New Concept To Develop And Optimise Drilling Well Gas In Salted Area

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Abstract

Well gas drilling is the operations making possible to reach the porous and permeable rocks under ground likely to contain liquid or gas hydrocarbons. During the process of drilling, the Cementing of the wells represents a capital stage because the quality of Cementing is related to the duration of exploitation of a well. This one is carried out in order to envisage the migration of the fluids and to avoid the losses of production or to isolate the productive zones to exploit later on. The quality of a Cementing depends primarily on the choice of Cements (with or without chemical additives) used, as well as, properties of the prepared slurry of Cement. The Cementing of oil wells in high salted area present little resistance to caving which can be completed with high weight Cement, in this sense, light materials are used in combination with salt in order to solve this problem.

The bentonite is used with much success like additive in the drilling fluids and the Cement slurry. It confers to the latter significant rheological properties; its capacity to absorb a significant quantity of water and enables it to be one excellent weight reducer. Bentonite system Cement is actually used; however, salt additions improve bentonite Cements by increasing swelling behaviour which leads to a high free water. Two processes are illustrated throughout the modes of incorporation of bentonite in the light weight Cement slurry:

- The first consists with prehydrater 2 to 5 % p.p.c (per Cement weight) of bentonite in mixing water 24 hours before their use.
- The second process, the bentonite is directly added during preparation of the Cement slurry at a rate of 5 to 20 % p.w.c.

We will carry out the preparation of various formulations of Cement slurry to 20 % p.w.c of bentonite in the presence of various concentrations of NaCL, in order to select the formulation which presents the optimum conditions of use in the saliferous zones.

This work describes in first part the effect of salt on the properties and uses of Cementineous mixtures containing Cement, bentonite and salt. In second part, we also approach the behaviour and characteristics of slurry using different rheological models.

The effectiveness of salt as a dispersant and accelerator of set was translated by: an improvement of the rheological parameters according to the concentration of salt (reduction in shear threshold and plastic viscosity), and accelerator of set to the weak concentrations (reduction in thickening time) and an increasing of the compressive strength.

a. Background

Oil drilling is the operations making possible to reach the porous and permeable rocks under ground likely to contain liquid or gas hydrocarbons. Well Cementing is the process of placing a Cement slurry in the annulus space between the well casing and the geological formations surrounding to the well bore. When a certain section of the depth of an oil or gas well has been drilled successfully, the drilling fluid cannot permanently prevent the well bore from collapsing. Therefore, well Cementing was introduced in the late 1920s with a number of objectives: (i) protecting oil producing zones from salt water flow, (ii) protecting the well casing from collapse under pressure, (iii) protecting well casings from corrosion, (iv) reducing the risk of ground water contamination by oil, gas or salt water, (v) bonding and supporting the casing, and (vi) providing zonal isolation of different subterranean formations in order to prevent exchange of gas or fluids among different geological formations. In addition to their exposure to severe temperature and pressure, well Cements (CEMENTs) are often designed to cope with weak or porous formations, corrosive fluids, and over-pressured formations.
The appropriate Cement slurry design for well Cementing is a function of various parameters, including the well bore geometry, casing hardware, formation integrity, drilling mud characteristics, presence of spacers and washers, and mixing conditions. The rheological behaviour of Cement slurries must be optimized to achieve effective well Cementing operation.
Strict control of the hardened Cement mechanical properties and durability during the service life of the well are very important criteria, especially under such severe environments. A number of additives have also been used to alter the chemical and physical properties of the Cement slurries as required for the flowability, and stability of the slurry and long term performance of wells.
Substantial research has been conducted to improve the efficiency of oil well production by improving the physical and mechanical properties of Cement slurries. Cement-based materials are subjected to deterioration under aggressive environments. The extreme temperature cycling of the well bore results in severe mechanical damage and ultimate failure of the Cement sheath, potentially leading to microannulus. The rate of deterioration is generally aggravated at high temperature and pressure such as in the case of oil and gas bores. A strict control of Cement reactivity and mechanical properties during the life cycle of the well is thus very important. The well Cemented system should meet a wide range of short-term criteria such as free water, thickening time, filtrate loss, development of strength, shrinkage, etc., in addition to various long-term requirements including resistance to chemical attack, thermal stability and mechanical integrity of the Cement sheath.
The expansion of Cement slurries is important to improve the quality of the well Cementing sealing. Expansion should take place after pumping Cement slurry into the annulus and the process should begin after the formation of the hardened Cement structure starts but not after the formation of a rigid crystalline structure, as it can cause fracturing and adversely affect the porosity. On the other hand, if the expansion takes place too early, i.e. when the suspension is in a liquid state, the quality of formation isolation get worsens. The well casing is in an expanded state during the initial setting of the Cement slurry due to the heat of hydration. Subsequent internal temperature reduction resulting from mud circulation may cause the casing to contract and destroy the Cement/casing bond partially or entirely. Expanding additives can overcome this problem as they tend to expand after the initial set, thus maintaining the bond between formation, Cement and casing during pressure and temperature changes.

