Optimization, Stress Analysis and Manufacturing Hard-Facing Machine Fixture Design

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Abstract

A fixture is a work-holding or support device used in the manufacturing industry. Conveyor used in decanters is nothing but a hollow shaft having an opening at its midpoint and flights surrounding its entire length.

The conveyors are very tedious to manufacture due to its shape, need of accuracy and precision in manufacturing. Conveyors are designated according to the size of the Decanter for which they are being made. Hard-facing is a metal working process, implemented on conveyors where harder or tougher material is applied to a base metal.

In this paper, we have proposed a new fixture design having a single base plate assembly and working plates replacing the conventional design of five different fixture assemblies. This new fixture design not only helps in saving manufacturing time but also saves the material cost to a large extent.

Keywords*:-Conveyors, Process selection, Hard-facing Machine Fixture, Optimized Base plate assembly, Shaft and Pin Design.*

1. Introduction

A decanter centrifuge is a sedimentation centrifuge for separation of suspended solids from one or two liquids. Decanters are used widely in the pulp, dairy industries, separating sewage water, etc. The most critical part of decanters is conveyors.

Conveyor used in decanter is nothing but a hollow shaft having an opening at its midpoint and flights surrounding its entire length.

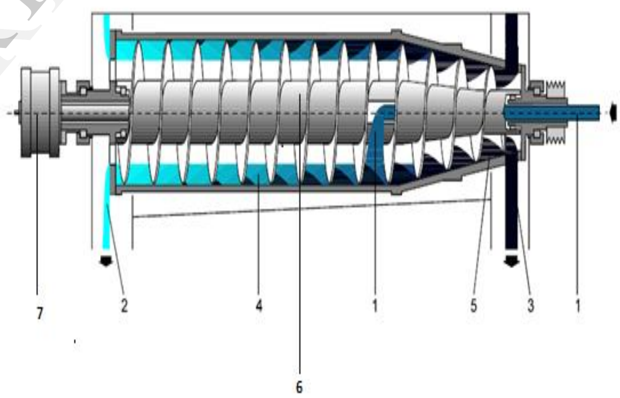

Fig1.Constructional Details of Decanter

1. Feed	4. Pond	7. Gear Box Motor
2. Liquid phase	5. Dry beach	
3. Solid phase	6.Conveyor	

The following table states the data about the sizes of conveyor and its other dimensions:-

Type of Conveyor	Internal diameter of shaft mm	Outer diameter of shaft mm	Weight kg
280	120	154	50
353	204.5	229.5	72.5
360	157	193	75
440	202	218	95
450	205	250	100

Table 1

Note: - all dimensions in mm

2. Process Selection.

Though the manufacturing of Conveyor consists of various operations such as: Machining, Cutting, Wielding, Finishing, Hard-facing, Tiling, etc. The most critical among them was the hard facing machine.

Reasons for selection:

I. Research gave us the results that this particular process was severely bottle necked.

II. It was the company requirement to reduce operation work cycle time and hence increases the output.

III. It is a locally designed machine and hence solutions are not readily available.

2.1 Hard-Facing Machine.

Hard-facing is a metal working process, where harder or tougher material is applied to a base metal. This is done to grant strength to the flights so that under high operating pressures they do not undergo distortion. Hard-facing is usually done by using tungsten carbide powder which is used as Heavy duty protection element.

Fig. 2 Hard-facing Machine Set-up

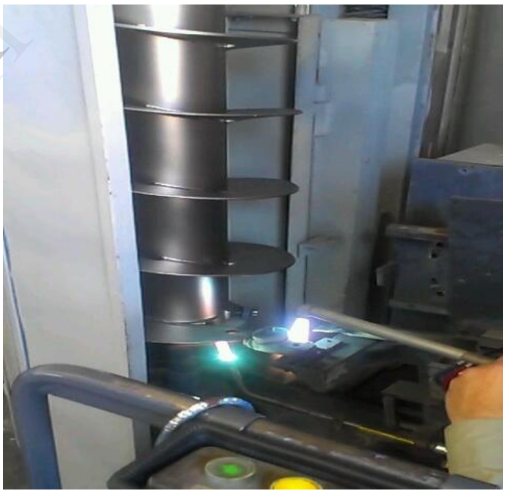

Fig. 3 working of hard-facing machine

The above figure gives an idea about Hard-facing machine and its working principle. The Hard-facing is done on the outer periphery of the flights; it is a one-two inch layer in width and has a thickness of few millimetres.

The hard facing machine is a locally assembled machine which requires certain accessories such as jigs, fixtures and tungsten-carbide powder. This powder is sprayed in presence of flame through a torch on the conveyor flights.

3. Optimized Fixture Design.

Fig 4. Old fixture.

