Module-22: An Ideal Fermenter Parameters & Basic Functions

What is Fermenter?

- A fermenter is an apparatus that maintains required optimal environmental conditions for the growth of industrially important microorganisms, used in large scale fermentation process and in the commercial production of a range of fermentation products like Antibiotics, Enzymes, Organic acids, Alcoholic beverages etc.
- To provide a controlled physico-chemical environment for the growth of a pure culture or a well-defined mixed culture of microorganisms is the key function of an ideal fermenter to obtain the desired fermentation products
- An ideal fermenter maintains optimal environmental conditions throughout the process for the process organisms, added substrates and additives for a quality end product
- Saving of energy and cost effective operation is very important concern as far as fermentation economics is concern
- Many times, the terms “Bioreactor” and “Fermenter” are used synonymously. There is a very minor difference between these two
- The bioreactor is used for the mass culture of plant and animal cells, while fermenter is mainly used for microbial culture
- The operational parameters and design engineering of fermenters and bioreactors are identical.

Parameters of an ideal fermenter

A fermenter should……..

- Facilitate the growth of a wide range of organisms capable of producing a varieties of fermentation products
- Do not allow entry to any sort of unwanted microorganisms thus to provide operation free from contamination
- Maintain a specific required temperature
- Provide adequate aeration and agitation to meet the metabolic requirements of the organisms during the process to attain mass and heat transfer within the system without damaging the process organisms
- Control the pH of the culture throughout the process
- Have provision of constant monitoring and control of level of dissolved oxygen
- Allow feeding of nutrient solutions and other supplementary requirements

- Provide access points for seed culture inoculation and sampling during the process
- Reduce liquid loss from the vessel during process by cooling system
- Be capable of being operated aseptically during the tenure of the process thus fulfilling the requirements of containment regulations
- Ensure that overall process period should have power consumption, as low as possible
- Be designed in such a way that it require the minimal use of labours during production process and downstream operations (i.e. harvesting, cleaning and maintenance)
- Should be suitable for a range of processes along with the containment regulations
- Be constructed in such a way that it ensure even internal surfaces, using welds instead of flange joints whenever possible
- Should have identical geometry at different operational level (i.e. both smaller and larger vessels in the pilot or scale-up plant)
- The material from which the fermenter is made up of should be inert and capable to withstand repeated stem sterilization conditions
- Apart from all these parameters, it is very imperative to have adequate service provisions for individual plants. The important service provisions are listed below.

✓ Provision of compressed as well as sterile compressed air
✓ Provision of chilled water, cold water and hot water
✓ Facility to supply steam (high pressure) and steam condensate
✓ Provision of continuous electricity and stand-by generator
✓ Confine and well protected storage facilities for media components
✓ Availability of control and monitoring equipment for fermenters
✓ Provision of instrument maintenance facilities
✓ Facilities for extraction and recovery equipment
✓ Arrangement of convenience and easy excess delivery of materials
✓ Appropriate containment facilities
✓ Facility for appropriate effluents treatment of generated from the production unit
✓ A well-equipped workshop for minor mechanical and electrical repair under urgent situation

Functions of different parts of a fermenter

Vessel: Size and Material

- Function of a fermenter is to carryout process under appropriate aseptic and pre-defined environmental conditions
- A fermentation vessel is designed in such a way that it requires minimal labour operation and maintenance
- It should have even internal surfaces with a similar geometry
- The volume capacity of the fermenter vary at different stages
- From laboratory experimental models with volume capacity of one or two litres, pilot scale fermenter up to one thousand litres
- Industrial scale fermenter are of several hundred litres capacity
- There are mainly two types of vessels base on the type fermentation process

1. Small scale fermenter (Laboratory scale fermenter)

a. These are made up of glass

b. The large vessels are made up of borosilicate battery jars

c. They have a round or flat bottom and a top flanged carrying plate

d. They are smooth, non toxic and corrosion free

e. These vessels can be sterilized by autoclaving

f. It is feasible to examine the interior of the glass vessels

g. The diameter of the vessel is usually more than 50 cm

2. Large scale fermenter (Industrial scale fermenter)

a. As, stainless steel is the most satisfactory material, it is used to manufacture vessels of high volume

b. These vessels can be sterilized in situ

c. They can withstand high pressure and corrosion

d. Corrosion resistance property is due to the thin hydrous film on the surface of the metal

e. This film is stabilized by chromium

f. This film is continuous, non-porous, insoluble and self-heating

g. The corrosion resistance property of the vessel can be improved by mixing tungsten, silicone and other elements at the time of manufacturing

Impeller (Agitator)

- This device is use for agitation (mixing up) of the medium
- Agitation creates a uniform environment in which all organisms remain in continuous contact with medium resulting in maximum up take of the nutrient.
- It also increase the air bubble path generated from the sparger (aeration device) hence more time to dissolve oxygen in the medium
- The impeller achieves a number of mixing objectives like suspension of solid particles, bulk fluid and gas phase mixing
- There are various types of impellers

1. Disc turbine
2. Vaned disc
3. Open turbine
4. Marine propeller

Sparger

- This device is used for aeration
- Aerobic fermentation process require sufficient oxygen to the microorganisms for metabolic requirements
- Depending on volume of medium in the fermentation vessel, different types of spargers are installed in the fermenter.

