# Design Approach and Fabrication of Prototype Centrifuge

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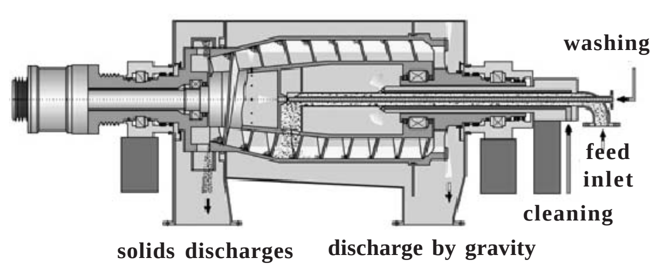
***Abstract:*** *This paper discusses and describes the design approach, raw materials/ parts processing, assembling, demonstrating and operating characteristic of the Decenter centrifuge. Centrifuge is working in industry using the concept to separate the solid and liquid materials/ manure. But, the lab scale/ prototype centrifuge is not available off the shelf in the market. The undertaken prototype project work on centrifuge is an out of the box attempt to do literature survey, fabricate/ assemble parts of centrifuge in lab to establish an easy technique of separation and sedimentation on the basis of particles/ macromolecules shape, size and density. The objective of this project based research work (design approach & fabrication) is to demonstrate a prototype centrifuge for its efficient operation by removing solid and liquid mixture. The key benefit of this project undertaking is to update knowledge on design approach, previous research work, fabrication, demonstration and leadership skill that can be developed by interacting industry people, market procurement procedures, research/ fabrication work and application focused at industry site or community manure treatment systems. It provides a solution for the capabilities of assemblies/ fabricated parts with different materials, which cannot be fully accomplished by existing facilities in the lab and traditional processes. The prototype centrifuge's tests performance has been satisfying while calibrated with the trend of industry size centrifuge performance during demonstrations/ results and drawing conclusions.*

*Key Words: Tank, feeding tube, bowl system, weir, liner, screw conveyor, main parts/panels.*

## 1. INTRODUCTION

Design and fabrication of the prototype centrifuge in university lab is a new initiative, process and its typical assembly strategy/ scheme is described in this research paper. The effectiveness of working process on mojor parts and materials is highlighted. Centrifuge is the device in which solid particles are separated from a liquid with the help of the centrifugal force developed by spinning the internal bowl of the centrifuge [8]. The separation can be of any type like Gas-Liquid, Gas-Solid, Liquid-liquid, Liquid- Solid, Solid-Solid [6]. All this separations can be done by exploiting the differences in densities between the particles. In centrifuge, there are different types of forces that are applied like gravitational force and centrifugal force etc. The velocities of the solids that occur are higher than the velocities that occur by the gravity forces. A decanter centrifuge produces high rotational speed to separate the particles of different densities [1]. Thus the centrifuge is used in wastewater treatment, chemicals, oil and food processing industries. High forces can be produced by the centrifugal action of the centrifuge. Industrial decanter centrifuge are used in a wide range of industries to separate mixtures of solids and liquids. Centrifuge is installed in a mobile trailer equipped with a tank, casting system, main parts/panels and feeding tube system. The Fig. (no. 1) of the internals or cross sectional view is given below.




**Cross-section of a flottweg DECANTER - In gas sight execution**

**Fig. 1. Typical view of internals or cross section of centrifuge**

Three kinds of equipment normally used for soild particles separation in industry is given in Fig. 2.

