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PREDICTION OF NEW CORRELATIONS RELATING RHEOLOGICAL PROPERTIES OF INVERT EMULSIONS WITH TEMPERATURE AND PRESSURE

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ABSTRACT:

The main aim of this research is to find the most suitable correlations which relating the rheological properties of invert emulsions of different densities (2.2, 2.4, and 2.5 gm/cm^3) with temperature and pressure. According to that an theoretical study has been done to predict these correlations, depending on Rosenbrock optimization technique.

Rheological properties such as plastic viscosity, and yield point data at different temperatures and pressures were selected from literature.

New correlations were predicted which show firstly the effect of temperature on the plastic viscosity and yield point, and secondly the effect of pressure on these rheological properties.

The results indicated that there are a correlations with high accuracy which can represented the effect of temperature and pressure on the rheological properties of invert emulsions (both plastic viscosity, and yield point) for each density which show that the rheological properties of invert emulsions decreased with increasing temperature and increased with increasing pressure.

New empirical formulae for the combined effect of temperature and pressure on the rheological properties of invert emulsions for different densities have been developed by using Rosenbrock optimization technique.

KEY WORDS: Emulsions, Rheology.

الخلاصة:

ان الهدف الاساسي من هذا البحث هو ايجاد افضل علاقات ملائمة تربط بين الخواص التيارية للمستحلبات العكسية ذات الكثافات المختلفة (2.2, 2.4, and 2.5 gm/cm^3) مع الحرارة والضغط. وطبقا لذلك اقيمت دراسة نظرية لايجاد هذه العلاقات بالاعتماد على طريقة روزنبروك للاختيار الامثل.

لقد اختيرت بيانات الخواص التيارية للمستحلبات العكسية مثل اللزوجة اللدائنية ونقطة الخضوع لقيم مختلفة من الحرارة والضغط من المسوحات الادبية.

لقد تم ايجاد علاقات جديدة توضح تاثير الحرارة على اللزوجة الدائنية ونقطة الخضوع اولا وتاثير الضغط على هذه الخواص التيارية ثانيا.

لقد بينت النتائج بان هنالك علاقات توضح تاثير الحرارة والضغط على الخواص التيارية للمستحلبات العكسية ممثلة باللزوجة اللدائنية ونقطة الخضوع لكل كثافة للمستحلب العكسي والتي بينت بان تلك الخواص تقل بزيادة الحرارة وتزداد بزيادة الضغط.

لقد تم تطوير معادلات جديدة تبين التاثير المركب للحرارة والضغط على الخواص التيارية (اللزوجة اللدائنية ونقطة الخضوع) للمستحلبات العكسية وبكثافات مختلفة باستخدام طريقة روزنبروك للاختيار الامثل.

NOMENCLATURES:

Pv Plastic Viscosity, cp

Yp Yield Point, Ib/100 ft^2

P Pressure, psi

T Temperature, F

INTRODUCTION:

Gary & Darely in 1981 stated that invert emulsions are consisting of hydrocarbon oil, either crude oil or refined, which may contain dispersed both solids and droplets of water. In all cases, oil is the external phase; and other components, unless soluble in the oil, are dispersed in the oil as discontinuous phases.

Chadwick in 1981 discussed that the rheological properties of the fluid must be determined under bottom hole conditions in order to show the effect of temperature on fluid properties and obtain accurate calculations of the friction losses in the drill pipe and annulus of pressure surge due to pipe movement, these properties cannot be predicted at atmospheric conditions.

Chilingarain and Vorabutra in 1981 defined plastic viscosity as the shearing stress in excess of yield point that will induce a unit rate of shear. It is a part of fluid resistance to flow caused by mechanical friction that occurs: between the solids presented in the fluid, between the solids and the liquid that surrounds them, and finally with the shearing of liquid itself. While the yield point is the second part of fluid resistance to flow, which is a measurement of the electrochemical forces, or attractive forces between the solid particles that encountered in the emulsion under flow conditions. These forces are a result of negative and positive charges located on or near the surface of the solid particles.

Taugbol et. al in 2005 said that with the advent of deeper drilling, the demand for a fluid that must perform the normal functions while it will be exposed to extreme conditions of pressure, temperature, and contamination is increasing.

Gregoire et. al in 2009 stated that one of the most obvious factors that have an effect on the rheological behavior of a material is temperature. Some materials are quite sensitive to temperature, and relatively small variations will result in a significant change in viscosity. Others are relatively insensitive. Consideration of the temperature on viscosity is essential in the evaluation of materials that will be subjected to temperature. Variations in use or processing, such as motor oils, greases, and hot-melt adhesives.

