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CHAPTER 1 : INTRODUCTION

1.1 Background Study

Sand production is a big challenge for the upstream oil and gas industry .The sand particles that being produced together with reservoir fluid does not have any economic value .Besides ,it will cause severe production restriction ,erode tubular goods including downhole pumps and surface pipeline and equipment .With that ,sand control method need to be apply during the completion and production stage .The purpose of having sand control is to prevent unwanted solids being produced into wellbore ,completion string and surface facilities. But ,the conventional sand control likes gravel packing and screen are less effective and not 100% isolate the sand particles from the wellbore.

Nowadays ,a lot of technology being introduced in the market to control this problem .Different company will introduce different method .Some of the technology that being introduced are based on some concepts likes chemical injection or improvement from the conventional method .The brand of method might be different because of different company will have different name. But, the similarities from all this method are their concept.

In this paper ,the new technology that will review are sand aid or also known as zeta flow and through tubing gravel pack (TTGP).Sand aid are chemical injection and it's being introduced in conjunction to improve the resin injection method .Both method are using the chemical but the different is their chemical fluid being inject and properties. Based on the real case study ,sand aid are more easy to handle compared to resin injection .This will be explain more in the next section.

Through tubing gravel pack are the conventional method that been improved to reduce the cost .A years ago, gravel pack are used in completion method to control the sand production .It will be installed either during completion or after the completion .The usual practice in industry today, completion engineer normally will install sand control device during the completion .It is because sand production can be predict at the early of exploration stage. But, the problem will occur when those well never install the sand control device .The only solutions that can be done are installing the gravel pack. To complete the gravel pack installation ,a complete work over need to done which required a lot of money .Because of gravel pack are most famous sand control in industry, the service company come up with the new method for installation .Rather than do the complete work over ,the engineer more prefer to pump gravel pack during the existing tubing. From here, cost installation can be reduced and these methods are more suitable for the marginal reserves .It is more valuable to use gravel pack through tubing for marginal reserves rather than the others method.

1.2 Problem Statement

Sand production problem need to be control and solve before it can disturb the production performance. Once it start to flow together with the reservoir fluid, it is very hard to clean the well. These will become more complex when the sand particles start to stuck in the downhole and surface equipment likes separator, heater treater and production pipeline. And sometime, this sand particle will fill up all the spaces in wellbore. This off course will give some restriction to hydrocarbon flow in the wellbore. When this restriction become more severe, the production rate will reduced compared to previous production rate.

Sand production also can cause a loss in production .It is happen because of sand plugging and sand bridging .Sand plugging occurs because of the little accumulation of sand at the wellbore. Over the time, this sand will continue to accumulate until it bridges all the wellbore .And that’s why production will start to decrease.

The other problems that can contribute to sand production are method to dispose these produced sand particles. For onshore operation, the disposal work will more simple compared to offshore operation .It is because for onshore it will only using truck to transport the produced sand. It will not give any environment impact since this sand can be used for others proposed and can be treated. But, it will be a problem for the offshore operation. Since the operators cannot just throw the produced sand to sea as it stated in environment law for offshore operation. Normally, the operator company needs to pay some of money just to transport this produced sand to some place in the land. These practices are not valuable since there's others well integrity job that can done instead of transporting the disposal material.

The others problem that related to sand production are well integrity .This happen when there's casing collapse occurs in the wellbore .This issue might happen when the external differential pressure exceeds the collapse resistance .This happen due to solids that being produced from the near wellbore region. That's why sand control need to be applied to avoid this kind of problem. That's why new technologies need be introduced and improves the existing sand management.

1.3 Objective & Scope Of Study

The objective of this study is to have a better understanding on sand production behavior and the new technologies that need to be applied to prevent this completion failure .By understanding the sand behavior, this can prevent any sand problem that might occur in the future .Hopefully ,by introducing the new technologies in these field will help the others engineer to make a better decision in controlling the sand production .It is because ,some of the sand control method are not valuable to be used in some well. Different well will have different condition and reservoir data. For example, screens methods are not suitable for high temperature and high pressure well. The failure percentage will more higher in these conditions.

Besides that, to study the problems related to sand production .So that, engineer will become more aware to this problem and the affect that might occurs to their production performance. And also to focus on importance of sand management at early stage of production. A better sand management will contribute to a better well performance. Some of the well, it can produced hydrocarbon only for just one month because of failure in sand management .The worst case might happen when that well need to be shut down due to severe sand production .This will give more losses to the operator company. These losses can be avoided by having a proper plan in sand control method.

This study also will focus more on real case study for each method that been proposed. The objective of this stage are to know their efficiency based on real production performance .Two case are selected based on SPE Paper which include one case in Malaysia and one case in others region. By having different region, a comparison can be done based on differences and similarities.

Production analysis also been included in these papers. Analyses are done based on the skin affect and cost estimation .It is because, some of sand control could give a high positive skin which are not good for reservoir .This stage can be done using some software and Inflow Relationship Performances (IPR) graph can be generated .From here ,the skin effect can be visualized. Cost estimation analyses are included since the finance management is very important in once project. From the skin and cost analysis, the final conclusion can be made. Hopefully, at the end the best solution can be concluded for sand control method.

1.4 The Relevancy Of The Project

This project are relevant to the scenario that happen in industry .Most of the well in Malaysia are having a same problem which is sand production .It is because, most of the well in Malaysia are already old and this will give more problem as the pressure start to decrease .These situation will become more severe as there’s no sand control been installed at the early stage. Findings from these project will helps the engineer to have a better decision in sand management .Having a good sand management will contribute to a better production performance.

1.5 Feasibility Of The Project

All the sand control method that been proposed in these paper are based on latest technology in the market. The case study also are review based on the real job .All the research regarding all these method can be complete in the given of period time.

CHAPTER 2 : LITERATURE REVIEW

2.1 Sand Production

Sand production is the sand particles that being produced together with the reservoir fluid .This sand production need to be controlled because producing sand would not give any value. Plus, it will cause some problem .For onshore operation , the sand disposal is simple by just using a truck and inexpensive .But, for the offshore operation it become more difficult as the sand cannot just be thrown to the sea .That's why the sand management is very important in oil and gas industry.

Sand problem occurs because of some factors such as when the formation stress is higher than formation strength .Normally ,sand problem would happen at the young tertiary formation .It is because at this age ,rock formation will have less cementation material .This means ,it have less strength .And the formation stress here are pore pressure where it support the weight of the overlying rock .Overtime ,this pore pressure will reduce and not support overlying weight anymore So ,this will give more stress to the rock .When stresses are higher than strength of the rock ,sand particles will start to produce .This is as shown as below :

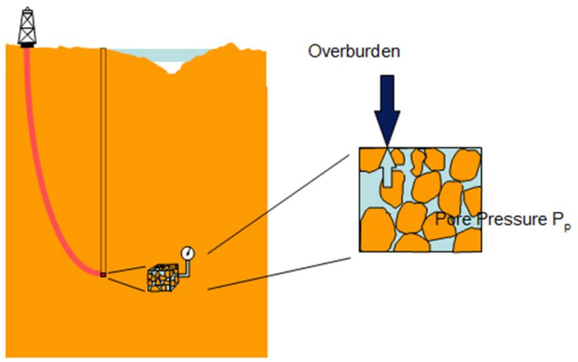


Figure 1 : Picture of overburden and pore pressure

(Source : ***Jon,1992,p 41*** **)**

The other factors that contribute to sand problem are effect of production rate .The increase in production rate will tends to draw sand together into the wellbore .The high production rate will cause instability of sand arches .If the sand arches breakdown ,the sand particles that being hold by sand arches will start to produce .

The reduce stress state at the wellbore face in the horizontal (radial) direction causes formations with low intrinsic strengths to form arches .For weakly cemented sands, resistance to sanding is dependent on the formation of stable load-carrying arches spanning the producing cavities .An arch is a curved structure spanning an opening, serving to support a load by resolving the vertical stress (overburden load) into horizontal stresses .**Figure 2** will shows how sand arches looks like.

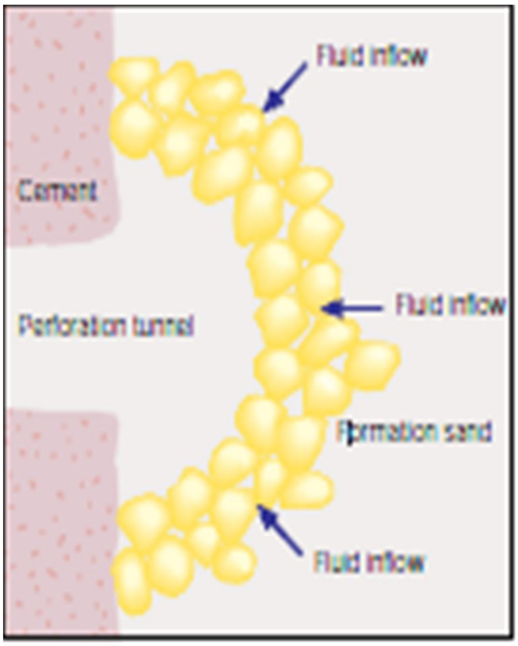


Figure 2 : Sand Arches (Source : *Jon,1992,p 42*)

The resolution of forces sets up a pattern of shearing stresses within the arch structure, and thus arch behavior is related to sand's shear strength .Through this arching effect ,a part or most of the vertical loading due to formation overburden at the wellbore face can be transferred to the formation adjacent to the arch structure. Arching is different from sand bridging.

Shear strength of the sand grains affects the formation of arches and their stability .Two conditions are necessary for the arch stability. These are dilantacy and cohesiveness or some other restraint on the surface grains of the arch.

While sand bridging is the blockage of an opening to sand movement through the opening by interlocking of the sand grains and transference of stress between grains within or at the mouth of opening.

The other factors that can cause sand production are reservoir fluid viscosity .Frictional drag force that exerted on formation sand grains is created by the flow of reservoir fluid. If the viscosity of reservoir fluid is high, a greater frictional drag force also need to apply to formation sand grains . So, this situation will give a greater stress to the rock. Then again, if stress that acts on the rock is much higher than rock strength, possibilities of having sand in production fluid are higher.

The other factors that can contribute to the sand production are increase of water production .The typical formation is water-wet sandstone formation .The grain to grain cohesiveness is provided by the surface tension of the connate water surrounding each sand grains .But ,when the onset of water production ,the connate water tends to cohere to the produced water ,resulting in reduce of the surface tension force and subsequent reduction in grain to grain cohesiveness .With this situation ,sand will start to produce together with the reservoir fluid.

