# KAUNAS UNIVERSITY OF TECHNOLOGY

# FACULTY OF MECHANICAL ENGINEERING AND DESIGN

**Sathish Kumar Kuppusamy**

# FEASIBILITY STUDY OF IMPELLER CASTING BY SAND CASTING TECHNIQUE

Master's Degree Final Project

**Supervisor**

Assoc. prof. dr. Antanas Čiuplys

**KAUNAS, 2017**

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Master's Degree Final Project

**MECHANICAL ENGINEERING, 621H30001**

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**KAUNAS, 2017**

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**Mechanical Engineering, 621H30001**

(Title of study program, code)


# "FEASIBILITY STUDY OF IMPELLER CASTING BY SAND CASTING TECHNIQUE"

Final project

## DECLARATION OF ACADEMIC INTEGRITY

2 JANUARY 2017

Kaunas

I confirm that the final project of mine, **Sathish Kumar Kuppusamy**, on the subject, **Feasibility study of impeller casting by sand casting technique** 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.

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**Approved:**

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| Head of study Programmers in the Field of Mechanical Engineering | _______________ (Signature, date) |
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**MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT**

Study program**:** Mechanical Engineering 621H30001

Approved by the Dean's Order No. V25-11-20 of December 8th , 2016 y

Assigned to the student Sathish Kumar Kuppusamy

_______________________________________________

*(Name, Surname)*

1. Title of the Project

Feasibility study of impeller casting by sand casting technique

2. Aim of the project

The objective of the project is to analyse the possibility to cast the impeller using sand casting technique.

3. Task of the project

1. 3D printing of the impeller (pattern).
2. Casting impeller by sand casting process.
3. Microscopic examination
4. Microhardness test

4. Specific Requirements

Conducting the final experimental project thesis according to KTU regulations and requirements.

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

6. Project submission deadline: 2017 January 2nd

Task Assignment received Sathish Kumar Kuppusamy ___________________

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

Supervisor Assoc. prof. dr. Antanas Čiuplys ______________________

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

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Study area and field: Mechanical engineering, Technological sciences.

Keywords: Sand casting, Impeller, 3D printing, Microscopic examination, Microhardness test.

Kaunas, 2017. 40 p

## SUMMARY

*In this research work, the impeller is designed in SolidWorks and developed by a 3D printer. By using the impeller as pattern cope and drag are made. Aluminium and silicon are heated at 800℃ in the furnace. Then the melted aluminium and silicon are poured in the downsprue to fill the cavity. The casted impeller is machined and tested. Nowadays there are different test are made to find the strength, hardness, castability, weldability and corrosion resistance. In this study, the impeller samples are grinded and polished.*

*For preparing the samples, the impeller is cross-sectioned and casted using synthetic resins. The samples are grinded at 300 rpm for 10 minutes using the grinding paper. After grinding it is polished using liquid diamond for 10 minutes with increasing to 300 rpm. Then the samples are examined in the optical microscope. The microscopic structure shows the image of a 10x,50x and 100x of the samples. The microhardness shows Vickers hardness values are much close enough.*

Kuppusamy Sathish Kumar. "Rotoriaus liejimo smėlio-molio formoje galimybių studija". Magistro baigiamasis projektas / vadovas doc. dr. Antanas Čiuplys; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Studijų kryptis ir sritis: Mechanikos inžinerija, Technologijos mokslai.

Reikšminiai žodžiai: liejimas smėlio-molio formoje, rotorius, 3D spausdinimas, mikrostruktūros analizė, mikrokietumo matavimai.

Kaunas, 2017. 40 p.

## SANTRAUKA

*Šio baigiamojo magistro darbo tikslas yra išanalizuoti galimybę lieti rotorių smėlio-molio formoje. Išanalizavus įvairių siurblių rotorius, buvo suprojektuotas ir SolidWork programine įranga nubraižytas rotoriaus brėžinys. Pagal brėžinį 3D spausdintuvu buvo atspausdinta detalė, kuri vėliau buvo naudojama kaip liejinio modelis. Paruošus atitinkamos sudėties smėlio-molio formavimo mišinius, buvo ruošiamos formadėžės ir liejami bandiniai. Liejiniams buvo naudojamas aliuminio ir silicio lydinys – siluminas. Išlieti bandiniai iš pradžių buvo vertinami vizualiai, vėliau, kritinėse liejinių vietose išpjaunami bandiniai, ruošiami mikrošlifai mikrostruktūrų tyrimams bei matuojamas mikrokietumas.*

*Išlietų bandinių tyrimai parodė, kad visame skerspjūvio plote formuojasi panaši mikrostruktūra. Mikrokietumo matavimai parodė, kad kietumas pagal HV/5 visame skerspjūvyje išlieka toks pat, su nedidele paklaida ± 10 vienetų. Galime daryti išvadą, kad rotorių galima lieti smėlio-molio formoje, tačiau norint pasiekti pakankamą detalės tikslumą, reikalingas mechaninis apdirbimas ir tokia gamyba tikslinga tik tokiu atveju, kai reikia tik keleto detalių.*

## ACKNOWLEDGEMENT

I would like to thank my supervisor Assoc. Prof. Dr. Antanas Čiuplys, Department of Production Engineering, Kaunas University of Technology, Lithuania, who gave wonderful guidance, patience and support right from the start of a research project I and II, and till the end of the master thesis project.

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# 1 INTRODUCTION

Expanding headway of science and innovation drove association to utilize more furthermore, more pumps with some new qualities in their industry. Surely pump is a machine which is utilized for exchanging the liquid starting with one then onto the next level of head [2]. Systems of most pumps are like each other's, they change active vitality to the dynamic vitality of the liquid and expecting to stream exchanging. Diffusive pumps are extremely regular hardware utilized as a part of habitation, horticulture and modern applications. It is basic for a pump fabricated requiring little to no effort and expending less power with high effectiveness. Radial pumps are the most well-known sort of dynamic pump, and are utilized regularly as a part of uses with direct to high stream and low head. As the workhorse of the substance-procedure enterprises (CPI), centrifugal are quite often more efficient to claim, work and keep up than different sorts of pumps [11].

Pump fabricates has been passed a noteworthy advance in the most recent decades. Because of the dire needs of industry, still there exist an enormous measure of the venture in this segment which are at last prompts to change in plan and assembling of this particular item.

## 1.1 OBJECTIVE

The main objective of this research is to design and study the properties of the impeller which is casted using sand casting process. The material composition of the impeller is aluminium alloy (aluminium and silicon). The optical microscope is used to analyses the morphological properties (i.e. Color, appearance and grain structure). Generally, morphology examinations are performed to investigate the question's structure furthermore shape, measure, position, relationship of its components either on surface or inside. VERZUS 750 series are a new generation of hardness testing instruments. VERZUS 750 Vickers Hardness Tester is used to analyzes the microhardness. The analyzers are developed around a stone strong C-outline with unparalleled unbending nature. The shut circle framework in view of a heap cell and exactness compel actuator ensures the best GR and R comes about ever observed on Rockwell hardness analyzers.

# 2 LITERATURE REVIEW

## 2.1 CLASSIFICATION OF CENTRIFUGAL PUMPS

Nowadays fluids are transferred from specific level to high level by the pumps [4]. Mostly the pump mechanisms are similar such as converting the kinetic energy of the fluid into dynamic energy. Pumps are used in many application, many different chemical industries and in the field of bio-mechanical industries. There are different kinds of pump classification. Pumps are classified based on applications, the type of fluid used in it, material properties and also the direction of formation [5]. Pumps are mainly classified into three types such as positive displacement, kinetic and direct pumps. Figure 1 represents the classification of pumps.

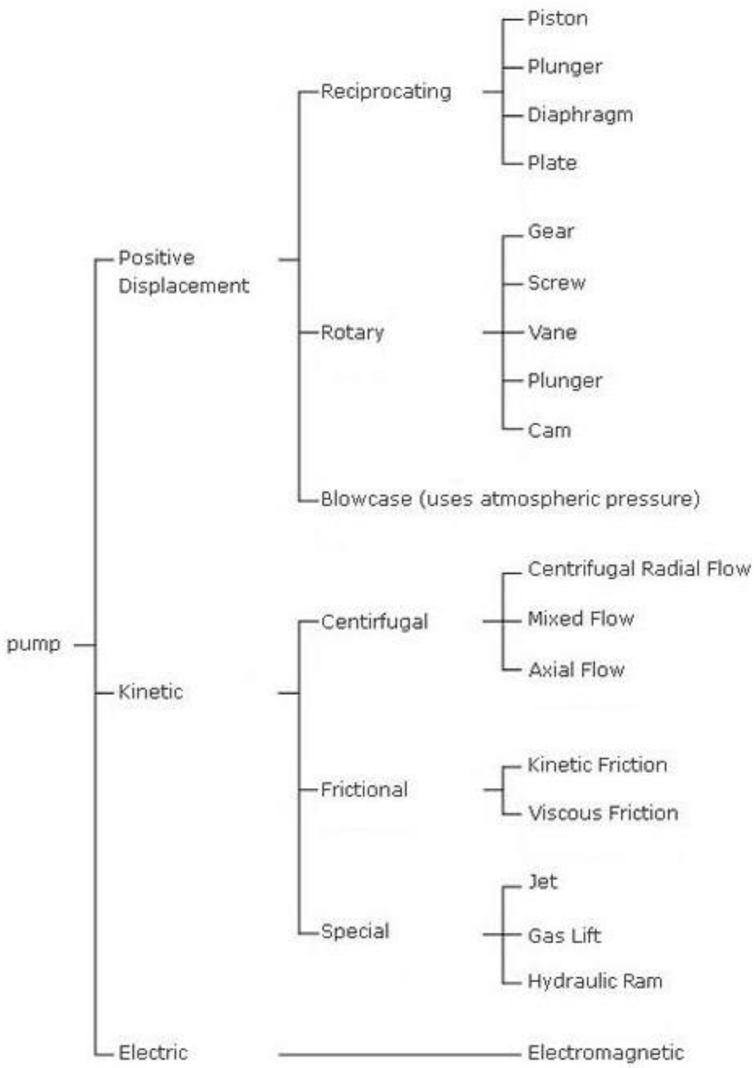



Fig. 1. Classification of pumps [5]

### 2.1.1 Centrifugal Pump

Centrifugal pumps are turbomachinery work absorbing with axis symmetric. Centrifugal pumps are used to transfer liquids or fluids by the conversion of rotational kinetic energy to dynamic energy of the fluid. Electric motor or engine produces the rotational energy. The fluid pump enters the impeller along the rotating axis and is accelerated by the impeller, flowing outwards the casing, where its comes out [2]. Figure 2 represents the centrifugal pump mechanism.

