CHEMICAL ENGINEERING TRANSACTIONS Volume 21, 2010
Editor J. J. Klemeš, H. L. Lam, P. S. Varbanov
Copyright © 2010, AIDIC Servizi S.r.l., ISBN 978-88-95608-05-1 ISSN 1974-9791
DOI: 10.3303/CET1021025

Shallow spouted beds for drying of sludge from the paper industry

María J. San José*, Sonia Alvarez, Alvaro Ortíz de Salazar, Alberto Morales, Javier Bilbao
Departamento de Ingeniería Química.
Universidad del País Vasco. Aptdo 644. 48080 Bilbao
mariajose.sanjose@ehu.es

With the aim of determining the applicability of shallow spouted beds to dry moist sludge wastes from paper industry, an experimental study, with different geometric factors and at different experimental conditions at gas inlet temperatures from room temperature up to temperature of 140 ºC, has been carried out. The stable experimental conditions have been determined and the experimental results of minimum spouting velocity have been fitted to the equation proposed by Mathur and Gishler (1955). The results prove the applicability of these contactors for drying of sludge from paper industry.

1. Introduction

Since the 20th century the disposal of sludge wastes from paper industry has become an environmental and social problem, since the physical-chemical and mechanical characteristic of the sludge provide a variable behaviour when they are exposed at environmental conditions, because of the normal process of decomposition. In addition, the great amounts produced daily cause that it would be considered a special waste. Therefore, other alternatives of use and valorization, different from the final disposition in the ground (Garrett and Garret, 1995; Hoyos et al., 2000; Tay, 2000), are required. Besides the environmental and sanitary problems, it is necessary to consider that sludge with mechanical drying contain great water content, greater than wt % 100 in dry base, which increases the costs of manipulation and transport and makes difficult a possible later incineration

The thermal treatment by drying would be the more suitable alternative because allows for reducing moisture content, therefore the weight of these wastes will be reduced too. Furthermore, drying is the first stage of the incineration process. Elsaesser et al., (2009) carried out dewatering of sewage sludge. Moreover, the first application of spouted beds was drying of grain. Several authors have used spouted bed in drying of granulated materials (Altzibar et al., 2007, 2008; Mujumdar, 1984; Passos et al., 1987; Strumillo et al., 1980; Viswanathan, 1986) and pasty materials (Almeida et al., 2010), sewage sludge (El-Naas et al., 2000) and paper sludge (Kudra et al., 2002).

Please cite this article as: San Jose M. J., Alvarez S., Ortiz de Salazar A., Morales A. and Bilbao J., (2010), Shallow spouted beds for drying of sludge from the paper industry, Chemical Engineering Transactions, 21, 145-150 DOI: 10.3303/CET1021025

In previous papers it has been proved that spouted bed technology is successful for wastes treatment (Olazar et al., 1994; San José et al., 2002a, 2002b, 2006) and drying of sludge from the paper industry (San José et al., 2008) and thermal treatment of sludge from the paper industry (San José et al., 2010). In addition, this technology removes the disadvantages of sludge treatment (stickiness, wide sizes distribution, etc), and allows for drying at low temperatures.
In order to dry sludge from paper industry, in this paper, shallow spouted bed has been chosen as a novel dryer, considering this technology suitable due to ability to handle solids and mixtures of different sizes and textures (stickiness and hardness with attrition) and with different water contents.

2. Experimental

The experimental unit designed at pilot plant scale, shown in Figure 1, allows for operation with contactors of different geometry. It consists of a blower that supplies a maximum flow rate of 300 Nm^3h^{-1} at a pressure of 15 kPa, and two high efficiency cyclones in order to collect fine particles. The flow rate is measured by means of two mass flowmeters in the ranges of 50-300 and 0-100 m^3 h^{-1}, both being controlled by a computer. The accuracy of this control is 0.5% of the measured flow rate.

