لزوجة وشد سطحي والتي تقلل من الحركة وتحسن من استخراج النفط. قيم الPH لهذا المحلول تتغير تدريجيا بالمقارنة مع النسب الاخرى وكذلك نلاحظ ان النقصان في الكثافة فتعطي بعض الفوائد في تقليل الاحتكاك والضغط خلال الجريان.

KEYWORDS: Water-PVAc solution, ZnO Nanofluids, viscosity, surface tension,PH ,density, oil recovery.

List of Abbreviations:-

PVAc: **polyvinyl acetate**
ZnO: **Zinc Oxide**
PVA: **polyvinyl alcohol**
Cp: **centipoise**

INTRODUCTION

The need to produce energy is growing every day in different areas of life, and the oil is one of the largest sources of energy present.Primary oil recovery extracts about 30% of the crude oil inside the reservoir depending on the natural conditions and pressure underground.

Enhance oil recovery EOR means injection of liquid or material not actually present underground to keep the pressure in the reservoir at the same level.Water floating and polymer floating are two types of EOR applications.Flotation water is one of the techniques that are used to extract the rest of theoil by injectinglarge amounts of water to the reservoir. Improving the efficiency of this method for the purpose of extracting the required oil and using reasonable quantities of water became very important issue nowadays.Mixing water with polymeric solutions and mixing of different nanoparticles with water-polymer solution to increase the viscosity and reduce the coefficient of mobility are two ways to improve the production efficiency in a floatingmethod [Ronald E, 2001, Kevin and C. Taylor, 2003, Wanli Kang, et al, 2012, - D.A.Z. Wever, et al 2011].

Mobility ratio is the ratio of moving fluid mobility to the moved fluid mobility and its value must be less than one. Increasing viscosity of water decreases the mobility ratio and increases the sweep area, which produce lower cost of oil lifting. When water flowing between two parallel plates or inside a pipe the shear rate or velocity gradient in the perpendicular direction to the flow indicating different behavior depending on the fluid type. Shear rate exhibits minimum value at the center of pipe and increasing gradually towards the wall. Water classified as Newtonian flow werethe viscosity is not changing with shear rate increasing, while water-polymer solution is non-Newtonian flow were the viscosity decreases with the shear rate increasing this is called shear thinning effect, which is the most important rheological phenomena in viscous fluids [MonraweePancharoen, 2009]. The polymer solution containslong chain molecules, which largely controlling on the non-Newtonian flow behavior. Viscosity of polymer solution is the resistance to the flow, which is decreases with the shear rate increasing due to the molecules alignment in the flow direction .The shear rate became lesser and viscosity indicates higher value at the center region when the flow transfers from Newtonian to the non-Newtonian [JohaanaAho, 2011, Ren Kun and et al, 2006, R.S. Seright and et al 2011].

Water-soluble hydrohpobically association polymers are examined with particular emphasis on their rheology for oilfield applications, [Kevin and C. Taylor, 2003].Recently all areas of the oil industry, such as exploration, primary and assisted productionmonitoring, refining and distribution, are approaching nanotechnologiesas the powerful tools for dealing with criticalissues related to the oil recovery technique improvement, [CocuzzaMatteo and et al, 2012].

Polysilicon Nanoparticles are advantageous agent for enhance oilrecovery because these particles are stable at high pressure and temperature. Therefore, in high pressure and temperatures conditions,where other surfactants lose their characteristic, the presence ofpolysilicon Nanoparticle is indispensable,[CocuzzaMatteo and et al, 2012, CocuzzaMatteoand et al, 2012].

This paper studies the effects of the polymer and then the non-metallic nanoparticles on the viscosity and related physical properties of water in order to reduce the mobility factor and improve the oil recovery. Inthis work river water mixed with different ratios of poly vinyl acetate PVAc to prepare solution1.Viscosity, surface tension, PH value, and density of solution1 are tested and water-5%PVAc solution are chosen to mix with the different ratios of ZnO nanoparticles to prepare solution2. Again Viscosity, surface tension, PH value, and density of solution2 are tested to obtain the better solution.

