The Use of Decanter Centrifuges in Surimi Processing

ABSTRACT: Conventional surimi processing systems include stages that are designed to remove certain water soluble components of fish mince. These processes also remove certain valuable insoluble components which reduce yield and potential returns. Decanter centrifuge technology was evaluated to determine if process efficiency would be improved. Results indicate centrifuging can recover from sixty to ninety-five percent of suspended solids in process wash water, and can reduce normal dewatering losses by approximately fifty percent. This level of improved efficiency indicates a considerable potential for decanter centrifuges in conventional surimi plant applications.

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I. Introduction

The traditional surimi process consists of heading and gutting and/or filleting, deboning (mincing), washing, dewatering, refining, dehydrating, and mixing. The applications for the decanter centrifuge that are examined here involve its use to minimize insoluble protein loss in the washing stage and its use for dewatering of the washed mince.

The purpose of the wash stage in the surimi process is to remove certain water soluble components of the mince. These include water soluble proteins, inorganic salts, and a variety of soluble compounds containing nitrogen. The traditional process uses a two-stage staggered batch system in which the mince is mixed with between one and five parts water, and dewatered. Dewatering is accomplished in a rotary screen between stages and after the second stage. This system has proven to do an adequate job of extracting the water soluble components, however it is not capable of doing so without significant losses of insoluble material.

Insoluble material "escapes" from the system by passing through the holes in the screens. Although these holes are quite small, significant amounts of insoluble protein escape in this manner. The screens assist in the production of these small particles by abrading the mince as it passes through.

An additional source of loss is the material, other than water, that passes through the screens on the press. All of the decanter applications discussed here are intended to either eliminate losses or recapture protein that has been lost in the system.

II. Separation Theory

The decanter centrifuge is one of many different types of centrifuges where centrifugal acceleration is used for separation. Today decanter centrifuges are commonly used in many industrial applications for continuous separation of solids from liquids with high solids contents.

All separation is a compromise. One of the phases has to be sacrified in favor of optimizing another. The ideal settings depend on the characteristics of the suspension to be separated.

Separation of solids from a slurry, actually the settling velocity (V_a) follows Stokes law:

$$V_a = \frac{dp^2 \times g \times (S_p - S_l)}{18n}$$

where: V_a = actual setting velocity [m/s]
dp = particle diameter [m]
g = gravitational acceleration [m/s^2]
S_p = particle density [kg/m^3]
S_1 = liquid density [kg/m^3]
n = dynamic viscosity [kg/m^3]

If the separation is taking place in a settling tank, g is equal to gravitational acceleration on earth (9.81 m/s^2).

When a centrifuge is used for the separation, the gravitational acceleration (g) is replaced by centrifugal acceleration ($r \times w^2$) developed in the "bowl". The settling velocity, V_a, in a centrifuge is thus

$$V_a = \frac{dp^2 \times (r \times w^2)\ (S_p - S_1)}{18n}$$

where r = radius of the bowl [m].

When continuous separation takes place, i.e. when the centrifuge is continuously fed with liquid to be separated and the separated phases are continuously discharged, the feed rate also has to be taken into consideration, as the retention time for the particles in the gravitational field is of great importance for the separation result.

There are three main factors affecting the separation result:

1) The design of the decanter centrifuge, including its geometrical configuration, the speed (rpm), the differential speed and conveyor type;

2) The characteristics of the liquid and particles to be separated, considering density, viscosity, particle size, particle configuration and concentration; and,

3) Conditions affecting processing, such as temperature and feed rate.

III. The Decanter Centrifuge

Description

Figure 1 shows a cross section of a decanter centrifuge. The main body of a decanter is the rotating bowl, wherein there is a rotating conveyor. A stationary inlet tube is inserted into the center of the conveyor. In the other end of the conveyor a gearbox is attached. The decanter bowl is enclosed in a vessel with discharge arrangements and mounted on a base frame with bearing houses in both ends. All parts that are in contact with product are made of stainless steel for easy cleaning.

The bowl consists of a conical section and one of several cylindrical sections flanged together (see figure 2). A large and a small end piece are mounted on opposite ends of the bowl, to which the bearing houses are attached.

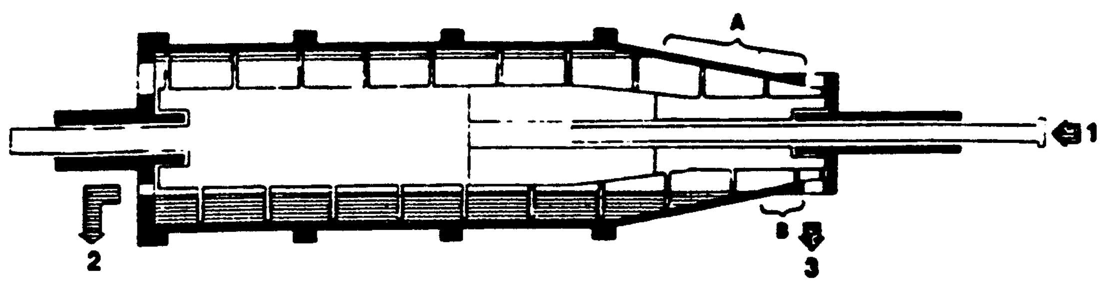

Fig. 1. Simplified cross-section of a decanter centrifuge.

