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Study the Effect of Proppant Concentration of Screen-Out Phenomena While Hydraulic Fracture Job

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Abstracta: screen out is a blocking of the fracture path caused by bridging the path or accumulation of the proppant inside the fracture, clumping or lodging of the (solid particles) proppant across the hydraulic fracture width that causes to restrict formation fluid to flow into the hydraulically fractured formation. To avoid the screen out happening needing to save fracturing fluids, hydraulic horsepower. Conditions that leading to screen out during the hydraulic fracturing job in a well, such as, the ratio between the fracture widths to particle diameter that called (β), proppant concentration, and wall roughness. The effects of these factors are investigated experimentally in the present work by building an apparatus that meet the shape of the real hydraulic fracture. The plugging time were measured and monitored through glass windows on both sides of the apparatus to follow the behavior of the proppant inside the fracture during the flow of the fracturing fluid or when the proppant plugs the fracture. To study the effect of the fracture wall roughness on the screen out phenomena, apparatus was build to get two different fracture shapes, to meet the real fracture wall in reality. Through the relation between the different proppant concentration and the plugging time, one can indicate on the graph the plugging region and non plugging region for different values of β, proppant concentration and fracture shape, in order to avoid the screen out. During designing the hydraulic fracture, the values of β were very important factor that can lead to screen out, through the results found that when β=1, the screen out happened very fast even at low proppant concentration, but for β=2, 3 and 4 the screen out depends on the proppant concentration and fracture shape. For β=5 it was found that, there is no screen out occurring for wide range of proppant concentration. The effect of hydraulic fracture wall roughness is important because it effect the speed of the suspension when passing through the fracture.

Keywords: experimental, proppant, hydraulic fractures, plugging time, particle diameter

1. Introduction

Hydraulic fracturing is a well stimulation method where a fluid is pumped into the rock to create fractures that called hydraulic fracture. These fractures are intended to function as high-conductivity fluid pathways enabling increased productivity of a well

After fracturing the reservoir, a propping agent which is non compressible solid particle material, such as sand or ceramic beads that are added to the fracturing fluid to form a slurry that is pumped into the new generated fracture in the formation, in order to prevent the fracture from fully closing again when the pumping pressure is released. This causes both sides or walls of the hydraulic fracture to compress onto the proppant, i.e. the proppant is trapped between the fractures faces, generating a high-permeable path way or high conductivity, that allows the oil and/ or natural gas to flow into the well and then to the surface. The proppant transportability of a base fluid depends on the type of additives which control the viscosity, added to the water base.

The main principal physical properties of the proppants affecting the hydraulic fractures conductivity are proppant grain size distribution, strength, roundness, quantities of fines (proppant), density, and sphericity (Gidley et. Al.1991).

Technically, screen out mean that the condition where continued injection of hydraulic fluid to the hydraulic fracture need pressures in excess of the safe limit of the wellbore or wellhead equipment. Operationally, screen out causes a severe confusion in fracturing job in wells and often requires stoppage of fracturing fluid pumping and cleaning of the wellbore before resumption of fracturing job. Screen out is an operational issue and does not necessarily mean damage to well productivity. Actually, many wells end up being active producers after a screen out happen. Screen out consumes time and money during the hydraulic fracture job, for that problem, the operator needs to avoid the parameters that may led to the screen out.

The concentrated proppant slurry causes plugging the hydraulic fracture, and preventing additional growth of the hydraulic fracture length. Additional continues of pumping of the proppant with the fluid slurry into the formation after the screen out happen, causes the hydraulic fracture to balloon. For that the fracture going to grow in width rather than length, and large concentrations of proppant per surface area will occur in the fracture.

Tip Screen Out (TSO) is a hydraulic fracture technique which can applied to the high permeability reservoir, in that case the main objective of the hydraulic fracturing is not to increase the formation production of the formation that is has high permeability, but to prevent the sand or solid particles movement (which is unconsolidated or poorly consolidated reservoir and to prevent and / or control the production of sand), by controlling or reducing the wellbore pressure gradient (Bryant W. et. al. 1996). The process includes as a first stage creating of a hydraulic fracture and breaks it’s growing more by using the tip screen out technique, (A. Konopelko, et. al. 2015), (Curtis L. et. al. 2003).

The objectives of this study are to investigate the behavior of the ceramic proppant during passing through the hydraulic fractures and study the conditions effecting or leading to the bridging or screen out inside the hydraulic fracture such as proppant concentration, value of β (the ratio between the fracture width to proppant diameter) and the effect of fracture wall roughness. For that the apparatus was build and designed to meet the real hydraulic fracture through changing the width of the fracture and the fracture wall roughness. The apparatus designed to meet the fracture shape by using irregular tube represent the hydraulic fracture wall and using ceramic proppant size type 20/40.

The results gotten can used by hydraulic fracture engineer to avoid the screen out occurs by controlling the proppant concentration and size. Also can design the tip screen out for the high permeability formation to control sand production and to reduce fines migration. The apparatus was build vertically to use the gravity to force the suspension flow through the fracture, in order to avoid the settling of the proppant after entering the fracture during the experiments because of gravity if the direction of the suspension flow in horizontal direction, as a real condition during hydraulic fracturing job (Shah, S., 2008) .

2. The Equipment

Figure (1) shows the apparatus used in this study, it consisted of the following parts:

(1) Pipe with one side open by a valve, to hold the suspension.

(2) Tortuous plate, to simulate the fracture walls shape from inside, designed to get different sizes of fracture (width) and shapes by moving one of the parallel side left or right.

(3) Cup put on digital balance to collect the sample after passing through the fracture.

(4) Two transparence windows to monitor the behavior of the proppant inside the fracture, in order to study the screen out phenomenon.

(5) Flow sensor to measure flow velocity for different conditions.

(6) Digital camera to record video of the scale screen, in order to record the cumulative weight on the balance screen vs. flow time. All experiments were done at room conditions.

Hydraulic fracture walls are always modeled as a smooth two parallel plates parallel separated by a slot of constant size or width. However, the real surface of hydraulic fractures is rough wall and can not be smooth. The transportation of proppant between the two smooth parallel walls is different from transportation of the proppant between two rough, parallel walls.

3. Material Used

The materials used in this work were water, Xanthan, and ceramic proppant. Carrier fluid used in this research was prepared from fresh water (450 cc) and 4.5 gm of Xanthan, to get suitable viscosity to suspend the proppant inside the fracturing fluid, and also suitable density to carry the particles through the pipe, uniformly, and have stable viscosity over a wide range of temperature and pH in the presence of added salt. Xanthan gum is thus an excellent stabilizer for a wide variety of suspensions, emulsions, and foams and is highly effective over a range of temperature, pH and ionic strength. The transparency of the Xanthan when mixing with water help to monitor the screen out inside the fracture is clearer. The proppant is added to the carrier fluid at different concentration. After preparing the carrier fluid proppant was added gradually during mixing the suspension.

Proppant:

The type of proppant used in the experimental work, was ceramic proppant type (20/40), density 2.76 gm/cm^3. Average diameter = 0.113 mm. The proppant measured in mesh size ranges within 90% of the proppant falls between 420 – 850 µm, Ceramic Proppant was imported from China. Proppant shape consists of two main properties: roundness and sphericity. The roundness mean a measure of the smoothness of the solid particles (proppant), and the sphericity is how well it resembles a sphere.

