Design, Development & Validation of Sand Washing Machine

S. H. Gawande, L. G. Navale, A. A. Keste
(Department of Mechanical Engineering, M. E.S. Collegeof Engineering, Pune, India)

ABSTRACT :*The Sand Washer machine is used to wash off impurities like clay, silt, and other unwanted particles from sand to make it fit for use. This sand washer is specially designed to wash sand used in construction and make it comply with Indian Standard. The USP of this machine is that it combines all three steps; screening, conveying, and washing, into one robust, compact machine. The screening is done with the help of a wire mesh. Sand is conveyed and washed simultaneously by a paddle screw conveyor. The rotary bucket elevator scoops up the sand from the tub and on its way to delivery, drains water from sand. In this context, the objective of this work was to design the transmission system to drive the machine to maintain the output of washed sand at 6m3/hr by A particular design was subsequently narrowed down with reference to certain criteria viz. Relative ease of use, ruggedness, space constraints and availability. While doing so, we explored manual as well as computer assisted design. A comprehensive account of such design-centric efforts and finite element analysis is furnished in the present work. The design, analysis, manufacturing and testing work is carried at Deccan Construction Equipment and Machinery, Pune.*

Keywords -*Sand Washing Machine, USP, FEA*

I.   INTRODUCTION

TheDeccan Construction Equipment & Machinery Pvt. Ltd is an ISO 9001:2008 certified company and one of the leading names engaged in manufacturing and supplying of construction machines in India. The company is widely acclaimed for offering a qualitative range of machines that stands high in terms of sturdiness and performance, conforming to international standards of quality.Leveraging on expertise and potentiality of workforce, they have developed innovative technology that is used in manufacturing of qualitative range of construction machines like bar cutting machine, bar bending machine, mini lift, multi rider, tower hoist, etc. Their range of machines not only caters to requirement of clients in domestic arena but they are in process of expanding their business in Europe, China, Saudi Arabia, South Africa, Australia, Far East and Sri Lanka.

II.   PROBLEM FORMULATION AND OBJECTIVE

According to Bureau of Indian Standards the sand used for construction purpose must meet the quality stated by IS383:1970 and IS650:1991. For different construction of works requires different standards of sands. **For brick works** requires the finest module of fine sand should be 1.2 to 1.5 and silt content should not be more than 4 %. **For plastering works** requires the finest module of fine sand, it should not be less than 1.5 and silt content should not be more than 4 %. **For Concerting Works works**requires the coarse sand with the finest modulus 2.5 to 3.5 and silt contents should not be more than 4%.Silt is granular material of a size somewhere between sand and clay whose   mineral origin is quartz and feldspar. In this context, the project team at Deccan Construction Equipment and Machinery was asked to maintain the output of washed sand at 6m^3/hr. In order to satisfy these requirements following objectives were set:
- Calculating power required to drive the sand washing machine by considering the various power losses in the system.
- Ensuring a sand delivery at rate of 6m^3/hr by selecting the appropriate prime mover based on power calculation.
- Designing a single stage worm type reduction gear box and a roller chain drive.
- To accommodate the power line within an area of 1x1m and design the required mountings.
- To perform structural analysis of chassis.

III.   CAD MODEL OF SAND WASHER MACHINE
The main components of the developed sand washer machine for technical specifications as given in Table1 as shown in Fig.1 [A, B] are as follows:

1. Screen
2. Chassis
3. Screw Conveyor
4. Rotary Bucket Elevator
5. Transmission

TABLE 1 TECHNICAL SPECIFICATION

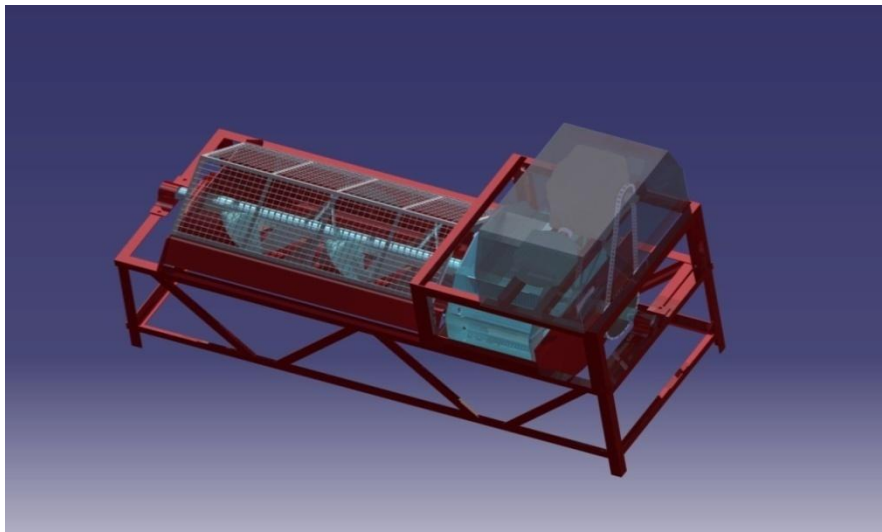|	
Wheel bucket diameter (mm)	920
Speed of impeller (rpm)	8.89
Output of washed sand (m^3/hr)	6
Screw diameter (mm)	490
Pitch of screw (mm)	670
No. of paddles	8
Screen designation (mm)	20
Length of tub (mm)	1430
Overall dimensions (L $\times$ B $\times$ H) (mm)	2400 $\times$ 1015 $\times$ 1721

Fig.1 [A] CAD model of Sand Washer machine
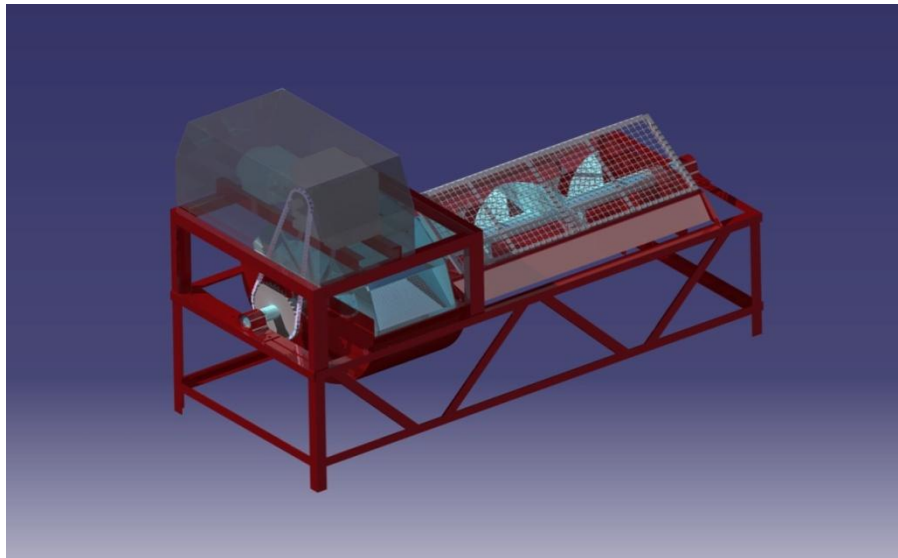

Fig. 1[B] CAD model of Sand Washer machine

Screen
A sand screen is typically categorized based on the size of hole of the weld mesh. This helps in preventing large stone particles present in sand from getting into the screw conveyor. The screen consists of a two   rectangular frame arranged at right angles to each other. A mesh is formed by arranging 3mm wire diameter in rectangular array as shown in the Fig.2. The screen designation for this machine is decided based on gap between the screw blade and tub, which is 20mm. If a particle with larger size enters the machine it might jam it, hence causing damage to the machine.
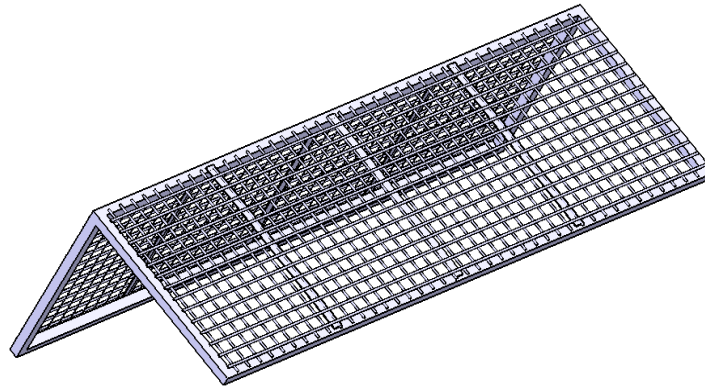