1. Porous sparger

a. It is made up of sintered glass or ceramics

b. It is used on the laboratory scale in non-agitated vessel

2. Nozzle sparger

a. It is a partially closed or single open pipe which provides stem to the air bubbles

b. As nozzle sparger causes a lower pressure and does not get blocked, they are used as a single nozzle

3. Combined sparger – agitator

a. It introduced air through a hollow agitator shaft
b. The holes are drilled in the disc, which remains connected to the base of the main shaft from where it is emitting the air bubbles
c. It provide excellent aeration in a baffled vessel

- The efficiency of aeration depends on operation of agitator at a range of Revolution Per Minutes (RPM)

Baffels

- This device is used to avoid the vortex formation generated during the agitation of the medium
- Baffles are made up of metal strips attached 90^0 to the wall of fermentation vessel
- The diameter of the baffles is nearly one tenth of the vessel diameter
- The gap between the vessel wall and the baffles strips should be maintain in such a way that scouring action of the minimise microbial growth on the walls of the fermenter

Foam control

- A medium rich in protein when subjected to agitation, it generate foam
- If the excessive foaming is not prevented, it results in the leakage of the medium from the lid of the fermentation vessel and hence lead to the contamination of the fermentation medium
- A foam sensing devised is usually installed from the lid in the fermenter, set at a definite level above the broth surface
- When the foam rises and touches the probe tip, a signal is generated in form current and pass through the circuit of the probe and gives a signal
- If the fermentation operation is automatic, then the signal triggers the pump and antifoam agent is released within seconds mechanically or robotically
- It is also possible to add antifoam manually in case the process is not automatic

Temperature controlling (heating and cooling) devices

- Mechanical agitation and exothermic microbial metabolic activity generates heat during the fermentation process
- Endothermic microbial metabolic activity lower down the temperature of the fermentation medium

- To maintain this temperature, heat is to be either added to or removed from the system
- The cooling system is used to remove excess heat from the system
- Internal heating coils are used for providing heat (Note: *In case of lab scale process, the fermenter is placed in thermostatically controlled bath*)

Feed ports

- Feed ports are the tubes (for Lab scale fermenter) and pipelines (for large scale fermenter) connected to the nutrient reservoir
- These tubes or pipelines are used to add nutrients and acid/alkali in the fermenter before and during the fermentation process
- They are heat sterilized in situ and /or ex situ with stem
- It is advisable to sterilize after connection has been done and before any additions are made

Flow regulation and controlling devices (i.e. Valves)

- Five types of valves are used.

1. Safety valves

a. Any pipe layout which work under pressure are incorporated with these safety valves to

b. These valves protect the pipe layout and ensures that the pressure never go beyond the upper limit of the specified value

2. Globe valves

a. These valves do not regulate the flow of steam or water

b. They are suitable for general purposes use like completely opened or completely closed

3. Butterfly valves

a. When the diameter of the pipes is large and there is low or no pressure butterfly vales are ideal choice

b. These valves do not ensure aseptic operation

4. Ball valves

a. These valves are appropriate when aseptic condition is required

b. These valves can also be operated under high temperature

c. Ball valves can handle mycelia broths

5. Diaphragm valves

a. They are used for flow regulation

Sealing assembly

- Stirrer shaft, a device providing agitation must be sealed properly ensuring long term aseptic operation
- There are various types of sealing assembly available in the market, of which three are mainly used

1. Mechanical seal

a. Made up of a stationary part in the bearing and the rotating part on the shaft

b. A spring is used to press these two components together

c. A suitable lubricant should be apply to ensure friction free smooth rotation and control the heat generation at the point of stationary and moving parts of the seal

2. Packed gland seal

a. Several layers of rings made up of asbestos are used to seal the shaft

b. Periodical monitoring and replacement of these rings advisable to prevent the penetration of heat

3. Magnetic drives

a. This assembly is made up of two magnets

b. The driving magnet is held in bearing on the outside of head plate and connected to the drive shaft

c. The driven magnet is placed on one end of the impeller shaft and held in bearings on the inner surface of the top plate

Summary: Functions of various parts of a fermenter

Sr.	Parts of fermenter	Function
1	Impellor (agitator)	To stir the media continuously and hence prevent cells from settling down, and distribute oxygen throughout the medium
2	Sparger (Aerator)	Introduce sterile oxygen to the media in case of aerobic fermentation process
3	Baffles (vortex breaker)	Disrupt vortex and provide better mixing
4	Inlet Air filter	Filter air before it enter the fermenter
5	Exhaust Air filter	Trap and prevent contaminants from escaping
6	Rotameter	Measure flow rate of Air or liquid
7	Pressure gauge	Measure pressure inside the fermenter
8	Temperature probe	Measure and monitor change in temperature of the medium during the process
9	Cooling Jacket	To maintain the temperature of the medium throughout the process
10	pH probe	Measure and monitor pH of the medium
11	Dissolve Oxygen Probe	Measure dissolve oxygen in the fermenter
12	Level probe	Measure the level of medium
13	Foam probe	Detect the presence of the foam
14	Acid	Maintain the required pH of the medium by neutralizing the basic environment
15	Base	Maintain the required pH of the medium by neutralizing the acidic environment
16	Antifoam	Breakdown and prevent foams
17	Sampling pint	To obtain samples during the process
18	Valves	Regulation and control the flow liquids and gases
19	Control panel	Monitor over all parameters

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