

3-D Designing of Sterilized DO Probe Chamber In Bioreactor

Submitted in partial fulfilment of the requirements for the award of Bachelor of
Technology in Biotechnology

Interdisciplinary Project

By

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**DEPARTMENT OF BIOTECHNOLOGY
SCHOOL OF BIO AND CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

CATEGORY -1 UNIVERSITY BY UGC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Karthikraaja U (41230026)**, **Vimal A (41230073)** and **Sanjay Kumaran M (41230053)** who carried out the project entitled **"3-D Designing of Sterilized DO Probe Chamber In Bioreactor"** under my supervision from January 2024 to April 2024.


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Submitted for Viva Voice Examination held on 06-05-2024


Internal Examiner


External Examiner

DECLARATION

We, **Karthikraaja U (41230026)**, **Sanjay Kumaran M (41230053)** and **Vimal A (41230073)** hereby declare that the Interdisciplinary Project Report entitled “**3-D DESIGNING OF STERILIZED DO PROBE CHAMBER IN BIOREACTOR**” is done by us under the guidance of **Dr. PRABHAKAR SINGH, D.Phil., PhD (Biochemistry), Assistant Professor** submitted in partial fulfilment of the requirements for the award of Bachelor of Technology in Biotechnology.

DATE: 06-05-2024

PLACE: CHENNAI



SIGNATURE OF THE CANDIDATE

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I wish to express my thanks to **all Teaching and non-teaching staff members** of the Department of Biotechnology who were helpful in many ways for the completion of the project

ABSTRACT

Precise measurement of Dissolved Oxygen (DO) levels is essential in bioprocess monitoring to guarantee ideal conditions and maximize the output. The measurement of dissolved oxygen (DO) is important in many industrial and scientific domains, especially in biotechnology, environmental monitoring, aquatic sciences and a key component of bioprocesses like fermentation and wastewater treatment. DO has a significant impact on cell growth, metabolism, and product formation in bioprocesses. In order to preserve ideal conditions and increase the effectiveness of biotechnological processes, monitoring DO levels is crucial. However, using conventional DO probe chambers to maintain sterility can be challenging, dangerous, and compromise data integrity. This abstract presents a novel approach to overcome these challenges by ingeniously constructing sterile DO probe chambers using 3-D design techniques. Using cutting-edge 3-D modeling software, the suggested design creates intricately engineered chambers with smooth surfaces and few crevices, maximizing sterilization processes and lowering contamination risks. These chamber's longevity in bioprocess environments is ensured by the materials used in their construction, which is resistant to aggressive sterilization procedures. It can prove to be cost efficient for the small bioprocess units. Furthermore, the modular design increases adaptability and versatility by being easy to integrate into pre-existing bioreactor systems.

Keywords: Dissolved Oxygen, conventional, sterile, 3-D modeling, durable materials, sterilization, cost efficiency, bioprocess units, integration, bioreactor systems.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE NO.
	ABSTRACT	i
	LIST OF ABBREVIATIONS	iv
	LIST OF FIGURES	v
1.	INTRODUCTION	1
	1.1 WORKING PRINCIPLE	2
	1.2 ADVANTAGES OF STERILIZED DO PROBE CHAMBER OVER TRADITIONAL DO PROBE CHAMBER.	4
2.	LITERATURE REVIEW	7
3.	AIM AND OBJECTIVE	15
	3.1 AIM	15
	3.2 OBJECTIVE	15
4.	MATERIALS AND METHODS	16
	4.1 MATERIALS	16
	4.2 METHODS	16

4.2.1	DESIGN	16
4.2.2	DESIGN PROCESS	18
4.2.3	TOOLS AND FEATURES	21
4.2.4	PRINTING	23
5.	RESULTS AND DISCUSSION	28
6.	SUMMARY AND CONCLUSION	32
	REFERENCES	33

LIST OF ABBREVIATIONS

TPU	Thermoplastic polyurethane
DO	Dissolved Oxygen
3-D	3 Dimensional
FDM	Fused Deposition Modeling
SLA	Stereolithography
SLS	Selective Laser Sintering
CFD	Computational Fluid Dynamics
ABS	Acrylonitrile Butadiene Styrene

LIST OF FIGURES

FIGURES NO.	TITLE	PAGE NO.
1.1	DO Probe Structure	1
1.2	Labman LMDO-50 DO Probe	2
1.3	Electrochemical DO Probe	3
2.1	3D designing of microfluidic device in healthcare	8
2.2	3D Printing of Cytocompatible Graphene/Alginate Scaffolds for Mimetic Tissue Constructs	9
2.3	Optical DO Probe working	11
2.4	3D Print of Bioreactor	14
4.1	3D Experience software	17
4.2	Homepage	18

4.3	Choosing part design	20
4.4	Part Design	20
4.5	Different planes available for designing	21
4.6	Components present on the part design page	21
4.7	DO probe container	23
4.8	Application of 3D printing	25
4.9	3D Printers	25
5.1	Acrylonitrile Butadiene Styrene	29
5.2	DO Probe Channel	30
5.3	Filter Funnel	30
5.4	Probe Holding Cork	31

CHAPTER-1

INTRODUCTION

Bioprocess monitoring relies heavily on accurate and reliable data, particularly in environments where cells are cultured for various purposes such as pharmaceuticals, food and beverage production, and industrial biotechnology. Dissolved Oxygen (DO) probes are integral components in monitoring these processes. Dissolved oxygen refers to the concentration of oxygen dissolved in a liquid, typically water. This parameter is vital for the survival of aquatic organisms and serves as a key indicator of the health and balance of aquatic ecosystems. In bioprocesses, DO is a critical factor influencing cell growth, metabolism, and product formation. Monitoring DO levels is essential for maintaining optimal conditions and maximizing the efficiency of biotechnological processes. The DO levels are hence quantified using a sensor called DO probes, also known as dissolved oxygen sensors or electrodes, function by measuring the partial pressure of oxygen in the liquid medium.

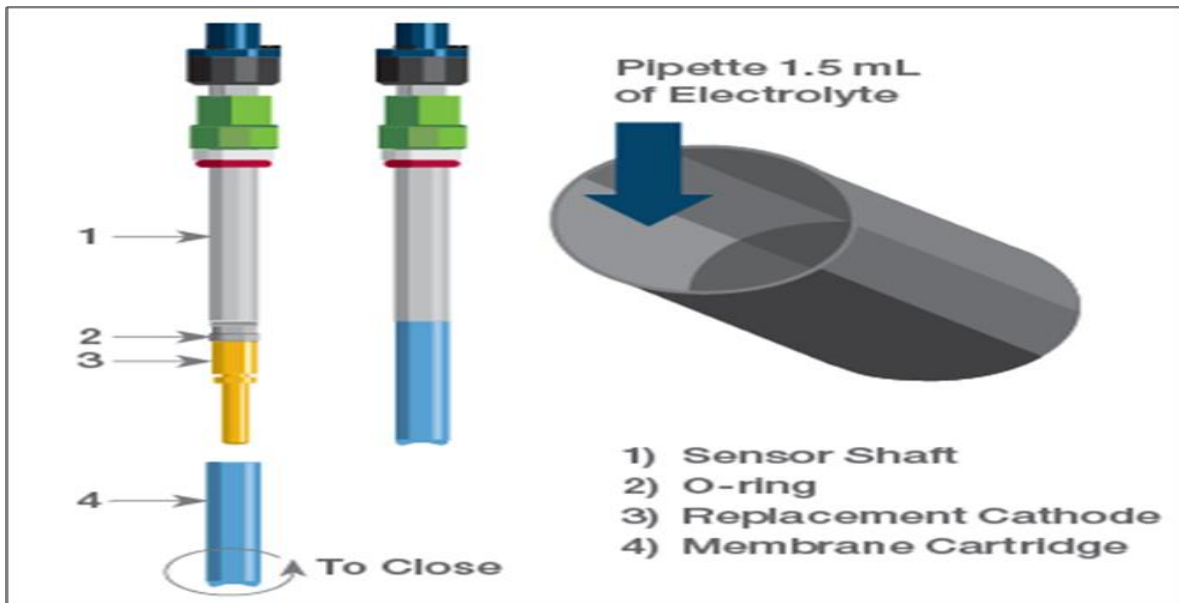


FIGURE 1.1 DO Probe Structure (Source: www.hamiltoncompany.com)

1.1 Working Principle

The principle behind DO probes is based on the fact that oxygen can dissolve in water due to its solubility, influenced by factors such as temperature, pressure, and the presence of other substances. DO probes typically utilize an electrochemical or optical method to determine the oxygen concentration in the liquid. Electrochemical DO probes consist of a cathode and an anode immersed in an electrolyte solution, separated from the sample by a gas-permeable membrane. Oxygen from the sample diffuses through the membrane, causing a chemical reaction at the cathode, which generates a measurable electrical signal proportional to the oxygen concentration. They typically consist of an electrochemical cell containing a sensing electrode and a reference electrode. The sensing electrode is coated with a material that facilitates the diffusion of oxygen molecules, while the reference electrode maintains a stable electrical potential. When submerged in the liquid, oxygen diffuses through a semi-permeable membrane onto the sensing electrode, generating a measurable electrical signal proportional to the dissolved oxygen concentration.



