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SISTEMAS DE ENERGIA**

# **Layers Porosity**

**Relatório interno**

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**December 2020**

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## 1 Layers Porosity

Different control volume means air, solid, and liquid. In this study, solid air was used in the ullage space, then alternating filler material and HTF, and at the end only filler material in the middle

It was also managed, to make the five filler bed in the middle, with different porosities.

### 1.1 INTRODUCTION TO POROSITY

The knowledge of the size of filler bed particles is very important for a thermocline design.

Porous media pores are adjustable to a certain degree of voids, that allowed the hot molten salt to reach the tank and thus to contribute to a full developed thermocline.

Permeability is an important concept for a given porous media concerning momentum transport as it is one of the factors that must be known for numerical simulation.

This property is often treated in an easily way as porosity or void fraction.

The thermal dispersion caused by a solid media plays an important role in the heat transfer enhancement.

Considering the heat storage tank with the filler material and the heat transfer fluid, the void fraction is the ratio of the volume occupied by the fluid as follows;

$$\varepsilon = V_f / V_{tank}$$

Where,  $\epsilon$  means porosity

This effect is related with materials properties of the filler and with the pretended demand thermal energy storage of the plant.

## 1.2 POROSITY AND CONDUCTIVITY

The Darcy's Law, formulated by Henry Darcy, is result of his experiments on water in the sandy environment is the scientific basis of hydrogeology. This Law is analogous to Fourier's in the field of heat conduction, Ohm's in electricity and Fick's in diffusion theory.

Figure 1 shows a section of a sand duct.

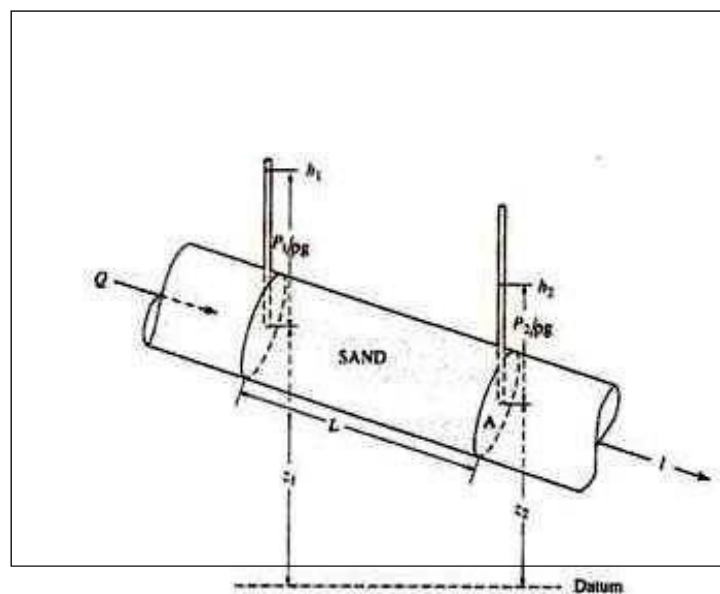


Figure 1 Duct filled with sand, with  $Q$  discharge (Bennett and Zhenhg (2000))

Water of uniform viscosity and density flows through the pipe under pressure. The pipe being filled with water and the sand remains saturated. The discharge, in volume of water per unit of time, is called  $Q$ . With the help of piezometers at each end of the tube, to measure the total load above a reference. The sectional area of the tube is designated by  $A$

and the length of the section with sand of  $L$ . The discharge through the section of sand is given by:

$$Q = KA \frac{h_2 - h_1}{L} \quad (1)$$

where  $K$  is called hydraulic conductivity of sand;  $h_1$  the total load on the water inlet face and  $h_2$  on the outlet face. Equation 1 is the form of Darcy's Law, which describes the flow in the porous medium.