Invert emulsions are used in the simplest sense, as a mean of avoiding the use of water in the well bore, therefore, filtrate from a water-base mud may cause clays and sands in the formation to swell and block, with severe damage to well productivity.

Nance in 1984 stated that invert emulsions can be compounded to be stable at high temperatures. Thus invert emulsion is used in deep drilling, where temperature is too high for water – base mud.

Gray & Darely in 1984 disussed that the rheological and physical properties of invert emulsion are affected by the change of the temperatures like any fluids, but it does not show a problem of gelation because no chemical relations leading to gelling occurrence. Invert emulsion prevents the settling of wetting material which may occur due to the reduction in viscosity with temperature, since a suspension or gelling agents were used in preparing invert emulsion.

Mohammed in 1989 discussed that there have been several studies to show how invert emulsions function during drilling operations, their advantages, disadvantages, preparation, treatment during drilling, maintains cost, but little studies have been concerned on how the effect of temperature & pressure on the rheological properties were correlated.

Kerston (1946), reported the results of using invert emulsions in drilling and completing oil wells. He stated that high temperature conditions do not offer a problem in using invert emulsions, because suspension of weighting material and viscosity control have been developed to a high efficiency. Also, he stated that water has a detrimental effect on all invert emulsions, but can be controlled by the addition of unslaked lime.

Gates and Pfenning (1952), mentioned to a new heavy invert emulsion, which is stable at temperatures up to 250 – 275 F, that is used successfully in drilling high pressures and temperatures formations. But, this mud has the problem of settling of weighting material which increases as the water content build up to 10 percent or over. He showed that this problem may be avoided by maintaining the water content less than 8 percent or by adding concentrated soap.

Hiller (1963), showed that the plastic viscosity of invert emulsion decreases with increasing temperature but this decrease is faced by an increase in plastic viscosity with pressure.

Mc Mordie et. al (1975), mentioned that the effect of temperature and pressure on the viscosity of invert emulsion can be described mathematically by a modified power – law model :

$$Ln\ \tau = Ln\ k + n\ Ln\ \gamma + AP + B/T \qquad (1)$$

Where; A = pressure constant, B = temperature constant, τ = shear stress, and γ = shear rate.

Nance (1984), showed the effect of down hole conditions on the rheological properties of invert emulsion where extreme high pressure and temperature are exposed. The invert emulsion appears to thin under down hole conditions., this thinning can be compensated by increasing viscosity at the surface.

Carbaja l, D. et. al (2009), described that north sea wells drilled in high – pressure, high – temperature, since temperature reaches 400 F, can adversely impact the rheological properties needed for reliable suspension. Micronized barite has been used to help lower equivalent circulating density values.

THEORETICAL RESULTS:

Empirical correlations were derived from the experimental data of Mohammed (1989), which relate the rheological properties (plastic viscosity Pv, and yield point Yp) of invert emulsions of different densities (2.2, 2.4, and 2.5 gm/cm3) with temperature and pressure.

Rosenbrock optimization technique has been used to derive these correlations, which optimize the experimental data and passing a best fitted curve for temperature or pressure effect for each density. Graphs where plotted between the rheological properties with temperature firstly, and secondly with pressure.

Three samples of invert emulsions have been taken. The first with density of 2.2 gm/cm^3, the second with density of 2.4 gm/cm^3, and the third one with 2.5 gm/cm^3 density.

(A) Correlations Related Temperature with Plastic Viscosity, and with yield point:

(1) The effect of temperature on plastic viscosity of invert emulsion of density of 2.2 gm/cm^3 is considered in the following equation;

$$Pv = 659.13\ T^{-0.527} \qquad (2)$$

For R^2 = 0.9749 as shown in fig. (1).

While; the effect of temperature on yield point of this emulsion with the same density is clearly shown in fig. (2); using the following equation:

$$Yp = 28.621 \quad e^{-0.003\,T} \qquad (3)$$

For $R^2 = 0.9838$

(2) The effect of temperature on plastic viscosity of invert emulsion of density of 2.4 gm/cm^3 is shown in fig. (3); using the following equation:

$$Pv = 3223.8 \; T^{-0.78} \qquad (4)$$

For $R^2 = 0.9659$

While; the effect of temperature on yield point of this emulsion with the same density is shown in fig. (4) as follows;