FIGURE 1.2 Labman LMDO-50 DO Probe Source: www.indiamart.com

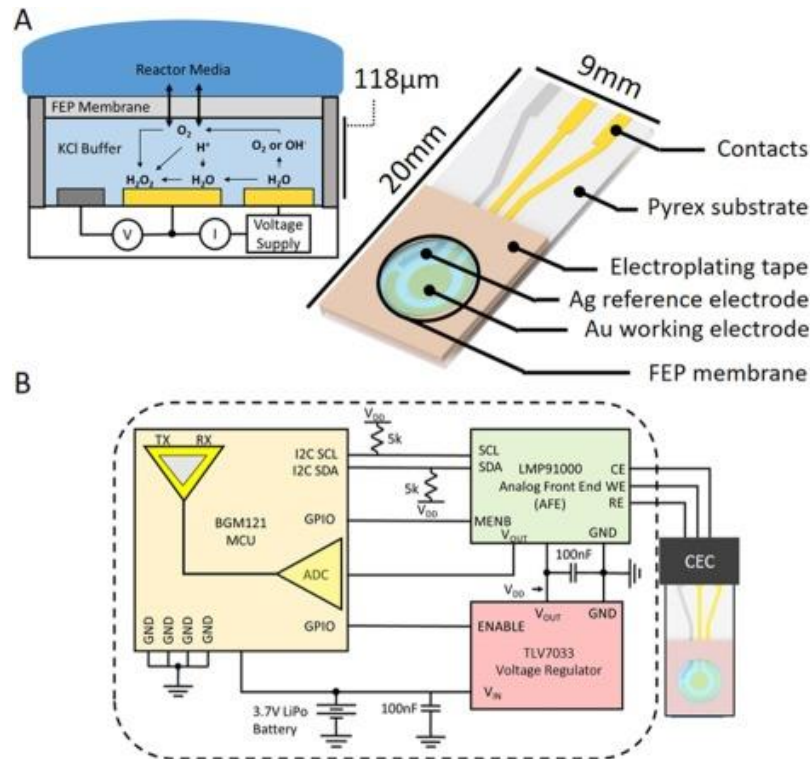


FIGURE 1.3 Electrochemical DO Probe (Source: www.sciencedirect.com)

In bioprocess monitoring and industrial applications where stringent hygiene standards are paramount, ensuring the sterility of equipment is crucial. Dissolved Oxygen (DO) probe chambers, where DO sensors are housed, play a significant role in maintaining sterility while accurately measuring DO levels in various liquids. However, the reliability and accuracy of these measurements can be compromised if the probes are exposed to contaminants or environmental factors. This issue can be resolved with the use of sterilized chamber. This introduction delves into the concept of sterilized DO probe chambers, their importance, and their applications. DO probe chambers provide housing for DO sensors, safeguarding them from external contaminants while allowing them to accurately measure DO levels in the liquid medium.

1.2 Advantages of Sterilized DO Probe Chamber over Traditional DO probe Chamber

Sterilized DO probe chambers are designed to withstand rigorous sterilization methods, ensuring that the entire measurement system remains free from microbial contamination. Sterilized DO probe chambers are engineered with materials and designs that facilitate thorough sterilization without compromising the integrity or functionality of the DO sensors. They typically feature smooth surfaces and minimal crevices along with the usage of mesh filters to prevent the accumulation of bacteria and other microorganisms. Additionally, these chambers are compatible with common sterilization techniques such as autoclaving, steam sterilization, or chemical disinfection, allowing for reliable and repeatable sterilization cycles. Utilizing specialized chambers in conjunction with dissolved oxygen (DO) probes offers several advantages over conventional DO probes, enhancing the accuracy and reliability of DO measurements in various applications.

- **Reduced Interference:** Chambers provide a controlled environment around the DO probe, minimizing interference from external factors such as turbulence, biofouling, and stray light. This ensures more accurate and stable DO measurements by isolating the probe from ambient conditions.
- **Enhanced Calibration:** Chambers enable precise calibration of DO probes by creating a stable and standardized environment. Calibration solutions can be introduced directly into the chamber, allowing for more accurate calibration compared to conventional methods where probes are exposed to varying environmental conditions.
- **Improved Sterilization:** Chambers can be designed for easy sterilization, which is crucial in applications where microbial contamination can affect DO measurements, such as in bioreactors or environmental monitoring. Sterilized chambers prevent

microbial growth around the probe, ensuring accurate and reliable measurements over extended periods.

- **Minimized Drift:** By enclosing the DO probe within a chamber, fluctuations in temperature and pressure that can cause drift in DO readings are minimized. This leads to more stable and consistent measurements over time, particularly in dynamic environments where rapid changes in DO levels occur.
- **Long-term Durability:** Materials used in sterilized DO probe chambers are selected for their resilience to harsh sterilization methods and corrosive environments. This durability ensures long-term reliability and minimizes the need for frequent replacements or maintenance, reducing overall operational costs.
- **Versatile Integration:** Sterilized DO probe chambers often feature a modular design, allowing for easy integration into existing bioprocess setups and compatibility with various probe configurations. This versatility enables seamless scalability and adaptability to evolving process requirements.

Considering all this, our project aims to design a sterilized DO probe chamber using 3D Printing Technology. The advent of 3D printing technology has revolutionized the way we approach manufacturing and design in various industries, including healthcare, biotechnology, and environmental monitoring. To address this challenge, 3D printing offers a versatile solution for creating custom-designed chambers that provide a sterile and controlled environment for DO probes. These chambers are typically designed to accommodate the dimensions of the probe and may include features such as access ports, seals, and mounting brackets. By using 3D printing technology, these chambers can be precisely tailored to fit the requirements of different probes and applications.

The advantages of 3D printing for creating sterilized chambers for DO probes are manifold. Firstly, it enables rapid prototyping and iterative design, allowing for quick adjustments and optimization of chamber designs to meet specific requirements. Secondly, 3D printing offers flexibility in material selection, allowing for the use of sterilizable materials that are compatible with the intended application and sterilization

methods. Moreover, 3D printing facilitates the integration of additional features and components into the chamber design, such as ports for calibration solutions. This customization capability ensures that the chamber not only provides a sterile environment but also enhances the functionality and usability of the DO probe system.

Overall, the combination of 3D printing technology and the creation of sterilized chambers for DO probes represent a promising approach to improving the accuracy, reliability, and sterility of dissolved oxygen measurements in various industrial and research settings. Opportunities for innovation in the design and production of specialized equipment for environmental monitoring and analysis will grow as 3D printing technology advances.

CHAPTER – 2

LITERATURE REVIEW

Andrew J. Capel, *et al.* (2018) provided an overview of how 3D printing has revolutionized traditional manufacturing processes by enabling the fabrication of complex structures and customized designs with high precision and efficiency. The authors discuss various 3D printing techniques, including Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), and inkjet printing, and their applications in chemical, pharmaceutical, and biological research and development. They highlight the advantages of 3D printing, such as rapid prototyping, cost-effectiveness, and the ability to produce patient-specific medical devices and personalized medications.

Furthermore, the review delves into specific examples of 3D printing applications in chemistry, such as the fabrication of reaction vessels, microfluidic devices, and catalyst supports. In the pharmaceutical industry, 3D printing is utilized for drug delivery systems, personalized medicine, and dosage forms with controlled release properties. In biology, 3D printing enables the creation of tissue scaffolds, organ models, and lab-on-a-chip devices for biomedical research and regenerative medicine. The authors also discuss the challenges and future directions of 3D printing technology in chemical, pharmaceutical, and biological applications, including material selection, regulatory considerations, and scalability. Overall, the review highlights the transformative potential of 3D printing in advancing research, innovation, and manufacturing in these interdisciplinary fields.