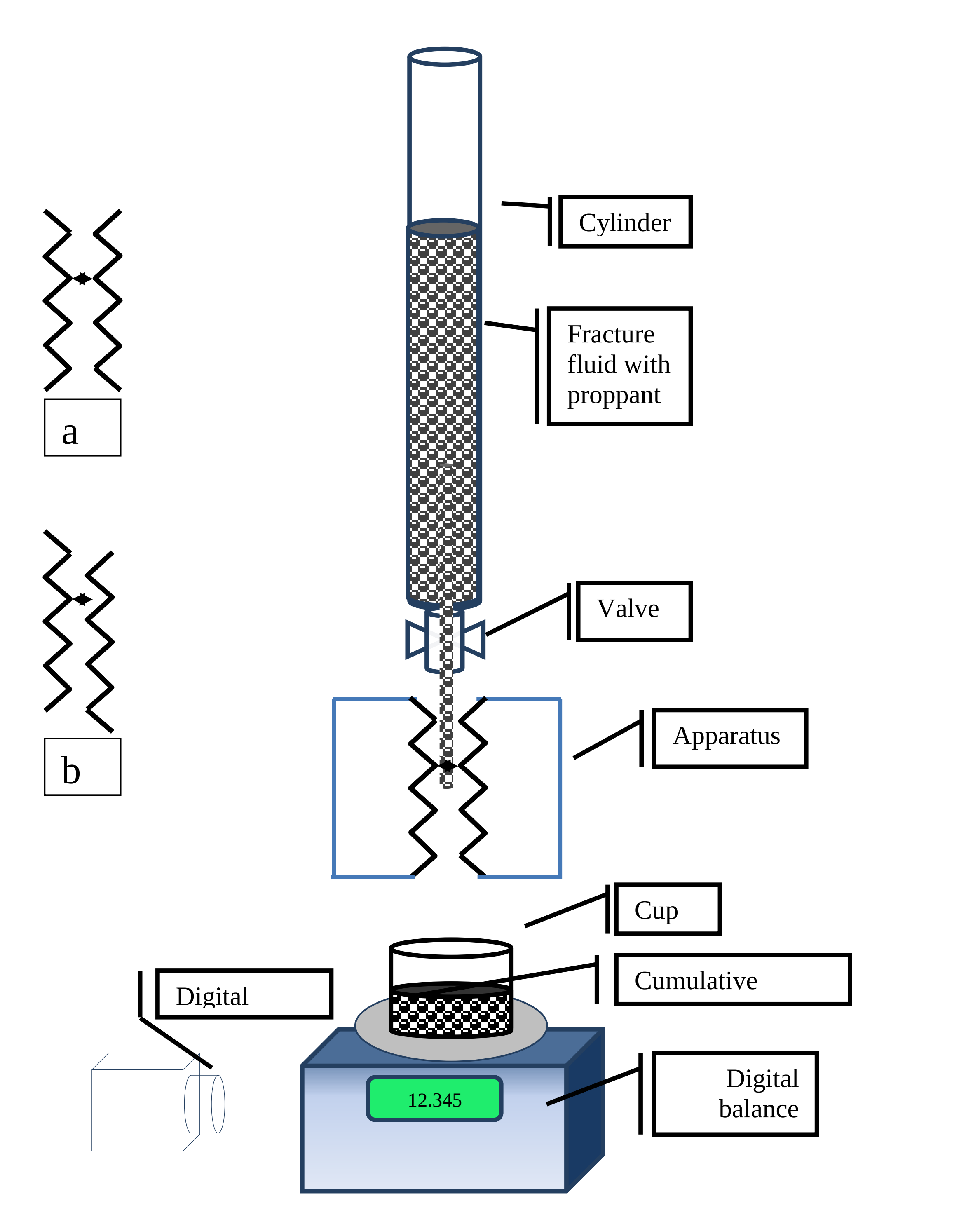

Fig (1- a& b) scheme of the equipment (a) fracture shape is without shift, (b) fracture shape is with shift.

4. Wall roughness of the fracture

One of the aims of this research is to investigate and study the effect of the wall roughness of the hydraulic fracture on the transportation of the proppant through the fracture and the effect of roughness of the fracture wall on the screen out, by set the cell with rough walls to measure the proppant transportation rates inside the fracture through the cell. Two shapes of walls were set and referred to as without shift and with shift. Figure (1- a) shows the shape of "without shift" and figure (1- b) shows the shape of "with shift". During the experiments it was easy to set the shape of the fracture as required, and set the width of the fracture as shown in fig (1), by moving the position of one of the walls forward or backward to set the fracture width or moving the movable plate upward or downward to set the fracture shape. The width of the fracture can be changed to meet the value of β considering diameter of the proppant.

Digital balance was used to measure the weight of the suspension that accumulated in the cup below the outlet of the fracture. Digital camera was placed facing the screen of the digital balance to record video for the weight that appears on the digital scale, Flow sensor was used and placed below the fracture to measure the velocity of the suspension of carrier fluid with proppant, during the run of experiments for different fracture shape (without shift, with shift). Flow sensor was used to detect the occurrence of the screen out for different conditions, because the velocity of the suspension is affected by the shape of the fracture (wall roughness), for that it was decided to use it as parameter affected by the wall (Mohammed A. A. Alhumairi, Samera Hamad Allah 2016).

5. Experimental procedure:

The apparatus was set as shown in fig (1-1), viscous fluid (suspension), was prepared by mixing fresh water and Xanthan for about 30 min and then used to carry and suspend the particles uniformly inside the cylinder. Gravity was used to force the viscous fluid to flow inside the fracture (apparatus), with the particles. The experimental work was carried out as follows

1- The fracture shape was set as without shift as a first fracture shape.

2- The transparence tube was filled with the suspension that consists from (viscose fluid + proppant).

3- The width of the fracture was set to be β=1, the ratio between the fracture width to proppant diameter D_W/D_P.

4- The bottom valve in the tube was open to allow the suspension to flow through the fracture.

5- The suspension pass through the fracture was collected in cup placed under the apparatus, on digital scale.

6- The cumulative weight of the suspension display on the screen of the digital balance was recorded by digital camera.

7- During the run of the experiments it was noticed that the flow was stopped, and the suspended proppant plug the fracture, i. e. screen out happened.

8-Through the transparence windows on both sides of the apparatus, the place of the plug could be monitored, which was at the entrance of the fracture.

9-The cumulative weight was plotted against the time. The screen out or plugging time, was indicated by sharp deflection in the curve.

10- The procedure was repeated for different values of β.

6. Results and Discussion

6.1 Experimental Work Results: In the present study, five values of β are experienced; these are 1, 2, 3, 4, and 5. For each value of β, the experiments were repeated several times in order to reduce the error in the measurement. The experiments were performed under different conditions which were; using two shapes of the fracture and using gravity and pressure to drive the suspension

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The results of plugging time for different values of β, without shift

The relation of this set of conditions is illustrated in fig (2), from this relation it can indicated that for β=1 and for different concentration (5, 10, 17.5 and 24.5) % by volume, that the plugging time was 1 "sec" for all concentration % by volume of proppant, and fracture shape was without shift, the plugging time can be indicated by the sharp deflection in the curve as shown in fig (2). The cumulative weight is plotted versus time for proppant concentration. The plugging time was found to be one second. This time is observed at the point where the shape of the curve is changed.

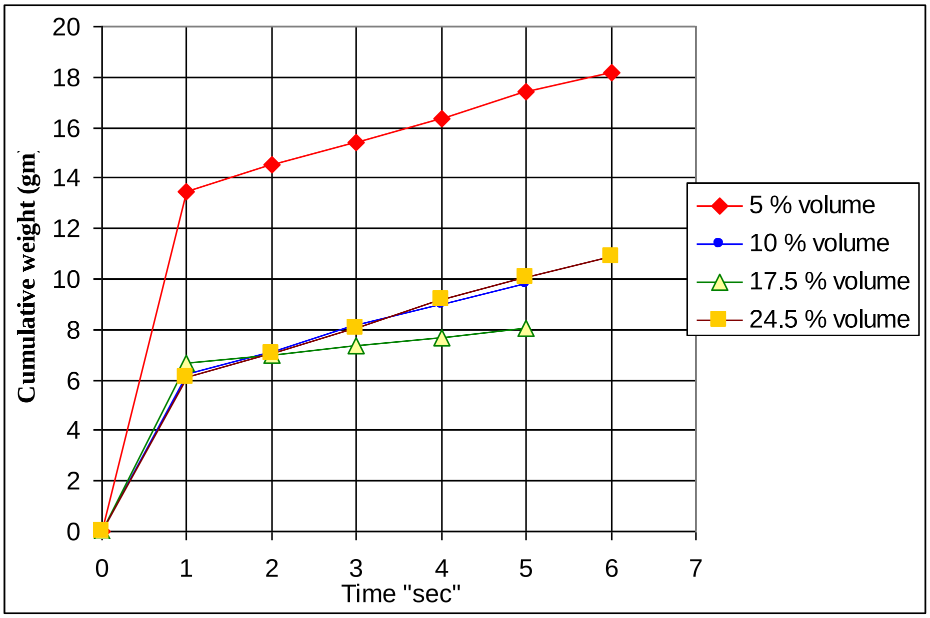

Fig (2) Relation between the cumulative weight (gm) and the time (sec), fluid flow by gravity force for β=1, concentration (5, 10, 17.5, 24.5) % by volume, without shift.

Similar results were obtained when setting β =5, for different concentration of proppant % volume since no plugging occurred when repeating the experiments. Fig (3) depicts the results for this case.

Fig (3) Relation between the cumulative weight (gm) and the time (sec), fluid flow by gravity force for β=5, different concentration, without shift.

The experiment was carried out at the same above conditions, but for β = 4. The experiment was repeated to check the results of the plugging time. It was noticed that the plugging time was not the same as the first run, for that the experiments were repeated for about 10 times these results were analyzed statically. The concentrations % by volume used for β = 4 was (25, 30, 35 and 45). The results for this set of experiments is illustrated in fig. (4, 5, 6, 7, 8). The relation between summed up of cumulative weight “gm “vs. time “sec”, for β =4, fracture shape without shift, concentration of proppant as shown above % by volume was summarized in fig (5, 6 and 7) for different proppant concentration as shown above (Mohammed A. A. Alhumairi, Samera Hamad Allah 2016).

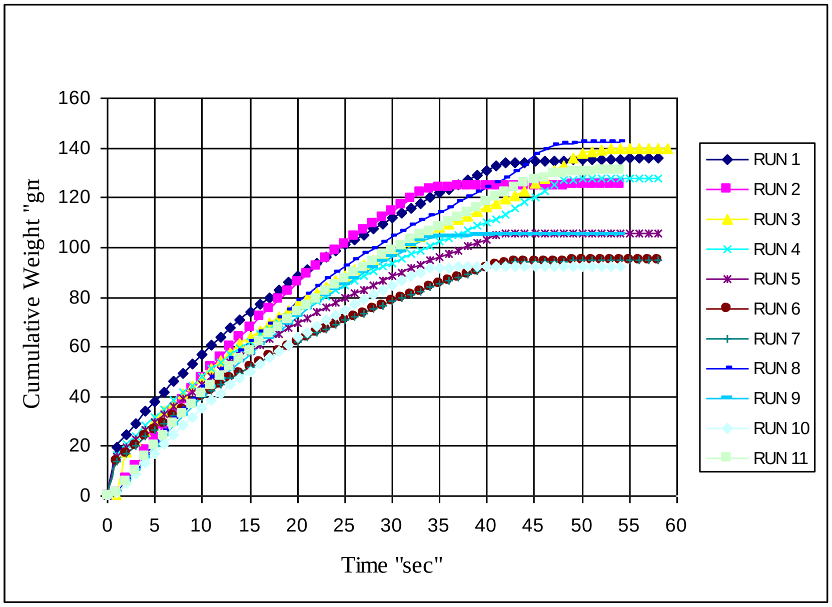

Fig (4) The relation between cumulative weight "gm "vs. time "sec", for β=4 fracture shape without shift concentration of proppant is 25 % by volume.

