KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

Suraj Ramdas Mahajan

ANALYSIS AND IMPROVEMENT OF SILICONE RUBBER MOULDING PROCESS

Master's Degree Final Project

Supervisor
Assoc. prof. dr. Marius Rimasauskas

KAUNAS, 2018

KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

ANALYSIS AND IMPROVEMENT OF SILICONE RUBBER MOULDING PROCESS

Master's Degree Final Project
Industrial Engineering and Management (code 621H77003)

Supervisor
Assoc. prof. dr. Marius Rimasauskas
(date)

Reviewer
Assoc. prof. dr. Darius Eidukynas
(date)

Project made by
Suraj Ramdas Mahajan
(date)

KAUNAS, 2018

KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING AND DESIGN

(Faculty)

SURAJ RAMDAS MAHAJAN

(Student's name, surname)

INDUSTRIAL ENGINEERING AND MANAGEMENT (code 621H77003)

(Title of study programme, code)

"Analysis and Improvement of Silicone Rubber Moulding Process”

DECLARATION OF ACADEMIC INTEGRITY

____ ________________ 20 _____

Kaunas

I confirm that the final project of mine, **Suraj Ramdas Mahajan**, on the subject “Analysis and Improvement of Silicone Rubber Moulding Process” is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources; all direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

I fully and completely understand that any discovery of any facts of dishonesty inevitably results in me incurring a penalty under procedure effective at Kaunas University of Technology.

(name and surname filled in by hand) *(signature)*

KAUNAS UN IVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:
Head of
Production engineering
Department

____
(Signature, date)

Kazimieras Juzėnas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

ANALYSIS AND IMPROVEMENT OF SILICONE RUBBER MOULDING PROCESS

Approved by the Dean Order No. V25-11-12, 11 December 2017

2. Aim of the project

TO ANALYSE AND IMPROVE THE SILICONE RUBBER MOULDING PROCESS

3. Structure of the project

Introduction, Literature Review, Moulding Process, Casting of Parts, Cost Calculations and at the end Conclusion.

4. Requirements and conditions

Various Types of Silicone Rubber for moulding process, Epoxy Resin, Polyurethane Resin, Air Bubble Elimination process for removing air bubble from silicone rubber.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 21 December 2017

Student ______________________ ______________________
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor ______________________ ______________________
(*Position, Name, Surname*) (*Signature, date*)

Suraj Mahajan. Liejimo silikono formose proceso tyrimas ir tobulinimas. Magistro baigiamasis projektas / vadovas doc. dr. Marius Rimašauskas; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Mokslo kryptis ir sritis: gamybos inžinerija, technologiniai mokslai.

Reikšminiai žodžiai: Liejimas silikono formose, epoksidinė derva, sąnaudų skaičiavimas.

Kaunas, 2018. 57 p.

SANTRAUKA

Baigiamajame darbe liejimo formos gamybai skirtas pagrindinis modelis buvo sukurtas naudojant 3D CAD projektavimo sistemą Solid Works su skirtingais konstrukciniais elementais, kurie galėtų padėti įvertinti liejimo efektyvumą. Modelis vėliau buvo pagamintas naudojant 3D spausdinimo technologiją ir paruoštas liejimui. Eksperimento metu buvo naudojami skirtingų gamintojų ir savybių silikonai: Bluesil RTV 3428 A, CENUSIL RTV-2 M 380, ADDV-10, KDSV THX-30. Vėliau buvo atliktas liejimo formų vertinimas.

Liejimui silikono formose pagrinde buvo naudojama epoksidinė derva, eksperimentai kartoti 4 kartus siekiant geresnių pagaminto modelio kokybinių parametrų, tokių kaip paviršiaus kokybė ir susidariusių kiaurymių ar porų skaičius.

Paskutinėje baigiamojo darbo dalyje buvo apskaičiuots gamybos sąnaudos naudojant liejimo silikono formose technologiją ir keičiant skirtingas medžiagas. Kainų skaičiavimas atliktas gaminant 1, 10 ir 100 tokių pat detalių.

Gauti rezultatai gali būti naudingi nedidelėms įmonėms, kurios naudoja ar pradeda naudoti liejimo silikono formose technologiją.

Suraj, Mahajan. ANALYSIS AND IMPROVEMENT OF SILICONE RUBBER MOULDING PROCESS: *Master's (choose one)* thesis in. Industrial Engineering and management / supervisor assoc. prof. Marius Rimasauskas. The Faculty of the Faculty of Mechanical Engineering and Design, Department of Production Engineering. Kaunas University of Technology.

Research area and field: Production Engineering

Keywords: Silicone Rubber, Mould, Epoxy Resin, Casting, Cost Calculation

Kaunas, 2018. 57 p.

SUMMARY

In this research project, for manufacturing the masterpiece or master model, the first 3D-CAD model was created by the solid work software, this 3D-CAD model was created with all parametric requirement which is possible to get all geometric parameter in the mould cavity. After that, the masterpiece generated in the 3-D printer. With the help master model, the moulds were created by various silicon rubber. For this experiment, we used various silicon which is Bluesil RTV 3428 A & B silicone rubber, CENUSIL RTV-2 M 380 silicone rubber, Silicone ADDV-10, Silicone Rubber KDSV THX-30. After producing the mould with silicones, we analysed the finishing of cavity surface.

In this project, the casting process was done by using the epoxy resin. By using the epoxy resin, we generate four casting product with improvement with every casting product, and after that, we analysed the accuracy and finishing in every casting.

And the last stage of the paper is to cost calculation of product cost, in which we calculate the cost of one product with all different silicon mould, cost calculation is done for one product, ten product and hundreds product of every silicone mould.

The result of the experiment would be beneficial for the rapid prototyping and the small moulding part producing companies.

CONTENTS

TABLE OF FIGURES

LIST OF TABLE

CHAPTER 1

1.1 Introduction

Silicon moulding is most of the use process in the production company for rubber or plastic function parts.it is the simplest and old procedure of moulding the parts in which the rapid prototyping is suspended. Silicon moulding is incomplete because of their inalienable low firmness characteristics, best permit that preparation about a set amount of practical parts with expectable calibre control. Silicon moulding is the process which is used to produce the extensive range of the parts in different sizes and mouldings. Large number parts are produced by the silicon moulding process in which the rapid prototyping technique is used to manufacture the parts.

There are three basic principles of the silicone moulding process 1) Injection moulding 2) Transfer moulding 3) compression moulding. This all the three methods are similar in which the rubber mould is the application of pressure and heat, which give the moulding and vulcanize the parts. That can be varied as the time, temperature and the mould loading method.

Silicon moulding is the easy-going tooling process because there is the flexibility of the rubber. Silicon moulding is the technique which characterized by the vacuum during the casting of mould process and the fabrication of mould process.

The design of the silicon moulding is same as the design of the thermoplastic mould. But there are some important changes in the thermoplastic mould as compare to the silicon mould. Silicon rubber does not shrink in the thermoplastic mould material it is the main difference which is found between silicon moulding process or thermoplastic moulding process for the rubber.

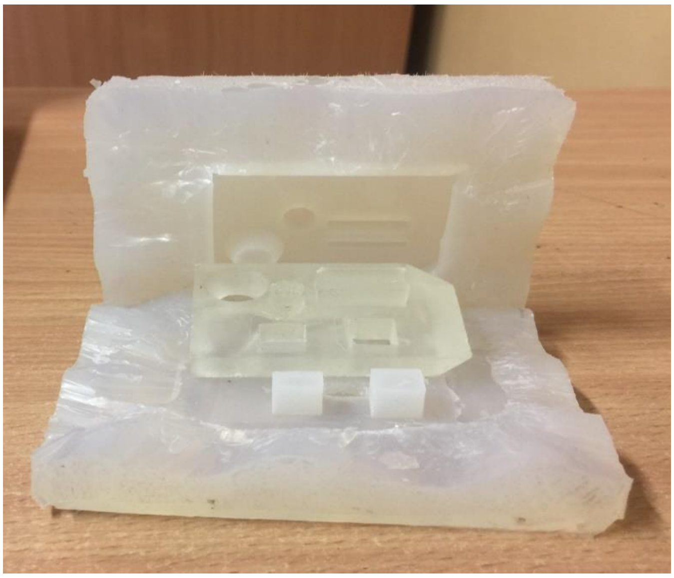


Fig.1.1 Silicone moulding

In the silicon moulding parts the dimensional accuracy could be very crucial, and in this situation, the layout of the mould should allow the shrinkage of the elements in the mould. This kind of straight shrinkage can be found through the test of the shaped specimen of the level elastic sheet and that might be utilized for the harsh outline of simple parts best.

1.2 Aim and Objectives

1. Aim

The aim of this paper is to analyse and improve the silicone rubber moulding process and changes in a mould with various silicone rubber.

2. Objectives of the paper

- Analysis of silicone rubber moulding process with various silicone.
- Investigation of the suitability of casting product.
- Analysis of silicone rubber moulding production cost.

1.3 Application, Advantages and disadvantages of silicone moulding process

1. Applications

- Small parts of industry
- Home craft material
- Medical used parts
- Agriculture parts
- Home or restaurant architecture
- Prototyping and Inventing
- Model making

2. Advantages

- Higher strength
- Low to moderate cost
- Wide range of Harnesses
- No release agent needed
- Excellent chemical resistance
- No shrink on cure

3. Disadvantages

- Requires careful application of release agent
- Moisture sensitive (in liquid form)

- Higher cost
- Shrinks on cure (~1%)
- Cured rubber has limited storage life
- Cure inhibited by some surfaces

1.4 Basic principle of silicon moulding

1. Injection moulding

In the injection moulding the high-speed reciprocating screw and the ram which forces to the unvulcanized rubber from the cylinder to a nozzle and goes in the close, heated mould which can hold the mould close by the independent pressure. There are two halves which attached to the heated platens.

For completely feeling the mould ram inject enough material to fill completely. After that, that will be withdrawn, and silicone rubber is ready for the next round which can be loaded into the cylinder. Advantages of the process it took short moulding cycle it is shorter than the compressive moulding process, In injection moulding process there is no or little perform preparation and no flash to remove and also to have the low scrap rate.

2. Transfer moulding

In transfer moulding, the unvulcanised rubber is set in a chamber which is called a pot, typically at the highest point of the moulding, and the get together is set in the press. The press applies weight to a chamber Ike associate with the open end of the pot, cutting the parts of the trim together and driving the elastic to course through no less than one spruces into the warmed frame.

Transfer moulding is particularly useful in making parts whose trim is the ultimate objective that the moulds can't give extraordinary stream and tend to trap air. It is the best procedure for trim parts that contain wires, pins and diverse supplements that require correct situating. In a few cases, the pot is incorporated into the moulding. In others, the pot is separate from the shape and is arranged by pins or territory marks. In the last case, the pot is normally ousted promptly after the shape is filled, to envision vulcanization of the elastic in the pot. With this structure, the pot can be stacked with elastic enough to stack the embellishment a couple of times.

3. Compression moulding

In compression, a preform is determined to one bit of a warped frame. At the point when the moulding is shut and placed under pressure in the press, the rubber is constrained into all parts of the formed pit; and overabundance rubber streams into a blaze groove around the formed pit. Silicone rubber is pressure moulding to frame gaskets, seals, 0-rings, and level sheets, texture strengthened overlays, and numerous different sorts of modern rubber products, of any size, wanted. Single cavity moulds are stacked by hand with some numerous depression moulds stacking sheets may give speedier form stacking, which forestalls singing of the preforms. Stacking sheets are gadgets on which the preforms are put in position for at the same time stacking the majority of the form cavities.

Moulding time and temperature differ with the vulcanizing operator utilized, the thickness of the part being moulded, and other creation conditions talked about under "Trim Issues" yet for every particular trim employment, and the greatest moulding of time and temperature must be dictated by experimentation.

1.5 Properties of silicone rubber

Silicone rubbers are comprehensively used as a piece of the industry, and there are different points of interest. Silicone rubbers are routinely maybe a couple portions of polymers and may have fillers to enhance properties or reduce costs. Silicone rubber usually does not respond, stable and unmatched for unique conditions and temperatures from -55 ° C to +300 ° C, while still maintaining its profitable properties.