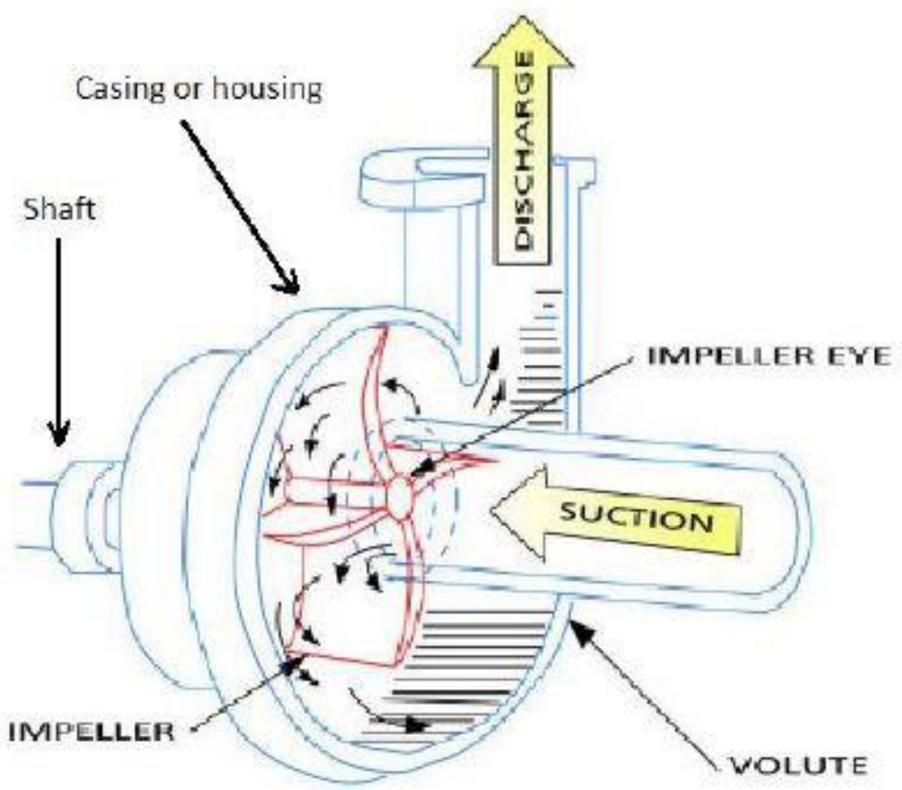



Fig. 2. The centrifugal pump mechanism [5]

Inside the housing, the impeller is located and the housing is closed and sealed. Electromotor which is coupled to the impeller gets the kinetic energy through the shaft. The kinetic energy of impeller is transmitted to the fluid via blades. Now the fluid is maintained under the pressure and the pressure is used to transfer the fluid to discharge. This is the mechanism of centrifugal pump [6]. The rotating element of the pump is called as the impeller. The impeller has blades which vary in size and number of blades. The liquid is under the pressure inside to outside has to be sealed to prevent the leakage. At the backside of housing on the shaft mechanical seals are installed. The impeller blades are enclosed with the circular disk which is known as the impeller casting [6].

### 2.1.2 Working of centrifugal pump

Mechanism of most pumps looks similar. Centrifugal pumps transform mechanical energy of motor to moving the energy of the liquid. Liquid enters in the direction of the casing is caught in the impeller blades and it is also rotated radially and tangentially outside until it leaves through all the impeller section into a section of the diffuser of the casing. Liquid increases both velocity and pressure while the liquid passes through the impeller. Deceleration of the flow is due to the doughnut-shaped diffuser section of the casing and increases the pressure further [7]. Centrifugal pumps can be further differentiated based on how the direction of flow in a centrifugal pump (Bloch & Budris, 2004). Figure 3, 4 and 5 illustrate the axial, radial and mixed flow of a centrifugal pump.

- The flow in which the pump accelerate liquid in a direction parallel to the pump shaft is called axial flow. They operate as same as a boat propeller.
- The flow in which the pump lift liquid through the center of the impeller and along the impeller blades at radially to the pump shaft is called radial flow.
- The flow in which the pump has the characteristics of both axial and radial flow pumps is called mixed flow. They push liquid out from the pump shaft at an angle greater than 90°.

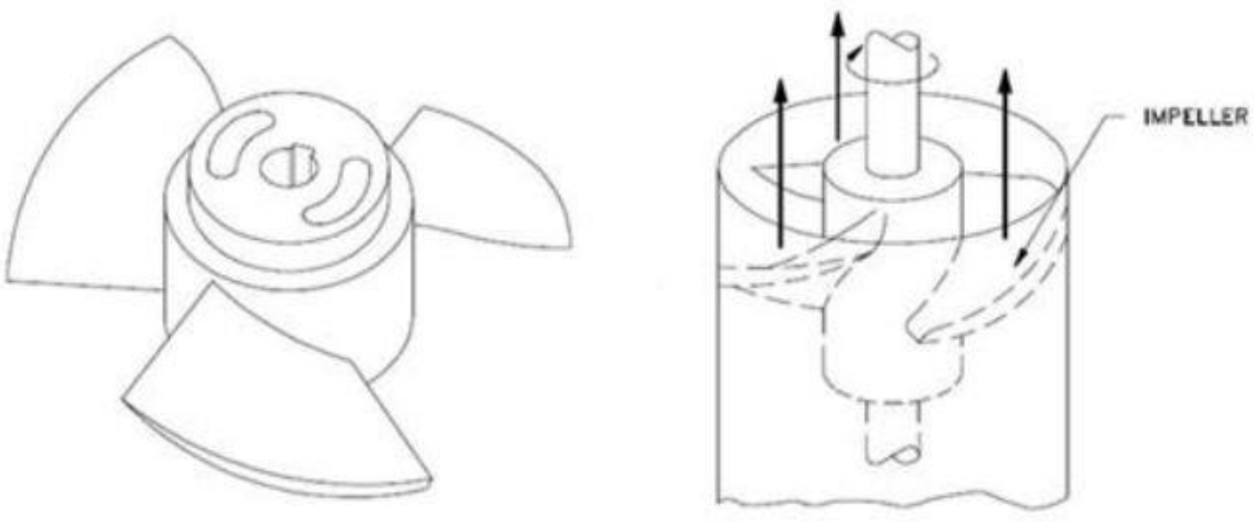



Fig.3.Axial flow centrifugal pump [5].

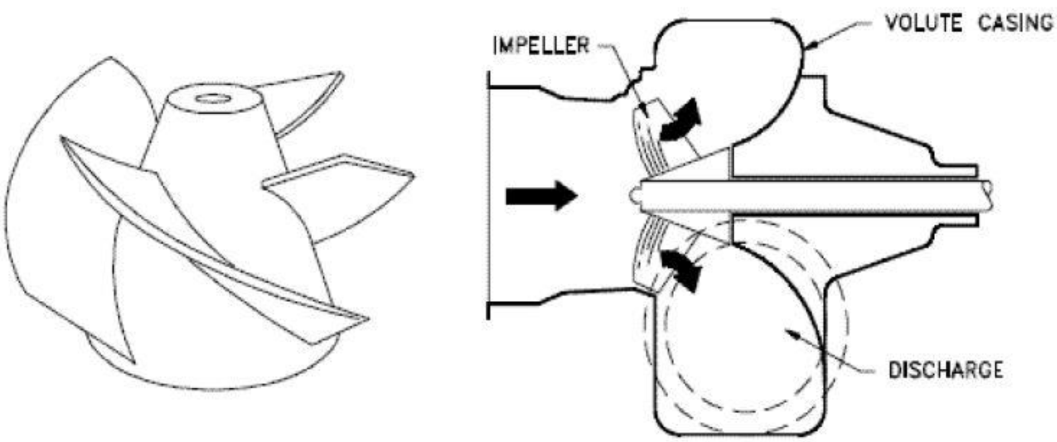



Fig.4.Mixed flow centrifugal pump [5].