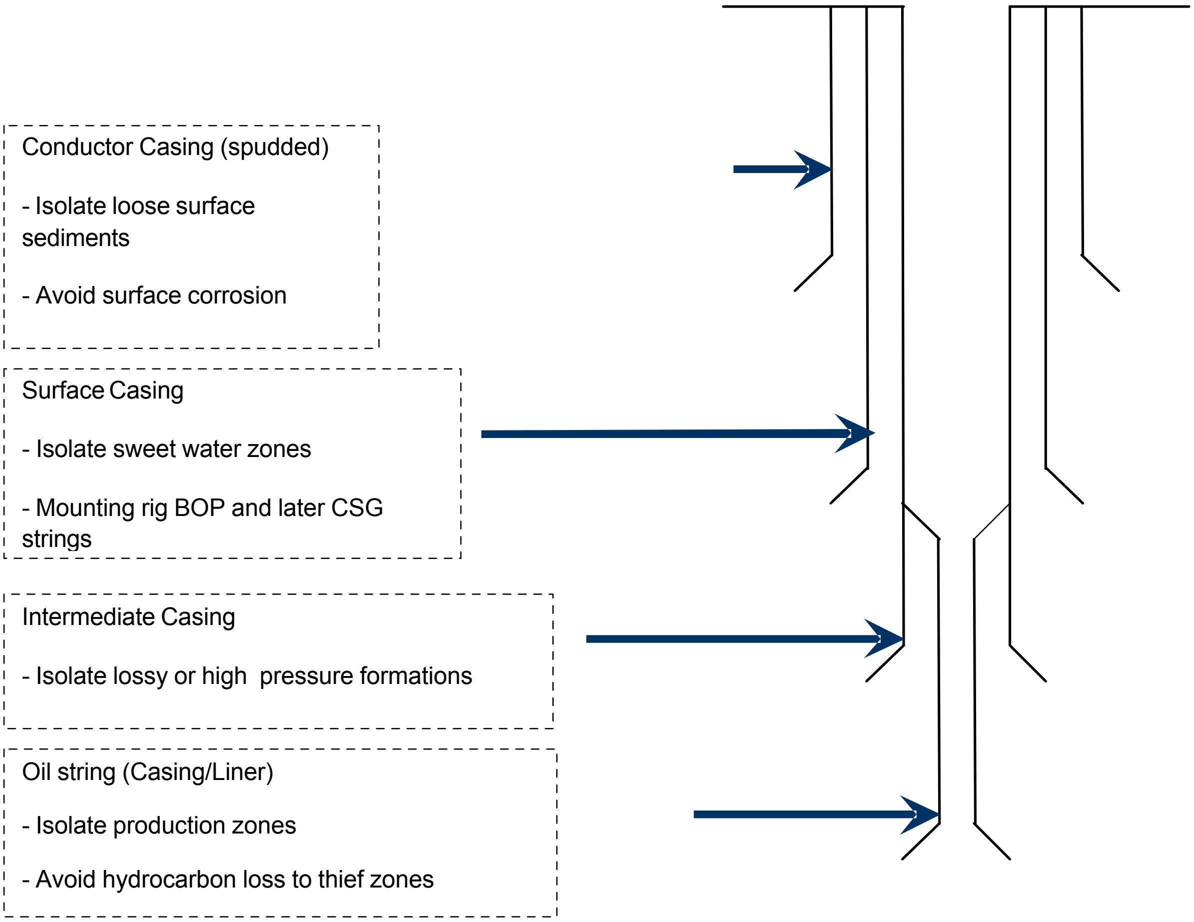

Fig.1: Cementing Objectives (Typical Casing String)

During the process of drilling, the Cementing of the wells represents a capital stage because the quality of Cementing is related to the duration of exploitation of a well. This one is carried out in order to envisage the migration of the fluids and to avoid the losses of production or to isolate the productive zones to exploit later on. The quality of a Cementing depends primarily on the choice of Cements (with or without chemical additives) used, as well as, properties of the prepared slurry of Cement. Cements are widely used in the oil surveys in order to carry out the separation of the various producing or fissured zones put in communication at the court of drilling and to ensure a good adherence with the walls of the geological layers and the casing. The bentonite is used with much success like additive in the drilling fluids and the Cement slurry. It confers to the latter significant rheological properties; its capacity to absorb a significant quantity of water and enables it to be one excellent weight reducer. Two processes are illustrated throughout the modes of incorporation of bentonite in the light weight Cement slurry:

- The first consists with prehydrater 2 to 5 % p.p.c (per Cement weight) of bentonite in mixing water 24 hours before their use.
- The second process, the bentonite is directly added during preparation of the Cement slurry at a rate of 5 to 20 % p.w.c.

We will carry out the preparation of various formulations of Cement slurry to 20 % p.w.c of bentonite in the presence of various concentrations of NaCL, in order to select the formulation which presents the optimum conditions of use in the saliferous zones. The principle of preparation of the Cement slurry consists has to calculate the quantity of water, necessary in order to have Cement of density equalizes to 1,58. The formulations of the various alternatives are given in the table hereafter:

