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RESEARCH ARTICLE

A new software developed for use in the creation of well control form

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INFORMATION

ABSTRACT

Technological changes make human life much easier. As in all sectors, technological innovations manifest itself in petroleum and natural gas engineering applications. In addition to being beneficial in terms of work safety and security, performing well production according to accounts by performing well control calculations also contribute economically. It takes a lot of time and leads to inaccuracies in production due to calculation errors, because the well control form was created with too much equalities. In this study, a software which forms well control form has been developed in order to avoid similar problems and to realize a safe production. With this software, well control form which is frequently used in production stage can be easily created and stored in computer. In this software encoded with C#, Microsoft Visual Studio is used as a compiler. In the software, the values such as drill pipe volume, stroke number, stroke time, kill mud weight, first and last circulation can be calculated with making measurable data entries such as borehole diameter, well depth, mud density, pump pressure, pump speed, drill pipe and weight pipe capacity and well control form can be created simply. The software has been tried on many examples and a sample tested in this study is given.

1. Introduction

Today, production in different areas is required to be done safely. Studies such as feasibility and optimization can be carried out to ensure safe production. For this purpose, specific standards have been developed. Some legal issues have been introduced about some matters. Since the term well control does not currently have a standardized definition, the term pressure control is also used. During drilling applications, the formation pressure may be large enough to actuate the drilling mud from hydrostatic pressure ($\Delta P \approx 25$-50 psi or more). This can be avoided by controlling fluid flow and pressure imbalance entering the well from the formation or by using appropriate techniques. The concept of well control also includes many drilling issues such as the selection of the protection pipe depths, pipe design, selection of sludge type and properties, equipment selection (series, etc.), blowout preventer (BOP), well demolition, leakage problem. Therefore, well control is involved in almost all drilling technology. As a result of the formation pressure is greater than the sludge hydrostatic pressure in the well ($\Delta P \approx 5$-50 psi or more) during drilling applications. If the fluid enters the circulation at a time when the circulation is not done, the sludge coming from the well is observed as if circulating. With the closure of the well, the pressures in the well are compensated, the shut in drill pipe pressure (SIDPP) and shut in casing pressure (SICP) are read on

the pipe stand and wellhead annulus, respectively. The well can behave as a revitalization of the drilling mud, especially as a result of the gas out mud (gas out mud) and the maximum expansion of these gases brought to the surface by circulation. In addition, in some special cases, such as when the sludge density in the drilling sequence is greater than the sludge density in the annulus for any reason, if circulation is stopped, sludge arrival from the annulus is observed and the well behaves as if the well is revitalized. Such false wells can be distinguished from the reality by flow check tests or status assessment. Well revitalization can be controlled or stopped using appropriate pressure control techniques (Akman, 1993).

Another important term is blowout, which cannot be controlled or kept under control. Drilling works are continued by controlling with the use of appropriate well control techniques. The importance of well control is listed below.

- It can be used to ensure the safety of drilling personnel and drilling wells and equipment.

- Well control form can be used since many well problems such as well revitalization and uncontrolled well revitalization will increase the normally high drilling costs.

- Well programs / planning can be used to prepare a balance

between drilling safety and drilling cost under current site conditions.

- The waste of oil and natural gas and damage to the active reservoir can be used because it is undoubtedly an undesirable situation.

- It is a fact that oil or natural gas or even salty reservoir water causes environmental pollution. In fact, relevant legal regulations have been introduced. Well control can be used to prevent environmental pollution.

- Because of the need for periodic training of drilling personnel on well control, well control courses were required. This shows us how important it is to create a well control form (Akman, 1993).

Drilling applications in oil and natural gas exploration are very expensive processes. It should be considered that the works to be done are both safe and economical. For this reason, two main elements such as drilling safety and drilling cost are evaluated together in well programs prepared according to formation characteristics or during drilling applications.

These two elements are connected. When the safety factors are desired to increase, drilling costs also increase. Safety factors are reduced when drilling costs are to be reduced. It is not desirable to increase unnecessary drilling costs and unsafe application. For this reason, it is desirable that the drilling safety and drilling costs are balanced in relation to each other as appropriate well programming or drilling application technique. In the first exploration wells where field data are insufficient, safety factors are consciously kept slightly high. If the subject is considered in terms of human factor, safe and economic drilling wells can only be excavated by experienced drilling personnel trained and experienced in this field. In this case, first of all, it should be given importance to the training of drilling programmers and practitioners who will do the job. The presence of well-trained and experienced drilling personnel in well control is a key factor in safe and economic drilling applications. In order to achieve a balance of safety and cost, well control is of particular importance for the following reasons.