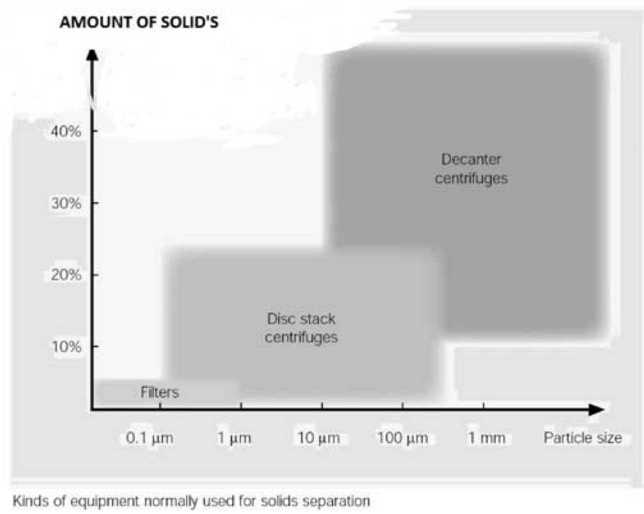



**Fig. 2. Equipment for solid separation**

## 2. DESIGN APPROACH, PARTS CONFIGURATION AND FUNCTION

### DESIGN APPROACH TO FUNCTIONAL PROFILE

The load carrying capacity, production rate and particles size (for solid raw materials) is the key factor for designing, fabricating or assembling and manufacturing an industrial requirement based Centrifuge. Gravitational force and centrifugal force are used to enhance this separation and this can be done either in vertical or horizontal position. The centrifuge is used in different industries; large, medium and SMEs/ tiny enterprises. The project based prototype centrifuge is having focus on conceptualization practical ideas, demonstrating its operation at lab scale to fulfill the UG student's curriculum requirement in Engineering Institution. However, the approach of centrifuge design is given in comprehensive manner, which is same for all purposes. The main thrust by project team was given for the strategic selection of compatible parts (irrespective of smaller sizes) and their assembly in time with the highest accuracy for its best performance and demonstration in lab. The salient points for parts selection, its functional profile, and smooth assembly work and calculating formulae is given in the following sections/ sub-sections.

### MAIN PARTS CONFIGURATION

### 2.1 Front hub

Front hub is the end part of the bowl from where the liquid get discharged and this discharge is known as cent rate. Its inner spindle is used to locate the conveyor, bearings and seals. While the outer spindle helps in lifting the front main bearing and pillow block. Figure 3 gives the view of front hub.

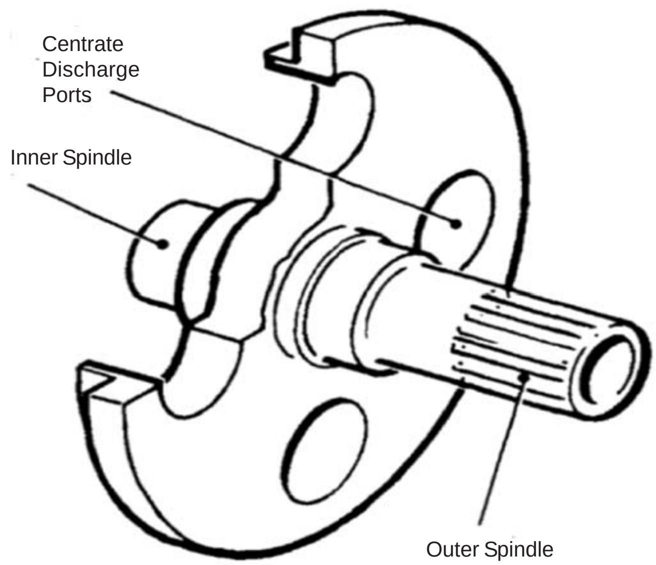



**Fig. 3. View of front hub**

### 2.2 Liner

Liner is sheet metal rolled inside the bowl. Longitudinal strips are welded in the inner side of the sheet. Liner will be off full length on the smaller and large centrifuges but sometimes on the larger machines. Only the partial length of the bowl will be covered. Figure 4 gives the view of liner.

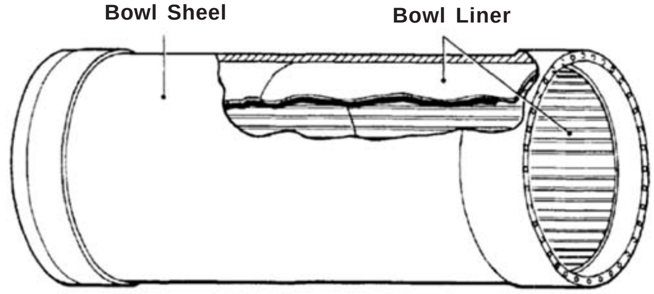
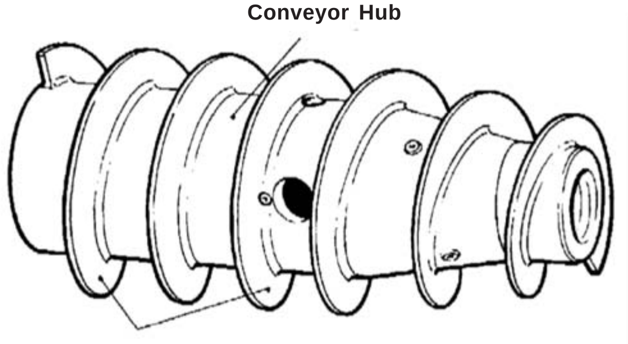



**Fig. 4. View of liner**

### 2.3 Screw Conveyor

The conveyor (or scroll) is in the form of an Archimedian screw, fitting inside the beach and bowl between the two end hubs, with a small clearance of less than 2 mm radially. It has a number of functions, not only does it convey the solids, along the cylindrical bowl section and up the beach, it also accepts the feed and accelerates it up to bowl speed. In its simplest form, the conveyor has a cylindrical central hub with a set of flights welded onto it, to form one continuous helix. Somewhere in between the bearings will be a chamber called the feed zone, sealed and isolated from both bearings. This part of the conveyor is a substantial tubular steel construction. It may be tapered at the beach end. It could, if necessary, be enlarged in diameter at each end to take the conveyor bearings. In each end of the conveyor hub will he the conveyor bearings with their associated scales [2]. Fig. 5 gives the view of screw conveyor.