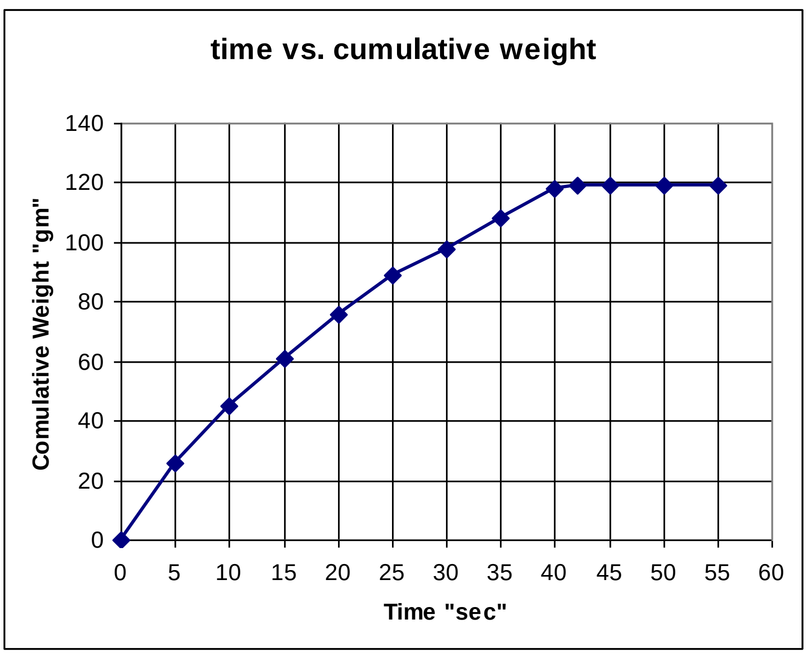

Fig (5) The relation between summed up of cumulative weight "gm " vs. time "sec" , for β=4 fracture shape without shift concentration of proppant is 25 % by volume.

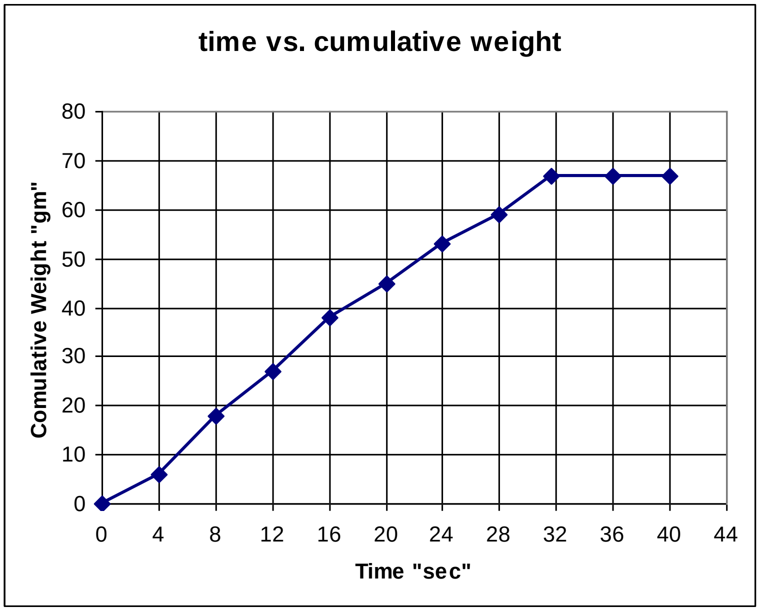

Fig (6) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=4 fracture shape without shift concentration of proppant is 30 % by volume.

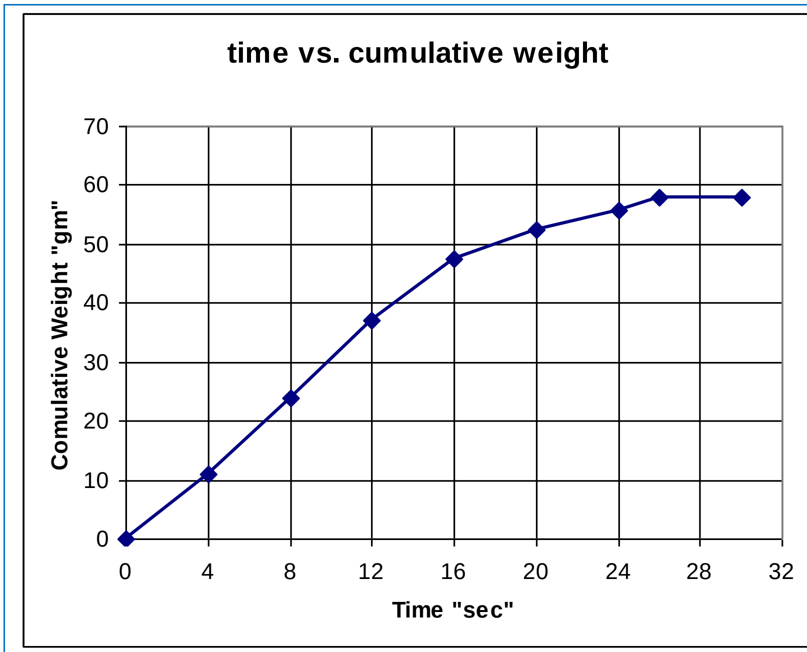

Fig (7) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=4 fracture shape without shift concentration of proppant is 35 % by volume.

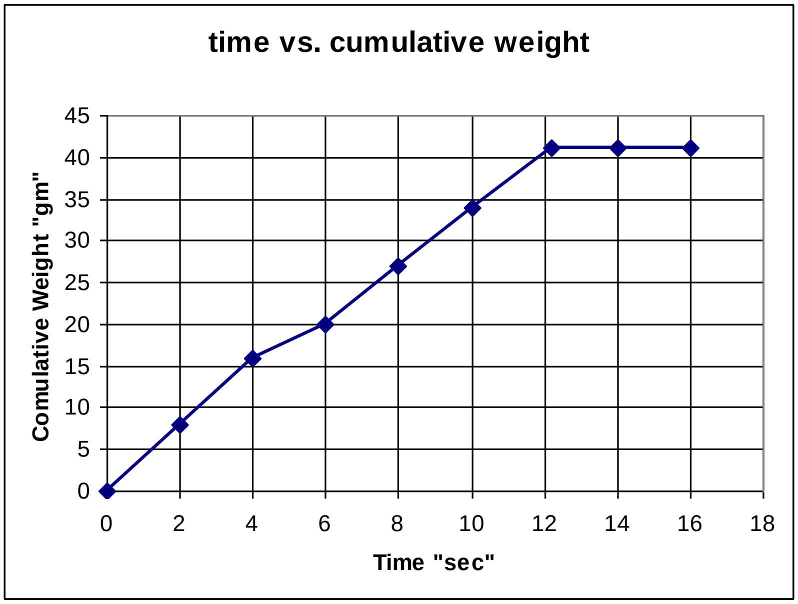

Fig (8) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=4 fracture shape without shift concentration of proppant is 45 % by volume.

The experiments for β= 3, proppant concentration of (27.6, 33.3, 38.9 and 44.1), were run at the same promotional conditions. The results are shown in figs (9, 10, 11, 12, 13) respectively. The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3, fracture shape without shift for different concentration of proppant (27.6, 33.3, 38.9 and 44.1) % by volume summarized in fig (10, 11, 12 and 13).

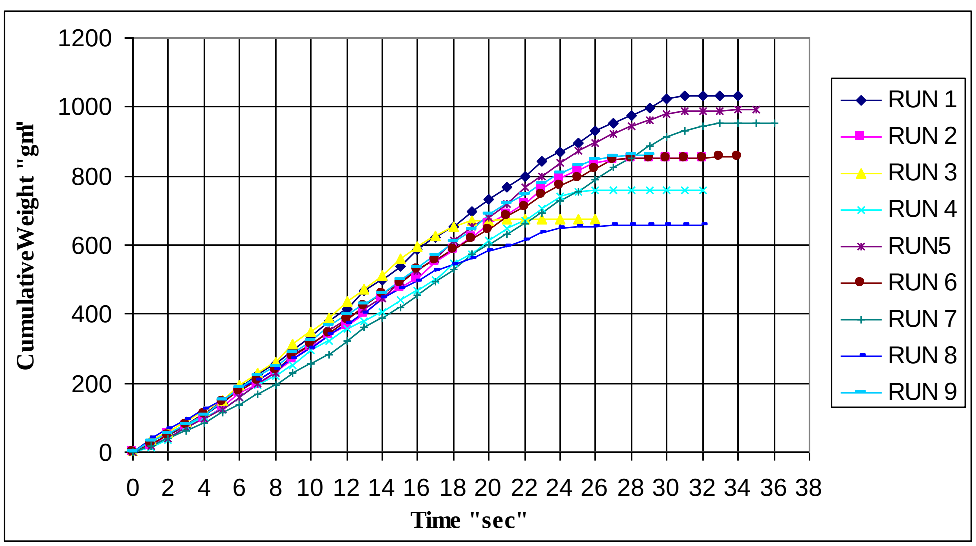

Fig (9) The relation between cumulative weight “gm “vs. time “sec”, for β=3 fracture shape without shift concentration of proppant is 27.6 % by volume.