MATERIAL AND METHOD

Different types of water are used in this work, riverwater, RO water, drainage water, distilled water, and tap water. Tests of viscosity, surface tension, PH, and density are performed on all water samples. Water sample of high viscosity is selected to be the base fluid in this work.

Polyvinyl acetate PVAc:is supplied in the solution form Changzhou haijiannew textile materials Co.LTD/ China.Polyvinyl acetate is a complex polymer resulting from the condensation reaction acetaldehyde and butyl aldehyde with polyvinyl alcohol PVA.

ZnO Nanoparticles: The ZnO nanoparticle, supplied form (Shijiazhuang Sun power Technology Co., Ltd, China). The specifications of ZnO nanoparticles illustrates in **Table (1).**

Solution Preparation

Water-PVAc Solution , SOLUTION(1):2, 3, 4, and 5wt% of PVAc is mixed with the river water.the mixing process performed using magnetic stirrer ; 30 mint at room temperature for both solutions.

ZnO Nano Water-5%PVAc Solution, SOLUTION (2):0.2, 0.3, 0.4, and 0.5 % of ZnO nanoparticles are mixed with the water-5% PVAc solution.

Viscosity: The viscosity of solution 1 and solution 2 ismeasured using cone on plate viscometer type Brookfield and rotary viscometer.

Surface Tension: Surface tension is tested using JZYW-200B Automatic Interface Tensiometer supply by BEING UNITED TEST Co. LTD.

Density: Densitymeasurement is obtained using Matsu haku liquid density mode of GP-120s instrument.

PH: Testing is performed bylapph 720 supplies by WTW.

RESULTS AND DISCUSSION

The physical properties of different types of water and the PVAc are tested. Viscosity, surface tension, PH value, and density of water are listed in the **Table2** and river water is selected to be the base fluid due to the viscosity value produced. The viscosity, surface tension, PH value, and density of PVAc liquid are 355.5 cp, 49.13 mN/m, 2.52, and 1.0467 g/cm^3 respectively.

Viscosity: solution (1).

Fig.1. shows the viscosity of solution1 increases with the PVAc percentages increasing due to the friction between polymer chains and between these chains and the water which increases the resistance to the flow. Viscosity also decreases with the temperature increasing due to the free volume increasing which makes the movement of the chains easier. At 5%PVAc the viscosity has approximately the same value at 25 and 30 ºC while a small reduction occurs at 35 ºC.This mean that the viscosity more stable at this ratio. At 3, and 4% PVAc the change in viscosity is clear due the change in temperatures which produces unstable viscosity value. Also the effect of temperatures on the viscosity at 2 and 5% PVAc is nearly similar

The effect of PVAc percentage on the viscosity of solution1 at different shear rate was illustrated in **Fig.2**.Again the viscosity increases with the PVAc percentage increasing due to the high viscosity of polymer compared with that of water. At 2, 3, and 4% PVAc the effect of shear rate is negligible, therefore the flow behavior is Newtonian. While the effect of shear rate at 5% PVAc is clear and non-Newtonian flow produced. The reduction of viscosity at this ratio with the shear rate increasing is so called shear thinning effect, which exits in the polymer solution due to the chains alignment during the flow.

With the shear rate increasing the viscosity keeps constant in Newtonian flow, while it decreases in non-Newtonian flow.**Fig.3.**shows the viscosity of solution1 decreases clearly with the shear rate increasing at 5% PVAc, this non-Newtonian flow behavior occurs due to the alignment of the polymer chains during the movement in the viscometer .At 2, 3, and 4% PVAc the solution behaves as Newtonian flow, were the change in viscosity is very small with the shear rate increasing. **Fig.4.** indicates that the shear stress of solution1 generally increasing with the shear rate increasing. The shear stress at 5% PVAc approximately not change, while the 2, 3, and 4% PVAc solutions produce clear increasing.