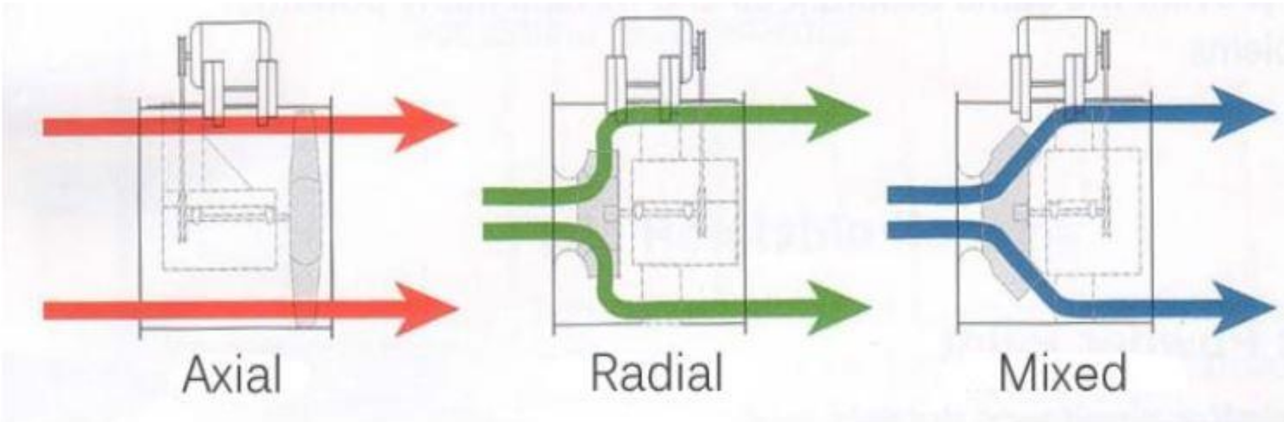



Fig.5.Comparison of axial, radial and mixed flow [5]

### 2.1.3 Impeller

The impeller is a rotating element of a centrifugal pump and it does as the heart of the centrifugal pump. Depending on the application it can be produced in different shapes and materials [8]. It is a greater challenge to the manufacturer to produce when the shape is complicated. There are many ways to produce impeller. There are traditional ways such as casting or machining and are also advanced manufacturing technology are available. The parameters such as the fluid type, the pressure, the velocities involved in the manufacturing process have to be considered by the manufacturers every time. In upcoming sections, we study the type of centrifugal impeller and how are they produced. Figure 6 shows the impeller part.

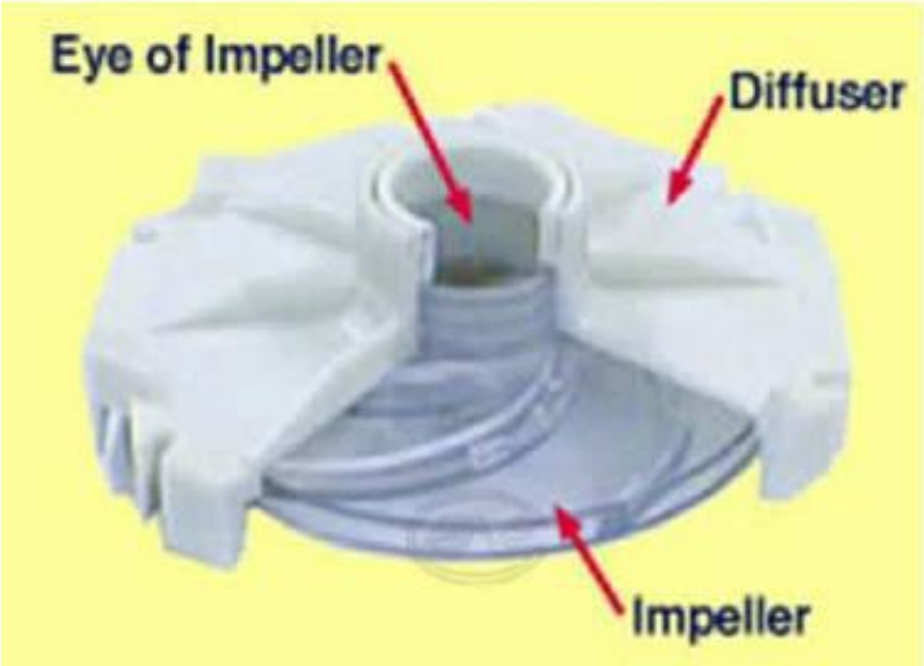



Fig.6.Impeller [2]

### 2.1.4 Classification of Impeller with Considering the Manufacturing Process

Pump impellers are based on the manufacturing process as three types such as:

- Open impeller
- Semi-open impeller
- Closed impeller

When the vanes are attached to the central hub is called open impeller. For this design is more sensitive to wear and tear of the blades. The range of the specific speed is higher. In an open impeller disassembling of the pump is not needed and it can be easily cleaned. The open impeller is less in cost.

Fig.7.open impeller [2]

When the vanes of the impeller attached to the either sides are called closed impeller. The range of the specific speed is lower. In a closed impeller, the pump must be disassembled when there is a wear in the rings. The cost of the impeller is more complicated and costlier than the open impeller.

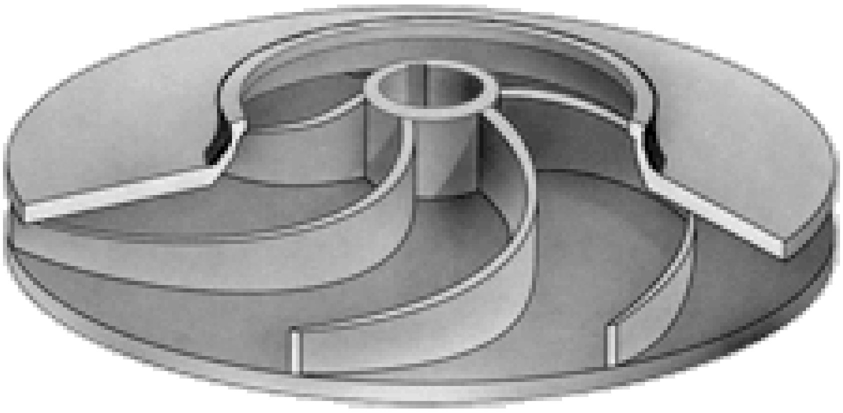


Fig.8.Closed impeller [5]

### 2.1.4 Disadvantage and Advantages of Centrifugal pump

Construction is simple and cheap. Large amounts of solids in the liquid can be handled by a centrifugal pump. Lower maintenance cost. The pump cannot handle highly viscous fluids. They cannot be operated when the heads are higher.

## 2.2 PROCESS AND METHODS FOR IMPELLER PRODUCTION

It is better to consider the shape and types for the impeller production. The commonly used impeller manufacturing processes are as follows.

- Sand casting method
- Welding
- Machining
- Rapid prototyping

For the impeller production sand casting process is the most popular and applicable methods. Compare to other methods sand casting process is low cost and convenient. In addition, it has some limitation in manufacturing to select other methods for manufacturing.

### 2.2.1 Sand Casting Process

A process in which the molten metal is poured into a cavity or a mold to form solid metal shapes. The sand casting process is used to make large parts (typically iron and steel but also bronze, brass, aluminum). The process of sand casting is discussed in the section include patterns, sprues, runners, design and casting. Figure 9 shows the sand casting process [9].

Sand casting is one of the old techniques. Approximately 75% of castings products are made in sand molding which they do not completely satisfy the required accuracy and surface finish. Because of this reason most improved methods such as investment casting, shell casting, die casting [9].

Operation sequences are consisting of

- Mold & core making
- Pattern making
- Melting & pouring
- Trimming
- Inspection

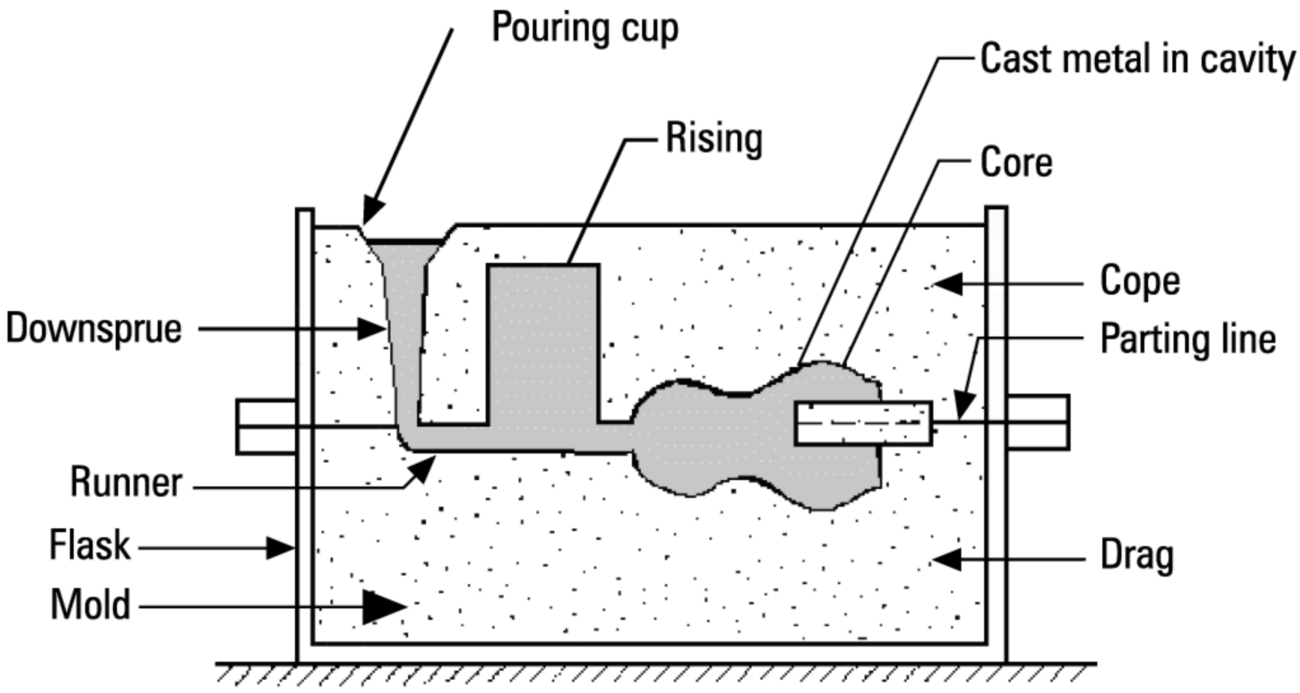



Fig.9.Sand casting process [9]