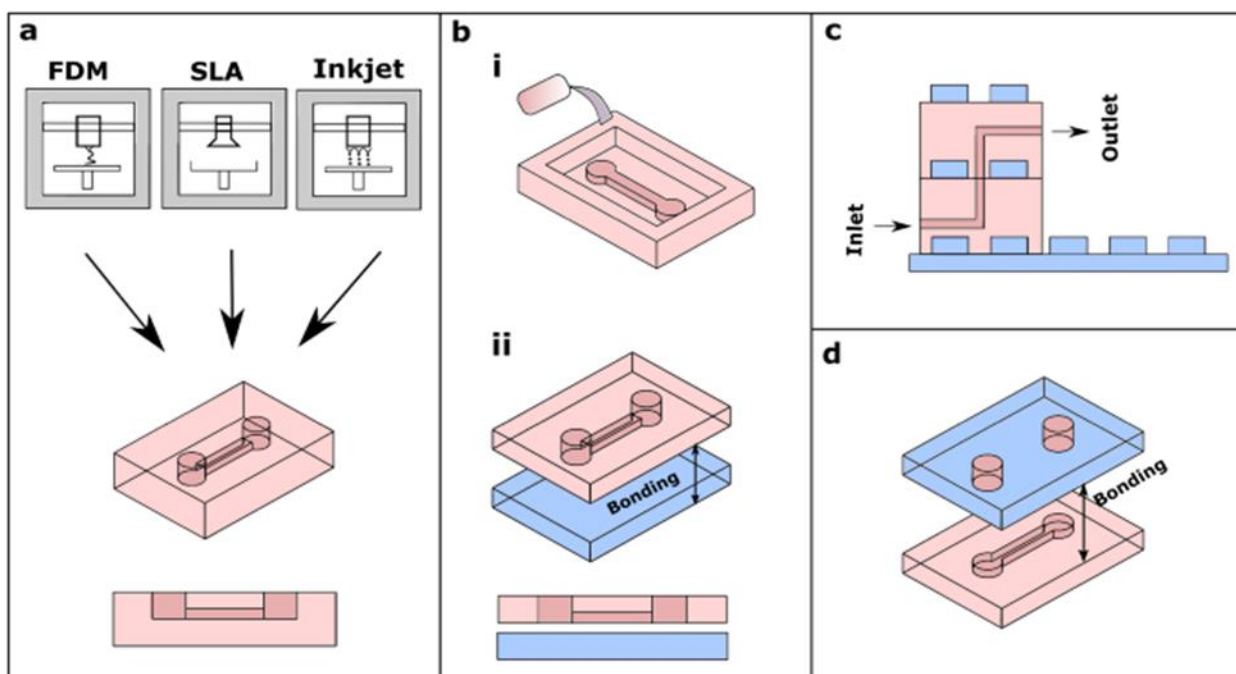


FIGURE 2.1 3D designing of microfluidic device in healthcare (Source: link.springer.com)

Christopher Heuer, *et al.* (2021) provided a comprehensive overview of the applications of 3D printing technology in the field of biotechnology, particularly focusing on miniaturized and microfluidic systems. The paper begins by discussing the fundamentals of 3D printing technology, including various printing techniques such as Fused Deposition Modeling (FDM), Stereolithography (SLA), and Selective Laser Sintering (SLS). It highlights the advantages of 3D printing in biotechnology, such as its ability to create complex and customizable structures, rapid prototyping capabilities, and cost-effectiveness. The authors then delve into the specific applications of 3D printing in biotechnology, with a focus on miniaturized and microfluidic systems. They discuss how 3D printing enables the fabrication of precise and intricate microfluidic devices for various applications, including cell culture, drug discovery, biosensing, and bioanalytics. These microfluidic systems offer advantages such as reduced sample volumes, enhanced automation, and improved control over experimental parameters.

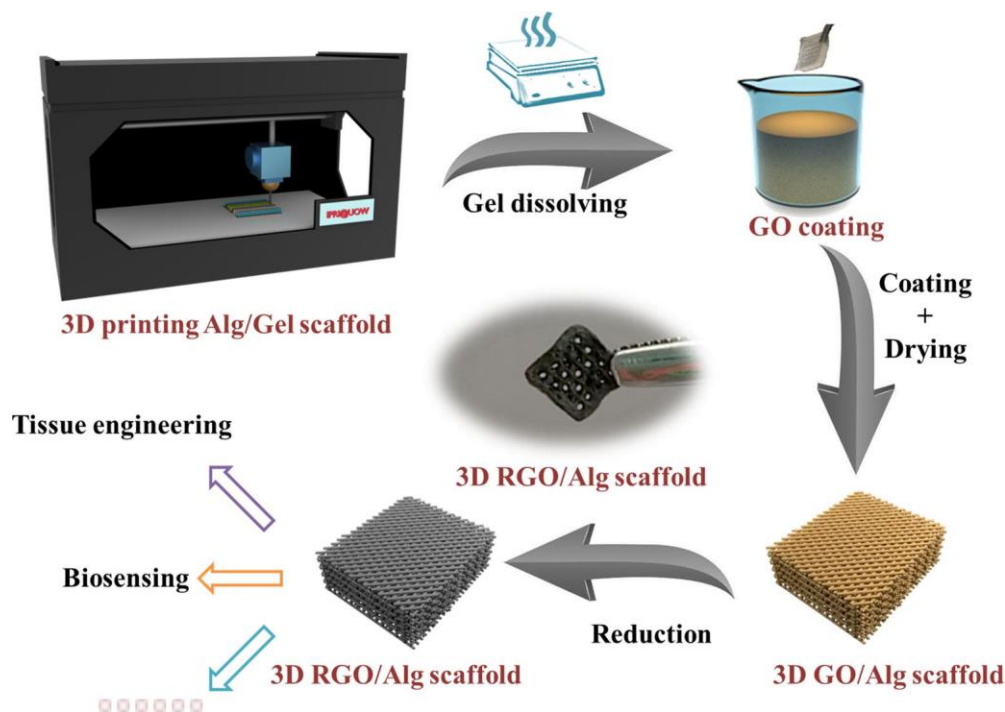


FIGURE 2.2: 3D Printing of Cytocompatible Graphene/Alginate Scaffolds for Mimetic Tissue Constructs (Source: www.frontiersin.org)

Additionally, the review explores the use of 3D printing in creating tissue engineering scaffolds, organ-on-a-chip devices, and lab-on-a-chip platforms for biomedical research and regenerative medicine. It also discusses the integration of 3D printing with other technologies such as 3D bioprinting and microfabrication techniques to develop multifunctional and customizable biotechnological solutions. The authors highlight key challenges and considerations in the use of 3D printing technology in biotechnology, including material selection, biocompatibility, surface properties, and scalability. They also discuss emerging trends and future directions in the field, such as the development of novel bioinks, advanced printing techniques, and the integration of artificial intelligence and machine learning for design optimization. Overall, the paper provides valuable insights into the applications of 3D printing in biotechnology, particularly in the context of miniaturized and microfluidic systems. It underscores the transformative

potential of 3D printing technology in advancing research, innovation, and applications in biotechnology and related fields.

Q. Wang, Jia-Ming Zhang & Shuai Li (2018) provided a concise overview of the latest advancements in the development of sensors for detecting both gaseous and dissolved oxygen. The paper began by highlighting the importance of oxygen sensors in various fields, including environmental monitoring, biomedical applications, and industrial processes. It emphasized the need for sensors capable of accurately and reliably detecting both gaseous oxygen in the atmosphere and dissolved oxygen in liquids. The authors discussed recent advances in sensor technology, focusing on innovations in materials, fabrication techniques, and sensing mechanisms. They explored various types of oxygen sensors, such as electrochemical sensors, optical sensors, and nanomaterial-based sensors, highlighted their unique advantages and applications. The review delved into the challenges and limitations of existing oxygen sensor technologies, such as sensitivity, selectivity, and stability. It discussed strategies for overcoming these challenges, including the use of novel materials, innovative sensor designs, and advanced signal processing techniques.

The paper also addressed emerging trends and future directions in the development of oxygen sensors, such as the integration of sensors with wireless communication systems for real-time monitoring, the miniaturization of sensors for wearable and portable devices, and the development of sensors with enhanced durability and longevity. Overall, the minireview provided a comprehensive overview of recent advances in oxygen sensor technology, offering valuable insights into the current state-of-the-art and future prospects in this rapidly evolving field.

