





Fig. 2. Sedimentation process under gravity and rotation induced gravity [3]



Fig. 3. A view of commercial decanter centrifuge [2]

Therefore when slurry of lighter liquid and denser particles is subjected to this centrifugal force, particles will move to periphery while liquid or centrate will remain at the center where gravity force is lowest. The scroll rotating at slightly different speed from the bowl continuously scrapes the sludge deposited at the wall to the discharge located on the beach. There are different configurations of decanter centrifuge available; however all have following basic components.

1. Rotating bowl assembly. It is essentially a thick wall cylinder with conical section called beach. It is within this conical section that the final dewatering, drying and discharge of the scraped cake took place.
2. Archimedean screw conveyor (scroll) placed concentrically within the bowl such that the conical part of the scroll matches that of the bowl; it rotates concentrically within the bowl with minimal clearance.
3. Gearbox: the gearbox effects differential speed between the bowl and the scroll. It is the differential speed that allows the scroll to scrape the cake from the wall of the bowl. Two common gearbox types usually employ in decanter centrifuge are planetary or epicyclic gearbox and Cyclo gearbox.
4. Support frame and casing. Support the rotating assemblies provide path for separate discharge of centrate and cake. Because decanter centrifuge always spin at high speed; possibility of severe vibration is real, therefore to minimize or eliminate destructive vibration the rotating assembly is normally mounted on the frame via anti-vibration dampers
5. Main drive System: comprises of the suitably size electric motor linked by means of drive belts and pulley to the main bowl
6. Backdrive: drive the conveyor via the gearbox; provide necessary change to required torque and differential speed.

Other critical components of decanter centrifuge include bearings, seals; feed pipes etc.

In comparison to other dewatering equipment decanter centrifuge have several advantages

- Clean appearance / contained compartment ensure almost odourless operation
- Fast installation, easier start up and shut down routine in comparison to other dewatering system such as filter press.
- Small footprint: comparatively smaller space is required in comparison to other dewatering equipment of similar capacity.
- Multiple design configuration could be chosen to address different slurry situation simply by varying size of the cylindrical bowl and the cone angle
- Due to its flexibility the machine has different functions like the operating for dewatering and thickening.
- Compared to other smaller machines, the decanter centrifuge operates on a high throughput capacity that minimizes the requirement of many units.
- Its variety and reliability feedback option makes the decanter centrifuge easy to operate and effective.
- Substantially reduced operational cost as it does not require continuous attention for maintaining and operating

There are two variants of decanter centrifuge; co-current and counter current, also it could be vertically or horizontally orientated, though horizontal bowl are more common. It comes in different sizes, very large unit with feed rates of up to 800 liters/min are available for municipal wastes dewatering application [4].

In spite of numerous usefulness and advantages of solid bowl decanter centrifuge these equipment are mainly manufactured by few companies e.g. Alfa laval, Sumitomo, Broadbent, Dry-cake etc.; .and all are based in more developed economy. In addition decanter centrifuges are quite expensive, in view of this development of this equipment locally will be beneficial to saving and generation of revenues among other several other benefits.

## MATERIALS AND METHODOLOGY

### *The developed decanter centrifuge*

All parts of the developed decanter centrifuge were fabricated from carbon steel. Special consideration was given to the target slurry, autolysed yeast, a biological slurry which is quite difficult to dewater. Therefore a length/diameter ratio greater than 3 was employed to ensure larger surface area of the bowl and higher residence time for the slurry. Fig. 4 shows the schematic diagram of the decanter centrifuge.

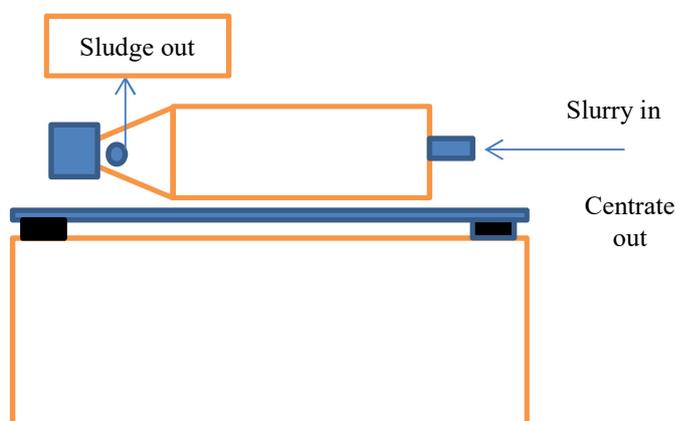


Fig. 4: Schematic diagram of decanter centrifuge

The bowl (Fig. 5) was made from 8 mm thick pipe, with internal diameter=250 mm and length=920 mm. It is covered at one end by 20 mm thick flange (Fig. 6) which also bears the pulley for rotation of the whole assemblies. The beach section is made from steel cone 250 x 150 x 200 mm long.