Fig. 2 Screen

Chassis
The chassis forms the basic structure of the machine [Fig.2]. It is a skeletal frame made by welding mild steel channels and angles together. The chassis is the seat on which trough, screw conveyor and the rotary elevator are mounted. It provides the machine with high strength and flexibility. The chassis supports the load of machine and also withstands various shocks and forces produced. The chassis is provided with wheels which makes the machine highly portable. The chassis' structure dimensions as shown in Fig.2 are: 2400 × 1015 × 1721 (L × B × H) mm.
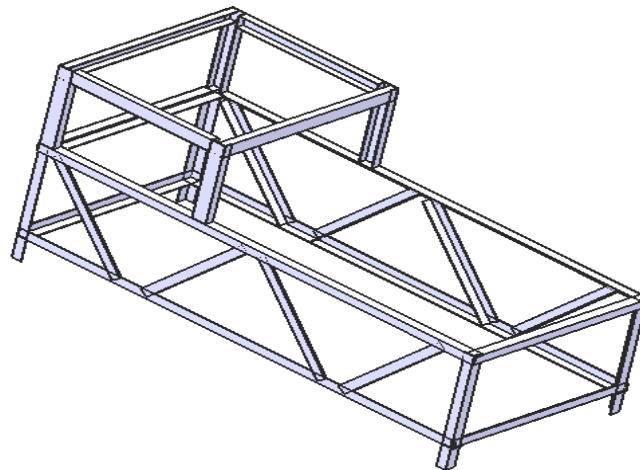

Fig. 2 Chassis

Screw Conveyor
It is a mechanism [Fig.3] that uses a rotating helical screw mounted on the shaft along with the bucket elevator and this is mounted in a trough made out of 3mm hot rolled sheet in which the water is contained. When the machine is started this screw conveyor churns and pushes the sand towards the rotary elevator. In this action the silt content in it dissolves in water and the washed sand is picked up and discharged by the rotary elevator. To avoid the saturation of the silt a continuous supply of water is maintained. The water flow required depends on the silt contained in sand. The rate of volume transfer is proportional to the rotation rate of the shaft. The screw conveyor is of paddle type which consists of eight blades arranged in a helical pattern of pitch 67mm and length 1430mm.
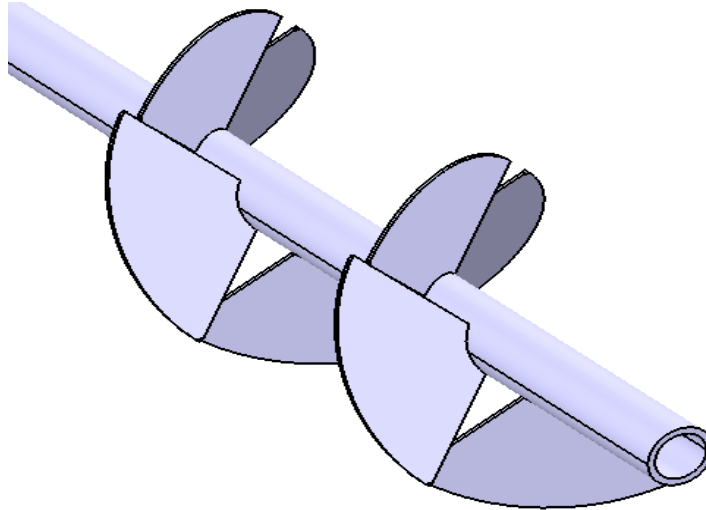
Fig.3 Screw Conveyor