Various	Components of Cement slurry				
	Cement (g).	Bentonite (g).	Anti-foamer (cm^3).	Salt (g).	Water of mixing (cm^3)
Cb0	1000	200	1	0	997,56
Cb2	1000	200	1	10	1002,36
Cb4	1000	200	1	30	1011,96
Cb5	1000	200	1	50	1021,56
Cb6	1000	200	1	100	1045,56
Cb7	1000	200	1	200	1093,56
Cb8	1000	200	1	450	1213,56

Table 1: formulations of the various alternatives of Cement reduced with bentonite

b. Rheology Of Oil Well Cement Slurries

The word "Rheology" originates from the Greek word "reo", meaning flow. Rheology is the study of the deformation and flow of materials. Typically, rheology studies the deformation of those materials whose behaviour falls between solids and fluids (viscoelastic materials). The study of rheological properties attempts to determine the intrinsic fluid properties; mainly viscosity, which is necessary to determine the relationships between the flow rate (shear rate) and the pressure gradient (shear stress) that causes the movement of a fluid. The science of rheology can be employed for instance for achieving the following goals:

- To understand the interactions between different ingredients in a material to get an insight into its structure.
- To control the quality of a raw material by measuring its rheological properties. The acceptance/rejection of a product can be determined based on rheological results.
- To evaluate the mixability and pumpability of a slurry.
- To determine the frictional pressure when a slurry flows in pipes and annuli.
- To evaluate the capability of a slurry or paste to transport large particles (e.g., some
- lost circulation materials and fibres).
- To evaluate how the surrounding temperature profile affects the placement of a slurry or paste.
- To design a processing equipment such as selecting the appropriate pump to provide sufficient power for a material to flow over a certain distance in pipelines. The relationship between the pump and flow in pipelines is governed by the rheological properties of the material.