Fig.5. indicates the viscosity decreasing of solution1 with the temperature increasing due to the free volume increasing and easy movement of PVAc chains. The 5%PVAc solution shows more stable behavior than that of other PVAc solutions with the temperatures change.

Solution (2)

At **Fig. 6,** the viscosity increased with the ZnO nanoparticles increasing at different velocity. The values of viscosity stable up to the 0.004 ZnO, after that the increasing is more clear specially at low velocity.

Fig.7. shows the viscosity decreases with the speed increasing of solution2. The behavior of viscosity consists of three stages, the first one drop rabidly, (the speed increase from 6 to 12), while the second stage indicates slower decreasing (the speed increase from 12 to 30) , then the last stage reach stable and approximately constant value(the speed increase from 30 to 60) . The viscosity increases with the ZnO nanoparticles increasing due to the interaction between ZnO nanoparticles and polymer chains and between nanoparticles itself.

Surface Tension

The surface tension of solution2 increases with the ZnO nanoparticles increasing as shown in **Fig.8**.In the solution2 the Van der Waals forces between the nanoparticles at the liquid/gas interface increases the free energy at the surface and then surface tension. At low ZnO nanoparticles concentration the distance between the particles increases and the attractive force decreases thus the surface tension decreases. The PVAc solution reduces the final surface tension due to the inserting of polymer chains between nanoparticles and around the fluid, which produces a repulsive force (electrostatic force) and reduces the surface energy.

PH value

PH of water reduces to about halve value after mixing with the 5%PVAc solution, then returns approximately to the origin value after ZnO nanoparticles filled the solution.**Fig.9.**illustrates that the PH value increases by about halve due to the ZnO nanoparticles increasing. Also a small gradually increasing in PH value occurs with the ratios of ZnOnano increasing. Therefor the viscosity increases with the PH value increasing, due to the reduction in the stability level.

Density

Fig.10. shows the density decreases of solution2 with the ZnO nanoparticles increasing. The decreasing in density after 0.2% ZnO became clearer and reaches minimum value at 0.5%ZnO, due to the low density of ZnO nanoparticles.

Conclusion

The flow behavior and viscosity are important parameters to cheek the oil recovery efficiency increasing.Selecting the riverwater to be the base fluid is the starting step due to the higher viscosity value.Adding the bio-polymer PVAc andnano-ZnO particles increasesthe viscosity without any reverse effect on the environment. The behavior of water flow transfers from Newtonian to non-Newtonian after adding a certain ratios of PVAc or ZnOnanoparticles. The viscosity value depends on the shear thinning effect, whichis change due to the non-Newtonian behavior. The 5%-PVAc-water solution and .0-005 ZnOnano-solution indicate approximately higher stability in viscosity value with the shear rate and temperature increasing. The results of the surface tension, PH and density are compatible with the flow characterization.

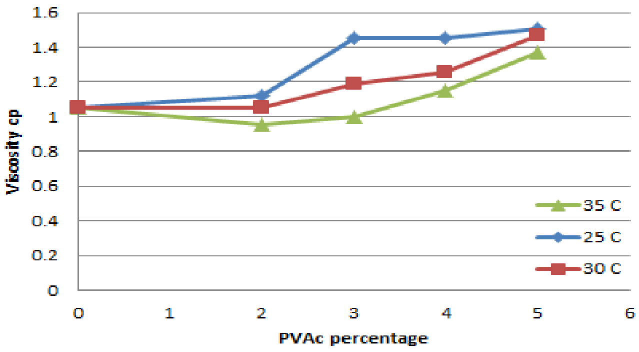

Fig.1. The viscosity behavior of solution1 with different PVAc percentage at different temperatures.