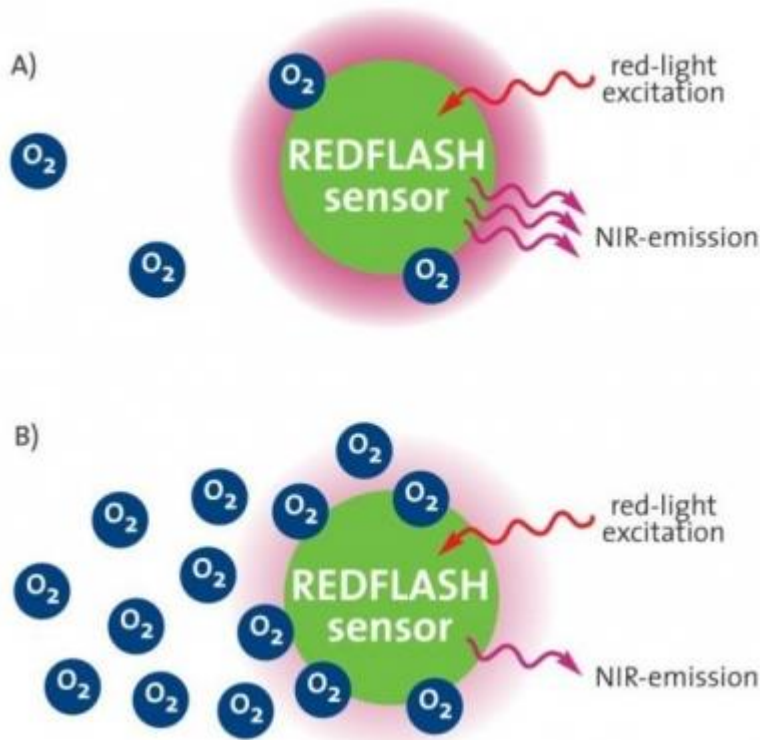


FIGURE 2.3 Optical DO Probe working (Source: www.pyroscience.com)

Dietmar W. Hutmacher and Harmeet Singh (2021) explored the utilization of computational fluid dynamics (CFD) in enhancing the design and operation of bioreactors for 3D cell culture applications. The paper began by discussing the importance of bioreactors in tissue engineering and regenerative medicine for cultivating cells in a controlled environment to mimic physiological conditions. It highlighted the need for efficient mixing, nutrient transport, and waste removal within bioreactors to support cell growth and function. The authors introduced computational fluid dynamics as a powerful tool for simulating and optimizing fluid flow patterns, shear stresses, and mass transfer properties within bioreactor systems. They discussed how CFD simulations can help in the design and optimization of bioreactor geometries, impeller configurations, and operating conditions to improve cell culture performance.

This review explored various applications of CFD in bioreactor design, including perfusion bioreactors, stirred-tank bioreactors, and microfluidic systems. It discussed

case studies and examples of CFD modeling in optimizing bioreactor parameters such as flow rates, mixing efficiency, and shear stress distribution to enhance cell viability, proliferation, and differentiation. The paper also addressed challenges and limitations associated with CFD modeling in bioreactor design, such as the complexity of biological systems, the need for accurate input parameters, and computational resource requirements. It emphasized the importance of validation and verification of CFD simulations through experimental validation to ensure reliability and accuracy. Overall, the paper provided valuable insights into the application of computational fluid dynamics for improving bioreactor design and 3D cell culture techniques in tissue engineering and regenerative medicine. It underscored the potential of CFD as a predictive tool for optimizing bioprocess parameters and enhancing the scalability and reproducibility of cell-based therapies.

S.M. Mousavi, et.al (2007) presented a study that combines experimental investigation and computational fluid dynamics (CFD) simulation to analyze ferrous bio-oxidation in a bubble column bioreactor. The paper began by introducing the process of ferrous bio-oxidation, which involves the oxidation of ferrous ions (Fe^{2+}) by microorganisms to produce ferric ions (Fe^{3+}) in an aqueous environment. This process plays a crucial role in various industrial applications, such as the treatment of acid mine drainage and the bioleaching of metal ores.

The authors described the experimental setup used to investigate ferrous bio-oxidation in a bubble column bioreactor, including details of the reactor geometry, operating conditions, and analytical techniques. They conducted experiments to measure important parameters such as dissolved oxygen concentration, pH, and ferrous ion concentration over time.

The paper also discussed the development and validation of a CFD model to simulate fluid flow and mass transfer phenomena within the bubble column bioreactor. The CFD model accounts for factors such as bubble size distribution, gas-liquid interfacial area, and microbial kinetics to predict the performance of the bio-oxidation process.

The results of the experiments and CFD studies are compared and analyzed to gain insights into the hydrodynamics and mass transfer characteristics of the bubble column bioreactor during ferrous bio-oxidation. The authors discussed the influence of operating parameters, such as gas flow rate and liquid circulation rate, on the overall process efficiency and reactor performance. Overall, the paper demonstrated the combined use of experimental and computational approaches to gain a comprehensive understanding of ferrous bio-oxidation in a bubble column bioreactor. It provided valuable insights into the design and optimization of bioreactor systems for industrial applications involving microbial oxidation processes.

Giovanni Putame, *et.al* (2021) discussed the utilization of 3D printing technology in the design and manufacturing of customized components for a mechanical stretching bioreactor. The paper began by introducing the concept of mechanical stretching bioreactors, which are used in tissue engineering and regenerative medicine applications to simulate mechanical forces experienced by cells in vivo. The authors highlighted the importance of customizable components in bioreactor design to accommodate various cell types, culture conditions, and experimental requirements. The authors described the application of 3D printing technology, specifically fused deposition modeling (FDM), in fabricating customized components for the mechanical stretching bioreactor. They discussed the advantages of 3D printing, such as the ability to produce complex geometries, rapid prototyping capabilities, and design flexibility. Furthermore, the paper presented detailed descriptions and illustrations of the customized components designed for the mechanical stretching bioreactor, including culture chambers, scaffold holders, and mechanical actuators.



FIGURE 2.4 3D Print of Bioreactor (Source: bpo.nl)

The authors discuss the design considerations, material selection, and manufacturing process for each component, highlighting their compatibility with cell culture and biomechanical stimulation.

The authors also discuss the experimental validation of the 3D-printed components in the mechanical stretching bioreactor, including assessments of mechanical performance, biocompatibility, and cell response. They present results demonstrating the feasibility and effectiveness of the 3D-printed components in supporting cell culture and promoting tissue growth under mechanical stimulation.

Overall, the paper demonstrates the potential of 3D printing technology in advancing bioreactor design and tissue engineering applications. It highlights the importance of customization and versatility in bioreactor design to meet the diverse needs of researchers and clinicians in the field of regenerative medicine.

CHAPTER 3

AIM AND OBJECTIVE

3.1 AIM

The aim is 3D designing of sterilized DO Probe chamber to create a controlled environment that guarantees accurate and reliable measurements of Dissolved Oxygen (DO).

3.2 OBJECTIVE

- Monitoring dissolved oxygen (DO) levels is crucial for maintaining ideal conditions and increasing the effectiveness of biotechnological processes.
- Conventional DO probe chambers can be challenging, dangerous, and compromise data integrity due to the high chances of microbial contamination.
- Inaccurate measurements and production of toxic compounds can result from the use of non-sterile DO probe chambers.
- The concept of a sterilized DO probe chamber has been introduced to address these challenges and provide 100% sterility, accurate measurements, improved performance, and cost efficiency.
- The proposed 3D design for the sterilized DO probe chamber ensures reliable, accurate, and consistent measurements of dissolved oxygen levels while maintaining the highest standards of sterility and quality assurance.

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS

The material used for the building of the parts is: ABS and TPU. Acrylonitrile Butadiene Styrene (ABS) was used to create the container and funnel. Its ability to withstand high temperature makes it suitable for sterilization in autoclave. Thermoplastic polyurethane (TPU) is used for creating the cork due to flexibility which makes it easier to fit.

4.2 METHODS

4.2.1 DESIGN:

The most important step in creating a new product is the process of designing it. In our case we made use of a designing platform known as “3D Experience”. In today's dynamic world of design, engineering and manufacturing, 3D Experience software stands out as a game changer that transforms product design, development and delivery. This advanced set of software tools transcends traditional design methods to provide a comprehensive platform that seamlessly integrates all stages of the product lifecycle. Our 3D Experience software harnesses the power of three-dimensional modelling to create digital replicas of physical materials, objects with unparalleled precision and realism. Advanced modelling techniques allow users to visualize concepts, simulate real-world scenarios, and refine designs with incredible efficiency and accuracy. But 3D experience software is more than just a design tool—it's a comprehensive ecosystem that encompasses all aspects of a product development.

From initial brainstorming and planning to design and manufacturing, 3D experience software provides a unified platform where teams can collaborate, communicate and

innovate together in real time. One of its standout features is collaboration. By breaking down barriers and facilitating offline communication between teams, locations and expertise, it fosters a culture of innovation and adaptation that accelerates market entry and creates competitive advantage. In addition, 3D experience software is forward-looking and constantly evolving to meet the changing needs of the industry.

With cloud-based deployment capabilities, automatic updates, and access to a wide range of applications and services, organizations can stay ahead of the curve and meet new challenges and opportunities. Our 3D experience software represents a significant shift in product development—one that enables organizations to unleash creativity, streamline processes and deliver innovative and state-of-the-art products that exceed customer expectations and drive business growth. Using 3D experience software is not only a choice for startups and large corporations alike, but rather a strategic necessity in today's fast-paced, fiercely competitive world.

