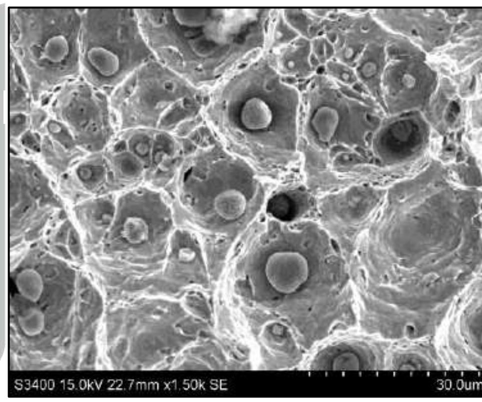
Journal of Materials, Manufacturing & Failure Analysis for Structural Integrity



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PILLAI HOC COLLEGE OF ENGINEERING & TECHNOLOGY RASAYANI

News at a Glance
• From the editor's desk
•Focus on

- Failure Analysis of the Cooling Water Pump Impeller of Centrifugal Pump, Prof. R.C. Prasad, Ex. Professor IIT Bombay, Professor, Department of Mechanical Engineering, PHCET Rasayani
- INDUSTRY 4.0 : 3D PRINTING OF ENGINEERING PLASTICS FOR DENTAL APPLICATIONS
- Events Organized / Forthcoming:
- Training workshop on Hot Bulk Forging simulation technology
- International Olympiad in Hot Bulk Forging & Extrusion Technologies using QFORM Software
- One Day Workshop On Failure Analysis of Centrifugal Pumps
- Two Days Intensive Workshop On Fracture Mechanics & Failure Analysis: Research Opportunities to Solve Industrial Problems

From Editor's Desk

WELCOME TO THE FOURTH ISSUE OF THE JOURNAL

Centrifugal pumps are widely used for an extensive range of applications. After a few years of operation, centrifugal pumps experience premature repeated failures of the same components. Failures at the end of the designed life are quite rare. This is because root cause of failures are not investigated and identified. Once root cause is known and understood, corrective action can be taken to solve the problem. Root cause failure analysis will increase the running time of pumps or minimize time between failures (MTBF).

Let us first define what a pump failure is. Pump failure can be defined as an incident which does not allow a pump to perform its intended function or prevents it to operate at a higher efficiency. There are many reasons that affect the efficiency or complete breakdown. It may be due to mechanical and hydraulic failures. Mechanical failure may constitute bearing failures, seal failures, excessive vibration and failures due to fatigue and wear. Hydraulic failure results when the pump does not deliver liquid or delivers with insufficient capacity and pressure. Hydraulic failures result due to pressure change in volute that may lead to cavitation. Cavitation results when there is a reduction in suction pressure. High flow cavitation occurs frequently when the Net Positive Suction Head (NPCH) is small. Cavitation (formation of vapor bubbles in moving fluid where the pressure of fluid falls below its vapor pressure) is accompanied by erosion. There is collapse of cavities in the area of higher pressure. Cavity collapsing results in sharp cracking noise. Level of noise is a measure of severity of cavitation. Pump starts vibrating due to cavitation. This causes damage to the pump and reduction in pumping efficiency.

The major categories of root cause failure is due to faulty design of pumps, faulty material selection, processing and manufacturing defects, assembly and installation defects, operation beyond design limit , improper maintenance and operation . Each category needs to be reviewed, systematically examined and diagnosed to find the root cause. RCFA helps diagnose the cause of failure and determines preventive methods to reduce mean time between failures. The generic areas of investigation such as faults in design, pump selection, impeller selection etc. may be represented in the form of a Fishbone diagram. A condition monitoring system may be installed to track the pump's operation using signal /symptoms like vibrations, noise etc. using AE, Infrared Thermography, Electrical signal analysis, Oil analysis and Vibration analysis. There are some modes of failure that are neither mechanical nor hydraulic e.g. Erosion and corrosion that results in excessive power consumption. Erosion can have five different forms like cavitation erosion, adhesive wear, abrasive wear, fretting and erosion by impact of solid particles. Corrosion that is a chemical reaction between materials and environment may be one of the seven types e.g. General, Dealloying, Galvanic, Stress corrosion cracking, Hydrogen embrittlement, Microbial induced corrosion and Inter granular corrosion. The future vision should be to provide a holistic interdisciplinary approach to bridge the skill gap in proper operation, maintenance for reliable performance of engineering components.

LET US LOOK FAILURE ANALYSIS THROUGH THE LENS OF RESEARCH,INNOVATION & ENTERPRENURESHIP

Failure Analysis of the Cooling Water Pump Impeller of Centrifugal Pump

Prof. R.C. Prasad

Ex. Professor IIT Bombay

Professor, Department of Mechanical Engineering, PHCET Rasayani

Preamble: Centrifugal Pumps are widely used in a variety of industries. After a few years of service life centrifugal pumps repeatedly fail prematurely due to hydraulic and mechanical problems. Pump failures are expensive therefore running time or mean time between failure of pumps needs to be maximized. Root cause analysis of pump failures needs to be pursued in a structured fashion. Currently there appears to be skill gap to diagnose the failure modes and effect analysis that can emanate due to faulty design, improper material selection, Improper processing and manufacturing defects, assembly installation defects , improper operation and maintenance. In the present case the centrifugal pump of an evaporative cooling tower of thermal power plant failed in service due to erosion-corrosion of impeller.

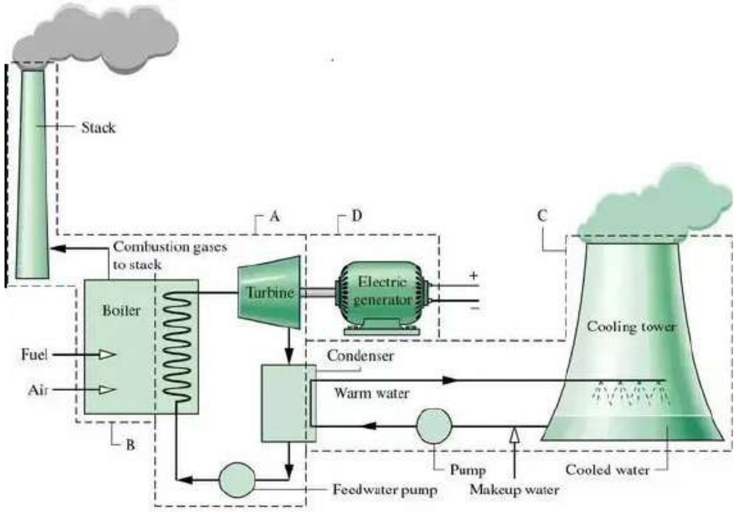


Fig.1: Schematic of Thermal Power Plant

A centrifugal pump is a rotary machine that imparts energy to a fluid. It consists of two basic parts: the rotating impeller and the stationary casing (volute). A typical centrifugal pump is shown in Figure.

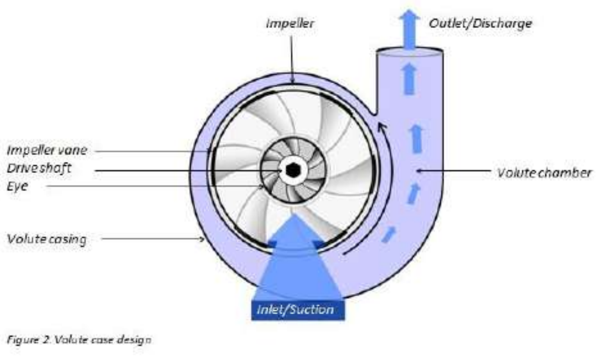


Fig.2: The impeller and rotation of a typical centrifugal pump.

Centrifugal pumps operate at high speed for instance 600 rpm and 10 m head, and can deliver water over a million gallons/min. At these severe operating conditions corrosion failure occurs frequently because turbulent flow conditions exist.

Corrosion in centrifugal pumps is a frequent nuisance in the water industry, including cooling towers, in particular when the water is polluted by corrosive agents. The first indication of pump corrosion is that the pump no longer meets the flow demands of capacity and head requirements. Water pumps require constant care to prevent or minimize corrosion in particular under deposits or scaling.

Fouling takes place when particulate matters adhere to internal surfaces. This decreases pump efficiency and flow capacity leading to failure. This is unavoidable problem. Particulate matters increase wear apart from fouling. Pump is worn out and unable to produce more lift thus cause excessive vibration.

A centrifugal pump, with fast moving parts like impeller or elements are subject to high velocity flow and are affected by cavitation-corrosion. Cavitation phenomena in pumps are generally accompanied by noise and vibration. Cast Iron is generally used for casing. Corrosion takes place due to chemical reaction between metal and fluid pumped in. It may be uniform or localized. Cast Iron has good corrosion resistance to neutral and pH liquid. However, it is not suitable for low pH where it becomes more prone to corrosion. In such cases higher grades of stainless steels are used

In the present case the Impeller fan made of CF80Mo circulates cooling water in evaporative cooling tower was heavily cavitated and eroded.

Stainless Steel is passive but above certain limiting velocities gets eroded. Other factors like (turbulence) and impingement of particles severely erode the surface.

Cavitation-corrosion is the conjoint action of cavitation-erosion and corrosion due to the formation and rapid collapse, within the cooling water, of cavities or bubbles that contain water vapor, sometimes under conditions of severe turbulent flow. In the case of a passive-active metal, e.g. austenitic SS, the bubbles' implosion is responsible for the breakdown of the passive film and the onset of active corrosion. This process is accelerated when the water is acidic, in particular when it contains strong, reducing acids.

The corroded impeller fan of cooling tower handles large volume of water. The water chemistry is given in Table 1.