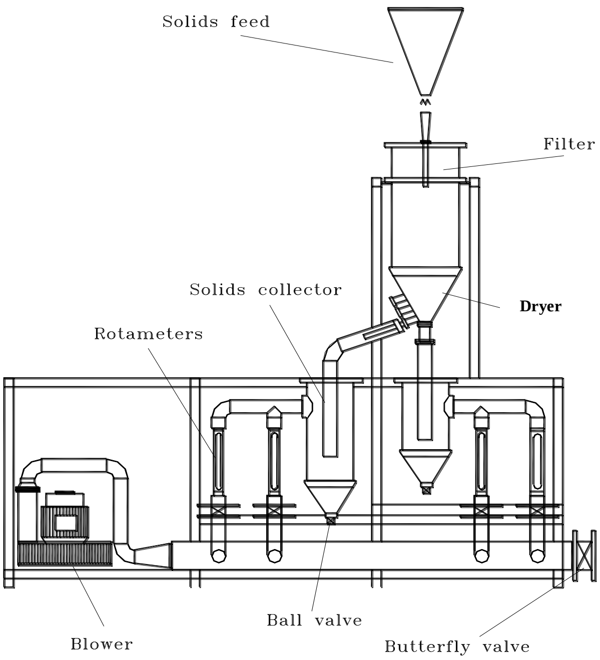

Figure 1: Experimental equipment

A novel drying contactor, Figure 2, a shallow spouted bed of angle of the conical base, γ_b, 60º; column diameter, D_c, 0.152 m; base diameter, D_i, 0.62 m; with different gas inlet diameters, D_o between 0.03 and 0.05 m and at different experimental conditions (stagnant bed height, H_o up to 0.4 m; Sauter mean diameter, $\overline{d_S}$, and gas velocity, u) has been used and the optimal design for the treatment of sludge has been obtained. The operation has been carried out at minimum spouting velocity and at higher gas velocities.

Sludge studied has Sauter mean particle diameter, $\overline{d_S}$ = 2.81 mm and density, ρ_s= 1123 kg/m^3. Solid moisture measured by means of a Mettler Toledo hygrometer and by an AQUA-Boy KPM HM III hygrometer is wt % 103 in dry basis.

The treatment of sludge at temperatures from room temperatures up to 140 ºC has been carried out with air heated by means of an electrical heating device, located at the inlet of the contactor.

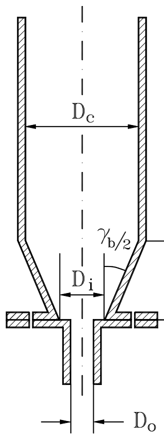

Figure 2: Geometric factors of the drying contactor

3. Results

In order to determinate the applicability of shallow spouted beds dryer for treatment of sludge from paper industry, the spouting regimes of uniform beds consisting of moist sludge have been determined experimentally and minimum spouting velocity has been calculated at temperatures from room temperatures up to 140 ºC with different gas inlet diameters and at different experimental conditions.

The experimental data of minimum spouting velocity of beds of moist sludge in shallow spouted beds dryer have been fitted to the equation proposed by Mathur and Gishler (1955):

$$u_{ms} = \left(\frac{d_p}{D_c}\right)\left(\frac{D_o}{D_c}\right)^{1/3}\left[\frac{2g\,H_o\,(\rho_s-\rho)}{\rho}\right]^{1/2} \tag{1}$$

The maximum relative error of experimental data to the calculated by this equation is 9%.

As is deduced from eq. (1), the minimum spouting velocity of beds consisting of sludge wastes for systems that are only different in temperature, depends only on gas density.

In Figure 3 the operating map in plots of gas inlet temperature, T, against gas velocity, u (referred to diameter of the cylindrical section) is shown for a system taken as an example (angle of the conical base, γ_b, 60º; gas inlet diameter, D_o = 0.04 m; stagnant bed height, H_o= 0.20 m; uniform beds consisting of sludge of Sauter mean particle diameter, $\overline{d_S}$ = 2.18 mm). In this map, the spouting regimes for different velocities and gas inlet temperatures are shown, points correspond to experimental values and lines to the theoretical values obtained with eq. (1). As it is observed in Figure 3, starting in the fixed bed as gas velocity is increased stable spouted bed regime is reached. As gas inlet temperature increases, gas velocity necessary to attain the spouted bed regime increases, so the spouted bed zone decreases. Nevertheless, shallow spouted beds dryer present a wide range of operating conditions for the treatment of sludge with high water content, as sludge from the process of paper manufacture. In addition, the system is stable for any the experimental conditions studied.