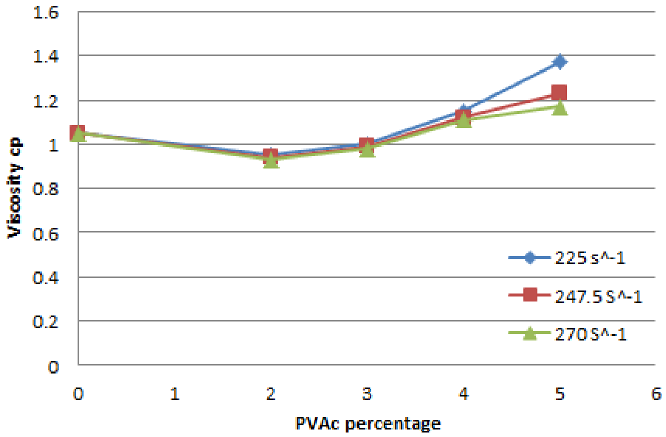

Fig.2. The viscosity behavior of solution1 with different PVAc percentage at different shear rate.

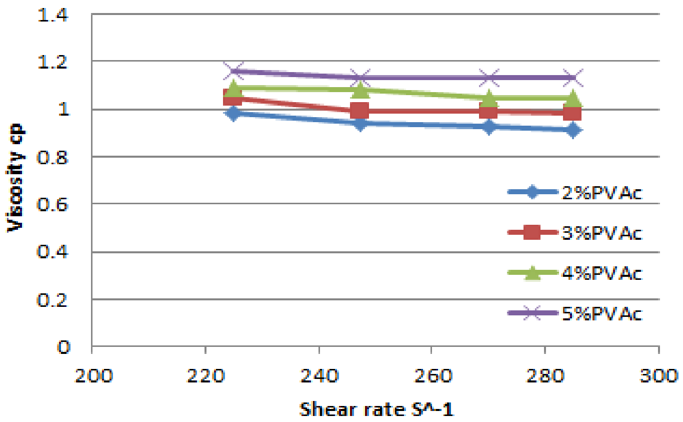

Fig.3. The viscosity behavior of solution1with shear rate increasing at different PVAc percentage.

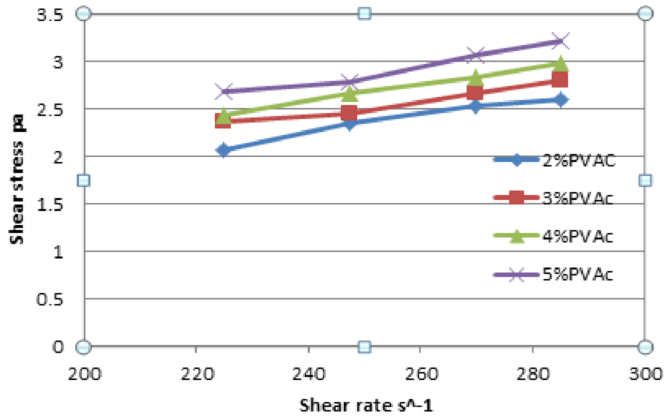

Fig.4. The shear stress behavior solution1with the shear rate increasingat different PVAc percentage

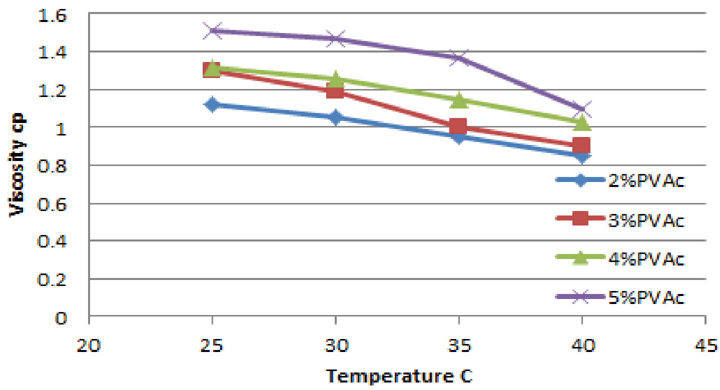

Fig.5. The viscosity behavior of solution1 with the temperatures increasing at different PVAc percentage.

