MIKOVINYI SÁMUEL

GRADUATE SCHOOL OF EARTH SCIENCES

Graduate School Leader:
Prof. Dr. Dobróka Mihály

EVALUATION OF DRILLING FLUID FILTRATION IN RELATION WITH CASING DRILLING

Doktori értekezés tézisei
For obtaining PhD degree

Research Institute:
University of Miskolc
Faculty of Earth Science and Engineering
Petroleum Engineering Department
&
Research Institute of Applied Earth Sciences

Supervisor:
Dr. habil. Szepesi József

Gabriella Federer dr. Kovácsné
Petroleum Engineer

2013.

Contents

1. Background and Objectives

The international literature deals with the introduction of casing drilling from the beginning of the second half of 90s. In the last 5 years the Mobil and the Amoco companies started to apply casing drilling, they recognized advantages in the application of the technique firstly in the case of penetrating transition zones and low pressure reservoirs as well as setting liners.

Currently the technique of casing drilling spreads rapidly. The application was extended for setting surface/safety casing string and was also applied for directional and horizontal drilling. In the development of machineries of the new drilling technique the TESCO company attained achievements.

Casing drilling is a brand new method which provides the possibility for drilling and casing at the same time. The well is drilled by applying either rotated casing or downhole motor. It can provide downhole measuring as well.

The determination of equivalent circulating density (ECD) in Casing Drilling operations is considered in this thesis. During circulation, the total bottom-hole pressure is the sum of the hydrostatic pressure and annular pressure loss. This can be also described as dynamic pressure.

The well geometry in casing drilling is a major difference from conventional drilling. The ratio of hole to pipe diameter is close to unity. The internal diameter of a casing is large therefore there is relatively little pressure loss inside the casing. However, the casing drilling annulus provides more restricted flow so that higher than normal annular pressure losses are encountered.

The determination of the bottom-hole pressure, during drilling operations, is very important. In most casing drilling situations the ECD will be higher than the ECD in conventional drilling, even though a lower flow rate may be used.

The most important part of the circulation is that cuttings and the drilling fluid should be emerged from the well; in the interest of this the adequate selection of the circulating fluid is important. It is essential that the formation should be able to hold the hydrostatic pressure of the entire circulating fluid without any damage; if it is not accomplished then mud loss must be counted.

When dealing with high temperature formation mud additives are chosen accurately but in this case we always should correct mud parameters for the exact circumstances. Mud parameters such as density, viscosity and therefore cutting carrying capability are all influenced by high temperature.

Each characteristics related to the well must be considered which can play a role in the success of the operation. The depth of the well determines the dimension of the casing needed. Dimensions of casing have an influence on the annular flow velocity of the drilling fluid, thus on the selection of the mud as well. It can be easily assessed with calculations what dimension of casing will be the most suitable. If the selected diameter is big, the specific annular volume decreases which results the increase of the flow velocity at the same flow rate.

Objectives of the thesis

Due to the ongoing depletion of available hydrocarbon reserves, the oil and gas industry was impelled to explore more daring depths and complex geological formations recently. This study aims at providing information about hydraulics and the importance of mud selection when drilling into unusual depths and formation structures, particularly at high temperature high pressure (HTHP) conditions.

However, despite all the precautions and proper geo-technical planning, unanticipated problems may arise, so the application of non-conventional methods may be necessary to make a well productive. Applying casing drilling in deeper or deviated wells is effective as a drilling method but requires challenging planning because of the special well geometry and therefore the unusual well hydraulics.

Planning the hydraulics of a HPHT Casing Drilling can be really difficult as due to special wellbore geometry and temperatures the calculations might not be accurate. My objective is to give an accurate calculation for ECD in high temperature environment that would be useful not only for casing drilling but conventional applications as well.

Also an objective is to present measurements to prove that the higher annular pressures can cause permeability damage in the productive formations and that by applying accurate drilling fluid the damage can be minimized even at very high temperatures.

My aim is to indite a complex relationship that takes temperature into consideration before planning a new operation. Its importance is great as by this circulating conditions can be optimized and losses, influxes and formation damage can be minimized. My research also reveals the fact that by applying the appropriate drilling method and providently designed drilling fluids, the damage of the productive reservoirs can be reduced and that temperature is always an important parameter what should be considered. It can also be useful for further study as better understanding of permeability damage at elevated temperatures is advantageous for correct reservoir characteristics calculations and production estimation.

2. SHORT DESCRIPTION OF LABORATORY EXPERIMENTS

The development of drilling mud technology follows the industrial needs but in the interest of reducing formation damage the object is choosing the most suitable mud. It is even more important question when the pressure and temperature in a well is high and/or special geometry exist in case of special for example casing drilling operations. I try to make this choice easier by measuring static and dynamic filtration of drilling mud at elevated temperature.