Table 1 Comparison of sand casting with other casting methods

| PROCESS | ADVANTAGES | LIMITATIONS |
|---|---|---|
| Sand Casting | • No limit to size and shape.<br>• Any metal can be casted.<br>• Low tooling cost. | • Machining is required.<br>• Poor surface finish. |
| Ceramic Moulding | • Intricate shapes can be produced.<br>• Surface finish is good.<br>• Close dimensional tolerance. | • The size of casting is limited. |
| Shell Moulding | • Good dimensional accuracy.<br>• Production rate is higher. | • Part size is limited.<br>• Patterns and equipment required is expensive |
| Die Casting | • Good surface finishes and dimensional accuracy.<br>• Low porosity.<br>• Production rate is higher. | • The cost of moulding is higher.<br>• Not suitable for intricate casting. |

| | | |
|---|---|---|
| | | • Not suitable for high melting point metals. |
| Centrifugal Casting | • Large cylindrical parts<br>• Production rate is higher | • Equipment required is costly.<br>• Part size and shapes are limited. |

Table 1 shows the comparison of sand casting with another casting process. In impeller manufacturing nowadays sand casting is also the most common method because of inherent features which make it possible to mould into complicated shapes, with low cost and no need of professional labor. These are the advantages of sand casting. But there is also disadvantages in the sand casting of impeller such as the dimension may not be the same and also poor surface finish. Figure 10 shows the sand casting procedure.

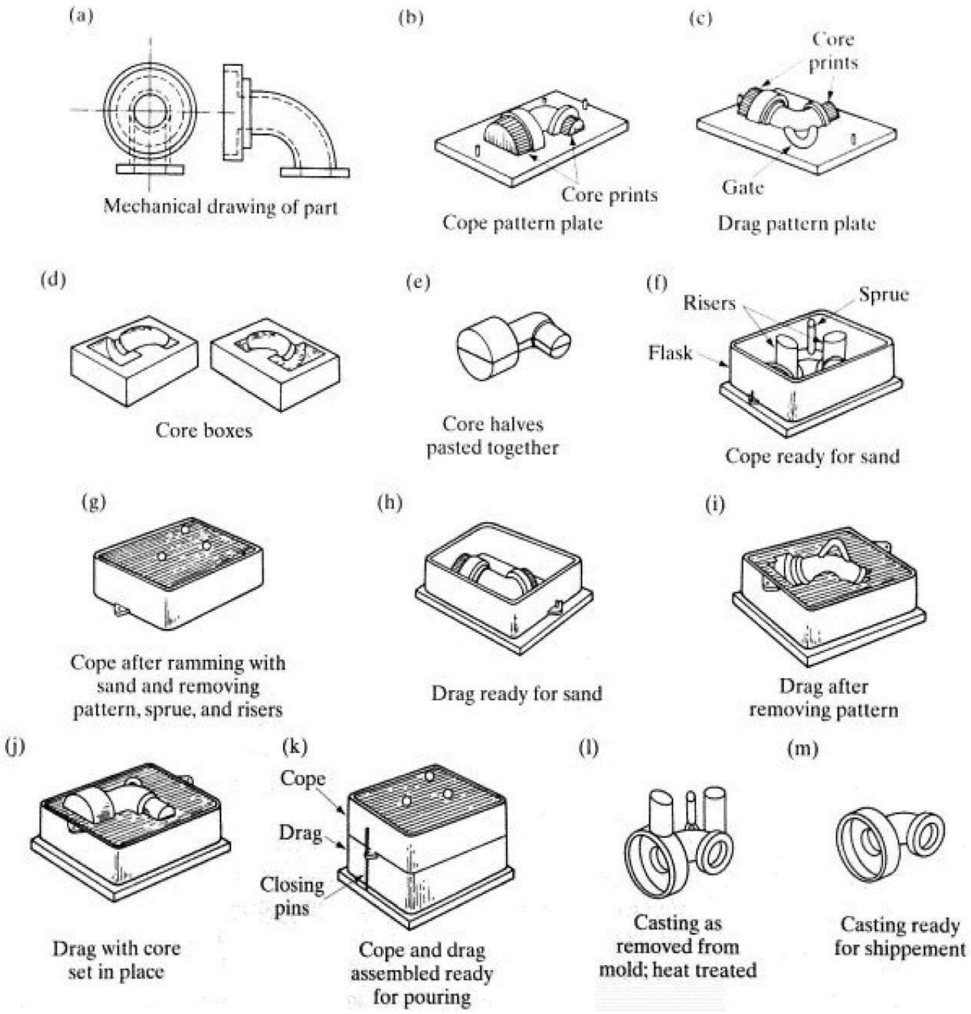



Fig.10.Sand casting procedure [10]

Steps involved in sand casting

1. The pattern is made first which is used to make the mould using sand.
2. The pattern is kept in the drag box and sand is filled and rammed to make pattern moulding.
3. The pattern is removed from the moulding and drag and cope is fixed and ready for pouring.
4. Raw materials are melted in a furnace at melting temperature.
5. Melted materials are poured into the mould at the gating system.
6. And then the mould is allowed for solidification and then cooled.
7. Sand mould is removed and then the product is cleaned and inspected.

## 2.3 MATERIAL PROPERTIES

An unexpected increment in the wear rates happened in the unreinforced aluminum-silicon composite at 95 N. SiC fortification was turned out to be successful in stifling the move to serious wear rate administration. Over a basic load dictated by the size and volume portion of SiC particles, carbide particles at the contact surfaces were cracked. A subsurface delamination handle by the decohesion of SiC-grid interfaces tended to control the wear, bringing about wear rates like those in the unreinforced network composite. At low loads, comparing to stresses lower than the molecule break quality, SiC particles went about as load-bearing components and their grating activity on the steel counterface created exchange of iron-rich layers onto the contact surfaces. In this administration, SiC strengthened composites showed wear rates around a request of greatness lower than those of the unreinforced compounds in which wear happened by subsurface break nucleation, around the silicon particles, and development.

# 3 METHODOLOGY

Nowadays there are more software's available for the mechanical design and analysis. The software in which the design is made using Solidworks, AutoCAD, Autodesk. Solidworks is used to produce simple and complex parts. In this project, SolidWorks is used for the design process. Solidworks is most popular software used by the company and the professionals due to its features. Solidworks is easy to understand and is used to make the complex parts. In this research work the impeller of a centrifugal pump is designed using the Solidworks.

