TECHNO-COMMERCIAL FEASIBILITY OF SLUDGE DRYING USING SCREW CONVEYOR DRYER

Environment Friendly
Engineering Solution Company

Kerone Engineering Solutions Limited

In Association with SVCH-Technologii, Moscow (Russia)

ISO 9001-2008 | ISO 9001-2015 | EMS 14001 | OHSAS 18001

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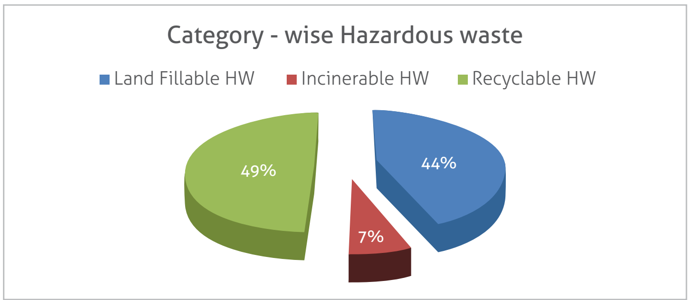
Abstract: Thermal drying of sludge is gaining popularity to reduce the numerous problems associated with its handling and disposal. Despite being many types of dryers available for sludge drying, market demands innovative drying technologies that can be cost-effective as well. With this in mind, a novel Screw Conveyor Dryer (SCD) has been designed for the drying of viscous industrial sludge with moisture content as high as 85 wt %. SCD consist of a jacketed cylinder which houses hollow shaft and piping arrangement to transport the drying medium from jacket and hollow shaft into the main dryer body. The dryer can utilize both modes of heat transfer, i.e. conductive and convective modes of heat transfer thus making design thermally more efficient. An arrangement of radial mixers and lifters on screw shaft at regular interval minimizes the agglomeration of sludge. This extremely important feature increases agitation and heat transfer to deal with stickiness of sludge. A procedure for the design of SCD is presented here with an example for drying of 100 kg/hr sludge using different heating media such as flue gas and condensing steam. Thermal drying of sludge is a very energy intensive process and hence it need to be justified economically. An attempt has been made to work out the economics of sludge drying for Indian scenario. It can be concluded from the results obtained through calculations that sludge drying using a novel SCD is technically as well as commercially feasible.

Introduction:

Hazardous Waste Generation in INDIA:

- 36,165 no of Hazardous waste generating industries
- 62,32,507 MT of hazardous waste generated every year



Need of Sludge Drying:

- It is mandatory to dispose off sludge in HWM sites approved by Government agencies
- The companies are paying Rs.16-17 per kg of sludge towards the disposal cost
- The sludge usually contains 80% to 85% moisture content. This means companies are paying Rs. 13-14 per kg of sludge just for disposing water which other wise can be removed by drying
- More cost effective to handle relatively dry sludge either through incineration or any other means of disposal, keeping in mind the minimum impact on environment

Advantages of Sludge Drying:

- Sludge weight will reduce approximately by 60%
- Volume of sludge will reduce by 4-5 times
- Because of weight and volume reduction, the transportation cost of sludge will reduce significantly. Also environmental problems associated with sludge will reduce substantially
- Because of reduction in moisture content, calorific value of sludge increases. This will result in efficient incineration without any additional fuel
- High drying temperature will sterilize and deodorize the sludge.

Sludge Drying Operation requirement:

- Drying is an energy intensive operation because of its high energy demand and inherently inefficient operation thus demanding economic justification
- Market demands innovative drying technologies with higher thermal efficiencies, lower emissions, less manpower requirement and affordable capital cost

Available Dryers:

- Direct drying system: less energy efficient, need expensive equipment for air handling
- Indirect dryer system: expensive in terms of capital cost
- Combined system

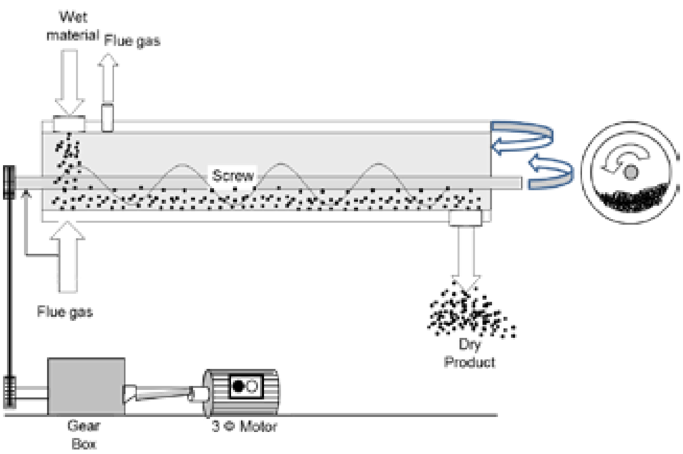
Objectives of the work:

- To give Design procedure for Screw Conveyor Dryer (SCD) with an example
- Techno-commercial feasibility of proposed SCD for Indian scenario

Features of SCD

- Designed to use both conductive and convective modes of heat transfer
- Screw shaft and flights are kept hollow to provide greater heat transfer area within the constrained space
- The heating medium will have two different paths
- First the steam will pass through the jacket and hollow shaft providing conductive heat transfer. Then the preheated hot air will provide convective drying action over the surface of sludge material. Alternatively we can use hot flue gases for both conduction as well as convection
- Twin screws can be installed for better mixing, to increase the heat transfer rate and to avoid fouling
- Innovative component: Radial mixers will be welded to screw shaft at fixed intervals along the length to minimize agglomeration of sludge on the way of transport. This will increase the agitation in dryer and will result in improved performance