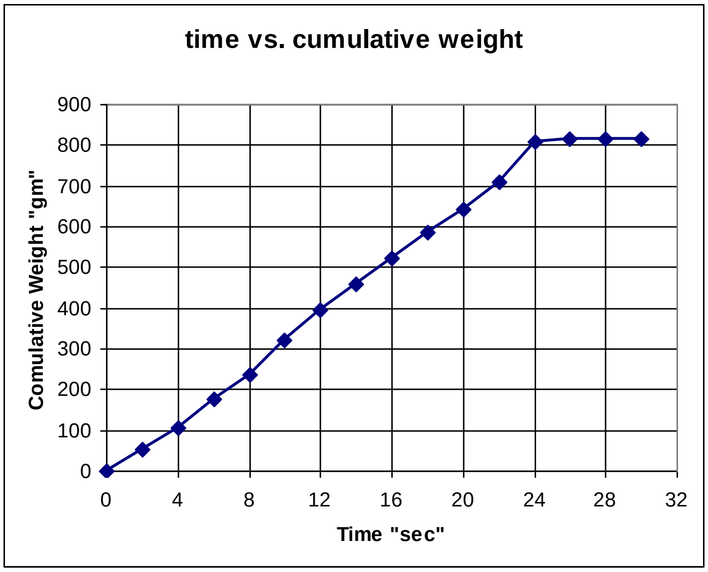

Fig (10) The relation between summed up of cumulative weight "gm " vs. time "sec" , for β=3 fracture shape without shift concentration of proppant is 27.6 % by volume.

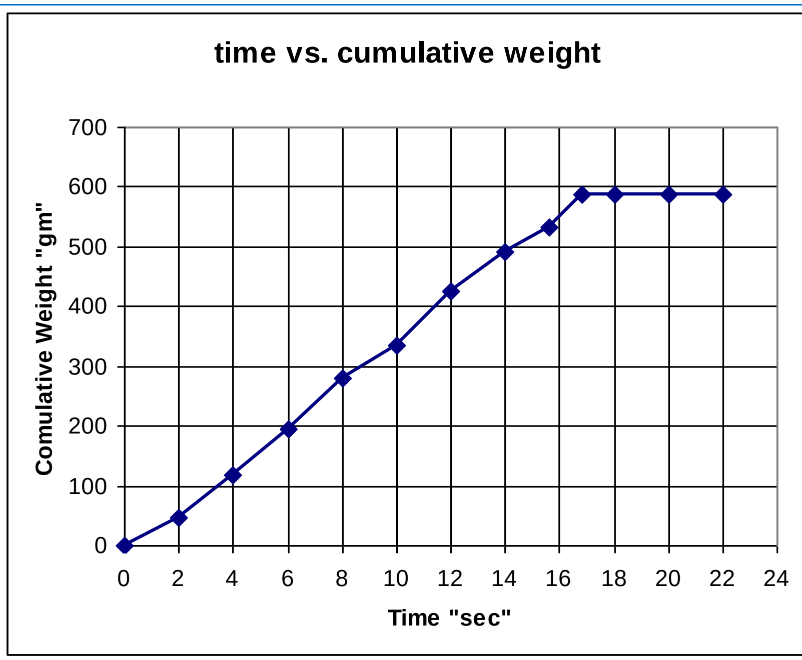

Fig (11) The relation between summed up of cumulative weight "gm " vs. time "sec" , for β=3 fracture shape without shift concentration of proppant is 33.3 % by volume.

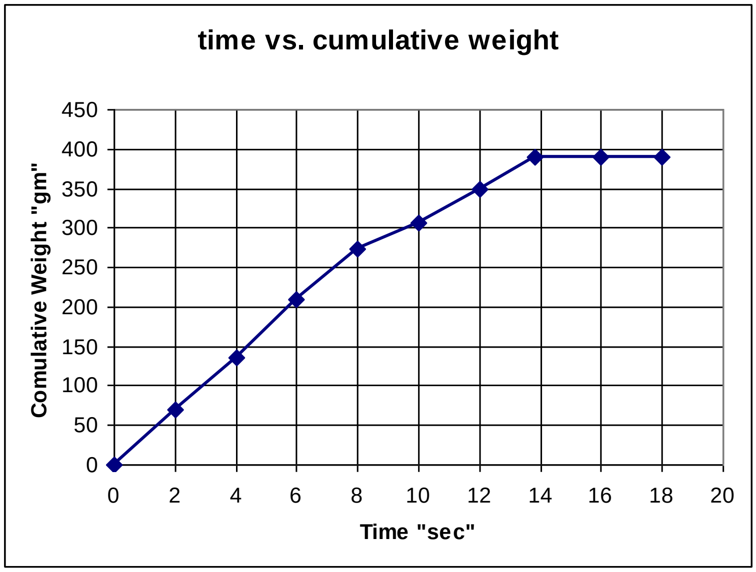

Fig (12) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3 fracture shape without shift concentration of proppant is 38.9 % by volume.

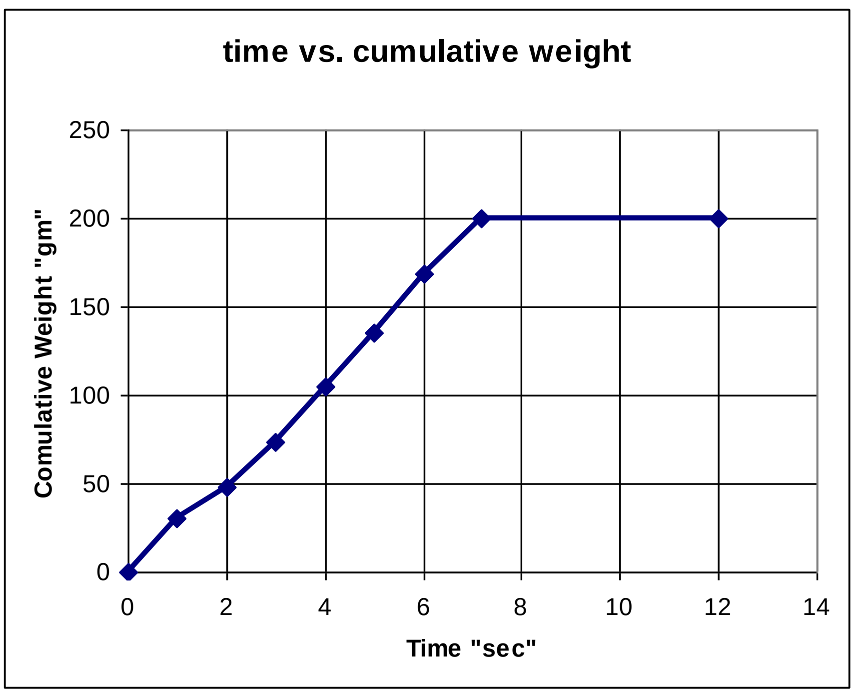

Fig (13) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3 fracture shape without shift concentration of proppant is 44.1 % by volume.

The experiments for β= 2, and different proppant concentration of (16.8, 21.66, 24 and 29.6), were run at the same set of conditions but for different concentration. The results are shown in figs (14, 15, 16, 17, 18) respectively. The relation between summed up of cumulative weight "gm " vs. time "sec" , for β=2, fracture shape without shift for different concentration of proppant (16.8, 21.66, 24 and 29.6) % by volume summarized in fig (15, 16, 17 and 18).

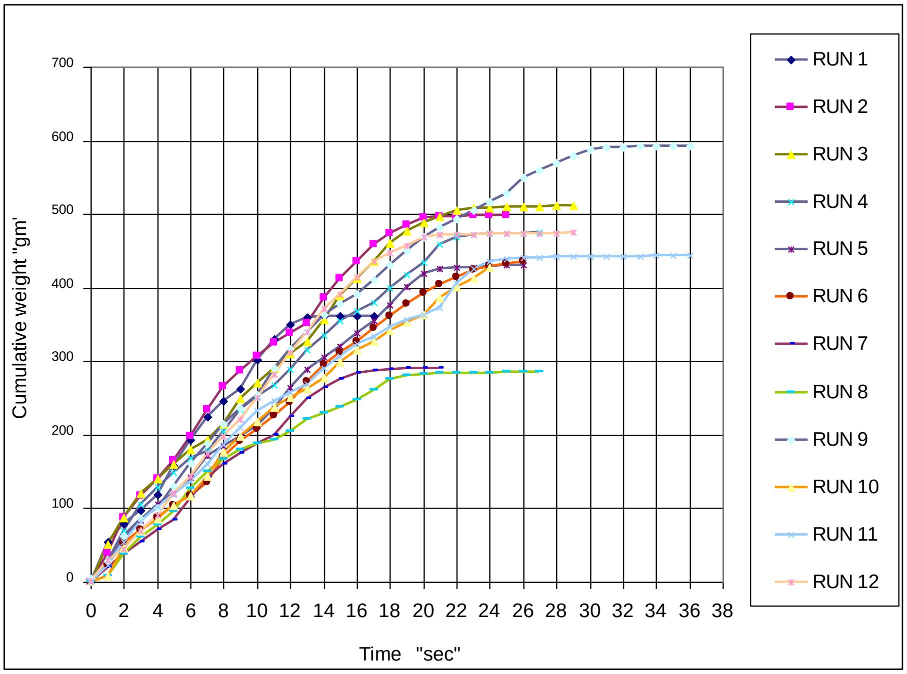

Fig (14) The relation between cumulative weight "gm "vs. time "sec", for β=2 fracture shape without shift concentration of proppant is 16.8 % by volume.