$$Yp = 39.275 \; e^{-0.003\,T} \qquad (5)$$

For $R^2 = \; 0.9768$

(3) The effect of temperature on plastic viscosity on invert emulsion of density 2.5 gm/cm^3 is shown in fig. (5); which can be expressed using the following equation:

$$Pv = 7099.5 \; T^{-0.891} \qquad (6)$$

For $R^2 = \; 0.9754$

While the effect of temperature on the yield point of the same emulsion with the same density is shown in fig.(6); which can be expressed in the following equation

$$Yp = 50.1 \; e^{-0.003\,T} \qquad (7)$$

For $R^2 \; = \; 0.964$

The general correlation which shows the effect of temperature on plastic viscosity is:

$$Pv = A \; T^{-B} \qquad (8)$$

While the general correlation which shows the effect of temperature on yield point is:

$$Yp = C \; e^{-D\,T} \qquad (9)$$

Since A, B, C, and D are constants depend on the value of density of the invert emulsion.

(B) The effect of pressure on plastic viscosity, and yield point of invert emulsions:

(1) The effect of pressure on plastic viscosity of invert emulsion of density 2.2 gm/cm^3 is shown in fig.(7); and expressed in the equation below:

$$Pv \; = \; 13.071 \; e^{0.0017\,P} \qquad (10)$$

For $R^2 \; = \; 0.9481$

While; the effect of pressure on yield point of the same emulsion with the same density is shown in fig. (8); which can be expressed in the following equation:

$$Yp = 2.8176 \quad e^{0.0028 \ P} \qquad (11)$$

For $R^2 = 0.9892$

(2) The effect of pressure on plastic viscosity of invert emulsion of density 2.4 gm/cc is shown in fig.(9); which can be expressed in the following equation:

$$Pv = 9.2355 \quad e^{0.0027 \ P} \qquad (12)$$

For $R^2 = 0.8975$

While the effect of pressure on yield point of the same emulsion with the same density is shown in fig.(10); and expressed in the following equation:

$$Yp = 4.2758 \quad e^{0.0026 \ P} \qquad (13)$$

For $R^2 = 0.9871$

(3) The effect of pressure on plastic viscosity of invert emulsion of density of 2.5 gm/cc is shown in fig. (11); and expressed in the following equation:

$$Pv = 8.5167 \quad e^{0.0031 \ P} \qquad (14)$$

For $R^2 = 0.9279$

While the effect of pressure on yield point of the same emulsion with the same density is shown in fig.(12); with the following equation:

$$Yp = 5.5933 \quad e^{0.0025 \ P} \qquad (15)$$

For $R^2 = 0.992$

Thus the general correlation which shows the effect of pressure on plastic viscosity of invert emulsion is as follows;

$$Pv = E \ e^{F \ P} \qquad (16)$$

While the general correlation which shows the effect of pressure on the yield point of invert emulsion is as follows;

$$Yp = G \ e^{H \ P} \qquad (17)$$

Since E, F, G, and H are constants depend on the value of the density of invert emulsion.

(C) Correlations Relating the Combined Effect of Pressure and Temperature of Invert Emulsions:

(1) For invert emulsion of density 2.2 gm/cm^3:

$$Pv = 659.13 \quad T^{-0.527} + 13.071 \quad e^{0.0017 \ P} \qquad (18)$$

While; the combined effect of temperature and pressure on yield point of this emulsion with the same density:

$$Yp = 28.621 \quad e^{-0.003 \quad T} + 2.8176 \quad e^{0.0028 \quad P} \qquad (19)$$

(2) For invert emulsion of density 2.4 gm/cm^3:

$$Pv = 3223.8 \quad T^{-0.78} + 9.2355 \quad e^{0.0027 \quad P} \qquad (20)$$

While; the combined effect of temperature and pressure on yield point of this emulsion with same density:

$$Yp = 39.275 \quad e^{-0.003 \quad T} + 4.2758 \quad e^{0.0026 \quad P} \qquad (21)$$

(3) For invert emulsion of density 2.5 gm/cm^3:

$$Pv = 7099.5 \quad T^{-0.891} + 8.5167 \quad e^{0.0031 \quad P} \qquad (22)$$

While; the combined effect of temperature and pressure on yield point of this emulsion with same density:

$$Yp = = 50.1 \; e^{-0.003 \, T} + 5.5933 \quad e^{0.0025 \quad P} \qquad (23)$$

Thus, the general correlation which shows the combined effect of temperature and pressure on plastic viscosity of invert emulsions as follows:

$$Pv = A \quad T^{-B} + C \quad e^{D \; P} \qquad (24)$$

While the general correlation which shows the combined effect of temperature and pressure on yield point of invert emulsion is as follows:

$$Yp = E \quad T^{-F} + G \quad e^{H \quad P} \qquad (25)$$

DISCUSSION:

The derived correlations have large values of correlation coefficients, which imply that they are better correlations.