The laboratory tests were done by OFITE Dynamic HTHP a dynamic high pressure, high temperature filter press. Against the normal size synthetic/ceramic filter disks, I designed and used a special core holder of which I was able to put real sandstone cores inside. The sandstone core plugs' geometrical and petrophysical parameters were previously measured and recorded. Before placing core plugs into the special holder they were placed in a rubber cover restraining the mud to filtrate in through the side wall of the core plugs. This effect could cause inaccurate measurement. My measurements can be grouped into two cases described below.

Case A *Filtration tests using high permeability core plugs*:

For each test the same drilling mud was used (Ca based/HT/Polymer 1.). The tests were conducted at different temperatures but the same differential pressure (500 psi) and in case of dynamic filtration 300 rotation per minute were used in order to get the most accurate results of temperature effect on filtration in either static or dynamic case. Therefore I choose the other parameters also similar. The core petrophysical parameters were similar as all the cores have good permeability which is between 400mD and 800mD and porosity value is approximately 30%. This was done to ensure consistent results for all core sample tests.

Case B *Filtration tests using low permeability core plugs*:

For every test an especially designed mud (Ca based/HT/Polymer 2./a.,b.,c. see Table 4) was used considering pore size distribution of the tested core samples to achieve the comparatively best filtration results. The tests were conducted at the same high temperature (~180°C), the same differential pressure (500 psi) and in case of dynamic filtration the same 300 rotation per minute was used. Using similar parameters can lead to find a more accurate correlation between filtration rate and one specific parameter. The core plug petrophysical parameters are similar since all the cores have low permeability between 6 mD and 12 mD.

In all tests 500 psi differential pressure was used because in a conventional rotary drilling operation at least 200 psi differential pressure forms on bottomhole but in case of casing drilling as the annulus is smaller the equivalent circulating density and differential pressure will be higher than normally.

3. Results and discussion, Scientific Thesis

Drilling mud is a vital element of the rotary drilling technology. Mud is usually made up with a base fluid, clay and other additives that give the desirable properties. The base fluid of a water based mud can be fresh water, sea water or brine. I conducted my tests with brine (5% KCl) also.

When circulated down and up in the hole, drilling mud have many functions. In most of the cases drilling fluids fulfill their functions but as most of the drilling process is performed overbalanced, cause of certain degree of formation damage is unavoidable. However we should not forget during planning that our aim is producing from the explored reservoirs so we have to keep in mind to protect them as much as we can. One aim of my research work and my scientific thesis is to support this aspiration.

1. **I have developed, applied and verified a new laboratory experimental technique based on HTHP dynamic filter press, a compatible, specially designed core holder and the use of selected real sandstone core plugs. This technique is applicable for measuring filtration properties of different drilling fluids under static and/or dynamic conditions for direct and/or comparative purposes at a wide temperature range (25-230°C) mostly simulating downhole conditions and providing the achievable most realistic results. Extension of the tests for brine permeability measurement of the used core samples enables the recognition and evaluation of potential permeability/formation damage effects.**

I conducted my laboratory measurements with Ofite Dynamic HTHP filter press. This equipment was originally designed for measurement with filter paper or synthetic ceramic filter discs with different pore size.

For fulfilling my goal I had to make a special core holder which is suitable for attaching real sandstone core samples. (Fig.18.) This core holder is capable for holding a 3.5 cm long and 3 cm in diameter core plug and by this making the filter press able to measure filtration on real core samples. The special core holder contains a rubber cover which purpose is restraining the mud to filtrate in through the side of the core plugs. This effect could cause inaccurate measurement.

Figure 18

Special core holder

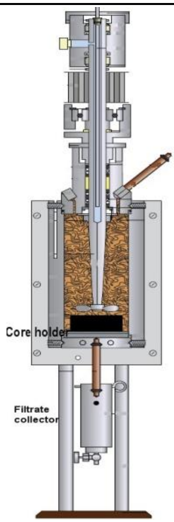

Figure 21

The cell inside with the modified core holder

The core holder takes place in the bottom of the cell that is part of the filter press equipment. (Fig. 21.) The cell is closed with a cap and a valve stem. Filtrate can be collected through this valve stem. The drilling fluid is poured on the top of the sample in the desired amount (taking expansion into account). The top of the cell is closed with a cap from which a shaft is hanging into the drilling fluid. Rotating fluid making not only dynamic filtration measurement possible but also prevents the settling of solids during heating period in case of static filtration measurement.The pressure can be adjusted from above and below for the necessary differential pressure with a nitrogen unit. The applied backpressure is defined by the testing temperature (it is a value that safely exceeds the vapor pressure). During heating period equal pressure has to be kept from both ends preventing filtration before the time and the desired temperature is reached.