## 3.1 IMPELLER SPECIFICATION

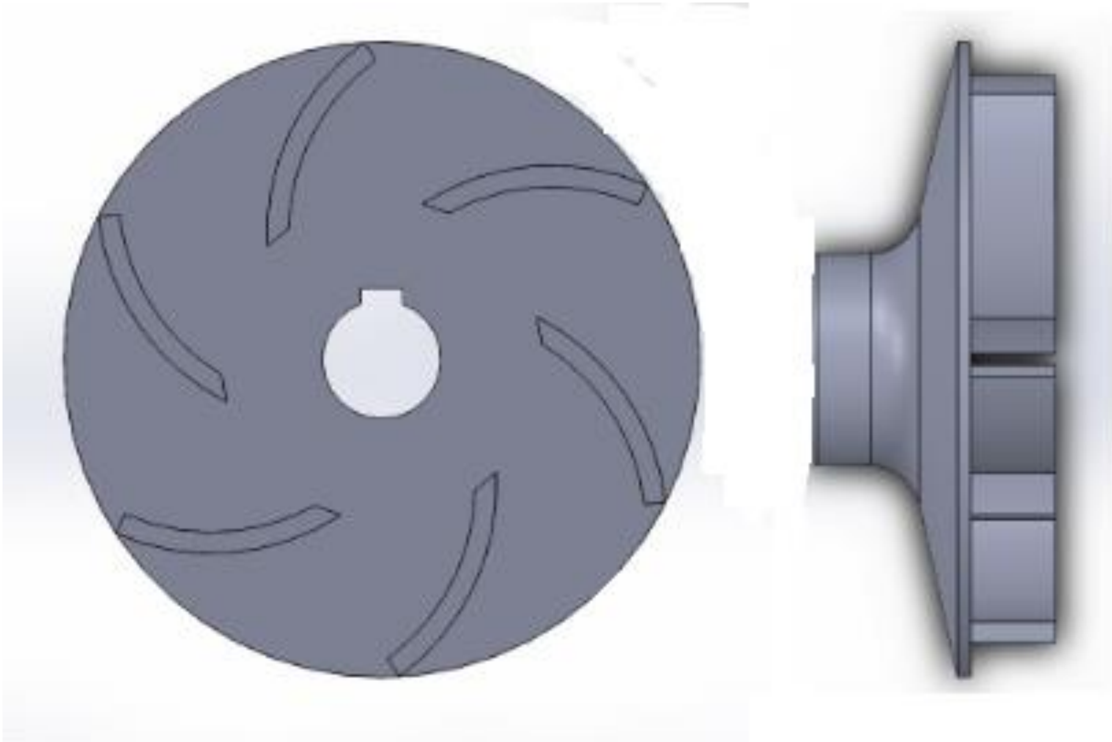


Fig.11.Solidworks model of impeller

## 3.2 3D PRINTING OF IMPELLER

Nowadays 3D printing plays an important role in the modern technology due to its fast making parts with absolute measurements. A strategy for assembling known as 'Added substance fabricating', because of the way that rather than expelling material to make a section, the procedure adds material in progressive examples to make the wanted shape [2]. 3D printing utilizes programming that cuts the 3D display into layers (0.01mm thick or less in most cases). Every layer is then followed onto the assembly plate by the printer, once the example is finished, the manufacturing plate is brought down and the following layer is included top of the past one.

Regular assembling strategies are known as ‘Subtractive Assembling’ in light of the fact that the procedure is one of expelling material from a preformed square. For example, processing and cutting are subtractive assembly systems. This kind of process makes a ton of waste since; the material that is cut off by and large can’t be utilized for whatever else and is basically conveyed as scrap [2]. To make a pattern for the sand casting process the impeller designed by the solidworks is obtained in 3D format using a 3D printer.

### 3.2.1 Types of 3D Printing

1. Fused Deposition Modeling.
2. Stereolithography
3. Selective Laser Sintering

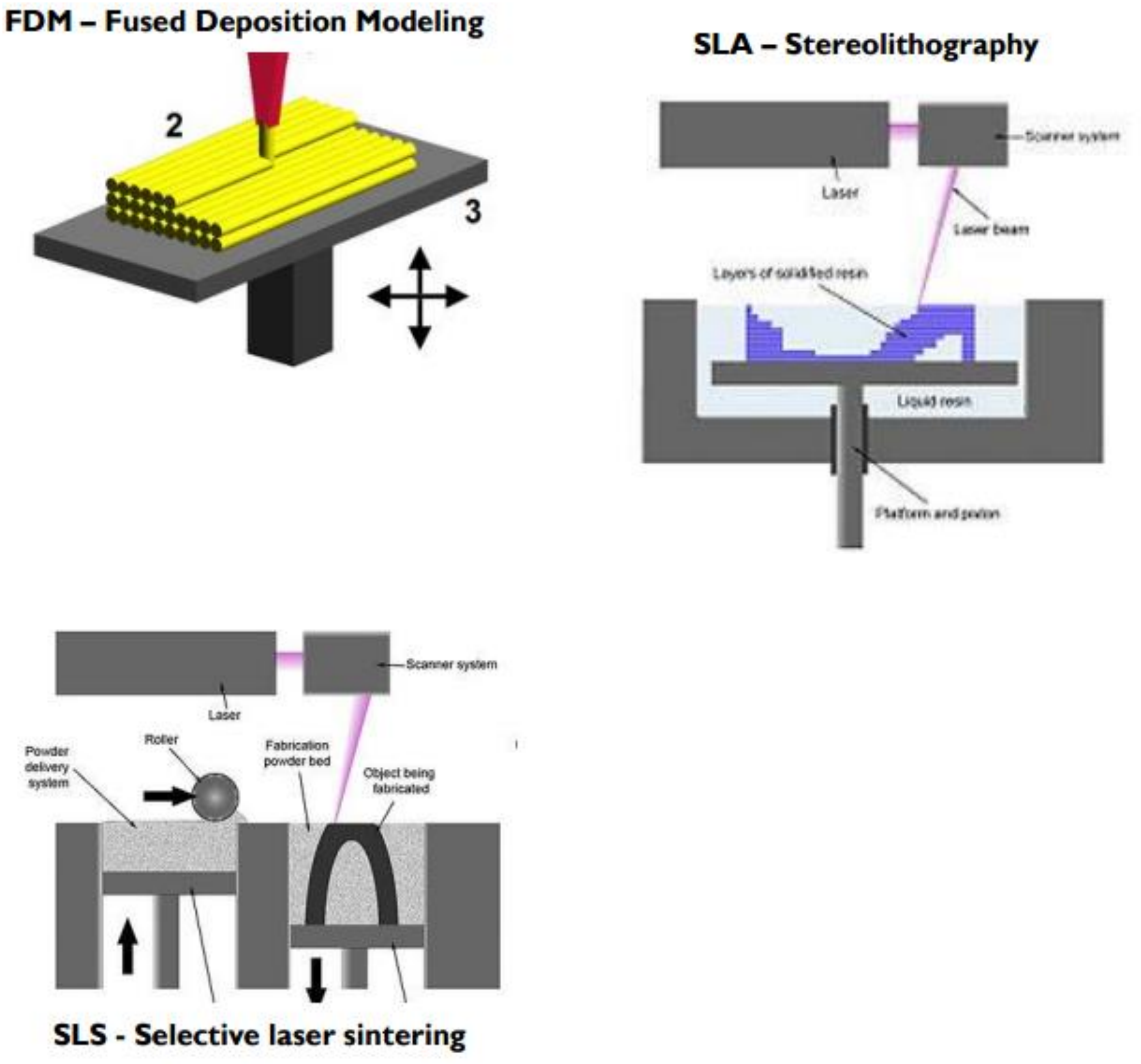



Fig.12.Types of 3D printing [2]

Table.2.Types of 3D printing [2]

| TYPE | TECHNOLOGIES | MATERIALS |
|---|---|---|
| Extrusion | Fused deposition modeling (FDM) | Thermoplastics (e.g. PLA, ABS), eutectic metals, edible materials |
| Granular | Direct metal laser sintering (DMLS) | Almost any metal alloy |
| | Electron beam melting (EBM) | Titanium alloys |
| | Selective heat sintering (SHS) | Thermoplastic powder |
| | Selective laser sintering (SLS) | Thermoplastics, metal powders, ceramic powders |
| | Powder bed and inkjet head 3d printing, Plaster-based 3D printing (PP) | Plaster |
| Laminated | Laminated object manufacturing (LOM) | Paper, metal foil, plastic film |
| Light polymerized | Stereolithography (SLA) | photopolymer |
| | Digital Light Processing (DLP) | liquid resin |

### 3.2.2 Advantages

Layer by layer generation considers much more prominent adaptability and imagination in the plan prepare. No longer do architects need to plan for produce, yet rather they can make a part that is lighter and more grounded by a method for a better plan. Parts can be totally re-planned with the goal that they are more grounded in the regions that they should be and lighter generally speaking [2].

3D Printing altogether accelerates the outline and prototyping process. There is no issue with making one section at once, and changing the plan every time it is delivered. Parts can be made inside hours. Conveying the planning cycle down to a matter of days or weeks looked at two months. Additionally, since the cost of 3D printers has diminished throughout the years, around 3D printers are currently inside money related reach of the customary customer or little organization [2].

### 3.2.3 Disadvantages

The confinements of 3D imprinting all in all incorporate costly equipment and costly materials. This prompts to costly parts, therefore making it hard if you somehow happened to contend with mass creation. It additionally requires a CAD-creator to make what the client has at the top of the priority list and can be costly if the part is extremely multifaceted [2].

### 3.2.4 3D Printing process

Every one of the parts made utilizing a 3D printer should be composed utilizing some sort of CAD programming. This sort of creation depends on the most part on the nature of the CAD plan furthermore the accuracy of the printer. There are many sorts of CAD programming accessible, some are free others oblige you to purchase the product or have a membership. Choosing what kind of CAD programming is beneficial for you will rely on upon the prerequisites of what you are outlining.

At the point when outlining a section to be 3D printed the accompanying focuses should be remembered:

- The part should be strong, that is, not only a surface; it needs a genuine volume.
- Making little, or fragile elements may not be printed legitimately, this depends enormously on the kind of 3D printer that will be utilized.
- Parts with overhanging components will require backings to be printed legitimately. This ought to be considered since after the model should be cleaned by expelling the backings.
- This may not be an issue unless the part is exceptionally sensitive, since it may break.
- Make certain to align the 3D printer before utilizing it, it is fundamental to guarantee that the part adheres legitimately to the assembly plate. In the event that it doesn't, sooner or later the part may come free and destroy the whole print work.
- Some idea ought to be given to the introduction of the part, since a few printers are more exact on the X, Y and Z axis.

Fig.13.3D printed impeller for sand casting process

### 3.3 SAMPLE PREPARATION

To prepare the sample the impeller must be cross-sectioned and synthetic resins are used to make the samples for microscopic testing. The samples must be grinded and polished. Polishing is a key component in the creation of a metallographic sample, thus picking the correct answer for your necessities in the polishing machine is basic. Client comfort, hush, dependability and simplicity of support are among the numerous criteria that have guided the improvement of LAM PLAN range. All practical and upkeep operations are streamlined to help you accomplish your objectives in an enhanced way. Whether you work in metallography research or creation control, we have a polisher which lives up to your desires. Every model meets particular reacts to corresponding needs, every development is an impression of our field involvement.