High temperature fluid is any system formulated or treated to minimize the effects of temperature on the properties of the fluid, since temperature is the most severe factor that must be taken in consideration when designing a high temperature fluid.

The effect of temperature and pressure on the rheological properties of invert emulsion is limited by their effect on the viscosity of the continuous phase. The viscosity of the continuous phase is diminished by increased temperature. The decrease in its viscosity should cause an impairment in plastering properties. In other words the response of invert emulsion to the changes in rheological properties with temperature and pressure might be approximately the same as for the continuous phase.

The general effect of pressure is to increase the plastic viscosity of emulsions. The percent increasing is greater at low temperature and at high solid content. The temperature has the opposite effect; it will decrease the plastic viscosity of emulsions strongly. However, the decrease in the plastic viscosity due to the temperature is offset by a considerable increase in it with pressure if they were applied together, but the overall effect is to decrease the plastic viscosity.

The general effect of temperature is to reduce the plastic viscosity and yield point of emulsions due to the expansion of these emulsions, which results in reducing the friction forces and attraction forces between the particles of the emulsions. The effect of temperature the rheological properties (plastic viscosity, and yield point is clearly shown in figures (1) through (6).

The effect of pressure is clearly shown in figures (7) through (12). Pressure will increase the plastic viscosity and yield point of emulsions, since it causes a compaction to emulsions, and this will result in decreasing the distance between the particles, friction and attractive forces will be increased.

CONCLUSIONS:

1-Temperature decreases the rheological properties of invert emulsions due to the decrease in the viscosity of the continuous phase of these emulsions.

2-Pressure increases the rheological properties due to that acts as a compaction to these fluids.

3-Empirical correlations were conducted, indicating the effect of temperature on the plastic viscosity of invert emulsions, with another correlation indicating the effect of temperature on the yield point, for three different invert emulsion densities.

4-Empirical correlations were conducted, indicated the effect of pressure on the plastic viscosity of invert emulsions, with another correlation indicated the effect of pressure on the yield point for three different values of densities of these emulsions.

5-New correlations were concluded relating the effect of temperature and pressure on the plastic viscosity firstly, and secondly related these effects on the yield point for three different invert emulsion densities, which are 2.2, 2.4, and 2.5 gm/cm^3.

