IB01x - 4.2 - The large-scale fermenter

In this unit we will focus on the large scale fermenter or bioreactor.

And as I explained in the previous unit, there are different types of fermenters, but there are three that you will encounter most frequently in the industry. These are the stirred tank reactor, the bubble column and the airlift loop reactor.

First of all, we have the stirred tank reactor. The stirred tank reactor is characterized by a stirring mechanism inside the tank. A rotating shaft is driven by a motor on top of the fermenter and passes through the lid into the reactor. It is important that this shaft has a good seal, to avoid leakage of fermenter contents or, even worse, contamination. The impeller connected to the shaft inside the tank will rotate and as a result the liquid in the STR will circulate. A different number of impellers can be placed on this shaft depending on the design of the fermenter. Sometimes 1, 3 or even 5 impellers are introduced with different shapes and sizes. Together, the number, size and shape of the impellers determine how the liquid is pumped in the radial, tangential and axial directions. This mixing is important because mass and heat need to be distributed all over the tank in order to keep optimal conditions. Another characteristic of the STR is the gas inlet in the bottom for oxygen supply. A sparger creates a flow of bubbles right under the impeller. The impeller re-disperses these bubbles and distributes them over the liquid. During their rise they transfer the oxygen from their content first to the liquid phase and then towards the cells. In a reversed path, they finally take up the CO_2 that is produced by the reaction inside the microorganisms, and remove it via the headspace. The STR is further characterized by baffles inside the tank, to create more turbulence and prevent the formation of vortex systems. This will help the mixing process inside the tank. Because of the rotating parts and the heavy construction with the motor on top, there is a maximum to the volume that can be set at about 500-1000 m^3, not bigger.

The advantage of a STR is that it is easy to control. The fermentation conditions like temperature and pH are well controllable. After the fermentation process is finished, the tank can easily be cleaned. Going from lab scale to full scale is well described and also it has a good gas transfer.

Also, there are also some disadvantages of a STR. The investment for such a reactor is high. Furthermore due to all the moving parts, quit a lot of maintenance is needed. And last the mixing of the fermenter is not optimal.

The bubble column is a much more simple design, because it does not contain any moving parts . Also the construction can be made much lighter, because you do not have a big and heavy impeller motor. This is not only an advantage for the reactor, but also for the building in which the fermenter is placed: there is simply more space for a taller reactor. Columns with a volume of more than 1000 m^3 have been implemented in the industry. Another special characteristic is that there is liquid mixing due to the flow of gas. Assuming the same total power input compared to the stirred tank reactor, that includes the sparger and the

stirrers, better mixing and mass transfer is achieved. However, this only works when the fermentation broth has a relatively low viscosity.

Due to the simple design of the reactor the investment cost is way lower compared to a STR. Because there are no moving parts, less maintenance is required. Furthermore the cleaning is very easy and it also has a good gas transfer. Disadvantages of the bubble column are that the parameters such as temperature and pH are less well controlled. Due to the high amount of gas pumping through the system, foam may be created. And last and one of the most major disadvantages of a bubble column is that this reactor will not work with liquids with a high viscosity. If the viscosity is higher than about 100 times the viscosity of water, then the energy from the gas is usually not enough to create sufficient mixing. In this situation you will have to resort to the stirred tank. In such stirred tank reactor you can put in more energy than in a bubble column, which enables you to bring viscous liquids also properly in motion. This allows broths over 1000 times more viscous than water to be fermented. So you have drawbacks and advantages in the bubble column and it depends very much from the composition of the broth what you should best select.

And then there is a third reactor design, the airlift loop reactor, this type of reactor is rather rare. You don't see them that much, but there are specific processes that can benefit from that due to some drawbacks of the bubble column. Liquid circulation is created by upward gas flow in one part of the reactor, forcing the liquid to rise upward as well, whereas the liquid flows back to the bottom of the reactor through an internal or external circulation loop.

Let's take a look to the advantages and disadvantages. The air lift reactor has no rotating parts, similar to the bubble column, and thus also has a simple design.

The ALR can also be cleaned easily and the gas transfer is very good. Furthermore the circulation loop allows to have some advantages over the bubble column like efficient heat removal. One of the disadvantages, just like the bubble column, is that the parameters such as the temperature and the pH are less controlled and due to high gassing foaming may be an issue. Mass transfer has been reported better than in a bubble column. But in general the mixing process is slower than of a bubble column, although still better than in a stirred tank.

In conclusion, for every design one needs to compare these three reactor options in order to select the best alternative. The table as given in this slide can help you in making this decision. You could, for example, consider viscosity, the need for high aeration, contamination sensitivity, maintenance requirements and then a choice can be made based on the comparison. The best option for our case study of 1,3-propanediol has been guided by using this table, and is the bubble column.

See you next unit!