In view of these properties and its straightforwardness of gathering and moulding, silicone rubber can be found in a wide combination of things, including car applications; cooking, heating, and sustenance stockpiling items; clothing, for example, underpants, sportswear, and footwear; gadgets; restorative gadgets and inserts; and in home. Repair and equipment with items, for example, silicone sealants. Polyclinics are different from different polymers because their rays include Si-O-Si units, not in the slightest degree like various diverse polymers that contain carbon spines. Polyclone is to a great degree versatile due to broad bond edges and bond lengths when appeared differently in relation to those found in more basic polymers, for instance, polyethene.

The siloxane spine contrasts incredibly from the fundamental polyethene spine, yielding a substantially more adaptable polymer. Polysiloxanes likewise tend to be synthetically dormant, because of the nature of the silicone-oxygen bond. Regardless of silicone being a congener of carbon, silicone analogise of carbonaceous blends overall show particular properties, as a result of the qualifications in electronic structure and electronegativity between the two segments; the silicone-oxygen security in polyclones is in a general sense more relentless than the carbon-oxygen security in poly ox methylene (a basically comparative polymer) because of its higher security vitality (likewise in light of the fact that polyoxymethylene deteriorates formaldehyde, which is unpredictable and avoids driving decay forward, however Si-containing disintegration results of silicone are less unstable).

CHAPTER 2

2.1 Literature Review

In this chapter, I will discuss all the theoretical aspects of silicone moulding process which is going to conduct an experiment in the research work. The main objective of the chapter is to collect all the relevant information which will be used for an experiment, analysis and the result.

For collecting all relevant information, it is important to know about silicone mould and process of making the silicone mould.

In this research paper E. J. McCormick, ALI [1] discuss what we need to know about the silicone moulding process. In which they said that the most common used silicone for mould making process is RTV ,which will mix in two part for inducing the curing.the disadvantage of the RTV material, it is more expensive than latex, having the tear strength and not quite as elastic [1].

After the shape of the silicone is healed, a sink is often used, which always maintains hardness. The shell form may contain glass fibre, mortar or urethane. The shape of the hull is often referred to as the "mother's form".

Typically, most silicones have a hardening time of 18 to 24 hours. In any case, the healing time can be incredibly reduced by the use of intelligent malfunctions [1]. When the moulds are moulded in a laboratory where such a mechanical connection is open, air suction in the vacuum chamber is set to clean the air bubbles. Nonetheless, paying more attention to a well-shaped vacuum cleaner can be considered as the main partition of the model silicone. The brush has a tendency to clean the surface air.

In this paper, they say that because of safety measures when working with silicone rubber, the proper use of RVT silicone rubber is very safe and tidy, but such hardening as toxic is harmful to the eyes and skin.

A quick catalyst is available for a specific silicone, which can reduce cure time, sometimes up to 60 minutes. With many silicone materials, the power bulkhead can be extended [1]. However, there are certain amounts that may be included that cover more than the intended impulse, or the use of a quick impulse, will shorten the life of the form, it will even tend to dry or become clearly brittle after a certain amount of time. There may be many forms of impulse in recent years or somewhere; one with a smaller pulse should last for a long time.

After the proposed elongation time passes, the outer surface of the form becomes rigid and dry; the shape is usually arranged so as to stand out or "push out". However, if there are no significant areas in the form or there is no time for the material, it is best to observe a longer period for the entire area to be completely cured [1]. When holding the mould, gently clean each of the edges and then the central segment. It is unlikely that any part seems too delicate, immediately withdraws from the traction and displaces any raised space, thereby giving more healing potential.

In this paper, EJ McCormick explains how to finish the process by using the silicone moulding process; he said that solid pencils could be made of silicone castings using conventional moulding materials such as Plaster-of-Paris, Hydrocal, Forton MG ", plastic, resin, epoxy materials, cement or other materials [1]. Typically, mortar molding operations are not required, but for the removal of urethane and resin or for the distillation of welded castings with severe disruptions or numerous rubble, for example, the specialist reduced the amount of petrol, as well as the barrier layer (eg, lacquer or paint applied to casting prior to casting), are careful. Depending on the idea of the mouse, it may be necessary to place the edge around it in order to be considered any mixture of flood moulding. Mix and pour the gauge material as shown in the developer's guideline. Quench is completely glued, step by step peel the mould from the mill. In each region that was previously drawn to the centre segments, resolve it. It is unexpectedly that the casting is deep, the remainder of the volume can be loaded with expandable foam, if desired, can also be used to fill the deep shapes [1].

In order to produce accuracy in the silicone moulding process S. Rahmati , J. Akbari ,and E. Barati [2]conduct an experiment in which they created the wax pattern by silicone moulding process with the Taguchi approach.

The methodology they use in this document is that they began to design the model using SLA, and then this SLA creates silicone mould. In addition, a vacuum throw machine was used to produce a wax design. The studies focused on how the parameter values, such as wax temperature, vacuum weight and form temperature, have improved in order to achieve better dimensional accuracy. During this exam, the Taguchi Test Detection Method (DOE) was linked. After confirming the ideal state by the methods used in Taguchi's view [2], other tests were completed using these ideal parameters, in view of the ultimate aim of verifying the results

The first step in the research paper is that to design the specific shape of the model, but in this paper, the facing some design issues and they are as follow.

- Various length for calculating or analysing the length effect.
- Various thickness of thickness effect
- constrained and unconstrained sections for comparing of these sections and their differences to influence on dimensional accuracy [2].
- Complexity of shape

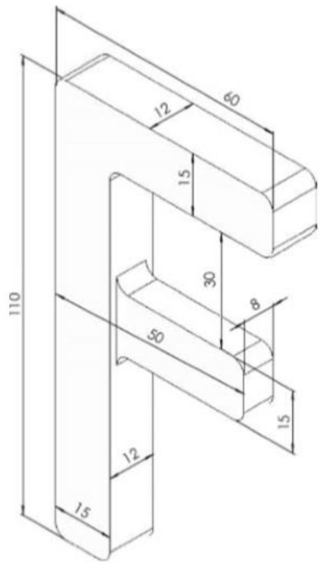


Fig. 2.1 the pattern shape [2]

By considering the designing issues, the final F shape design is as shown in fig 2.1.

After designing the model, they created a 3D model using SolidWorks software, and this model was converted to STL. In this project, the main model was made by the photocatalyst Cibatool SL 5195e resin with 3D systems SLA5000e machine [2]. They then made a silicone form using a vacuum moulding method.

In this work, the experiment was conducted using the Taguchi method in which they adopt the design examination, require n control variables and m control levels according to the control factor in order to understand its information about its performance and its interface. By using the usual research processes, each of the possible outcomes (mn tests) should usually be accurately determined until the ideal event can be completed.

According to author S. Rahmati, J. Akbari and E. Barati [2], they conclude that the wax parameters have a great influence on the accuracy of the dimensions of this form. The significance of each factor was analyzed, and it was concluded that the weight of the vacuum and its relationship with the wax temperature are the best general precision factors. According to Taguchi's method, they eventually said that the wax model created by silicone formation is a successful alternative to the traditional tool [2]

Mold casting of silicone rubber is the most common casting process in which Jeff LeFan [3] experiments with silicone rubber in injection moulding presses. In which he used two compounds of a weight of 200 kg and 18 kg of bunkers [3], and a suction mechanism for pump transfer into a casting machine. The progression of the spare valves on the pump unit takes into account positive transfers of materials which are of little interest to the pump category. For example, a gauge device, for example, a mounting pump, is used to ensure the proper supply of A and B segments to the mixing head. The most known mixing ratio is 1: 1; In any case, 10: 1 is also used with a pulse that is on the smaller scale of the B proportional segment. Parts A and B merge into the mixing area, where colouration can also occur. The connection is usually carried out via a stationary mixing device, for example, a Kinex mixer in which the material is designed to be 90 or more units. [3]. The parts "An" and "B" blend in the mixing square, where it can also be hid. The connection is usually carried out via a static mixing device, such as a Kinex mixer, which has a 90o greater material flow than several wound strips.

Prior to the prologue in the infusion set, the LSR is often inspected to evacuate any gels, contaminants or curative substances that may form in the blended apple. Screen packs containing several distinctive work sizes are stored in a steel furnace with a delta and drain hole. The average maximum work is 200 strings / in, with branching out (60/100/150/200) from the gulf course [3].

Weight control is regularly required before the blended material enters the infusion unit. This gadget takes into account a limitation in the liquid way that can build weight, which considers legitimate shot dosing. Weight controllers are flexible, yet regularly kept in the 0.7-3.5 MPa (100-500 psi) range to anticipate over-pressure of the metered shot.

From the price point of view, LSR is aggressive with conventional silicone rubber, priced at € 7.00 / € 14.00 per kilo (from $ 5.00 to £ 10.00 per pound). It is essentially an assessment of the meter: the request for payment of materials and the implantable reproductive silicone can be much more expensive at the request of 140,00 EUR / kg (100,00 USD per pound). [3] In any case, when looking at the procedures, LSR has undoubtedly reduced the number of contrast and regular silicone due to the much faster process length. The LSR cycles are also aggressive with thermoplastic elastomers, and therefore their higher material costs less obstacles.

What is the best place for a hinge Similar to the formation of a thermoplastic infusion, bottom loading should be performed from the thickest parts of the territory, If the assembly part, the door area should not interfere with the merging of the last object's activities?

Object plan and tool configuration are launched as one with LSR formatting. Device planners need to consider not only the customer's needs for measurement and cavity geometry but also how to apply these assumptions to limited space in infusion sets. These are some queries made by form makers and tool creator.

LSR materials require a consistent weight between pumps, and along these lines, material pumps cannot be replaced until the pump is running. This means that the infusion set machine must be stopped in order to pull out the unopened holder and replace the new material [3]. The best way that this circumstance can be maintained at a strategic distance is a momentary suction unit that can be changed by the valve, in view of the ultimate goal of continuously finishing the finishing machine. In any case, these units are very expensive and, therefore, in order to ensure a continuous operation, there is a need for high capital speculation.

In the same process as Jeff LeFan[3], he did with the injection moulding, the author A.J. MillaÂ n 1, M.I. Nieto,[4] conduct the experiment with silicone nitride injection moulding. In which he describes that the manufacture of fragile parts of silicone nitride with a weak pressure weight infusion embellishment fluid depicted sculptures. The essential condition for this procedure is the confirmation of constant suspensions with a high content of solids and rheological properties [4]. The temperature has a decisive part in comparison to the slip strength states. In this work the parameters of the pressure, such as flocculent type and centralization, pH, ageing, etc., have been taken into account, temperature rheological behaviour of the silicone nitride liquid vertebrae. When the stiffness conditions were resolved, the accuracy of the gel operator (agarose) was also taken into account on the slim rheology with a specific final aim to update the infusion conditions [4]. The rheological behaviour of layers containing 1% by weight agarose was considered as a component of the temperature and added to the effect of sintering [4]. Infusion formation was carried out at a temperature of 60 ± 65 ° C and a weight of 0.4 MPa. The latter theoretically about 90% positive-dense are caused by sintering at 1750 ℃.

In the experiment, authors did that commercial silicone nitride powder (Hermann C. Starck LC12N, Germany) with an average molecule of 0.7 mm and a specific surface area of 18 m2 / g is used. During the propagation process compression without pressure requires sintering. For this reason, aluminium oxide and yttria were used as part of the centralization, corresponding to 3% by weight each [3]. The average particle size of Al_2O_3 powder (CondeaHPA05, USA) was 0.4 mm, and the surface area was 9.5 m2 / g. The resulting Y_2O_3 powder contained an average molecular size of 3.5 mm, but they were worn to an average of 0.8 mm.

The infusion tests were performed using a manual LPIM device (Peltsmann MIGL28, USA) controlling the tank temperature at 55 and 65 ° C, and the lifetime clearance time in the form of a cavity of 2 ± 30 s. Added 0.4 MPa weight. The steel form, cooled by running water, was used to create 60 × 10 × 10 mm test rods. During drying, asphalt crumbs were dried for 24 h. Green mass is measured by mercury shaking. Direct shrinkage measured by drying. Suction was performed at 1750 ℃ / 2 h. After the flow of N_2 in graphite chamber heater (Astro, Thermal Technology, USA). The green and sintered microstructure were evaluated by filtration microscopy of an electron on the break surface.