Table (1) Effect of Temperature on Plastic Viscosity of Invert Emulsions

$Pv = A\ T^{-B}$

Density, gm/cm ^{3}	A	B
2.2	659.13	- 0.572
2.4	3223.8	- 0.78
2.5	39.275	- 0.003

Table (2) Effect of Temperature on Yield Point of Invert Emulsions

$Yp = C\ e^{-DT}$

Density, gm /cm ^{3}	C	D
2.2	28.621	- 0.003
2.4	39.275	- 0.003
2.5	50.1	- 0.003

Table (3) Effect of Pressure on Plastic Viscosity of Invert Emulsions

$Pv = E\ e^{FP}$

Density, gm/cm ^{3}	E	F
2.2	13.071	0.0017
2.4	9.2355	0.0027
2.5	8.5167	0.0031

Table (4) Effect of Pressure on Yield Point of Invert Emulsions

$Yp = G\ e^{H\ P}$

Density, gm/cm ^{3}	G	H
2.2	2.8176	0.0028
2.4	4.2758	0.0026
2.5	8.5167	0.0031

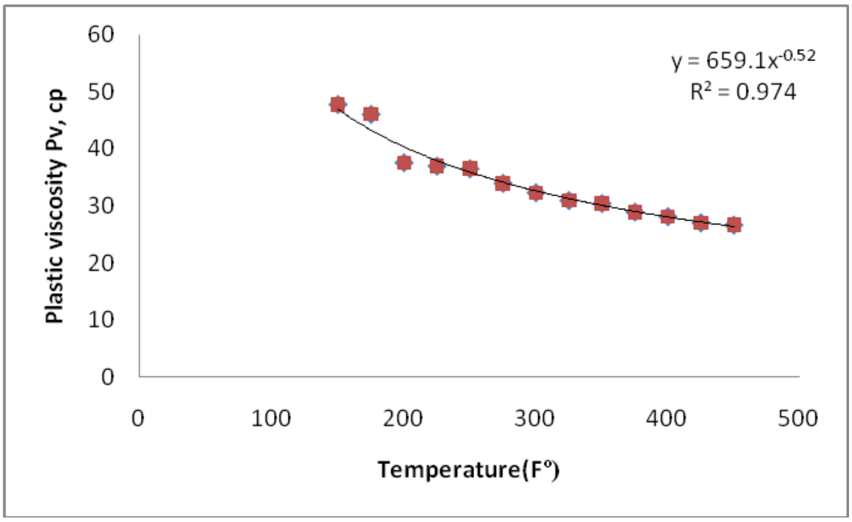

Figure 1: Effect of temperature on plastic viscosity of invert emulsions of density 2.2 gm/cm^3

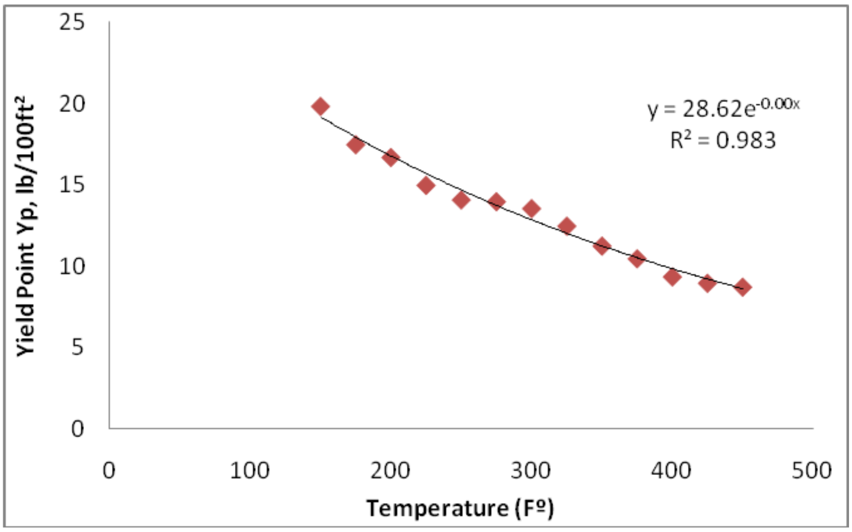

Figure 2: Effect of temperature on yield point of invert emulsions of density 2.2 gm/cm³

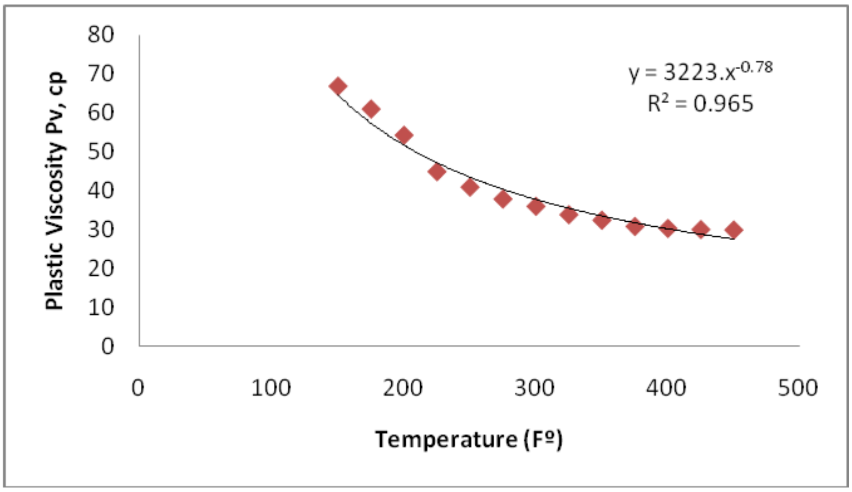

Figure3: Effect of temperature on plastic viscosity of invert emulsions of density of 2.4 gm/cm³