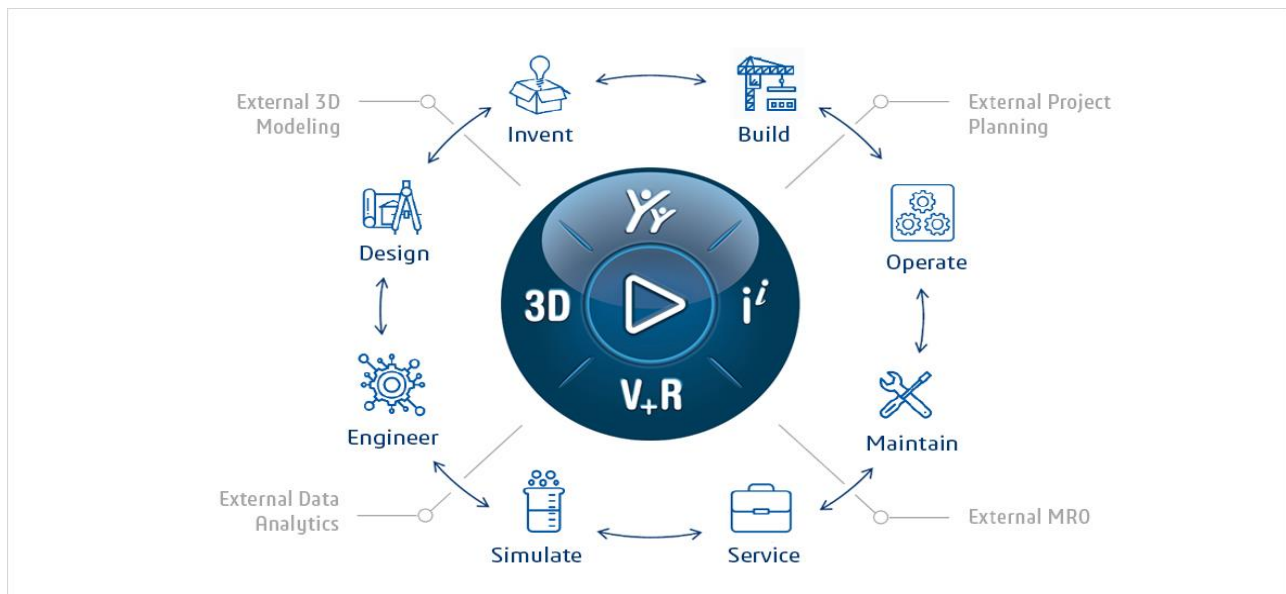


FIGURE 4.1 3D Experience software (Source: SolidWorks)

Our aim was to design a simple yet effective tool using this software. The platform was easy to understand and use even for beginners like us. We were taught the basics of designing an object. The platform contains many features which allows us to choose the right tool for the object that we wish to design.

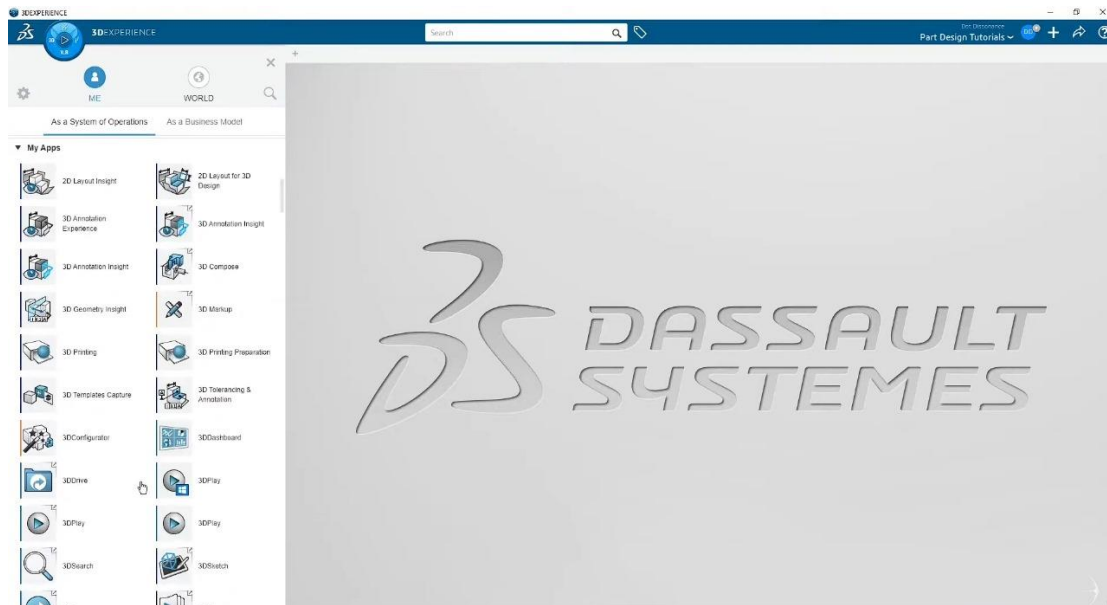


FIGURE 4.2 Homepage (Source: 3D experience CAD)

We made use of a feature called as Part Design which allows to create/design models that we desire. This feature has tools of its own which helps us in effectively creating a model of our interest. This can be found among the various apps present in the platform.

4.2.2 DESIGN PROCESS

Part design in 3D experience software involves a systematic process of creating digital models of individual components that make up larger assemblies or products. Here's an overview of the part design process in 3D experience:

- **Conceptualization:** The design process typically begins with conceptualization, where designers brainstorm ideas and concepts for the part based on project

requirements, functional specifications, and aesthetic considerations. We should have proper understanding about the concepts of DO probe and bioreactors and other parameters related to the project.

- **Sketching:** Using the digital sketching tools included in the 3D experience software, designers proceed to create preliminary outlines and concepts for the part. This aids in the refinement and visualization of design concepts prior to moving forward with detailed modeling. Rough sketches of chamber were made using the software.
- **3D Modeling:** Following concept development, designers proceed to 3D modeling, where they use parametric or direct modeling techniques to produce a digital representation of the part. The model was designed with different parameters.
- **Detailing:** During the detailing phase, additional features, details, and annotations were added to the part to enhance its functionality, manufacturability, and aesthetic appeal. This includes adding holes, threads, ribs, bosses, and other design elements.
- **Surface Modeling:** The complex surface geometry was designed using surface modelling techniques to create smooth and organic shapes. Surface modelling tools allowed for the creation of complex curves, sweeps, lofts, and blends to achieve the desired shape.
- **Validation:** Once the part design is complete, validation and analysis are performed to ensure that it meets performance requirements and specifications. This involve running simulations for structural analysis, thermal analysis, fluid flow analysis, or other types of analysis depending on the application.
- **Documentation:** Finally, detailed documentation and drawings of the part were created, including dimensions, tolerances, materials, finishes, and other relevant information. This documentation was used for manufacturing, assembly, and quality control purposes.

Throughout the part design process, 3D experience software provides a comprehensive set of tools and features to support designers at every stage, from initial concept to final production. These tools enable designers to create innovative and high-quality parts that meet the needs of their projects and industries.

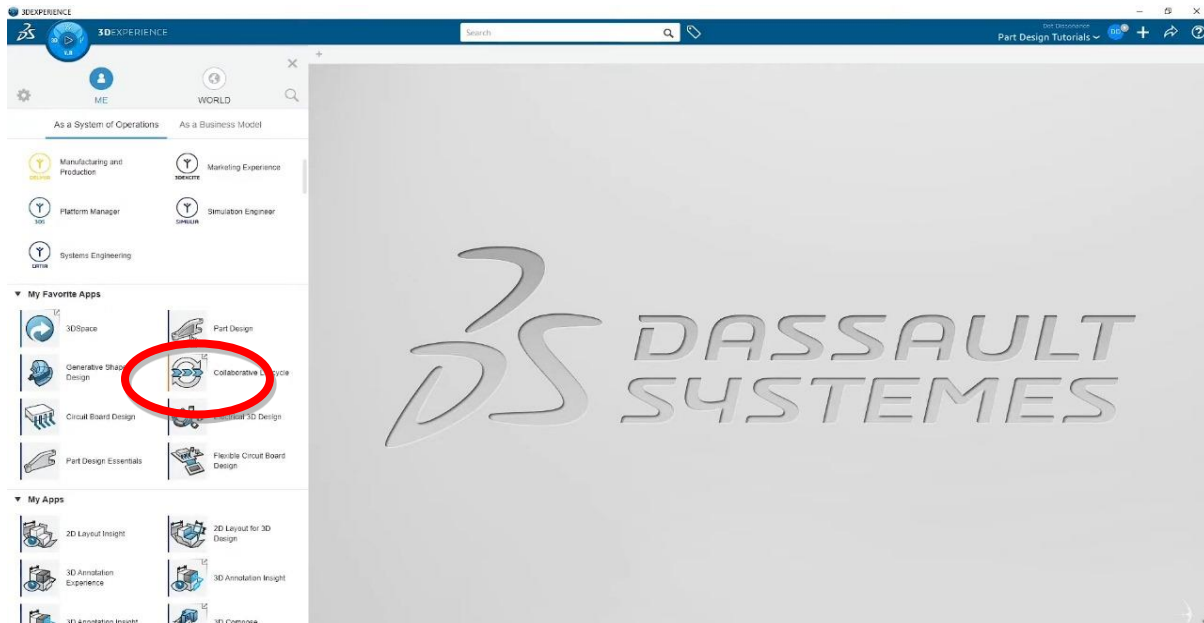


FIGURE 4.3 Choosing part design (Source: 3D experience CAD)