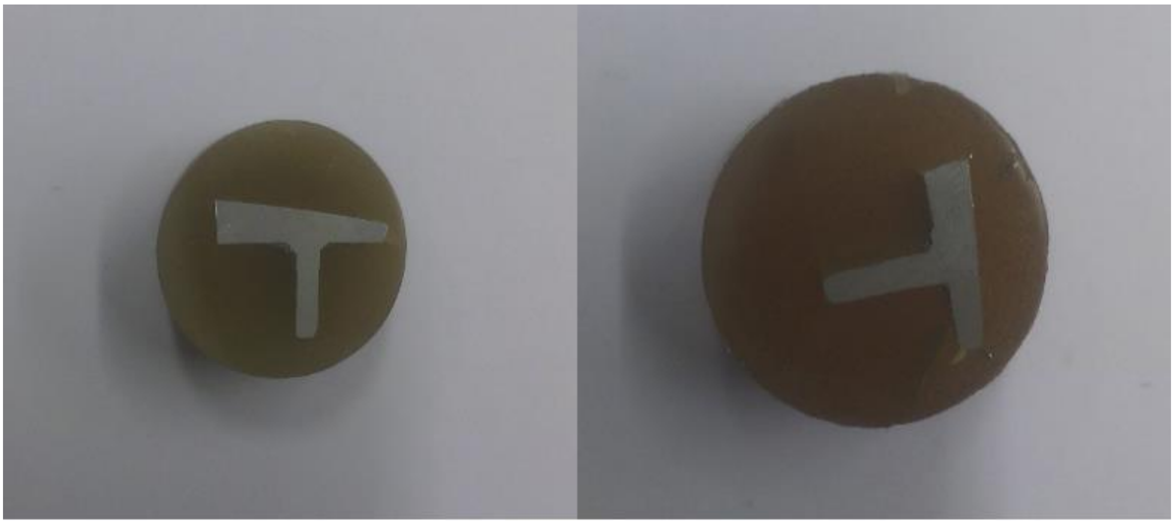


Fig.14.Sample for testing

## 3.4 POLISHING MACHINE SMARTLAM


Fig.15.Polishing machine SMARTLAM

The SMARTLAM®2.0 is a compact, single-plate polishing machine that gives you a wide range of possibilities both in manual and semi-automatic polishing. Ergonomic and easy-to-use, the SMARTLAM®2.0 is entirely controlled by a colour touch screen equipped with an intuitive interface. The internal memory can store 9 programs that can be exported via the USB port. The power of the bidirectional rotation, variable-speed, constant-torque motor and the possibility to use plates with a diameter from 200 to 300 mm are exclusive assets that will allow you to face up to all situations encountered in metallographic research polishing.


Fig.16.Display of smartlam

### 3.4.1 Grinding and pre-polishing

The LAM PLAN rough papers react to exceptionally strict quality measures. The alignment of the silicon carbide grains is ensured for the European benchmarks FEPA paying little heed to their sizes (P80 to P4000). The resistance of the pitches used to keep up the rough grains provides for the LAM PLAN grinding papers a high imperviousness to warmth and dampness. The introduction of the grains is acquired by an electrostatic procedure. The decision of the bolster paper (thickness and premise weight) is adjusted to the grain's thickness used to decrease the wear of the rough papers. The paper is made impermeable in its mass and at first glance.

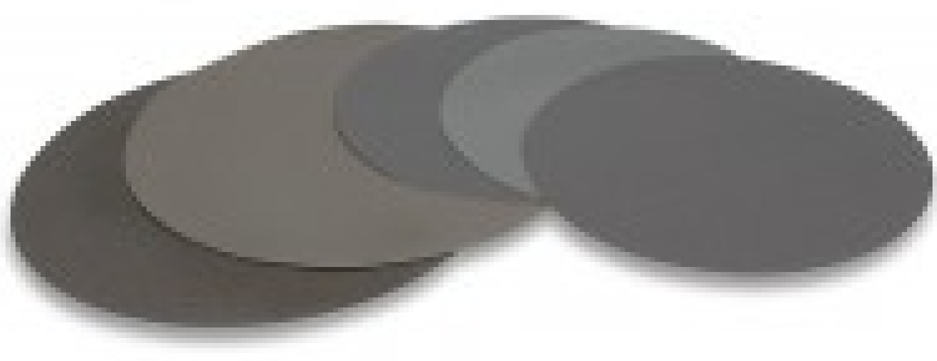


Fig.17. Grinding paper

### 3.5 MICROSCOPIC TESTING

Microscopy is a specialized field of utilizing magnifying lens for examination of items (or their components) too little to be seen with the exposed eye. Generally, morphology examinations are performed to investigate the question's structure furthermore shape, measure, position, relationship of its components either on the surface or inside.

There is an assortment of minuscule methods. Be that as it may, the fundamental standards of a wide range of microscopy are about the same and can be obviously clarified by the case of optical microscopy, which includes noticeable light transmitted through or reflected from the specimen. Most extreme amplification gave by the optical magnifying instrument is 1500x. Hypothetically, it is conceivable to make a framework with higher magnification. In any case, the primary thought of microscopy is not to get as high amplification as would be prudent, but rather to characterize the littlest components of the structure, i.e. to utilize the most astounding determination. The latter is restricted because of the wave properties of light (diffraction) and for the optical magnifying lens is roughly 0.2 μm.

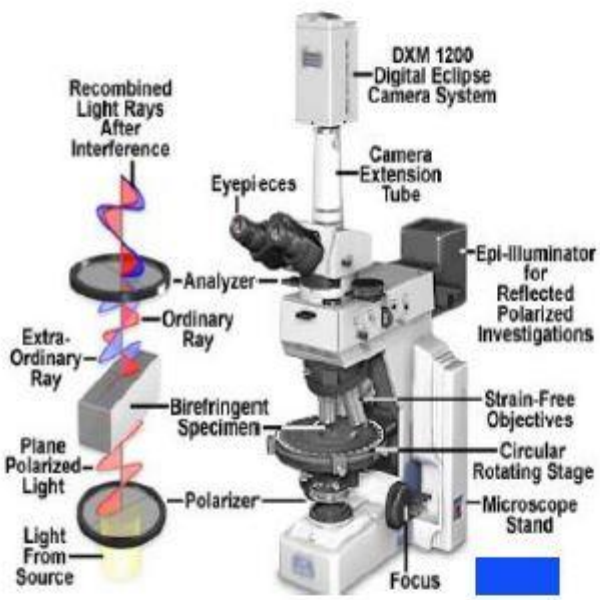



Figure 18 3D view of optical microscope [3].

The protest structure can be explored just if its components reflector assimilates the light in various ways or vary from each other by refractive file [3]. Properties cause the distinction in stage and abundance of the light waves which experienced diverse parts of the question thus have an impact on the picture differentiate. That is the reason the utilized differentiation strategy ought to be picked by properties of the protest.

Polymers are inspected by both transmitted and reflected-light microscopy. It is worth to note that immaculate polymers barely retain any light, thusly splendid field transmitted light difference strategy is not exceptionally valuable for them. Then again, polymers grow mostly crystalline or shapeless structures, which are considered optically anisotropic thus can be uncovered by spellbound transmitted light. Thus polarization is the most widely recognized differentiation technique for the examination of polymers.

### 3.6 MICROHARDNESS TESTING

General hardness analyzers are in actuality crossover instruments permitting the client to make Rockwell, Vickers and Brinell hardness tests as per the relevant ISO, ASTM and JIS models, with one single machine. Widespread hardness analyzers don't change over hardness values yet apply tests as per standard methodology. While most hardness analyzers specifically measure just a single sort of scale either Rockwell or Vickers or Brinell, the Universal analyzers cover an extensive variety of test burdens and estimation techniques.

Fig.19. VERZUS 750 series

The VERZUS 750 arrangement are another era of hardness testing instruments. The analyzers are developed around a stone strong C-outline with unparalleled unbending nature. The shut circle framework in view of a heap cell and accuracy 9constrain actuator ensures the best GR and R comes about ever observed on Rockwell hardness analyzers. The analyzer meets or surpasses the ISO, ASTM and JIS measures and adjusts to Nadcap evaluating. Test strengths go from 1kgf/9.8N to 250kgf/2.45kN, Advanced calculations, computerized channel innovation and cutting edge gadgets give unmatched constrain control. The test cycle can be as meager as 13 seconds (at an abide time of 10 seconds). Profundity estimation by means of an optical framework with an immediate perusing of 0.1 microns. VERZUS remains for flexible. The 750CCD is furnished with Rockwell, Superficial Rockwell, Vickers, Brinell, HVT, HBT and Depth ball estimation. All models likewise incorporate Plastic testing scales as per ISO 2039/1 [22].


Fig.20.Suitable and Unsuitable Adjustment

### 3.6.1 Suitable and Unsuitable Adjustment

If the difference between the length of the horizontal and vertical diagonal varies with 5% or more measurement out of ISO/ASTM applications. Therefore, the hardness value will be showed in a background. Figure 16 Suitable and Unsuitable Adjustment.