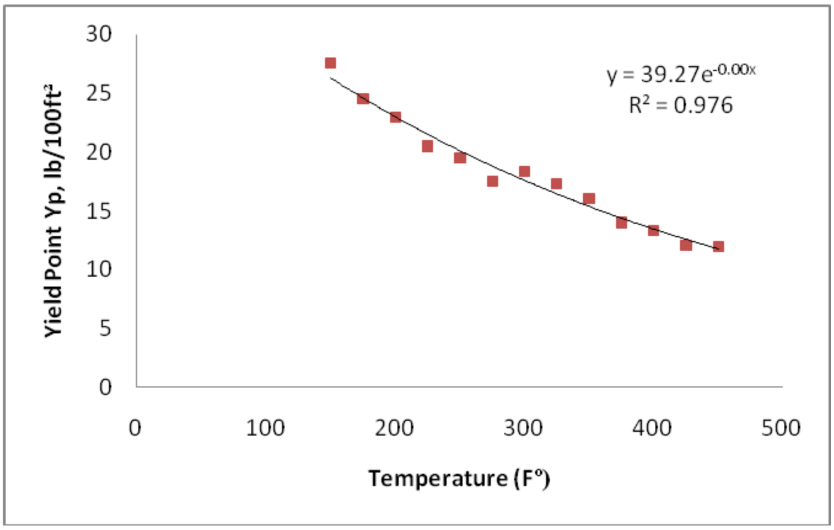

Figure 4: Effect of temperature on yield point of invert emulsions of density 2.4 gm/cm³

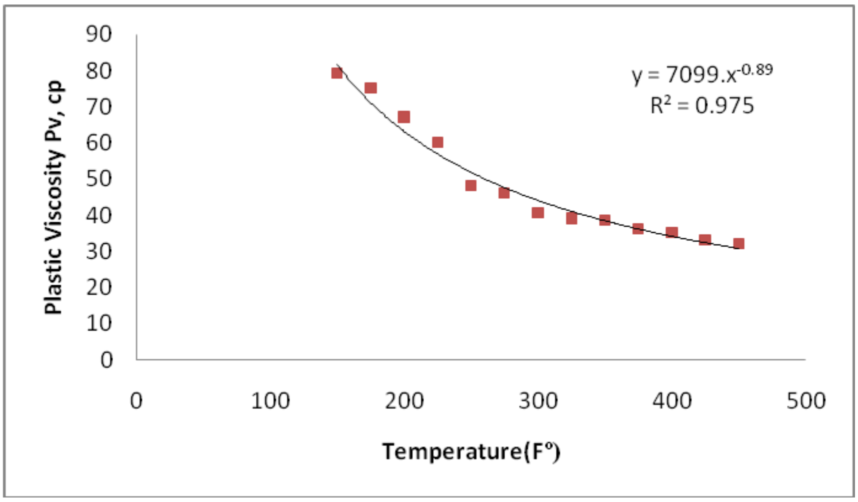

Figure 5: Effect of temperature on plastic viscosity of invert emulsions of density of 2.5 gm/cm^3

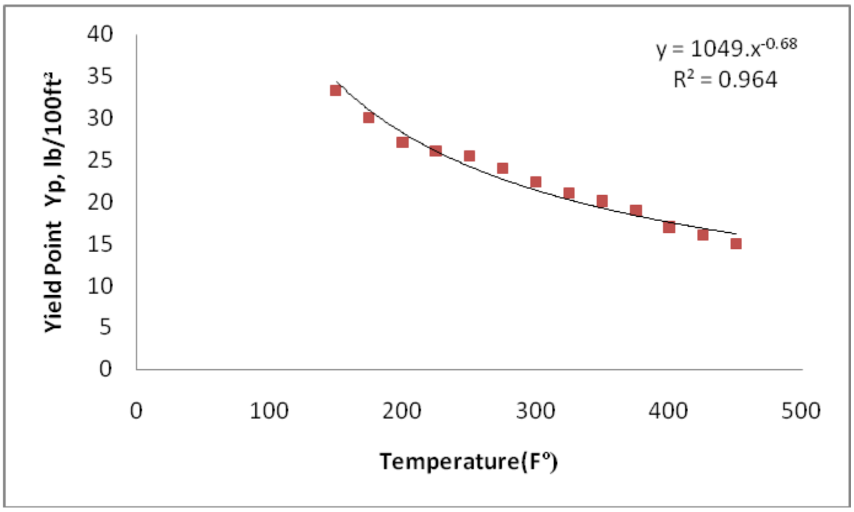

Figure 6: Effect of temperature on yield point of invert emulsions of density of 2.5 gm/cm^3