**5. View of screw conveyor**

### 2.4 Feed Zones

The large number of designs of the feed zone is there. Feed through the feed port enter into the feed zone chamber. As soon as the feed zone is filled, now it will be accelerated up to the bowl speed. The vanes should be radial or at an angle to the radii or it should be curved. The feed zone will be built into the hub to discharge at the start of the cylindrical section of the bowl. The next chamber is fabricated into the hub. In most cases the feed leaving the feed port will be at higher axial velocity and when it comes in contact with the rotating target some splash occur. Fig. 6 gives the view of feed zones.

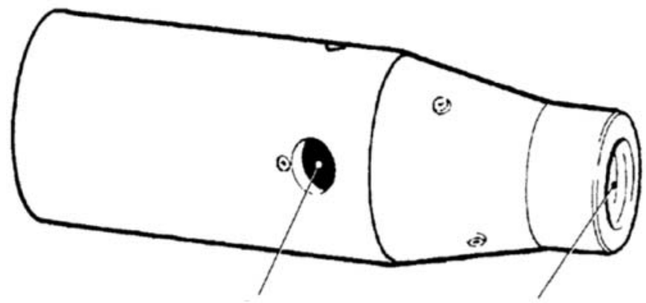



**Fig. 6. View of feed zones**

## 3. SCHEMATIC DIAGRAM APPROACH

Fig. 7 indicates the schematic diagram approach.

**3. Schematic Diagram Approach**

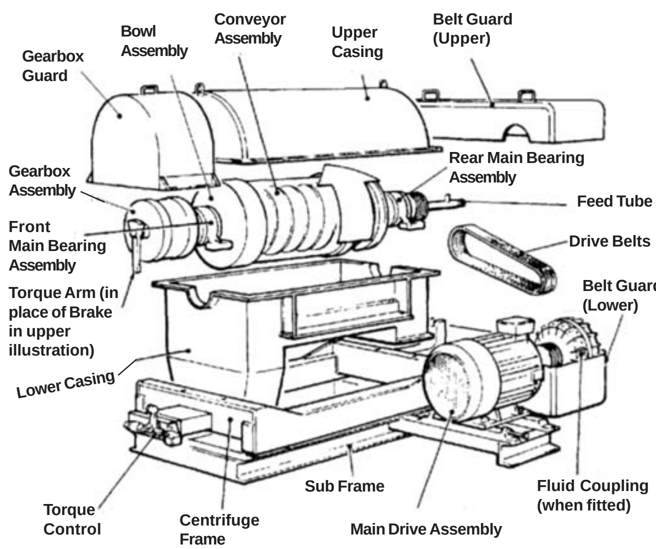



**Fig. 7**. Schematic diagram

## 4. LITERATURE SURVEY

The literature describes the utilization of the decanter centrifuge to separate the particles of different density; like, solid and liquid. The stronger stainless steel increases the manufacturing of the large diameter bowls. The very high rotational speed produces forces 1000 times than the force of gravity. The new machines working mechanism include inverter drives and back drives with power regeneration. A continuous feeding is done in solid bowl centrifuge with intermitted rim discharge. Different forces act during the process to separate the particles. Each member has a peripheral edge portion extended about the common rotational axis with the portions being spaced from each other to create an angular gap there between [4].

## 5. THEORY, TESTING & DEMONSTRATION

### Test and Demonstration In LAB

Bowl speed and feed rate are the parameters for investigation is used sparingly and is generally brought in for demonstration and investigation and the earlier results have suggested a benefit. In changing the bowl speed from the standard pond depth is usually fixed early in the test programme/ trial and only changed after data analysis to show that a pond depth change would be of benefit [7]. The lab experiment compared/ proved the typical variation in the solid recovery rate, as shown in the Fig. 8.