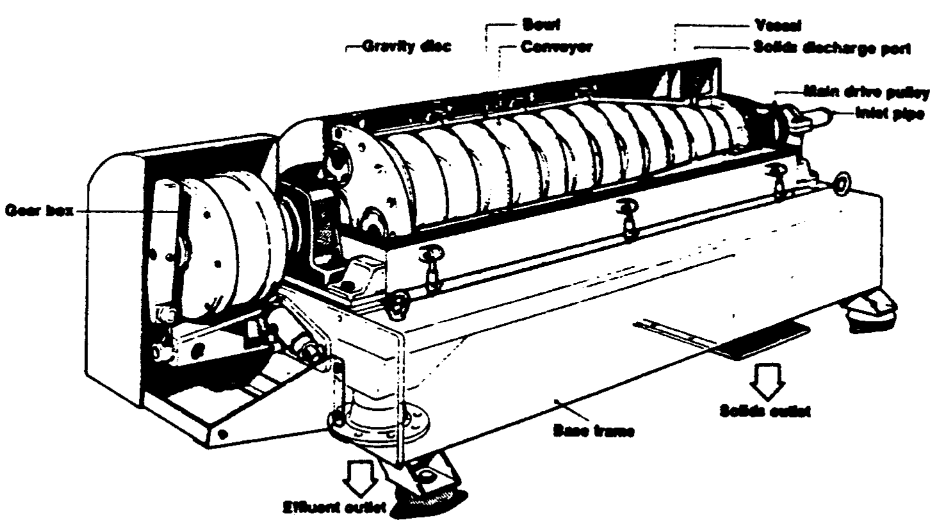

Fig. 2. Cutaway illustration of a decanter centrifuge adapted for use in a surimi production line.

The inner walls of the bowl are grooved in order to increase the friction between solids and the drum so that the solids are prevented from slipping backwards as the conveyor pushes it forward to the discharge ports. Solids are discharged through ports located in the small end of the conical section on a fixed radius. The effluent exits the bowl through holes in the big end-piece, wherein exchangeable gravity discs are mounted.

The conveyor is coaxially mounted in bearings inside the bowl and rotates in the same direction as the bowl but at a slightly different speed, in most applications from 5 to 100 rpm. The flights of the rotating conveyor push the separated solids to the discharge ports in the narrow end of the conical section.

There are many different types of conveyor designs for different applications. A conveyor with small pitch is normally used for soft sludge with "slip-back" tendency. The large pitch conveyor gives a higher solids handling capacity and is used for sludge that is easily conveyed. The small pitch conveyor also forms a narrower channel than the large pitch conveyor for the liquid to flow toward the liquid outlet. The narrower the channel, the sooner turbulent flow will occur and settled solids will be remixed with the clean liquid. The difference between bowl speed and conveyor speed is referred to as differential speed.

There are two reasons why a gearbox is used for the conveyor drive: to maintain a small differential speed, and to cope with the torque generated when conveying the cake. A large electrical motor is required to handle the torque generated by both the conveyor and the bowl. The gearing system is designed in such a way that the torque developed in the conveyor shaft is equalized by the torque developed in the rotating bowl assembly.

The feed is introduced through the stationary inlet tube into the feed zone in the conveyor body. The feed zone is designed to accelerate and distribute the feed into the liquid pool at the same rotational velocity as the bowl itself. The effluent and the cake are discharged from the bowl into the collecting vessel mounted in the baseframe.

Decanter Centrifuge Tuning

For best separation results, it is necessary to tune the decanter for the specific application. There are several functions that should be adjusted for surimi applications.

Increased main speed increases the g-force with a better liquid clarification and a dryer cake as a result, but when the main speed increases, the shear forces on the feed increase as well, which results in separation of more small particles. In some applications, where the feed is sensitive to shear, a worse result will be obtained when the main speed is increased.

A small differential speed allows the solids to dry out on the "beach" more than with a high differential speed. However a certain minimum differential speed has to be maintained in order to convey the volume of solids separated from the feed. The minimum differential speed is determined by the solids content in the feed and by the conveying-capacity per rpm of the conveyor. If the differential speed is too low, solids will escape with the effluent. In the worst case the bowl can become plugged with solids.

By changing the gravity discs in the large end piece (see figure 2), the depth of the pool and the length of the drying zone change. By using gravity discs with a large liquid radius, a shallow pool and a long drying beach are obtained. Conversely, gravity discs with a small liquid radius give a deep pool and a short drying beach.

A deep pool gives a long residence time in the gravitational field at a certain feed rate and therefore gives a better liquid clarification then when operating with a shallow pool. This means that an increased feedrate, which shortens the residence time in the gravitational field, can be compensated for by a deeper pool but with a slightly wetter cake.