With my modifications real core samples can be measured which is significant since tests with filter paper and ceramic disc give good estimation but does not reflect on real processes. Beyond this core plugs pore size and pore size distribution represents the properties of the formation and longer then the thickness of ceramic discs therefore also good for studying solids invasion.

By measuring brine permeability before and after the filtration tests permeability reduction can be detected and formation damage can be studied.

2. **Based on my laboratory test results I state that with special drilling fluid (Ca based/HT/Polymer 1. type) at low-medium temperatures (25°C-120°C) on relatively high permeability real cores plugs (400-800 mD) and at high temperature (180°C) on low permeability (6-12 mD) real core samples the volume of static filtrate is 1.3-4.7 times of the volume of filtrate obtained under dynamic conditions in contrary with former results in the literature.**
   These are compatible with my following statement that core permeability reduction (damage) caused under real dynamic filtration is higher (3-75%) than the results of static filtration tests and that lower filtrate volume is coupled with higher core permeability reduction (damage).
   Furthermore I proved that the new experimental technique is applicable for selecting filtration control additives and therefore optimizing fluid-composition.

After the measurements the gained laboratory data have been analyzed and illustrated graphically. Comparing experiments “A” results of 25°C, 60°C, 90°C, 120°C additionally the data gained from experiments “B” on 180°C I have proved that higher temperature causes higher filtration rate is valid (except at 120°C where the filtration control additive specially designed for this temperature was effective).

On the other hand besides the above mentioned temperature effect on filtration, static filtration rate compared to dynamic filtration rate was higher at each temperature for both type of temperature stable mud formulation. These results also demonstrate that in the dynamic case a less permeable filter cake is formed than in the static case. (Fig.22) This is contrary to the results-measured on different filter media-published in former literature.

The static and dynamic filtration results can be seen in Table 5a and 5b.

Table 5.a Volume of filtrate for Case "A"

Type of drilling fluid	T (°C)	30 minute filtrate (ml)	
		static	dynamic
Ca base/HT/Polymer 1 mud	25	84	65
Ca base/HT/Polymer 1 mud	60	111	38
Ca base/HT/Polymer 1 mud	90	184	68
Ca base/HT/Polymer 1 mud*	120	22	5

*- treated with special filtration control additive

Table 5.b Volume of filtrate for Case "B"

Type of drilling fluid	T (°C)	30 minute filtrate (ml)	
		static	dynamic
Ca base/HT/Polymer 2/a mud	180	240	180
Ca base/HT/Polymer 2/b mud	180	184	144
Ca base/HT/Polymer 2/c mud	180	376	130

After evaluating the experimental data from driller's perspective and found it successful, I started to evaluate it from a reservoir engineer's perspective. According to this task I made reverse brine permeability tests on the core plugs that were exposed to filtration procedure and the value of the return permeability was given by equation (27):

$$k_{wr} = \frac{k_{wmudy}}{k_w} * 100 \qquad (27)$$

Where k_{wmudy} is the brine permeability measured on the contaminated sample and k_w is the original brine permeability and k_{wr} is the return permeability in percentage. The permeability damage was higher than expected based on former literature which reported 40-70 % return permeability measured on ceramic discs.

In case of the real core samples at such high temperature by comparison the reverse return permeability values I have measured were only 5-24% in dynamic cases.

Detailed results can be found in Table 6. In case of static filtration the return permeability was higher than in dynamic case, nevertheless increasing temperature in both cases made these values even lower. (Fig. 27).

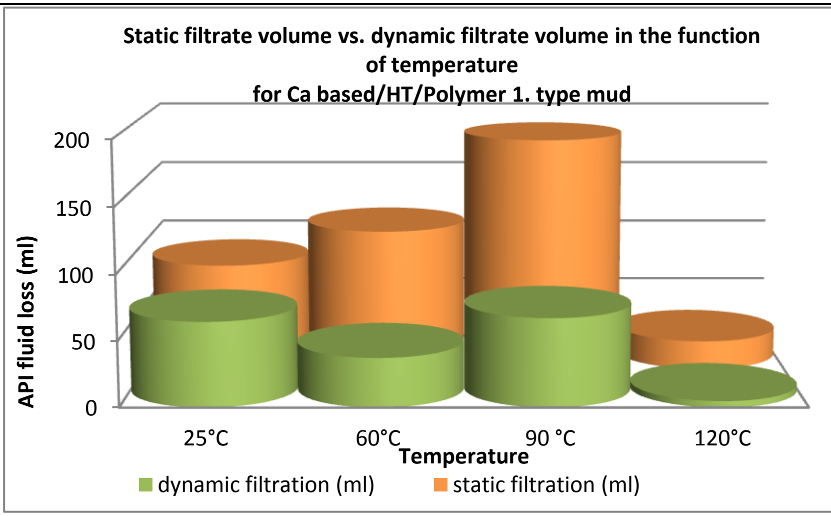

Figure 22

Static and Dynamic filtration comparison

Table 6. Return permeability comparison

Mud type	T (°C)	k_{wr} (after static filtration) (%)	k_{wr} (after dynamic filtration) (%)
Ca-based/HT/Polimer 1.	25	99	24
	60	33	8
	90	53	10
	120	14	6