The rheological properties of well Cement slurry determines the quality of the final product and helps predicting its end use performance and physical properties during and after processing. Rheological measurements can determine the flow properties of the Cement slurry such as its plastic viscosity, yield point, frictional properties, gel strength, etc. Rheology studies the flow of fluids and deformation of solids under stress and strain. In shear flows, imaginary parallel layers of liquid move over or past each other in response to a shear stress to produce a velocity gradient, referred to as the shear rate, which is equivalent to the rate of increase of shear strain. In extensional flows, elements flow towards or away from each other. Elongational or stretching flows are seldom found in Cement systems. However, it may be possible to experience some elongation at the entry or exit of a pipe. The rheological properties of Cement slurries are important in assuring that the slurries can be mixed at the surface and pumped into the well with minimum pressure drop.

The rheological properties of the Cement slurry also play a critical role in mud removal. A proper flow regime must be maintained for complete removal of the mud from the well bore. The flow regime of a Cement paste or slurry can change with time, temperature, pretreatment, application of shear, type of application, type of dispersion, physical and chemical characteristics of solid and liquid ingredients, the addition of special surface-active agents, and the extent of grinding and mixing. The rheological behaviour of the Cement slurry also depends on a number of factors including the water-Cement ratio, size and shape of Cement grains, chemical composition of the Cement and the relative distribution of its components at the surface of Cement grains, presence of additives, mixing and testing procedures, etc.
The concentration and shape of solid particles has a significant effect on the rheological properties of an Cement slurry. The yield stress and plastic viscosity of Cement paste usually increase as the Cement becomes finer and/or as the particle concentration increases.
The rheology of Cement slurries is generally more complicated than that of conventional Cement paste. In order to contend with bottom hole conditions (wide range of pressure and temperature), a number of additives are usually used in the Cement slurries and the slurry shows different characteristics depending on the combination of admixture used.

c.Apparatus

The Cement slurry preparation is very important because of the influence of the shear history of the mixture on its rheological properties. The Cement slurries were prepared using a variable speed high-shear blender type mixer with bottom drive blades. A high accuracy advanced rheometer was used to measure the rheological properties of Cement slurries. The rheometer is capable of continuous shear rate sweep, stress sweep and strain sweep. The geometry of the test accessory and the gap and friction capacity of its shearing surfaces have a significant influence on the measured rheological properties. The coaxial concentric cylinder geometry was considered suitable for this study because of the typically low viscosity of Cement slurries. The geometry consists of a cylinder with a conical end that rotates inside a cylinder with a central fixed hollow as shown in Fig.2. The radius of the inner solid cylinder is 14 mm. This inner solid cylinder rotates inside a fixed hollow cylinder of 15 mm radius. The gap between the head of the conical end and the bottom of the hollow cylinder was set to 0.5 mm for all experiments. It is required to use such a narrow gap in order to maintain a constant shear rate across the gap,which is important, especially in case of static flow studies to minimize the error caused by wall slip in rheological measurements. The rheometer has an auto gap system which compensates for the expansion of the stainless steel of the coaxial concentric cylinders under a wide range of temperatures, thus keeping the gap constant during experiments.
The rheometer has a smart swap technology for temperature control in the range of -10°C to 150°C in the case of the concentric cylinder system. The device keeps the temperature constant during the entire time span of the rheological test through a water circulation system. A solvent trap was used to prevent evaporation from the tested Cement slurry sample by covering the top of the hollow cylinder. This solvent trap has an adequate mechanism to allow rotation of the shaft without any interference.
The rheometer(Fig.2) was calibrated using a certified standard Newtonian oil with a known viscosity of 1.0 Pa.s and yield stress = 0 Pa at 20°C. The measured yield stress was 0 Pa and viscosity was 1.009 Pa.s with an error of 0.9%, which is less than the tolerated error of 4% specified by the manufacturer. This computer controlled rheometer is equipped with rheological data analysis software, which can fit the shear stress-strain rate data to several rheological models. The Bingham model was used throughout this study to calculate the rheological properties of Cement slurries.