All this concludes that concentrated silicone nitride sheets (> 40% vol) can be balanced at pH 11 ± 11.5 with solid bases such as TMAH and TPAH. The temperature has a significant influence on the rheology of the layers, especially above 65 ° C [4]. Although the temperature rises, the pH decreases somewhat, but this change is reversible, and it tends to refresh by cooling.

Injection moulding can be performed at high-temperature variations above Tg and not the probability that the agarose can be assured to be fragmented. Then the infusion temperature is not the main parameter that affects the properties of the green cells if it is above the gel structure of Tg and there is no contraction of life or combined weight. The green density was higher than 50%. After sintering, homogeneous microstructures with a density of about 90% appeared. The LPIM Aquarium turns a powerful minimum effort into an effective method for delivery of complex, formed silicone nitride parts without pressure sintering.

In the rapid manufacturing world for silicone moulding process the Ramona PĂCURAR, Petru BERCE, Dănuţ LEORDEAN, Adrian RADU [5] conduct an experiment for a complex part in food industries. In which they did that silicone elastomer used to fabricate some cake frames, to enhance item quality, increment productivity, decrease the time required for hygienization, lessen the microbial heap of the shape, and the means required to acquire these moulds by vacuum casting. The intense connection of silicone-oxygen gives silicone elastic its own execution and qualities comprising in expanded protection from different compound operators and varieties in temperature, magnificent mechanical and dielectric properties, biocompatibility, straightforwardness and regular lucidity.

In this paper, the author did the experiment in vacuum casting process in which they describe that the vacuum casting is the best to process in which used for the silicone mould and it is the oldest method used to produce the product in silicone moulding. Vacuum Casting is a strategy that has demonstrated the propriety and effectiveness in the phase of growing new items, step when prototyping of complex parts must be utilized for little groups (30-50 sections)[5], for testing new item usefulness or potentially advertise testing of the new item. In the process the reproduce part quality fulfil all the requirement of the masterpiece, in the process of vacuum casing the material used as the resin,plastic,and rubber[5].

For the experiment author used the vacuum casting machine type of MCP-001 P is shown in fig 2.2, and the mould is prepared from ESSIL 291.and this silicone is used with one of the catalysts like A38 and A40.

Fig.2.2 MCP-001P Vacuum Casting Machine [5]

In this paper, the process used for making the silicone mould in the food industry is as follow,

- Developing the cad drawing for the masterpiece
- Separation of plane
- Coloring of counter in the separation plan
- mould box.
- Silicone rubber casting
- Air bubble elimination
- Getting the silicone mould

In this paper, authors conclude that the silicone rubber mould is very soft material and good for the food industry. As contrasted and other elastic like materials, silicone elastic has the best extraction properties of the models from moulds. This is preference when pitches (polyurethanes, polyesters, epoxy) are utilized as a part of assembling[5]. Silicone elastic does not require discharge specialists, so there is no requirement for cleaning after utilize. Silicones likewise display a decent substance protection and protection at high temperatures (over 205°C). The blend of good extraction properties, substance protection and warmth protection makes silicone the best arrangement for assembling when saps are utilized.

One of the authors from Columbus name of Peng He, Likai Li, conducts an experiment on compression moulding of glass by using the silicone rubber mould in which author explains that In accuracy glass embellishment of freestyle optics, form material determination and shape creation are two noteworthy difficulties. In this letter, we propose a technique to create silicone moulds for small-scale freestyle optics utilizing ultra precision jewel machining. In particular, two microlens exhibits and a kino form focal point moulds were made on a 5.0 mm thick silicone wafer utilizing ultraprecision precious stone processing. The manufactured silicone moulds were covered with a graphene-like carbon covering utilizing substance vapour affidavit to forestall glass to silicone attachment [6]. To exhibit the usefulness of the single point precious stone machined silicone moulds, glass small scale segments were created utilizing accuracy pressure shaping. Contrasted and regular pounding process required for tungsten carbide, the technique explored in this examination gives a more adaptable, speedier and reasonable contrasting option to manufacture moulds for complex accuracy glass freestyle optics.

In this experiment, silicone is not directly used as a mould because of the addition of glass is on high temperature. The attachment can either be caused by a procedure like anodic holding or on the other hand substance holding. Luckily, it has been illustrated that carbide-reinforced graphene covering can viably avoid grip amongst silicone and glass[6]. In this exploration, a substance vapour affidavit (CVD) covering was created to deliver a covalent-fortified graphene-like organize covering on silicone substrate utilizing benzene as a carbon source under a dormant gas stream at high temperature quickly portrayed underneath.

The silicone substrate was put in a nitrogen gas cleansed heater. At the point when the temperature in the heater achieved 950 ℃, benzene was swung to gas as rises outside of the heater. The foaming rate was around 3 to 5 bubble/s. The benzene bubbles were blown into the heater under Ar gas stream (200 ml/min). After 30 min of response, the benzene source was cut off, and framework was killed for regular cooling. It is trusted that the benzene carbon sources frame graphene-like structures on the substrate surface. The covered silicone form surface displays a silver shading.

The conclusion of the paper is that the produced glass moulding process is free to form the optics by using the silicone mould process. of small-scale freestyle, structures were initially machined on a 5.0 mm thick silicon wafer to be utilized as moulds. These silicone moulds were then covered utilizing CVD technique with graphene-like carbon to keep the glass from adhering to silicon amid embellishment. Two miniaturized scale freestyle glass optical parts were then manufactured by utilizing exactness glass shaping. Contrasted and the glass shaping procedure are utilizing tungsten carbide shape by the granulating process, the introduced technique gives a more adaptable, quick and financially savvy process to manufacture complex yet exact freestyle optics.

In this paper, the authors Yong gang Jiang, explains the silicone moulding process for the pattern of NdFeB/ multilayer magnetic field and NdFeB magnetic powder [7]. The topographic view and the magnetic field distribution pattern are measured by an anatomical microscope and a magnetic field microscope. Using the silicone moulding process, supplemented by the lifting process, magnetic powder NdFeB is used to produce magnetic microstructures. Silicone trench was 20 mm, filled with a mixture of magnetic powder and wax powder.

The following is a silicone form production method for producing NdFeB magnetic powder; using the silicon form, the developed model was successfully developed [7]. As shown, shows that the width of the NdFeB magnetic tape of 50 mm [7] indicates 70 mm rectangular magnetic points. The cross-section of the magnetic microstructure of NdFeB is investigated using SEM. Both magnetic strips with a width of 1.00 mm and attractive strips with a width of 20 mm are uniformly filled with NdFeB magnetic powder of a thickness of 20 mm. As far as we know; this is the best attractive example when using stuffed, powdered powders. The attractive properties of lower NdFeB magnetic powder are measured by VSM using a sample integrated into attractive strips with a width of 100 mm and a thickness of 20 mm. their operation vertically, but also more, the direction of the plane is more than 0,37T.

In this experiment, the authors concluded that the microstructure was made of high-performance NdFeB micro-magnets using silicone-based moulding processes for sprayed NdFeB / Ta multilayer films and NdFeB powders [7]. It was found that NdFeB / Ta multilayer magnetic film sputtering on 12 mm thick upper redesigned silicone grooves is appropriate, although the silicon groove widths exceed 10 mm. The NdFeB / Ta multilayer magnetic film obtained by sputtering shows a magnetic resistance of up to 1.3T. The base of silicone materials with trenches filled in the plane. To sum up, the procedure for the formation of NdFeB / Ta multi-layer films and NdFeB attractive powder silicone was developed with attractive MMS applications.

In this paper authors M Wang, J. Li [8] discussed the Silicone moulding methods for combined MEMS inductors, authors explain Solid coordination of DC-DC converters within-chip inductors have risen, as expected, expect a reduction in size and short-term production of minimal contraception.MEMS procedures utilized to organize the shock inductors on-chip, yet these MEMS inductors are small impact overseeing limit because of high DC protection, high concentration hardship or little submersion current [8]. This paper reports an interesting silicone framing approach that is fit for embedding's thick electrolytic metal layers (both Cu and permeate mixtures) into a silicone substrate, in which, in the form of electrolytic moulding, tubular silicone trenches are used. These silicone trenches are interconnected with the SU-8 to improve the electrical partition and relax the warm anxiety. The thickness of the introduced metal is the same as that of a silicone substrate ranging from 200 m to 500 m, affecting a low DC gain. A couple of charming the panels are constructed on both sides of the silicone base, which are joined by tubes transferring the vials to achieve significant induction. Pot-center inductor with low rehash inductance 134 NH, DC 9, 1 m and more than 1 A submersion current has been shown. In the experiment of silicone subtract moulding technique authors explain the conception of inductors based on silicone substrate moulding method in which the idea of the coordinated The inductors in the silicone substrate molding system represent the upper perspective of the coordinator inductor, in which two fragile substrate sides are separately made of two attractive panels, and Cu windings and attractive arches are implanted into a silicone substrate [8]. Shows a measure of a square-area inductor in which the Cu winding has a silicone substrate of the same thickness and the attractive walled interlacing wafers connect the best and most attractive panels. Cu winding wraps and attractive materials are made by galvanizing inside the silicone moulding tube because they are made using the technique of silicone substrate forming, as shown in the attached segment.

In straight silicone moulding, the faces some issues such as the metals are galvanized specifically in the silicone moulds. Because of vast contrast of the warm development numbers of metals and silicone, high warm anxiety might be produced. Subsequently, splits might be exhibited both in silicone and metal windings when a PECVD oxide affidavit is required for passivation [8]. The PECVD temperature is 250-300 ◦C regularly. Displays the SEM photo device after the Cu winding, and permalloy tries to galvanize the silicone grooves and clean the surface. Another issue is the root of the misfortune. Since the windings are separated from the silicone particles only by a thin layer of silicon dioxide, the solid oxide layer will have a solid capacitive bond, and the inductive coupling between the windings and the silicone particles will induce a real substrate failure and low-quality factor [8]. The use of high-strength silicone bases may, to a certain extent, reduce the cost of these adverse effects due to higher costs. An auxiliary change can be made by completely displacing silicone particles with polymers. And the author concludes that the idea of integrated power MEMS inductors has been preliminarily approved, taking into account the silicone-based moulding system. It has been found that immediate use of the silicone trench as an electrolytic mould immediately results in a stress-induced fracture problem. The SU-8 has been developed to address this problem using SU-8 as dielectric layers and is also a source of warm concern [8]. Pot-center induction with 134 NH inductance at 200 kHz, 9.1 m DC and over 1 A submersible current were effectively demonstrated. The current turbulent disaster has broadly expanded at frequencies exceeding 1 MHz This disaster will soon be reduced by replacing highlights and using high-quality recurrence of attractive materials to evacuate the permalloy.

In this article, the authors explain the powder injection process for UAV engine components using Nano silicone nitride powder in an exposure study to assess the availability of powder infusion finishes to create segments of the silicone nitride engine. The exams were carried out with raw materials consisting of Nano silicate silicone nitride powder mixed with magnesia, yttrium and paraffin wax, a polypropylene cap. The target rheological and thermal raw material properties have been used to restore the flow of material by creating infusion moulding in the ignition engine in an unmanned vehicle (UAV). Based on the Box-Behnke configuration, the basic parameters influencing the infusion formation procedure [8] were used. The temperature is required to dissolve as a huge variable, acting on the infusion weight, closure limitations, shear force and shell inspection depth, the temperature at the front of the current, and volume contraction. Infusion time was observed to be the predominant component affecting mass temperature and end-time pressure. The ideal infusion formation parameters were additionally evaluated using an indirect programming (NLP) cable [8]. It is common practice that the design team can use the conversion strategies that were discussed during the study to distinguish ideal conditioning conditions for imaginary engine parts, and then maintain a strategic distance from iterative costly, as well as tedious testing. In this work, the design and optimization carried out by the authors, the moulding flow software is used to determine the injection moulding state that the selected part for reproduction is from NWUAV pulse systems [9]. Fictitious raw materials used a premium that needs to be redefined. The three levels of the factoring Box-Behnke plan, which has 15 distinct features, is an individual procedure for determining.

