

Lesson-14

Homogenization: Classification, Single Stage and Two Stage Homogenizer Pumps, Power Requirement for Homogenization

14.1 INTRODUCTION

Homogenizing in the dairy industry is used principally to prevent or delay the formation of a cream layer in full cream milk, by reducing the diameter of the butterfat globules.

The average storage temperature and duration of storage play an important part in determining the requirement of homogenization of milk, whether, as in pasteurized milk, it is stored for 1 to 2 weeks at refrigerator temperatures, or, as in UHT milk, at room temperatures for longer period.

In the past it has been very rare for pasteurized liquid milk to be homogenized, although the flavour of milk becomes fuller by homogenizing. A certain amount of cream was permitted to form to show the consumer clearly the full cream character of the milk. However, Homogenization process has become more common for Toned milk also. Sterilized milk, evaporated or condensed milk and sterilized cream are generally homogenized. Ice cream mixes, milk for yoghurt production and milk for milk powder manufacture are also homogenized.

The purpose for which the following are homogenized is:

Milk, cream, condensed milk	Prevention of cream separation
Coffee cream	Improvement in flavour, increased Whitening power, increase in Viscosity
Yoghurt	a more stable gel
Ice cream mix	less fat separation during freezing
Full cream milk powder	less separation of free fat

14.1.1 Mode of operation

In milk greater part of the fat volume consists of globules with a diameter ranging from 2 to 6 mm. A few fat globules may exist which have a diameter of 10 mm or more. Milk fat contains also a large number of small fat globules with diameters down to 0.1mm, but these do not greatly increase the total volume of the fat. The largest fat globules in liquid milk intended for only a few days' storage need not be smaller than 1 - 2 mm. If sterilized milk is to be made suitable for several weeks' storage, the range of diameter of the fat globules should lie between 0.2 and 0.7mm. Researchers found that the diameter of 0.7 mm is critical for fat clumping. With a diameter less than 0.7 mm the dispersion fat globule-milk serum is stable, since aggregates of fat globules become separated again by Brownian movement. This is not so for formation of clusters at higher fat contents (> 20 %) where the sub-units of the casein micelles keep fat globules together by bridge formation.

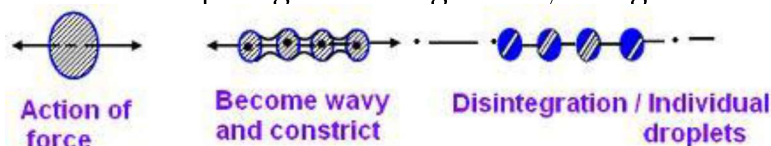


Fig.14.1 Principle of fat globule disintegration

Homogenization divides globules into smaller ones with diameters down to $<1\ \mu\text{m}$, depending on the operating pressure. This is done by forcing all of the milk at high pressures through a narrow slit, which is only slightly larger than the diameter of the globules themselves. The velocity in the narrowest slit can be 100 to 200 m/s. This can cause high shearing stresses, cavitation and micro-turbulence. The globules become deformed, then become wavy and then break up (fig 14.1).

Intense research activities in the last few years have been very successful in elucidating the actual mechanism of homogenization. There is a definite relationship between the Laplace number La , a dimensionless homogenizing pressure, and the degree of particle size reduction, irrespective of whether flow is laminar or turbulent.

$$La = \Delta p \cdot d_{mo} / \sigma$$

where Δp = pressure difference

d_{mo} = mean initial particle size.

σ = Interfacial tension.

When cavitations were suppressed, the degree of homogenization was the same at the same Laplace number, independent of the type of flow. This shows that turbulence is not a decisive criterion for the results of homogenization. However, the effect of homogenizing can be improved if cavitations take place.