# 4 EXPERIMENTAL WORK AND RESULT

## 4.1 CASTING PROCESS

In the casting process, the pattern is prepared by 3D printer which is used to create the mould for the casting. Green sand is a total of sand, bentonite earth, pummeled coal and water. Its key utilize is in making molds for metal throwing. The biggest segment of the total is dependably sand, which can be either silica or olivine. There are numerous formulas for the extent of dirt, yet they all strike distinctive adjusts between malleable, surface complete, and capacity of the hot liquid metal to degas. The coal, regularly alluded to in foundries as ocean coal, which is available at a proportion of under 5%, incompletely combusts in the surface of the liquid metal prompting to off-gassing of natural vapors [12]. The casting process involves the amount of material which is casted in the sand casting. The materials that are used is aluminum and silicon which are melted at 800°C. Casting is a procedure which conveys the danger of disappointment event amid all the procedure of achievement of the completed item [15].

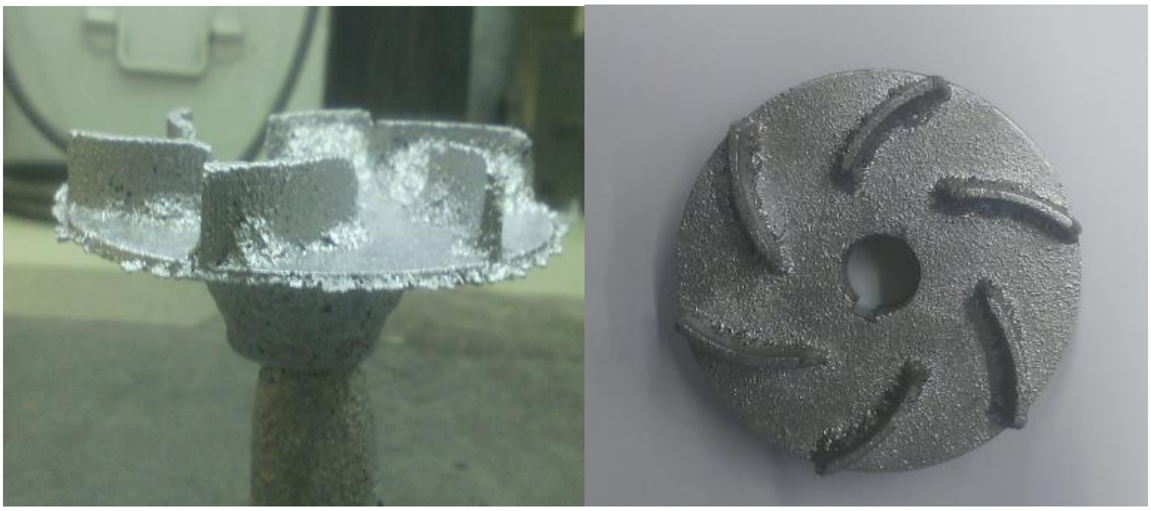


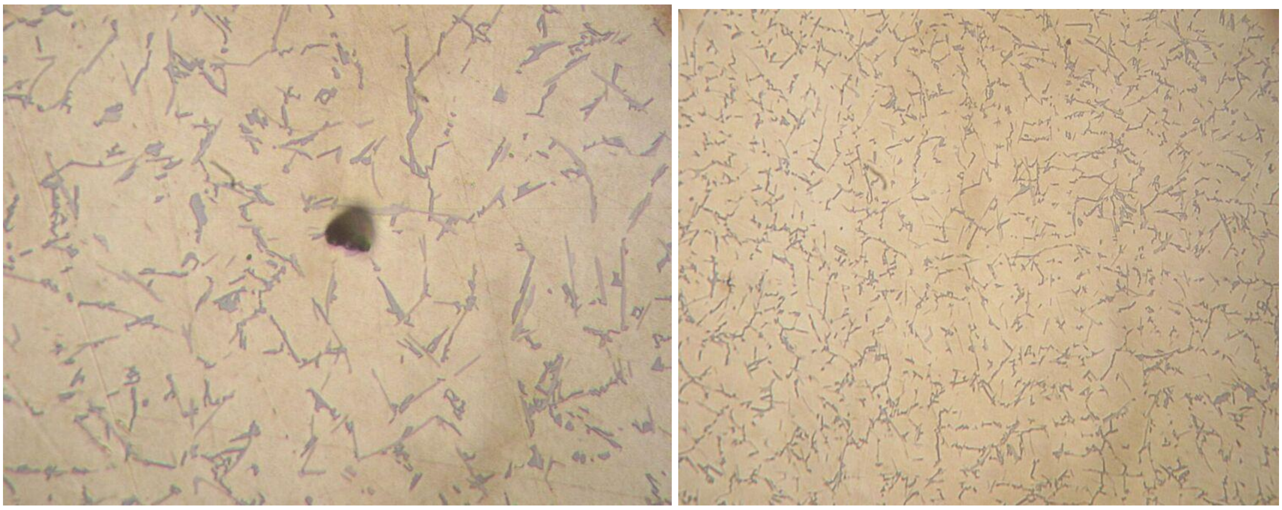
Fig.21.Casted Impeller

### 4.1.1 Defective Surface

Stream marks. On the surfaces of generally solid castings, the deformity shows up as lines which follow the stream of the floods of fluid metal. Oxide films which lodge at the surface, partially marking the paths of metal flow through the mold. Increase mold temperature. Lower the pouring temperature. Modify gate size and location. Tilt the mold during pouring.

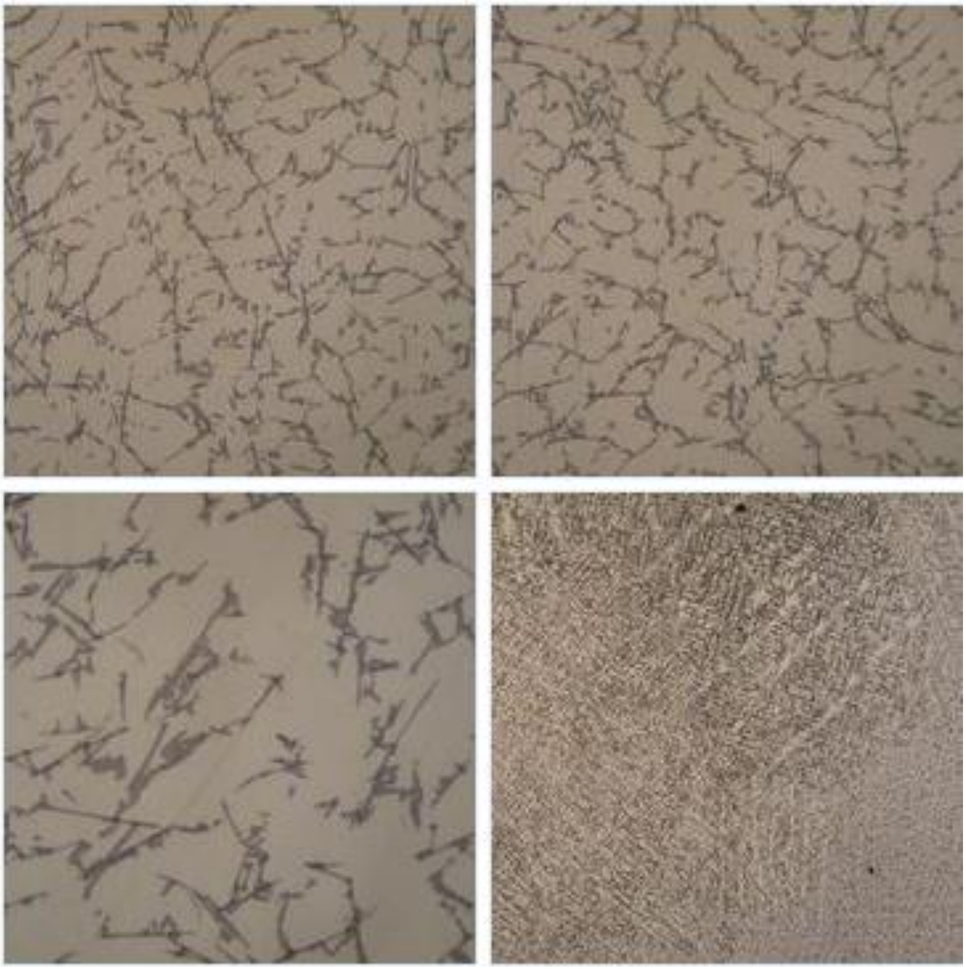
## 4.2 MICROSCOPIC TESTING

There are the samples which the microscopic testing. Sand inclusion and slag inclusion are likewise called as scab or blacking scab. They are incorporation abandons. It would appear that there is a slag within metal castings. Sporadically shaped sand incorporations, near the throwing surface, consolidated with metallic projections at different focuses. Sand consideration is a standout amongst the most successive reasons for throwing dismissal. It is regularly hard to analyze, as these deformities for the most part happen at broadly differing positions and are in this manner exceptionally hard to describe neighborhood cause. Regions of sand are frequently torn away by the metal stream and afterward buoy to the surface of the throwing on the grounds that they can't be wetted by the liquid metal. Sand incorporations much of the time show up in a relationship with CO blowholes and slag particles. Sand considerations can likewise be caught under the throwing surface in the mix with metal oxides and slag's [15].