Because of all factors that stated above, it shows here how importance the sand management at the production stage .In normal practice, sand control can be divided into two categories which are passive and active sand control. Passive sand control are done during production stage .Sand prevention by passive method incorporates techniques to minimize or eliminate the amount of sand produced and also to reduce the impact of produced sand without evolving the mechanical solution. It include the perforation technique either oriented perforation or selective perforation and choke management .Another one method under passive sand control is by shutting the well in or reducing production rate. But, shutting the well means no production and cash flows. While, the low producing rate that will not cause sand production is uneconomical.

Normally, sand production will occur at minimum horizontal stress .By applying the oriented perforation, it will help to aligned with maximum horizontal stress. Plus, oriented perforation can perform at only one direction .Selective perforation also are done by selecting the best interval to perforate based on rock mechanics test. With this, sand production can be avoided by perforate far from the target zone of sand production.

By manage choke properly, zero sand production can be achieved .Based on stimulation using some software like wellflo or prosper software ,there is a combination of reservoir pressure and flowing bottom hole pressure where sand are not produced .From here, choke size can be determine for certain drawdown. Normally ,allowable drawdown in Malaysia are around 100 psi with a certain choke size .If the technician are not following this guideline ,there's a possibility of having sand in the production fluid. It is because, when choke are fully open, the force that exerted on reservoir pressure are high which can contribute to the high drawdown .When there's high drawdown ,it will bring together the sand particles with the production fluid .This scenario will be more severe when it happens in unconsolidated sandstone formation .Important note choke also cannot open drastically .When turning the choke, technician need to leave it for about 4 hours to be stable .It not ,there's an effect on the production.

The active sand controls are done during the completion which includes mechanical method, chemical method and combination method. All this method will further discuss in the section.

2.2 New Technologies On Sand Control

There's a lot of sand control method that being introduced in the market now a days. The conventional method such as gravel packing and screen are widely used in the industry .Over the time ,both devices will have failure because of the some problem that happen in the wellbore. Therefore, the new technologies are being implemented in industry such as sand aid or zeta flow and Through Tubing Gravel Packing (TTGP).

Sand aid are defined as the " patented chemical that simultaneously increase the bond between particles ,reduce water cut ,and trap fines to increase the maximum sand-free rate and reduce water production"(*Alfredo,2011,p.1*).Sand aid is a chemical method that apply the Sand Agglomeration System (SAS).SAS means changing the zeta potential where materials will agglomerate and attract each other after the treatment .While zeta potential is a charge that develops at interface between liquid and solid particles surface (involved the Van Der Waals force).

Sand aid is similar to Plastic resin consolidation. But ,the difference between this two method are the fluid that being used for each of treatment .Fluid that being used for sand aid are special design by the service company and for plastic consolidation ,resin with catalyst are been pumped into the formation .Different fluid would give different result after the treatment.

In practice by some of service company ,sand aid fluid are been made from inner salt of a very low molecular weight polymer .This inner salt when added to base fluid will disperses and rapidly coats any metal oxide substrate such as sandstone .Chemically, inner salt are neutral molecule with a positive and negative electrical charge .And this neutral molecules will neutralizes the sand particles that have negative electrical charge This can be seen in the **Figure 3**.Sand aid fluid also have penetrating alcohol that will disrupt the water layers that may coat solid surfaces in the formation .As mention above, one of the factors that can cause sand production are the increase of water production. By having this penetrating alcohol ,it will avoid the connate water from cohere with the produced water. Later ,the grain to grain cohesiveness can be increase by increasing the surface tension force .And the end ,sand production can be avoided from occur in the wellbore.

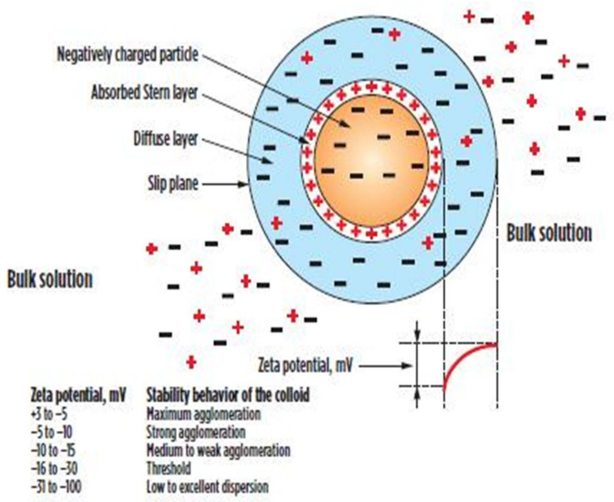


Figure 3 : Zeta Potential effect on colloid behaviour

(Source : *Tim Walker,2011,p 38*)

Picture below shows the result after the sand aid or zeta flow treatment. How the sand particles will conglomerate with each other's.

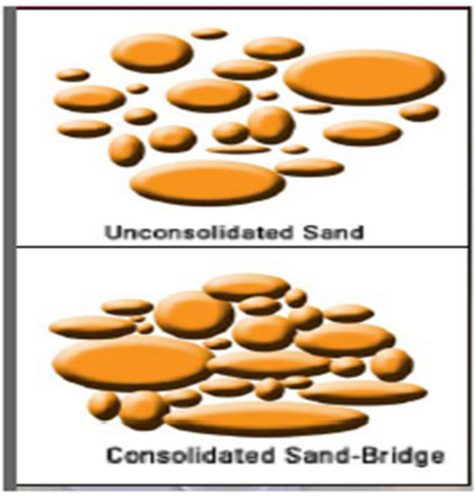


Figure 4 : Result of Sand Aid / Zeta Flow

(Source : http://www.weatherford.com)

Through-tubing gravel packing (TTGP) is a new technique by placing a downhole sand filter across the perforated intervals .TTGP are using vent screen which is two screen assemblies separated by blank pipes that are placed and packed in the casing.

Based on (*Karim,2010,p.2*),Through-tubing gravel packing (TTGP) is similar to the regular Inside Casing and Open Hole conventional circulation gravel packs but the important point here is the innovation that being implement in this new technology TTGP will install gravel pack through production tubing as small as 2 3/8" and can be deployed with coiled tubing .Plus ,TTGP are suited with bottom completion in the wells with stacked completion.

Vent plug that being used in TTGP installation are available for tubing sizes which is 2 3/8" (same to production tubing size).This tool have expendable sand height control valve which can diverts slurry from entering and dehydrating across vent screen while pumping slurry .Installation of this plug are shown in **Figure 5** below .**Figure 6** shows the figure of vent plug.

TTGP is one of rig less technique for sand production that happen in failed gravel pack or zones that started the production without sand control barriers .The most effective sand control methods are those implemented early in the life of well before sand production becomes a problem (*Restarick et al.1991*).Therefore ,a remedial sand control technique need to be considered .TTGP technique are widely used in the field nowadays because it can reduce the production cost .TTGP are very suitable sand control method that can be used for marginal reserves compared to the others sand control method .It is because this technique are more cheaper compared to conventional gravel pack .The difference between these two method are TTGP required only existing tubing to pump the gravel while conventional need a full workover to complete the job .That's why cost can be reduced in TTGP compared to conventional gravel pack.

All the method that stated above are the method that normally done during the completion or known as active sand control.

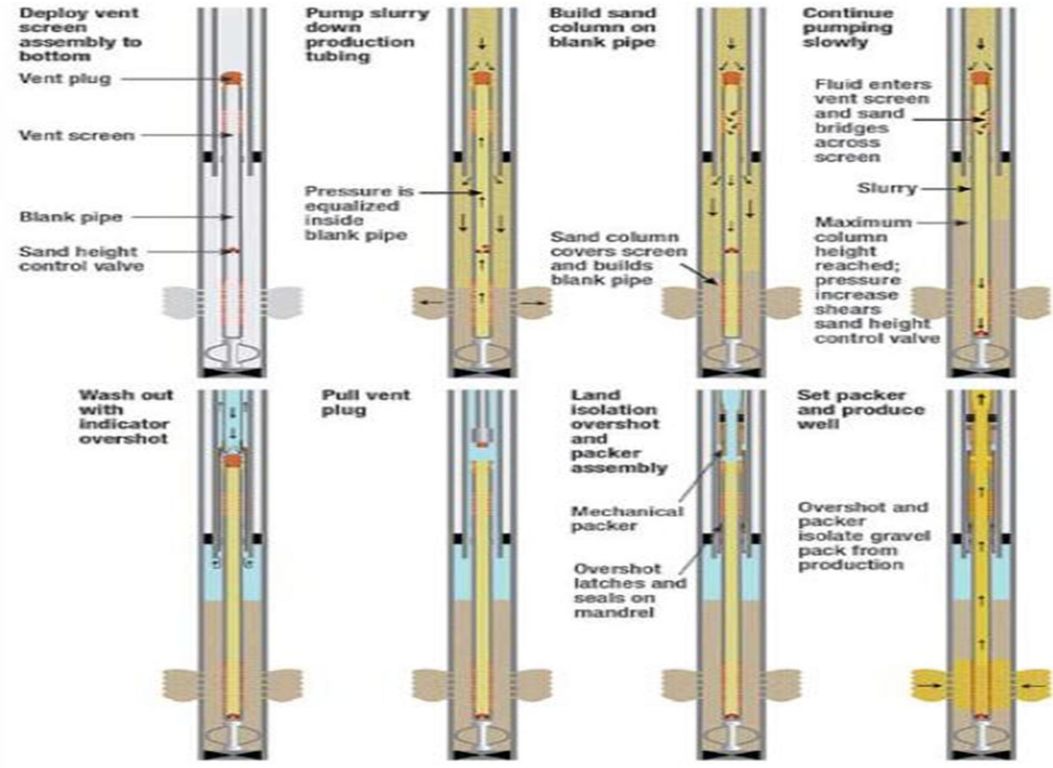


Figure 5 : TTGP completion method using vent screen and isolation packer

(*Source : M.R.Roslan,2010)*

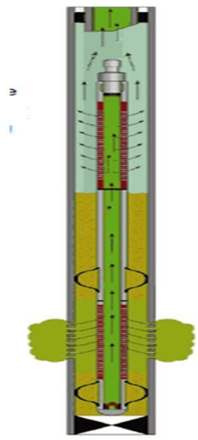


Figure 6 : Vent Plug (*Source : www.thrutubingsystems.com)*

2.3 Effect Of Sand Production

One of the side effect**s** of sand production are erosion of downhole and surface equipment .This happen especially in high produce well .Normally ,fluid flowing at high velocity while carrying sand and this will give excessive erosion of both downhole and surface equipment .So ,all this equipment need a frequent maintenance .When the erosion is severe ,complete failure may occur and this will tend to a critical safety and environment problem .When this problem occur ,a rig assisted workover may be required to repair the damage .And this will required to a larger maintenance cost .It will give a problem for a well with a marginal reserves .**Figure 6** shows the surface choke failure due to erosion by formation sand.