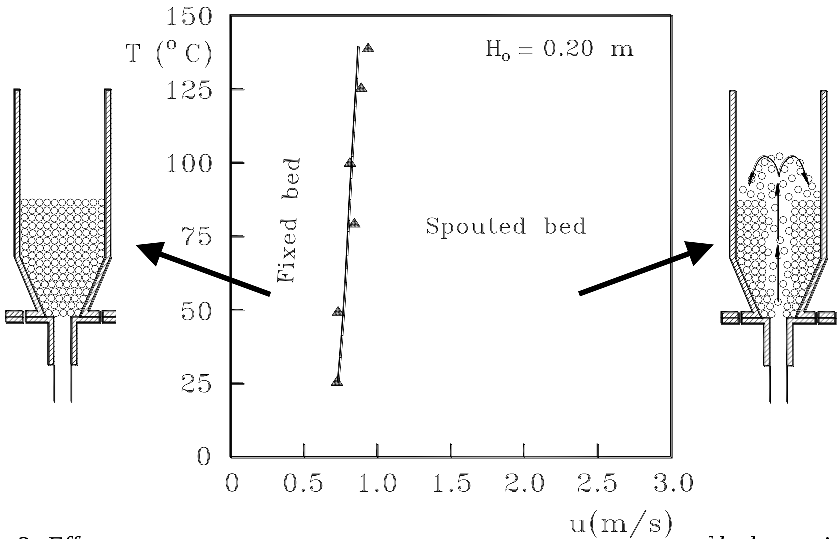

Figure 3: Effect of the gas inlet temperature on the spouting regimes of beds consisting of uniform beds of sludge wastes of $\overline{d_S}$ = 2.81 mm. Experimental system: γ_b= 60º; gas inlet diameter, D_o= 0.04 m; stagnant bed height, H_o= 0.20 m; gas inlet temperatures, T= 25, 50, 80, 100, 125 and 140 ºC. Points: experimental values, lines: calculated values.

Conclusions

An experimental study has been performed to determinate the stability of beds consisting of moist sludge wastes in shallow spouted beds at temperatures over room temperature.

Operating maps at temperatures over room temperature in dryers with different gas inlet diameters and at different experimental conditions have been obtained. It is observed that as gas inlet velocity is increased, the system passes from the fixed bed to spouted bed regime. Minimum spouting velocity increases slightly as gas inlet temperature increases from room temperature up to 140 ºC. In spite of stable operation zone decreases, this zone is wide enough up to 140 ºC to treat sludge wastes from paper industry with a shallow dryer spouted bed.

The validity and applicability of the correlation proposed by Mathur and Gishler (1955) for calculation of minimum spouting velocity in spouted beds has been proven for treatment of beds consisting of moist sludge wastes for paper industry in shallow spouted beds in a wide range of operating conditions at different gas inlet temperatures from room temperature up to 140 ºC.

From the experimental results can be concluded that the system is stable for any experimental conditions studied and that shallow spouted beds have a good behaviour for stable treatment of beds consisting of moist sludge wastes. Therefore, shallow spouted beds dryers are suitable for the drying of beds consisting of moist sludge wastes in a wide range of gas inlet diameters and operating conditions.

Nomenclature

D_c, D_i, D_o	Diameter of the column, of the bed bottom, and of the bed inlet, respectively, m
$\overline{d_S}$	Sauter mean diameter, m
H_c, H_o	Height of the conical section and of the stagnant bed, respectively, m
g	Gravity, ms^{-2}
T	Temperature, ºC
u, u_{ms}	Velocity and minimum spouting velocity of the gas, respectively, $m\ s^{-1}$

Greek Letters

γ_b	angle of the conical base of the contactor, deg
ρ_s	density of the solid, kg m^{-3}
ρ	density of the gas, kg m^{-3}

Acknowledgements

This work was carried out with the financial support of the University and of the County Council of Biscay (Project DIPE 07/09) of the Spanish Ministry of Science and Innovation (Project TRA2009-0318 and Project CTQ2010-18697).

References

Almeida, A.R.F., Freire, F.B., Freire, J.T., 2010. Transient analysis of pasty material drying in a spouted bed of inert particles. Drying Technology 28(3), 330-340.