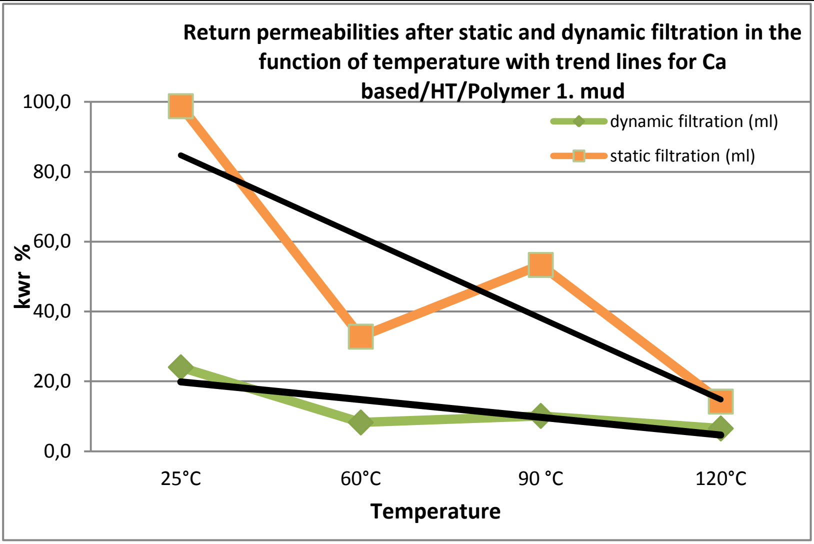

Figure 27

3. **Based on my laboratory data-in a different context- I have concluded that at 25°C-180°C temperature range the temperature dependence of 5% KCl brine reverse flow permeability reduction after dynamic filtration can be calculated by using the following mathematical equation that I have created to quantify the permeability reduction constant: $\kappa_{kwm/kw} = 1.89 \times T_b^{-1.68}$. This method can be applied for estimating and forecasting changes that can occur at high temperature for specific systems (Ca based/HT/Polymer type muds tested on Algyő sandstone core plugs with permeability range of 6-12 mD and 400-800 mD).**

Based on my filtration measurements with Ca based/HT/Polymer type drilling fluids and reverse brine permeability tests on the selected core samples; which were all sandstones from Algyő, Hungary; I found a relationship between permeability change and temperature. Since in the drilling practice we are not able to determine the permeability of the drilled formation after contamination a reliable calculating method can be really useful.

Out of this consideration and scrutinize my results of the permeability before and after the contamination I made an equation what is suitable for calculation or give a good estimation of the "after damage" decreased reverse flow brine permeability in case if we know the original brine permeability and the bottomhole temperature:

$$\kappa_{kwm/kw} = \frac{k_{wmudy}}{k_w} \qquad (28)$$

Where k_{wmudy} is the 5% KCl reverse (return) permeability after the contamination caused by the dynamic filtration, k_w is the original brine permeability of the formation and $\kappa_{kwm/kw}$ is the permeability reduction constant.

The permeability reduction constant can be determined by reading from the chart or by the equation (Eq. 28a) made by me if T_b

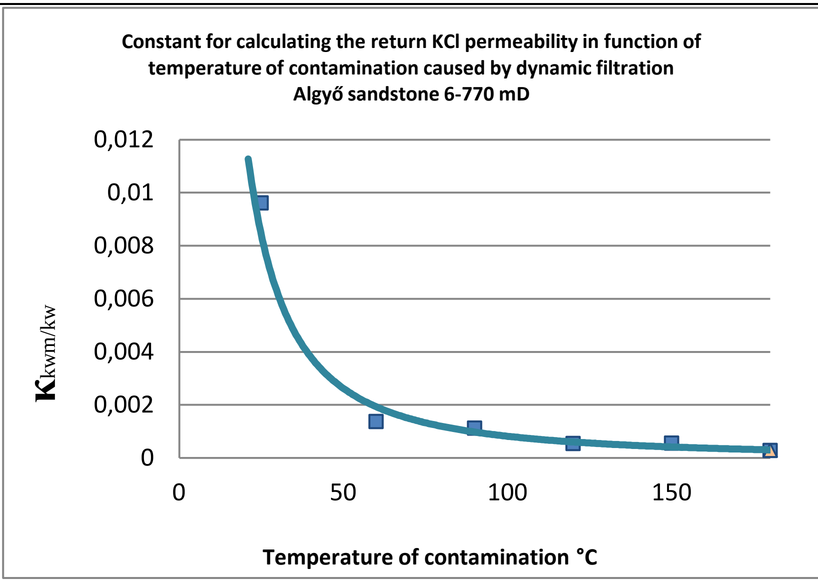

Figure 28

Chart for permeability decrement constant (κ)

$$\kappa_{kwm/kw} = 1.89 \times T_b^{-1.68} \qquad (28a)$$

bottomhole temperature is known. (Fig.28.)