Table 1: Water Chemistry

Date	Location	PH	Conductivity (micro S/cm)	T.D.S. (ppm)	T.H. (ppm)	Chloride (ppm)	M Mk. (ppm)	Turbidity * (NTU)	Make up (NTU)	COC
	Limit		< 9000 Max	< 6500 Max	< 100 Max	< 1800 Max		< 50 Max	(ppm)	< 9.5
21/12/2016	Cooling Tower # 2 & 3	9.35	5330	3620	42	930	1390	18.10	118	7.88

A good designed propeller fan achieves water velocities across the effective area of fan from hub to blade tips that are as uniform as possible. For this the blade is tapered and twisted. Normally cast Al blades are used due to low cost, good internal vibration damping and resistance to corrosion in most cooling tower environments

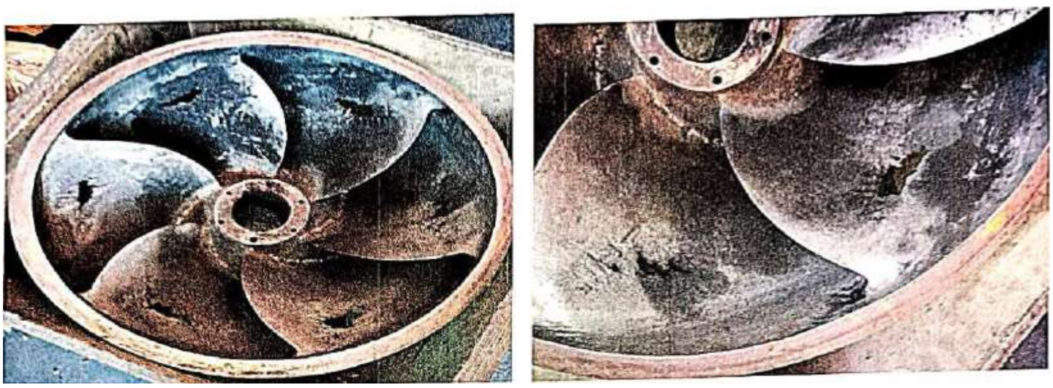
. One of the most common causes of pump failure is cavitation, that resolves due to insufficient pressure at suction end of pump or net positive suction head available (NPSHa). This causes liquid in a pump to turn into vapour at low pressure. At low pressure this creates air bubbles which implode as the liquid moves from suction side of impeller to delivery side. Air bubble implosion generates shock waves that stress the pumps internal surface, creating vibration and mechanical damage and ultimately resulting in failure. Repeated cavitation causes pitting and fracture in impeller volutes and casing, weakening the metal, increasing resistance to flow and reduce pump efficiency. Shock loads and cavitation can also decrease service life of shaft and motor. Cavitation can easily be avoided during design stage. It should be ensured that the chosen pump has sufficient NPSHa so that liquid remains above vapor pressure.

Currently lighter but exceptional corrosion resistance FRP blades cast in precision molds are used. When the hub and blades are of dissimilar metals they are insulated to prevent electrolytic corrosion. When fan vibrates at high frequency, there is formation and collapsing of cavities leading to cavitation damage on the fan blade. When a corrosive liquid is involved cavitation corrosion occurs.

Failure Analysis

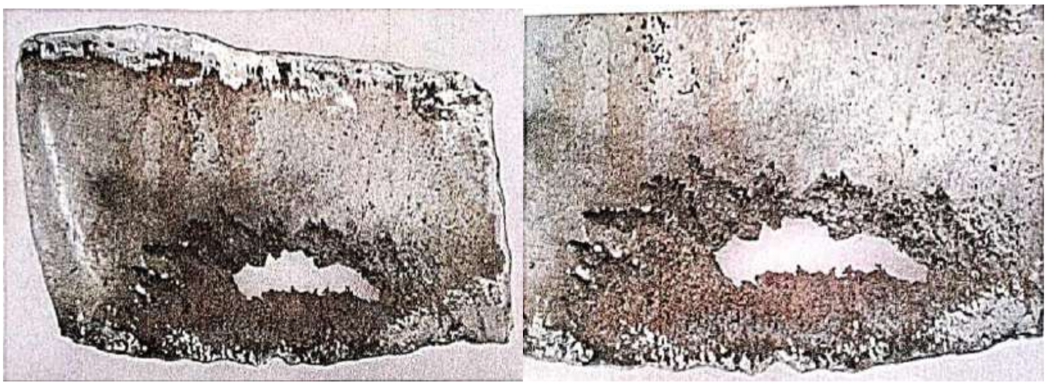
Visual inspection

The corroded impeller fan of the cooling tower is shown in Fig.3 (a &b). The enlarged view of the cavitation damage Fig.3 (c & d) shows pits, craters and grooves.



a b

Fig.3(a-b): Cavitation damage to centrifugal pump impeller used to pump cooling water



c d

Fig.3(c-d): Cavitation damage to centrifugal pump impeller used to pump cooling water

The cavitation erosion in the present case results from combined attack of cavitation erosion and corrosion.

The material of construction of impeller fan is CF8M. It is a CF8 alloy containing Mo that is equivalent of wrought AISI 316 SS. The Mo is added to increase the general corrosion and pitting resistance by chloride. It is austenitic stainless steel but contains 5-20% ferrite. Normally stainless steels have excellent corrosion resistant but low hardness, high Stacking Fault Energy and low tendency to stress induced martensitic transformation. As a result it has low resistance to cavitation erosion.

In stainless steel a hard, dense and adherent continuous film forms which gives good resistance to pitting corrosion. However, due to impact of suspended hard solid particles, rapid change in direction of water (excessive turbulence) high velocity of impingement of water may be responsible for removing the protective films. There is generation and collapse of cavities (bubbles) due to pressure fluctuation arising due to change in flow and vibration. This results in numerous rounded pits. There is also a possibility of shrinkage pits in cast blades. The presence of small amount of chloride in water may be responsible for the breakdown of passive oxide film and deepening of the pits.

Microstructural Examination

The microstructural examination of the blade material from adjacent areas from fracture zone shows large grains and numerous pits Fig.4 (a & b).

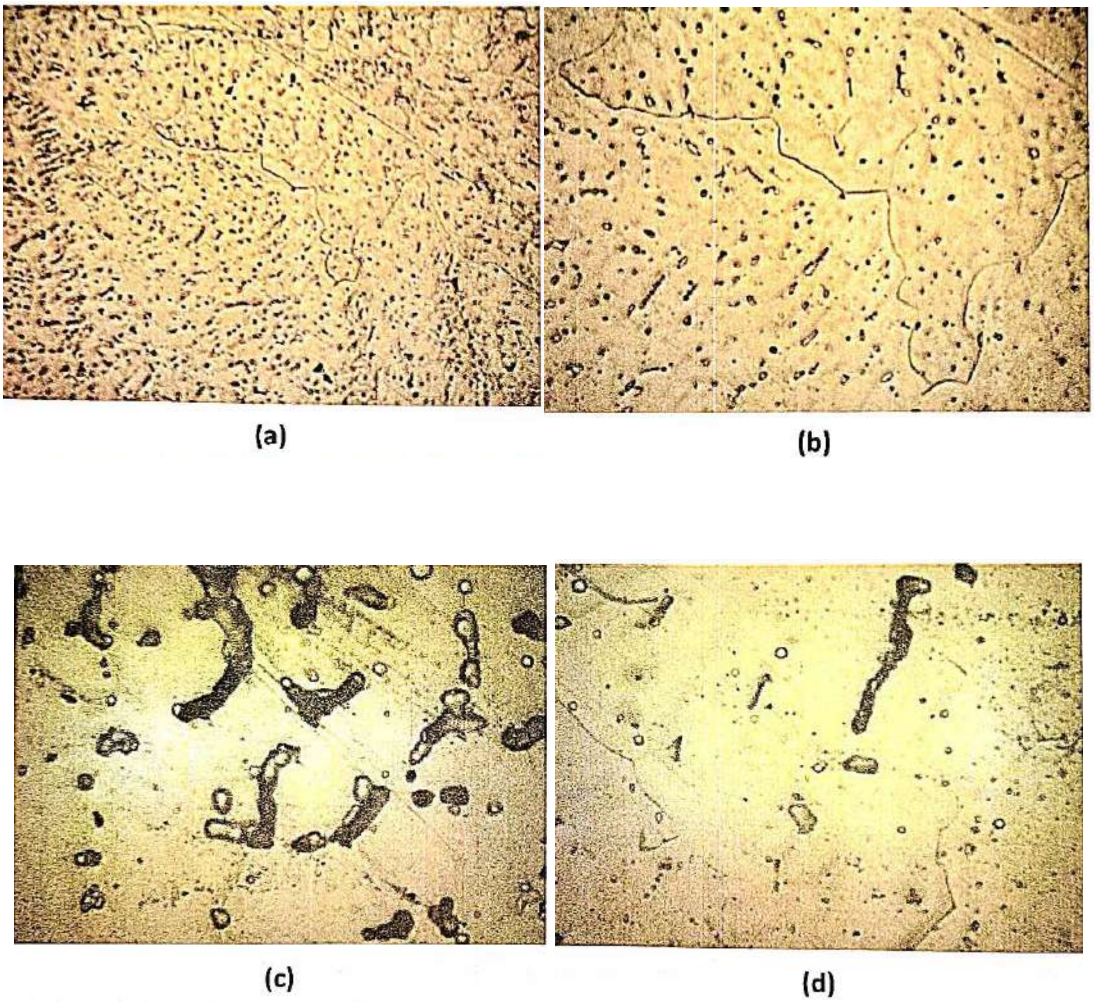
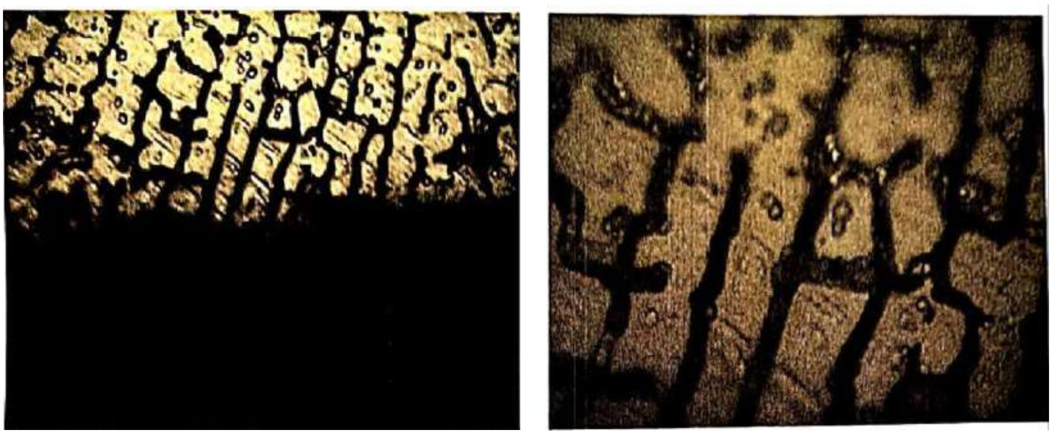


Fig.4(a-d): Light Optical photomicrographs show extensive pitting and shrinkage porosity (a&b) and (c&d) photomicrographs at higher magnification shows the joining and coalescence of pits

Fig.4(c&d) photomicrographs at higher magnification show the joining and coalescence of the pits. High speed pressure oscillations near the edge of the blade create shock waves. Extensive attack at the edge results in wavy ripple surface profile due to coalescence of closely spaced pits Fig.5(a&b).