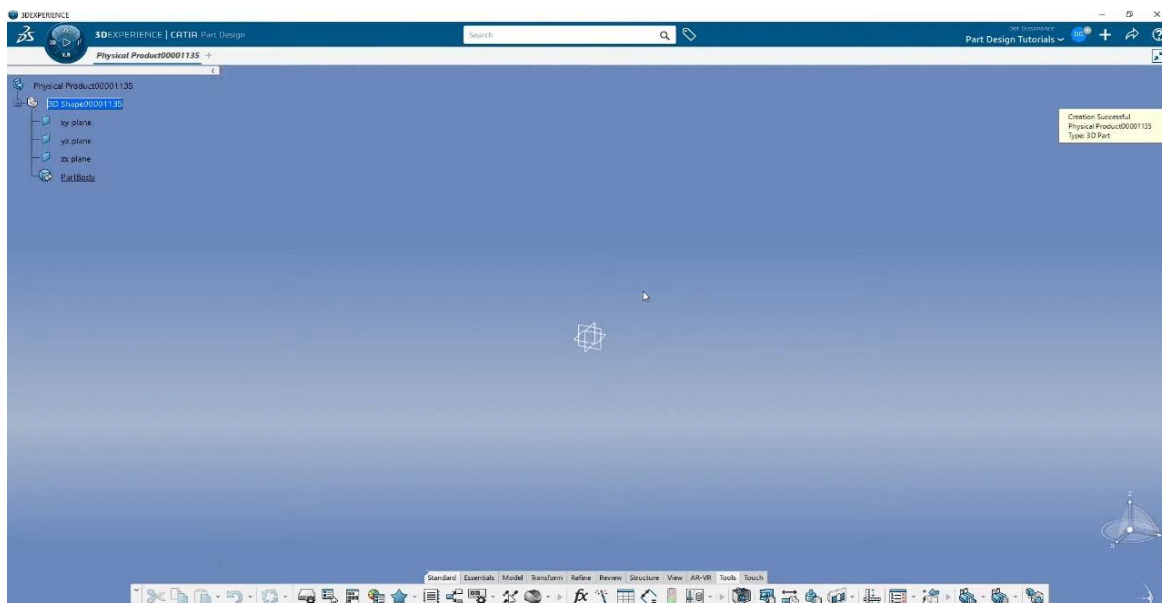


FIGURE 4.4 Part Design (Source: 3D experience CAD)

Our project primarily had one part which was the container for the DO probe. On the process of designing, we discovered that we needed more parts for the sole reason of creating a sterile environment. We designed a cork which was designed in order to insert the probe inside. It was made using a flexible material in order to make it air tight. We also designed a funnel which helps in the transfer of the fermented product from the

fermenter to the container. When we enter the part design page, we can see on the top left corner the model's name, the planes present and the different parts present. On the bottom we have the tools that are necessary for the design of the model.

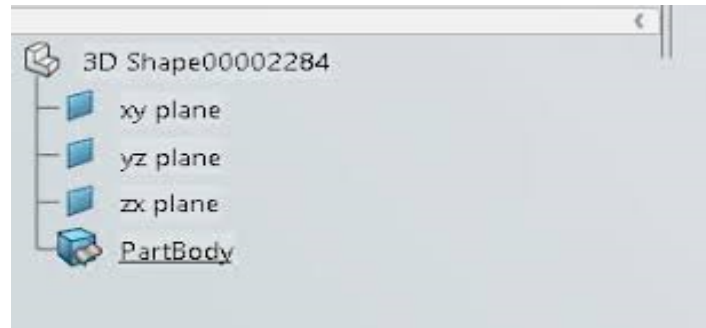


FIGURE 4.5 Different planes available for designing

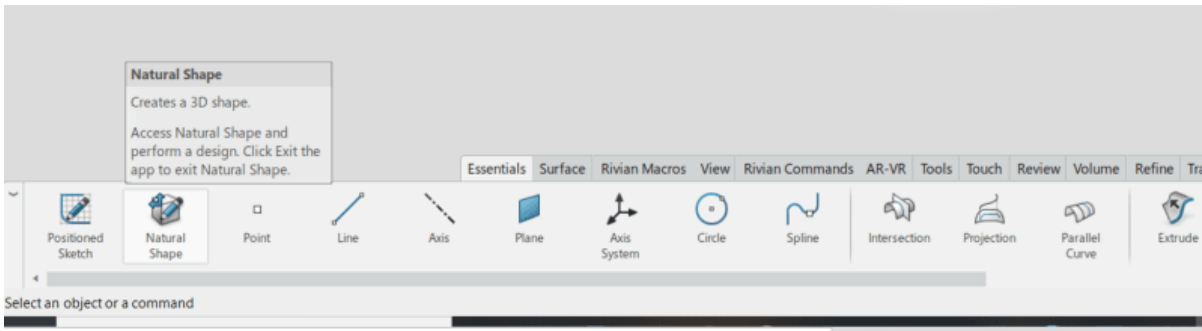


FIGURE 4.6 Components present on the part design page

(Source: 3D experience CAD)

Based on product requirements we must first choose the plane, after selecting the plane we make use of the annotation option to create the product of interest. We are able to create products of different 3-dimensional shapes like cube, cylinder, cuboid, etc.

4.2.3 TOOLS AND FEATURES

In part design using 3D Experience software, several major tools and features are commonly used to create, modify, and analyse parts. Here are some of the key tools:

- **Sketching Tools:** Sketching tools allow designers to create 2D profiles that serve as the foundation for 3D geometry. These tools include lines, arcs, circles, rectangles, polygons, and spline curves, as well as constraints and dimensions to control the shape and size of sketches.
- **Extrusion:** The extrusion tool is used to create 3D geometry by stretching a 2D sketch along a specified direction. Designers can extrude profiles to create prismatic shapes such as blocks, cylinders, and rectangular solids.
- **Revolve:** The revolve tool rotates a 2D sketch profile around a specified axis to create symmetrical 3D shapes. This is commonly used to create rotational features such as cones, spheres, and cylindrical components like screws and bolts.
- **Sweep:** The sweep tool allows designers to create complex shapes by sweeping a 2D profile along a specified path. This is useful for creating features like ribs, fillets, chamfers, and other intricate details that follow a specific trajectory.
- **Blend:** Blend tools are used to create smooth transitions between different shapes and surfaces. This is often used to create ergonomic features, transitions between different parts of the design, and organic shapes such as curves and contours.
- **Boolean Operations:** Boolean operations such as union, difference, and intersection are used to combine or subtract multiple shapes to create more complex geometries. This is useful for creating features like holes, cutouts, and complex patterns.
- **Surface Modeling:** Surface modelling tools allow designers to create and manipulate complex surface geometry. This is often used for parts with freeform or organic shapes, such as automotive body panels, consumer products, and aerospace components.

- **Filleting and Chambering:** Filleting and chambering tools are used to create rounded or bevelled edges on parts, improving aesthetics, ergonomics, and manufacturability.
- **Analysis Tools:** Analysis tools allow designers to evaluate the performance of parts through simulation and analysis. This includes tools for structural analysis, thermal analysis, fluid flow analysis, and other types of engineering analysis to ensure that parts meet performance requirements and specifications.

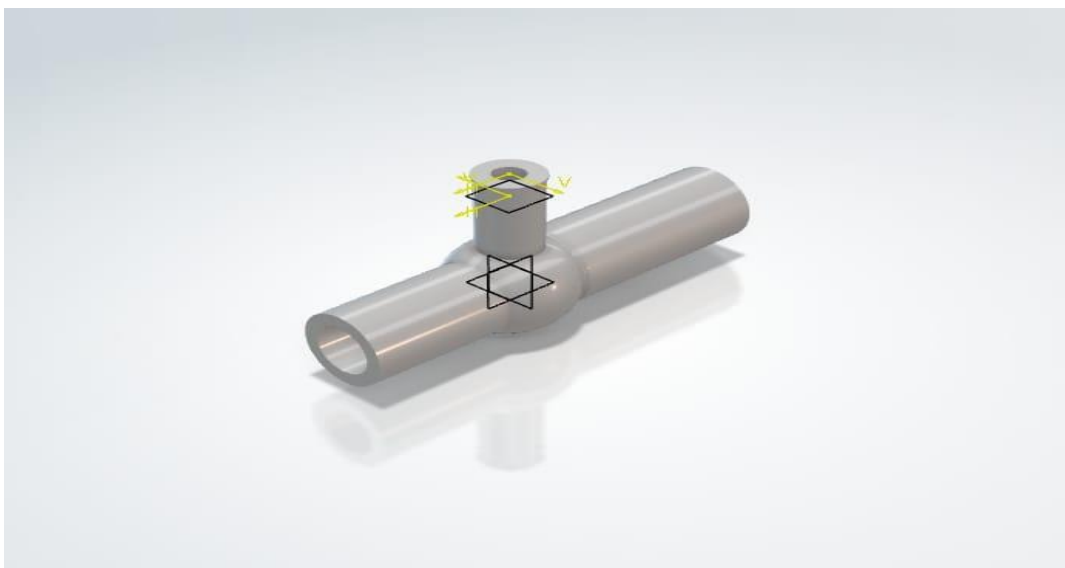


FIGURE 4.7 DO probe container

The model present in the figure 4.7 was designed using the part design feature of the 3D experience platform.