a b

Fig.22.Sample 1 before etching: a – magnification100x, b – magnification 50x

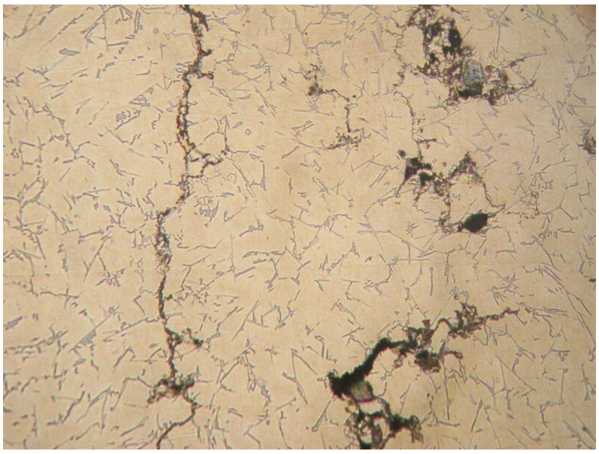


a b

Fig.23. Sample 1 after etching: a) magnification 100x b) magnification 10x

**Remedies**

- Low compatibility.
- Avoid high pouring rates and effect of the metal stream against shape dividers.
- Shorten pouring circumstances, enhance circulation of gates.
- Bentonite content too low, or inadequately treated bentonite.
- Inert material substance too high.
- Lump content too high.
- The high substance of radiant carbon maker.
- Improve design plates, increment design decreases and radii.
- Increase the quality of the centers. Use a greater proportion of binder.



a b

Fig.2. Sample 3 a) maginification50x b) magnification 10x

- Minor cracks.

  In the sample 3, there is a minor crack which is caused in casting process as shown in figure 25.

  Hot tear

  Removing from the mold immediately after freezing.

  Remedy

  Avoid excessive ramming.

## 4.3 MICROHARDNESS TESTING

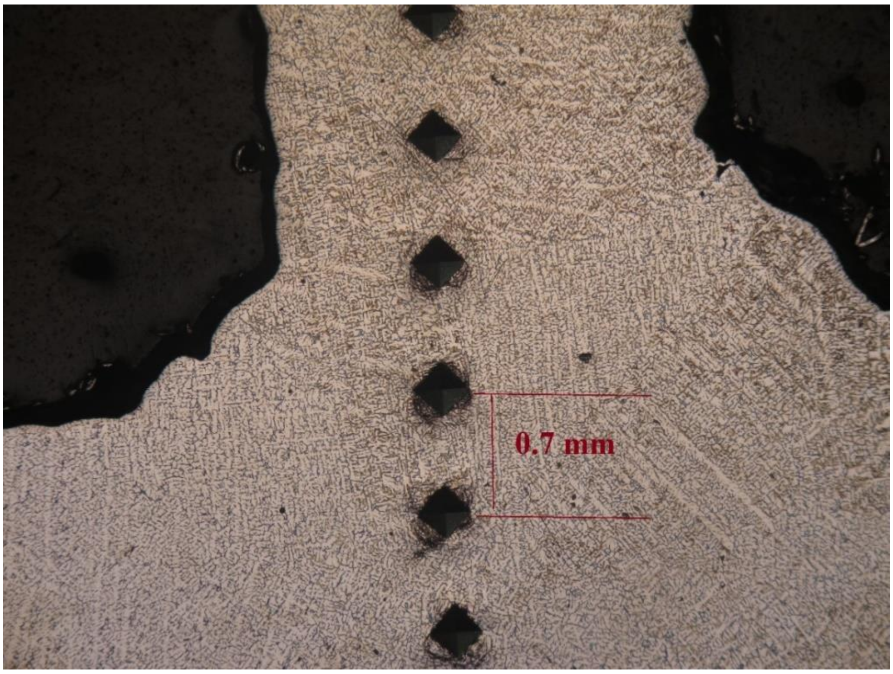
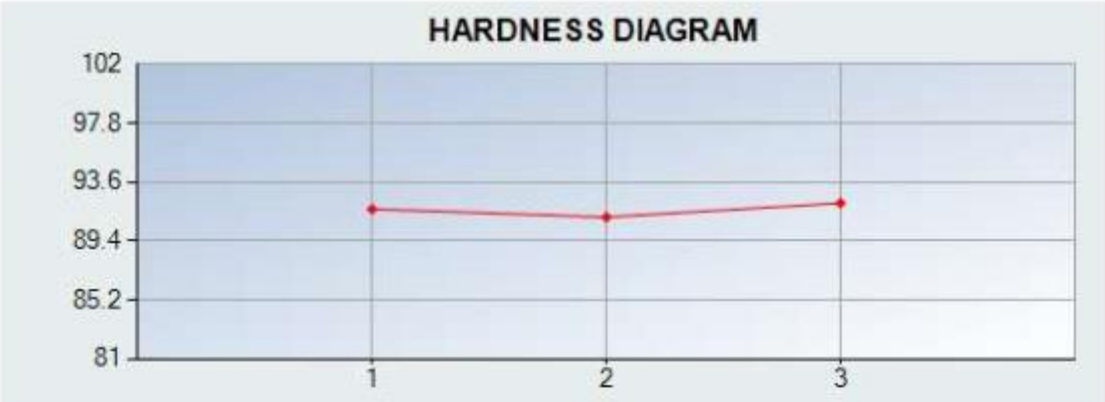



Fig.25. Sample 1 After Vickers hardness test

| | | | |
|---|---|---|---|
| Type | VERZUS 750 | Nr of measurements | 3 |
| Date | 12/22/2016 | Max | 92.1 |
| Operator | Admin | Min | 91.1 |
| Test | VICKERS HV/5 | Average | 91.6 |
| Dwelltime | 1 sec. | Standard Deviation | 0.4 |

Notes:




| | | | | | |
|---|---|---|---|---|---|
| 1 | 22 Dec 2016 02:3 | 91.7 | HV/5 | d1: 0.3113 | d2: 0.3123 |
| | X=0.00m Y=0.00m | XXX HRC | | 81.7 HBS500 | XXX Mpa |

Comment

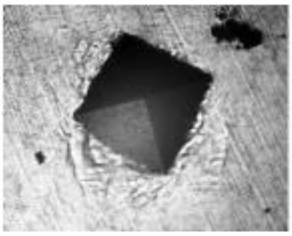


Fig.26. Microhardness test sample 1

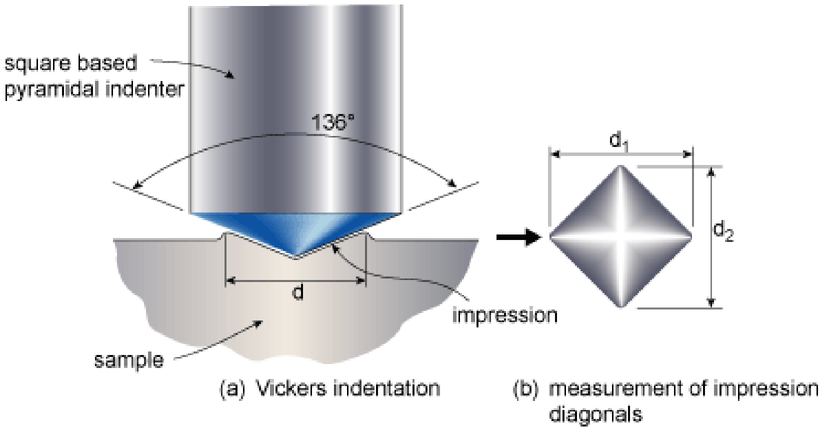



Fig.27. Vickers hardness test

INNOVATEST®

1065 Easton Road
Horsham, PA 19044-8009
U.S.A.
+1-2156757100

| Tester Info: | | Statistics: | |
|---|---|---|---|
| Type | VERZUS 750 | Nr of measurements | 17 |
| Date | 12/22/2016 | Max | 104.7 |
| Operator | Admin | Min | 94.0 |
| Test | VICKERS HV/5 | Average | 100.9 |
| Dwelltime | 1 sec. | Standard Deviation | 3.0 |

Notes:


| | | | | | |
|---|---|---|---|---|---|
| 1 | 22 Dec 2016 04:0 | 94.0 | HV/5 | d1: 0.3117 | d2: 0.3162 |
| | X=0.00m Y=0.00m | XXX HRC | | 83.0 HBS500 | XXX Mpa |

Comment

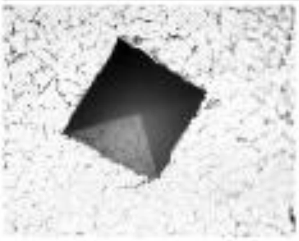


Fig.28. Sample 2 microhardness

# 5 CONCLUSION

1. 3D printing process is easy and fast way to produce a pattern for casting. The dimensions of the pattern are accurate. 3D printing can be used only for the selected patterns.

2. To cast the impeller usually, investment and die casting is used. With the sand casting technique, the accuracy is not good as investment and die casting. Comparing with the results of the microstructural analysis sand casting technique can also be used for impeller production. But with the certain accuracy, and machining is necessary for every casting.

3. The images of the microscopic test sample 1 have the sand inclusion defect which does not occur in the other two samples. The sample 2 has no defects and silicon and aluminium are uniformly concentrated.

4. In microhardness test, the hardness values do not differ much as shown in the hardness diagram. The values can be up to +10 or -10.

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