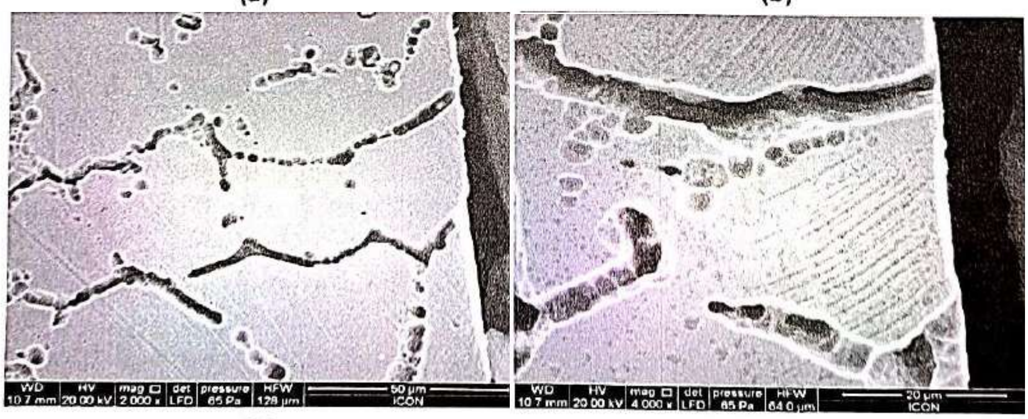


(a) (b)

Fig.5(a&b): wavy ripple surface profile at the edge of the blade due to coalescence of closely spaced pits

SEM micrographs are shown in Fig.6(a-d). Fig.6(a) shows elongated large size grains with grain boundary pits. Fig.6(b) illustrate the attack along the grain boundary. The coalescence of pits are clearly visible in Fig.6(c &d). In addition to this, ripples can be seen in Fig.6(d). These ripples are similar to ripples that are found in desert / river beds due to flow of wind and water.

(a) **(b)**



(c) **(d)**

Fig.6(a-d): SEM Micrographs showing attack along grain boundaries, coalescence of pits and ripples

SEM Fractography

The severely rippled region was observed at higher magnification and is shown in Fig.7(a-d).

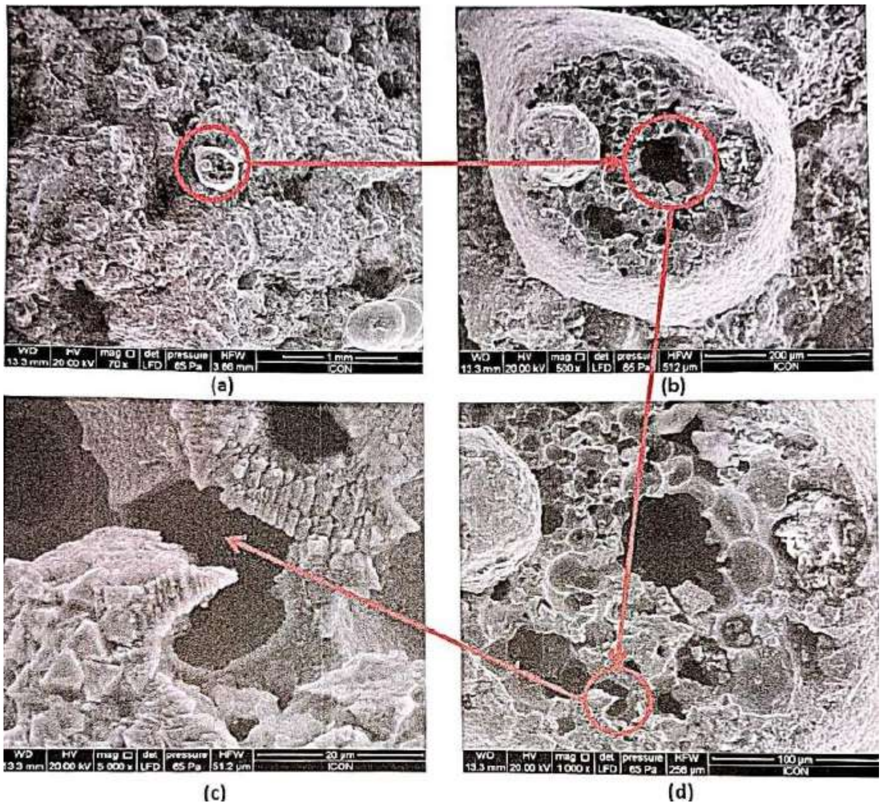


Fig.7(a-d): SEM Fractographs of severely ripple region at higher magnification

Fig.7(a) Circled region looks like a rotating eddy that may be formed perpendicular to flow direction. The high magnification SEM fractographs of this ripple region is shown in Fig,7(b-d). Synergistic action of suspended particle impact and eddy turbulent fluid flow appears to enhance premature erosion-corrosion damage. A common feature of erosion is wavy surface profile ripples Fig.7(c&d) that form on surface due to flow of water characteristics. The ripple formation induces cavitation that increases with time. Dendrites with inter dendritic region in the cast structure can easily form the ripples that subsequently induce the cavitation erosion-corrosion. In the case of austenitic SS, the bubbles' implosion may also be responsible for the breakdown of the passive film and the onset of active corrosion.

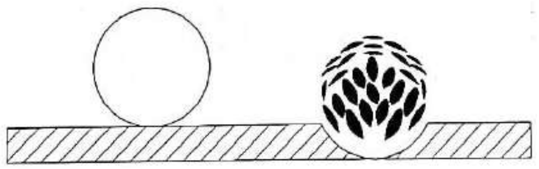
Conclusion

• The pump impeller suffers cavitation-corrosion in the cooling water due to the conjoint effect of breakdown of passivity, active corrosion and cavitation.

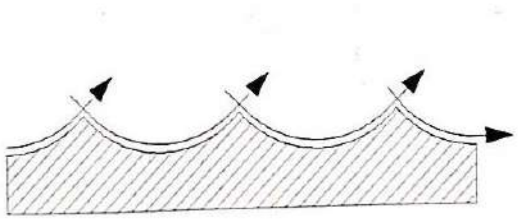
Mechanism of cavitation erosion - corrosion and ripple formation

A model based on experimental observation is shown systematically in Fig.8 (a-c)

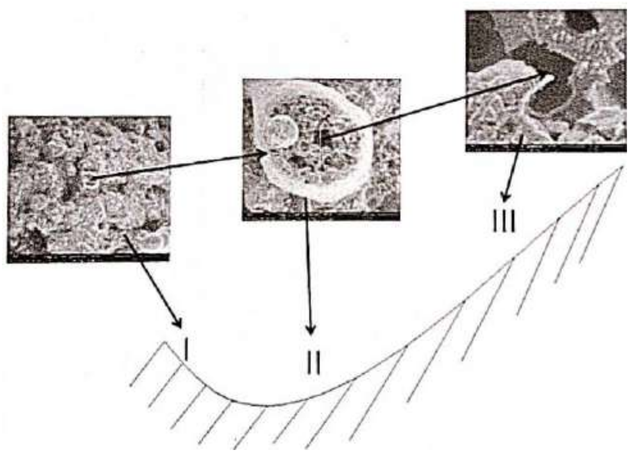
Cavitation erosion-corrosion is a type of wear fracture where materials contact flowing water containing hard suspended particles and corrosive species. Based on our experimental observation a mechanism of cavitation erosion-corrosion is schematically shown in Fig.8 (a-c).



(a) Impact of suspended hard particles break protective or passive film. Surface roughness creates eddies due to excessive turbulence



(b) High velocity impinging water creates large eddies and formation of ripples



(c) Cavitation occurs under condition of extreme ripple formation. Region I is worn by cavitation, Region II by large — angle impact and Region III by large angle impact erosion.

Fig.8(a-c): Mechanism of cavitation erosion - corrosion and ripple formation

Steps to minimize cavitation erosion-corrosion failures

1. Cavitation and erosion in stainless steel takes place at liquid/surface interface and therefore related to surface properties rather than bulk properties. Proper choice of material which is not only corrosion resistant but hard faced by laser surface modification that may help prevent cavitation and erosion. Use of lighter FRP blades cast in precision molds may be an alternative consideration.

2. Protective coatings/ Protective film by inhibitors: though not so effective but welded overlays and hard facing may be applied at times along with repair of the attacked area by welding.

3. Removal of hard material and lower velocity: Effective filtration and settling to remove hard solid particles and low liquid velocity may help in reducing cavitation erosion-corrosion.

4. Avoid Turbulent flow (solids and gas bubbles) that aggravate impingement attack.

5. Vibration in pumping equipment should be avoided to eliminate the possibilities of cavitation-corrosion and further related failures.

6. An adequate water treatment program may be considered if required, including acidity neutralizer and corrosion inhibitors to prevent corrosion events.

INDUSTRY 4.0 : 3D PRINTING OF ENGINEERING PLASTICS FOR DENTAL APPLICATIONS

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**** Professor, Department of Mechanical Engineering , Pillai HOC College of Engineering and Technology, Rasayani**

1. Introduction

Industries have gone through several evolutionary processes Fig. 1. The first industrial Revolution (Industry 1.0) came with the invention of wheel. The Second Industrial revolution (Industry 2.0) was brought through mass production by Henry Ford through the assembly lines. The introduction of electronics and control systems on the shop floor brought the third industrial revolution (Industry 3.0) followed by Industry 4.0.