According to the theories of flow mechanics, a particle size reduction should only be possible if the viscosity ratio η_{oil}/η_{water} is less than 4. In the homogenization of milk this ratio is 2 to 4 times larger. Nevertheless, the shearing effect at the homogenizer slit can not be excluded since there are high shear gradients as well as very high velocity gradients which can have an accelerating as well as a retarding action. As soon as a liquid thread is produced by deformation only small forces are needed to break it up. Some research workers established the following proportionality for the mean globule diameter d_m :

Cavitation occurs when the kinetic energy ($m \cdot v^2/2$) increases during flow through the slit and when, according to Bernoulli's equation, disregarding friction and deformation losses, the potential energy ($P \cdot v$) decreases to such an extent that the static pressure becomes as low as the vapour pressure of the liquid. The pressure distribution during flow through a homogenizer slit is qualitatively shown in Fig.14.2 Shortly after the liquid enters the homogenizer slit, the initial homogenizing pressure P_1 decreases sharply due to the sudden increase in velocity. Depending on the value of the back pressure P_2 which exists outside the slit, the pressure can drop to as low as the saturated vapour pressure. P_{2k} shows that a critical back-pressure must be present for cavitation to occur. For the formation of vapour bubbles due to cavitation it is necessary to have a local pressure of less than P_v and gas nuclei to trigger it off. De-gassing of milk can influence cavitation negatively. Cavitation does not take place if the back pressure P_2 is higher than P_{2k} .

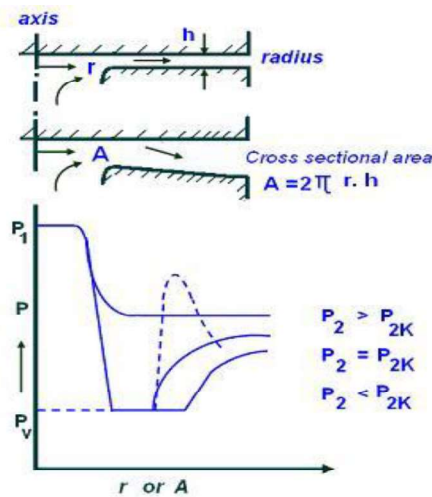


Fig.14.2 Homogenization

Implosion, of cavitation bubbles is one of the main indications of good homogenization. This is shown by a steep rise in pressure. Similar sudden pressure changes are also known to happen in the Laval valve which is of the continuously widening type. There, compression occurs when a uni-phase flow accelerated up to supersonic velocity abruptly changes into sonic velocity. Figure 14.3 shows further that the cross-sectional area of a homogenizer valve behaves like a Laval valve. Using Bernoulli's equation one finds, from the relationship,

$$\sqrt{v} \approx \sqrt{\frac{2}{\rho} (P_1 - P_2)}$$

that

the homogenizing velocity can be as high as about 250 m/s. The requirements for a compression shock can be fulfilled also in homogenizing, depending on the shape of the slit and the pressure conditions. The intensity of the compression shock depends on the geometry of the slit and it can be influenced as by the value of the applied back pressure. As in the valve with varying gap, the compression shock can also reach a maximum within the homogenizer slit, as shown by the dotted line. These are conditions which give optimum homogenizing results.

It is not known how implosions of bubbles disintegrate droplets. The following hypotheses have been proposed: Extremely high local pressure gradients form during spreading of the shock waves. An overlapping of many shock waves produces cavitation noises. The implosion of a single bubble cannot contribute to the disintegration of the fat globule. According to one of the hypothesis of researchers only the overlapping of shock waves, which cause cavitation noises, stimulates the fat globules to resonate near their own frequencies and disintegration occurs when the critical amplitude is exceeded.

With regard to shear stress, fat globule disintegration occurs mainly in flows which have high shear gradients. Flows which cause cavitation are responsible for pressure fluctuations. Water is required in medium sized homogenizer for cooling of piston rods.

14.2 TYPES OF HOMOGENIZER VALVES AND THEIR PROFILES:

Figure 14.3 shows types of homogenizer valves. Valve plugs are pressed with an adjustable force F onto the corresponding valve seat. In this way the homogenizing slit is formed when the incoming liquid has adjusted to the pressure P_1 ,

