Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 57 (2014) 633 – 642

Energy Procedia

2013 ISES Solar World Congress

# Evaluation of pressure drop and particle sphericity for an air-rock bed thermal energy storage system

Jamie Trahan[a], Alessandro Graziani[b], D. Yogi Goswami[a]*, E. Stefanakos[a], Chand Jotshi[a], Nitin Goel[c]

[a] *USF Clean Energy Research Center, University of South Florida, 4202 E. Fowler Ave. ENB 118, Tampa, FL 33620 USA*
[b] *Department of Management and Engineering, University of Padova, Stradella San Nicola, 3 - 36100 Vicenza, Italy*
[c] *SunBorne Energy Inc., Gurgaon, India*

**Abstract**

The pressure drop of a packed bed thermal energy storage system with irregular shaped solid pellets and tank-to-particle diameter ratio of 10.4 is investigated. The bed height to diameter ratio is 2. The particle sphericity is calculated and used to compare pressure drop correlations to the measured values in the particle Reynolds number range of $353 \leq Re_p \leq 5206$.



*Keywords:* packed bed; pressure drop; tank-to-particle ratio; particle sphericity

## 1. Introduction

A packed bed thermocline system is a promising thermal energy storage (TES) concept due to its single tank design and employment of cheap and abundant storage media such as sand and rock. Laboratory-scale and pilot-scale packed bed systems have been tested and used to develop empirical correlations and validate numerical models that describe fluid flow and heat transfer within these systems. The models provide an avenue by which the parameters of a packed bed and their influence on performance and thermal behaviour can be investigated.

Within packed bed systems, pressure drop pumping losses can be significant. Thus many studies focus on developing pressure drop correlations which are based on key parameters that affect the transport properties of a system. These parameters must be optimally chosen such that they minimize pressure losses without compromising heat transfer and efficiency.

**Nomenclature**

$A_p$ surface area of particle, $m^2$

$A_{sp}$ surface area of sphere, $m^2$

* Corresponding author. Tel.: 1-813-974-7322; fax: 1-813-974-2050.
*E-mail address:* goswami@usf.edu.


doi:10.1016/j.egypro.2014.10.218

| | |
|---|---|
| d | diameter of packed bed tank, m |
| $D_{eq}$ | equivalent particle diameter defined by Li and Ma [4], m |
| $D_p$ | particle diameter, m |
| $D_{sd}$ | Sauter diameter - equivalent particle diameter by specific surface, m |
| $D_v$ | equivalent particle diameter by volume, m |
| f | dimensionless friction factor |
| L | height of packed bed, m |
| $Re_h$ | hydraulic particle Reynolds number |
| $Re_p$ | particle Reynolds number |
| U | superficial bed velocity, viz. average velocity in an empty tank, m/s |
| $V_p$ | volume of particle, $m^3$ |
| *Greek letters* | |
| ε | void fraction |
| ΔP | pressure drop of packed bed, Pa |
| μ | dynamic viscosity of the fluid, kg/(m-s) |
| ρ | density of the fluid, $kg/m^3$ |
| ψ | particle sphericity |

Of the various pressure drop correlations that have been presented, the Ergun equation [1] is one of the most widely adopted:

$$\frac{\Delta P}{L} = A\frac{(1-\varepsilon)^2}{\varepsilon^3}\frac{\mu U}{D_p^2} + B\frac{1-\varepsilon}{\varepsilon^3}\frac{\rho U^2}{D_p} \tag{1}$$

where the coefficient *A* is 150 and *B* is 1.75.

In Ergun's seminal publication, previous theories and equations on pressure loss through a bed were utilized in conjunction with experimental data to establish the above relationship. The first term on the right-hand side represents viscous energy losses that dominate during laminar flow and the second term accounts for kinetic losses that govern in the turbulent regime. Experiments used in the development of the correlation included particles of various shapes such as spheres, cylinders, tablets, and crushed solids. The only factors considered in the analysis were fluid flow rate, particle diameter, fluid viscosity and density, and fractional void volume. The correlation should be valid for hydraulic particle Reynolds numbers between 1 and 3000. The hydraulic particle Reynolds number differs from the particle Reynolds number that is typically used, in that it has a dependence on the void fraction. The hydraulic particle Reynolds number and particle Reynolds number are defined respectively as [2]:

$$\mathrm{Re}_h = \frac{\rho U D_p}{\mu(1-\varepsilon)}, \tag{2}$$

$$\mathrm{Re}_p = \frac{\rho U D_p}{\mu} \tag{3}$$