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MULTIFUNCTION TEST CELL FOR CAKE FILTRATION STUDIES

FIELD OF THE INVENTION

Filtration is a process for separating suspended solids from a liquid. Cake filtration employs the porous cake formed from the settled solid as a filter medium. An understanding of the filter cake properties, namely the local porosity, permeability and compressibility, the constitutive relations for dependence of these quantities on the applied pressure, and the solid matrix stresses are vital to the design, operation and optimization of cake filtration processes.

This invention relates to an apparatus for the precise determination of filter cake properties such as porosity, permeability and compressibility, and, more particularly, the invention relates to a multifunction test cell wherein cake compression, liquid permeation and constant pressure filtration tests can be carried out.

BACKGROUND OF THE INVENTION

The apparatus known as the compression-permeability cell (or C-P cell) has been used to study the effect of applied pressure on the porosity and specific resistance (or permeability) of a compressible filter cake. In the past, experimental studies on a wide range of materials and conditions have yielded constitutive relationships for filter cakes. Several inherent uncertainties in C-P cell results have been pointed out, including the effects of side-wall friction and cake inhomogeneity. In addition, the exact correlation between conditions in a C-P cell and in actual cake filtration operations has not been satisfactorily established. In spite of these difficulties, C-P cell results have been used extensively in the design of filtration processes.

Advantageously, the invention provides an apparatus that can be used at different times as a C-P cell, as a variable volume filtration chamber, and as a device for measuring wall friction exerted by a filter cake.

The invention also advantageously provides means for the precise setting or determination of applied and transmitted pressure, cake displacement, chamber volume and filtrate

flowrate.

Other features and advantages of the present invention will become apparent from the detailed description which follows.

SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided a multi functional test cell for conducting filter tests and for measuring compressibility and permeability of a filter cake material, said test cell comprising:

an upper piston;

a complementary lower piston; and

housing means for housing said upper and lower pistons, said upper and lower pistons defining a test chamber, wherein said upper piston is adaptable between (i) a first filter test configuration comprising a slurry inlet and a liquid outlet for filtering a slurry in said test chamber, and (ii) a second compressibility and permeability test configuration in which said upper piston comprises a liquid inlet and a distributor means for compressing a preformed filter cake in said test chamber and subsequently measuring its permeability.

According to another aspect of the invention there is provided a method for determining the permeability and compressibility of a medium, said method comprising:

feeding a slurry of the medium into a test chamber of a test cell at constant pressure to form a filter cake having a determinable mass of said medium, said test cell comprising an upper piston, a complementary lower piston, and housing means for housing said upper and lower pistons, said upper and lower pistons defining said test chamber, wherein during said feeding step said upper piston is in a first filter test configuration;

continuously measuring filtrate volume emitted from an outlet of said test chamber during said feeding;

once said filter cake has been formed, adapting said upper piston to a second compressibility test configuration;

compressing said formed filter cake at constant pressure;

monitoring vertical position of said upper piston during said compression to determine variation in filter cake thickness with time during said compression.

Furthermore, following compression of the filter cake in the method, further permeability studies may be conducted by feeding a liquid into the test chamber at constant pressure, and measuring flow rate of the liquid through the filter cake to enable the determination of the permeability of the compressed filter cake.

Although the means for distributing the liquid into the test chamber according to the second compressibility test configuration of the upper piston may be of any suitable form, in a preferred embodiment the upper piston comprises a piston head which integrally comprises the distributor means, the distributor means being closed when the upper piston is in the first configuration, and being open when the upper piston is in the second configuration. Preferably, the distributor means comprises a plurality of grooves on the lower face of the piston head.

In a particularly preferred embodiment, the piston head is adapted to receive a first insert to close the distributor means and to provide the liquid outlet of the first configuration, and a second insert which leaves open the distributor means. Preferably the first insert comprises a single orifice insert plate having a sharp orifice opening, and the second insert comprises a multi-orifice insert plate having a plurality of orifices distributed over the surface thereof. When conducting compressibility tests in the second configuration, the multi-orifice plate supports a filter medium on its lower surface.

When conducting compressibility tests in the second configuration, the upper piston preferably comprises an air bleed which enables air entrapped in the test chamber to escape from the test chamber during compression.

The test cell preferably comprises control means for controlling the vertical travel and applied force of the upper piston. In a preferred embodiment the control means comprises a load frame device which is instrumented for stroke, traverse speed and load hold. Furthermore, it is preferred that the lower piston is supported by a load cell for measuring pressure transmitted through the lower piston.