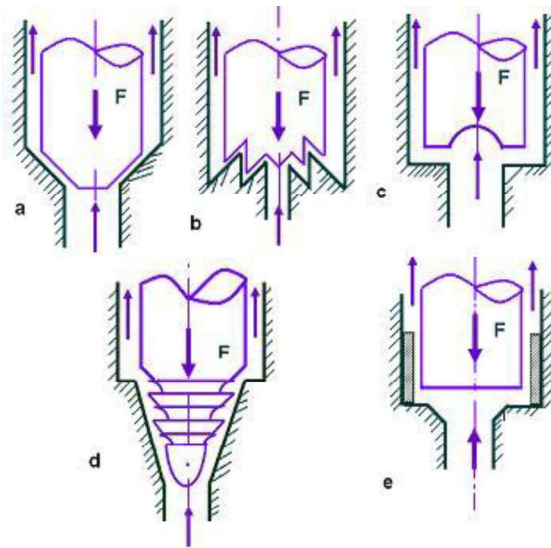


Fig.14.3 Homogenizer valves and their profiles

A conical shape, (b) causes changes in direction due to its profile, (c) shows a simple plate valve and (d) a conical shape but with a grooved valve face which forces alternating stresses onto the liquid to be homogenized, e shows a valve with a breaker ring which has a flat valve face and a conical seat. Changes in the radial cross section can be brought about by means of the cone. By altering the internal diameter of the breaker ring, the back pressure P_2 and therefore the position of the zone of cavitation can be adjusted.