Another of them concludes with a PIM raw material consisting of a mixture of nano-sized Si3N4 powder mixed with magnesia and a paraffin wax-polypropylene zipper base that has been studied for its features and features of decoration. The exact raw material properties have been used as information parameters to restore material flow through the injection moulding process [9]. The restoration has shown that the softening temperature is the dominant element affecting the weight of the infusion, strengthening it, the sheer deficit, the depth of the shell seal, the temperature at the front flow and the volume contraction. Infusion time was found to be the main factor influencing the mass temperature and time to pressure end [9]. In general, the reciprocating legislation on injection moulding has recommended the intangibles of the infusion process to effectively produce engine segments for use in UAV applications using Si3N4 nanoscale. It is common practice for a group of buildings to use the re-entry procedure discussed in the study to recognize ideal conditioning conditions for unimaginable parts of the engine, thus maintaining a strategic distance from iterative costly and tedious tests [9]. Reproduction procedures may also be used to assess whether it is possible to assemble different basal parts in the infusion formation process.

CHAPTER 3

Methodology

Making the silicone mould is very simple and easy which will release many errors.This process can be used for making the some of the industrial and household parts. The consideration is in the process the first the place the master part. The masterpiece can be represented by supporting it on spacers and walling it in holding the frame. For making the silicone mould, it is very important firstly need to collect all needed material and equipment for the experiment. The experiment will be with polymers, so it is important to have already and handily because the flow time of polymer is not very long.

To arrange the masterpiece in a position, need a base plate, wooden plates for mould box, glue gun, and gums. Additional equipment includes interaction paper, paper cloths, two mixing tumblers, and a tube with a chimney, masking tape, covering, and gum.

The silicone material come in two parts that blend by volume proportion of 1:1. Propanol liquor is utilised to clean the polymers previously they cure. The throwing material used to make parts likewise blends on a volume premise of 1:1. At last, you require the discharge operators. For the safety precaution need to wear respirator mask lab coat, gloves, and goggles.

3.1 Procedure for mould making

The first step to making the silicon rubber mould is to design the master part with the help of solid work design software as shown in fig. 3.2.1 and produce it with verogray RGD 850 polymer in 3D printer which is shown in fig (3.1.2). To making the silicon rubber mould is to examine the master for imperfection.Silicon rubber mould and its polyurethane part reflect the exact surface of the master part. For accuracy and the high quality of the product, it is important to examine the master part.

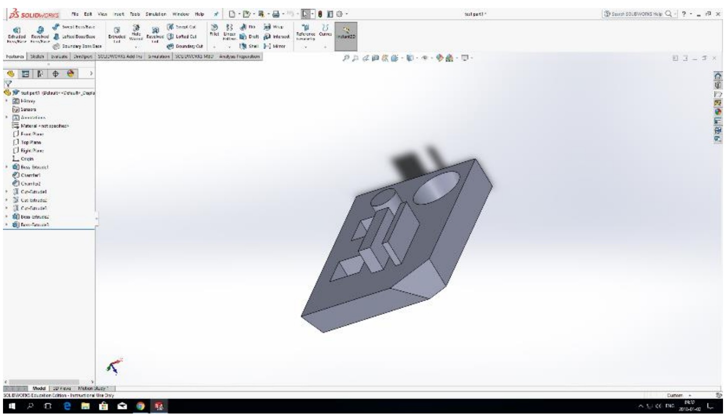


Fig. 3.2.1 master piece 3D design

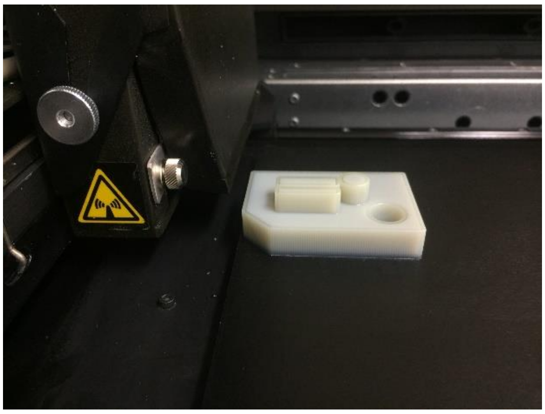


Fig. 3.1.2Master part in 3D printer

Fig 3.1.3.Master part

After producing the master part by 3D printer wash it with the water jet cabinet (fig.3.1.4) with high-pressure water for an imperfection or removing the extra material from the masterpiece. The exact dimensions of the masterpiece with Length 6cm, Width 4cm, Height 1.8cm, the masterpiece is also with the two upwards rectangular walls, one circular bar, one square hole, and one rectangular hole which is shown in fig 3.1.3.

Fig. 3.1.4 Water Jet

Fig 3.1.5 Base Plate

The next step is to make the mould box with the dimension length 9cm, height 4.8cm, and width 7cm, in this experiment I took 2 cm wider wall for mould. For making the mould box need to place the base plate which is as shown in fig. 3.1.5. And draw the box with the help of marker on the base plate and stick all the wooden plates on the drawn box by glue gun pack it with a glue gun and the mould box is ready which is as shown in fig 3.1.6.

Fig 3.1.6 Mould Box

Fig.3.1.7 Lifting Masterpiece

Lift the master starting from the earliest stage appending a help to it. The motivation behind raising the master over the base plate in mould box is to enable the silicone to mould a foam divider that is 2 cm thick on the base. If the divider is more slender then 2 cm in any area, then form may be sufficiently frail to tear amid de-moulding. We lifted our master by sticking a glue stick with super glue as shown in fig 3.1.7. Since polymer from which new parts will be thrown will enter the silicone form the upside, air in the moulding must have an approach to exit. That can be accomplished by super sticking meagre wires on the best most edges of the master, i.e. the edges where air will catch. We cut the thin wire by cutting pincers and sanded one edge level to build the wire holding zone. Before getting the master to the plate (the base of the moulding), the plate treated, so the foam material doesn't stick to it. We utilised contact paper to maintain a strategic distance from the utilisation of wax glues. We secured the master to the plate utilising super paste to stick the glue stick the upside surface of the mould box.

Now, prepared to blend the silicone rubber materials with the ratio of 100:10 means 100% of silicone by weight is to 10% of hardener. For our mould approximately the volume of the silicon rubber material required to fill our mould is 390g (355+35). Prepare about 20% more to account for loses. The material needed for silicone mould depends on the volume of the mould box and specific gravity of the silicone rubber. Since the silicone material mixes on 100:10 ratio per volume, one half the required material should come from each component. Mix the material in the plastic flask for 5 min, Ensure the material is completely blended remembering that blending ought to be done delicately so air can not bring into the material. Remember that the working existence of the silicone rubber material is 25-30 minutes, which implies once the parts are in contact with each other, you have at most 30 minutes to blend and pour them.

After ensuring the material can completely blend kept it into air bubble removing machine for 10 minutes for removal of bubbles from silicone which is as shown in fig 3.1.8.

Fig 3.1.8. The air bubble is removing

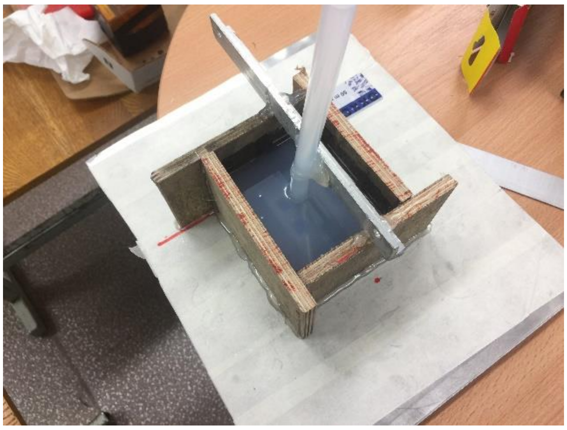


Fig 3.1.9. Material filling

Pour the silicon gradually, so no air pockets left around the master dividers. The moulding plan can be tilted at a slight edge if an even expansive surface is available. Tilting will diminish the odds of getting air pockets caught underneath even expansive surfaces as shown in fig 3.1.9. After pouring the silicon into the mould, box kept it into bubble removing machine for removing the bubble from a material which is accruing while pouring the material into the mould box which is as shown in fig 3.1.10.

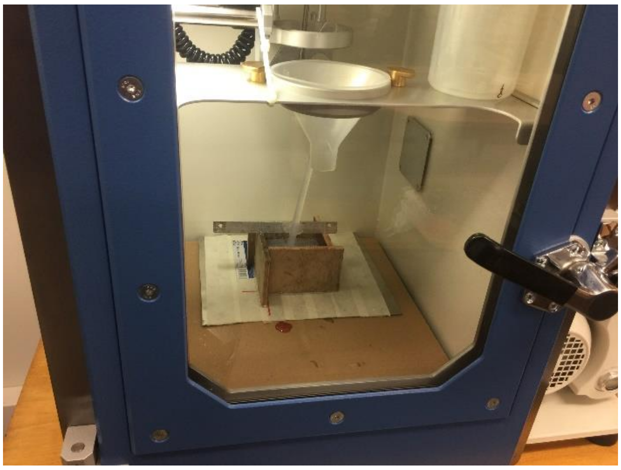


Fig. 3.1.10 Removal of bubble after poring the material

Once the removal of the remaining bubble done, it will take 24 hours for curing process at room temperature 23°c. To guarantee that the silicone jars remain appropriately fixed for some time later, shower some discharge operator around the front of the Prepolymer silicone segment.

After completing 24 hours or curing process, the mould is ready to take out from the mould box. Remove all the wooden walls and take the mould out and cut it into two parts with parting line, cut the mould very gently in the zip zap way as shown in fig.3.1.11.

Fig 3.1.11. Cutting of silicone mould Fig 3.1.12.Silicone Mould

Next is to remove the masterpiece from the mould and open it very gently as shown in fig 3.1.12. And finally, silicone rubber mould is ready to produce the parts.

For producing the part in the given mould need to assemble the two parts of mould very gently and pack it with the black tape as shown in fig 3.1.13. Next is to prepare the filling material epoxy resin and calculate the exact material need to fill in the mould for this we need to calculate the volume of the masterpiece and multiply it with a specific gravity of material.

In our case, the volume of the masterpiece is length 6cm × height 1.8 cm × width 6 cm and the volume of masterpiece is $21.03cm^3$, and the specific gravity of epoxy resin is $1.15cm^3$.material required to fill in the mould is $21.03cm^3 \times 1.15cm^3$ = 24.18 grams. The mixing ration of the epoxy resin is 10:2, blend the epoxy resin and hardener and mix colour in the and blend it very well as shown in fig 3.1.14.

Fig 3.1.13. Mould Assembly Fig 3.1.14. Epoxy Resin

After ensuring the epoxy resin is completely blended, pour it into the silicone mould with the help of filler and leave it for 12 to 24 hours for curing process because the curing time of the epoxy resin is 12 hour at room temperature 23°c. After 12 hours removes the packing of silicone mould and disassemble the two parts of the mould and take out the final produced part from the mould very gently without damage of mould or cavity of mould as shown in fig 3.1.15.

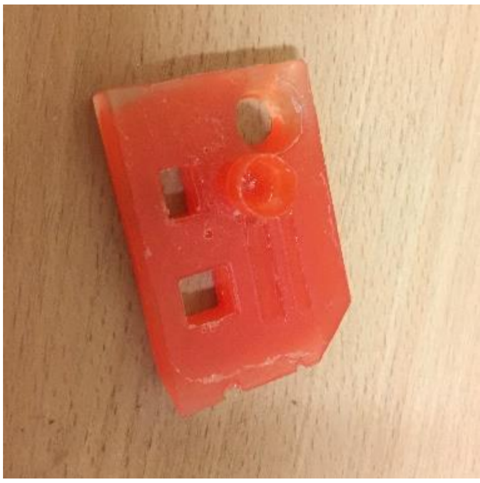


Fig. 3.1.15 Final Part

3.2 Mould Making With Different Silicons

1. Bluesil RTV 3428 A & B

The Bluesil RTV 3428 A & B is a two component which is used while making the mould.The mixing ratio of silicon is 100:10, and the specific gravity of this silicone is 1.1,this silicon is transport in colour. Making the mould for our product with this silicon, we needed the 390 gram (355A+35B) of silicone.The preparation time of the silicon is 25 to 30 minutes and the curing time is 24 hours at the room temperature 23°c.We created the mould with this silicon as shown in fig.3.2.1.