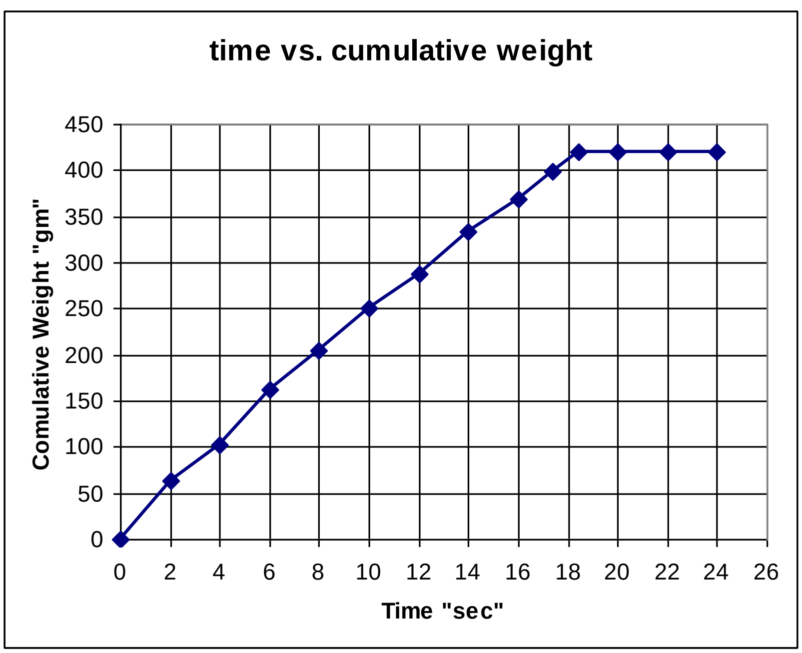

Fig (15) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2 fracture shape without shift concentration of proppant is 16.8 % by volume.

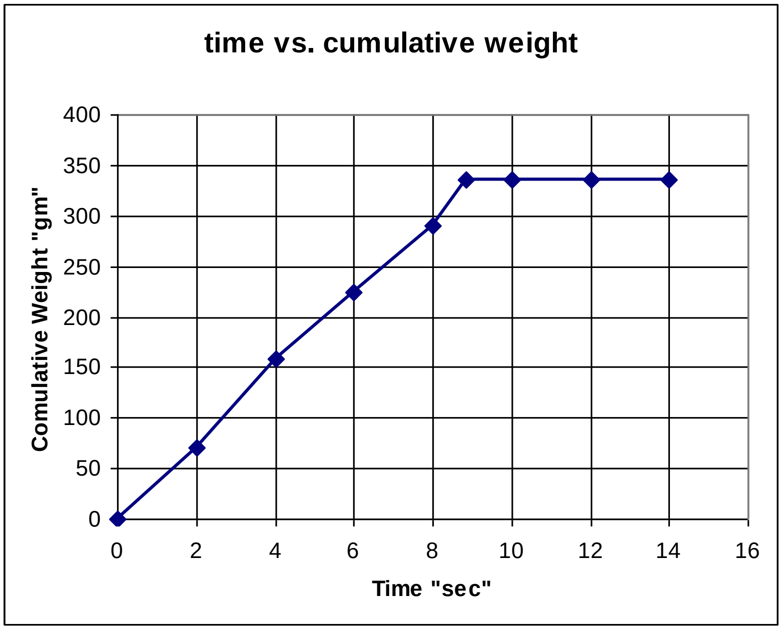

Fig (16) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2 fracture shape without shift concentration of proppant is 21.66 % by volume.

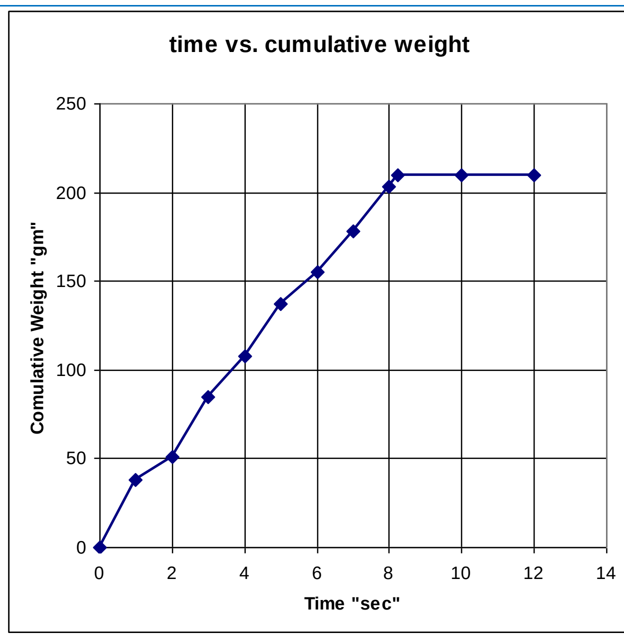

Fig (17) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2 fracture shape without shift concentration of proppant is 24 % by volume.

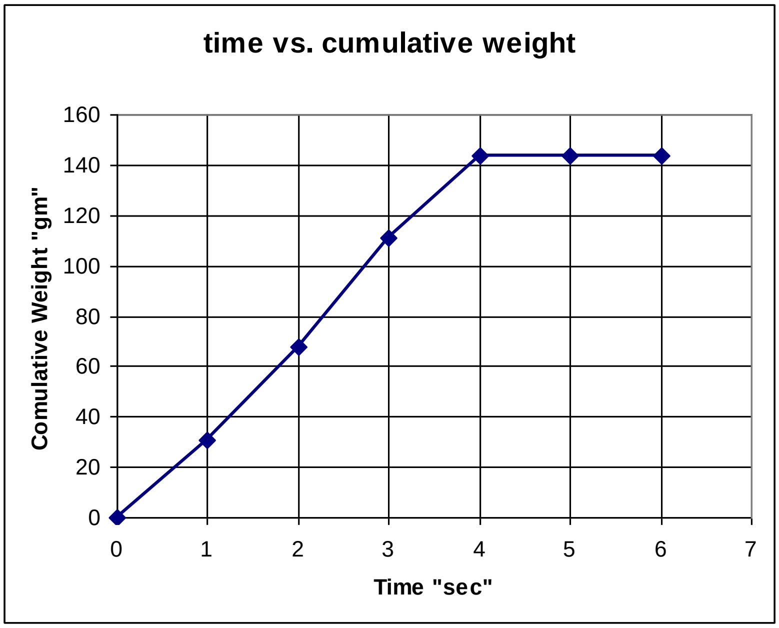

Fig (18) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2 fracture shape without shift concentration of proppant is 29.6 % by volume.

6.2 With shift, using gravity force.

A set of experiments was carried out for the same β values under gravity force as had been made in previous set but at different fracture shape, which is with shift. The results for β value of 3, proppant concentration of (27.6, 33.3, 38.9 and 44.1) % by volume, as shown in figs (19, 20, 21, 22, 23) respectively. The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3, fracture shape without shift for different concentration of proppant as shown above summarized in fig (20, 21, 22 and 23).

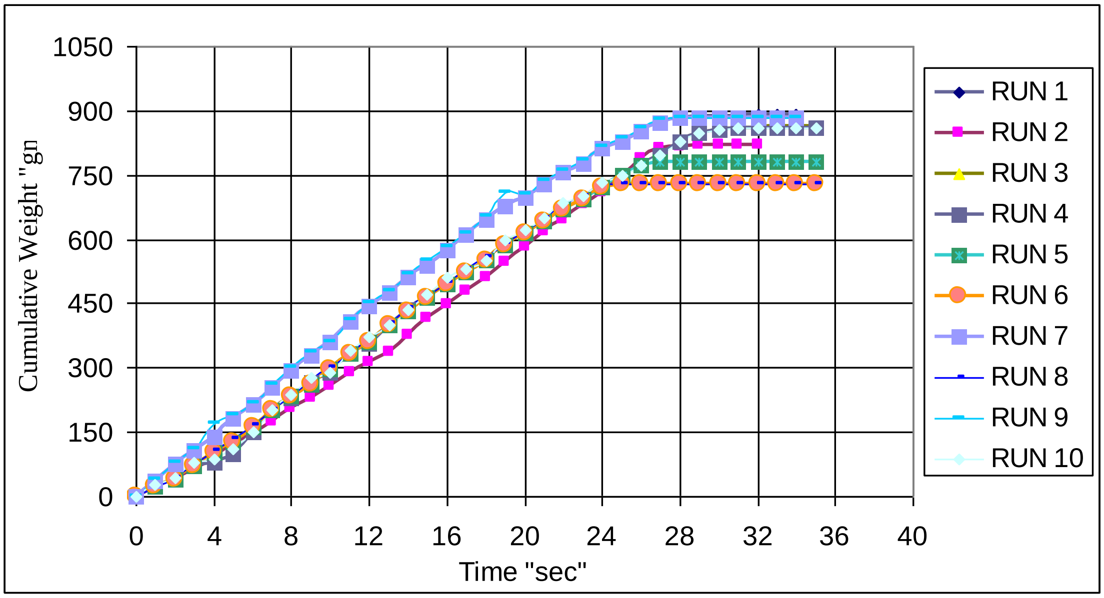

Fig (19) The relation between cumulative weight “gm “vs. time “sec”, for β=3 fracture shape with shift concentration of proppant is 27.6 % by volume.

