employee cost) was calculated: using 3D printing the price is 74,63€, vacuum casting – 137,70€, but for the second model price would be 61,77€, because silicone mold was already made. Analysis of marketing elements showed that:
   a) According to macro environment analysis the biggest influence for selling air ionizer is: documentation and quality assurance, minimum monthly wage, population, unemployment rate.
   b) After segmentation analysis, target market segment was composed: people who are 23 years old or more, who are aware of a healthy lifestyles, live in urban places and receive medium and higher income
   c) Based on SWOT analysis it was identified that biggest threats are: decreasing population, new competitors and economic recession.

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APPENDIX

Appendix 1 – First and second model drawing

Appendix 2 - Photo-polymer "Vero Gray" main characteristics

Appendix 3 - Isocyanate PX 226 and Polylol PX 226-245 physical properties, mechanical and thermal properties

Appendix 1