The cone was welded to the steel cylinder and flanged at the other end for mating with the epicyclical gearbox. The beach bears 4 rectangular holes 20 x 30 mm, through which the dewatered cake is flung out of the rotating bowl. The scroll (Fig. 7) has 15 flights of 50 mm pitch strongly welded to 150 mm diameter pipe. The scroll flight was fabricated from 5 mm thick plate with internal grooving for slurry flows. The 150 mm pipe bears internal arrangements on which roller bearings with inner diameter=50 mm were placed. The pipe has an internal steel structure on which front side of the feed tube is attached. The feed tube is made from steel pipe of diameter 30 mm, carefully fabricated for leak proof attachment to the inner part of the scroll pipe. The other end of the feed pipe was attached to the rear end of the bowl via threaded joint and locknut. The bowl front flange and the planetary gearbox are shown as Fig. 8 and Fig. 9 respectively.

The centrifuge was equipped with a 5 hp, 2800 rpm motor for rotation of the main bowl and 3 hp, 2800 rpm that rotate the scroll via planetary gear-box. The main electric motor is placed on the same base on which the main bearing were attached. See Fig. 10. Bowl speed ( $S_b$ ) was set to 1445 rpm and 2650 rpm, while impacts of differential speed ( $n$ ) of 10, 25 and 35 rpm were examined.

## Design calculations

Basis for design

1. Target slurry is autolysed yeast 10%DM
2. Target dry cake at 25% DM; 30000 kg /month
3. The bowl speed must develop sufficient g force to ensure sedimentation of the cake within the residence time.
4. Clear centrate with residual solid content <0.1%

The target slurry for dewatering is autolysed yeast solid content = 10%.

30000 kg at 25% DM.= 7500 kg completely died yeast in a water of 22,500 kg.

Define % DM as  $M(DM)/(M(DM) + M(W))$  (1)

Where  $M(DM)$  =mass of dry matter in the slurry

$M(W)$  =mass of water in the slurry

From the above, volume of the 10%DM slurry needed is calculated as 75,000 liters/ month. Based on 22 working days, we estimated that a decanter that can handle 500 liters/hr slurry flowrate is adequate [2] showed that a decanter centrifuge with bowl diameter of 200-250 mm has effective capacity of 30 m<sup>3</sup>/hr. Such machine use on slurry of 10%DM will conveniently deliver a cake of 3,000 kg/hr; therefore a bowl diameter of 250 mm considered for this work will undoubtedly serve the purpose.

Similarly it was calculated that with 250 mm bowl, differential ( $n$ ) from 1 – 6 rpm will suffice to achieve the discharge for the targeted flowrate. To establish this, the formula underneath was used

$$Q_c = \pi D h n p \quad (2)$$

Where  $Q_c$  is the quantity conveyed by a conveyor with effective diameter  $D$ ; Pitch ( $p$ ), rotating at speed ( $n$ ). scroll's flight thickness ( $h$ )

We consider that at the discharge point on the beach  $D = D_B = 150$  mm, the thickness of the cake = flight width  $\leq 40$  mm. With this as the highest cake thickness we cannot experience chocking or disruptions of cake scrolling. However other differential speeds were examined for purpose of analysis.

The bowl speed determine the sedimentation rate per hour, however the differential speed gives the actual discharge per hour.

Therefore to prevent chocking,

Amount collected by scroll per hour  $\geq$  cake sedimentation rate in the bowl

## **Balancing Procedure**

High speed rotating assemblies need to be balanced properly to prevent vibration, damages to equipment and to prevent personnel injury. Presence of unbalance in addition limits the maximum speed at which a decanter centrifuge could be operated.

Attempt to reduce the rotational unbalance in this work were approached in 2 ways

1. Static unbalance reduction: The only requirement for static balancing is to add correction mass in such location that the resultant moment on the rotor is statically zero, so that the center of gravity is restored to the center of rotation.

In this work weight in form of washers were added to the flanges of the bowl at the 2 ends. It was ensured that when the bowl is giving small rotation it stop without rotating back or forward. It was ensured that there is no oscillation of the rotating assembly; this is necessary evidence though not sufficient proof that the rotating assembly is statically balance

2. Dynamic Balancing: For decanter centrifuge 2 plane dynamic balancing is necessary to ensure minimal vibration and to ensure attainment of high rotation which is necessary for optimum dewatering. 2 planes dynamic balancing machine is not available so the following steps was taken to try to attempt mitigation of dynamic unbalance.
  - a. First the equipment was operated at 1445 rpm. The magnitude of vibration was measured with the aid of android based vibration analyser called VibSensor. The magnitude of the vibration was noted
  - b. The machine was stopped; 20 g nut was attached to one of the flange bolt. The equipment was again rotated at 1445 rpm and the magnitude of the vibration was again recorded
  - c. This process was repeated many times until the magnitude of the vibration obtained was minimal
  - d. This trial and error method was employed due to non-availability of the 2-plane dynamic balancing machine.