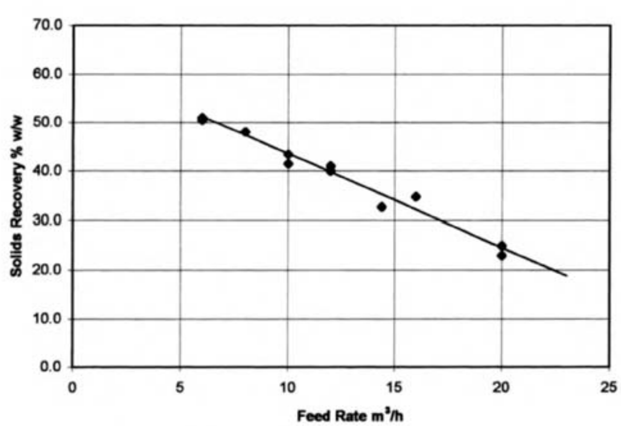



**Fig. 8. Variation in the solid recovery**

Following are some of the key parameters used for centrifuge design purpose.

- Inside diameter of the bowl
- Conveyor pitch and number of leads
- Baffle diameter and its position
- Clarifying length
- Diameter of the cake discharge
- Conveyor hub diameter

The prototype parts/ components function and centrifuge's tests performance has been satisfying while calibrated with the recommended trend of industry size centrifuge performance during testings, demonstrations/ results and drawing conclusions. Due to the time limitation in semester course work, the demonstrating/ operating the centrifuge at different load conditions was not possible.

### Design Related Key Definitions

- **Centrifugal force**

The force that from the centre of the body towards outwards direction and make the body to follow a circular motion. We can easily understand this force with the example of rotation DVD.

- **Centripetal force**

The force that makes a body to follow a curve path. The direction of the centripetal force is always orthogonal to the motion of the body and towards the fixed point of the instantaneous centre of the curvature of the path.

- **Sedimentation**

It is process of separation the solid particles or settles down the particles from the liquid because of the gravity. The particles that are separated or settled down during the process are known as sediments [5].

- **Gravitational force**

The force that acts on any object by mass is a gravitational force. Universal gravitational Newton law states that particles in the universe attract to each other. And this attraction occurs when their product of masses is directly proportional and their square of distances is inversely proportional [3].

## 6. FORMULA USED/ REFERRED

### Speed Ratio

- For bowl
  $R_{S1}$ = RPM1/RPM2

- For conveyor
  $R_{S2}$ = RPM1/RPM2

**Centrifugal Force**

$G = n^2 \times D_B/1800$

n = bowl diameter(rpm)
$D_B$= inner bowl diameter(m)

**Suspension Volume**

$V_{cyl} = \pi/4 \times (D^2{}_B - D^2{}_W) \times L_{cyl}$

$V_{cn} = \pi/8 \times (D_E - D_W)/\tan\alpha \times (D^2{}_B + D_B \times D_W + D^2{}_W)/3 - D^2{}_W)$

$V_{cyl}$= Volume of cylindrical section

$V_{ca}$= Volume of conical section

$D_W$= Weir diameter(m)

$D_B$ = Bowl diameter(m)

$L_{cyl}$= cylindrical length

**Retention Time**

$T_R = (3600 \times /Q$

$T_R$= retention time(sec)

$V_S$= suspension volume($m^3$)

Q = volume feed rate(/sec)

**Beach Angle**

$S = G \times \sin\alpha$

G = gravitational force generated by centrifuge

**Clarifying Area**

$A_c = \pi \times D_B \times L_{GYL}$

$A_C$= Clarifying area ()

$D_B$= Inner bowl diameter (m)

$L_{CYL}$= Cylinder length (m)

## 7. SAMPLE CALCULATIONS

1. Bowl length 18 inch = 0.4572m
2. Cake discharge dia. 14mm = 0.014m
3. Pond dia. 106mm = 0.106m
4. Flight pitch 1inch = 0.0254m
5. Main drive 1450rpm
6. Back drive 2800rpm
7. Inner bowl diameter 108mm =0.108m
8. Weir dia. 60mm=0.06m
9. Clarifying length 16.5inch =0.4191m
10. Cylinder length 304.8mm =0.3048m
11. Bowl speed 1300rpm
12. Cone angle 17degree

The force with which the solid and liquid particles separated are computed in the calculations.