Rotary Bucket Elevator

It is a mechanism for hauling flowable bulk materials as shown in Fig.4. It consists of buckets to contain the material. The buckets are made from perforated sheet to drain out water. The rotary elevator is formed by welding bent plates   between two rimmed discs. The plates are so arranged that they form 12 trapezoidal buckets. Each bucket can hold a maximum of 0.832 litres of wet sand. It receives sand and water mixture from the screw conveyor which is collected in the circular tub. During its operation it scoops up the wet sand from the circular tub and discharges. The direction of rotation is as shown in the Fig.4 below.
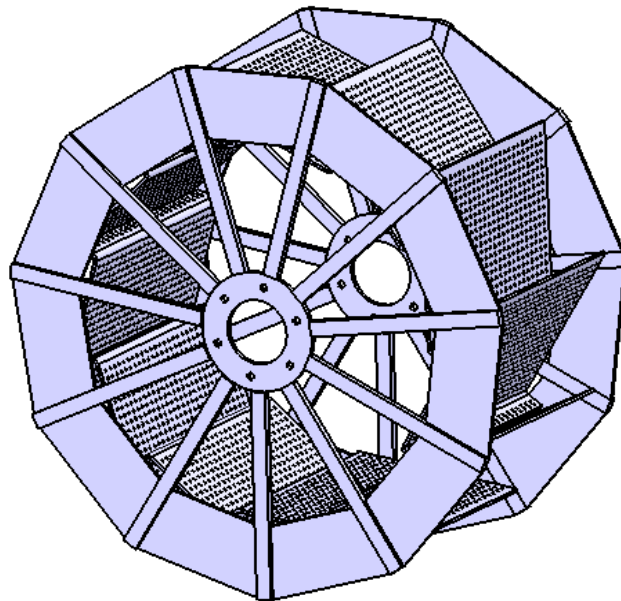

Fig. 4 Rotary Elevator

Transmission Rotary Bucket Elevator

It transmits power from the electric prime mover to screw conveyor and rotary elevator through worm type reduction gearbox as shown in Fig.5. The transmission system consists of 5 HP foot mounted electric motor coupled with   flexible roller chain coupling. The ratio of the gearbox is 50:1.There is a second reduction between gearbox and screw conveyor coupled by 25.4 mm pitch chain and sprocket. The system is mounted on the chassis above the rotary elevator within an area of 1m x 1m.
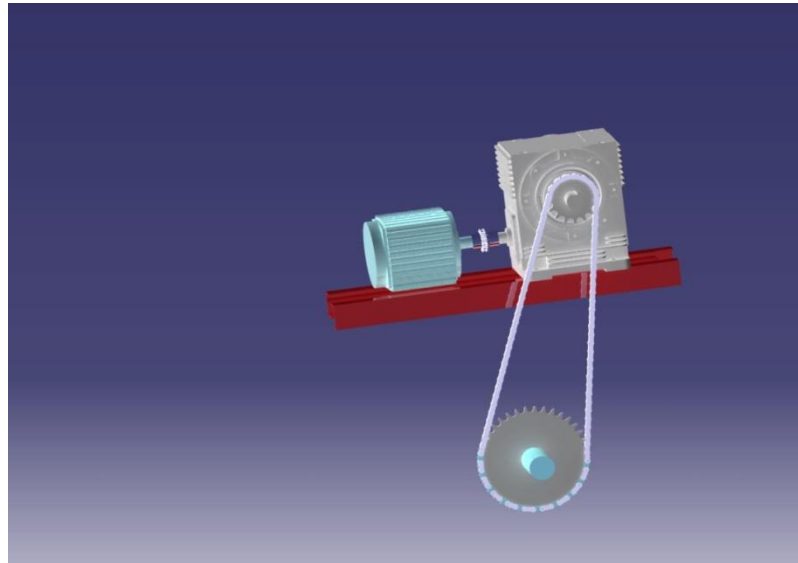
Fig.5 Transmission

IV. WORKING OF SAND WASHER MACHINE

1. The electric motor runs the impeller after decelerated by the gear wheels and chain drive.
2. Sand and water flow into the washing tub in opposite direction with each other, rolls with the impeller, and grinds with each other.
3. The impurity covering the sand is washed away with the cross flow.
4. By adding more water, the strong water flow will take away waste and some low-weight wastes from the washing launder.
5. Through the above process the cleaning function is done.
6. The clean sand is lifted up by the rotor buckets and when it goes up the water remaining in clean sand begins to drop from the holes in the buckets.

V. DESIGN VALIDATION

This section focus on the validation of the design performed by using CAD software explained in earlier section to maintain the output of washed sand at 6m³/hr.