Figure 7 : Surface choke failure due to erosion of formation sand

(*Source :www.i.sereneenergy.org)*

Sand production also will give an accumulation in surface equipment .If velocity are great enough to carry sand up to tubing ,it will trapped in the separator ,heater treater and production pipeline .When the volume is large enough ,cleaning job is required .Plus ,this situation also will reduce the separator capacity to handle the reservoir fluid. For example,1 cubic foot of sand in oil or water separator with 2 minute residence time will cause the separator to handle 128 fewer barrels of liquid per day. Therefore, this also will contribute to decreasing of daily production.

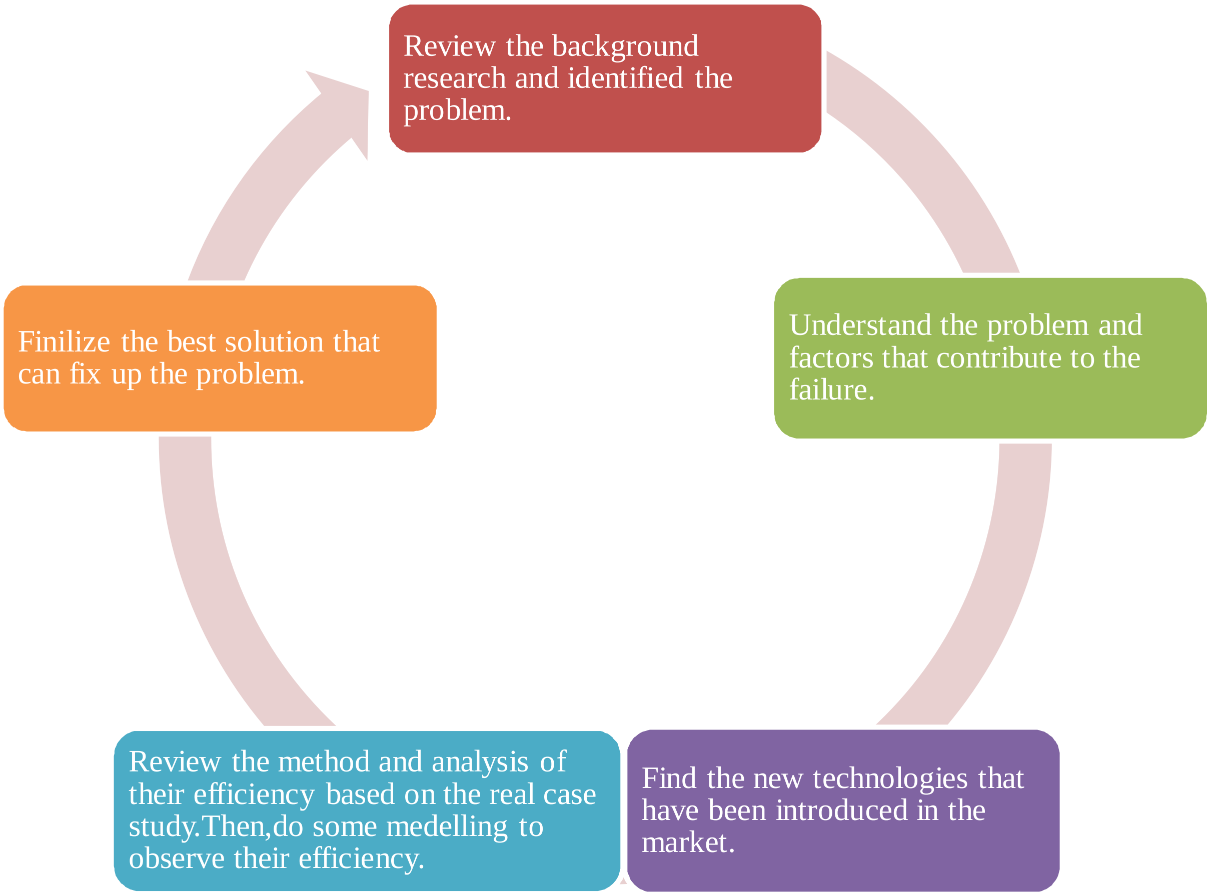
The other effect of sand production are accumulation of downhole equipment .If the production velocity is not enough, sand will bridge off in the tubing or fall and begin to fill inside of the tubing .And if the producing interval covered with the sand, production will decline .Solution for above problem are by run bailer on the end of slickline to remove sand from the production tubing or casing .But, bailer are only can remove small amount of sand and need of multiple run. And these applications are not applicable for larger amount of sand particles. Another option for solving these problem are by pump some gel using the coil tubing to bring the sand particles to the surface. When involving in coil tubing operation, the only concern is the operation cost which much higher than slickline operation.

Sand production also will cause a collapse of formation .When the rate of sand production are great enough with a period of time ,there will be empty area or void develop behind the casing that will grow larger as more sand is produced .When this void become more larger ,the overlying shale or formation sand above the void may collapse into the void .It is because of lack material to support these overlying material .If the overlying shale collapse ,there’s will a loss of productivity .It is because ,shale are knows as rock of having a low permeability and porosity.

CHAPTER 3 : METHODOLOGY

3.1 Research Methdology

The method that being used for this research work are shown as below:



The first stage of this research work is to understand the problem and factors that can contribute to the problem .After understanding how it happens, then find the newest solution for this sand problem .There's a lot of solution that have been applied in the real well nowadays .Method that being used for this stage are based on the article and real case study in Malaysia and others region .Out of these , the best solution be shortlisted that can fix the problem perfectly .Next stage is comparison between different method based on some reservoir criteria such as skin and cost .Skin analysis are done by construct a well modeling using a Prosper Software .From here , the best solution to solve the sand problem can be obtained .After that ,continue with the next stage which is study the other problem that related to sand production .So that ,all engineers and person in charge with the well project will become more alert with this sand problem. A better sand management, it can contribute to higher production rate and well life. A well with zero sand production will have higher production and also longer life compared to others well which having severe sand production.

3.2 Project Activities

Activities	Timeline
Study the factors that can cause the sand production.	FYP 1
Research on the new technologies that have been applied in Malaysia.	FYP 1
Understand the basic concept of the new technologies	FYP 1
Analyze of each new technologies based on the real case study	FYP 1
Construct a calculation and theory on the effectiveness for each method.	FYP 2
Evaluate of the new technologies based on some of factor (cost and skin effect) by construct a reservoir model using prosper software.	FYP 2
Research on some effect of sand production.	FYP 2
Construct a conclusion based on evaluation to obtain a better solution for sand production in offshore.	FYP 2

Table 1: Project Activities

3.3 Gantt-Chart

FYP 1

No	Detail/week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project topic															
2	First meeting with sv															
3	Study the behaviour and factors of sand production															
4	Find the new technologies on sand control method.															
5	Submission of extended proposal defense.															
6	Preparation on proposal defense															
7	Proposal defense															
8	Study the operating concept of each new technologies.															
9	Analyze each of new method based on real case study.															
10	Calculation to prove effectiveness of each method.															
11	Preparation of Interim Draft Report															
12	Submission of Interim Draft Report															
13	Preparation of Interim Report															
14	Submission of Interim Report															

Note :

Semester Break

FYP 2

No	Detail/week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project work continues																
2	Submission of progress report																
3	Construct a well modelling using the prosper software																
4	Pre-EDX																
5	Preparation for Draft report																
6	Submission of draft report																
7	Preparation for dissertation (soft bound)																
8	Submission of dissertation (soft bound)																
9	Submission of technical paper																
10	Preparation for oral presentation																
11	Preparation for project dissertation (hard bound)																
12	Submission of project dissertation (hard bound)																

Note :

Semester Break

3.4 Hardware And Software Required

This project will not intend to use any kind of hardware for an experiment. It is because, the experiment that supposed to be done to prove the effectiveness of each new sand technologies are difficult to be complete in UTP. It need the collaboration with the service company laboratory and research team.

So, to overcome the problem above, a reservoir model have been construct using the prosper software. The objective of this modelling is to observe the skin effect of each new technology. Prosper software is one of the production performance software .By using this software, the production engineer will be able to determine the inflow performance relationship (IPR),PVT and VLR correlation. By playing around with the value of skin, a graph of IPR can be obtaining. From here, an assumption on production performance after treatment can be obtained. As we know that skin effect is based on two definitions.

The positive skin effect will occur when there's a mechanical causes such as partial completion, a perforated height that is less than the desired or reservoir height or inadequate number perforations and also the decrease of the permeability of the reservoir around the well bore can also increase skin effect. While for the negative skin, this will happen when the pressure drop in the near wellbore zone is less than would have been from the normal undistributed reservoir mechanisms and acid fracturing or hydraulic fracturing which increase the permeability .Plus ,production rate increase if the skin effect decrease .Another factor that can contribute to positive skin are if there's underground geological activities create large cracks near the wellbore region ,a sudden increase may be observed in production rate ,however the change in skin is slow and continuous process.

Based on some study that has been done, TTGP have shown that it will make the skin increase. This higher skin are because of the residue from broken fluid loss control agent plugging near wellbore formation and gravel pack .And this event will create the low permeability and off course it contribute to the positive skin evaluation.

Sand aid or zeta flow will contribute to negative skin effect which is good for reservoir .Based on this info ,a reservoir modelling can be run using the prosper software .Because of skin value are known ,others reservoir data are set to default .It is because of the difficulty in obtaining the real data from the operating company.

In prosper software ,there’s section known as mechanical or geometrical skin .In this section ,it allowed the user to enter the skin value by hand .Since skin value are already known as positive or negative sign ,any value within this sign can be used.