**Speed ratio**

For bowl

$Rs_1$ = rpm1/rpm2 = 1450/1450=1:1

For conveyor

$Rs_2$= rpm1/rpm2=2800/700=4:1

**Centrifugal force**

$G = n^2 \text{ x } D_B/1800$

G=G-force, n=bowl speed(rpm)

$G = (1300)^2 \text{x } 0.108/1800$

G= 182520/1800

G = 101.4N/m

**Suspension Volume**

$V_{cyl} = \pi/4 \times (D_B{}^2 - D_W{}^2) \times L_{cyl}$

$V_{cn} = \pi/8 \times (D_B - D_W)/\tan\alpha \times ((D_B{}^2 - D_B \times D_W + D_W{}^2)/3 - D_W{}^2)$

$V_{cyl}$= Volume of cylindrical section

$V_{cn}$= Volume of conical section

$V_{cyl} = \pi/4 \times ((0.108)^2 - (0.060)^2) \times 0.3048$

$V_{cyl} = 3.14/4 \times (0.011664 - 0.0036) \times 0.3048$

$V_{cyl} = 0.785 \times 0.008064 \times 0.3048$

$V_{cyl} = 0.00192945 \ m^3$

$V_{cn} = \pi/8 \times (0.108 - 0.060)/\tan 17 \times ((0.018)^2 + 0.108 \times 0.060 + (0.060)^2)/3 - (0.060)^2)$

$V_{cn} = 3.14/8 \times 0.048/0.305 \times ((0.011664 + 0.00648 + 0.0036)/3 - 0.0036)$

$V_{cn} = 0.3925 \times 0.1573 \times 0.003648$

$V_{cn} = 0.000225228\ m^3$

$V_s = V_{cyl} + V_{cn}$

$V_s = 0.00192945 + 0.000225228$

$V_S = 0.002154678\ m^3$

**Retention Time**

$T_R = (3600 \times V_S)/Q$

$T_R$ = retension time (sec)

$V_S$ = suspension volume ($m^3$)

Q = volumetric feed rate ($m^3$/sec)

Q =assume 0.0015 /sec

$T_R = (3600 \times/\ 0.0015$

$T_R = 7.7568408\ /0.0015$

$T_R = 5171.2272$ sec

**Beach Angle**

S = G × siná

S = 101.4 × sin 17

S = 29.64 degree

**Clarifying Area**

$A_c = \pi \times D_D \times L_{CYL}$

$A_C$ = Clarifying area ($m^2$)

$D_B$ = Inner bowl diameter (m)

$L_{CYL}$ = Cylinder length (m)

$A_C = 3.14 \times \times 0.3048$

$A_C = 0.10336$

A typical distribution of solid particles and liquid materials/ manure is shown in the Fig. 9.

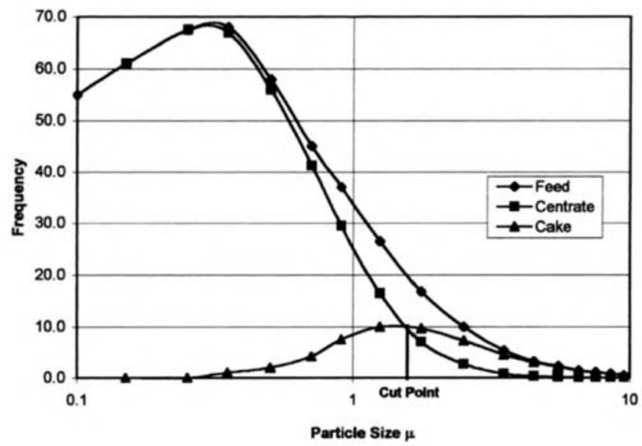



**Fig. 9. Typical distribution of solid particles**

## 8. CONCLUSIONS

The purpose of this research oriented project/ assignment was to do the literature survey, design, and parts procurement, assemble them, demonstrate, and test the operation of prototype centrifuge at lab scale to fulfill the UG student's curriculum requirement in the Mechanical Engineering Department. The centrifuge may potentially used to separate the solid and liquid particles. From the overall literature review and ideas conceptualization it got concluded that there are different ways to fabricate/ procure the lab scale (smaller) prototype project components and model with the reasobable effort, in-house resources support and moderate manufacturing cost etc. which we obtained from assembling and operating prototype model. The objective of this assignment is to check the efficient operation of the prototype centrifuge also. The benefit of this project led research oriented assignment is to advance the engineering knowledge on the decanter centrifuge. This research primarily supports the students for their engineering course curriculum and knowledge advancement, practical learning on resource utilization, promote innovation in resource procurement/ planning/ assembling for the development of practical course work activities in the institution.

Hence there is a need to adopt practices for team member's practical learning for application of knowledge, skill, facilities/ space utilization, accuracy and speed in making a successful prototype or pilot project once in the academic course. As a part of research oriented assignment extension, it is also possible for demonstrating/ operating the centrifuge at different load conditions and makes comparison of data with the small size existing in industry, calculate performance, and monitor actual production level as well as reduction in resource wastage.

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