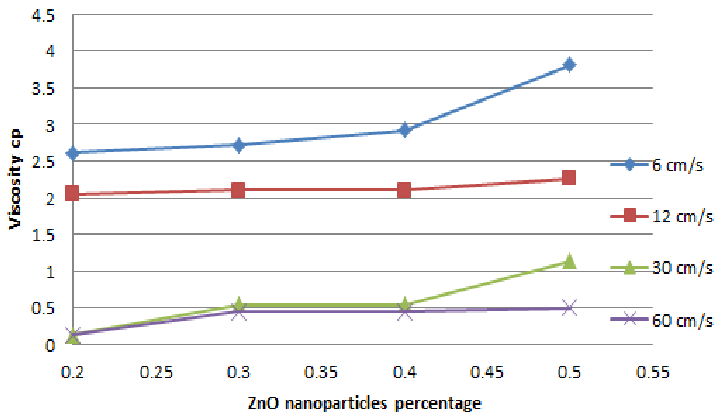

Fig.6. The viscosity behavior of solution2 with ZnO nanoparticles concentration increasing at different

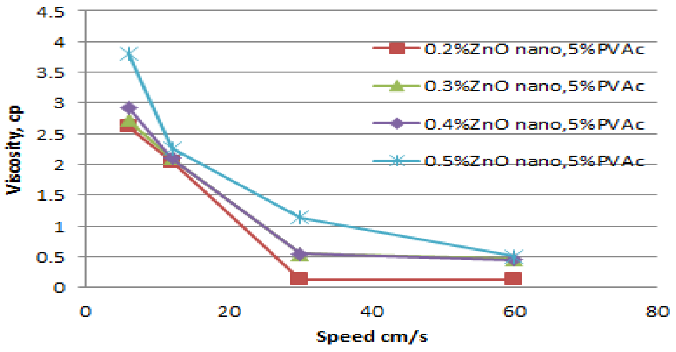

Fig.7. The viscosity behavior of solution2 with speed increasing at different ZnO nanoparticles

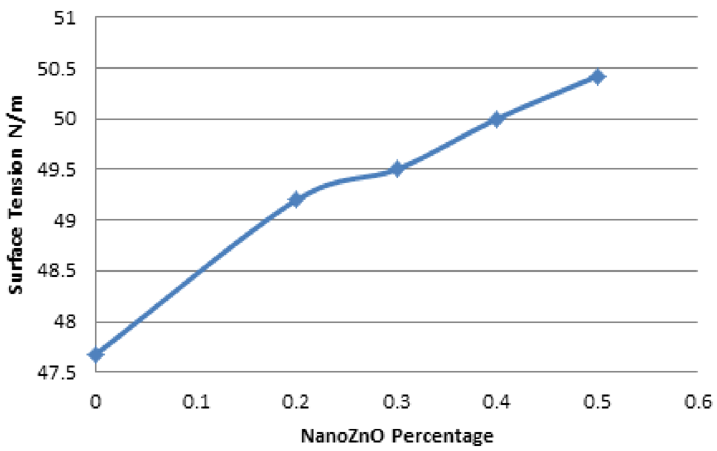

Fig.8. The surface tensionbehavior of solution2 with the ZnO nanoparticles

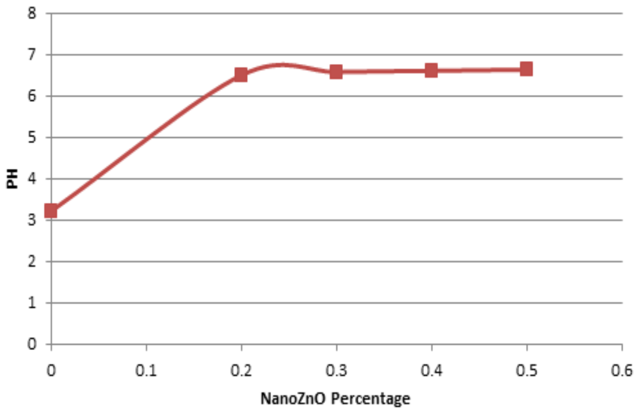

Fig.9. The PHbehavior of of solution2 with the ZnO nanoparticles increasing..