Based on (*Karim Shaikh,2010,p 14*),the IPR graph that supposed to generate are shown as below

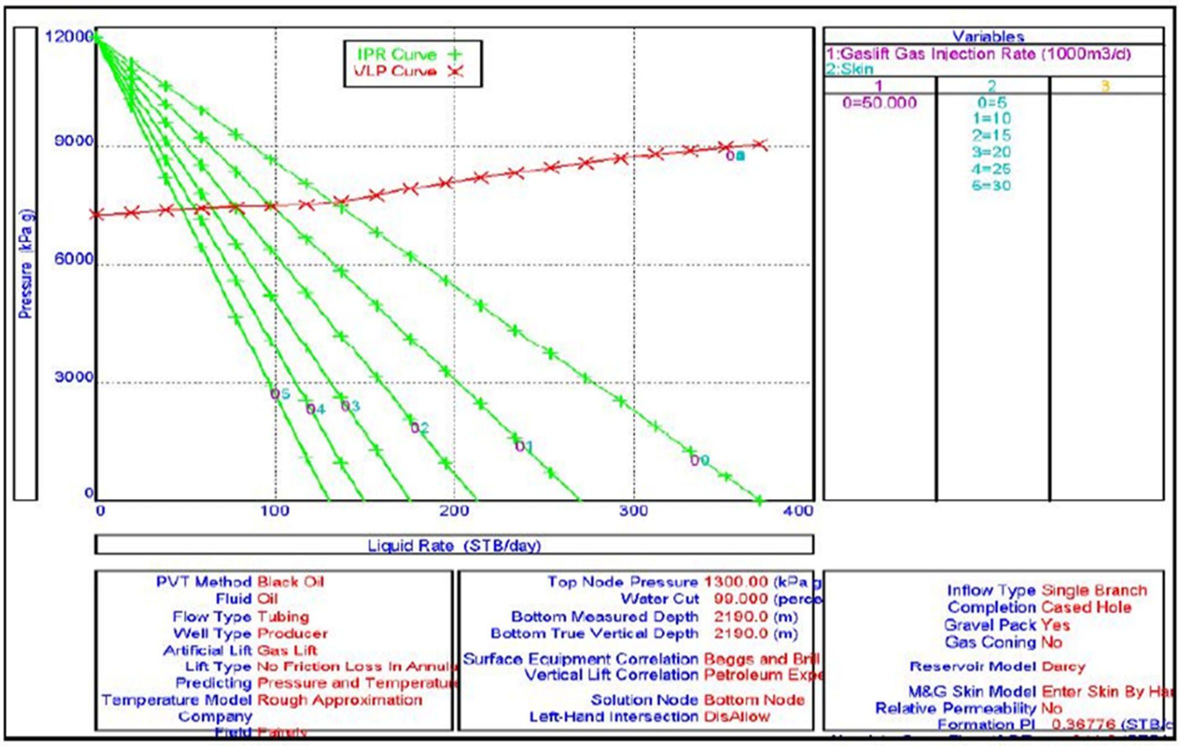


Figure 8 : IPR graph based on skin effect by Prosper software

(Source : Karim Shaikh,2010,p 14)

IPR graph that generate above are applicable for gravel pack operation .For sand aid or zeta flow treatment, simulation are also based on prosper software but with the different value which is negative skin value.

By evaluating both IPR graph for gravel pack and sand aid ,the best method for sand control based on skin effect can be obtained .Hopefully from the IPR graph that generated ,an assumption can be obtained based on how the production rate varies with negative and positive skin effect .It is because ,previously it mention that production rate can be increase if the skin effect are decreasing. Picture below shows how the Prosper software looks like:

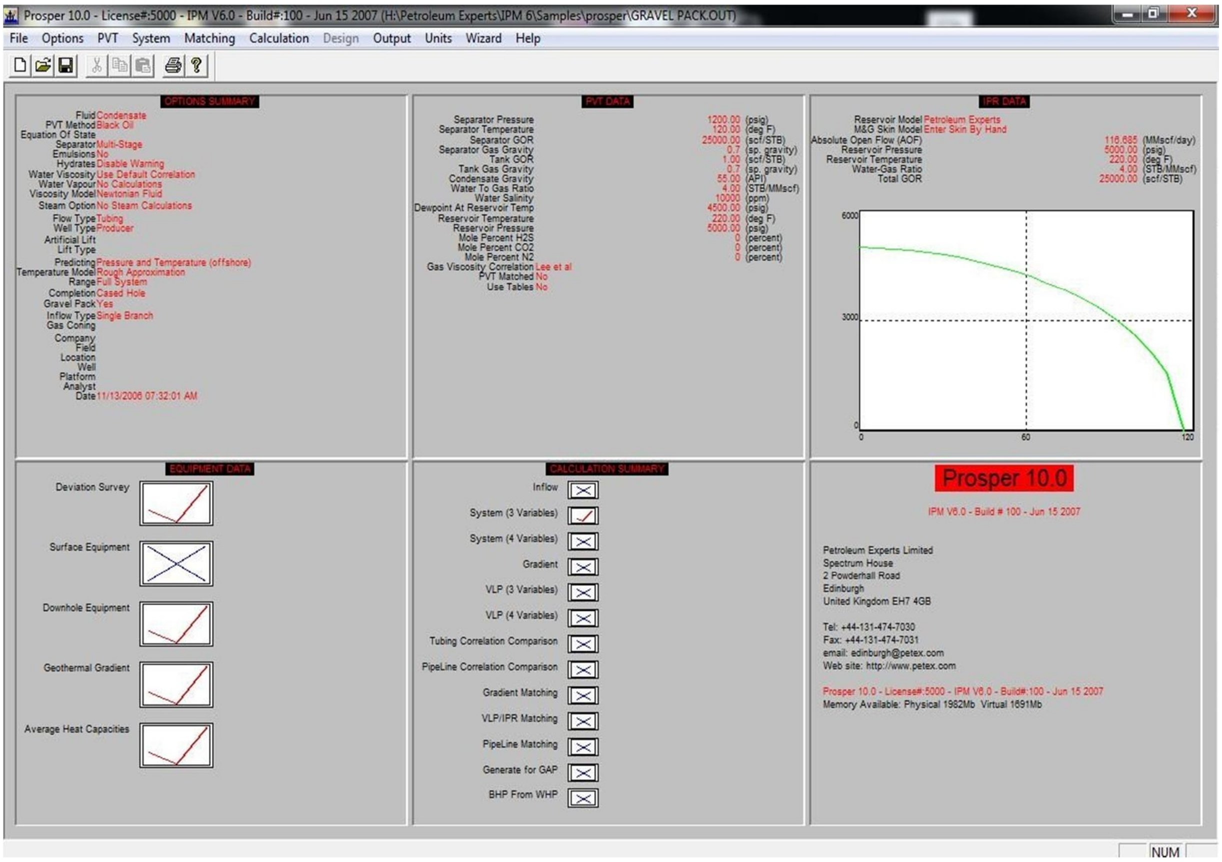


Figure 9 : Prosper Software

(Source : Prosper Software)

CHAPTER 4 : RESULT AND DISCUSSION

4.1 Data Gathering And Analysis

4.1.1 Case Study For Sand Aid

Well A in Peninsular Malaysia

Well A is one of oil well under X company .It is completed by 1986.During the completion stage, this well are not installed with any sand control device as it is not expected to have a sand problem at that time. Then when production rate starts to decrease, it has expected of having a sand particles in the wellbore.

Over the time, this sand problem has become more severe because of this sand start to fill the wellbore space .So ,the management team decide to implement the sand control solution .And sand aid or zeta flow treatment has been chosen as this method are suitable for a severe sand problem.

Based on (*Alfredo,2011,p.7*),procedure of sand aid or zeta flow treatment are shown in table below :

Activities	Explanation
1.Preflush	Use KCI brine to remove any accumulated solids in the wellbore. This is very important to avoid from any ions or material from disturb the chemical reaction in the treatment later .If this happen, it might reduce the treatment efficiency.
2.Spearhead	Use water and sand aid 1%.This stage are to prepare the well to receive the chemical

	treatment. To observe if there's any problem that might happen in the future during the treatment.
3.Main Treatment	Use water and sand aid 10%.To treat the sand particles.
4.Overflush	Use the KCI brine .To flushes the main treatment deeper in the wellbore.

Table 2 : Procedure of Sand Aid/Zeta Flow Treatment

After the overflush stage, well have been soak for minimum 12-24 hours. After 7 months of treatment, production performance curve shows there's water cut decreasing from 85 % to 74 % and additional crude produced about 12,585 bbl. From this case, it prove that sand aid can reduce the water cut and increase the Maximum Sand Free Rate (MSFR).Plus, it also have short payout period and do not cause any formation damage.

Well B in Offshore West Africa

Another case study on this sand aid treatment was at West Africa. This well B was having a sand problem and was shut down. The well was completed with an ESP and this need to be removed before do the SAS treatment .And there's no surface-sand handling capabilities which means this well are expected with zero sand production.

The procedure for this treatment are same as the job that have been done in Malaysia. And after the treatment, production result shows that there's an increment in oil production about 950 BOPD. Plus, it also shows reduced in water cut from 84 % to 74 %.

From this production result, it prove that sand aid or zeta flow treatment can be implement to solve the sand production problem.

Based on (*Alfredo,2011,p 6*), the overall procedure of the entire intervention program is presented below :