3.1 Old Fixture.

The above shown Hard-facing machine uses fixture to clamp the screw conveyor in vertical position. The fixture is simply a shaft of certain height and a plate fixed above it. The plate on its upper side has spigot which fits inside the conveyor shaft, which makes the conveyor concentric with the chuck and fixture. It also has two clamps opposite to each other so as to fix the conveyor using Bolts.

Demerits of old fixture:

I. Utilizes a lot of time while changing the fixture.
II. Requires frequent tightening of chuck.
III. The Tungsten carbide powder settles down in the chuck, which jams its teeth.
IV. Reduced productivity.

3.2 New Fixture Design:

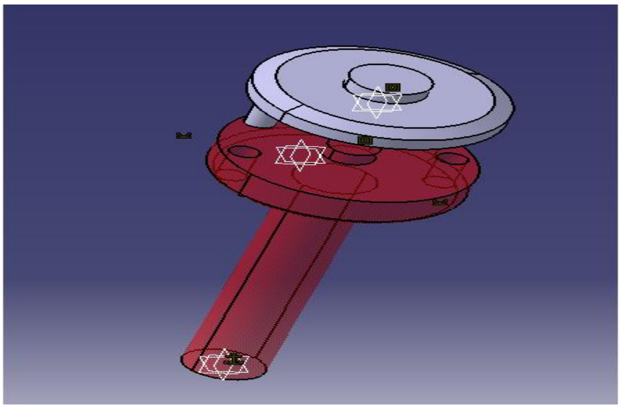

Fig 5.New Fixture Design

The new fixture was that we divided the fixture in two parts:

1. Fixed portion- Shaft and base plate assembly.
This part of the fixture is fixed one, i.e. once the shaft is fixed inside the chuck perfectly it remains their forever.
The shaft on its top end has a baseplate, welded to it. The baseplate has two holes exactly opposite to each other, which are used to fix the main plate using pins.

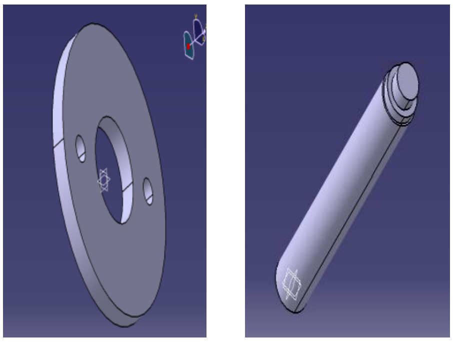

Fig6. Shaft and base plate

2. Main plates.
As the figure shows, a main plate is exactly above the baseplate and is perfectly concentric to it. The main plate has a spigot above it which is used for the centering of conveyor. So its diameter (outer diameter of spigot) is exactly equal to the inner diameter of conveyor. Pins can be used, so as to maintain the alignment between the two plates and are also used to avoid relative motion between them.

But as we know we have five different types of conveyors to operate, we need five different main plates. The only difference between all these main plates would be the different spigot diameters.

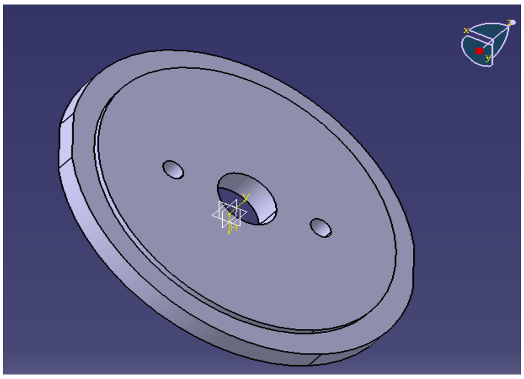

Fig7. Main plate modeling

4. Design.

Except for the shaft and pin all the remaining parameters will remain same. Thus checking the safety of shafts and pins in our design analysis:-

4.1 Calculations for shaft.

Available Data:

I. Diameter of shaft: 60mm
II. Length of shaft: 414mm
III. Load on shaft:100 kg (maximum loaded condition)+ 10% Clamping load= 110Kg
IV. Nature of load: Axial, Compressive

- The design procedure will follow checking the shaft for buckling/crippling since load is axial, static.

Slenderness ratio:

It is the ratio of the effective length to the least lateral dimension. Slenderness ratio decides whether the shaft, here being treated as a vertical column, is long or short.

Modes of failure:

I. A long column tends to experience failure through buckling.
II. A short column tends to experience failure through crippling.

To find slenderness ratio:

Effective length is calculated based on their end conditions.

I. Both ends fixed
II. One end fixed and other end free - $L_e = 2\times L$
III. One end fixed and other end hinged
IV. Both ends hinged

One end of the column in consideration is fixed at one end in chuck at the bottom and the other end is free. Hence, case 2 is applicable here.