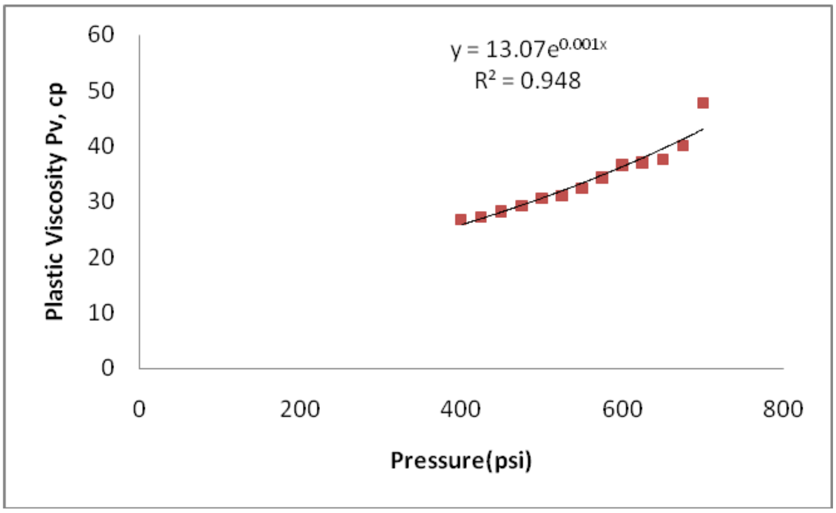

Figure 7: Effect of pressure on plastic viscosity of invert emulsions of density 2.2 gm/cm^3

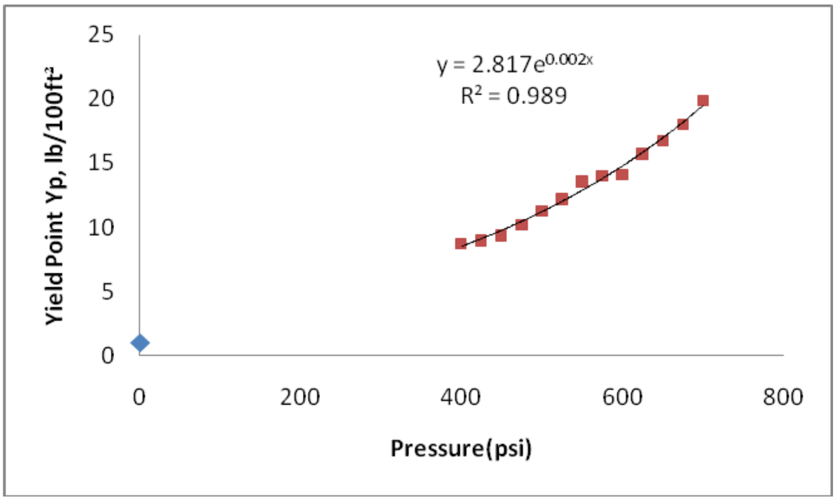

Figure 8: Effect of pressure on yield point of invert emulsions of density 2.2 gm/cm^3

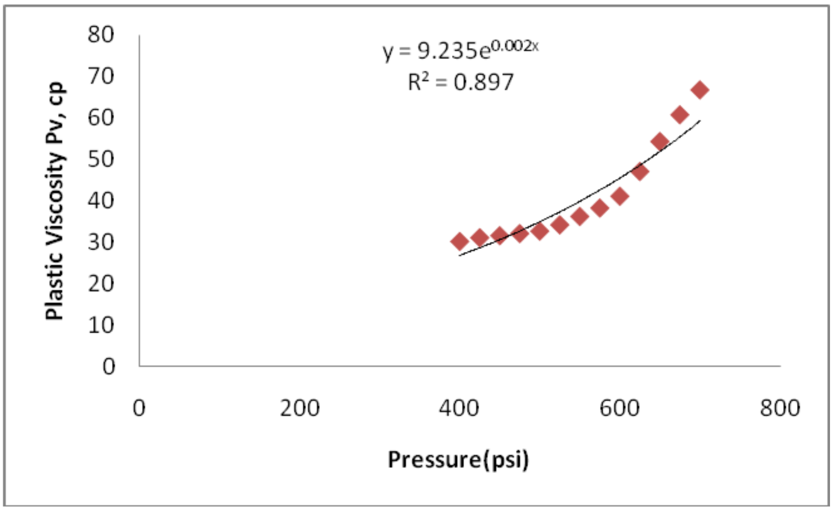

Figure 9: Effect of pressure on plastic viscosity of invert emulsions of density 2.4 gm/cm^3