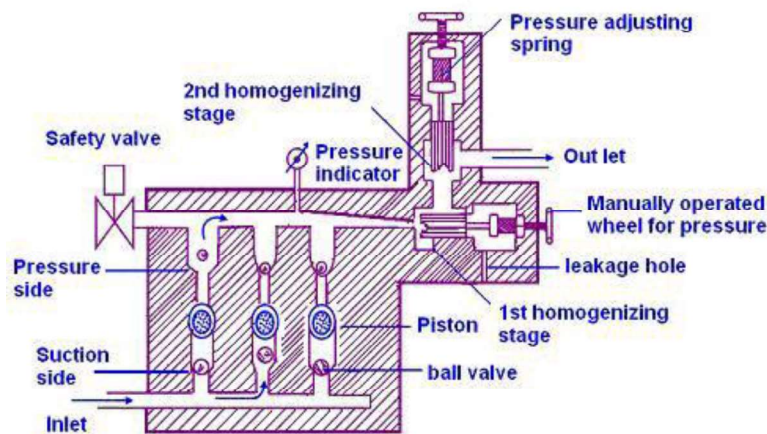


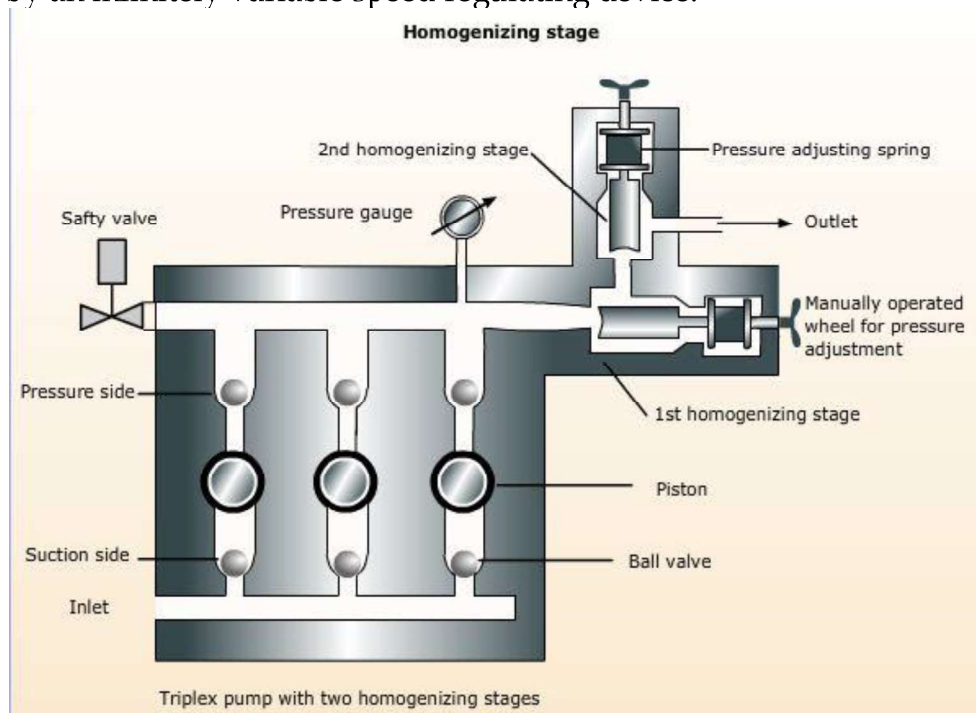
Fig.14.4 Homogenization

Figure 14.4 shows the mechanism of a 3 stage piston pump with two homogenizing steps joined in series. The 120 phase shift of each working piston respectively, sucks in the liquid while the valves open on their suction side and are closed on their delivery side. The pistons finally force the liquid through the homogenizer valve when the valve positions are reversed. The required pressure can be regulated from outside by pressure springs while the machine is in the operation. Beside triple stage piston pumps, five- stage ones are often used for homogenizing because of their even feed characteristics.

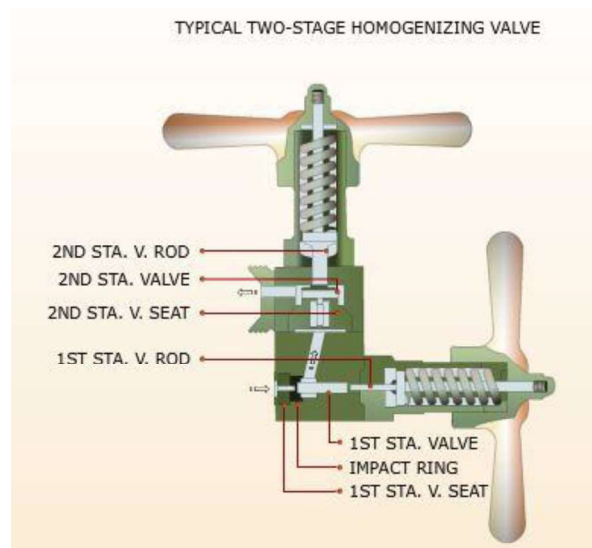
Two-stage homogenizing is not always necessary. It is used, however, if the broken up fat globules have a tendency to agglomerate after the first homogenizing stage (150 - 200 bar) in order to re-disperse them at 20 - 40 bar in the second stage. By a suitable construction of the valve, both

processing stages can be combined, A homogenization procedure of two or several stages has only a slight effect on the mean particle size. In modern homogenizer, the adjustment of pressure is done by pneumatically operated valve.

The throughput through a homogenizer can be regulated by either adjusting the piston stroke of a piston pump or by an infinitely variable speed regulating device.



Homogenizing Stage14.1



Typical Two- Stage Homogenizing Valve 14.2

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Lesson-15

Care and Maintenance of Homogenizers, Aseptic Homogenizers

15.1 INTRODUCTION

Homogenizer is heavy equipment, operating at high pressures. Hence, the care and maintenance is important for the long useful life of machine, and safe operation of this high pressure machine.

The condition of Homogenizer can be known from the extent of breaking of fat globules after homogenizing. The Homogenizing efficiency is found by either direct microscopic method or by cream layer method.

15.2 VALVES

The homogenizer valves over a period of use, will lose its proper shape, and may form grooves. It needs to be reground or replaced. If the seals of the valves are leaking, they have to be replaced immediately. The faces of the valve and valve seat must be kept in good serviceable condition to retain an efficient homogenization of the product. This can be recognized by the amount of wear that initiates at the bore of the valve and radiates out across the face. If the wear is up to two-thirds of the surface area, relapping of the valve with carborundum paste between faces can rectify this but further wear will allow erosion grooves to appear, recognized by straight lines radiating outward, and loss of homogenization will rapidly occur.