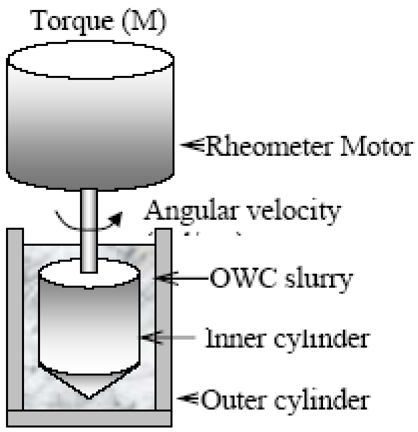

Figure 2 : Rheometer

d. Mixing and Preparing Cement Slurry

The Cement slurries were prepared using a high-shear blender type mixer with bottom driven blades according to the following procedure. First, the weighed amount of Cement and the solid admixture (if any) were dry mixed in a bowl by hand using a spatula for about 30 sec. The mixing water was subsequently poured into the blender. Then the required quantity of liquid admixture was added into the mixing water using a needle, and the mixing started at a slow speed for 15 sec so that chemical admixtures could be thoroughly dispersed in the water. The Cement solid ad mixture was added to the liquids (liquid admixture and water) over a period of 15 sec.
Manual mixing was conducted for 15 sec and a rubber spatula was used to recover material sticking to the wall of the mixing container to ensure homogeneity. Finally, mixing resumed for another 35 sec at high speed. This mixing procedure was strictly followed for all Cement slurries.
All mixing was conducted at a controlled ambient room temperature of 23±1°C. The prepared slurry was then placed into the bowl of a mixer for preconditioning over 20 minutes at the test temperature (23°C, 45°C, or 60°C) at a speed of 150 rpm. The total time between the beginning of mixing and the start of the rheological tests was kept constant to avoid the effect of exogenous variables on the results. The rheometer set-up was also maintained constant for all slurries. The concentric cylinder test geometry was kept at the test temperature so as to avoid sudden thermal shock of the slurry.

e. Effect of salt and bentonite on the properties of light weight Cement

The measurement of certain characteristics of the Cement slurry to knowing the rheological parameters, filtration and free water are made only after conditioning of this last in an atmospheric viscometer in order to simulate the temperature at the bottom of the well.

e.1. Free water

Table 1: Free water values in the various suggested.

Various	Cb0	Cb1	Cb2	Cb3	Cb4	Cb5	Cb6	Cb7	Cb8
Free water (ml)	0,5	0,8	1,2	1,5	2,5	3	4	6	26

e.2. Rheological Parameters

Coaxial cylinder viscometers have been used for the evaluation of the rheological properties of Cement slurries. If the slurry rheological properties are well characterized, the friction pressure drop and the flow regime in the annulus of the oil well can be predicted with reasonable accuracy. Rheological measurements of Cement slurries suffer from several limitations including slip at the walls of the measuring device, migration of the particles due to centrifugal forces, shear induced migration or gravity induced migration known as settlement/sedimentation, and plug flow. A review of the literature concerning these effects is provided elsewhere. Similar problems have also been encountered in the case of pile-flow viscometers and vane rheometers.
Though Cement slurry rheology is a widely studied subject, correlations between chemical, microstructural and mechanical behaviour of the slurry before and after setting have not yet been clearly defined, and thus require more dedicated research.
We give in table (2) the values of the shear stress (Yv) and the plastic viscosity (Vp):

Table 2: shear stress (Yv) and the plastic viscosity (Vp) of Cement slurry.

Various	Cb0	Cb1	Cb2	Cb3	Cb4	Cb5	Cb6	Cb7	Cb8
Yv(Lbf/100ft^2)	138	102,5	58	46,5	53	65,5	32,5	17,5	7,5
Vp(cp)	24	16,5	15	13,5	18	10,5	10,5	10,5	7,5

The reduction in the values of plastic viscosity and the shear stress, facilitates the pumpability of Cement slurry in annular space. The swelling of bentonite is opposed by the presence of salt in high concentrations.