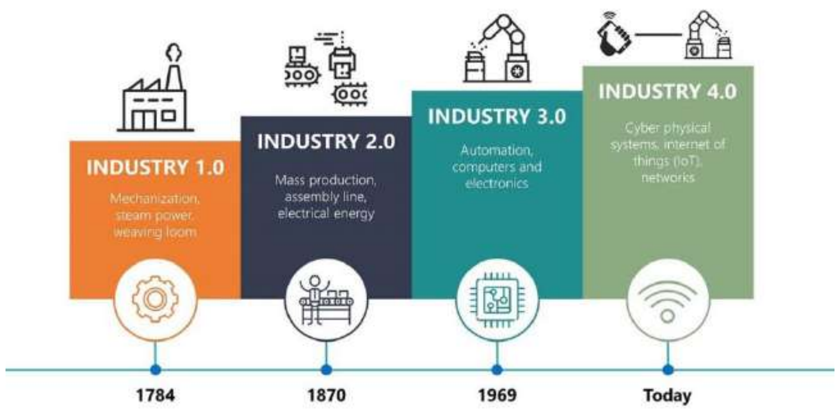


Figure 1 Industry Evolution

Industry 4.0 is being increasingly used for smart factories. Here the manufacturing is loaded with automation and robotics. The technologies in Industry 4.0 are shown in Fig. 2

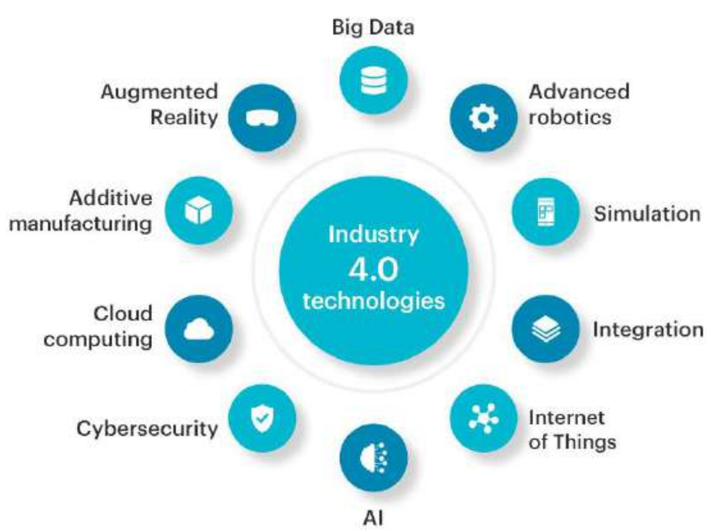


Figure 2 Industry 4.0 Technologies

3D printing is a high-tech disruptive manufacturing process of making products layer by layer. It has brought the 4th Industrial revolution and revolutionized the manufacturing sector. The use of 3D printing in rapid prototyping and production has increased significantly in recent years. Current 3D printers can produce complex geometries or a whole assembly with high accuracy in a short period of time; this made 3D printing very popular in dentistry, aerospace, automotive, electronic, and healthcare sectors. The steps in 3D printing are as shown in Fig. 3

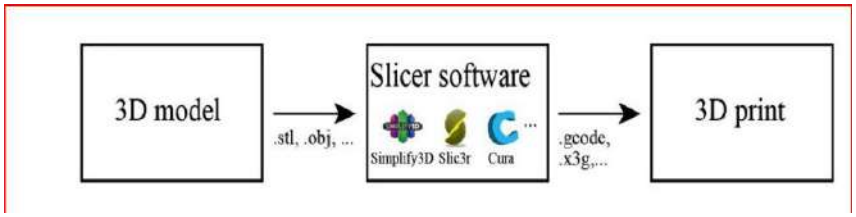


Figure 3 Steps in 3D printing

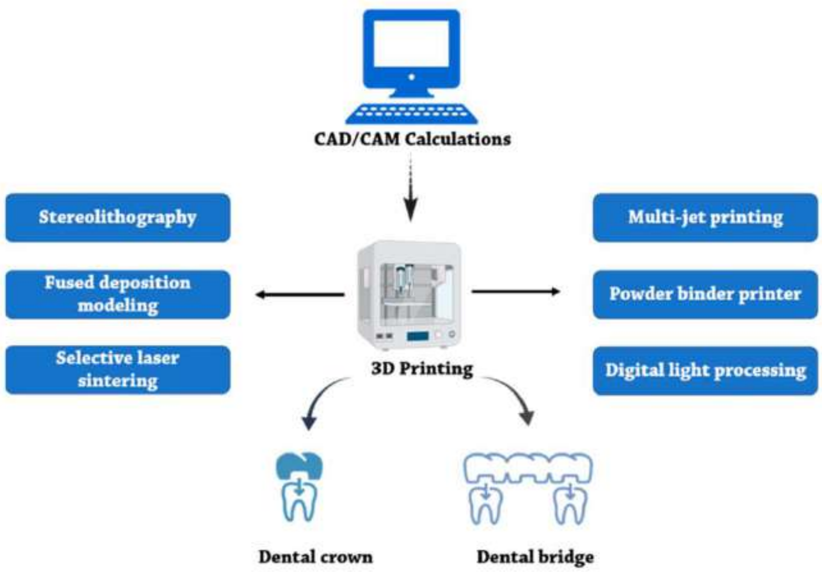


Figure 4 3D printing processes in dentistry.[30]

3D Printing has various ranges of applications as shown in Fig. 5 and Fig. 6

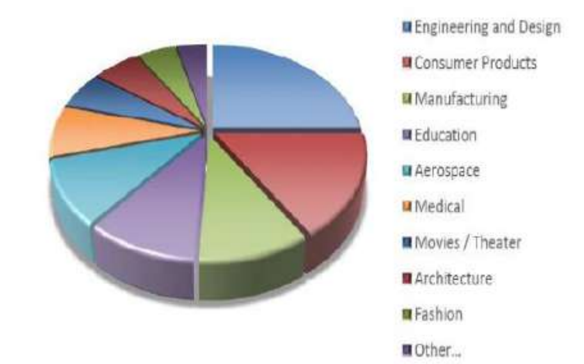


Figure 5 Shows applications of AM[2]

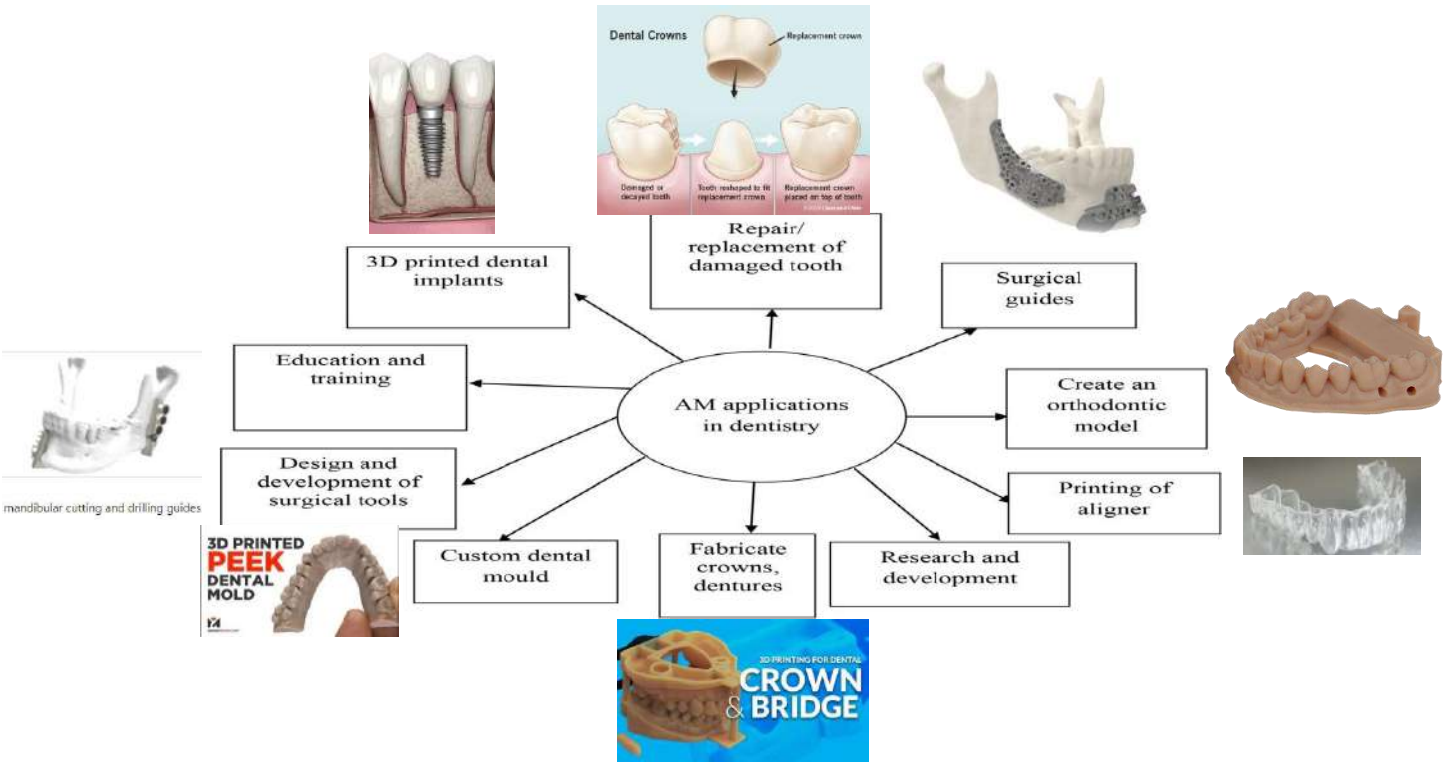


Figure 6 Ten major applications of additive manufacturing in dentistry.[2]

As compared to conventional manufacturing the strength of the parts/models manufactured by 3D printing is less. Traditional manufactured parts are isotropic and homogeneous due to applied pressure. But 3D printed parts have layered structure and contain imperfections like voids and may not be highly packed. These Imperfections can cause anisotropic mechanical properties due to its layered structure. The fabricated components / medical implants are evaluated on the basis of mechanical and environmental durability. There is no method currently available to predict mechanical properties without physical testing the finished sample. Strength of such 3D-printed parts using specific materials is still an area of current research. The present paper aims to fill this gap by conducting tensile, CTOD tests and understand modes of fracture of the low cost 3D printed samples by FDM for dental prosthetics.

2. Experimental

2.1 Tensile and Fracture toughness samples were fabricated as per ASTM standards

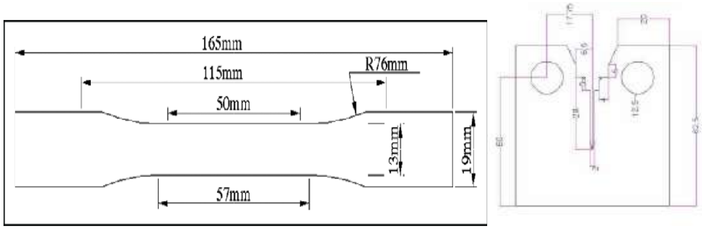


Fig. 7 Dimensions of (a) Dog bone Tensile testing specimen ASTM D638[2] and (b) CTOD specimen ASTM e1820

2.2 Materials and Methods

In this investigation material PLA (Poly(lactic acid) or polylactide (PLA) , Chemical Formula:- ($C_3H_4O_2$)n) is used.