You can define the interstitial speed  $v$ , through the sand section as:

$$v = \frac{Q}{\varepsilon A} \quad (2)$$

where  $\varepsilon$  is called porosity, which ranges from 0 to 1 and can be defined as the ratio of the void volume between the grains to the total volume of the porous medium. The differential form of equation 1 is shown below:

$$v = - \frac{k dh}{\varepsilon dl} \quad (3)$$

Darcy speed  $q$ , can be defined as  $Q/A$  and  $v \varepsilon$

Which turns equation (3) to be written as:

$$q = \frac{Q}{A} = -k \frac{dh}{dl} \quad (4)$$

per unit area section and is often called a specific discharge. It represents the average speed in the open tube, outside the sand section.

It is also noted that:

$$v = \frac{A}{\varepsilon} \quad (5)$$

the term ( $\varepsilon.A$ ) is smaller than  $A$ , on the outside of the sand section, and as the discharge passes through all the sections, it is assumed that the speed is higher inside the sand than in the sand. outside of the sand.

$$k_x = \frac{k_x \rho g}{\mu}$$

$k_x$  is defined as intrinsic permeability;  $\rho$  is the density of the fluid and  $v$  is the viscosity. Observing equation 6, it can be seen that intrinsic permeability is a function only of the porous medium while the hydraulic conductivity incorporates the properties of the fluid.

## 2.Porosity in ANSYS Fluent

When making a modelation with ANSYS there are some steps before establish the properties of the componentes.

This procedure was usual until version 16. After that things change and even before going to set up, that is during the preptocessing it tis possible to establish the properties of componentes from Engineering Data.

This works together with Excel and allows to pick existent propertirs from a list or, if not, to construct our list from the beginning without any more problems during set up.

Previously, this part was contorned making well C++ UDF's that contained the information we need. Nevertheless, those UDF could have problems each ime a modification is performed and we do not remember, So it must be compiled again. When the Ansys Version is diferent there is also a problem.

## 2.1 DEFINING THE POROUS MATERIAL

If you choose to model heat transfer in the porous medium, you must specify the material contained in the porous medium.

To define the material contained in the porous medium, scroll down below the resistance inputs in the **Fluid** panel, and select the appropriate solid in the **Solid Material Name** drop-down list under **Fluid Porosity**.

If you want to check or modify the properties of the selected material, you can click **Edit...** to open **Material** panel; this panel contains just the properties of the selected material, not the full contents of the standard **Materials** panel. In **Material** panel, you can define the non-isotropic thermal conductivity of the porous material using a user-defined function (UDF). The user-defined option becomes available in the corresponding drop-down list when the UDF has been created and loaded into **FLUENT**. Note that the non-isotropic thermal conductivity defined in the UDF must utilize the `DEFINE_PROPERTY` macro. For more information on creating and using user-defined function, see the separate UDF Manual.

## 2.2 DEFINING SOURCES

If you want to include effects of the heat generated by the porous medium in the energy equation, enable the **Source Terms** option and set a non-zero **Energy** source. The solver will compute the heat generated by the porous region by multiplying this value by the total volume of the cells comprising the porous zone. You may also define sources of mass, momentum, turbulence, species, or other scalar quantities.

### 2.2.1. Defining Fixed Values

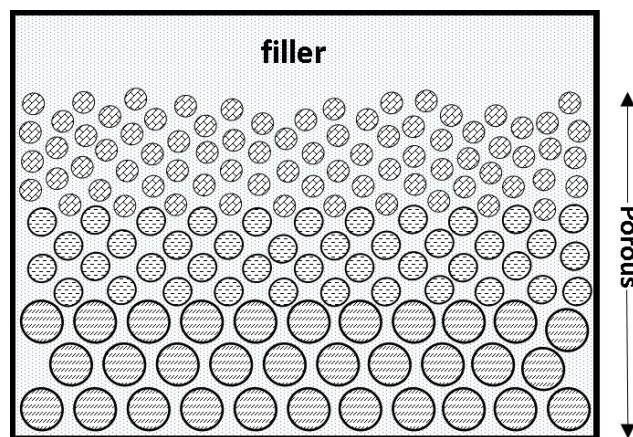
If you want to fix the value of one or more variables in the fluid region of the zone, rather than computing them during the calculation, you can do so by enabling the **Fixed Values** option.