The rheological properties of Cement-based materials determine the quality of the hardened Cementitious matrix and help predicting its end use performance and its physical properties during and after processing. Measuring rheological properties of Cement based materials in the laboratory remain a challenging task. The rheological properties are affected by numerous factors including the w/c, size and shape of Cement grains, chemical composition of the Cement and relative distribution of its components at the surface of grains, presence and type of additives, compatibility between Cement and chemical admixtures, mixing and testing procedures, etc. Moreover, slip at the slurry-shearing surface interface, particle-particle interactions, chemical reactions, non-homogeneous flow fields, and human errors can make the rheological experiments difficult to reproduce. Above all, the equipment used to quantify
the rheological properties of Cement based materials is relatively expensive, difficult to operate, and may not be suitable for use in construction sites because of its large size and/or complicated set up.

e.3. Thickening time

As mentioned above, Cements are subjected to a wide range of pressure and temperature, which has a major effect on the time required for their setting and hardening. The setting time is an important requirement in well Cementing. A premature setting can have disastrous consequences due to loss of circulation in the well, whereas too long setting times can cause financial losses due to lost productivity, in addition to possible segregation of the slurry or contamination by fluids. Cement slurries must also harden rapidly after setting. A slow setting behaviour can be achieved by adjusting the composition of the Cement and or by adding retarders. Constituents of the Cement slurry and their percentage can affect the hardening time. The results of the tests are given in the following table:

Table 3: Thickening time of light weight Cement slurry according to salt slurry with 20 p.w.c of bentonite.

Various	Cb0	Cb1	Cb2	Cb3	Cb4	Cb5	Cb6	Cb7	Cb8
Thickening time (min)	595	469	444	469	465	514	583	>600	>600

For a weak sodium chloride concentration (up to 1% p.w.c), a maximum of acceleration was noted, and beyond 5 p.w.c, a prolongation of the thickening time is observed.

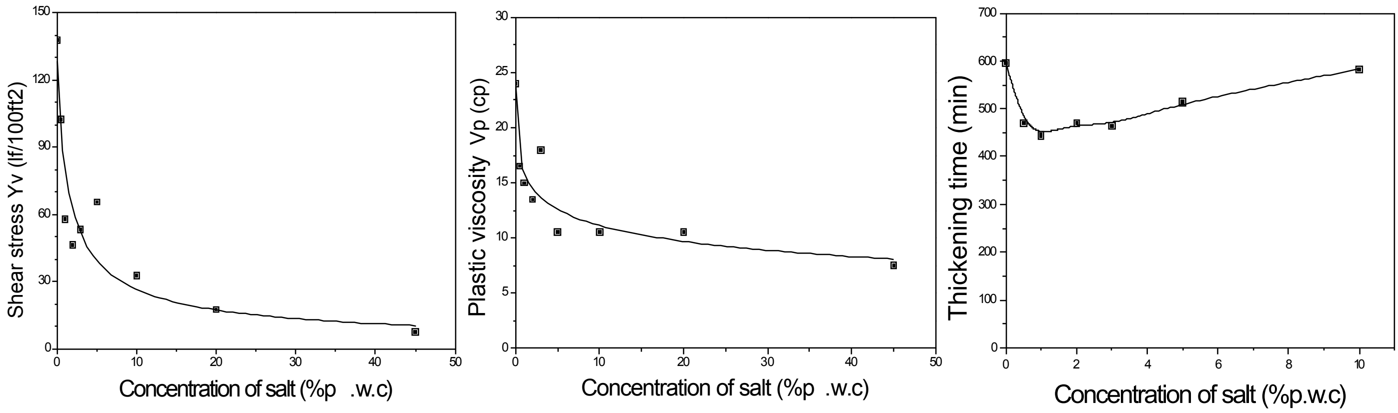

Figure 2: Influence of salt on shear stress, plastic viscosity, and thickening time of light Cement

$$Yv = \frac{a}{(1+Cs)^b}$$

a = 128, 40327

b = 0, 65859

$$Vp = \frac{1}{(a'+b'Cs)^{c'}}$$

a' = 0,04218

b' = 0,02108

c' = 0,35455

Where : Yv : Shear stress (lbf/100ft2); Vp : Plastic Viscosity (cPoises);