Major Methods used in 3D printing :

Stereo lithography (SLA): In this process product is made by applying an ultraviolet laser to a resin container. The materials available for this technique are limited because it uses light-sensitive polymers. It provides a better surface finish and reduces raw material waste. The Details of SLA are shown in Fig. 8

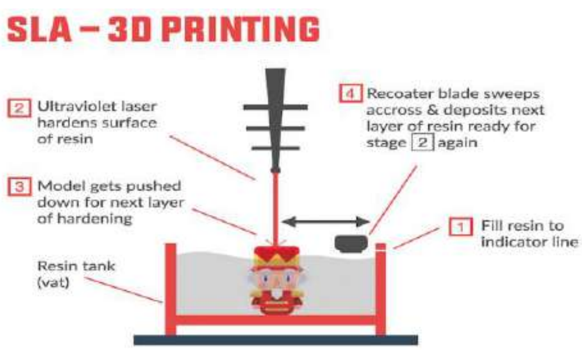


Figure 8 Details of SLA[2]

Selective laser sintering (SLS): This additive manufacturing technique accomplishes sintering with the application of a laser beam. The material used is in powder form and the laser sinters the powder. The Details of SLS are shown in Fig. 9

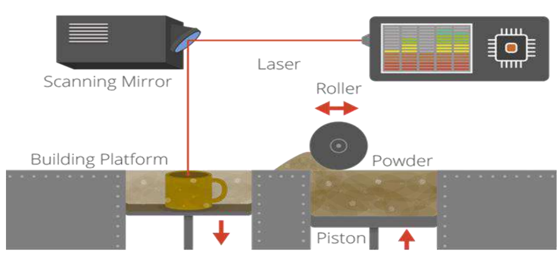


Figure 9 Details of SLS[2]

Fused deposition modelling (FDM): In this process manufacturing the product is similar to the extrusion process, adding layer by layer of heated thermoplastic material to produce the model. In this process, the printhead consists of multiple nozzles that simultaneously print different types of materials. In this investigation FDM method is used. The Details of FDM are shown in Fig. 10

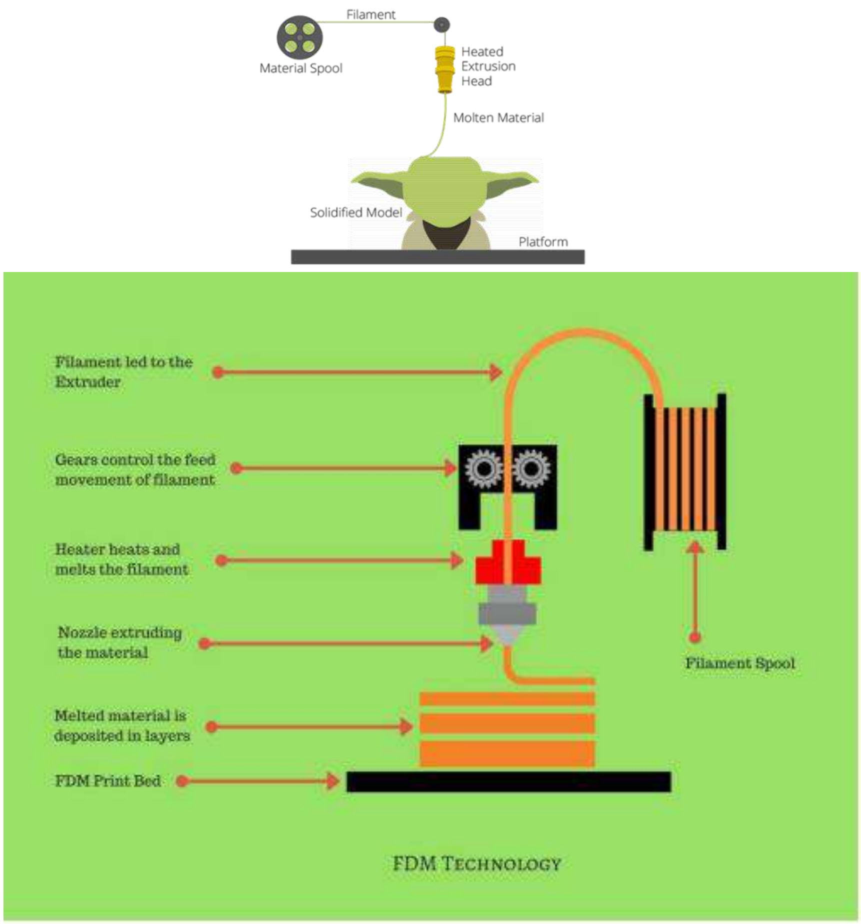


Figure 10 Details of FDM [2]

2.3 Slicing Software used in Ultimaker 2+

In 3D printing CAD file is converted to STL file format. . Before sending the file to print, a slicer program slices the digital model into several layers across its cross section and the printing parameters such as infill, layer height, printing speed, or cross-section pattern etc. are adjusted to suit the user’s need. In Ultimaker cura is used for slicing the model into layers and generating a printer specific G-code. Once finished, the g-code can be sent to the printer for the manufacture of the physical object.

2.4 Printing Parameters

Table 1: Details of the printing parameters for ASTM D638 Type I :-

Material : PLA					
Sample A	**Parameters Varied**			**Sample Type**	**Common Parameters**
	Infill Density	**Infill Pattern**	**Orientation**		
	100%	Grid	90°	Tensile Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec
Sample B					
	100%	Grid	0°	Tensile Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec
Sample C	20%	Grid	90°	Tensile Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec
Sample D	20%	Grid	0°	Tensile Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec

Table 2 Details of the printing Parameters for ASTM E1820:-

Material : PLA					
Sample 1	**Parameters Varied**			**Sample Type**	**Common Parameters**
	Infill Density	**Infill Pattern**	**Orientation**		
	40%	Grid	0°	Compact Tension Specimen (CTS) for Fracture Toughness Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec

Sample 2	60%	Grid	0°	Compact Tension Specimen (CTS) for Fracture Toughness Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec
Sample 3	100%	Grid	0°	Compact Tension Specimen (CTS) for Fracture Toughness Testing	Nozzle Diameter = 0.6 mm Layer Thickness = 0.15 mm Temperature PLA= 210 °C Build Plate Temperature = 60 °C Speed = 55 mm/ sec

2.5 Images of 3D printing:-

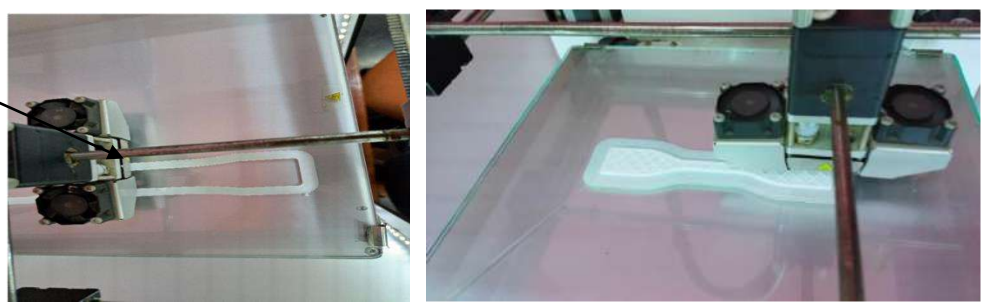


Fig. 11 Images of tensile testing samples during 3D printing

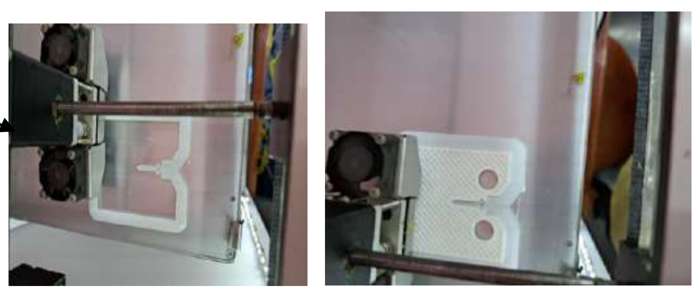


Fig. 12 Images of CTOD samples during 3D printing

Each layer is first printed at the outermost contour and then filled in the inside. The image above shows the formation of Grid Infill pattern.

3. Results and Discussion

3.1 Results of Tensile Testing

Table 3 Comparison of Results of test

Sample A	Parameters Varied			Ultimate Tensile Load N	Ultimate Tensile Strength N/mm^2	% Elongation
	Infill Density	Infill Pattern	Orientation			
Sample B	100%	Grid	90°	2320	42.33	1.40
	100%	Grid	0°	2320	44.43	1.44
Sample C	Parameters Varied			Ultimate Tensile Load N	Ultimate Tensile Strength N/mm^2	% Elongation
	Infill Density	Infill Pattern	Orientation			
	20%	Grid	90°	1380	25.32	0.3
Sample D	20%	Grid	0°	1915	36.79	0.4

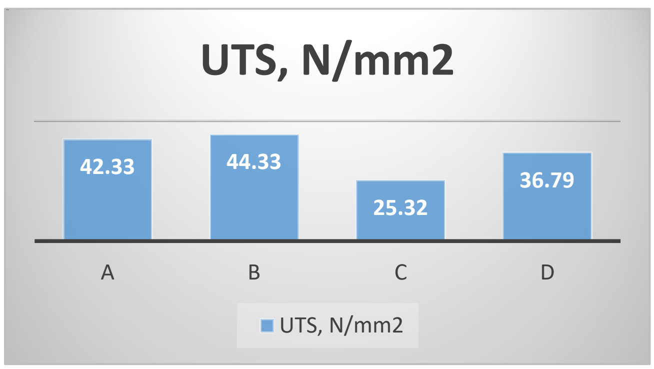


Fig. 13 Comparison of Tensile test results with varying infill and orientation

The results of the tensile test sample fabricated with 100% infill density and 0^o and 90^o orientation show negligible variation in tensile strength and % elongation. Contrary to this 20% infill density with 0^o orientation shows 45% increase in tensile strength with almost same elongation.

3.2 Interpretation of tensile test results based on fractography

3.2.1 Tensile Test of Specimen with 100% Infill & 90^{o} orientation Figure 14

The secondary electron images of the tensile sample with 100% infill and 90^{o} orientation are shown in Fig. 14 (a&b). They indicate river lines indicative of cleavage fracture (hackles). Since the samples were printed in 90^{o} orientation, the layered deposition (marked by arrow) are clearly visible. The backscattered image Fig. 14c indicates flat brittle fracture with no voids except for some inclusions appearing as white dots. The interlayer fracture resulting from 90^{o} orientation results in marginal decrease in tensile strength and ductility.