Hence, $L_e = 2\times L = 2\times 414$

$L_e = 828\text{mm} = 0.828\text{m}$

Slenderness ratio = $\frac{L_e}{D}$ (least lateral dimension)

$$= \frac{0.828}{0.055} = 15.054$$

Slenderness ratio = 15.054>12

Hence, column is long.

For slenderness ratio >12, the column is considered long and the column will fail through buckling. Hence we check safety for buckling.

- Checking for Buckling Failure-

As we have selected the column material to be Mild Steel. We check the properties off this material and their suitability for our application as follows –

Mechanical properties-

E = 200 GPa

Syt = 250 N/mm^2

Buckling load-

$$P = \frac{\pi^2 \times E \times I}{L_e 2}$$

Where,

- E = modulus of elasticity
- I = moment of inertia
- L_e= effective length

To find I:

The cross section of shaft is circular. For circular cross section,

$$I = \frac{\pi}{64} \times D^4 = \frac{\pi}{64} \times 55^4$$

I = 449180.254 mm^4

Hence,

$$P = \frac{\pi^2 \times E \times I}{L_e 2}$$

$$P = \frac{\pi^2 \times 200 \times 449180.254}{828^2}$$

P = 1293.271N

P actual = 110 kg = 1079.1N

Since P_{actual} < P, design is safe.

Calculating Factor of Safety:

FOS = $\frac{P}{P_{actual}}$

FOS = 1.2

This value of FOS is acceptable for a static uniaxial loaded condition.

Hence, we conclude that shaft is safe from Buckling and Crippling Failure.

Calculations for pin-

Available data:

Power of motor: 1 H.P (746W)

Rpm at output: 10 rpm

Location of pins: 50 mm from central axis

No. of pins: 2nos

Material for pins- M.S 30c8,

S_{yt} = 400N/mm^2 ……….. (of pin material)

The design procedure will follow checking the pins for shearing and crushing failure.

- **Checking for Shearing Failure:-**

To determine optimum Diameter of Pin using maximum shear stress theory:-

To calculate output Torque:

P = $\frac{2\times\pi\times N\times T}{60}$; 746= $\frac{2\times\pi\times 10\times T}{60}$

T = 712.377N-m = 712377.5N-mm

To find shear force

F = $\frac{T}{arm}$

F = $\frac{712377.5}{50}$

F = 14247.55 N

S_{sy} = 200N/mm^2

τ = 100N/mm^2

D = 14mm

Checking for crushing:-

In crushing, area of cross section is the projected area in the direction of the force.

$\sigma_c = \frac{F}{A}$

$\sigma_c = \frac{14247.55}{14\times 14}$

σ_c = 72.69N/mm^2

The permissible crushing stress in the pin can be calculated using the maximum shear stress principle as follows:-

$\sigma_c = \frac{S_{yt}}{FOS}$

$\sigma_c = \frac{400}{2}$

σ_c = 200N/mm^2

Parameter	Dimension
Diameter for top 21mm length	16 mm
Diameter for lower side of pin	14 mm

Table no 2

Now, after performing the calculations we can say that the design is perfectly safe from any kind of failure.

5.Modelling in Catia V5R20

Final Model View in Catia:

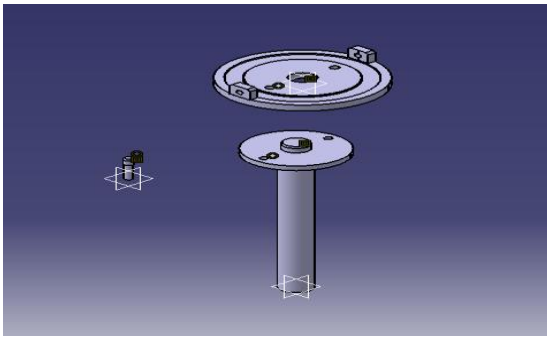

Fig 8.Optimized fixture model

6. Manufacturing.

Fig 10. Manufactured Fixture Assembly

7. Results.

7.1Material Saved

- Initial weight of collective assemblies : 105 kg
- Weight of optimized assemblies : 65 kg
- Total saving in weight : 40 kg of M.S

7.2Saving in cost

- Cost per kg of M.S.: 92.3 Rs.
- Rs. Saved: 3692 Rs.

7.3Time saved

- Initial work cycle time : 5 minutes
- Optimized work cycle time : 20 seconds
- Saving : 4 minutes 40 seconds per cycle

8.Conclusion:

The optimized design consists of single mounting fixture and 5 separate specialized plates for different conveyors thus saving time, material and cost.

9. Referances

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