In a preferred embodiment the lower piston comprises a filter support which, in use, supports a filter medium, and a liquid outlet to facilitate the outflow of liquid from the test chamber.

The method according to the invention as described above advantageously makes it possible to conduct constant pressure filtration tests as well as compressibility and permeability tests of a medium sample. As discussed above in relation to the test cell according to the invention, the lower piston is preferably supported by a load cell such that pressure transmitted through the load cell may be monitored to facilitate calculation and sheer stress between the walls of the test chamber and the filter cake in the test chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and constitute a part of the description of the invention, illustrate embodiments of the invention and serve to explain the principles of the invention. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

FIG. 1 is a sectional view of the multifunction test cell configured as a filtration test cell with filtration chamber of variable volume.

FIG. 2 is a sectional view of a multifunction test cell constructed according to the present invention showing the cell configured for measuring the compression and permeability characteristics of a filter cake.

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

FIG. 1 shows an embodiment of the test cell of the invention in which the multifunction test cell is configured for use as a filtration test vessel. The test cell indicated generally by reference numeral 10, consists of a cylindrical vessel 12 an upper piston 40 and a lower piston 30. The upper piston 40 contains a slurry inlet 42 and the bottom of the piston is provided with a distributor region 26 consisting of a plurality of grooves. In this embodiment of the invention, the bottom of the upper piston 40 is fitted with an interchangeable insert plate 20 with a sharp orifice opening 44. The insert plate 20 is designed with a raised cylindrical portion surrounding the central orifice opening such that when it is fitted into place, the distributor region 26 of the upper piston 40 is closed off, thereby allowing slurry to flow into the filtration chamber only through the central orifice opening.

In typical operation and use of the embodiment of FIG. 1 the vessel 12 and lower piston 30 are fitted into place. Upon the support plate 34 is placed a filter medium such as a circular sheet of filter paper with the same diameter as the piston. The position of the upper piston 40 is fixed, thereby enclosing between it and the lower piston 30 a filtration chamber 18 of known volume.

The lower piston 30 contains a liquid outlet 32, and a multi-orifice support plate 34, below which is located a liquid collection region 36.

A slurry of the solid-liquid system of interest, with a known mass concentration of solid, is introduced into the filtration chamber through the slurry inlet 42 at a constant filtration pressure. In the process of filtration, solid particles are retained by the filter medium placed on the support plate 34, while liquid passes through to the liquid outlet 32. The volume of filtrate collected at the liquid outlet 32 is measured continuously. The solid particles eventually build up to form the filter cake 50. The thickness of the filter cake 50 increases with time, eventually reaching the orifice opening 44 in the upper piston to mark the end of the filtration test. This instant is conveniently detected by a sharp change in the filtrate flowrate. From the values of filtrate flowrate and the final mass of solid particles in the filter cake, the cake specific resistance (or equivalently, its permeability) can be evaluated.

By varying the filtration chamber volume, and by investigating the different times required for the filter cake to fill the filtration chamber 18, the growth rate of the filter cake can be deduced.

During the filtration test as described above, the transmitted pressure at the lower piston can be measured by the load cell 16. The difference between the values of set pressure of the upper piston and the transmitted pressure at the lower piston provides a measure of the shear stresses due to friction between the filter cake and the wall of the test vessel 12. The actual mean pressure experienced by the filter cake would be some appropriate mean value between the set pressure and the transmitted pressure.

Referring to FIG. 2 another embodiment of the present invention is illustrated in which the test cell is configured for compressibility and permeability testing. The test cell 10 once again consists of a cylindrical vessel 12 housing the upper piston 40 and lower piston 30.

The upper and lower pistons enclose a pre-formed filter cake 14 consisting of solid particles of the material of interest. The vertical travel and applied force of the upper piston is controlled by a commercially supplied load frame device which is typically instrumented for stroke, traverse speed and load hold. The lower piston 30 rests on a lower load cell 16 which measures the transmitted load. The lower load cell 16 is optional and this invention may be operated with or without it.

In this embodiment of the invention, the upper piston 40 contains a liquid inlet 22 by which liquid can be delivered to the filter cake. A separate opening 24 acts as an outlet for entrapped air. The bottom of the upper piston is, in this instance, fitted with a multi-orifice support plate 28. The distributor region 26 is left open to allow incoming liquid to be distributed throughout the entire cross-section of the cylindrical test cell 12. A filter medium such as a circular sheet of wetted filter paper with the same diameter as the piston head is placed below the multi-orifice plate 28.