4. I proved by my measurements that at 180°C testing temperature the weighting (bridging) additives, in special Ca based/HT/Polymer 2.type drilling fluid, which changed the particle size distribution of the solid phase compared to the sandstones' pore size distribution resulted lower permeability reduction (4-11%) in dynamic filtration cases.

My statement that higher temperature leads to higher filtration was proved for different composition drilling fluid compositions. Based on the statement, that higher temperature leads to higher permeability damage, it is obvious that I have measured the lowest return permeability percentage value at 180°C. My statement in the previous thesis that the higher the volume of the filtrate typically the higher the return permeability percentage is valid and this statement proved to be relevant for Ca based/HT/Polymer 2 type mud.

This testing named Case B, detailed in section 7, was conducted to prove that by changing the particle size distribution in the drilling fluid still can result satisfactory filtrate volume at high temperature. I stated that by adjusting on pore size of the cores the return permeability is higher, compared to Ca-based/HT/Polymer 1 type, on despite of the almost same filtrate volume. This happened because small particles' plugging effect is less relevant.

It can be seen from detailed results in Table 7 that by using thermal stable mud with modified particle size distribution I got favorable return permeability for dynamic cases primarily. This result indicates that changing particle size distribution in a drilling mud is important both for the drilled formation and the temperature effects.

Well completion in case of casing drilling is made with perforation so the permeability damage caused by higher temperature and higher differential pressure, if it is limited to near wellbore area, can give positive result since therefore productive formation can be shielded against higher fluid and solids invasion.

Table 7. Return permeability comparison

Mud type	Temp. (°C)	k_{wr} (static filtration) (%)	k_{wr} (dynamic filtration) (%)
Ca based/HT/Polymer 2./a	180	16	13
Ca based/HT/Polymer 2./b	180	18	5.3
Ca based/HT/Polymer 2./c	180	39	5.1
Ca-based/HT/Polimer 1.	180	15.8	1.4

5. **Based on my measurements conducted with Fann M50 HTHP type rheometer I concluded that the applied special drilling fluid's (Ca based/HT/Polymer 2. type, density:1200kg/m^3) viscosity change (measured at 511 s^{-1} shear rate) in function of temperature (at 45°C-200°C range) can be determined by** $\mu = -a * ln(T) + b$ **equation. This provides a close estimation for viscosity changes with depth and results a more accurate and reliable calculation for hydraulic parameters (ΔP_a, ECD, CCI).**

In water based drilling mud bentonite and typically water soluble polymers are applied for controlling rheological parameters and viscosity. The viscosity of the drilling mud, its resistance to flow, is one of the most important parameters. Its viscosity determines how well the drilling fluid can carry cuttings up from the hole. As an important parameter viscosity is very important during proper hydraulic calculations.

The increase of the temperature causes reduction in drilling fluid and its fluid phase viscosity. When viscosity decreases cutting carrying capability deteriorates and higher amount of filtration is expected. As in high temperature wells the temperature changes are significant from the surface to down hole, being able to estimate viscosity on the bottomhole is a key element. Based on the results of viscosity measurements on Fann M50 HTHP rheometer I made an approximate equation (Eq. 29) for calculation of estimate viscosity reduction. Fann M50 on the given rotation (typically at 511 s^{-1} shear rate) measures the mud's viscosity in centipoises (cP) which equals 1 mPas (see Fig.30).

$$\mu = -a * \ln(T) + b \tag{29}$$

Where μ in viscosity of the drilling fluid, T is temperature and a and b are constant depending on the additives.

On the bases of the similarity of the equations of viscosity reduction curves (Table 8.) I made an approximate equation which gives a quite accurate result for calculating viscosity reduction versus temperature increasing of Ca based/HT/Polymer 2 type drilling fluid.