As a result of continuous determination and evaluation of borehole data, well control (well revitalization, demolition, string compression, leakage etc. control) can be achieved in a shorter time and safer. For example; if the appropriate well control techniques are not applied after the revitalization of the well, the time spent unnecessarily increases the cost of drilling. If an incorrect or incomplete technique is applied, well revival may turn into an uncontrollable flow. This flow is very dangerous for the safety of drilling personnel. It may cause the well to dispose of or the entire tower equipment becomes unusable. In addition to these, there will be waste of unwanted natural resources (oil / natural gas) and environmental pollution.

Today, in order to make more economical/cheaper drilling applications, care is taken to keep the drilling sludge concentrations as low as possible compared to formation pressure. This, of course, increases the likelihood of well revitalization and uncontrollable flow (Akman, 1993).

Many software has been developed for convenience in different areas (Nasuf, 1983; Ergin et al., 1998; Erarslan, 2003; Doğan and

Ağaçgözcü, 2015; Sakcali et al., 2016a; Sakcali et al., 2016b; Ergüzen and Lüy, 2017; Berber et al., 2019). The oil sector in the world is a very important business line both in terms of economy and life. In the field of oil and gas, the following studies have been carried out. Some of these are for locating oil and gas deposits. In their study, Nuri (2018) addressed the problems of optimal placement and integration of platforms for the processing of oil and gas deposits at sea with directional wells. They examined the mathematical models of the problems and developed a more comprehensive mathematical model considering the shortcomings of these models. With the proposed model, he prepared an approximate solution algorithm based on K-Means algorithms used in some problems and developed a software in C # programming language to solve the problem.

Özdemir (2017) contained in any oil exploration in the region, a software has been developed from Turkey that will be used in determining the location of oil and gas deposits. This package program evaluates the results of chemical analysis of water samples taken from surface and ground water (spring waters, cold and hot water wells) in the area where oil and natural gas will be explored in the computer program. In the maps prepared as a result of the evaluation, it is provided to identify the areas with oil and natural gas. Be extremely expensive and difficult because of the oil and gas exploration in different geological structure also permits the use of Turkey as well as geophysical methods of exploration drilling. Seismic method, which is one of the geophysical methods and frequently used in oil and natural gas exploration, is difficult to use in some cases. The package program is designed in two languages, Turkish and English, in order to eliminate the inconvenience of seismic methods that cannot be done in all areas and to reveal the unknowns about our country's oil and natural gas deposits.

In this study, it is aimed to form well control form. The software has been developed using simple interfaces for the convenience of the user. The software has been confirmed with several examples.

2. Material and Method
2.1. The language used in the software
The computer usage is increasing day by day with the development of technology, it is possible to hear new things from day to day in the software industry, which started from the 1950s to the present. Because throughout history, humanity has been inclined to produce products to facilitate their work. Programming in the 20th and 21st centuries has been a tool used to produce products that make life easier for people.

Many programming languages have been developed to date. They are used in different areas according to the platforms to be used or language structure. Among all languages, there are two most commonly used programming languages, especially in the field of objective programming. The first of these languages can be run as a Java platform and the second is integrated with the .net library, all languages can be programmed on a common platform and C # (CSharp) programming language with easy coding structure (Teknokolikler, 2019).

C # is an object-oriented programming language developed by Anders Heljsberg and his team for Microsoft's .NET platform. The first version was released in 2002 with the .NET Framework 1.0.

The C # language forms the basis of the Microsoft .NET platform with its powerful object-oriented structure. The C and C ++ analogy in terms of coding makes it easier for programmers to learn (Süzen and Taşdelen, 2013).

As it is easier, flexible and portable, it stands out because of its C # structure. Therefore, it is expressed by the pound sign (#) as a combination of 4 + signs. C # programming language, which is the next generation programming language, brings innovations. Designed for C # server and embedded systems (Smartpro, 2019).

C # is one of the most widely used programming languages in the software industry. It is derived from the interaction of C and C ++. C # is an object-oriented programming language. In short, object oriented programming means that the objects to be used are defined in classes. These objects are used during development. Such programming is also called object oriented programming. The C # programming language was developed by Microsoft. It has quickly become one of the most advanced programming languages in object oriented languages. This programming language, which evolves over time, is now used in most places, whether desktop or web applications. It also eliminates the possibility of errors with its advanced compiler (debugger). After the written program is executed, the class and syntax errors detected by the compiler are shown to the developer in detail on a separate screen, and the developer can easily detect and correct errors from this error window. As it is a language used by many programmers, it is possible to get help from different users around the world where coding is difficult (Yusufdinçyar, 2019).

C # is an easy to learn and object-oriented language (Algan, 2009; Sharp, 2009). Therefore, C # is preferred in the development of the software. The developed software uses the C # language in the free Microsoft Visual Studio Community 2017 version, the compiler of the software (MVS, 2019).