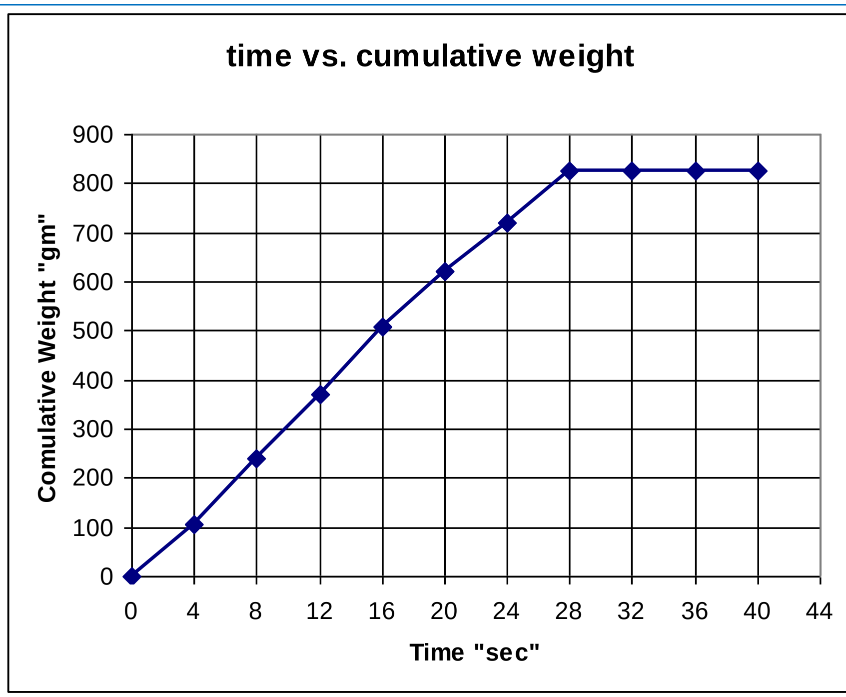

Fig (20) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3 fracture shape with shift concentration of proppant is 27.6% by volume.

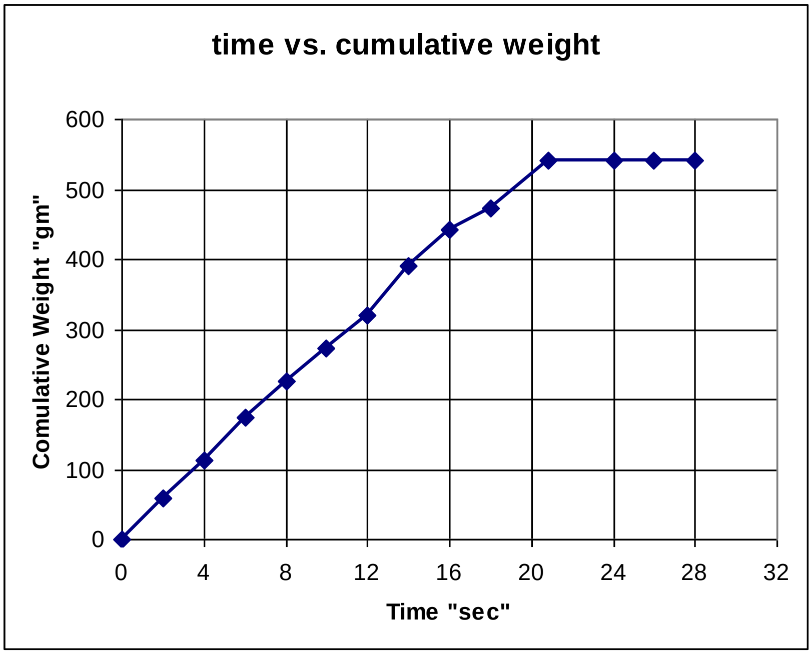

Fig (21) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3 fracture shape with shift concentration of proppant is 33.3 % by volume.

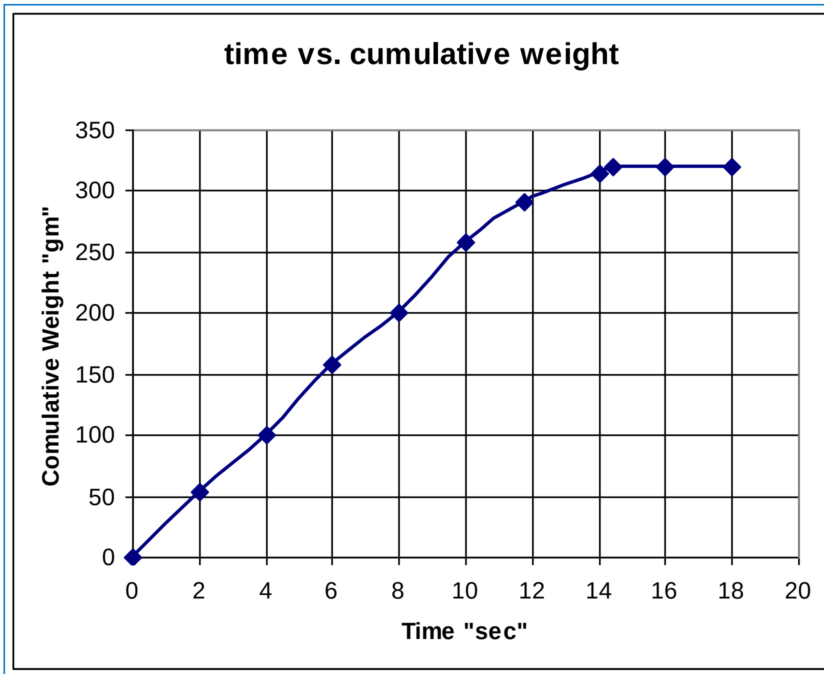

Fig (22) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3 fracture shape with shift concentration of proppant is 38.9 % by volume

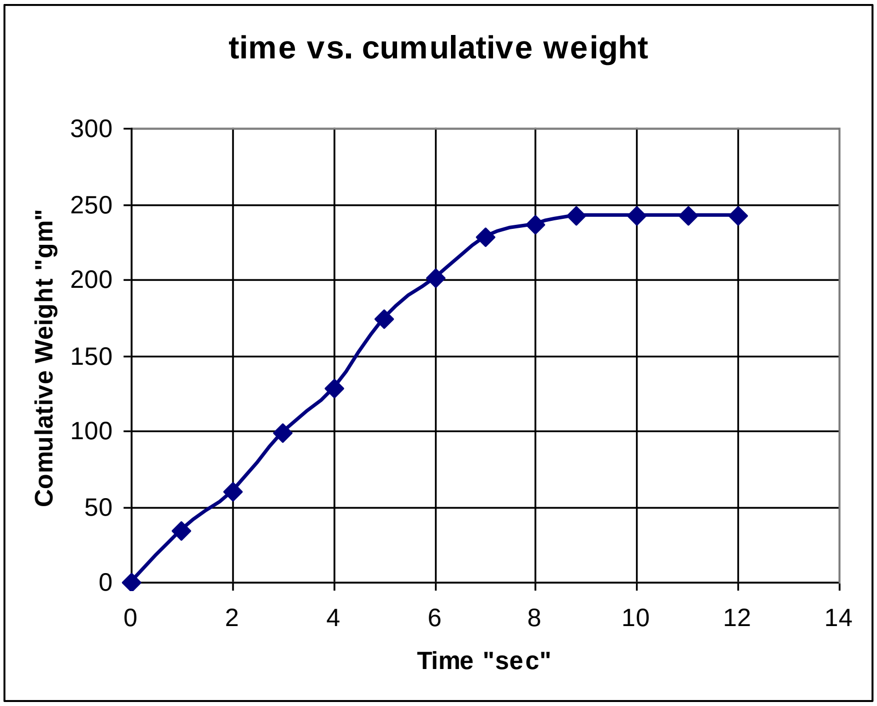

Fig (23) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3 fracture shape with shift concentration of proppant is 44.1 % by volume.

The results for β value of 2, proppant concentration of (11.8, 16.8, 21.66 and 24.7) % by volume, as shown in figs (24, 25, 26, 27, 28) respectively. The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=3, fracture shape without shift for different concentration of proppant as shown above summarized in fig (25, 26, 27 and 28) (Mohammed A. A. Alhumairi, Samera Hamad Allah 2016).

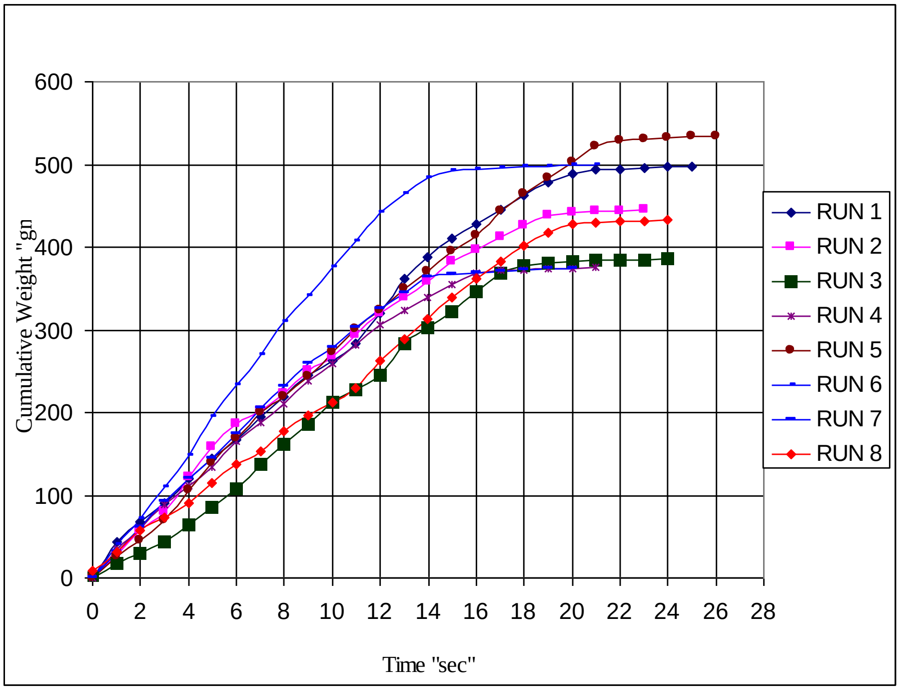

Fig (24) The relation between cumulative weight "gm "vs. time "sec", for β=2 fracture shape with shift concentration of proppant is 11.8 % by volume.

