The most selective hydrogenation

Hydrotherm® Technology

**Main features**
- Improved gas dispersion;
- High flexibility with selectivity;
- Low specific energy consumption;
- Steam production
- Fully automated plant;
- Reliable controls;
- No venting required as hydrogen is entirely consumed at the end of the reaction

**Improve melting properties**
Hydrogenation is an oils and fats modification process. It is mainly used on vegetable oils like soya, rape, cotton or sunflower to increase their oxidative stability and to improve their melting properties by reducing their degree of unsaturation. As a result, these oils or fats reach a consistency that is ideal for use as margarine or shortening components.

**Stable high-quality oils**
It is also possible to hydrogenate soyabean oil and fish oil and then to winterise or fractionate them for the production of very stable high-quality salad oils.

Hydrogenation is a reaction involving the use of a catalyst, most generally nickel, and is also an exothermic reaction.

For each iodine value unit drop, the oil temperature increases by 1.6 – 1.7°C. This heat is generally recovered to supply the factory low pressure steam headers.
**Perfect mixing**

Careful and precise hydrogenation requires that the constituents – oil or fat, gaseous hydrogen and solid catalyst – should be mixed perfectly. This is done in a closed vessel – the hydrogenator – by agitation of the catalyst – fatty material suspension in contact with hydrogen.

The purpose of agitation is to promote hydrogen absorption and to maintain a permanent flow of fatty material through the pores of the catalyst.

To do this, we use the so-called “dead-end” hydrogenator, in which hydrogen is forced into the oil and remains in it until the gas is fully consumed.

The dead-end hydrogenator is semi-continuous. It is equipped with several features to control and master reaction pressure, reaction temperature and the quantity and flow of hydrogen injected, all of which are essential to guarantee selective hydrogenation.

The feedstock used for hydrogenation is usually caustic refined and bleached oil. With the improvement of the degumming processes, there is a tendency to hydrogenate degummed oils.

After hardening, those oils are bleached and physically refined.

Oils for hydrogenation must respond to the following quality requirements.

- Free fatty acids: < 0.05%
- Soaps: < 25 ppm
- Phosphorus: < 2 ppm
- Moisture: < 0.05%
- Peroxide value: < 0.5 meq/kg
- p-Anisidine value: < 10

**Selectivity**

Selectivity is a determining criteria in the reaction as the saturation of the double bonds must not take place at random but according to a specific pattern.

Selectivity is more than a single concept:
- Selectivity (S1) is high when multiple unsaturation in the fatty acid chains is preferentially eliminated and the formation of saturated acids reduced to a minimum.
- Triglyceride selectivity is high when the attack on the fatty acid groups in the triglycerides is at random, that is as if they react as independent molecules.
- It is low when the attack of the 3 fatty acids in a triglyceride is correlated. Then $S_3 > s_3$, where $S$ is the stearic acid concentration.
- Specific isomerisation. In any catalytic hydrogenation, isomerisation takes place. The number of trans double bonds formed per double bond eliminated is a measure of the degree of isomerisation.

**Gas dispersion**

The Desmet Ballestra batch reactor is equipped with an agitator having 5 dual-flow impellers.

They have a large diameter to improve the homogeneity of the catalyst in the oil mass, to ensure good heat transfer to the coil and to disperse the hydrogen gas in the oil.

The upper impeller also creates a vortex to force headspace hydrogen back into the oil mass.

**Catalyst**

There exist different types of catalysts, each with its specific properties. Improved oxidative stability requires a high selectivity of poly-unsaturated acids. Most commercial catalysts however tend to increase the stearic and trans-fatty acids content at the same time, and this - in turn - affects the cold stability of the oil.

In industrial practice, dry reduced heterogeneous nickel catalysts are usually used. The nickel is supported on a natural earth such as kieselguhr and suspended in a fully hydrogenated fat, usually hardened palm oil or soybean oil.

The nickel content is about 25% of the total catalyst mass.

**Hydrogen**

The purity of the hydrogen used in this process is of great importance.

A purity of more than 99.8% is usually required. The impurities can be divided into two categories, those which act as catalyst poison (e.g. sulphur, chlorine, carbon monoxide, water, oxygen) and those which slow down or even stop the reaction due to an accumulation in the headspace during hydrogenation (inert gases like nitrogen, argon, methane).