As an example consider a Darcy speed  $q$ , can be defined as  $Q/A$  and  $v \varepsilon$

tank w Darcy speed  $q$ , can be defined as  $Q/A$  and  $v \varepsilon$

without layers where three types of porosities are being considering:

The knowledge of the size of filler bed particles is very important for a thermocline design. Porous media



pores are adjustable to a certain degree of voids that allowed.

the hot molten salt to reach the tank and thus to contribute to a full developed thermocline. Permeability is an important concept for a given porous media concerning momentum transport as it is one of the factors that must be known for numerical simulation. This property is often treated in an easily way as porosity or void fraction. The thermal dispersion caused by a solid media plays an important role in the heat transfer enhancement.

### **2.2.2 Comparison of three values for porosity of filler**

Three values for the porosity were taken into account;  $\varepsilon = 0.14$ ,  $\varepsilon = 0.22$  and  $\varepsilon = 0.46$ . The first one is considered the lower limit and the last one is taken as a higher possible value for porosity. Their performance was analyzed at 4h, 12h, 16h and 22h.

The purpose is to analyze which is the value that contribute to a better develop of the thermocline and consequently to reach a higher temperature.

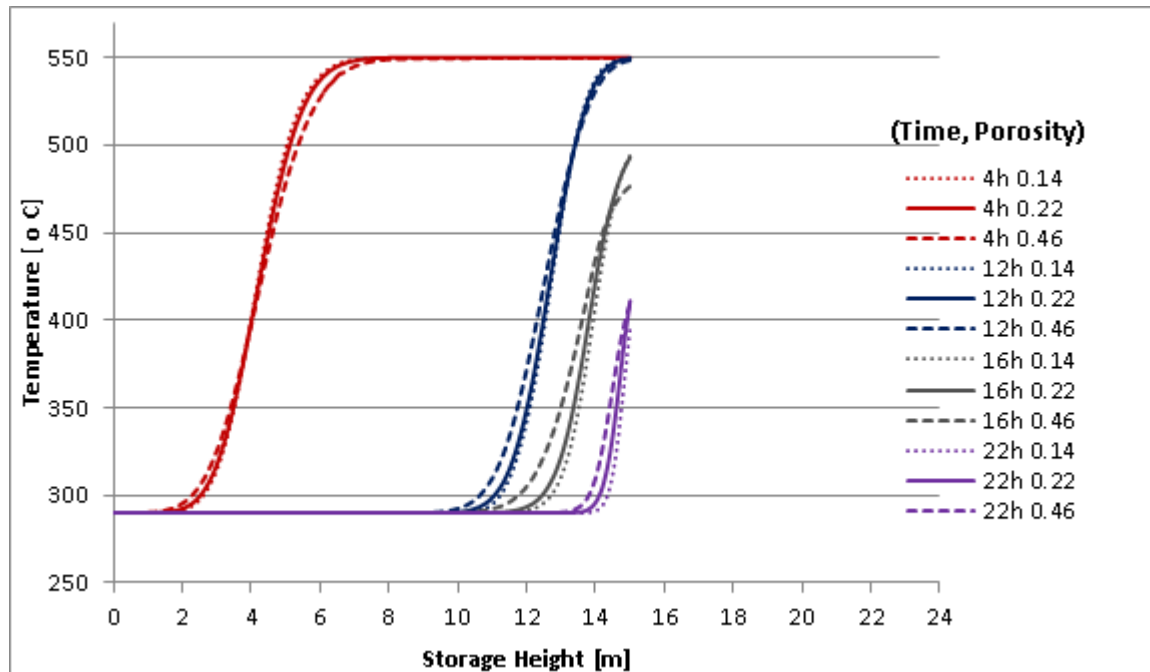


Fig. 3 Porosities for situation of  $H/W < 1$

This Fig. allows to take some conclusions about the situation where in the tank the considered geometry is  $H/W < 1$  (Height/Weight).