Gear Box Efficiency:

As per the technical specification of sand washer machine in Table 1 and for the selected specifications of the gearbox we have,

Velocity Ratio (V.R.) = 50

We have relation for lead angle (λ) and velocity ratio as,

$$\text{Cot}^3\lambda = \text{V.R.}$$
$$\text{Cot}^3\lambda = 50$$

Lead angle, λ = 15.18°

Rubbing velocity, $v_r = \dfrac{\pi \times D_w \times N_w}{\cos \lambda}$

Where; D_w = Pitch circle diameter of worm(m)

N_w = Speed of worm(rpm)

$$v_r = \frac{\pi \times 0.04712 \times 1440}{\cos 15.18}$$

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$$v_r = 220.872 \text{ m/min}$$

Coefficient of friction, $\mu = 0.025 + \dfrac{v_r}{18000}$

$\mu = 0.025 + \dfrac{220.872}{18000}$ ... (Since v_r is greater than 180 m/min)

$\mu = 0.0372$

Angle of friction, $\phi_1 = \tan\text{-}1 \; \mu$

$\phi_1 = \tan\text{-}1 \times 0.0372$

$\phi_1 = 2.134^{c}$

Efficiency Of Gear Drive, $\eta = \dfrac{\tan \lambda}{\tan (\lambda + \phi_1)}$

$\eta = \dfrac{\tan 15.18}{\tan (15.18 + 2.134)}$

$\eta = 87.03 \%$

Flow Calculation:

Using the above selected specifications for the prime mover, gear box and chain drive we have,

Speed of Motor = 1440 rpm
Gearbox Reduction = 50:1
Chain Drive Reduction = 2.643

Actual Speed of Screw Shaft (n):

$n = \dfrac{Speed of motor shaft}{Gear Box Reduction \times Chain Drive Reduction}$

$n = \dfrac{1440}{50 \times 2.643}$

$n = 10.89 \text{ rpm}$

Actual Sand Delivery Rate:

Sand delivery rate (Q'):

Q' = 60 × (π/8 ×D²) × S × n × ψ × C

Where; Q' = max wet sand discharge
S = pitch of screw in m
Ψ = loading efficiency
n = actual rpm of the screw shaft
C = fac tor for inclination to horizontal
D = screw diameter in m

Q' = 60× (π/8 × 0.432²) × 0.67 × 10.89 × 0.3 × 1

Q' = 9.625 m³ / hr.

The flow able bulk is a mixture of sand and water. Thus for the volume of sand discharged by the screw conveyor;

(Sand occupancy assumed to be 65% for proper churning to take place.)

Q = 0.65 × Q'

Q = 6.545 m³ / hr.

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Advantages:

1. Simple structure: The structure is made of standard material and size in an orthodox shape making manufacturing easy.
2. Low Maintenance: The machine is robust and can be used at construction sites.
3. Transmission isolation: The power train is placed in a separate compartment above the machine, hence isolating it.
4. No pollution: Electric motor is used to operate the washer.
5. High Durability: The machine can operate even in harsh working conditions.
6. Less wastage of sand:Unlike manual labour where sand is cleaned by blowing off impurities which also results in wastage of fine sand, the sand washer uses water for cleaning.
7. Higher Discharge: More output in a given time frame over manual labour.
8. User friendly: No skilled labour required for operating the machine.
9. Portability: Wheels are provided to enhance mobility

Applications:

The developed sand washer machine for given technical specifications can be widely used for cleaning materials in the following industries:

1. Quarry
2. Minerals
3. Building materials
4. Transportation
5. Chemical industry
6. Hydropower
7. Cement mixture station
8. Especially applicable for washing construction and paving sand.

VI.   CONCLUSION

In this paper the stated objective to design of the sand washer machine with advanced transmission system to maintain the output of washed sand at $6m^3$/hr is presented. The paper confined to carry out the selection with justification and validation of the setup by developing the 3D model of the machine and related design calculations. In the second part of this paper detailed finite element analysis to perform structural analysis is explained. It is anticipated that our design centric efforts would contribute to some extent in   realizing the objectives of the modifying the Sand Washer System for Deccan Construction Equipment and Machinery Ltd.

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