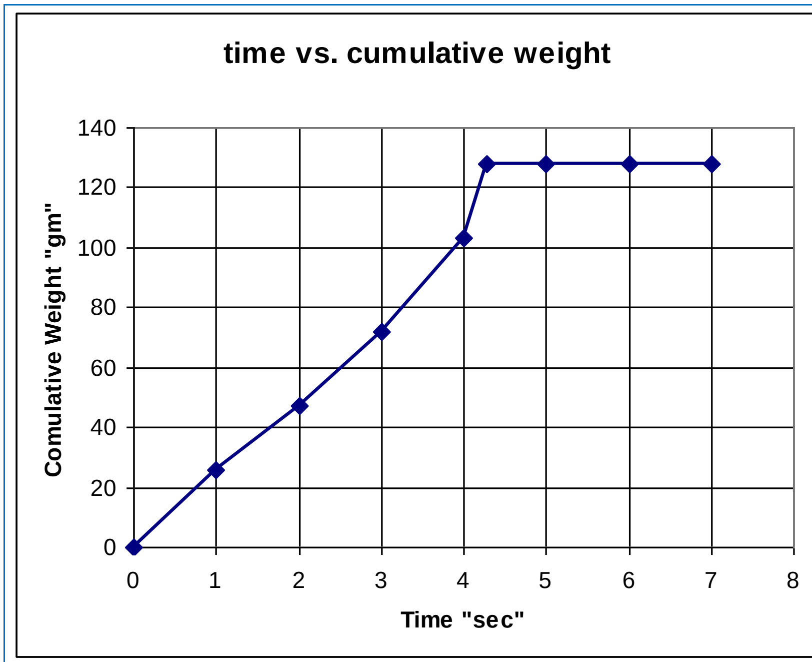

Fig (25) The relation between summed up of cumulative weight "gm " vs. time "sec" , for β=2 fracture shape with shift concentration of proppant is 11.8 % by volume

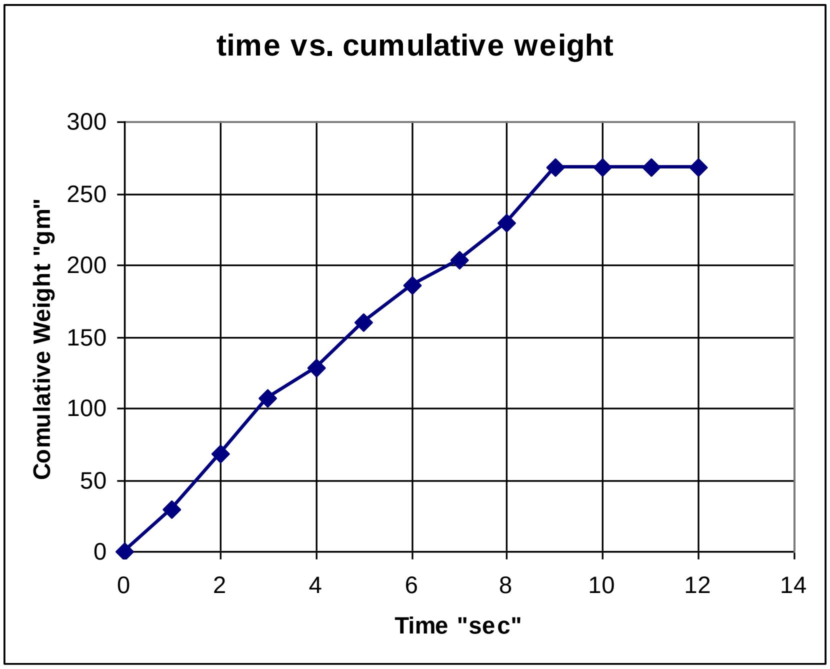

Fig (26) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2 fracture shape with shift concentration of proppant is 16.8 % by volume.

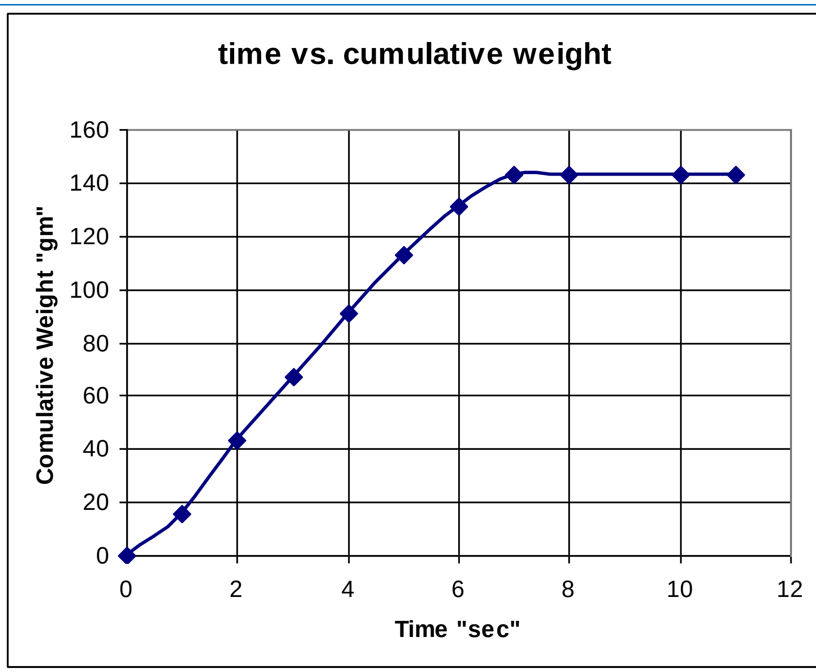

Fig (27) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2 fracture shape with shift concentration of proppant is 16.8 % by volume.

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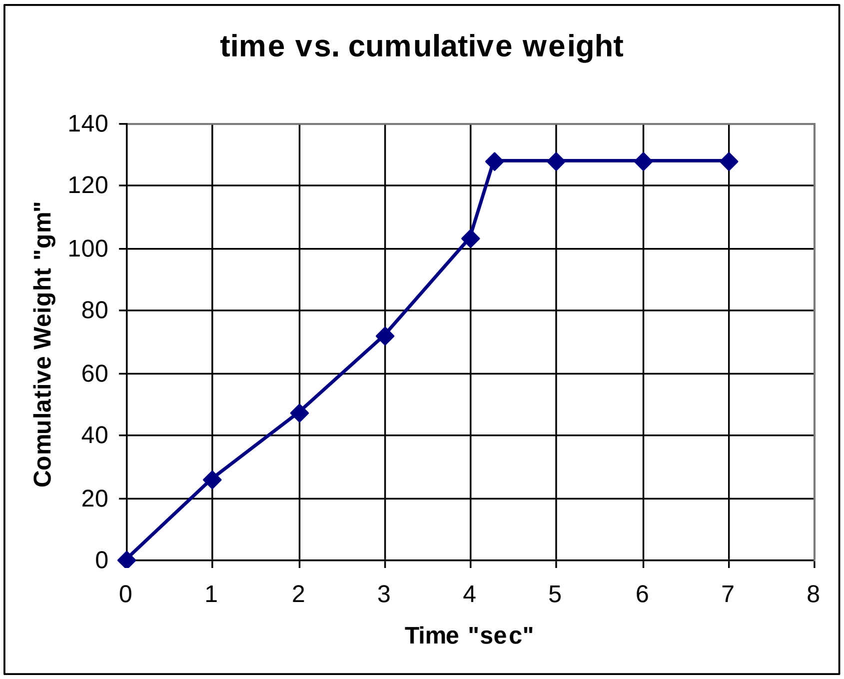

Fig (28) The relation between summed up of cumulative weight “gm “ vs. time “sec” , for β=2, fracture shape with shift concentration of proppant is 24.7 % by volume.

The summery of different conditions adopted in the present work are given in table [1].

Table [1] Parameters of experiments conditions.

No.	**β value**	**Proppant Concentration % by volume**	**Fracture Shape**	Slurry density gm/cc
1	3	27.6	without shift	1.38
2	3	33.3	without shift	1.43
3	3	38.9	without shift	1.5
4	3	44.1	without shift	1.54
5	3	27.6	with Shift	1.38
6	3	33.3	with Shift	1.43
7	3	38.9	with Shift	1.5
8	3	44.1	with Shift	1.54
9	2	16.8	without shift	1.25
10	2	21.66	without shift	1.31
11	2	24	without shift	1.35
12	2	29.6	without shift	1.4
13	2	11.8	with Shift	1.19
14	2	16.8	with Shift	1.25
15	2	21.66	with Shift	1.31
16	2	24.7	with Shift	1.35
١٧	١	5	without shift	1.03

18	1	10	without shift	1.06
19	1	17.5	without shift	1.10
20	1	24.5	without shift	1.145
21	4	25	without shift	1.148
22	4	30	without shift	1.17
23	4	35	without shift	1.2
24	4	45	without shift	1.24

7. Detecting screen out by using flow sensor:

The objective of this section was to detect the occurrence of screen out or plugging by measuring the suspension velocity when passing through the fracture. A flow sensor is connected to the apparatus to measure the velocity, figure (29) shows the scheme of the apparatus with flow sensor. Two values of β were used, which are 2 and 3, with two fracture shape, i. e. with and without shift at different proppant concentration (16.8, 21.66, 27.6 and 33.3) volume %, using the gravity force (Mohammed A. A. Alhumairi, Samera Hamad Allah 2016). The relation between the velocity with time is given in fig (30) for the conditions; β=3 and proppant concentration of 33.3 for both with and without shift fracture shape. The velocity oscillated around certain velocity and it suddenly became zero which indicate the occurrence of screen out (Kristian Brekke, 2014). It is also noticed that the velocity for the without shift shape was greater than that of with shift because the effect of different fracture shape and the roughness of the fracture wall obstruction the flow and reduce the velocity of the suspension (mixture) until screen out occurring._Figure (32) is similar to fig. (31) accept the concentration which it was 27.6 % by volume._For β=2 and concentration of 16.8 and 21.66 % by volume, the results are shown in fig (32) and (33) respectively.

