Tensiometer Reaction Related to Its Filter Dimensions

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Abstract. A theoretical model for tensiometers is presented. It is based on a new physical considerations: the tensiometer filter is a quasi-saturated porous medium and the transmission fluid in the cavity is in hydrostatic equilibrium and is incompressible. The evolution equations form a complete system which could be used and coupled in a wide number of situations once filter dimensions and geometry have been correctly defined. The model is applied to tensiometer design and leads to new design recommendations. It predicts the existence of two distinct evolution modes for tensiometers. The time constant of the first varies linearly with the ratio of filter thickness to contact area and that of the second varies according to the square of the filter thickness and is independent on the contact area. The model leads to the formulation of an equation for fine-filter tensiometers. This extends Richards and Neal's equation by taking fine-filter geometry and gravity into account.

Key words: Cavity, contact area, design criteria, evolution mode, filter dimensions, fine-filter tensiometer, quasi-saturated, transmission fluid, thickness.

0. Nomenclature

\[ A \] area of surface \( S_i \)
\[ A_n, B_n \] coefficients defined in Appendix B
\[ C \] filter capacity
\[ da \] boundary integration element
\[ g \] constant gravity vector field
\[ K \] permeability
\[ L \] filter thickness
\[ M_f \] mass of transmission fluid exchanged for a unit variation of the potential
\[ M_{mn} \] components of a matrix defined in Appendix B
\[ n \] porosity
\[ n \] outward unit vector to filter rim (boundary)
\[ N \] number of terms (Appendix B)
\[ p \] pressure
\[ p_i, p_e \] internal, external pressure
\[ q \] volume flux
\[ r \] variable defined in Appendix B
\[ r_n \] coefficients defined in Appendix B
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$S$  global sensitivity and gauge sensitivity
$S_i, S_e, S_r$  filter rim
$S_f$  saturation of filter
$t$  time
$U$  velocity of the transmission fluid in the cavity
$V$  volume of filter
$V_c$  volume of cavity
$V_p$  volume of parasitic fluid
$x$  positional vector
$z$  spatial coordinate

Greek letters

$\beta_p$  compressibility of the parasitic fluid
$\phi$  potential
$\phi_e$  potential outside of tensiometer
$\phi_i$  potential inside of tensiometer
$\phi_0$  initial potential
$\phi_p$  potential of parasitic fluid
$\eta$  adimensional parameter defined in (5.8)
$\kappa$  conductance
$\mu$  dynamic viscosity
$\pi$  pi
$\rho$  density of transmission fluid
$\rho_p$  density of parasitic fluid
$\tau$  temporal parameter and time constant
$\omega$  adimensional temporal coordinate
$\zeta$  adimensional spatial coordinate

Symbols

$\nabla$  gradient operator
$a \cdot b$  scalar product of $a$ and $b$
$a \times b$  vector product of $a$ and $b$
$\phi'$  partial derivative of $\phi$ with respect to $\zeta$
$\phi'$  partial derivative of $\phi$ with respect to $\omega$
$\phi_e(t)$  mean geometrical value of $\phi_e(t, x)$ defined in (4.7)
$x \in V$  $x$ belongs to $V$

1. Introduction

A tensiometer is an instrument designed to measure fluid potential in a porous medium. It is particularly useful when the fluid for which it is designed does not saturate the porous medium which contains it. All tensiometers comprise three essential elements which are a pressure gauge, a porous filter and transmission fluid. The pressure gauge and porous filter are placed alongside a hollow body.