An evidence of figure 3 is that higher temperatures are obtained when the porosity of the filler bed is higher ( $\epsilon = 0.46$ ). At this situation the thermocline is less defined. Discharge efficiency is increased by smaller filler-bed particles that are in the tank where are more voids. The filler can move very quickly and in a very free way through the rocks. It is impossible to establish a thermocline, and a great discharge is not always desirable

The situation that corresponds to better defined thermoclines is when  $\epsilon = 0.14$ . The situation is the inverse of the first one but, however, it could not be the ideal. The intermediate situation,  $\epsilon = 0.22$ , can be a good compromise between a well- defined thermocline and a reduced loss of charge, in order to obtain a better storage unit functioning.

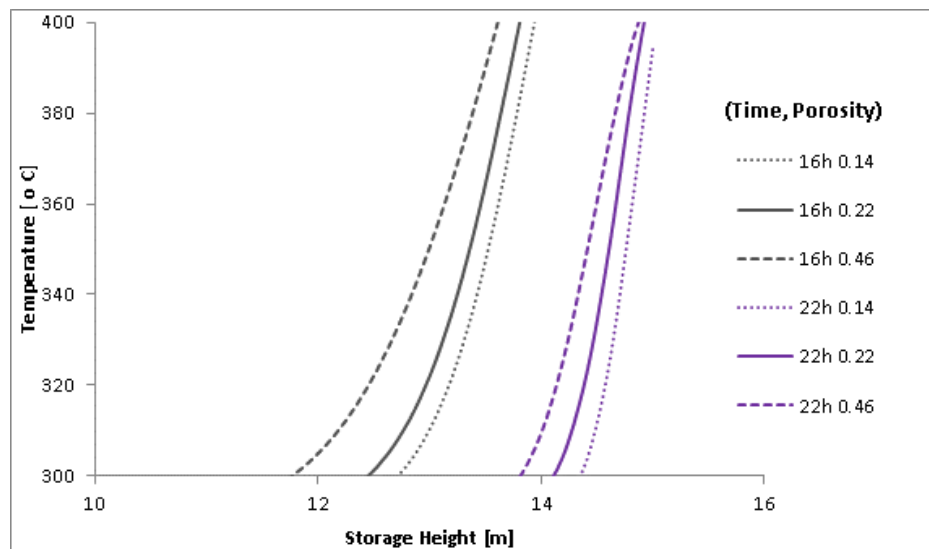


Fig. 4-Amplification for the results of 16h and 22h for T in [300, 400] [° C]

Figure 4 clearly shows the difference of temperatures when considering the porosities of 0.14, 0.22 and 0.46 for 16h and 22h in the range of 300 to 400 degrees. Temperature profiles for lower values of porosities are almost parallel being the profile for 0.14 more straight. This profile as well as the one corresponding to 0.22 conducts to higher temperatures than the one corresponding to 0.46.

After building the geometry and eventual the mesh the tank has eight zones. Each one has a different constitution thus a different porosity that goes from 0 to 1.

The five zones in the middle (two above, and one below) are constituted by filler bed and are those that we are interesting in.

After having the mesh, set up begins with general conditions, the model and boundary conditions. Now the porous zone model inside model and boundaries must be activated through the cell zone conditions. The Direction-1 Vector and Direction-2 Vector are assumed.

For the viscous and inertial resistance directions must enter in each filler zone (filler-zone-1, filler-zone2 ..) the values calculated according the RV formula. (Ergun Formula).

The default number is assumed for ANSYS to be 500,000, but with porosity and cells diameter the real number can be properly calculated.

## 2.3 USING THE ERGUN EQUATION TO DERIVE POROUS MEDIA INPUTS FOR A PACKED BED

Consider the modeling of a packed bed. In turbulent flows, packed beds are modeled using both a permeability and an inertial loss coefficient. One technique for deriving the appropriate constants involves the use of the Ergun equation a semi-empirical correlation applicable over a wide range of Reynolds numbers and for many types of packing:

$$\frac{|\Delta p|}{L} = \frac{150\mu}{D_p^2} \frac{(1 - \epsilon)^2}{\epsilon^3} v_\infty + \frac{1.75\rho}{D_p} \frac{(1 - \epsilon)}{\epsilon^3} v_\infty^2$$

Filler bed layers are obviously different. So in each one a different value of porosity must be attributed corresponding to the material.

Each correspond to a set of boundary conditions and have different properties being one of them the porosity.