4.2.4 PRINTING

After the designing we go for the printing of the model which can done using various 3D printing machines. 3D printing, also known as additive manufacturing, is a revolutionary technology that allows the creation of three-dimensional objects by adding material layer by layer. Here's an overview of 3D printing:

1. **Printing Process:** In 3D printing, a digital model of the object is created using Computer-Aided Design (CAD) software. This digital model is then sliced into thin horizontal layers using slicing software, which generates instructions for the 3D printer.
2. **Materials:** A wide variety of materials can be used in 3D printing, including plastics, metals, ceramics, and even food-grade materials. The choice of material depends on the requirements of the final object, such as strength, durability, flexibility, and appearance.
3. **Printing Technologies:** There are several different 3D printing technologies, each with its own advantages and limitations. Some of the most common 3D printing technologies include Fused Deposition Modelling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), and Direct Metal Laser Sintering (DMLS).
4. **Applications:** 3D printing has a wide range of applications across various industries, including manufacturing, healthcare, aerospace, automotive, consumer products, and education. It is used to create prototypes, custom parts, functional components, medical implants, architectural models, and much more.
5. **Benefits:** 3D printing offers several advantages over traditional manufacturing methods, including rapid prototyping, customization, design freedom, cost-effectiveness for low-volume production, reduced material waste, and decentralized production.
6. **Challenges:** Despite its many benefits, 3D printing also presents some challenges, such as limited material selection, slower production speeds compared to traditional manufacturing methods, post-processing requirements for surface finishing, and quality control issues.
7. **Future Trends:** The field of 3D printing is constantly evolving, with ongoing advancements in materials, printing technologies, software, and applications. Future trends in 3D printing include the development of new materials, faster printing speeds, larger build volumes, improved resolution and accuracy, and the integration of 3D printing with other technologies such as artificial intelligence and robotics.

3D PRINTING TECHNOLOGY

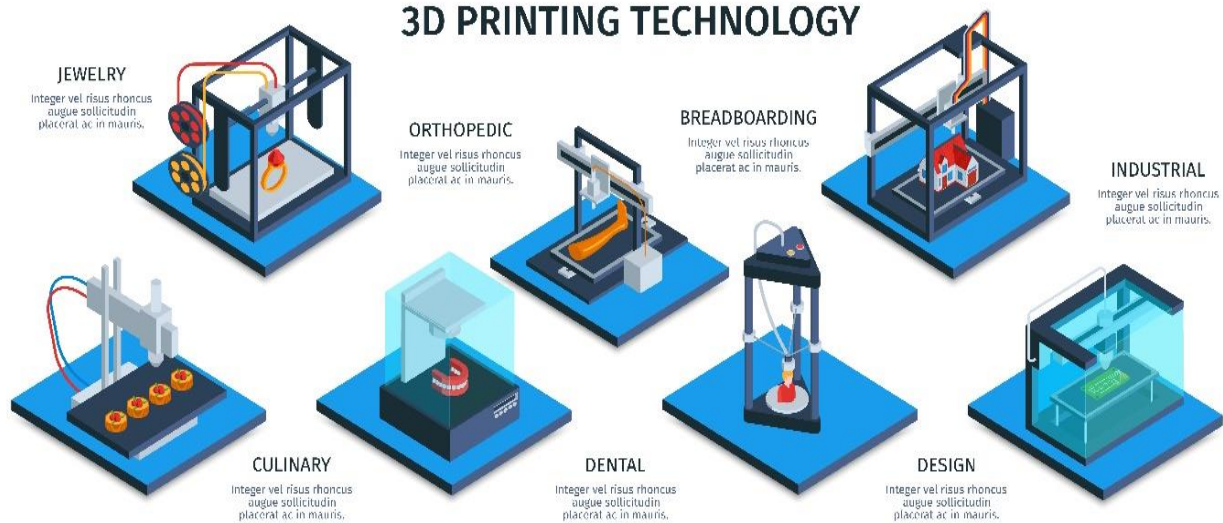


FIGURE 4.8 Application of 3D printing (Source: 3DPrinterOS)

Printing technology	Fused Deposition technology
Maximum Build Size (XYZ)	355 x 254 x 355 mm
Model Materials	PLA, ABS-M30, ASA, PCABS, Ditan, ABS ESD 7, ABSCF, QSR support material and more
Accuracy	+/- .200 mm (.008 in), or +/- .002 mm/mm (.002 in/in), whichever is greater.

Printing technology	Fused Deposition technology
Build volume	11.6 L x 7.6 W x 6.5 H in
Layer resolution	100 Microns 400 Microns
Filament compatability	MakerBot PLA , MakerBot Tough PLA Filament

MAKERBOT REPLICATOR
+

STRATASYS F370 (FDM)

Printing technology	Polyjet technology
Maximum Build Size (XYZ)	140 x 200 x 190mm (5.51 x 7.87 x 7.48 in.); Up to 1,174cm ²
Model Materials	Biocompatible Clear MED610™ VeroGlaze™ (MED620) Flexible clear biocompatible material MED625FLX™ VeroCyanV™ (RGD845) and more.
Layer thickness	Horizontal build layers down to 18 microns (0.0007 in.)

Printing technology	Fused Deposition technology
Build volume	30.5 L x 30.5 W x 45.7 H cm
Layer resolution	100 microns [0.0039 in]
Software file types	STL OBJ THING MAKERBOT

MAKERBOT (REPLICATOR-Z18)

STRATASYS DENTAJET (POLYJET TECHNOLOGY)

POLYGA H3 Polyga Scanners

POLYGA S1 3D SCANNING SYSTEM
Field of view (mm): 95 x 75 – 115 x 100
Point-to-point distance (mm): 0.07
Accuracy: Up to 35 micron

POLYGA H3 HANDHELD SCANNER
Field of View (mm): 300 x 180 to 500 x 310
Point-to-Point Spacing: 0.5mm or better
Accuracy (µm): 80

FIGURE 4.9 3D Printers (Source: 3DPrinterOS)

There are many 3D printers available for the purpose of 3D Printing as shown in the fig 4.10. Our model was designed with the use of “STRATASYS F370”.

The STRATASYS F370 is a professional-grade 3D printer designed for reliable and efficient production of prototypes, manufacturing tools, and end-use parts. Here's a detailed introduction to its features and capabilities:

1. **Advanced Printing Technology:** The F370 utilizes Fused Deposition Modeling (FDM) technology, which extrudes thermoplastic materials layer by layer to build 3D objects. This technology allows for high precision and accuracy in printing.
2. **Large Build Volume:** It offers a spacious build volume of up to 14.8 x 13.4 x 12.6 inches (375 x 340 x 320 mm), enabling the printing of large parts or multiple smaller parts in a single print job.
3. **Wide Range of Materials:** The printer supports various engineering-grade thermoplastics, including ABS, ASA, PC-ABS, Nylon, and more. This versatility allows for the creation of parts with different mechanical properties, heat resistance, and durability.
4. **User-Friendly Interface:** The F370 features a user-friendly touchscreen interface that simplifies the printing process. Users can easily monitor print progress, manage print queues, and adjust settings with intuitive controls.
5. **High Reliability:** Designed for industrial use, the F370 offers high reliability and consistency in print quality. It features automated calibration and material loading, reducing the need for manual intervention and ensuring repeatable results.
6. **Remote Monitoring and Management:** Users can remotely monitor and manage print jobs using the GrabCAD Print software, which offers features like job scheduling, print queue management, and real-time status updates.
7. **Scalable Workflow:** The F370 is part of Stratasys' F123 Series, which includes printers designed for different levels of production needs. This allows for a scalable

workflow, from rapid prototyping to low-volume manufacturing, within the same ecosystem.

8. Application Versatility: With its ability to produce durable, high-quality parts, the F370 is suitable for various applications across industries, including automotive, aerospace, consumer goods, and education.

9. Support and Services: Stratasys provides comprehensive support and services for the F370, including training, maintenance, and technical assistance, ensuring users can maximize the printer's capabilities.