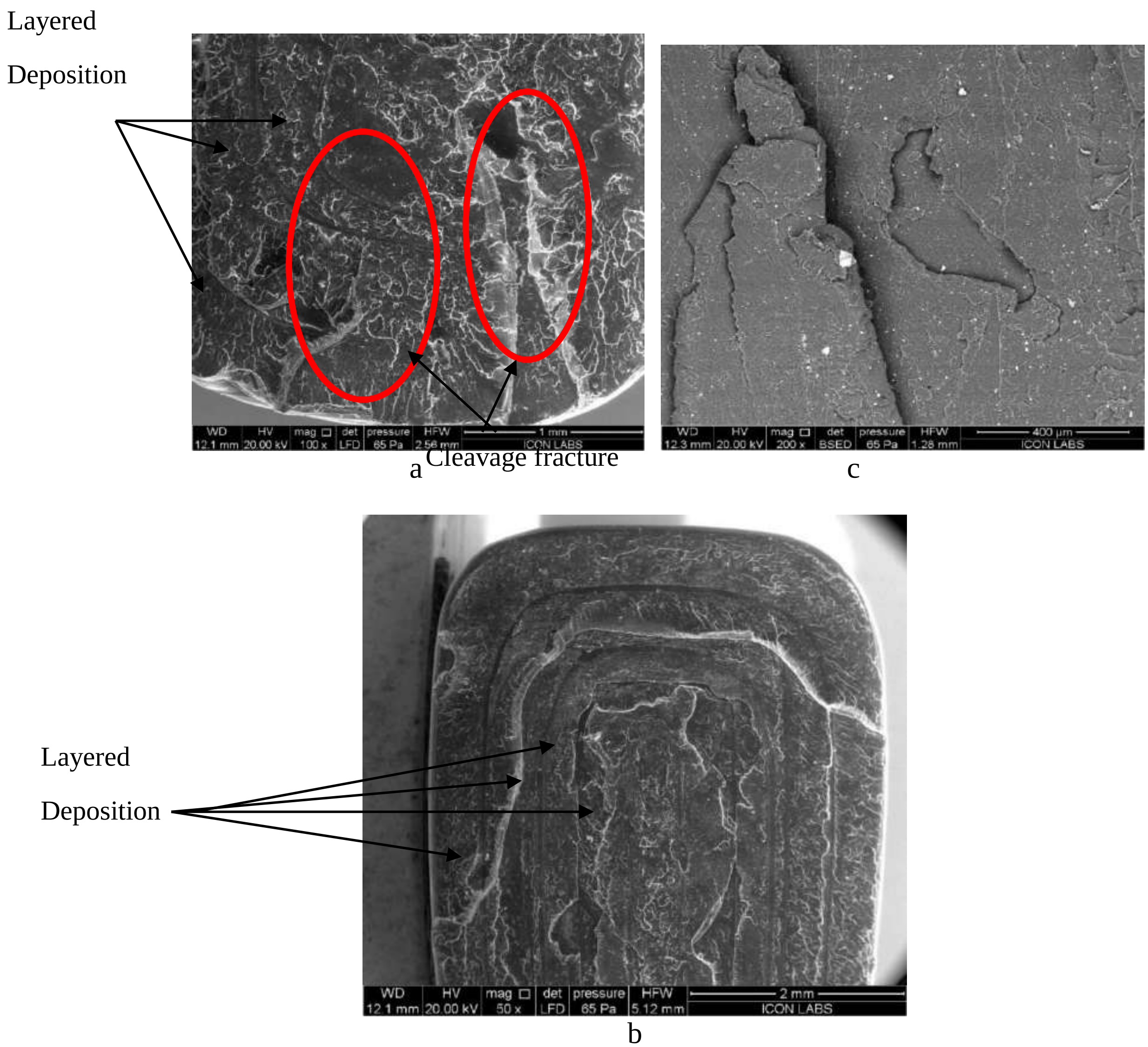
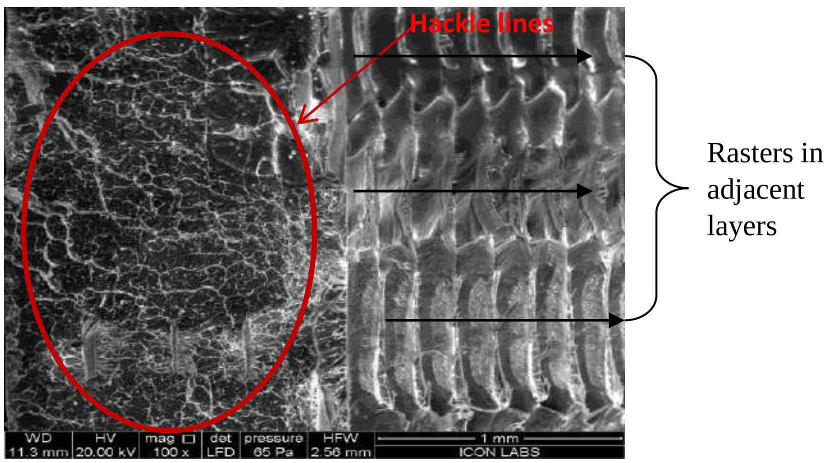


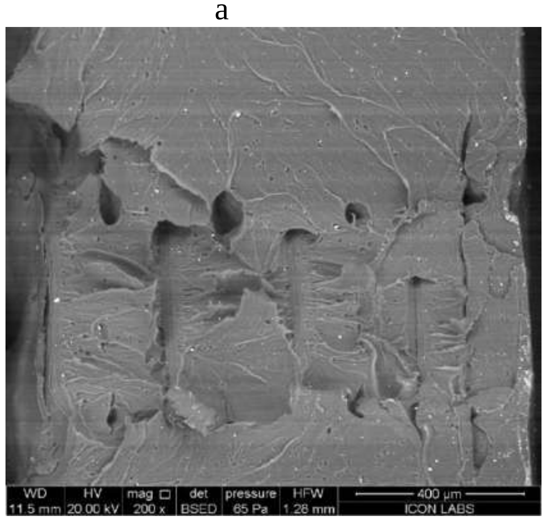
Figure 14 (a, b&c) Fractographs of Tensile Tested Specimen A with 100% Infill & 90^{o} orientation

3.2.3 Tensile Test of Specimen with 100% Infill & 0^o orientation Figure 15

The secondary and backscattered images of tensile fracture with 100% infill and 0^o orientation are shown in Fig. 15 (a&b). They indicate failure of the rasters and the matrix. The matrix failure consists of hackles as seen in Fig. 14 (a&b). The only difference with Fig. 14(a&b) is the appearance of rasters that are visible with printing in 0^o orientation. However, the backscattered image in 14b shows flat fracture with small porosity that was not visible in the case of printing with 90^o orientation. The tensile strength and percentage elongation of 100% infill with 0^o and 90^o orientation differ by very small margin. The results are based on testing single samples in each condition. More tests are required to show reliable trend.



a

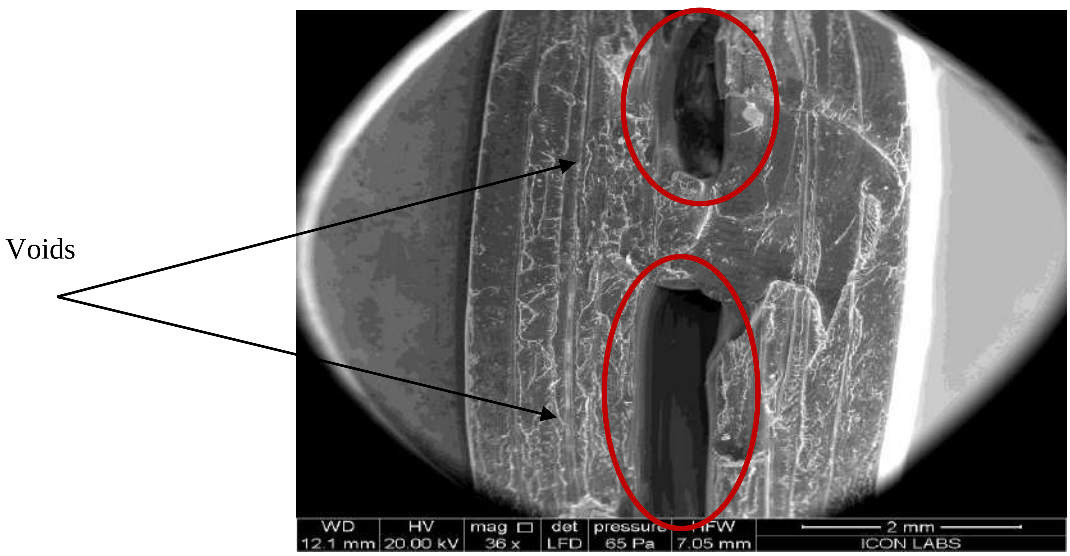


b

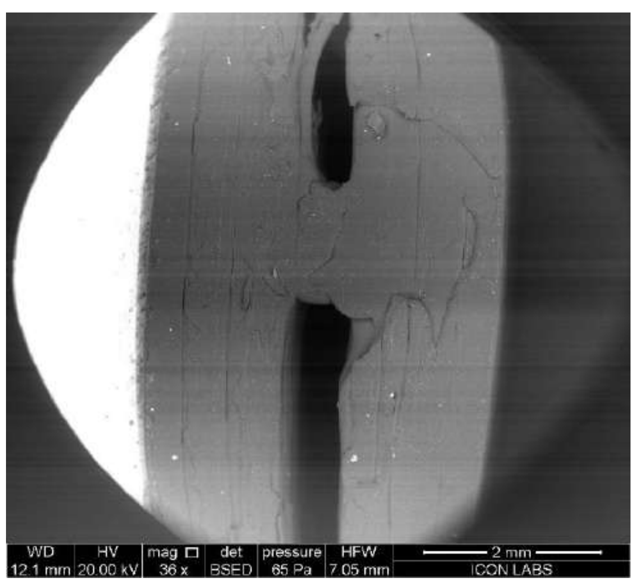
Figure 15 (a&b) Fractographs of Tensile Tested Specimen B with 100% Infill & 0^o orientation

3.2.3 Tensile Test of Specimen with 20% Infill & 90^{o} orientation Figure 16

The secondary and backscattered images of the tensile fractured specimens are shown in Fig. 16(a&b). The matrix fractures shows hackles as in the previous cases. However, since the infill is only 20%, therefore, large voids can be seen in Fig. 16(a&b) that work as sites for stress concentration. This appears to attribute the substantial drop in tensile strength.