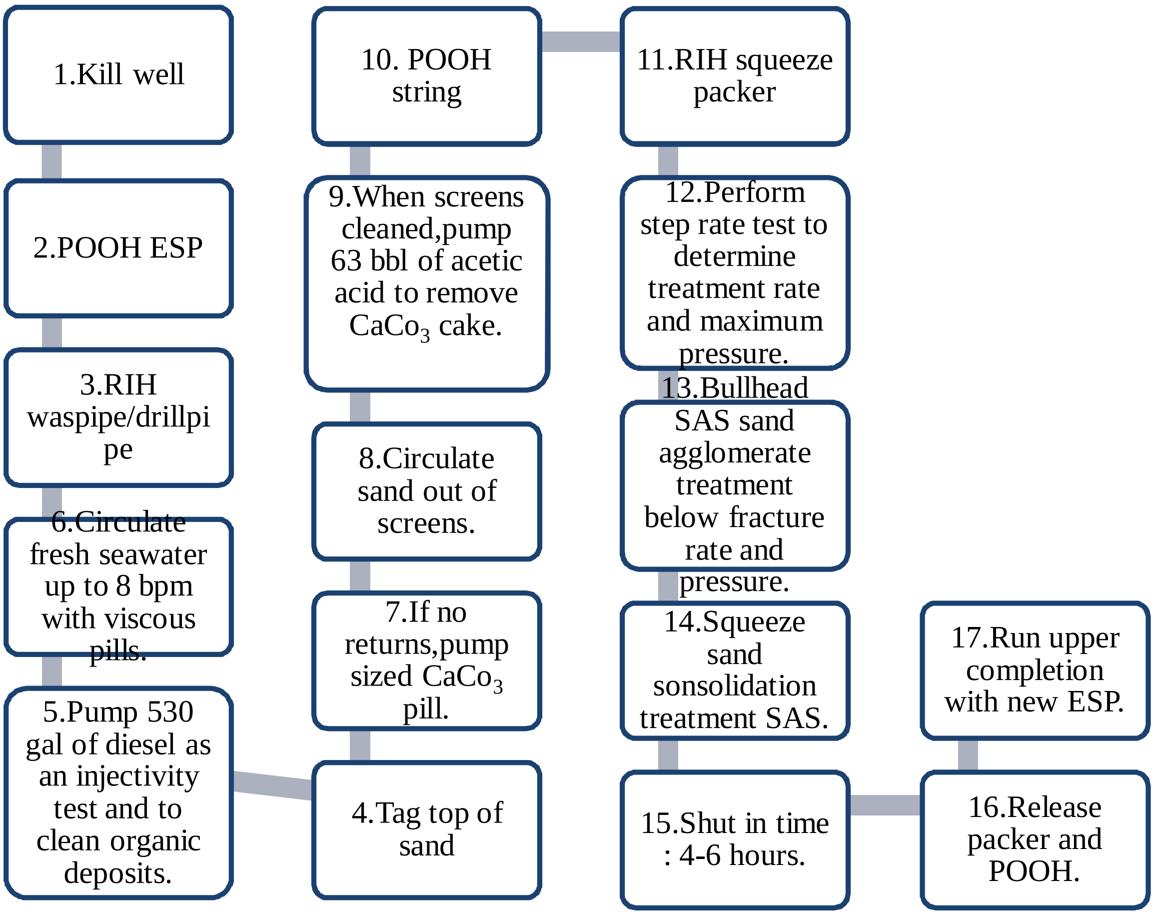


Figure 10 : Job Procedure for Well B

Similarities and differences between two case study

Similarities	
Based on both case study above ,it shows that sand aid or zeta flow can be used to control sand production .It is suitable to be used for a well which having a severe sand problem .Plus ,all this case study prove that sand aid can conglomerate sand particles ,reduce the fines migration and reduce water cut. When all the factors above can be controlled, at the end production performance will be increase.	
Differences	
Case in Peninsular Malaysia	**Case in West Africa**
Use the KCI brine for the preflush stage. Previously, it mentions that preflush stages are done to remove any organic deposit and material that will disturb the chemical treatment later.	While for West Africa, it use diesel for preflush stage. The objective for this stage are the same objective as case in Peninsular Malaysia .The difference is, diesel being used because it will remove any wax deposition near the wellbore region. Based on the work flow above, it mentions that after pump the diesel, they still need to pump acetic acid to remove $CaCo_3$ cake. These acids also are used to remove the organic deposits that still left behind in the wellbore region.

Table 3 : Similarities and Differences of different case study

Previously, it mentions that these sand aid treatments are similar to resin consolidation treatment. A long time ,resin consolidation treatment are been introduced in the market as one of the chemical treatment for sand control .After it have been applied to real field ,it shows that this resin will contribute to some problem which can cause some losses and effect to production performance. The table below will show the differences between sand aid and resin consolidation treatment:

Sand aid/ Zeta flow	Resin Consolidation
Sand aid remains ductile during the stress changes in matrix. Stress change here means when the drawdown forces, reservoir depletion or downhole condition. These sand aids are very ductile as it can adapt to new condition and will re-conglomerate back the sand particles that might parted during this changes.	Resin does not have enough strength to overcome the changes that might happen in the reservoir. Situation will become more worse when this failing resin combined with produced sand. These combinations will produce some fines very close to the wellbore which causing significant skin. And this will contribute to decrease in production performance.
Sand aid can be used for longer interval. For this treatment, it more prefer to over displace to ensure deeper treatment .If not over displaced, excess will just produce out.	In resin job, the over flush fluid that been pumped need to follow the resin and over-displaced the resin into the formation. If the over flush does not follow the path of the resin, there will be 100% permeability lost .That's why limited to interval length about 2-3m.
Based on some others research, sand aid will not cause any permeability reduction .For 2 successive sand aid, will cause only 1 % permeability reduction.	While for resin,2 successive resin will cause about 20 % or more permeability reduction. Even for the success treatment, permeability to oil is reduced because the resin occupies a portion of original pore space and because resin is oil wet.
Sand aid will reduce the water cut and increase the hydrocarbon performance. When increase the Maximum Sand Free Rate (MSFR) and reduce the water cut ,the production will also increase.	Resin does not reduce water cut and increase the MSFR. So ,it will only control the sand production .Production performance might increase or not .Even resin might control the sand problem ,that does not means that production can increase .

Table 4 : Differences between Sand Aid/Zeta Flow and Resin Consolidation

4.1.2 Case study for Through-Tubing Gravel Pack (TTGP)

Well C in Peninsular Malaysia

One of the wells in Peninsular Malaysia, known as Well C have been shut in due to severe sand production .Based on Particle Size Distribution (PSD),this well have the J sand on extremely no uniform profile. But this well have the marginal reserves .So, the operator choose to recomplete the well using the rig less technique that allowed gravel pack to be placed through the existing completion tubing.

Method that been used to install TTGP in this case are vent screen and isolation packer. The first step for this project was to re-perforated the existing interval to increase perforation density and a new interval was perforated to maximize the length .It is because, for effective gravel pack wells, we need a lower velocity which can be obtain from high perforation density with larger diameter perforation .Then, screen erosion can reduced and increase the life of sand control. Higher density perforation also means that less pressure drop because of higher wellhead pressure and it will give a greater oil and gas production.

After that, prepare the gravel pack by using KCI 3 % brine as the gravel pack slurry. Then ,run the sand control assembly using coil tubing which consist of vent screen assembly and others required assembly. The process begin when assembly was set in position and coil tubing was retrieved .Gravel pack was performed through the existing production tubing with no indication of screen out .When there's an increment in gravel concentration ,pumping rate need to be reduced to achieved the screen out. To confirm the screen out, squeeze the gravel pack and lastly retrieving the vent plug using the slickline.

Result after treatment shows that production rate was 180 BOPD after 9 months of production .In conclusion ,TTGP are a good rig less technique to control sand production for marginal reserves. Plus, the advantages using TTGP are it will ensure a better perforation pack efficiency and overall productivity .The only disadvantages of this method are it requires a multiple trips to pump gravel pack before it reach screen out and also side effect of gravel pack to the formation. Picture below shows the downhole assembly for gravel pack operation :

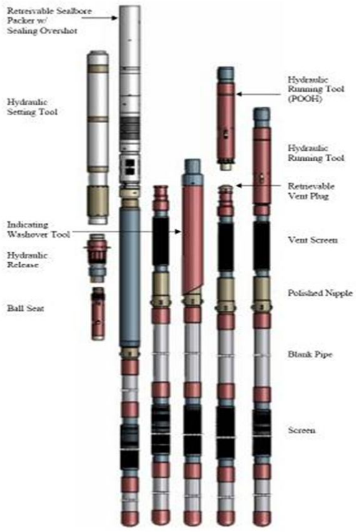


Figure 11: Configuration of TTGP by Coil Tubing (*Source :S.Saebi,2009,p 7)*

Well D in Gulf of Mexico

Well D are having a severe sand production .But ,it have marginal reserves .This means, it will not valuable if used the conventional gravel pack .This problem can be solved by using the new method gravel pack through tubing .In this case ,gravel pack through tubing performed by electric wire line are being proposed by the operators. For case study above ,the method that being proposed are gravel pack through tubing using the coil tubing .As we know that ,well conveying method that been practice today are slickline ,electric and coil tubing .Coil tubing are the latest method been used in the industry.

Based on (*R.T.Rice,2000,p 2*),there's about twelve wells in Gulf of Mexico with depth range from 4200 to 11,050 TVD (true vertical depth) and range initial bottom hole pressure (BHP's) from 1,900 psi to 4,700 psi .While ,the bottom hole temperature are around the range 150 to 224 degrees Fahrenheit .Almost all the wells are completed in unconsolidated sandstone formation. This is the initial indicator for the sand production. The well completion must include the sand production protection .The expected reserves for this reservoir are about 5500 MMCF for gas wells and 50 to 530 MBO for oil wells. The general procedure for this job is shown as below:

Through tubing wireline gravel pack (TTWGP) is deployed with electric wireline.This TTWGP consits of centralizers which have the bow springs.The function of bow springs is to allow the assembly pass through any restriction in tubing.

Gravel pack with slurry are being dumped through tubing wireline gravel pack

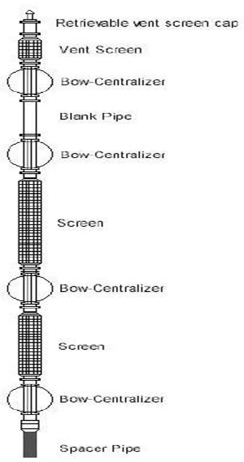
Hydrocarbon will pass through the gravel pack,scree up to blank and went out from the vent screen as shown in figure 12(d).

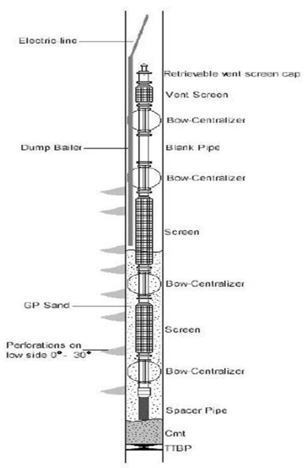
After check the top of gravel pack depth,brine are dumped to wash residual slurry away from the casing.