Cs : Concentration of salt (%p.w.c)

Accurate control of the thickening time, i.e. the time after initial mixing at which the Cement can no longer be pumped, is crucial in the well Cementing process. It is important to simulate the well conditions (temperature, pressure, etc.) as precisely as possible in determining the thickening time. There are some other factors that affect the pumpability of the slurry, but are very difficult to simulate during determining the thickening time of the slurry, such as fluid contamination, fluid loss to formation, unforeseen temperature variations, unplanned shutdowns in pumping, etc.

f. Conclusions

This work is related to the study of the rheological and physico- mechanical properties of the light weight Cement slurry used for the Cementing of the oil wells in the saliferous zones.
The effectiveness of salt as a dispersant and accelerator of set was translated by:
An improvement of the rheological parameters according to the concentration of salt (reduction in shear threshold and plastic viscosity).
From the obtained results, we conclude that the use of bentonite in light weight Cements in presence of salt is effective only in weak concentrations of this last.

First part, a successful oil well Cementing should satisfy two basic criteria: (a) it should be easily pumpable for a sufficient time to allow proper placement of the slurry in the well bore subjected to extreme levels of temperature and pressure, and (b) the Cement slurry should develop and maintain sufficient mechanical strength to support and protect the casing, and must have low permeability and adequate durability to ensure the long-term isolation of the producing formation. With the advent of API well Cements, achieving these goals has become easier than before when only one or two Portland Cements were available for well Cementing. Chemical admixtures and mineral additives play an important role by altering the chemical and physical properties of the oil/gas well Cement slurry and maintaining the proper rheology necessary for the placement of the Cement slurry in typically deep well bores. The appropriate oil/gas well Cement slurry design is a function of many parameters including the well bore geometry, casing hardware, formation integrity, drilling mud characteristics, presence of spacers and washers, and mixing conditions. An adequate rheological characterization of the slurry is required to optimize Cementing properties. Though Cement slurry rheology is a widely studied subject, correlations between rheological properties and the chemical, microstructural and mechanical behaviour of the slurry after setting have not yet been fully defined.

Second hand, Rheological tests can determine the flow properties of the cement slurry such as its plasticviscosity, yield point, gel strength, thixotropic behaviour, etc. The rheology of cement slurries is a manifestation of the interactions between cement particles, water and other constituents, which makes its characterization difficult. Cement slurries are visco-elastic materials; they exhibit properties characteristic of both elastic solids and viscous fluids. To

Characterise the rheology of cement slurry, rheological parameters such as the yield stress, apparent viscosity, plastic viscosity, shear thinning, or shear thickening behaviour have been studied. The Bingham plastic model and the Power law are widely used to describe the rheological properties of cement slurries. The Bingham plastic modelling includes both yield stress, and a plastic viscosity at finite shear rates. The yield stress indicates the minimum effort needed for a material to start moving and is the intercept of the flow curve (shear stress vs. shear rate) with the shear stress axis. Below the yield stress, a material behaves like a solid. The plastic viscosity governs the flow after it is initiated and is the contribution of suspending liquids resulting from viscous dissipation due to the movement of water in the sheared material. Cement slurries are usually subjected to high levels of pressure and temperature depending on the height and density of the column of material above, which makes the characterization of their rheological properties even more complicated than that of normal cement pastes or grouts. A number of admixtures have thus been developed to alter the chemical and physical properties of cement slurries as required for flowability, stability of the slurry, and long-term performance of wells. The conventional admixtures which have been developed in areas with moderate temperatures for cementing work above ground, may lead to disappointing results when exposed to high temperature during oil well cementing. Uses of supplementary cementing materials are also being encouraged in the petroleum industry as a sustainable solution. Mineral and chemical admixtures play an important role in controlling the physical and chemical properties of both fresh cement slurries and hardened cementations systems. Moreover, the coupled effects of temperature, chemical admixtures and mineral admixtures on the rheological properties of oil well cement slurries remain largely unexplored.