a

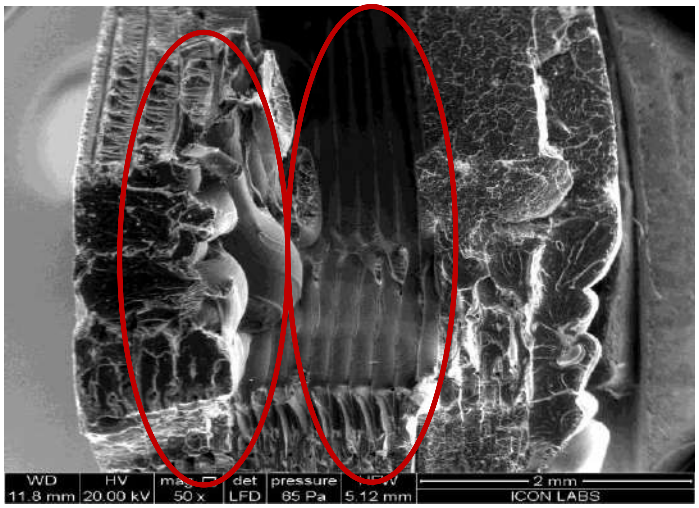


b

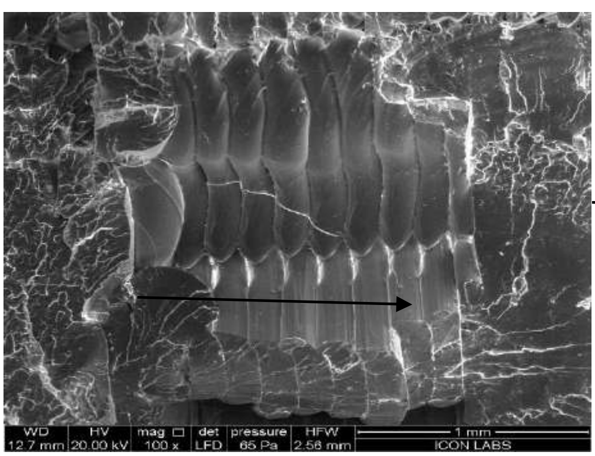
Figure 16 (a&b) Fractographs of Tensile Tested Specimen C with 20% Infill & 90^{o} orientation

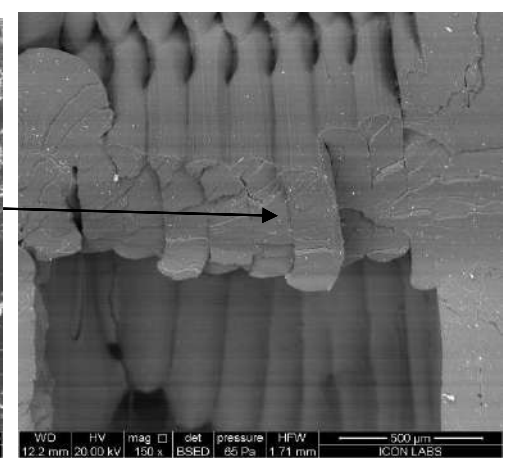
3.2.4 Tensile Test of Specimen with 20% Infill & 0^o orientation Figure 17

The secondary and backscattered images of the tensile fractured specimens are shown in Figure 17 (a,b&c). Compared to Fig. 16 with 90^oorientation the 0^o orientation of printing with 20% infill shows large raster failures containing voids. The backscattered image shows the crack initiation and propagation on the plane with cleavage cracks. Both the crack initiation and propagation through rasters results in higher tensile strength compared to the 90^o orientation in Fig. 16



a





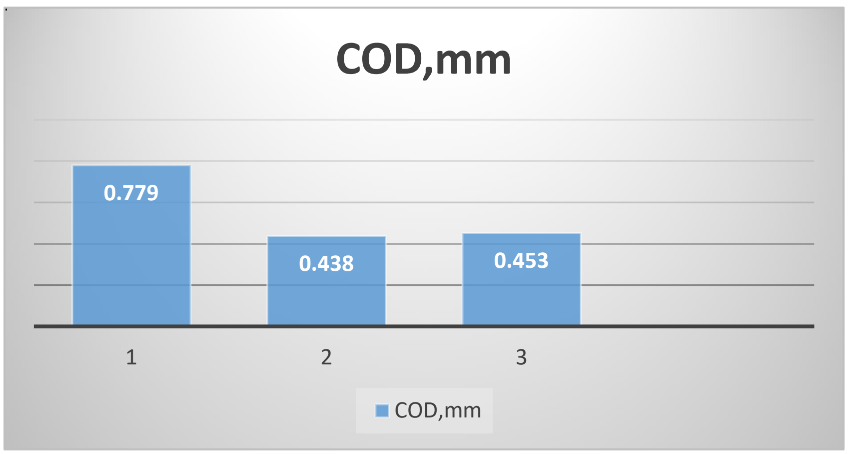
b **c**

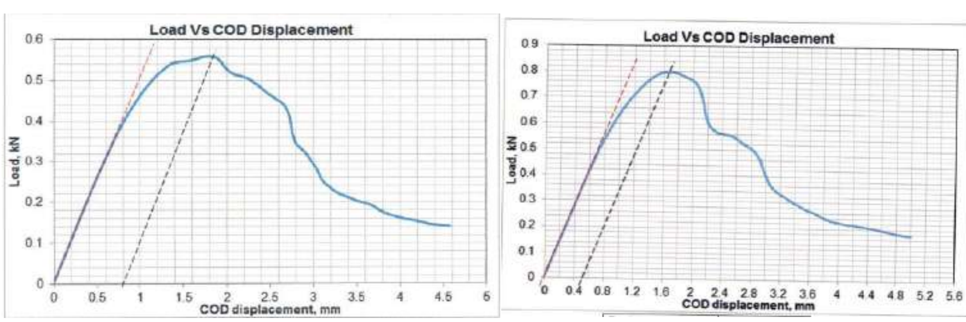
Figure 17 (a,b&c) Fractographs of Tensile Tested Specimen D with 20% Infill & 0^o orientation

3.3 Fracture toughness Test Results

Table 4 Comparison of CTOD test results

	Parameters Varied			Peak Load N	COD Mm
	Infill Density	**Infill Pattern**	**Orientation**		
Sample 1	40%	Grid	0°	559	0.773
Sample 2	60%	Grid	0°	559	0.438
Sample 3	100%	Grid	0°	800	0.453



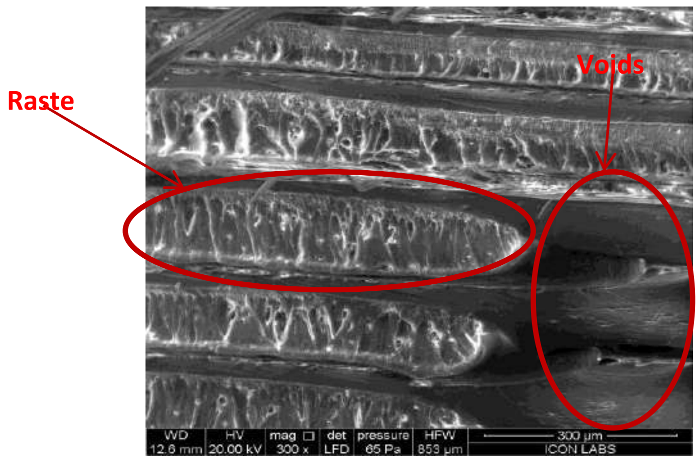


1 **2**

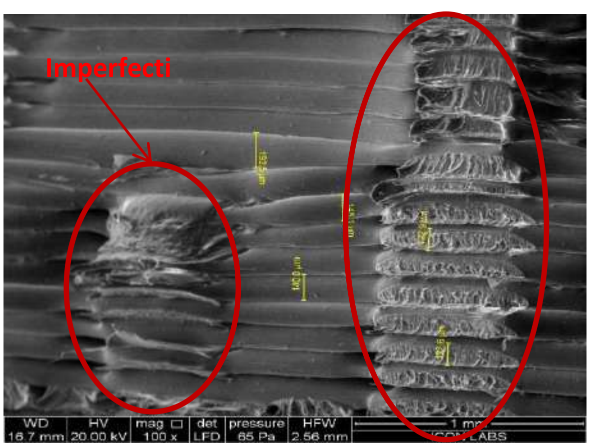
Figure 18 Comparison of Load v/s COD graphs

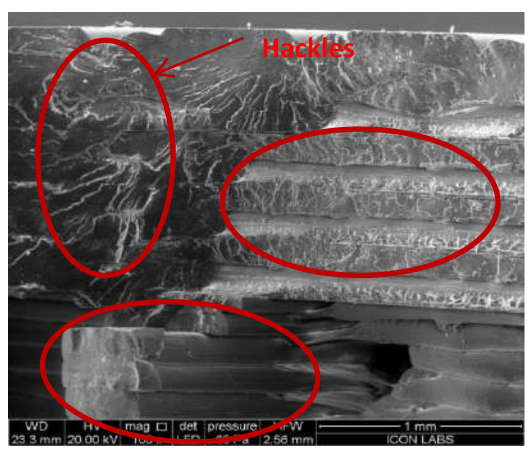
3.3.1 CTOD Test of Specimen with 60% infill density Figure 19

The secondary electron images of the fractured surface of CTS samples with different infills show raster failure & interlamilar fracture. However, the maximum crack tip opening displacement is with lower infill of 40%. This is attributed to the arrest of the propagating crack at the cavity.



1





2 3

Figure 19 (a,b &c) Fractographs of CTOD Tested Specimen 2 with 60% Infill

4. Conclusion

The Mechanical test results indicate that increased infill density increases the tensile strength. This may be attributed to reduction of voids and imperfections. The stress vs strain graphs show the brittle fracture in samples having 90^o orientation, while on the other hand sample with 0^o orientation shows the ductile fracture. Also, the orientation of printing affects the strength. Results show higher tensile strength at 0^o than 90^o. But in the case of the CTS test, we get opposite results which indicate that low infill gives high resistance to fracture. Also, the load crack tip opening displacement curve obtained on CTS sample indicates that the 3D printed PLA initially has linear slope followed by stable crack growth. This is indicative of the fact that PLA has enough crack resistance capability and cannot be termed as brittle material.

Fractography indicates that in the case of tensile testing samples having 100% infill with 90-degree ordination are more brittle as compared to 0-degree orientation. In the case of 20% infill, sample with 90-degree orientation is more filled than 0-degree orientation. In the case of fracture testing sample with 60% infill the linear fracture is shown which are different at different points. There was only one common point in all the samples the crack initiates from void and through hackle lines like spider web.

With the combination of test results and fractography we conclude that the PLA is not a brittle material it also has stress resistance property. Also, more infill increases with proper orientation [varies model wise] gives the higher strength in fused deposition modelling process.