Cement are dumped to hold the gravel pack around the the blank pipe.See figure 12(c)

Figure 12 : Job Procedure TTWGP (Source : *R.T.Rice,2000,p 1*)

Picture below are according to (*Source R.T.Rice,2000,p 9)* :





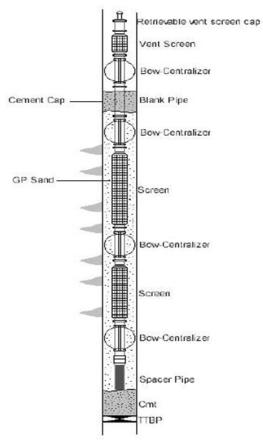


Figure 12(a) **Figure 12(b)** **Figure 12(c)**

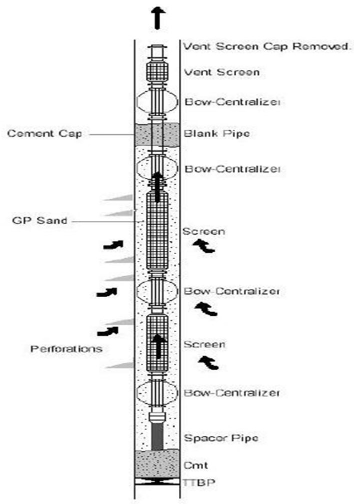


Figure 12(d)

Production performance shows an increment after the treatment. Out of twelve wells in Gulf of Mexico, only one well that still having a sand problem .It is because this is an old zone and there's some damaged on casing due to previous coil tubing operation. Production performance after this treatment shows some increment. One advantage that makes this TTWGP different from TTGP is it is more cheaper than TTGP. R.T.Rice (2000) says that cost comparison of this method versus coil tubing conveyed methods shows 50% advantage to this electric wire line technique .And this will give more choice to the operators for their well surveillance program. Table below shows the similarities and differences between two different case study of Through Tubing Gravel Pack:

<table>
<tr><th colspan="2">Similarities</th></tr>
<tr><td colspan="2">Both case studies shows the increment in production performance after the treatment. The operation cost for both case also are more cheaper compared to the conventional gravel pack.</td></tr>
<tr><th colspan="2">Differences</th></tr>
<tr><th>TTGP using Coil Tubing</th><th>TTGP using Electric line</th></tr>
<tr><td>For coil tubing, gravel packs are pumped</td><td>Method that been used for this case, gravel</td></tr>
</table>

thru the coil tubing itself. Coil tubing also allowed small acid job to be performed which will result to clear perforation tunnels. From here, it shows that coil tubing operations are more effective and easy to operate. And that's why through tubing gravel pack via coil tubing become more popular among the oil operators compared to the electric wire line.	are dump across and into the perforations. For electric line, it will tag the gravel top, dump bailed remaining gravel pack and cement cap. Even though electric line are cheaper but the operation are more complex and some time the result are not good.

Figure 13 : Similarities and Difference of Thorugh Tubing Gravel Pack (TTGP)

4.1.3 Calculation to prove the effectiveness of each new technologies

The calculation that will be discussed in this section are mathematical method used to calculate the rock strength and the effect of chemical solutions on the strength of sandstone .The objective of this calculation are to understand on how the rock strength can be increased and the effect of sand aid solution to rock strength.

Study the relationship between rock strength and zeta potential

Based on (*V.S.Vutukuri,1998,pg 199*),the strength criteria can be written in terms of either a) principal stresses,ρ_1 and ρ_3 at fractured or normalized principal stresses at fracture obtained by dividing the principal stresses, ρ_1 and ρ_3 at fracture by the relevant uniaxial compressive strength, ρ_c or b) shear and normal stresses at fracture or normalized shear and normal stresses at fracture with respect to uniaxial compressive strength.

The empirical strength criteria for rock and rock mass proposed by *Bieniawski* (*1974).*

The formula below shows the modified *Bieniawski* criteria :

$$P_1/ P_{cm} = 1 + B_m (P_3/ P_{cm})^{am}$$

Where P_1 and P_3 = Principal stresses at fracture ;

P_{cm} = uniaxial compressive strength of rock mass.

B_m and a_m = rock mass parameters.

But, according to (*V.S.Vutukuri,1998,pg 199*),because of popularity of Hoek-Brown criterion,the following modification are obtained :

$$P_1/ P_{cm} = P_3/ P_{cm} + (1+m_m P_3/ P_{cm})^{0.5}$$

Where m_m =rock mass constant.

From the Hoek-Brown criterion, the formula for rock mass is obtained as below:

For undisturbed rock mass:

$$P_{cm} / P_c = [\exp ((RMR – 100) /9)]^{0.5}$$

$$m_m / m = 1/ [(P_{cm}/ P_c)^{0.3588}]$$

Where RMR = Rock Mass Rating (Bieniawski,1974);

P_c = uniaxial compressive strength of intact rock comprising the rock mass and

m= constant for intact rock.

According to (*V.S.Vutukuri,1998,pg 200*),the relationship between uniaxial compressive strength as shown above also can be obtained for sandstone. For sandstone :

$$m_m / m = 1/ [(P_{cm}/ P_c)^{0.4949}]$$

Based on the formula for sandstone as shown above, it can conclude that when the rock mass increase, the rock strength will decrease .So, a less rock mass will have a great rock strength .It is because, when the rock mass is small, the cementation material will be able to bound the rock tightly.

As the objective of this mathematical calculation are to prove that sand aid treatment will help to increase the rock strength ,so from the formula above there's some assumption that can be made. The condition that happen during the sand production are when the sand particle are parted from each other .In this time ,the rock strength are almost zero because of the continuous decreasing. By adding the sand aid fluid, it will able to conglomerate back all this parted sand particles .In is because, the objective of sand aid are to change the charges around the sand particles that will induced the material agglomeration and attract each other .Previously, zeta potential are defined as the charge develops at interface between liquid and solid particles surface (Van der Waals force) which range between -20 to + 20 mV.

When the sand particles are agglomerate with each other, the rock mass will decrease and this will contribute to increasing of rock strength .With believes by increasing the rock strength, the percentage of having a sand problem in wellbore will be also being decrease.

This is because the rock strength will contribute to the sand production .When the rock does not have an enough strength, it will fail to support the underlying weight .This underlying weight are supposed support by the pore pressure in formation .But, as time goes, the pore pressure will decline and will not be able anymore to support this underlying weight .With the combination of less rock strength and decline pore pressure, there's will be a possibility of having a sand production.

Study on effect of sand aid to cementation material

Zeta potential or sand aid is just to alter the charges at grain surface to attract other grains to agglomerate together .So , it will not affect the cementation material like what acid do.

When two particles are attract to each other ,there will be some energy of interaction. Based on (*Khilar,1998,p 171*),this total energy of interaction are consist of electric double layer repulsion London Van der Waals attraction ,Born repulsion and hydrodynamics forces .From this references, there's no statement that shows any chemical interaction between the cementation material. Previously ,it mention that cementation material will affect the rock strength .If the cementation material are decrease or increase ,it will directly affect the rock strength .It is because ,the function of this cementation material are to combine together all the sand particles .So ,when this material are interact with the treatment fluid ,it will no longer agglomerate the particles. That's why there's a sand production. As mention, sand aid or zeta flow is just to alter the charges and it will not react with cementation material .This can conclude that it will not affect the rock strength.

4.2 Modelling

4.2.1 Evaluation the new sand control technologies based on some factor

The new sand control technologies will be evaluated based on some factor such as skin and cost. It is because, from here the best solution can be obtained for this sand problem.

Skin analysis using the Prosper software

For the first run, skin evaluations for gravel pack operation are done based on value from the resources .As mention previously ,the skin value for gravel pack operation are assume to be in region positive. This higher skin are because of the residue from broken fluid loss control agent plugging near wellbore formation and gravel pack .And this event will create the low permeability and off course it contribute to the positive skin evaluation.

Based on information above, the skin value for gravel pack operation that been used are between region value 0 to 30.From this stimulation, graph of inflow (IPR) versus outflow (VLP) curves can be generated.All the components upstream of the solution node comprise the inflow section and all the components downstream of the solution node comprise the outflow section. The intersection between these two graphs will show the actual conditions at which the well will flow for a given set of constraints. Inflow performance relationship (IPR) is a production potential as a function of production rate. While the Well outflow relationship performance (VLP) is a bottom hole pressure as a function of flow rate. By playing around with value for skin, the curves that will be affected by this action are inflow performance relationship. Off course, it affect IPR since skin normally happen at near wellbore region. The result from this stimulation for gravel pack operation is shows as below:

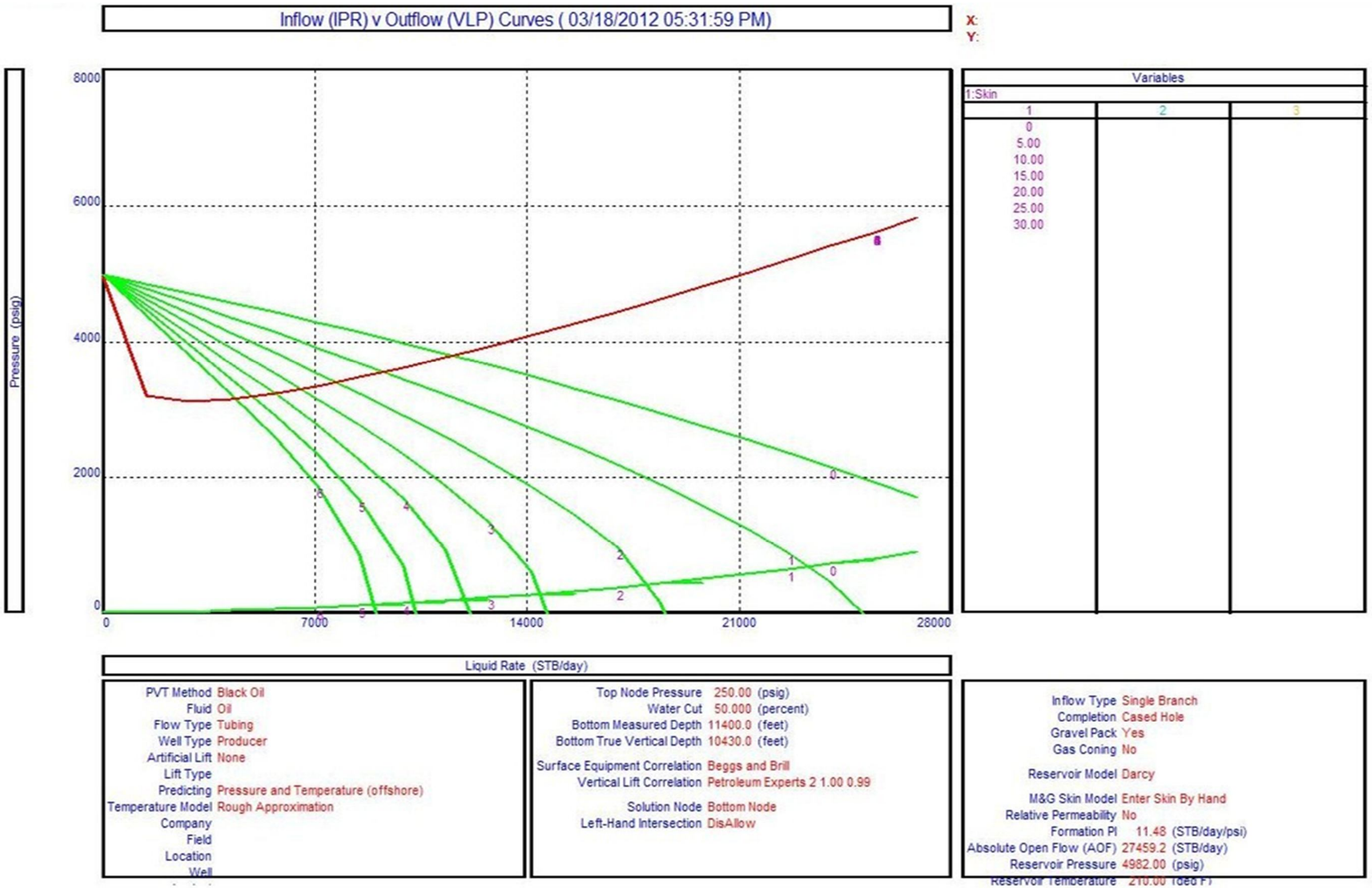


Figure 14 : Skin Evaluation for Gravel Pack Operation

From the graph above, it shows that when skin increase the production will automatically decrease .As mention previously, this higher skin are because of the residue from broken fluid loss control agent plugging near wellbore formation and gravel pack .And this event will create the low permeability and this will restrict the production performance. At the end, this will affect the overall production performance. As an operating company, we should avoid this positive skin value as it affects the production performance. One of the objectives in production phase is to minimizing the formation damage which will have a great impact on improving well performance.