Fig.3.2.1 RTV 3428 silicon mould

There are two moulds which created by the RTV 3428, and the finishing of the cavity in both moulds is good.

Fig.3.2.2 Upper Cavity

Fig.3.2.3 bottom cavity

The finishing of the upper and bottom side cavity is very good as shown in fig. 3.2.2 and fig. 3.2.3.this silicon is very good for producing perfect part or for the prototyping in the industrial areas.the cavity which I found with the RTV 3428 is perfect and well finish as shown in fig.

The advantage of this silicone is 1) Processing and curing are very easy 2) Linear shrinkage is very low.3) Tensile strength is very outstanding.

2. CENUSIL RTV-2 M 380

The CENUSIL M 380 silicone is white colour silicone which cured by adding the catalyst T37 for long-term pot life and curing time.The viscosity of the silicon is very high that's why the preparation time of this silicone is very small that is 15 minutes after mixing with the catalyst T35.The density or the specific gravity of the silicone is 1.22 g/cm³.And the curing of the silicon is 24 hours.

For the experiment, we create the mould by this silicone with the same mould making process and result fount as shown in fig.3.2.4.

Fig.3.2.4 CENUSIL M 380 Silicone Mould

The colour of the silicone is white because of this the parting line is not visible, it is hard to cut the mould in s two-part with exact parting. The finishing of the surface is not that much good to produce the product or the part of this mould.

The finishing of the bottom surface cavity of the mould is good, but the upper surface of the cavity is very bad. It is because during the removal of the masterpiece silicon rubber stick on the upper surface of the masterpiece and result is damage surface of the cavity.

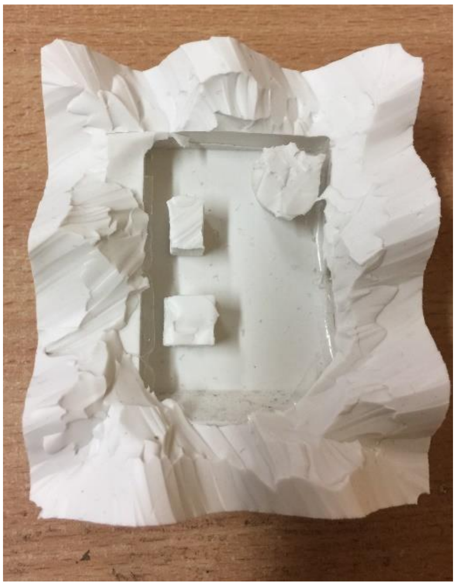


Fig.3.2.5 Bottom Cavity

Fig.3.2.6 Upper Cavity

A special feature of the silicone is 1) good flowability 2) tear strength is too high 3) low shore hardness A.

3.Silicone ADDV-10

The ADDV-10 silicone rubber is suitable for the reproduction of the model by using the epoxy resin and polyurethane. The specific gravity of this silicone is 1.15 g/cm^3.and the mixing ration of the silicone is 1:1 with the viscosity 8000-10000 mpa.s, this silicone is very flexyble meaans the flexibily of the silicone very soft.

For making the mould with this silicone, the needed silicone for us is 380 grams.we produced the mould with ADDV-10 silicone by the same mould making process; the produced mould is as shown in fig 3.2.7.

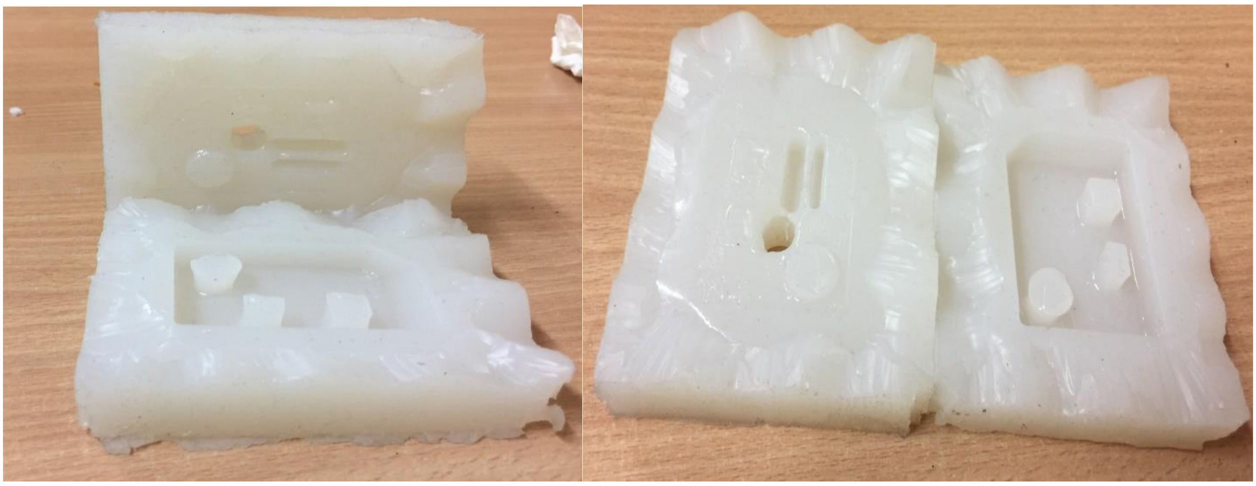


Fig.3.2.7 Silicone ADDV-10 Mould

Fig. 3.2.8 Upper Cavity Surface

Fig.3.2.9 Bottom Cavity Surface

Because of chemical reaction, the bottom surface and the upper surface is sticky as shown in fig 3.2.8 and fig 3.2.9. The surface of the mould is well finished and perfect as a masterpiece.this silicone is very good to produce the part and the prototype.

A feature of the ADDV-10 silicone is 1) superior flowability 2) high tear and tensile strength 3) this silicone is fast and shrinkage free at room temperature.

4.Silicone Rubber KDSV THX-30

The KDSV THX-30 is a good silicone for the silicon moulding process,because of the high viscosity the processing time of the silicone is very low it's only 10 minutes for mixing and pouring into the moulding box.the specific gravity of the silicon is 1.09 g/cm^3 and the curing time is 12 hours. The mixing ratio of the silicone is 100:2 by the weight.

During the production of the mould using this silicon we took some more time for preparation, because of this, the flowability of the silicone becomes little hard. In the final produced mould some part are missing and incomplete as shown in fig 3.2.10.

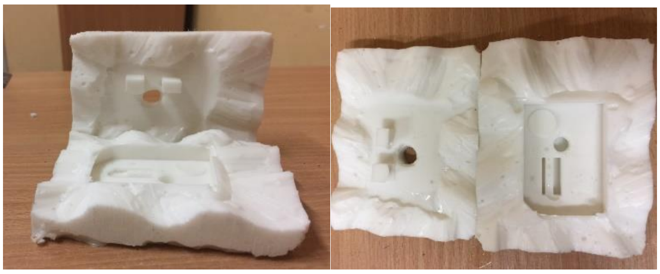


Fig. 3.2.10 KDSV THX-30 silicone mould

The finishing of the upper and bottom cavity surface is very good as compared to other silicone rubber mould as shown in 3.2.11 and fig 3.2.12.this silicone is more suitable for producing the prototype and the part, but the problem only is that the high viscosity and low preparation time.

Fig.3.2.11 Upper cavity surface

Fig. 3.2.12 Bottom Cavity Surface

Features of KDSV THX-30 is 1) this silicone is fast vulcanisation at room temperature 2) this silicone having the good tear strength and propagation strength.

3.3 Description of produced product by epoxy resin

1. First Part

This is the first part which is produced by using the silicon mould which prepared by given method and result which I got is as shown in fig 3.3.1. The upper surface finishing of the part is very bad that comes with the air bubble marks or the unfilled material spots which are shown as in fig 3.2.2,that come because of air which is remaining in the mould while pouring the epoxy inside the mould.

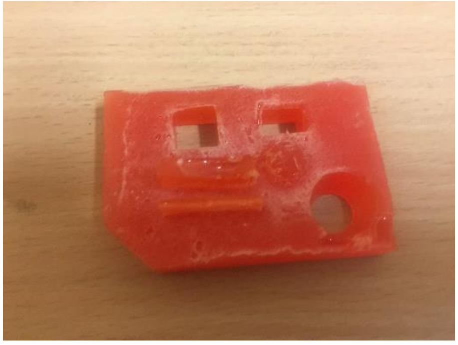


Fig 3.3.1. First part

Fig 3.3.2. Upper surface of part

While producing this part I used the air removal process after pouring the epoxy into the silicone mould. In this process, air comes from the bottom side of the mould to the upper side, and because of this the finishing of the bottom surface is better than the upper surface, but at the bottom surface, there is some air bubble mark also remaining which is shown as in fig 3.3.3.

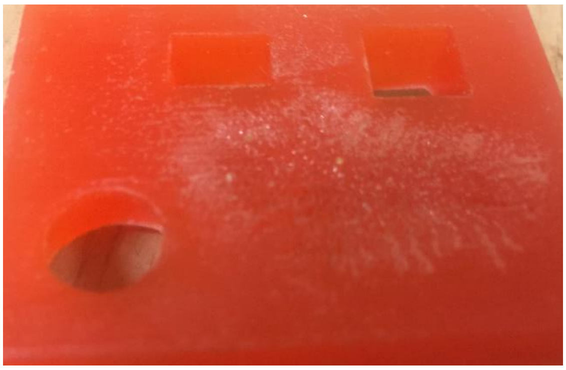


Fig 3.3.3. Bottom Surface of Part

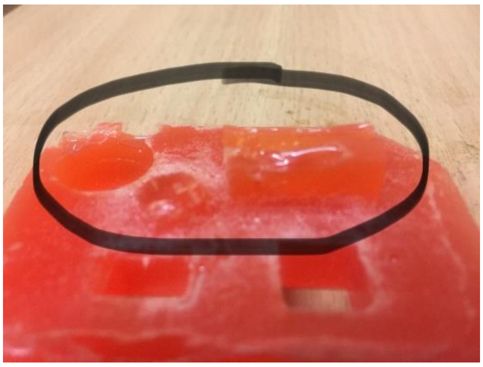


Fig 3.3.4.Incomplete part of upper surface

There are some incomplete parts of the upper surface this is because of the air bubble removal process after pouring the epoxy into the mould. During the air bubble removal process the air start coming bottom to the upper side and this air stuck on the upper surface part cavity and remain in it which causes the incomplete part as shown in fig 3.3.4.

The finishing of all side surfaces and slide cuts are better than the upper and bottom surface which is shown as in fig 3.3.5.

Side Surfaces

Slide Cut Surface

Fig. 3.3.5 Side and Slide cut surfaces

2. Second part

As I found problems of surface finishing in the first part because of the air is remaining in the cavity of the mould. After finding the reason behind the problem with first part I produce the second part in same procedure with some improvement in the procedure for the finished surface of the parts and result found is really better than the first part as shown in fig. 3.3.6.The upper surface finishing of this part is good or better than the first part as shown in fig 3.3.7.

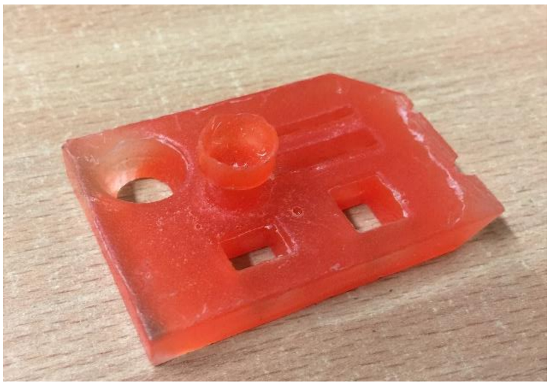


Fig 3.3.6. Second Part

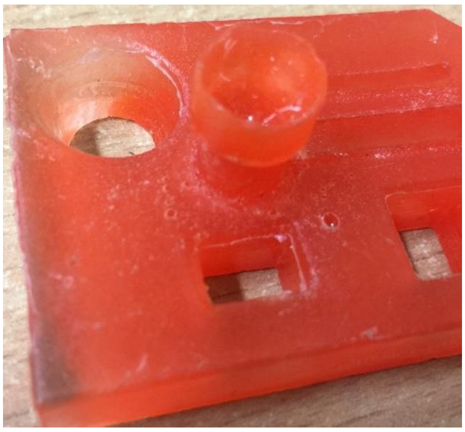


Fig 3.3.7. Upper surface

During the production of this part, we avoid the air removal process after pouring the epoxy into the silicon mould. As the result of this improvement in the process, the finishing of the surfaces in the second part is improved. And the finishing of the bottom surface is good and well finished as shown in fig 3.3.8.