Table 8. Equations of different mud samples viscosity reduction

Mud type	Heating	Cooling
Ca based/HT/Polymer 2./a (Sample 1)	μ = -5,462 ln(T) + 32,629	μ = -4,111 ln(T) + 25,234
Ca based/HT/Polymer 2./b (Sample 2)	μ = -7,411 ln(T) + 41,942	μ = -5,506 ln(T) + 31,574
Ca based/HT/Polymer 2./c (Sample 3)	μ = -3,964 ln(T) + 23,72	μ = -3,271 ln(T) + 19,749

This calculation is important because this type of drilling fluid is applied in Hungary when drilling high temperature wells.

The approximate equation is the following:

$$\mu = -4{,}954 * \ln(T) + 29{,}941 \qquad (30)$$

On Figure 30 a combination of the three samples measured viscosity reduction and the calculated graph can be seen using Equation 30. This proves how good approximation this calculation can simulate the changes in the drilling fluid's viscosity while it reaches the bottom of the well.

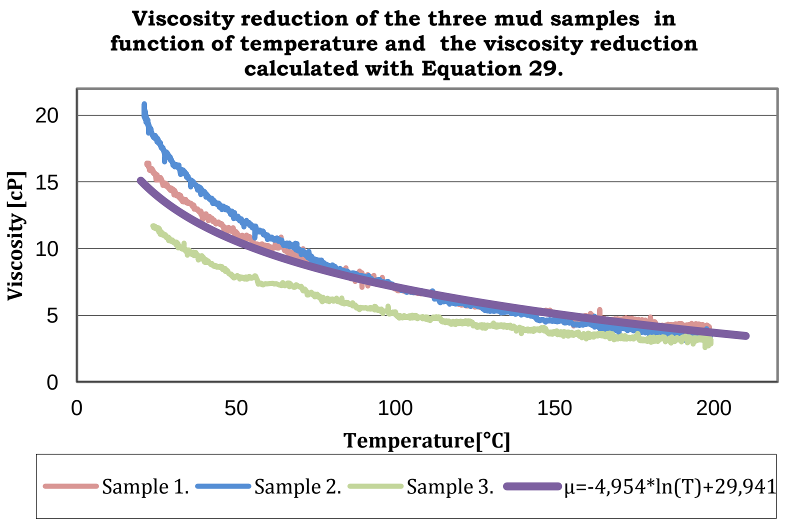

Figure 30

6. Based on the evaluation of my filtration measurements results I proved that in case of dynamic filtration of special drilling fluids (Ca based/HT/Polymer 1. and 2. type) tested on natural sandstone core samples there is a linear relation between the filtrate volume and the square root of time as well as for static filtration equation.
Furthermore I concluded that the amount of spurt loss in dynamic filtration cases was smaller than in static filtration (such as the total volume of filtrate).

Before the filter cake is fully formed solids and a higher volume of fluid invade the formation which is called spurt loss. This happens in the first few tenths of second before filtrate volume becomes proportional to square root of time.

The primary object of this work is to compare filtration properties under extreme conditions and the permeability damage obtained in the case of sandstone reservoirs. The kinetics of mud filtration is an important parameter in terms of wellbore invasion since both spurt loss and overall filtration rates impact the depth of fluid (filtrate) invasion. Generally the higher the filtrate losses into the formation the larger the depth of fluid invasion is.

To show the hydrodynamic condition on spurt losses I made Figure

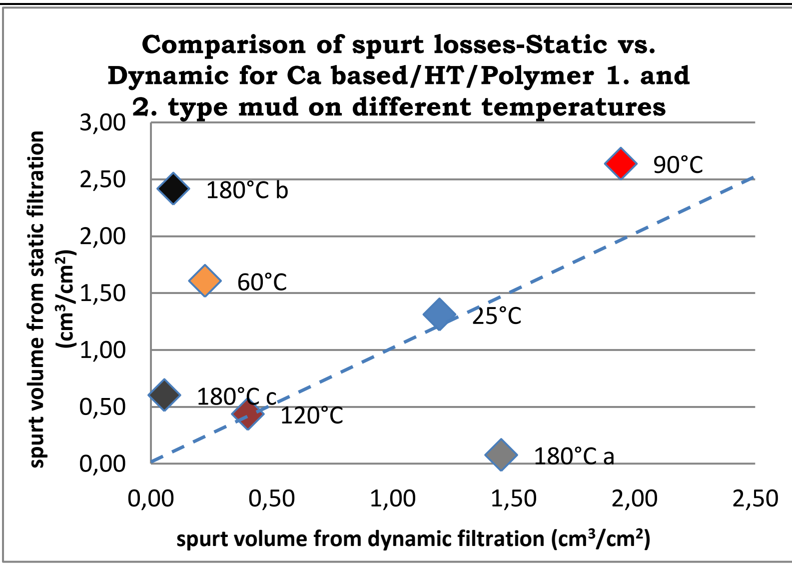

Figure 31

31 with values under static condition as a function of values under dynamic conditions. This figure proves also that in case of Ca based/HT/Polymer type drilling fluids' filtration through sandstone

