mechanical properties expressed as a function of time, and as a function of different pressures and temperatures corresponding to the conditions encountered along a wellbore.

Another aim of the invention consists of supplying a method that can easily be applied industrially for characterizing the mechanical behavior of a cement system, which uses simple measurements that can be standardized.

Another aim of the invention consists of supplying a method for estimating the evolution of the mechanical parameters of a cement system over time, from the start to the end of hydration thereof.

The invention also aims to provide estimation of the static mechanical parameters of the cement, which constitute the parameters used for reliable simulation of the mechanical behavior of cement sheaths or plugs over their life.

The present disclosure provides a method for determining mechanical parameters of a cement system of initial composition $C_0$ and of fineness $\Phi$, as a function of time, and as a function of the fineness of the cement system, pressure and/or temperature, comprising the following steps:

(A) determining the degree of hydration of the cement system as a function of time $\alpha(t)$ from the velocity of the compression waves as a function of time $V_p(t)$ measured in a specimen of the cement system, at a pressure $P_1$ and a temperature $T_1$;

(B) determining the degree of hydration $\alpha(t)$ as a function of desired values of fineness $\Phi_n$ of the cement system, of pressure $P_n$ and/or of temperature $T_n$;

(C) determining the composition of the cement system as a function of time C(t) and as a function of desired values of fineness $\Phi_n$ of the cement system, of pressure $P_n$ and/or of temperature $T_n$, from the degree of hydration $\alpha$ (t) determined in step B;

(D) determining at least one mechanical parameter of the cement system as a function of time, and as a function of the desired values of fineness $\Phi_n$ of the cement system, of pressure $P_n$ and/or of temperature $T_n$, from the composition of the cement system C(t) determined in step C,

wherein the fineness of the cement system means the specific surface of said cement system measured using apparatus of the Blaine type according to standard NF EN 196-6.

The present disclosure further provides a software product for storing, in a memory of a unit of a processor or on a removable storage medium suitable for interacting with said processor unit, the software product comprising instructions for carrying out the method as described above and as otherwise set out herein.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows the logic diagram of the method according to the invention.

Fig. 2 is a schematic diagram illustrating the different stages of the process of hydration of a Portland cement.

Fig. 3 presents an example of a device of the Ultrasonic Cement Analyzer type (UCA) for measuring the velocity of the compression waves in a cement specimen used in the method according to the invention.

Fig. 4 is a diagram showing the velocity of the compression waves as a function of time $V_p(t)$ measured during a test of the UCA type on a cement system comprising Portland cement, as well as the degree of hydration as a function of time $\alpha(t)$ of the same cement system measured during a calorimetric test.

Fig. 5 is a diagram illustrating the linear relation between the velocity of compression waves as a function of time $V_p(t)$ and the degree of hydration as a function of time $\alpha(t)$ as shown in Fig. 3.

Figs. 6 to 8 are diagrams comparing the degree of hydration as a function of time $\alpha(t)$ determined by the method according to the invention for a given cement system, and the degree of hydration as a function of time $\alpha(t)$ for this same system, determined experimentally. The degrees of hydration are shown for different values of pressure and temperature. In Fig. 6, $\alpha(t)$ is shown for a low pressure of 0.3 MPa and at different temperatures (7°C, 13°C, 25°C, 40°C and 60°C). In Fig. 7, $\alpha(t)$ is shown at higher pressures, for the following pressure/temperature pairs: (40MPa, 30°C), (40MPa, 15°C), (20MPa, 30°C). In Fig. 8, $\alpha(t)$ is shown for the following two pressure/temperature pairs: (0.3MPa, 60°C), (20MPa, 60°C).

## CLAIMS

1. A method for determining mechanical parameters of a cement system of initial composition $C_0$ and of fineness $\Phi$, as a function of time, and as a function of the fineness of the cement system, pressure and/or temperature, comprising the following steps:

(A) determining the degree of hydration of the cement system as a function of time $\alpha(t)$ from the velocity of the compression waves as a function of time $V_p(t)$ measured in a specimen of the cement system, at a pressure $P_1$ and a temperature $T_1$;

(B) determining the degree of hydration $\alpha(t)$ as a function of desired values of fineness $\Phi_n$ of the cement system, of pressure $P_n$ and/or of temperature $T_n$;

(C) determining the composition of the cement system as a function of time C(t) and as a function of desired values of fineness $\Phi_n$ of the cement system, of pressure $P_n$ and/or of temperature $T_n$, from the degree of hydration $\alpha$ (t) determined in step B;

(D) determining at least one mechanical parameter of the cement system as a function of time, and as a function of the desired values of fineness $\Phi_n$ of the cement system, of pressure $P_n$ and/or of temperature $T_n$, from the composition of the cement system C(t) determined in step C,

wherein the fineness of the cement system means the specific surface of said cement system measured using apparatus of the Blaine type according to standard NF EN 196-6.

2. The method as claimed in claim 1, further comprising an initial step of measurement of the velocity of the compression waves as a function of time $V_p(t)$ in a specimen of the cement system.

3. The method as claimed in claim 1 or 2, wherein said mechanical parameter is selected from the static deformability parameters, preferably the static elastic parameters, such as static Young's modulus E, static Poisson's ratio $\nu$, bulk modulus K, shear modulus G, and combinations thereof.

4. The method as claimed in claim 3, wherein two static elastic parameters are determined.

5. The method as claimed in claim 3 or 4, further comprising determination of a mechanical parameter selected from the parameters of hydro-mechanical coupling, such as Biot's coefficient or Skempton's coefficient, and combinations thereof.

6. The method as claimed in one of the preceding claims, wherein the degree of hydration of the cement system as a function of time $\alpha(t)$ is calculated from $V_p(t)$ according to a linear relation.