Even though gravel pack operation is the most popular method that been used in the industry to control the sand control, but it have an effect on formation damage that might happen during the operation .In this case, we are trying to solve the sand problem but at the end we still cannot increase the production performance as there's a possibility of having a higher skin value.

The well sketch bellow shows the gravel pack geometry:

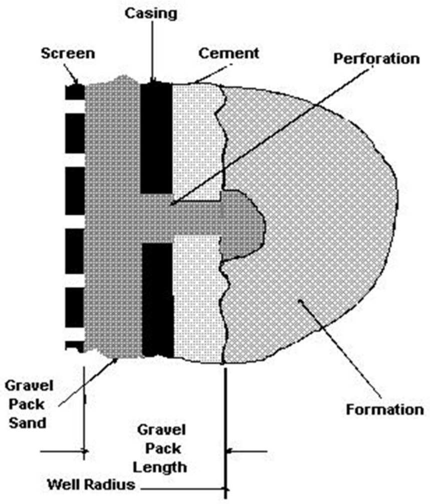


Figure 15 : Gravel Pack Geometry (Source *: Prosper Software)*

Beside the IPR versus VLP curves, prosper software also can generate the wellhead system curves. The outcome graph for wellhead system is shown below:

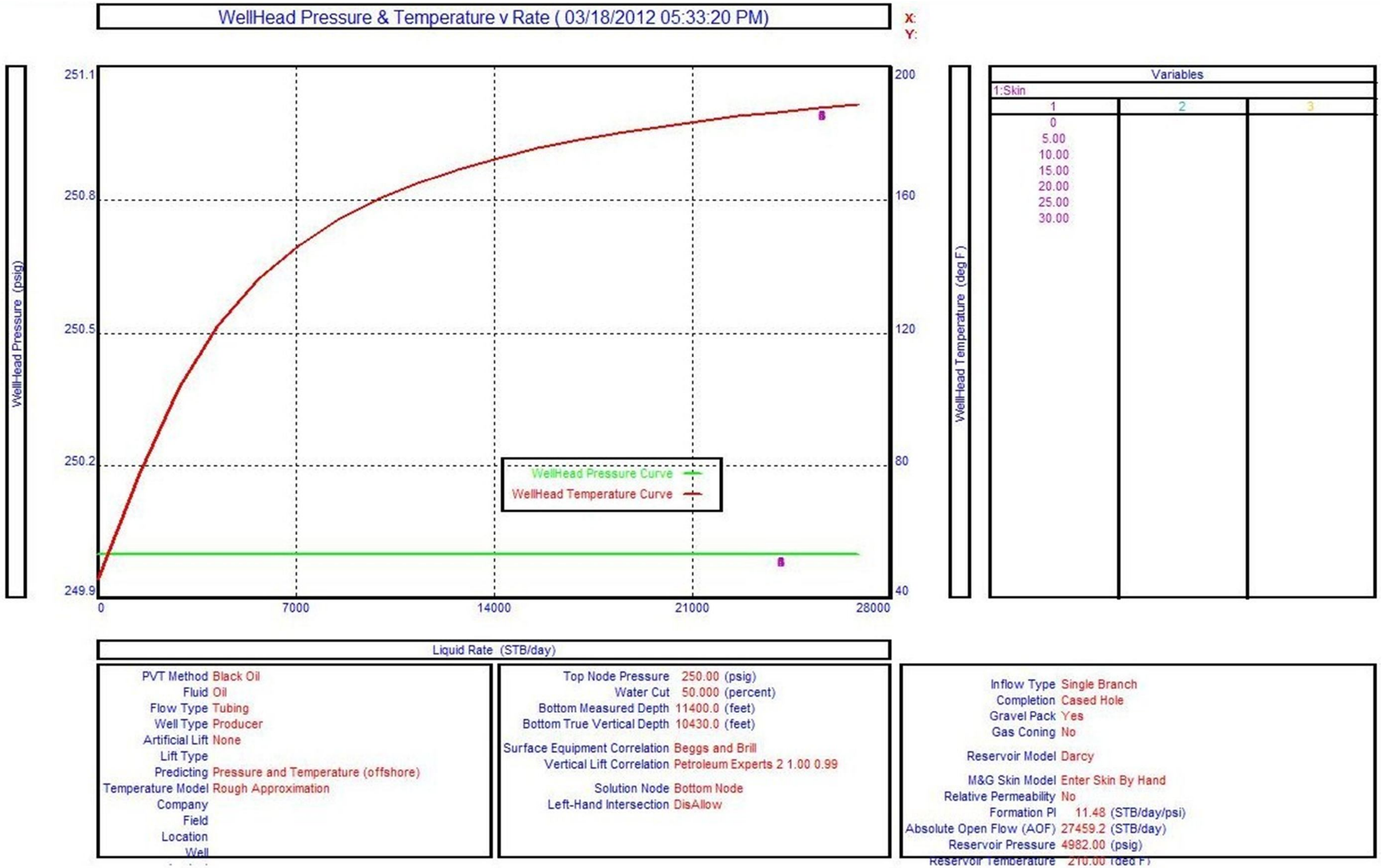


Figure 16 : Wellhead System Curves for TTGP

From the wellhead system curves above it shows that for this stimulation, wellhead pressure will be constant. But, this constant wellhead pressure does not mean that there's a constant sand face pressure. There will be a possibility of having a sand problem in the future for this well. Wellhead temperature will be increase as this is gravel pack operation. The temperature will increase as the gravel packs are pumped to the wellbore. And this increment will not affect the production performance.

Now, stimulation for zeta flow or sand aid is done. As mention previously, the expected skin value for this method is negative skin value. Normally, the negative skin value denotes that the pressure drop in the near-wellbore zone is less that would have been from the normal undisturbed reservoir flow mechanism. The normal causes for negative skin value are matrix stimulation, hydraulic fracturing and highly inclined wellbore. The result from the prosper software are shown on the page. Based on the graph below, there are two variables which are skin value and water cut. As mention previously, sand aid or zeta flow treatment also will reduces the water cut .From here, we can see how the these two parameters will affect the production rate.

As known, negative skin value indicates that there is improvement in wellbore performance. Based on the graph plotted, the negative value will not give much affect to the liquid rate unlike the positive skin value. No matter how much the negative value for skin, the liquid rate still at the highest point. Unlike the positive value for skin, it will show a lot of difference between those values. For water cut, as the values decrease the liquid rate will increase. Logically, when the produced water reduced, the amount of hydrocarbon will automatically increase. So, from this stimulation, it can approve that sand aid or zeta flow treatment can reduce the water cut and also minimize the formation damage. That's why the production performance can be improved through this method.

The second graph for this stimulation is wellhead system curves. The outcome for this stimulation does not have a much difference with wellhead system curves for gravel pack operation.

So, the first assumptions that have been made for the first wellhead system are accepted as it does not differ from the second wellhead system. Even though the sand aid will successful conglomerate the sand particles, but there will be possibility of this operation to fail. That’s why the wellhead pressure is constant which same as previous graph. The wellhead temperature increase because of the main treatment are been pumped into the wellbore.