The beach length is the determining factor for the dryness of the cake. The longer the beach, the dryer the cake and vice versa.

Another major factor that changes with the pool depth is the shear force, which is as important as all other factors. Shear forces will always be present when accelerating the feed to the same rotational speed as the liquid surface, which is determined by the pool depth. This means that with a deep pool and small liquid radius, the feed will be accelerated to a lower speed than if a shallow pool is used. The shear forces generate small particles, and create an emulsion if any fat is present. So it is most important to minimize the shear forces in the inlet zone.

Optimizing the decanter is like a giant loop. Increased mainspeed gives increased shear forces that generate more small particles that need longer residence time in the gravitational field to be separated; longer residence time can be obtained by deeper pool or lower feed rate. In many applications a lot of work can be saved simply by operating the decanter at a low main speed.

The way that the feed is handled before entering the decanter is most important for the separation efficiency. The feed should be continuously fed by a positive displacement pump from a tank with a minimum volume to ensure gentle treatment without allowing air to mix with the feed. A centrifugal pump is not recommended as it runs at high speed and the risk of shear and airmixing is high.

IV. Applications For Decanter Centrifuge in Surimi Production

For Recovery of Wastewater Protein

Since the losses of suspended solids in the wash and press water in a conventional surimi plant may be as high as 35% of the amount entering the wash stage, it is of greatest importance to recover as much as possible in order to boost the overall yield.

The amount of suspended solids in the wash water varies quite a bit depending on fish age, fish type, hole size and residence time in the screens, speed and types of pumps. These factors also have an influence on the amount of suspended solids in the press water, but more factors have to be added to the list such as dry matter content of the screen mince, speed and hole size of the refiner -- and of course, the characteristics of the press.

The best way to recover as much as possible of the suspended solids is to use the screen waste water to flush the press vessel, collect the water stream in a stirring tank before feeding it to the decanter centrifuge. This solution might seem complex, but it ensures a constant feed with constant feed composition which is, as said before, of greatest importance for the separation results in the decanter centrifuge. By using a decanter centrifuge for recovery of solids from screen and press waste water, up to 95% of the suspended solids can successfully be recovered, with a range from 60% to 95%.

The recovered solids should be mixed with the press cake even if the dry matter content of the decanter cake is a little lower than in the presscake. If the solids are added to the press, chances are large that a lot of it will pass through the screens to the press water again. This is because the particle size is very small because the recovered particles came through the screens in the first place.

For Dewatering of Washed Mince

The decanter centrifuge can successfully replace rotary screens or other types of screens in conventional surimi production plants.

When using a decanter centrifuge for dewatering the washed mince, the losses are approximately 50% of normal losses using rotary screens. This changes, depending on fish quality and capacity.

The decanter centrifuge, with its ability to recover small particles, allows an efficient wash of small particles and thus improves the wash of the mince. As the washed mince contains the fraction of small particles that normally are lost in the washwater, the demands on the screw press itself are higher. If a screw press of poor construction is used, the losses might be so high that the compression in the press decreases to the degree that no dewatering takes place. A small particle wash allows for lower water consumption and a shorter leaching time for the same wash effect that takes place in tanks and rotary screens as it is more efficient.

In a continuous process all parameters such as flow rates, rentention times, temperatures, and pH are well defined and controllable through to the finished product.

The decanter centrifuge, with its relatively small volume, responds quickly to any changes. Its ability to continuously dewater the washed mince with low losses is well suited for continuous production. As emphasized earlier, it is important to have a well designed feed system that delivers feed to the decanter centrifuge continuously with a constant composition.

V. Discussion Examples

Wastewater Protein Recovery

A conventional surimi line with an input of 2200 lbs. of mince/hr will use about 10,000 lbs. of washwater/hr. This produces about 10,000 lbs. of screen and press waste water containing 0.3% suspended solids, which equals 30 lbs of dry suspended solids/hr. If we obtain 75% recovery in the decanter, this gives 22.5 lbs of dry solids/hour corresponding to 139 lbs of presscake with 20% dry matter/hr which equals 150 lbs of surimi/hr. Assume internal value of $1.00/lb and a purchase price of $150,000 for the decanter. This gives a payoff time of 1,000 hours, or 50 days, when the line is operating 20 hours a day.

Dewatering Washed Minced

A conventional surimi line with an input of 2,000 pounds of mince/hour will use about 8,000 pounds of washwater per hour. Recovery in the wash system of 66% with 2,112 pounds of mince with 10% dry matter. With a recovery of 89% in the refiner state (including #2 grade surimi) and 98% in the screw press, the output will be 1,227 pounds of surimi per hour.

When using a decanter the recovery will be at least 80% corresponding to 2,560 pounds of washed mince with 10% dry matter. With the same recoveries in the refiner stage and press, the output of surimi will increase to 1,487 pounds per hour. Assuming internal value of $1.00 per pound of surimi and a purchase price of $150,000 for the decanter, with the extra 260 pounds of surimi per hour and 20 hour per day production, the system will pay for itself in 29 days.