Altzibar, H., Lopez, G., San José, M.J., Alvarez, S., Olazar, M., 2007. Drying of Fine Sand in a Pilot Plant Unit Provided with a Draft-Tube Conical Spouted Bed. Chemical Engineering Transactions 1, 725-730.

Altzibar, H., Lopez, G., Álvarez, S., San José, M.J., Barona, A., Olazar, M., 2008. A Draft-Tube Conical Spouted Bed for Drying Fine Particles. Drying Technology 26, 308-314.

El-Naas, M.H., Rognon, S., Legros, R., Mayer, R.C., 2000. Hydrodynamics and mass transfer in a spouted bed dryer. Drying Technology 18(1 & 2), 323-340.

Elsaesser, T., Boran, J., Houdkva, L., 2009. Dewatering of thermally disintegrated sewage sludge. Chemical Engineering Transactions 18, 983-988.

Garret, R. and Garret, D., 1995. Beneficial use of paper mill sludge, BioCycle 36, 69-71.

Hoyos, M.T., López, Y., Mejíal, C.A., Rojas, J., Vargas, S., 2000. Aprovechamiento de los lodos primarios de las fábricas de papel. UPB, 7.

Kudra, T., Gawrzynski, Z., Glaser, R., Stanislawski, J., Poirier, M., 2002. Drying of pulp and paper sludge in a pulsed fluid bed dryer. Drying Technology 20(4 & 5), 917-933.

Mathur, K.B. and Gishler, P.E., 1955. A technique for contacting gases with coarse solid particles. AIChE Journal 1, 157-164.

Mujumdar, A.S., 1984. Spouted bed Technology. In Drying'84; Mujumdar, A.S., Eds., New York: Hemisphere Publishing Corporation, pp. 151-157.

Olazar, M., San José, M.J., Llamosas, R., Bilbao, J., 1994. Hydrodynamics of sawdust and mixtures of wood residues in conical spouted beds. Industrail and Engineering Chemistry Research 33, 993-1000.

Passos, M.L., Mujumdar, A.S., Raghavan, V.G.S., 1987. Spouted beds for drying: principles and design considerations. In Advances in Drying, Mujumdar, A.S., Ed.; Hemisphere Publishing Corporation, pp. 359-396.

San José, M.J., Alvarez, S., Aguado, R., Bilbao, J., 2002a. Combustión de Serrín y Residuos Agroforestales en Spouted Beds Cónicos. Información Tecnológica 13(2), 127-131.

San José, M.J., Alvarez, S., Izquierdo, M.A., Ortiz de Salazar, A., 2002b. Fluidodinámica de los Lechos de Borbor Cónicos (Spouted Beds) para el Tratamiento de Residuos Plásticos. Información Tecnológica 13(5), 21-24.

San José, M.J., Alvarez, S., Ortiz de Salazar, A., Morales, A., Bilbao, J., 2006. Treatment of Cork Wastes in a Conical Spouted Bed Reactor. International Journal of Chemical Reactor Engineering 4, A15, 1-7.

San José, M.J., Alvarez, S., Ortiz de Salazar, A., Morales, A., 2008. Design of conical spouted bed contactor for drying of sludges from the paper industry. In CHISA 2008 Proceedings, Summaries 3, pp. 959-960.

San José, M.J., Alvarez, S., Morales, A., Ortiz de Salazar, A., 2010. Diluted Spouted Bed at High Temperature for the Treatment of Sludges Wastes. Chemical Engineering Transactions 20, 303-308.

Strumillo, C., Pakowski, Z., Stolarek, P., 1980. A survey of recent polish research on drying. In Drying'80, Vol. I, McGraw-Hill, pp. 4-15.

Sundstrom, D.W. and Klei, H.E., 1979. Wastewater treatment. Englewwod Cliffs: Prentice Hall, p. 387.

Tay, J.H., 2000. Reuse of industrial sludge as pelletized aggregate for concrete. Journal of Environmental Engineering 3, 279-287.

Viswanathan, K., 1986. Model for continuous drying of solids in fluidized/spouted beds. Canadian Journal of Chemical Engineering 64, 87-95.

Wang, M.C., Hull, J.Q., Jao, M., Dempsey, B.A., Cornwell, D.A., 1992. Engineering behaviour of water treatment sludge. Journal of Environmental Engineering 118, 849-864.