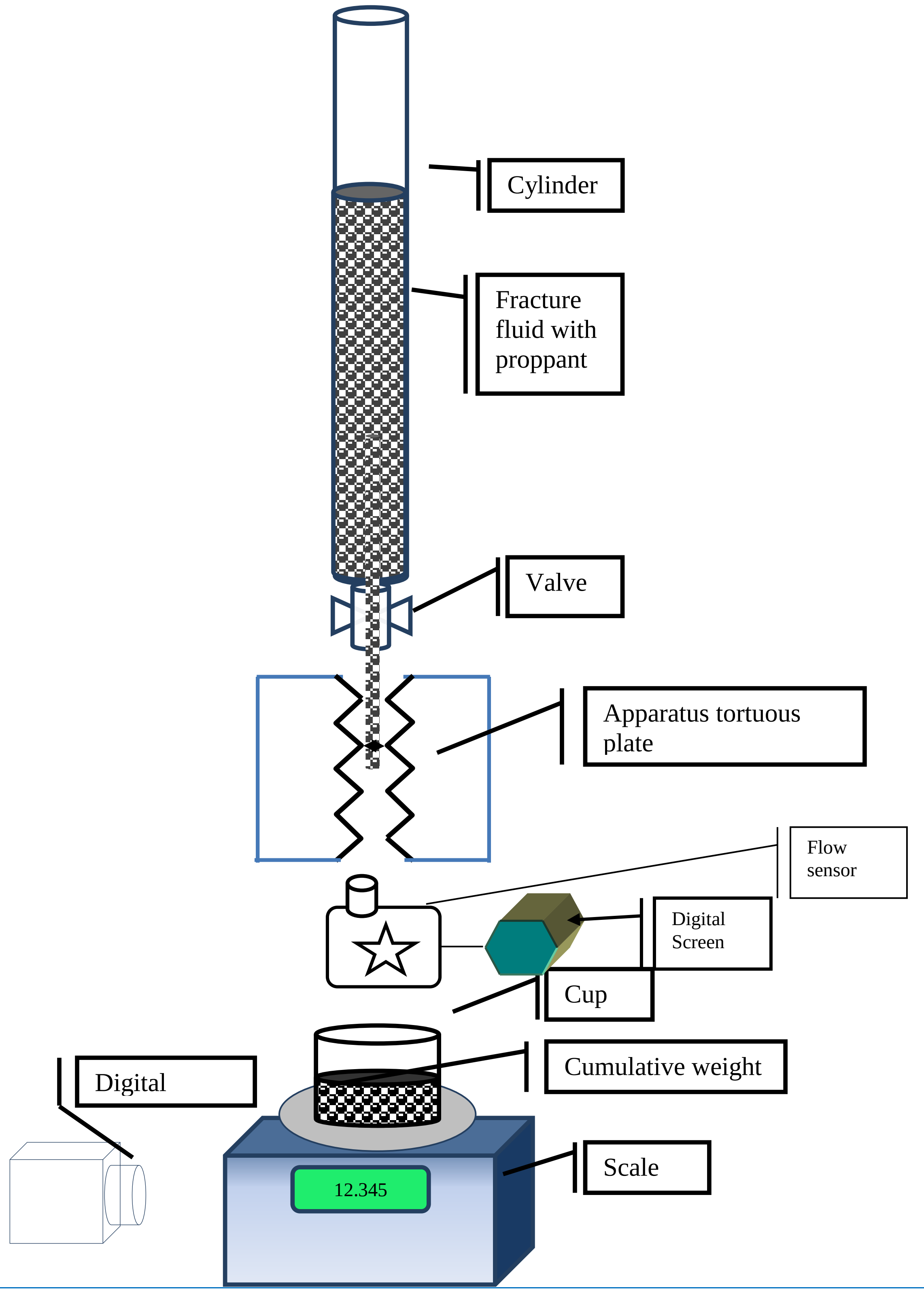

Fig (29) the scheme of the apparatus shows the flow sensor that use to measure the velocity

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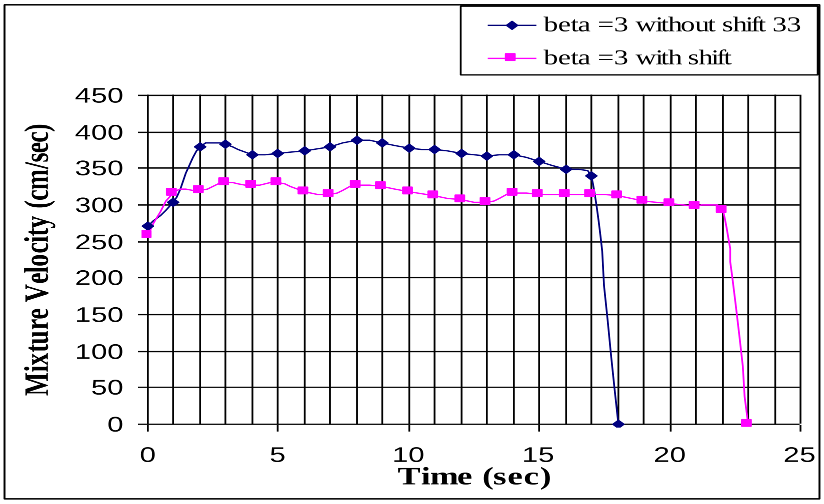

Fig (30) Relation between the velocity and the plugging time, fluid flow by gravity for β=3, concentration (33.3) % by Volume (with and without shift) fracture shape.

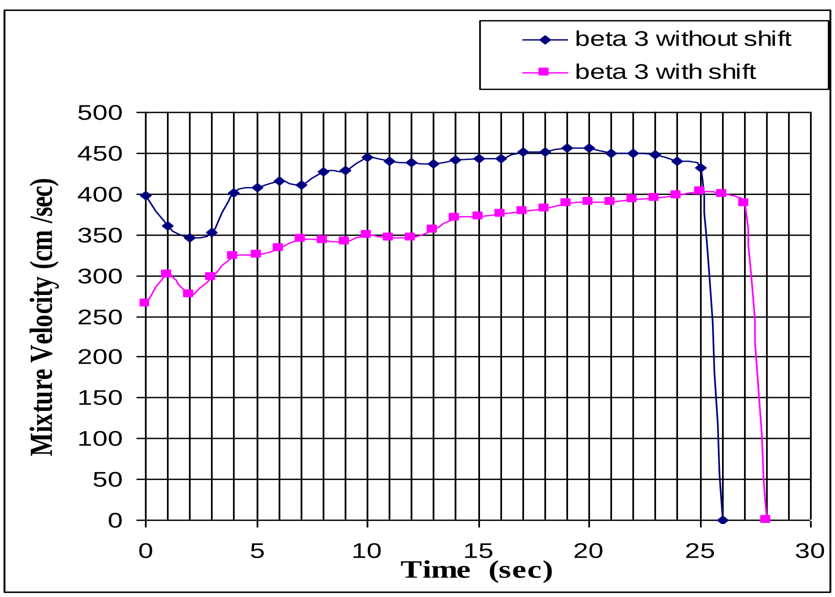

Fig (31) Relation between the velocity and the plugging time, fluid flow by gravity for β=3, concentration (27.6) % by Volume (with and without shift) fracture shape.

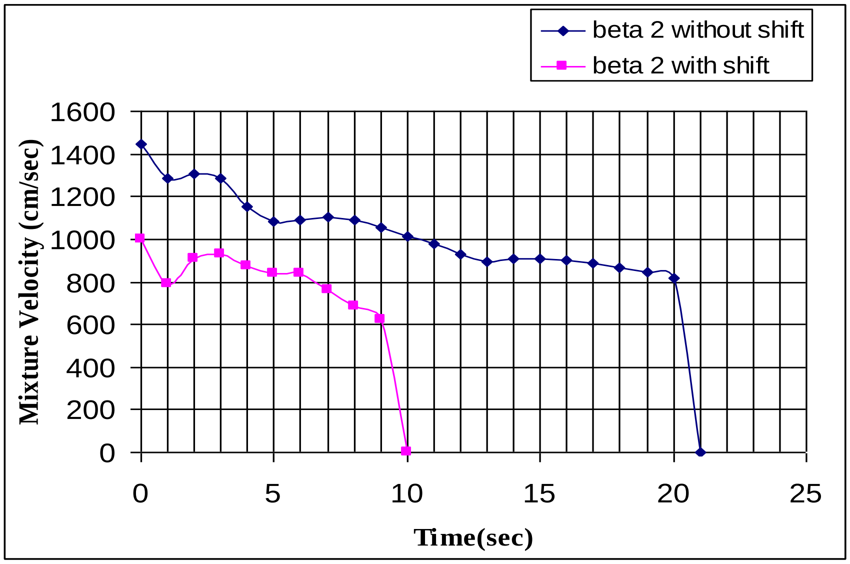

Fig (33) Relation between the velocity and the plugging time, fluid flow by gravity for β=2, concentration (21.66) % by Volume (with and without shift) fracture shape.

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