In summary, the Stratasys F370 is a reliable, user-friendly 3D printer that offers high-quality prints, a wide range of materials, and scalability to meet the demands of industrial production and prototyping environments.

CHAPTER 5

RESULTS AND DISCUSSION

The bioprocess industry has great potential to improve bioreactor operations' efficiency and quality control through the 3D design of a sterilized DO probe chamber. First off, the sterilizable materials and design of the chamber reduce the possibility of contamination at crucial bioprocess stages, protecting sensitive cultures and averting expensive batch failures. Furthermore, the chamber's accurate dissolved oxygen level control and monitoring promote the development and productivity of microbial cultures, increasing the yields of beneficial bioproducts. Additionally, the chamber can be seamlessly integrated into current bioprocess setups, minimizing downtime and streamlining maintenance procedures, due to its compatibility with a variety of bioreactor configurations. Applications of this technology in the bioprocess sector are in line with the growing need for dependable and expandable solutions that can satisfy expanding production needs while upholding strict quality standards. Optimizing the chamber's design for particular bioreactor systems and investigating cutting-edge sensor technologies to improve real-time monitoring capabilities could be the main goals of future research and development in this field.

In the field of bioprocess industry, the 3D design of the sterilized DO probe chamber demonstrated several significant advantages. The exact positioning and safeguarding of the DO probe inside the chamber was one important advantage. By doing this, the probe could be positioned in the sample column as efficiently as possible, reducing the possibility of disturbances from things like turbulence or sedimentation that might skew the results of DO measurements. More dependable data on dissolved oxygen levels might be obtained by researchers by making sure that the probe is positioned steadily and consistently. To ensure accurate and dependable DO measurements, the design integrates sterilizable materials and a thoughtfully engineered chamber structure.

Moreover, the implementation of sterilization protocols within the chamber design proved crucial for maintaining the integrity of the DO probe and preventing microbial contamination. The sterilization methods employed in the chamber design effectively mitigated this risk, ensuring that the measurements obtained remained accurate and trustworthy over time. The 3D model was designed with the material named ABS. Acrylonitrile butadiene styrene (ABS) (chemical formula $(C_8H_8)_x \cdot (C_4H_6)_y \cdot (C_3H_3N)_z$) is a common thermoplastic polymer which is found to be thermally stable and best material which can withstand high temperatures. ABS (Acrylonitrile Butadiene Styrene) plastic typically melts at a temperature of around 220 to 250 degrees Celsius (428 to 482 degrees Fahrenheit). The main melting point of ABS is approximately 230 degrees Celsius (446 degrees Fahrenheit). This makes it suitable for a range of applications, including 3D printing, where it can be extruded and molded at these temperatures according to Alain Alonso. *et al.* (2023)



FIGURE 5.1 Acrylonitrile Butadiene Styrene (Source: waykenrm.com)

The use of 3D printing technology was instrumental in realizing the design and fabrication of the sterilized DO probe chamber. 3D printing offered unparalleled flexibility and speed in prototyping, allowing researchers to iterate on the design rapidly and customize it to suit specific research needs. According to the study by Christopher Heuer *et al.* (2021), 3D printing has been incorporated into the field of biotechnology for miniaturized systems for various applications.

5.1 3D DESIGN OF STERILIZED PROBE CHAMBER

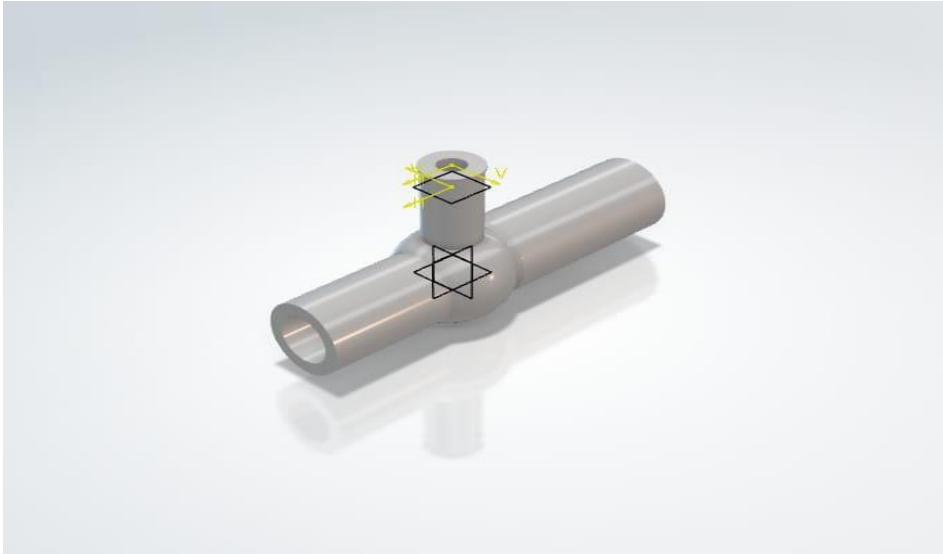


FIGURE 5.2 Probe Channel

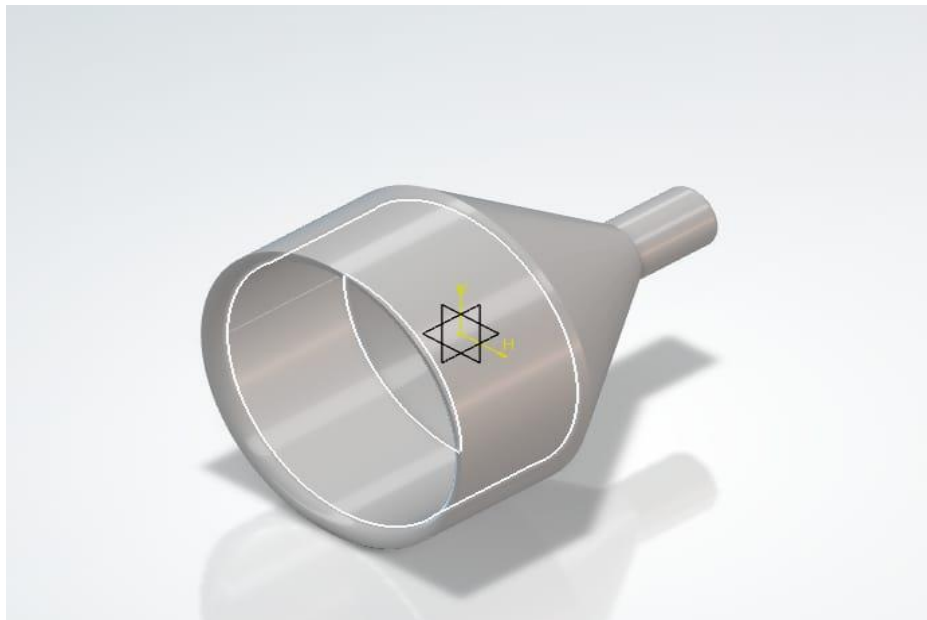


FIGURE 5.3 Filter Funnel



FIGURE 5.4 Probe Holding Cork

The above mentioned figures 5.2, 5.3, 5.4 have been designed with the help of a software named “3D Experience CAD” and the 3D model has been printed using the STRATASYS F370 printer.

Overall, this study finding demonstrates that how much 3D designing can advance the instruments and methods used for bioprocess monitoring. Through the integration of 3D printing technology, sterilization protocols, and precise design, researchers can create novel approaches to precisely measure important bioprocess parameters like dissolved oxygen. The limitations of conventional DO probes in terms of measurements, accuracy, sterility, cost, and other factors are found to be well-served by the sterilized DO probe chamber. The sterilized DO probe chamber has an extremely straightforward 3D design, a low level of complexity, and is simple to simulate.

CHAPTER 6

SUMMARY AND CONCLUSION

The design of a 3D-printed sterilized DO probe chamber offers a practical solution for ensuring accurate and contamination-free DO measurements in sterile environments as there is no exposure of the sample to the external environment. This innovation contributes to the advancement of bioprocessing and other applications reliant on precise dissolved oxygen monitoring. Future studies might concentrate on investigating new sterilization techniques and refining the design to meet particular industrial or laboratory needs like introducing filters into the chamber, etc. This design shows to be highly accurate and sterile, while also being cost-effective. The 3D model was constructed using ABS and TPU, materials that have been found to be inert and thermally stable. It has been discovered that the sterilized DO Probe Chamber produces accurate results and reduces errors in measurement.

Hence, we conclude that the sterilized DO probe chamber model has been found to be a great idea of improving the accuracy of the Dissolved oxygen data in bioprocess industry and also in other fields. It is found to be advantageous but still it requires many modifications and research in order to improve the filter attachment inside the chamber to avoid any contamination by the microbes present in the sample or culture medium. Additionally, the designed probe chamber is not universal which means it is not fixable with all the outlet of the bioreactors. It is required to be modified according to the sample outlet design. It requires some modifications in the design which can make it universal.

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