2.2. The development of the software

Today, computers have become indispensable for human life. Developing different softwares for computers that are frequently used in many tasks such as receiving, processing and analyzing information provides the user with convenience. Many software has been developed from research to production in petroleum and natural gas and these programs are available in programs that analyze by using different analysis methods.

Well control form is a widely used form that has been proposed to be useful in oil production activities (Akman, 2015). Many calculations are made when creating a well control form, which requires time-consuming operations. In addition, a simple error in these operations causes the control to go wrong during production (Akman, 2019a).

The creation of a well control form is an application that often causes many errors because the processing density is high. Since it takes a separate time to perform these operations in the intensive workplaces, the development of a software provides convenience to the practitioner. A software was developed for this purpose and the equations used in the software are given in Equations 1-19.

These Equations are;

$$MW_{\max} = MW_{test} + \frac{LOP}{0,052.TVD_{shoe}} \tag{1}$$

$$MAASP_f = 0,052.(MW_{\max} - MW_{use}).TVD_{shoe} \tag{2}$$

$$\lambda = \frac{MG}{0,052} \tag{3}$$

$$V = L.C \tag{4}$$

$$S_t = \frac{V}{PC} \tag{5}$$

$$t = \frac{S_t}{VPV} \tag{6}$$

$$V_{sd} = DP_{vol} + HWDP_{vol} + DC_{vol} \tag{7}$$

$$V_{dc}^{oh} = L_{dc}.C_{dc} \tag{8}$$

$$V_{dp}^{oh} = L_{dp}.C_{dp} \tag{9}$$

$$V_{cas}^{dp} = L_{cas}.C_{cas} \tag{10}$$

$$V_{ak}^{oh} = V_{dc}^{oh} + V_{dp}^{oh} \tag{11}$$

$$V_{ta} = V_{ak}^{oh} + V_{cas}^{dp} \tag{12}$$

$$V_{ts} = V_{sd} + V_{ta} \tag{13}$$

$$V_{tac} = V_{ts} + V_{ay} \tag{14}$$

$$KMW = MW_{use} + \frac{SIDPP}{TVD.0,052} \tag{15}$$

$$ICP = SCP + SIDPP \tag{16}$$

$$FCP = SCP.\frac{KMW}{MW_{use}} \tag{17}$$

$$K = ICP - FCP \tag{18}$$

$$P_{st} = \frac{K.100}{SS_f} \tag{19}$$

where; MW_{max}: maximum allowable mud density (ppg), MW_{test}: mud density at leak-off test (ppg), LOP: surface leak-off pressure (ppg), TVD_{shoe}: true vertical depth of casing (feet), 0.052: constant factor, $MAASP_f$: first maximum allowable annular surface pressure (psi), MW_{use}: current mud density weight (ppg), λ: density of mud (ppg), MG: mud gradient (psi/ft), V: volume (bbl), L: heavy weight drill pipe and drill collar length (ft), C: heavy weight drill pipe and drill collar capacity (bbl/ft), S_t: pump strokes (strok), PC: pump capacity (bbl/stroke), t: time (min), VPV: slow pump rate (stk/min), V_{sd}: drill string volume (bbl), DP_{vol}: drill pipe volume (bbl), $HWDP_{vol}$: heavy weight drill pipe volume (bbl), DC_{vol}: drill collar volume (bbl), V_{dc}^{oh}: drill collar volume in open hole (bbl), L_{dc}: length of drill collar (ft), C_{dc}: drill collar annulus capacity (bbl/ft), V_{dp}^{oh}: drill pipe volume in open hole (drill pipes and heavy weight drill pipes are attached to each other and their outer diameters are equal to each other) (bbl), L_{dp}: drill pipe length (ft), C_{dp}: drill

pipe annulus capacity (bbl/ft), V_{cas}^{dp}: casing DP annulus volume (bbl), L_{cas}: casing length (ft), C_{cas}: casing annulus capacity (bbl/ft), V_{ak}^{oh}: open hole volume (bbl), V_{ta}: total annulus volume (bbl), V_{ts}: total well system volume (bbl), V_{tac}: total activate mud volume (bbl), V_{ay}: active surface volume (bbl), KMW: kill mud weight (ppg), $SIDPP$: shut in drill pipe pressure (psi), TVD: true vertical depth (ft), ICP: initial circulation pressure (psi), SCP: system