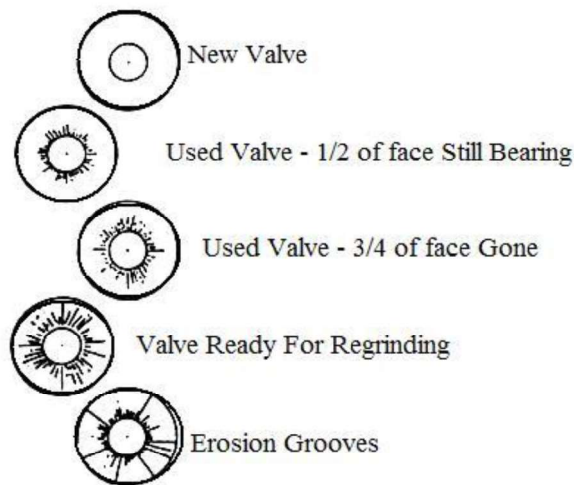


Fig.15.1 Homogenizer valve wear

15.3 PRESSURE GAUGES

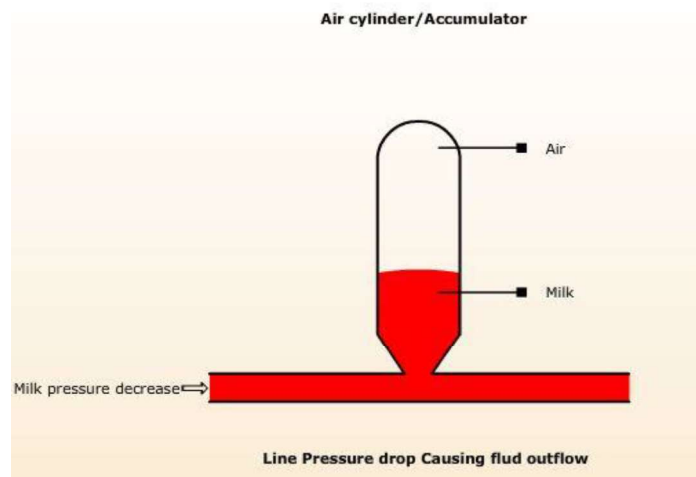
The pressure gauges measuring the pressure of milk must have stainless steel components and should be filled with glycol fluid to reduce corrosion and damping the vibrations. The gauges must be calibrated from time to time. The pressure gauges measuring the oil gauges must also be check for calibration frequently.

15.3.1 Safety Valve

It has to be tested for its setting, and whether it releases pressure at the set point, by use of Hydraulic test pump.

15.3.2 Reducing Pressure fluctuations

Reducing pressure fluctuations in suction side and discharge side is very important in effective operation of Homogenizer, as well as its effect on the related equipment like Pasteurizer to which it is connected. For this, generally, the Air cylinders are fixed both on suction and discharge pipelines connected to Homogenizer. The Air cylinders have air in the vessel that is cylindrical and in an inverted position, connected to the pipeline. As the pressure increases in the pipe line, the air in the cylinder gets compressed, resulting in a slight reduction in the line pressure. In the next stage in the cycle of operation, during suction stroke, the pressure in the line decreases, during which, the air in the vessel, which is at higher pressure related to the line pressure, will now expand, replacing some of the fluid that has entered into the vessel. Thus, the pressure fluctuations in the pipeline are reduced to some extent.



Air Cylinder Operation 15.1

15.4 POWER DRIVE

1. Whenever drive motor is repaired / replaced, the direction of rotation has to be checked, as the same shaft is most probably driving the lubrication mechanism, and would not deliver the lubrication oil at the required pressure, even if the rotation is slow.
2. The bearings, belts are to be replaced when necessary as per the preventive maintenance schedule. The lubrication oil, or the cooling water should not be spilling where belt drive is located, as it would cause slippage and damage to the belt.
3. Replacing V-belts one at a time (when wear is detected on one only) is a risky operation since the new one - being shorter - is likely to carry most of the load. Belts must be tensioned correctly to transfer the drive and prevent unnecessary wear. The following are suggestions on how to do a simplified testing during routine maintenance inspection. When stopped, a correctly tensioned V-belt should, if pressed firmly with the thumb near the mid-point (half way from centre to centre), depress $3/4$ of its own thickness for each one metre centre to centre distance.

During assembling and disassembling, the dismantled parts must be kept on table over a rubber mat to prevent damage to the parts as well as to avoid any contamination.

A daily inspection should be made of the oil level visible through the sight glass at the rear of the machine. Lubrication oil should be replaced regularly, as per manufacturer's instructions, and its pressure to be maintained while running the equipment. After draining off any condensate from the oil sump through the pet cock, oil should be added if required, before starting up the homogenizer. The oil should be completely drained and replaced, after every 6 months.

The levelling of homogenizer should also be maintained, as it is likely to get disturbed over the period due to vibrations during operation.

Cooling water should of the quality and flow rate recommended by the manufacturer. The flow to the piston rods should be sufficient, especially if water is cooling the oil.

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