## **Start Up procedure**

Operation of decanter centrifuge requires strict adherence to safety. These steps are imperative during start-up

1. Ensure all bolts are secure and all guards are well tightened
2. set the slurry flow rate to the desired value
3. Start the main motor, and then start the backdrive. Allow the motors to stabilize at their normal speed.
4. Open the valve and allow slurry to flow in.

## **Shut down procedure**

1. Stop feed flow
2. Allow the cake and centrate to discharge completely
3. Open cleaning water (preferably hot) through the feed pipe for 5 minutes or until cake inside the bowl is completely off.
4. Turn of cleaning water
5. Turn off the main motor and allow the bowl to slow completely, then turn of the backdrive motor
6. Turn off the main power supply.

## **Dewatering of autolysed yeast and testing of the decanter centrifuge**

The following steps were taken for dewatering of autolysed yeast in the developed decanter centrifuge

1. Yeast flowrate was set to 480 liters per hour. To do this the slurry tap was calibrated. Several runs were done such that the valve opening that corresponds to 8 liters per minute was obtained. The gate valve was locked in this position.
2. The decanter was started and allowed to stabilize at the target speed. With the aids of different pulley the scroll speed was set as necessary.
3. The slurry tap was opened.
4. The routine itemized on Table 1 was followed



*Fig.5. Rotating bowl*



*Fig. 6: Main bowl rear flange, bearing and main drive pulley*



*Fig. 7: A view of the scroll outside the bowl, the feed tube could be seen in the picture next to the scroll*



*Fig.8. Front flange and bearing, the smaller flange connect the epicyclic gearbox*



*Fig.9. Epicyclic gear box, front bearing house and differential drive pulley*



*Fig.10. Frame, the differential drive motor, upper frame mounted on the main frame via 4 rubber damper.*

Table 1: Test data

T1	S <sub>B</sub> (rpm)	n (rpm)	Slurry	Flowrate (Litre/hr )	Run time
T1	1445	10	AY	480	45 mins
T2	1445	25	AY	480	45 mins
T3	1445	35	AY	480	45 mins
T4	2650	10	AY	480	45 mins
T5	2650	25	AY	480	45 mins
T6	2650	35	AY	480	45 mins

## RESULTS AND DISCUSSION

### Start up and operational issues.

All components of the developed decanter centrifuge functions as planned. Picture of the decanter centrifuge during operations is displayed in Fig. 12.



Fig.11. A snapshot of the decanter during operation, the whitish water is the clearer centrate

### Machine Unbalance/Vibration

It was observed that the machine had significant vibration issue when first tested. The noise and physical movement was of such magnitude that the machine was stopped for rebalancing.

After balancing and installation of new set of anti-vibration rubber pads, vibrations and noise reduced markedly. The machine was then able to run at the 2 speeds examined in this work, in spite of the trial and error method used. However, there is potential for better, smoother operation if a proper balancing tool is used for further balancing of the machine.

### Effect of operating at S<sub>B</sub> = 1445.

No dewatering or cake formation was noticed at this bowl speed. Observations revealed that the discharge is the same as slurry infeed. This speed for developed centrifuge corresponds to a g-force of 291.8 g. This is quite low in comparison with what is obtained in commercial decanter centrifuge (normally > 1000g).

This showed that for this flowrate cake could not sediment in time, therefore the slurry moves in out of discharge in spite of varying differential speed.

**Effect of operating at  $S_B = 2665$ ;**

Observations revealed that running at this speed had positive impact on the performance of the machine. The machine operations was smooth and vibration of the components was significantly less in comparison with  $S_B = 1445$ . It was noticed that at higher differential  $n= 25$  and  $35$  rpm, only thickened slurry was obtained at the cake discharge port. In spite of reduction from  $35$  to  $25$  rpm no solid cake was discharged. See. Fig. 12.



*Fig. 12. A thickened discharge from the operation*

At  $n = 10$  rpm, dewatering and centrate clarification was observed. The solid content of the cake at  $25\%$  DM compared favorably with was reported in the literature [5]. Views of the cake on the scroll and inside bowl are shown Fig. 13 – 14. Sample of the collected sludge is shown as Fig. 15.



*Fig.13. Dewatered yeast on the scroll as its being removed for inspection after operation*



*Fig. 14. Discharged cake from the scroll*



*Fig.15. Sample of cake collected from the decanter centrifuge.*

### **Conclusion**

Local development of decanter centrifuge offers a wide opportunity for effective and efficient phase separation in our industries therefore local fabrication of this equipment will enhanced industrial development. Also lot of money will be saved from local manufacturing of this equipment over buying at exorbitant rate from other countries. The result of this work revealed that decanter centrifuge though complex could be designed and fabricated locally. This work also showed that autolysed yeast slurry which is quite difficult to deal with using other dewatering equipment will successfully dewater in decanter centrifuge if bowl speed and differential speed is maintained at  $> 2650$  rpm and  $n < 10$  rpm respectively.

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