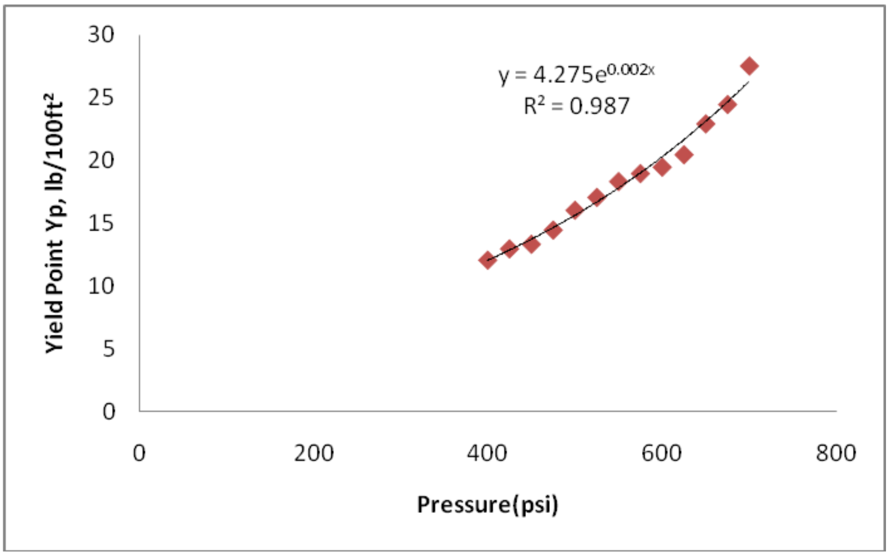

Figure 10: Effect of pressure on yield point of invert emulsions of density 2.4 gm/cm^3

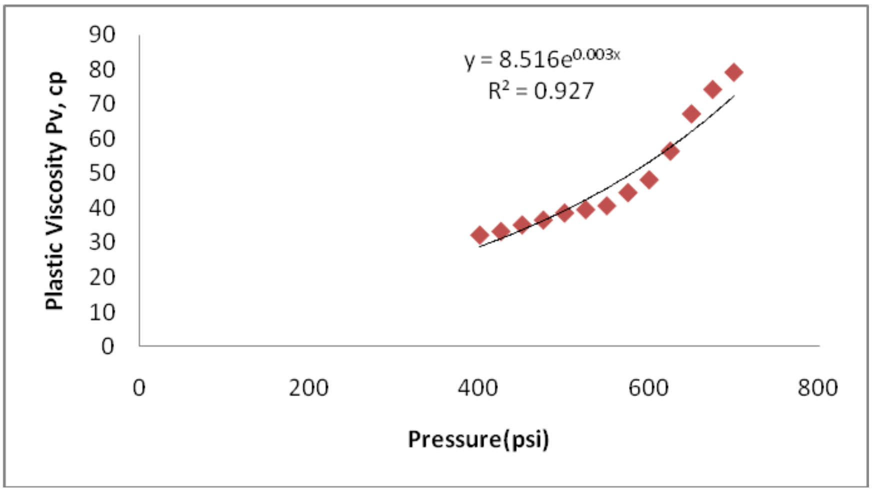

Figure 11: Effect of pressure on plastic viscosity of invert emulsions of density 2.5 gm/cm^3

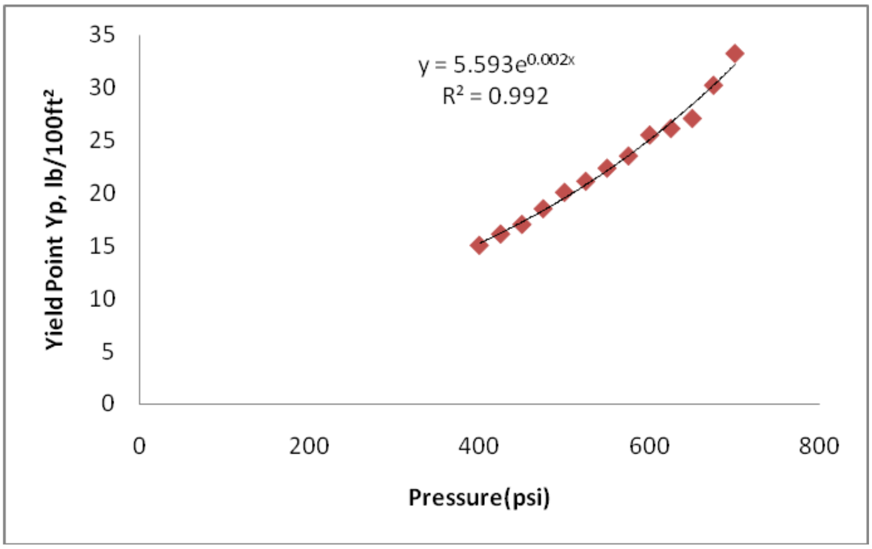

Figure 12: Effect of pressure on yield point of invert emulsions of density 2.5 gm/cm^3

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