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One Day Training workshop on Forging Process Simulation held on February 24, 2023
Some of the glimpses are given below

Introductory lecture by Prof. R.C. Prasad and Mr. Saurabh Sirsikar on forging simulation

Certificate distribution to previous year participants of International Olympiad

Half Day Hands-on Training workshop on Hot Bulk Forging Process Simulation held on April 12, 2023

Activities Proposed

PHCET

QFORM

MAHATMA EDUCATION SOCIETY'S

PILLAI HOC COLLEGE OF ENGINEERING & TECHNOLOGY

ORGANIZES

INTERNATIONAL STUDENTS OLYMPIAD

ON

HOT BULK FORGING AND EXTRUSION TECHNOLOGIES USING QFORM SOFTWARE

Date: April 2023

International Students Olympiad in Hot Bulk Forging and Extrusion Technologies 2023

Students of mechanical engineering are invited to take part in the International Students Olympiad in Hot Bulk Forging Technologies, which will take place in April 2023 at universities around the world.

The competition between students will consist of the following parts: students will get a drawing of an axisymmetric part after machining and should design the hot forged part and die impression for the final forging and then determine necessary technological chain for its manufacturing and then simulate proposed forging process. Students can choose an alternative task for developing technological process of hollow aluminium profile extrusion. Simulation will be performed in QForm software for estimation and verification of the developed technology.

Organizers are asked to submit a competition entry with a list of applicant students. If the local organizer invites students from multiple universities then each university is limited to 3 participating students so if more are interested in participating, then each university must pre-select 3 most qualified participants. If only one university is involved with a local organizer, then more than 3 students may participate. On the day of the event in April 2023 competing students should arrive to assigned class room and each student will work on a personal computer with QForm simulation and CAD software installed and will have 6 hours to design the technology, to simulate it and to create a report using text editor such as Microsoft Word. Students' reports should include calculations and justification of the proposed technology, applications and drawings in text file as well as saved QForm FE-simulation file. Each report will have special random number to achieve fair and unbiased judging. The results will be judged by a local committee. Winners will get diplomas and prizes. Then 1st place winners from each country will move on to the Scientific Committee judgment between countries where three best students' reports from around the world will get special diplomas and prizes.

Designed technology will be judged by the following criteria:

- computation of hot forged part drawing;
- justification of designed bulk forging technology;
- effectiveness and efficiency of proposed technology based on the results of simulation in QForm. Optimally designed technology should provide no defects, complete filling of the die impression, consist of minimum number of technological chain steps with high forging energy efficiency and high material consumption efficiency with optimal grain flow.

Basic language of the Olympiad is English. Each Organizer may use different languages for reports but the students' reports for International Committee judgment have to be translated into English.

Deadlines:

- January 2023: Organizational Committee membership confirmation (including contact person) to market@qform3d.com
- January 2023: Competition entry from universities (including request for QForm license if needed)
- March 2023: List with applicant students
- April 2023: Recommended date of the Olympiad at universities

Additional conditions:

All universities taking part in the Olympiad will get a free 3-month network QForm software license for 3 places to practice before the Olympiad by request. The universities will also get the solved example from the previous Olympiad for review as well as a training course of simulation in QForm.

Several participants of the past years:

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Dr. R. C. Prasad, Professor Department of Mechanical Engineering

Hebei University of Science and Technology (China),
Materials Science and Engineering Department
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Professor Shibo Ma

One Day Workshop On Failure Analysis of Centrifugal Pumps

SFA Mumbai Chapter

http:// www.sfa.mes.ac.in

Organized by

SFA Mumbai Chapter & Institute Innovation Council at PHCET

along with Department of Mechanical Engineering at

PILLAI HOC COLLEGE OF ENGINEERING & TECHNOLOGY RASAYANI

Centrifugal Pumps are widely used in a variety of industries. After a few years of service life centrifugal pumps repeatedly fail prematurely due to hydraulic and mechanical problems. Pump failures are expensive therefore running time or mean time between failure of pumps needs to be maximized. Root cause analysis of pump failures needs to be pursued in a structured fashion. Currently there appears to be skill gap to diagnose the failure modes and effect analysis that can emanate due to faulty design, improper material selection, Improper processing and manufacturing defects, assembly installation defects , improper operation and maintenance.

This one day program intends to bring together the associated industries, experts from academic and research institutes to brainstorm and identify the root cause that is the origin of failure and mitigate repeated frequent failures.

Convener: Dr. R.C. Prasad

Former HAG Professor ,IIT Bombay

President IIC@PHCET and Vice chairman SFA Mumbai chapter

Tentative Date : June / July 2023,

Venue: Conclave 1, PHCET, Rasayani

Activities Proposed

Two Days Intensive Workshop
On
Fracture Mechanics & Failure Analysis: Research Opportunities to Solve Industrial Problems
Organised by

SFA Mumbai Chapter

Preamble

The Industry today faces challenges to prevent degradation and failure of its ageing infrastructure. Failures eat 4-5% of the economic output of a developing country by reducing the production efficiency and the increasing the cost of production. Fracture performance is a matter of serious concern. Systematic analysis of the cause of failure and taking suitable preventive methods is essential for the economic growth of the country. Fracture control based on conventional design using charpy and tensile tests are considered no longer adequate to ensure safety and reliability. A large number of components are retired prematurely because of lack of our knowledge in determining useful life. The industries ensure structural integrity by periodic inspections. However the decision on inspection, repair and maintenance so far has been made based on experience. This needs to be rationalized through integration of Fracture mechanics, NDE and Failure analysis. The combined advances in these areas have radically changed the approach to design and manufacturing in recent times. Fracture mechanics and Failure analysis have emerged as powerful tools in designing processes and products to enhance operational efficiency and safety. Industries today need a skilled manpower conversant with Fracture mechanics and Root cause failure analysis. This Workshop is designed to provide training and learning to cover the gap between the syllabus prescribed by Universities and the Graduate attributes required by the Industries. The objective is to bridge the knowledge gap between existing course curriculum and connect academic research with Industrial problems. It intends to develop a skill and sound understanding of how to evaluate products and processes, predict and eliminate defects, increase productivity and quality at decreased cost.

Course coverage (SEPTEMBER 26-27,2023)

The following topics are tentatively planned to be covered

- Defects leading to fracture, Role of Failure analysis in design
- Basic approaches to failure analysis
- Overview of Fracture Mechanics and Defect tolerant design
- Determination of material toughness parameters like K_{Ic}, J_{Ic} and CTOD
- Application of Fracture mechanics for Fatigue and Environmental assisted cracking
- Detection and characterization of defects using NDT techniques
- Degradation monitoring, Life assessment and its extension
- Quantitative NDE for fitness for purpose assessment.
- Modes and Mechanism of Failure and Root cause failure analysis
- Corrective and preventive measures to minimize failures in different sectors of industries
- Application Fracture mechanics in failure assessment diagram and industrial problem solving

The theory lectures shall be supplemented by hands-on training on fracture toughness testing and fracture characterization using optical and electron microscopy

Faculty

Faculty will be drawn from educational institutes and research establishments like IITs and Department of Atomic Energy as well as from outside research establishments including industry.

Registration Charges

Category	Fees
SFA & Members of other professional societies	3000/-
Non Members	5000/-
Faculty Members	1500/-
Student Participants	500/-

The event can be sponsored by donating Rs. 25000/-
Sponsorship entitles mention on banners and free registration for two delegates.

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DEGREE COLLEGES

Bachelor and Master

(Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)
- Mahatma Night Degree College of Arts & Commerce- Chembur
- Pillai College of Arts, Commerce & Science - New Panvel Re-Accredited 'A' Grade by NAAC
  B.Com.
  B.Com. (Accounting & Finance)
  B.Com. (Financial Markets)
  B.M.S.
  B.M.M.
  B. Sc. (I. T.)
  B. Sc. (Computer Science)
  B.Sc. (Biotechnology)
  M.Sc. (I.T.)
  M.Sc. (Biotechnology)
  M.Com.(Business Management)
  M.Com. (Accounting & Finance)
- Pillai HOC College of Arts, Science & Commerce - *Rasayani*
  B.Com.
  B.M.S.
  B.Sc. (I.T.)
  B.Sc. (Computer Science)
  B. Com. (Accounting & Finance)
  B.M.M.
  B.Sc. (Maths, Chemistry, Biology & Physics)
  B.A. (English Ancillary, History & Economics)

ARCHITECTURE

Bachelor and Master

(Approved by the Council of Architecture and AICTE) (Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)
- Pillai College of Architecture - New Panvel
- Pillai HOC College of Architecture- Rasayani (B.Arch. 5-year degree course)

***M.ARCH.* (Urban Design)**
- Pillai College of Architecture - New Panvel
- *Ph.D.*

MANAGEMENT COURSE

MMS

(Approved by AICTE)
(Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)
NBA Accredited
'A' Grade by DTE, Govt. of Maharashtra
Pillai Institute Of Management Studies & Research - *New Panvel*
- (MMS: 2-year Post-Graduate Course)
  Executive MBA
- Pillai HOC Institute Of Management Studies & Research - *Rasayani* (MMS: 2-year Post-Graduate Course)

ENGINEERING COURSE

Bachelor, Master & PhD

(Approved by AICTE)
(Affiliated to the University of Mumbai & Recognised by Govt. of Maharashtra.)
NBA Accredited
- Pillai College of Engineering- New Panvel
  B. E. in Information Technology
  B. E. in Computer Engineering
  B. E. in Electronics Engineering
  B. E. in Mechanical Engineering
  B. E. in Electronics & Tele- communication Engineering
  B. E. in Automobile Engineering
  M. E. in Information Technology
  M. E. in Computer Engineering
  M. E. in Electronics Engineering
  M. E. in Mechanical Engineering (CAD/CAM, Robotics)
  M. E. in Mechanical Engineering (Thermal)

PhD (Technology)
Computer Engineering
Mechanical Engineering
Information Technology

- Pillai HOC College of Engineering & Technology, *Rasayani* Accredited 'A' Grade by NAAC
  B.E. in Mechanical Engineering
  B.E. in Electronics & Telecommunication Engineering
  B.E. in Automobile Engineering
  B.E. in Information Technology
  B.E. in Computer Engineering
  B.E. in Civil Engineering
  B.E. in Electrical Engineering
  M.E. in Mechanical Engineering (Machine Design)
  M.E. in Electronics & Telecommunication Engineering
  M.E. in Computer Engineering
  M.E. in Civil Engineering (Construction & Management)

PhD (Technology)
Civil Engineering
Computer Engineering

EXECUTIVE SPORTS MANAGEMENT

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  EXECUTIVE PROGRAMME IN SPORTS MANAGEMENT

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