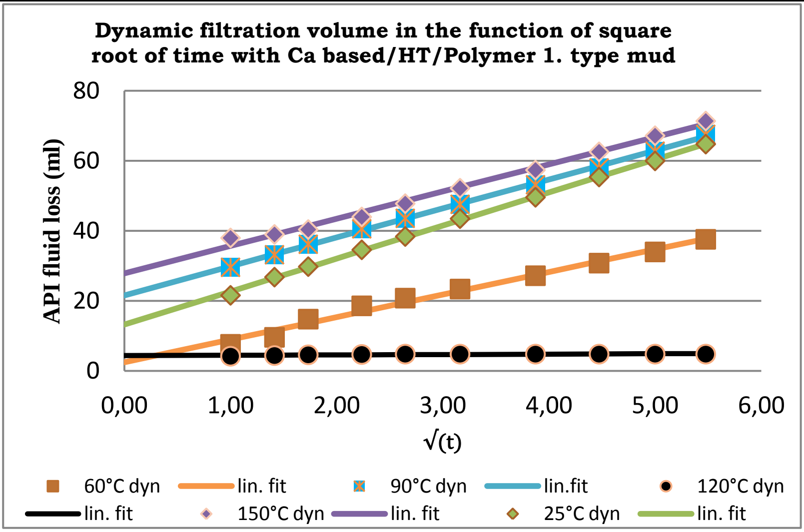

Figure 32

core plugs from Algyő the spurt loss of static filtration is higher than under dynamic circumstances.

Filtration diagrams composed of two parts, the *spurt period* that shows a quick invasion of the fluid phase and the *filtration period* where the invasion occurs at a stabilized or even decreasing flow rate. When I plotted the cumulative fluid filtrate volumes as a function of square root of time in dynamic cases I received the same linear relationship as it is well known for static filtration. This relationship is illustrated on Figure 32 and 33.

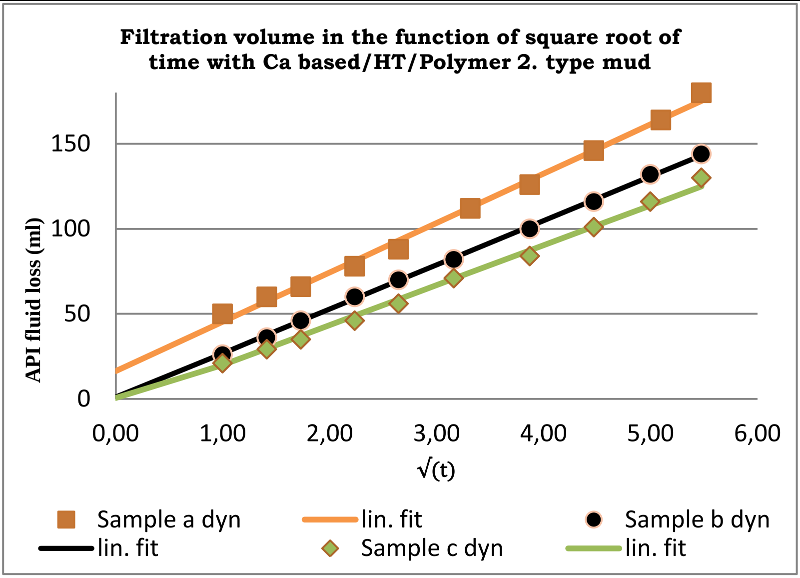

Figure 33

7. I made combined measurement simulating real downhole drilling conditions where dynamic and static filtration periods change. I applied 10 minutes dynamic than 10 minutes static filtration and 10 minutes dynamic filtration right after that. I concluded that filtrate volume gained from the 30 minutes combined test on low permeability core plug (7 mD Algyő sandstone with Ca based/HT/Polymer 2./a type mud) was smaller and the permeability reduction was higher than in only static or only dynamic cycles.
I concluded therefore that combined/simulated filtration tests provide a more accurate picture about real conditions and make estimation of the volume of downhole fluid invasion more reliable.

Laboratory tests and within filtration tests are elementary for drilling practice. Measurements are usually implemented under static circumstances therefore dynamic measurements have great significance primarily because these tests are exceptional in the industry. All around the world the number of dynamic measurements are few so the results are very important. Dynamic filtration tests under pressure and temperature are even more valuable as these can result better approximation for down hole circumstances.

Nevertheless even only static or merely dynamic filtration tests are not able to give a realistic image about the bottomhole happenings. I aimed to simulate downhole conditions therefore I ran a test when the 30 minutes API filtration measurement consisted of three, individually 10 minutes, parts.