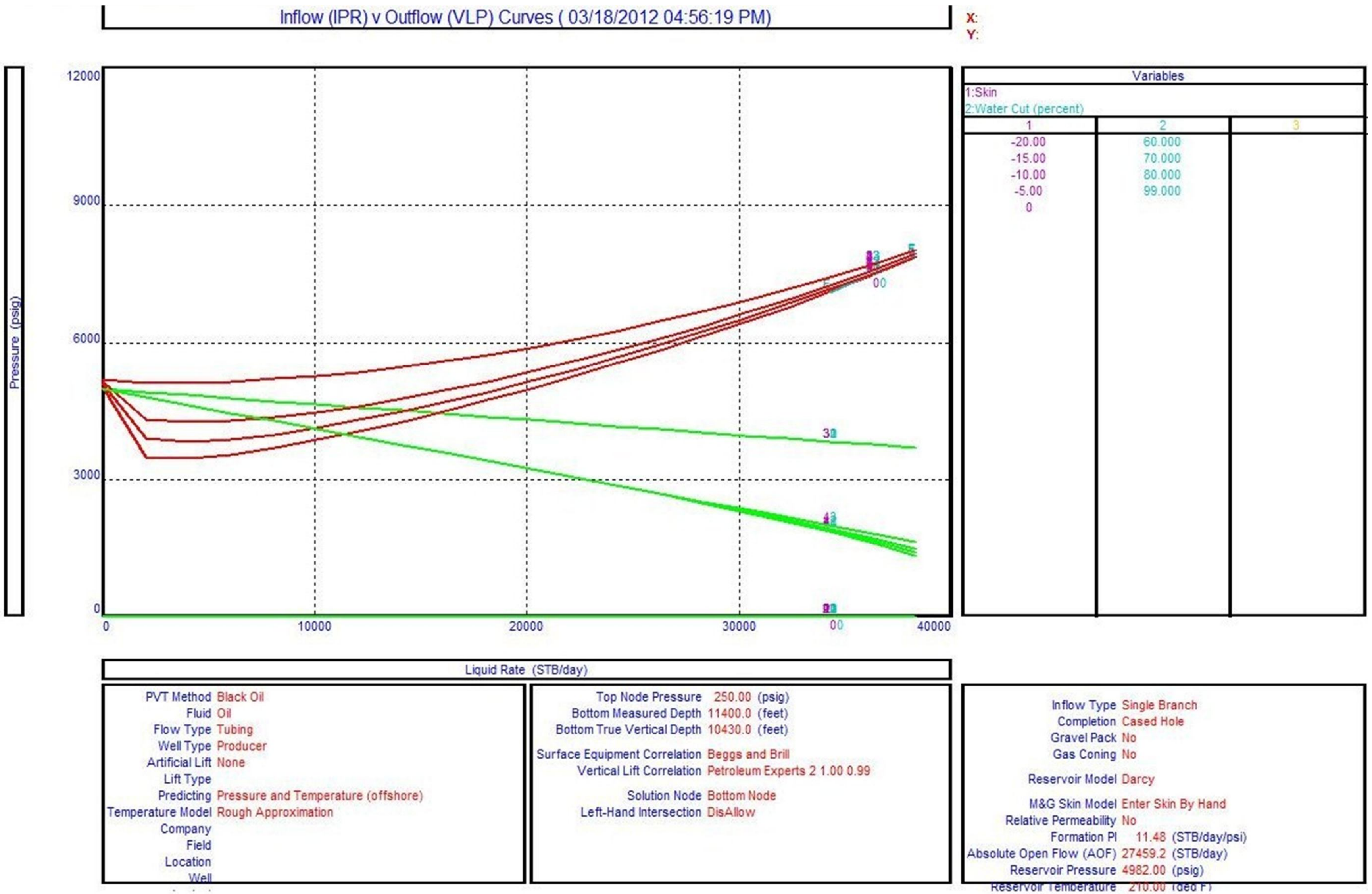


Figure 17 : Skin Evaluation for Sand Aid/Zeta Flow

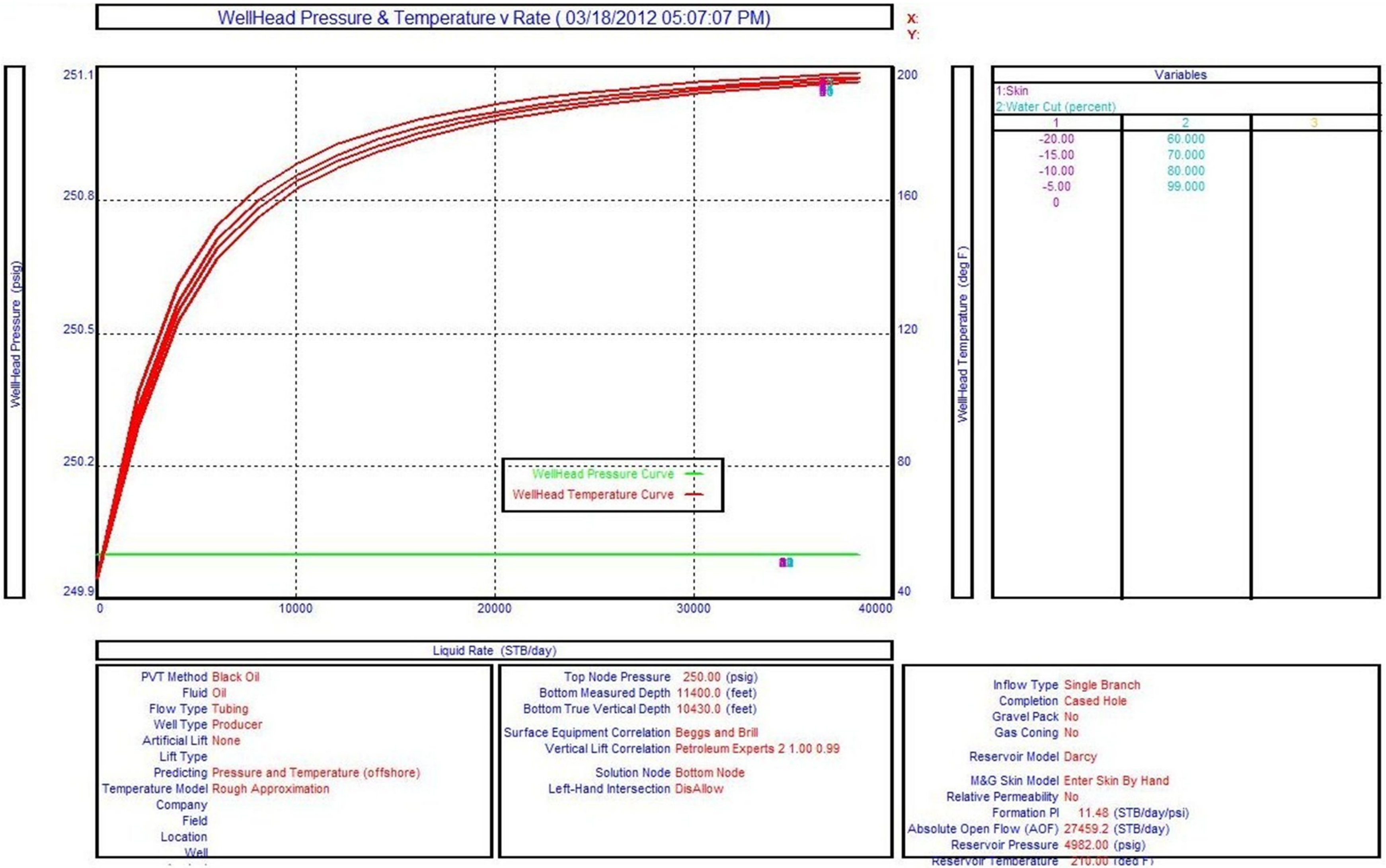


Figure 18 : Wellhead System Curves for Sand Aid/Zeta Flow

Cost evaluation based on case study

At the early stage, it mentions that gravel pack through tubing is an economic solution for marginal reserves as compared to convention gravel pack. It is because ,gravel pack can be pumped through the existing tubing without considered the overall work over job .But ,in the skin analysis section ,gravel pack are suspect of having the positive skin value which is not good for production curve. Economically, this method will be suitable for the marginal reserves and not for bigger reserves .But ,there some other aspects that need to be consider during the operation such as the conveyed method that will been used during the operation such like coiled tubing or wire line service. If coiled tubing being chosen, then operating cost will be much higher compared to other wire line service. Technically, there's other equipment that need to be considered when using the coiled tubing such as control cabin, prime mover ,coil tubing reel and injector head. This will make the job procedure more complicated and time consumed. There's also had the possibility of having a problem during the coil tubing operation.

But the sand aid is having the advantages in the cost estimation side. Unfortunately, these treatments are based on period of time. Some operating company ,set up period of re-eject the treatment in eight months or one year .Interval time are sometime based on reservoir condition. If there's no sand production observed, then there's no need to re-eject in eight months period. This re-eject treatment need to be done because it helps the sand particles agglomerate again after some changes that might happen in the reservoir .After some period of production, reservoir might change because of the pressure and temperature changes .Even though sand aid are very brittle where it can adopt with the changes that happen in reservoir .But, it still need to re-eject back to make it more stronger.

The operating cost for sand aid will depends on treatment zone. It might be cheaper or expensive which depends on the amount of sand aid fluid needed for that job. Plus, it also depends on the reservoir condition. Weather, it will produce sand again or not.

Table below will summarize the cost evaluation for both methods:

Sand Aid / Zeta Flow	Through Tubing Gravel Pack (TTGP)
Average cost for sand aid might be around 60-100 k. This cost depends on the treatment zone and reservoir condition. But, the operation cost will be much cheaper compared to TTGP since do not need to considered the conveyed method. It is because, sand aid fluid are been pumped using the wash pipe or drill pipe. The job procedure will be simpler compared to TTGP since it used the wash pipe or drill pipe. Skin evaluation approve that sand aid treatment will give a negative skin value which is good for production performance.	TTGP are much cheaper compared to the conventional gravel pack since the gravel is pumped through the existing tubing. But, the overall cost for TTGP will be more higher compared to sand aid since it need to considered the conveyed method been used in the operation. The conveyed method that been used during the operation will make the job procedure more complicated and a lot of problem might occur in operation stage. Skin evaluation for TTGP shows that it might have the positive skin value which is not good for production performance. The TTGP required a multiple trip. This will make the job procedure become more complicated.

Table 5 : Economic Analysis

CHAPTER 5 : CONCLUSION

As mention above, sand production is a common problem that always happens in offshore wells. This kind problem need to be control and solved in the early of production .The situation will become more severe when the failure sand start to fill up the wellbore. Therefore by finding the new sand control technologies as explained above hopefully can control this problem in the wells. The new sand control that mention above are Through Tubing Gravel Pack (TTGP) and Sand Aid or Zeta Flow. Both method are already been used in Peninsular Malaysia field.

TTGP are the advanced gravel pack where the gravel is pumped through the existing production tubing. This method are popular among the oil company since it reduced the operating cost .It also are more cheaper compared to the conventional gravel pack .But, based on the evaluation above ,it shows that TTGP operation might have a positive skin value which means not good for production performance This method are suitable for marginal reserves. Previous, gravel pack operations are popular among the oil company because it has long life in controlling the sand problem in reservoir. It is because, gravel are been used to avoid the movement of sand particles into the wellbore. But, in the future there will be a possibility of having a failure screens which happens because of sand particles movement and reservoir conditions. This might happen when the sand particles are hitting the screen with a high speed. Screen also can fail because of the high temperature and high pressure in the wellbore. When there’s a leak at screen body, the sand particles will again enter the production path. Then, it can disturb again the production performance.

Sand aid or zeta flow is using the special fluid to agglomerate back the sand particles. It will not disturb the cementation material but alters the zeta potential at the sand surface. By alter the charges, it will attracts each other’s and conglomerate back. This special fluid is more brittle compared to conventional resin consolidation. It will conglomerate back during the reservoir changes.

And based on the interpretation and analysis that have been done above, it shows that both methods have an advantages and disadvantages. TTGP are more suitable for marginal reserves. While sand aid will for suitable for severe sand problem. Based on the skin evaluation , TTGP are having a positive skin value while sand aid have a negative skin. Sand aid operation also has advantages on operating cost compared to the TTGP. Overall the operating cost are depends on the reservoir condition and others components that involve during the operation.

In conclusion, sand aid operations are more preferable which based on the evaluation that has been done in this project. This method has more advantages compared to the TTGP. But, when treating the marginal reserved, TTGP will more suitable to be used. In reality, sand aid operations also are the leaders in controlling the sand problem in the offshore. The oil company will choose this method since the job procedure are much simpler and have a better result.

Technically, this study was relevant to the crisis that happens in oil and gas industry now. Hopefully, result that been obtained from this work will be very useful in the industry. There's some aspect in this project work need to be improved such as the method that been used in order to prove the effectiveness of each method. The experiment can be done by collaborate with the service company. From here, effectiveness of each method can be more visualized. Overall, this project is useful for the engineer to decide which method that can be used for their field to solve the sand problem.

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