Fig 3.3.8. Bottom surface

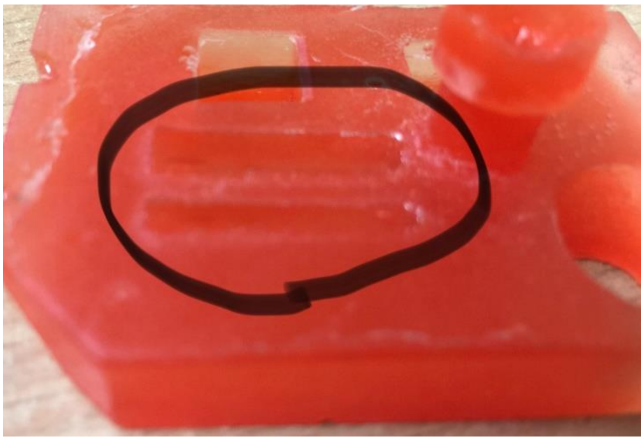


Fig 3.3.9.Incomplete Part

While pouring the epoxy in the silicon mould the air is coming from bottom side of the cavity to the upper side of the cavity in the mould, and all the air is removed but some air is stuck in the upper side cavity, because of this air the epoxy not reached to the cavity of part and part in incomplete as shown in fig. 3.3.9. There is some air bubble marks on the edges of the slide cut surface on the upper side of the part as shown in fig 3.3.10, this is because some air is remaining on the edges of the upper part.

Fig. 3.3.10 Upper Side Edges

Finishing off all side surfaces and the slide cut surfaces are better than the first part as shown in fig 3.3.11.

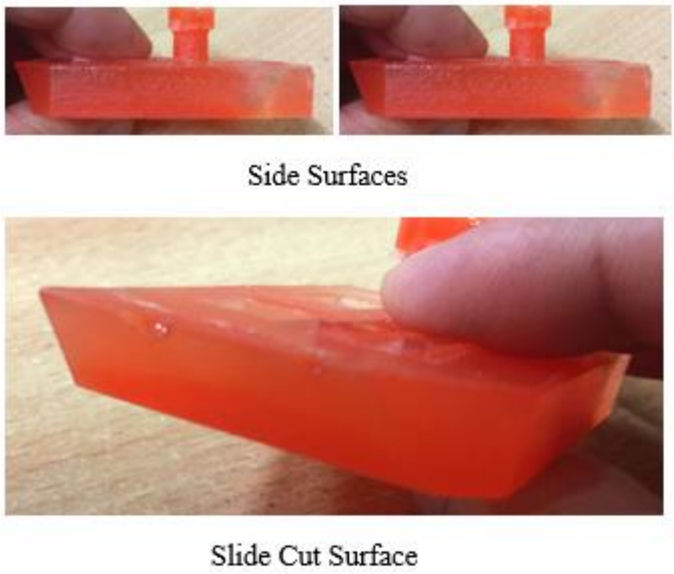


Fig 3.3.11.Side surfaces and slide cut surface

3. Third Part

For producing the third part, we made some implementation in the process of silicon moulding, for this, we create the new mould in which the masterpiece is hanging on the opposite side which is shown in fig 3.3.12. This implementation or changes in the mould are because of avoiding the incomplete part in the final product, which we are facing in first and second part.

Fig 3.3.12.Masterpiece Position

After making the mould according to the new implementation, we poured the epoxy resin into the mould,while pouring the epoxy into the mould at first the epoxy covers the all essential part cavity which missed in the first part and the second part. The finishing of the final produced part by this mould is very good or better than the previous parts.

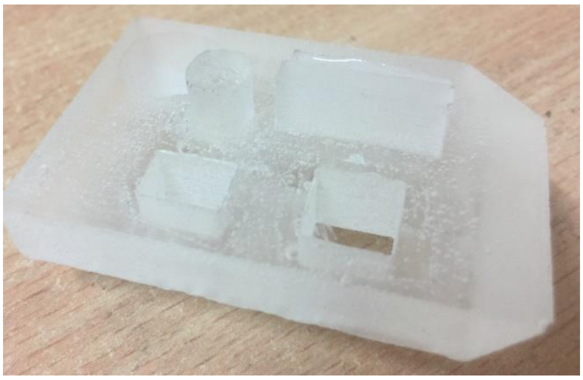


Fig.3.3.13 Third Part

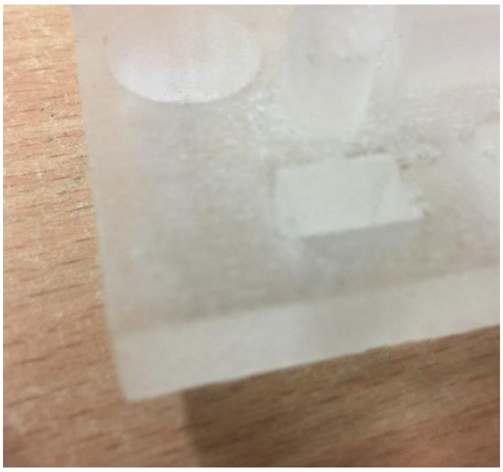


Fig.3.3.14 Upper Surface

The finishing of the upper surface of the product is very good or better than the first and the second part is as shown in fig 3.3.14, it is because of the upper surface of the part is on the bottom side of the silicone mould, and epoxy resins went to all corner of the cavity and filled it fully.The result of this process is there is no incomplete part of the final product as shown in fig 3.3.15.

Fig.3.3.15 All complete parts

Fig. 3.3.16 Bottom Surface

Fig. 3.3.16 shows that the finishing of the bottom surface of the part which is not that much good because that surface acquires some air bubble marks.Air bubbles marks came on the bottom surface because while pouring the epoxy inside the silicone mould,the epoxy cover the bottom side of the silicon mould and the air comes on the upper side of the cavity and stuck on it, after finishing the epoxy resin some air is remaining inside the mould.

In the third part, the finishing of all the inside cuts is perfect and very good which shown in fig 3.3.17. And also the finishing of all sides and the slide cut side is good.

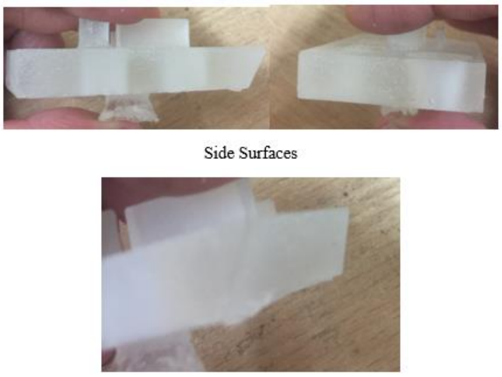


Fig. 3.3.17 inside Cut

Fig. 3.3.18 Side and Slide Surface

4. Forth Part

The fourth part is produced by the same procedure is used for producing the third part, but the result got very different than the third part. The finishing of the surface in the forth part is too much better than the third part which is shown in fig 3.3.19.

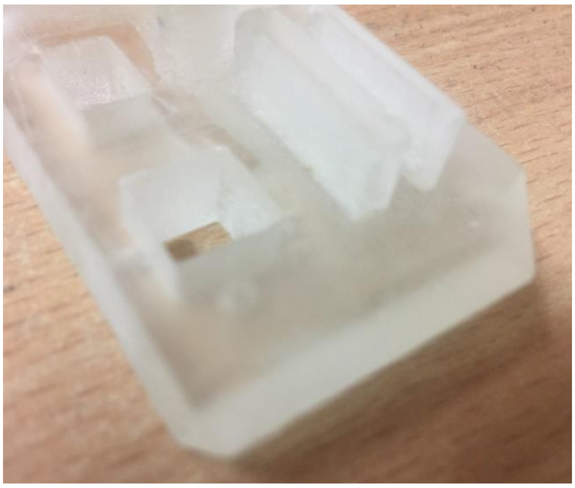


Fig. 3.3.19 Fourth Part

Fig 3.3.20 Upper Surface

The finishing of the upper surface of the forth part is better than the expectations and the third part which is shown in fig 3.3.20. It is because of while pouring process we pour the epoxy resin into the silicon mould slower than the previous parts. There is no incomplete part of the fourth product as shown in fig 3.3.21

The finishing of the bottom surface is good, but there is one unfilled material area on the bottom surface.This is because while poring the epoxy resin very slowly inside the silicone mould some area remains unfilled which is shown in fig. 3.3.22.

Fig. 3.3.21 Completed Part

Fig. 3.3.22 Bottom Surface

All circular and the square cut surface is very good and perfect in dimension as shown in fig. 3.3.23. All side surfaces and the slide cut surface are also well finished.

Fig. 3.3.23 inside Cut Surface

Fig. 3.3.24 Side and Slide Cut Surfaces

3.4 Casting of part by Polyurethane in silicone mould using vacuum casting method

In this process the part is produced by polyurethane by using the vacuum casting methode in with all the casting process done in vacuume cabinet. For producing the part in vacuum methode need to preheat all the essensial material in the heating cabine,for this it is very important to have two hesting csbinets. In one heating cabinet silicone rubber mould, and in another cabinet polyurethane resin, beakers and stirrers. Plyurethane resin and silicone mould must preheate on different tempreture, silicone ruuber mould needed higher tempreture for preheating.

After preheating all the needed material in heating cabinet, all the material are kept inside the vaccume cabinet in proper posirtions which as shown in fig. 3.4.1.further step is elimenating the all air from casting resin (polyreuthane) and start mixing the hardener in polyurethane blend it till well mixed, and again start elimating the air from blend material after that pour the material inside the silicone rubber mould as shown in fig 3.4.3.

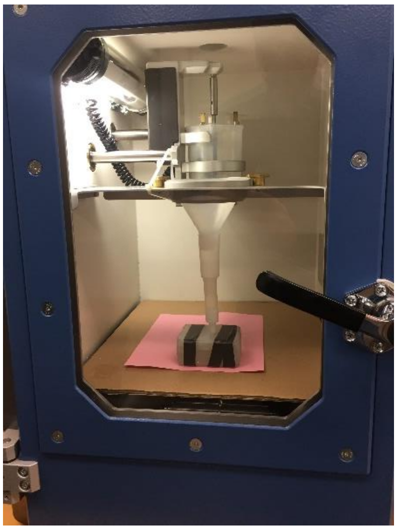


Fig. 3.4.1 Material Position

Fig. 3.4.2 Mixing of casting resin

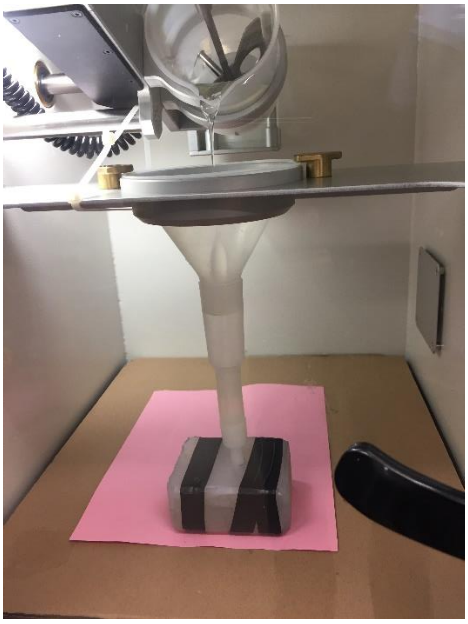


Fig 3.4.3 Material filling in mould

After filling the casting resin in to the silicone mould switch off the vacuum cabinet. And take out mould for curing the material it takes 3 to 4 hours for curing.