The two current methods for the production of hydrogen are by electrolysis of water or by the steam reforming process.

To reduce the iodine value of an oil by 1 IV, 0.0795 kg or 0.883 m³ of hydrogen (at STP) per ton of oil are theoretically required. The practical amount of hydrogen required per ton of oil is 0.93 m³.
Reactor
The central unit in hydrogenation is the reactor. Two main types are in use: the dead end reactor and the gas loop reactor. In the first case, hydrogen is introduced into the oil and remains in the reactor until it is consumed. In the second system, hydrogen gas is forced through the oil in the converter, withdrawn from the headspace and sparged back into the oil. Over the last ten years, the dead end reactor has gained in popularity because plant, installation and maintenance costs are lower and because the process is easier to control.

The IV reduction rate is strongly determined by the operating conditions (temperature, pressure, catalyst concentration and activity) and is in the order of 0.5 to 3 IV units per minute.

Due to the high exothermicity of the reaction, efficient cooling is required to maintain a stable temperature.

The completion of hydrogenation is largely determined by the amount of hydrogen dosed in the reaction vessel. It is however not so easy to dose hydrogen accurately. One of the most accurate volumetric counters is the diaphragm gas meter which measures the gas volume over a very wide range (1/100) with an accuracy below 1%.

Oil/Oil heat exchanger
The oil/oil heat exchanger is a vertical cylindrical tank operating under vacuum. There are a number of concentric stainless steel coils inside the tank. Inside the coils the hydrogenated oil catalyst mixture is pumped from bottom to top.

The incoming oil flows over the coils from top to bottom. Perfect countercurrent heat exchange combined with systematic drying and deaeration of the oil is therefore guaranteed.

The preheated incoming oil flows from the oil/oil heat exchanger to the oil buffer/feed tank. The tank operates under vacuum and is located above the converter. The exact amount of oil the converter requires is measured here.

The dry hot deaerated oil is then discharged by gravity into the converter.

The catalyst is added, and the reaction starts.

In the converter, pressure, temperature and quantity of hydrogen are properly controlled.
Filter
When the reaction is over, the hydrogenated oil is cooled and filtered to remove the nickel catalyst.

The type of black filter determines to what extend the catalyst can be reused. The most popular filter is the conventional plate and frame filter (P&F), usually in combination with a polishing bag filter. Recent plants operate with semi-automatic horizontal or fully automatic vertical leaf filters.

The relatively large heel volumes of such filters however make them unsuitable for frequent feedstock changes. In such a case, the P&F filter remains the best option.

Removal traces of nickel
The oil from the black filter usually contains between 1 and 10 ppm of nickel. But the residual nickel content normally needs to be further reduced to below 0.1 ppm.

This can be achieved by addition of diluted citric acid (0.01%) in combination with 0.2-0.5 % of bleaching clay, in the post - bleaching section. The oil can then be deodorised to close the sequence.

Hydrotherm® Management

Process Automation

Easy management
Whatever the size of the plant, the various processes used in winterising are easy to manage today, thanks to the rational approach offered by computers and programmable logic controllers.

Reduction of risks
Automation serves various purposes, among which we would like to mention the reduction of risks attributable to human mistakes, the obtention of a better and constant quality, superior yields, reduced consumptions and a higher degree of safety.

Any framework of any network
The framework of automation networks – to which it is easy to add other digital systems- is so flexible that numerous solutions exist, for both new and old plants. These networks do meet the requirements of all the processes used today.

Centralised Supervision

Permanent follow up
Centralised supervision is the most efficient tool to permanently follow production.

Overall view
The method, using selected softwares, continually offers an overall view of the ongoing activities and of their historical account.

Reports
• Analogic reports
• Reports on variables
• Preventive maintenance reports
• Production reports: flowrates, quality controls, etc

Easy to analyze, these reports are the undeniable witness of the complete activity of a process.

No data unattented
Central supervision is the ultimate management tool that leaves no data unattended.

For more information on Hydrotherm®Technology for your specific process, contact your local Desmet Ballestra office!