As it seems from the chart (34) in the more realistic case, when I supposed connection time (static section), the total filtrate volume proved to be less than in the entirely dynamic case. The formed inner filter cake resulted higher permeability damage (in the static section)

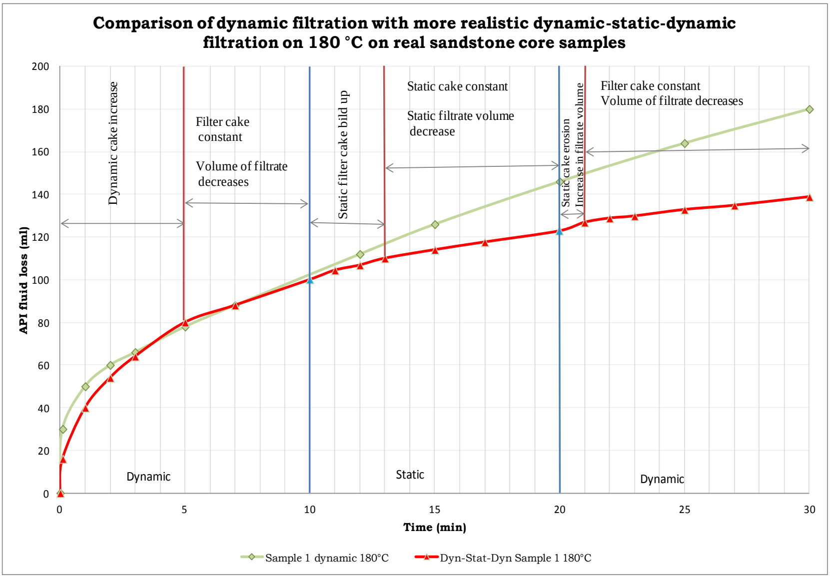

Figure 34

than expected therefore shielded the formation against higher volume and depth of drilling fluid filtrate invasion.

4. Relevant Publications

1. Gabriella Federer: **Well hydraulics in relation with casing drilling** microCAD 2005 International Scientific Conference ISBN 963 661 649 3., University of Miskolc, 2005 p.7-14
2. Federer G.P.: **Comparison of well hydraulics between conventional**

rotary drilling and casing drilling, Neftyeganotvoje Delo ISBN 5-98755-003-3., Ufa-Miskolc 2, 2004 p.53-60 (published in Russian)

3. Gabriella Federer-Kovács, Andrea Mátrai: **Examination of Static and Dynamic Filtration on Core Plug Samples on High Temperature**, SPE 165083
4. Gabriella Federer-Kovacs: **Simulation of a Re-entry With Casing Drilling Under HPHT Conditions**, Geosciences and Engineering, Vol. 1, No. 2(2012), pp. 51-56, HU ISSN 2063-6997
5. Tibor Bódi, Gabriella Federer-Kovacs: **Calculation of the capillary pressure for water versus the water saturation**, 2nd Central And Eastern European International Oil And Gas Conference And Exhibition, Šibenik 02.-05.10.2012.
6. Gabriella Federer-Kovacs**: Examination of Static and Dynamic Filtration on Core Plug Samples on Increasing Temperature**, 2nd Central And Eastern European International Oil And Gas Conference And Exhibition, Šibenik 02.-05.10.2012.
7. Csaba Szepesi; Gabriella Federer-Kovacs: **Analyze of useable well control method for long open hole section**, Well Control and Well Capping Conference, Szolnok, Hungary, September 8-9, 2009.
8. Tibor Szabo; Gabriella Federer-Kovacs: **Underbalanced drilling well control**. Well Control and Well Capping Conference, Szolnok, Hungary, September 8-9, 2009.
9. Gabriella Federer-Kovacs: **Feasibility of the application of underbalanced drilling during domestic drilling operations**, Conference of PhD Students, University of Miskolc 11.09.2005. p. 55-59 (published in Hungarian)
10. Gabriella Federer-Kovacs: **Feasibility of the application of gas circulation during domestic drilling operations**, 26^{th} International Petroleum & Gas Conference and Exhibition, September 21-24 2005 (published in Hungarian)
11. Gabriella Federer-Kovacs: **Improve efficiency of cutting transport with foam drilling**, 5th International Conference of PhD Students, University of Miskolc 14-20 August 2005
12. Gabriella Federer: **Well hydraulics in relation with casing drilling**, microCAD 2005 International Scientific Conference, University of Miskolc 10-11 March 2005.
13. Gabriella Federer: **Evaluation the well hydraulic in relation with casing drilling**, Freiberger Forschungsforum, TU Bergakademie Freiberg 16-18 June 2004.
14. Gabriella Federer: **Search of the effects of equivalent circulating density in relation with casing drilling**, Conference of PhD Students, University of Miskolc November 6. 2003. (published in Hungarian)