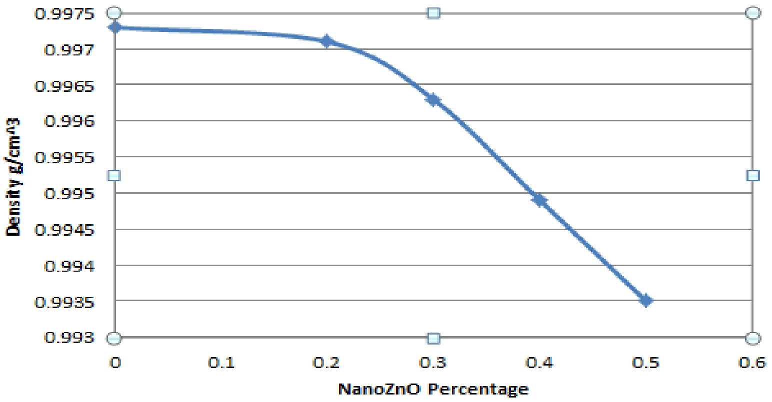

Fig.10. The densitybehavior of solution2 with the ZnO nanoparticles increasing.

Table (1): The specifications of ZnO nanoparticles

ZnO %	95.2
Pb %	0.03
Mn %	0.005
Cu %	0.003
Water soluble matter %	0.7
Specific surface area (m^2/g)	36
Particle size	40 nm

Table2: The physical properties of different types of tested water.

	Distill water	River water	Drainage water	Tap water	RO water
Viscosity cp	0.95	1.05	1.02	0.92	1
Surface tension mn/cm	71.95	76.1	76.91	72.44	84.47
PH	7.67	7.3	7.05	7.29	7.62
Density g/cm^3	0.9963	0.9941	0.9955	0.9971	0.9964

REFRENCES:

-CocuzzaMatteo, et al"**Current and Future Nanotech Applications in the Oil Industry**" ,American Journal of Applied Sciences 9 (6): 784-793, 2012.

- CocuzzaMatteo,etal"**Current and Future Nanotech Applications in the Oil Industry"** American Journal of Applied Sciences 9 (6): 784-793, 2012 ISSN 1546-9239,2012.

- D.A.Z. Wever, et al "**Polymers for enhanced oil recovery: A paradigm for structure–property relationship in aqueous solution** Progress in Polymer Science 36 (2011) 1558–1628,2011.

- JohaanaAho, " **Rheological Characterization of Polymer Melt in Shear and Extension: Measurement Reliability and Data for Practical Processing**" Thesis for the Degree of Doctor,Tampor University for Technology,2011.

- Kevin, C. Taylor,"**Rheology of Hydrophobically Association Polymer for Oilfield Applications**" Annual Transaction of Nordic Rheology Socity, Vol, 11,2003.

- MonraweePancharoen, "Physical **Properties of Associative Polymer Solutions**", Thesis, Stanford University,2009.

- Ronald E. Terry, "**Enhanced Oil Recovery**" Encyclopedia of Physical Science and Technology 3rd Edition, vol. 18,pp 503-518, Brigham Young University,2001.

- RenKun,et al "**Rheological Properties of Hydrophobically AssociatingPolyacrylamide Solution**" Petroleum Science Vol.3 NO.2,2006.

-R.S. Seright, etal "**Rheology of a New Sulfonic Associative Polymer in Porous Media** SPE International Texas, USA, 11–13 April ,2011.

-WanliKang,et al **"Designing water-soluble polymers for enhanced oil recovery** 2012 Society of Plastics Engineers (SPE),2012