In typical operation and use of the embodiment of FIG. 2, the column 12 and lower piston 30 are fitted into place. Upon the support plate 34 is placed a filter medium such as a circular sheet of filter paper with the same diameter as the piston. A filter cake of the solid-liquid system of interest is formed by suspending a known mass of solid particles in the liquid to form a slurry, and carefully transferring the slurry onto the filter medium in the test cell. The liquid phase is usually (but is by no means restricted to) water.

The upper piston is then lowered into position to compress the pre-formed filter cake at a constant set pressure. The vertical position of the upper piston is recorded continuously thereby providing a measure of the variation of the cake thickness (and hence its porosity) with the time during compression.

When an equilibrium cake thickness is attained, the permeability (or equivalently the specific cake resistance) of the filter cake can be determined by allowing liquid at a constant pressure head to flow in through the liquid inlet 22 and to pass through the compressed filter cake, and by measuring the flowrate of filtrate collected from the outlet 32.

During the compressibility test and permeability test as described above, the transmitted pressure at the lower piston can, once again, be measured by the load cell 16. The

difference between the values of set pressure of the upper piston and the transmitted pressure at the lower piston provides a measure of the shear stresses due to friction between the filter cake and the wall of the test vessel 12.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications which fall within its spirit and scope.

Claims

1. A multi functional test cell for conducting filter tests and for measuring compressibility and permeability of a filter cake material, said test cell comprising:

an upper piston;

a complementary lower piston; and

housing means for housing said upper and lower pistons, said upper and lower pistons defining a test chamber, wherein said upper piston is adaptable between (i) a first filter test configuration comprising a slurry inlet and a liquid outlet for filtering a slurry in said test chamber, and (ii) a second compressibility and permeability test configuration in which said upper piston comprises a liquid inlet and a distributor means for compressing a preformed filter cake in said test chamber and subsequently measuring its permeability.

2. A test cell according to claim 1, wherein said upper piston comprises a piston head which integrally comprises said distributor means, said distributor means being closed when said upper piston is in said first configuration, and being open when said upper piston is in said second configuration.

3. A test cell according to claim 2, wherein said distributor means comprises a plurality of grooves on the lower face of said piston head.

4. A test cell according to claim 2, wherein said piston head is adapted to receive a first insert to close said distributor means and to provide said liquid outlet of said first configuration, and a second insert which leaves open said distributor means.

5. A test cell according to claim 4, wherein said first insert comprises a single orifice insert plate having a sharp orifice opening, and wherein said second insert comprises a multi-orifice insert plate having a plurality of orifices distributed over the surface thereof.

6. A test cell according to claim 1, wherein, when in said second configuration, said upper piston comprises an air bleed which enables air entrapped in said test chamber to escape from said test chamber during compression.

7. A test cell according to claim 1, comprising control means for controlling the vertical



travel and applied force of said upper piston.

8. A test cell according to claim 7, wherein said control means comprises a load frame device which is instrumented for stroke, traverse speed and load hold.

9. A test cell according to claim 1, wherein said lower piston is supported by a load cell for measuring pressure transmitted through said lower piston.

10. A test cell according to claim 1, wherein said lower piston comprises:

a filter support which, in use, supports a filter medium; and

a liquid outlet to facilitate liquid outlet from said test chamber.

11. A method for determining the permeability and compressibility of a medium, said method comprising:

feeding a slurry of the medium into a test chamber of a test cell at constant pressure to form a filter cake having a determinable mass of said medium, said test cell comprising an upper piston, a complementary lower piston, and housing means for housing said upper and lower pistons, said upper and lower pistons defining said test chamber, wherein during said feeding step said upper piston is in a first filter test configuration;

continuously measuring filtrate volume emitted from an outlet of said test chamber during said feeding;

once said filter cake has been formed, adapting said upper piston to a second compressibility test configuration;

compressing said formed filter cake at constant pressure;

monitoring vertical position of said upper piston during said compression to determine variation in filter cake thickness with time during said compression.

12. A method according to claim 11, comprising feeding a liquid into said test chamber at constant pressure following compression of said filter cake; and

measuring flow rate of said liquid through said filter cake to enable the determination of the permeability of said filter cake.

13. A method according to claim 11, wherein said lower piston is supported by a load cell, transmitted pressure through said lower piston to said load cell being monitored to facilitate calculation of shear stress between walls of said test chamber and said filter cake.