After 4 hour disassemble the mould and take out the casted part. The final casting part is ready as shown in fig. 3.4.4.

By using the polyurethane resing for casting the part the part is exactly same as the master piece and and the exact empresion of cavity on the surface of part.

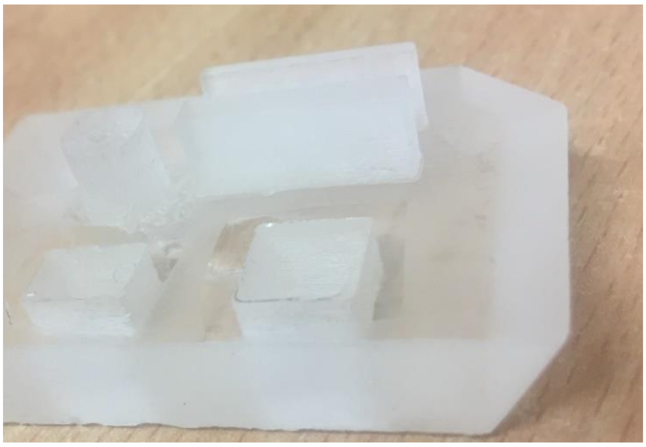
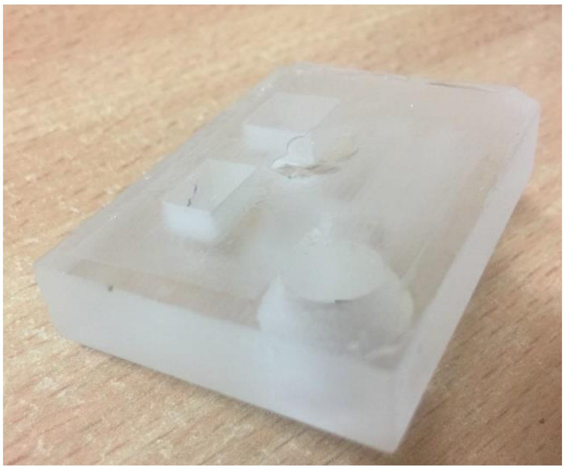


Fig 3.4.4 casted part by polyurethane

Fig. 3.4.5 Upper surface of part

The upper surface of the casted part is very finishe and perfect as compaired to the casted parts by epoxy resin as shown in fig 3.4.5. and the bottome surface finishing is also very good as shown in the fig 3.4.6.

There is no any air bubble on the surfacr of the part it is because of vacuum casting method, and all the componunts of the part is completed is as shown in fig 3.4.7. Is means that the polythurethane resing completely goes to every cornar of cavity in the mould.



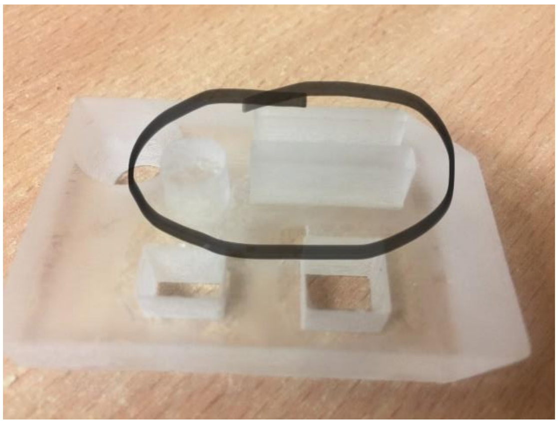


Fig 3.4.6 bottom surface of part

Fig. 3.4.6 Components of part

As according to the quality and the finishing of the surfce of casted part from plyeurethane is perfect and very good as compaired to the casted part from epoxy resin. It means that the polyeurethane resin is more sutaible for silicone moulding process than epoxy resin.

CHAPTER 4

MANUFACTURING COST CALCULATIONS

4.1 Manufacturing Cost

The manufacturing cost of the product depends on the sum of all cost of resources which is consumed or used in the manufacturing of the product and part.it is classified into two part 1) Direct Cost 2) Indirect Cost.

1.Direct Cost

Direct cost is the cost which is directly consumed or used for manufacturing of the product such as material cost, the salary of employee etc.

2.Indirect Cost

Indirect cost is the cost which is not direct consumed or use in the manufacturing of the product; the indirect cost may be variable or the constant. The example of the indirect cost is rent of place, process cost etc.

Direct and Indirect Cost of product

Table no. 4.1 Direct and Indirect Cost for silicone moulding process

Direct Cost		Indirect Cost	
Resource	Cost	Resource	Cost
1.Silicone Rubber	8 Euros	1.Processinng Cost	20 Euros
2.Base Plate	1 Euros	2.Design Cost	10 Euros
3.Wodden Frame	4 Euros	3.Devlopment Cost	10 Euros
4.Glue Stick	1 Euros		
5.Packing Tape	0.5 Euros		
6.Cutter	2 Euros		
7.Epoxy Resin	2 Euros		
8.Employee Salary	5 Euros		
Total	23.5 Euros	Total	40 Euros

4.2 Cost calculation of the product cast by epoxy resin in silicone moulding process.

The total time required for producing our product is 40 hours for one product, and the total work time for the employee is 3 hours 30 min.(17.50 euro/product).

The total time required for 10 product is up to 11 days with one mould, and total working hours of the employee is 35 hours, the cost of producing 10 product is shown in below table.

For producing the 100 product in silicone moulding process, it required the total time 12 days with 10 moulds. And the working hours of an employee for 100 products with 10 mould is 88 hours.the cost of producing the 100 product is as shown in the table. 4.2.

Table 4.2 Cost Calculation of product

Product Quantity	1/ 1 mould	10/1 mould	100/10 mould
Cost of Product	66 Euro	150 Euro	881 Euro

In the process of manufacturing part, the cost of the product is reducing when the quantity of product is increasing.

During the production of one product the cost of the product calculated is 66 euros, and in the production of 10 product it reduces around 75%, it's 15 euro/product and 150 euro for 10 product.

In the production of 100 product, the cost of the product reduces 88% as compared with the manufacturing of 1 product while producing the 100 product the manufacturing cost of one product is only 8.81 euros.

In mass production, the manufacturing cost will decrease as per increasing the quantity of the products.

4.3 Cost calculation of product cast by epoxy resin with different silicon moulds.

1.Bluesil RTV 3428 A

The cost of bluesil RTV 3428 is 30.2 per 1 kg, Specific gravity of the silicon is 1.1 g/cm^3.According to the specific gravity of silicon and volume of box the material needed to make mould with this silicon rubber is 390 g of the cost 12.8 euro.The cost calculation of the product which produced using this mould is as shown in table 4.3.

Table 4.3 Cost of product produced by Bluesil RTV 3428 silicon mould

Product Quantity	1/ 1 mould	10/ 1 mould	100/10 mould
Cost of product	70.8 euro	165 euro	958 euros

In the production of one product with this silicone, the cost of the product is 70.8 euros; this is because of a single production. Further that we produce the 10 product with 1 mould of this silicon and the production cost of the 10 product is 165 euros according to this the cast of a single product is 16.5 euros.In the manufacturing of 10 product, the price per product 78% decreased.

After the production of 10 product, we produce the 100 product with 10 different moulds of same silicone, and the cost of 100 product is 958 euros.and the price per product is 9.58 euro/ product, in this mass production of 100 product the cost of per product 88% decreased.

2.CENUSIL RTV-2 M 380

The cost of CENUSIL RTV-2 M 380 silicone rubber is 23.50 euro/kg,the specific gravity of this silicon is 1.22 g/cm^3, according to the specific gravity of silicon and the volume of mould box the material needed to make mould with this silicon is 405 grams of the cost is 9.5 euros.

The cost calculation of the product which is produced by using this silicon is shown as in table 4.5.

Table 4.4 Cost of product produces by CENUSIL RTV-2 M 380 silicon mould

Product Quantity	1/ 1mould	10/1 mould	100/ 10 mould
Cost of Product	67.8 euros	155.5 euros	920.7 euros

In the production of one product by using the CENUSIL RTV-2 M 380 silicon mould the cost of the product calculated is 67.8 euros, but while production of 10 product by using the one mould of the CENUSIL RTV-2 M 380 the cost of 10 product is 155.5 euros and cost per product is 15.5 euros per product. In the production of 10 product by using this silicon price per product is 78.4 % decreased.

After the cost calculation of 10 product, we calculate the cast of 100 product produced by 10 moulds using CENUSIL RTV-2 M 380 silicon the cost is 920.7 euros for 100 product, and the cost per product is 9.2 euros per product. In the production of 100 produced by using CENUSIL RTV-2 M 380 silicon mould the price per product is 87% reduced.

3. Silicone ADDV-10

The cost of Silicone ADDV-10 rubber is 28.50 euros/kg, and specific gravity of this silicon is 1.15 g/cm^3. According to the volume of mold box and specific gravity of the silicon the material needed to make mould is 370 grams of the price 10.54 euros.

The cost calculation of the product which is produced by ADDV-10 silicone mould is shown as in

Table 4.5 Cost of product produced by ADDV-10 silicone mould

Product Quantity	1/1 mould	10/1 mould	100/10 mould
Cost of Product	68.54 euros	158.5 euros	960 euros

The production cost of one product by using ADDV-10 silicon mould is 68.54 euros. The cost of production while producing the 10 product by using ADDV-10 silicon mould is 158.5 euros for 10 product, and the price per product calculated is 15.8 euros/product. The cost per product is decreased by 76.4 % as compared to single product production.

After calculating the cost of 10 product, we calculate the cost of 100 product which is produced by one ADDV-10 silicon mould. The estimated cost is calculated from 100 product is 158.5 euros, it means the cost of one product is 15.8 euros/product. The decreased in the cost per product as compared to single production is 98.6%.

4. Silicone Rubber KDSV THX-30

The cost of Silicone Rubber KDSV THX-30 is 27.5 euros/kg, and specific gravity of this silicon is 1.09 g/cm^3. According to the volume of mold box and specific gravity of the silicon the material needed to make mould is 380 grams of the price 10.25 euros.

The cost calculation of the product which is produced by the Silicone Rubber KDSV THX-30 is as shown in table 4.6.

Table 4.6 Cost of product produced by Silicone Rubber KDSV THX-30

Product Quantity	1/1 mould	10/1 mould	100/ 10 mould
Cost of Product	67.25 euros	151.8 euros	948.50 euro

The cost of the single product produce by Silicone Rubber KDSV THX-30 is 67.25 euros. In the manufacturing of 10 product by using the KDSV THX-30 silicon mould is 151.8 euros and the estimated cost per unit is 15.1 euros/product. Decreasing in the cost as compared to single product manufacturing cost is 76.5 %.

The batch of 100 product which is produced by 10 moulds of Silicone Rubber KDSV THX-30, the price of this product is 948.50 euro and 9.48 euros/product. The calculated price of the single product in this batch production is decreased by 87.60 % as compared with single production of the product.

4.4 Cost calculation of the product cast by polyurethane in silicone moulding process.

The total time required for the produced product by polyurethane in silicone moulding process by using the vacuum Castine is less than the by using the epoxy resin because curing time of polyurethane is 3 to 4 hours.

And the processing time for casting the product with polyurethane is 5 hours. According to this all time the processing cost of casting the product with polyurethane is less than with epoxy resin.

The cost of producing the silicone mould for casting with polyurethane is as same as for epoxy resing.

The cost of the product with polyurethane is shown in below table no. 4.6.

Table 4.7 cost of product produced by polyurethane in a silicone mould.

Products	1/1 mould	10/1 mould	100/ 10 mould
Cost of products	59.96 euro	146 euros	870.59 euros

The cost of the single product produced by using polyurethane is 59.96 euros in silicone moulding process. In the production of 10 product in 1 mould by using the same material in silicone moulding process is 146 euros and the estimated cost of the single product is 14.6 euros/ product, in the casting of 10 product by using single silicone mould the price of the single product decreases by 78%.

The of manufacturing 100 product with the polyurethane in silicone moulding process is 870 euros, and the cost per product is 8.8 euros/ product. And the price decreases per product by 88.57% as compared to produce one product in one mould.