Schematic of SCD



Design Procedure

Compartment model approach:

- SCD is divided into 'n' compartments of equal length 'l_{mix}' termed as 'mixing length' such that

$$n = \frac{\text{Length of SCD}}{\text{Mixing Length}} = \frac{L}{L_{mix}}$$

'l_{mix}' is termed as the length required for sludge to get perfectly mixed during its transport through SCD

- Sludge enters at 1st compartment and leaves at nth compartment
- Total residence time of sludge in SCD is τ and the residence time in a single compartment is given by

$$t = \frac{\tau}{n}$$

- Sludge enters the SCD at ith compartment in perfectly mixed form. During its residence time 't', sludge is assumed to be stationary in the given compartment. As per Page model, drying kinetics is applied for static sludge which is treated as horizontal slab drying heated from bottom. During this process, the moisture is lost from the sludge
- At the end of time period 't', sludge is instantaneously well mixed again and transferred to (i+1)th compartment
- Neglecting the sensible heat changes, Page model is applied for sludge drying and the same procedure is repeated till nth compartment
- Moisture contents are calculated whenever sludge is transformed to the next compartment and this new moisture content is used for calculating drying kinetics through Page model for the next compartment
- To ensure that the required heat is supplied for drying as predicted by Page model, heat transfer calculations are carried out. The highest possible heat transfer should be always higher than that required for drying

Calculation steps

Determination of energy required for drying

$Q_{in} = Q_{sen} + Q_{lat} + Q_{loss}$ .... (1)
Since $Q_{sen} = 0$, $Q_{in} = Q_{lat} + Q_{loss}$ .... (2)
The drying rate at the bed surface is given by assuming Page model as follows: $MR = \exp(-k\,X\,t^{n})$ .... (3)
Where MR is the moisture ratio. Values of constants k and n should be found out experimentally
In this case, $t = t_R$ and $t_R = N_{mix} \,.\, T_{mix}$ .... (4)
$t_{mix} = 1/N$ .... (5)
Moisture content at the outlet of first fictitious period t_R is given by, $X_{D1} = MR \,.\, X_{Di}$ .... (6)
$m_{m1} = m_{DS} \,.\, X_{D1}$ .... (7)
$m_v = m_{DS}\,(X_{D,i} - X_{D,1})$ .... (8)
$Q_{lat} = m_v \,.\, \lambda$ .... (9)
$Q_{in} = Q_{lat}/\eta$ .... (10)
$Q_{loss} = Q_{lat}/\eta - Q_{lat}$ .... (11)

Determination of energy transfer possible in the SCD

$Q_{poss} = U.A.\Delta T$ .... (12)
$1/U = 1/h_h + 1/h_w + 1/h_c + 1/h_b$ .... (13)

$$h_b = 2\sqrt{\frac{(\rho c_p k)_b}{\pi t_R}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$h_c = {}_{A}.h_{cp} + (1 - {}_{A}).\frac{2k_G/d}{\sqrt{2}+(2l+2\delta)/d} + h_{rad} \quad \ldots(15)$$

3. Check if $Q_{poss} \geq Q_{in}$
$Q_{poss} \geq Q_{in}$ .... (16)

Conclusion:

SCD with improved mixing and heat transfer is proposed for sludge drying. The design procedure for SCD based on Compartment model approach is proposed with detailed equations which take into account drying, mixing, heat transfer and flow from inlet to outlet of SCD under certain assumptions. Simple design procedure allows calculating moisture ratio, heat transfer and steam requirement at certain intervals of length. Based on proposed design procedure, a SCD of 100 kg/hr sludge inlet capacity is illustrated along with economic returns as an example. SCD for sludge drying, when sludge disposal is mandatory, seems to be a good option giving payback within a year

Results

Summary of results

Compartments	Sludge inlet flow rate Kg/hr	Moisture content Dry basis	Moisture evaporated Kg/hr	Steam required Kg/hr
1	100	5.667	5.240	9.628
2	94.8	5.317	4.917	9.030
3	89.8	4.990	4.614	8.469
4	85.23	4.628	4.329	7.943
5	80.9	4.393	4.062	7.450
6	76.8	4.123	3.812	6.987
7	73.0	3.868	3.577	6.553
8	69.4	3.630	3.357	6.146
9	66.1	3.406	3.150	5.765
10	62.9	3.196	2.955	5.407
11	60.0	2.999	2.773	5.071
12	57.2	2.814	2.602	4.756

Summary of results

Particulars	Quantity	Unit
Sludge flowrate @ inlet	100	Kg/hr
Moisture evaporated	45.4	Kg/hr
Sludge flowrate @ outlet	54.6	Kg/hr
Sludge disposal cost	16.5	Kg/Kg
Sludge disposal cost w/o drying	1650	Kg/hr
Disposal cost for outlet sludge	901	Kg/hr
Steam required	83.2	Kg/hr
Steam cost	124.8	Rs/hr
Sludge disposal cost after drying	1025.9	Rs/hr
Savings	**624.1**	**Rs/hr**
	44,93,526	**Rs/year**

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