RESULT

In the manufacturing of the mould by using silicone rubber, as according to analysis the CENUSIL RTV-2 M380 and KDSV THX-30 silicone (white in colour) is not suitable for the moulding process and casting the product as compared to the Bluesil RTV 3428 silicone and ADDV-10 silicone (transparent and semi-transparent in colour) silicone rubber. In the CENUSIL RTV-2 M380 and KDSV THX-30 silicone mould, there is a problem with visualising of the parting line and also with cutting mould. The white colour silicone is having the high viscosity because the high viscosity there is a problem with pouring the silicon rubber into the mould box. The preparation time of white silicone rubber is to low; white silicone needs the fast preparation as compared to RTV 3428 silicone and ADDV-10 silicone mould. The surface finishing in white silicone mould is not good, and some part of the cavity is not covered in this silicone. So, it is concluded that for silicone moulding process transparent silicon rubber is more suitable than white silicone rubber.

In the casting process in a silicone mould, the epoxy resin is not suitable for the product surface finishing. After analysing the all casting product which is produced by using the epoxy resin, there is a problem with the air bubble marks on every product. While pouring the epoxy resin into the silicone mould, the air remains into the mould. According to all results, it is concluded that the epoxy resin is not that much suitable for the silicone rubber moulding process as compared to the polyurethane.

In the product cost calculation, after calculating the cost of casting product, it is concluded that producing the single product by using the silicone moulding process is costly than the mass production in the silicone moulding process. And the cost os varies according to the type of silicone rubber used for the mould.

CONCLUSION

1. It is conclude that in the silicone moulding process CENUSIL RTV-2 M380 and KDSV THX-30 (white in colour) silicone rubber is not sutable for moulding process than Bluesil RTV 3428 silicone and ADDV-10 (Transperant in colour) silicone rubber because of :-

   a) Problem with pouring of silicone in mould box because of high viscosity.
   b) Problem with cutiing the mould because of invisibility of partning line because of white in coloue.
   c) Problem with surface finishing of cavity.

2. It is conclude that in casting process the epoxy resin is not suitable for silicone moulding process as compaired to polyurethane resin because of :-

   a) Problem with surface finishing of casted part by epoxy resin because of air bubble accure on surface.
   b) Problem with unfinished componunt of casted part because of air is remain in cavity of mould.

3. It is conclude that in the cost of production:-

   a) Cost of single product in epoxy casting is to much high and it is nearly 67.25 euro. And it reduced by 76.5 %. in the production of 10 product with one mould the price is 15.1 euros/product.in the production 100 product it reduces nearly 87.60 %.
   b) Cost of single product in polyurethane is 59.96 euros. And in the manufacturing of 10 product it reduced 14.56 euros / product means 78%.and in production of 100 product it reduced 88.57%.

REFRANCES

[1] Eyeka, ‘All you need to know about’, vol. 15, no. 8, pp. 1–8, 2015.

[2] S. Rahmati, J. Akbari, and E. Barati, ‘Dimensional accuracy analysis of wax patterns created by RTV silicone rubber moulding using the Taguchi approach’, *Rapid Prototype. J.*, vol. 13, no. 2, pp. 115–122, 2007.

[3] J. LeFan, ‘Liquid Silicone Rubber Injection Molding’, *Saint-Gobain Perform. Plast.*, 2011.

[4] A. J. Millán, M. I. Nieto, and R. Moreno, ‘Aqueous injection moulding of silicone nitride’, *J. Eur. Ceram. Soc.*, vol. 20, no. 14–15, pp. 2661–2666, 2000.

[5] P. Berce and A. Radu, ‘RAPID MANUFACTURING OF SILICONE RUBBER MOLDS AS’, pp. 189–193.

[6] P. He, L. Li, ‘Compression moulding of freeform glass optics using diamond machined silicone mould’, *Manuf. Lett.*, vol. 2, no. 1, pp. 17–20, 2013.

[7] Y. Jiang *et al.*, ‘Fabrication of NdFeB microstructures using a siliconeee moulding technique for NdFeB/Ta multilayered films and NdFeB magnetic powder’, *J. Magn. Magn. Mater.*, vol. 323, no. 21, pp. 2696–2700, 2011.

[8] M. Wang, J. Li, K. Ngo, and H. Xie, ‘Silicone moulding techniques for integrated power MEMS inductors’, *Sensors Actuators, A Phys.*, vol. 166, no. 1, pp. 157–163, 2011.

[9] J. Lenz, R. K. Enneti, S.-J. Park, and S. V. Atre, ‘Powder injection moulding process design for UAV engine components using nanoscale silicone nitride powders’, *Ceram. Int.*, vol. 40, no. 1, pp. 893–900, 2014.

[10] Shin-Etsu Silicones, ‘RTV Siliconeeee Rubber for Moldmaking’, 2010.

[11] S. Delagnes and A. K. A. Darley, ‘Making a Silicone Mold A Tutorial by ’:

[12] B. Sabart, ‘Silicone moulding with FDM Presenter : Brian Sabart Silicone moulding with FDM’, pp. 1–13.

[13] J. Song, ‘How to Make a Two-Part Silicone Mold’, pp. 1–5, 2014.

[14] V. Muros *et al.*, ‘objects the use of copyflex food grade silicone rubber for making impressions of archaeological objects’, 2015.

[15] H. Yang, H. Zhao, Z. Li, K. Zhang, X. Liu, and C. Tang, ‘Microstructure evolution process of porous silicone carbide ceramics prepared through coat-mix method’, *Ceram. Int.*, vol. 38,

no. 3, pp. 2213–2218, 2012.

[16] L. M. Rueschhoff, R. W. Trice, and J. P. Youngblood, ‘Near-net shaping of silicone nitride via aqueous room-temperature injection moulding and pressureless sintering’, *Ceram. Int.*, vol. 43, no. 14, pp. 10791–10798, 2017.

[17] J. F. Li, S. Tanaka, T. Umeki, S. Sugimoto, M. Esashi, and R. Watanabe, ‘Microfabrication of thermoelectric materials by silicone moulding process’, *Sensors Actuators, A Phys.*, vol. 108, no. 1–3, pp. 97–102, 2003.

[18] R. E. Chinn, K. H. Kate ‘Powder injection moulding of silicone carbide: processing issues’, *Met. Powder Rep.*, vol. 71, no. 6, pp. 460–464, 2016.

[19] O. Of and M. Design, ‘M silastic sr’, no. 1, pp. 3–6.

APPENDICES

APPENDICES 1

Drawng of 3D design master part from solidword software with all diamensions and views.

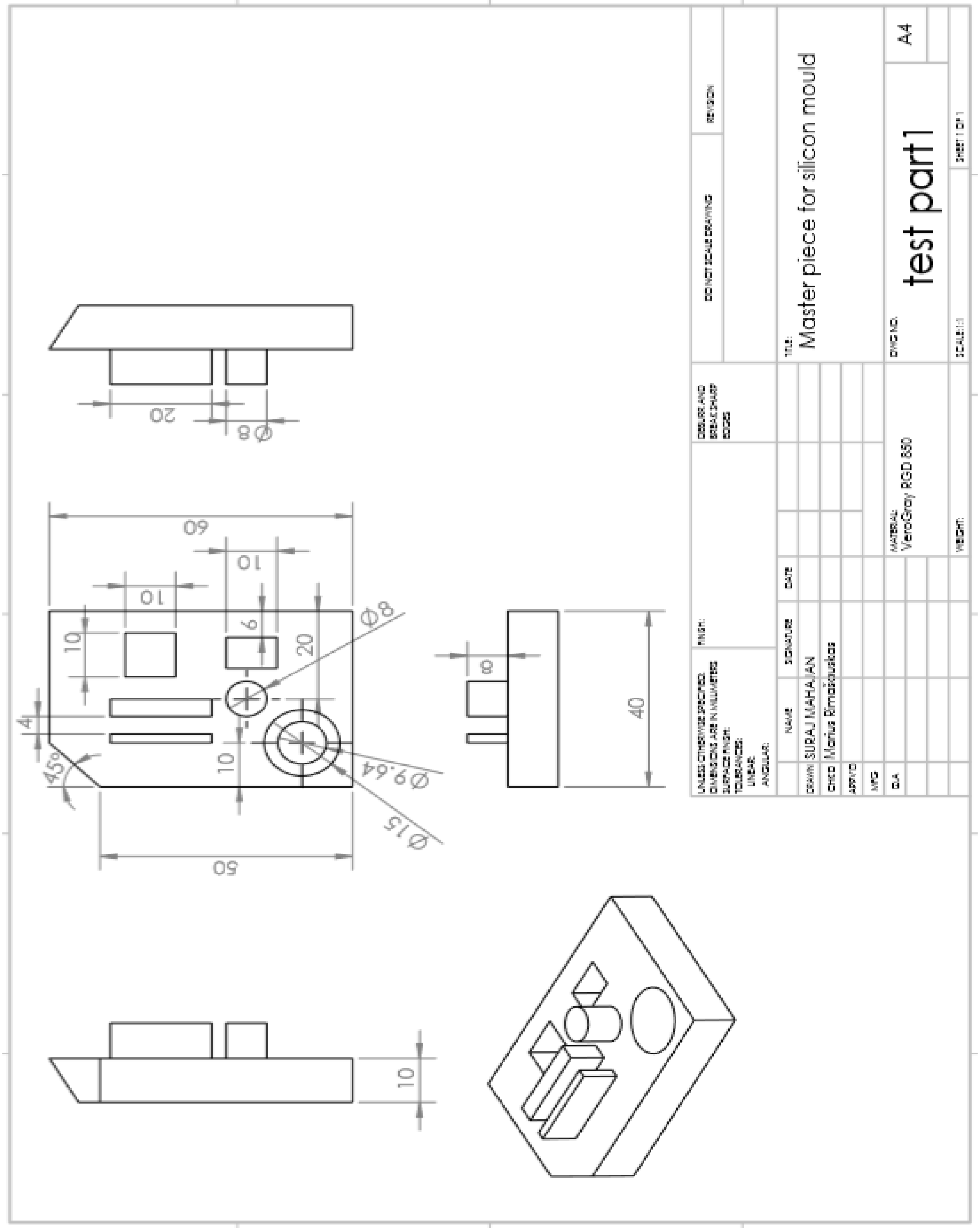


Fig. 1.1 Drawing of master piece

APPENDICES 2

Physical Properties of Silicone Rubber

1.Bluesil RTV 3428 A and B

Table 2.1.1 Characteristic of non cure material

properties	Bluesil RTV 3428 A	Bluesil RTV 3428 B
Appearance	Viscous liquid	Viscous liquid
Specific Gravity(at 23℃)	1.1 g/cm^3	1.1 g/cm^3
Viscosity (at 23℃)	25000 mpa.s	8000mpa.s

Table 2.1.2 Characteristc of cure material

Properties	Properties BLUESIL RTV 3428 A&B
Hardness	28 (shore A)
Tensile strength at break	7.5 mPa
Elongation at break	600%
Tear strength	20 KN/m
Linear shrinkage	0.1%

2. CENUSIL RTV-2 M 380

Table 2.2.1Characteristic

Properties	CENUSIL RTV-2 M 380
Density at 23 °C 1013 hPa	1.22 g/cm^3
Elongation at break	300%
Hardness shore A	15
Tensile strength	3 N/mm^2
Viscosity at 23℃	15000 mPa.s
Tear strength	10 N/mm

3. Silicone ADDV-10

Tabel 2.3.1 charateristic of Silicone ADDV-10

Properties	Silicone ADDV-10
Density at 23 °C	1.15 g/cm^3
Elongation at break	620%
Hardness shore A	10
Tensile strength	3.2 N/mm^2
Viscosity at 23℃	10000 mPa.s
Tear strength	16 N/mm

4. Silicone Rubber KDSV THX-30

Tabel 2.1.1 charateristic of Silicone Rubber KDSV THX-30

Properties	Silicone ADDV-10
Density at 23 °C	1.09 g/cm^3
Elongation at break	420%
Hardness shore A	35
Tensile strength	4.2 N/mm^2
Viscosity at 23℃	40000 mPa.s
Tear strength	25 N/mm