pressure loss (psi), FCP: final circulation pressure (psi), K: pressure drop (psi), P_{st}: pressure to be reduced every 100 strokes (psi/100 strokes), SS_f: number of first stroke (strokes). The algorithms are at the core of the programming language and can be implemented through them (Cormen et al., 2001). The algorithm of the software is given in Fig. 1.
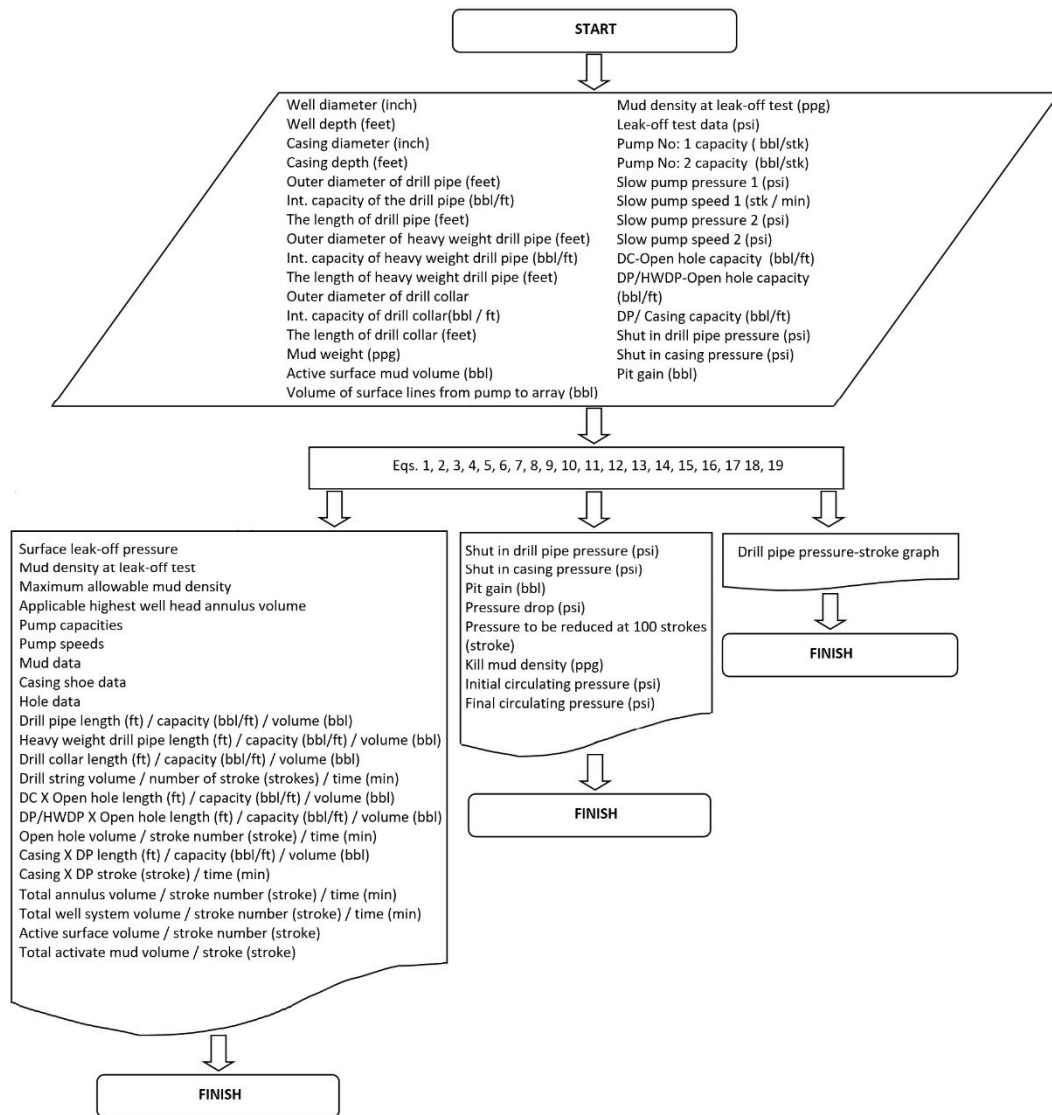
Fig. 1. Algorithm of developed software

3. Developed Software

The software developed within the scope of this study can enter by entering the user name and password. In this study, user name creation and encryption was performed for a single user for trial purposes and another user using the program could not interfere. By spreading the use of the software, this section will be developed to create a new user, user information, such as updating operations can be performed.

The first window that appears when we start running the software is the main window which consists of the user name and password given in Fig. 2. If the user name or password is entered incorrectly, the software gives the warning and (s)he cannot enter the software.

Fig. 2. Main window of the software

By entering the user name and password correctly, the window for the well control accounts will be opened. The software has been developed for the simplest results and is intended for every user, whether they understand it or not. After user input is done correctly, input window is entered in the well control data given in Fig. 3. This panel is the window where data entries are made and the measurable data that must be in the form or used in the calculations are entered in this panel.

In this window, the information about the well is requested to be entered. Well diameter, well depth, casing diameter, casing depth, drill pipe data, heavy weight drill pipe data, drill collar data, mud density, the active surface of the volume of the pump-to-array surface lines of volume, resulting leak-off test and the weight of the sludge used in the test, pump capacity, low pump pressure and speed, the annulus capacity of the pipe, the drill pipe closing pressure, closing pressure casing, including the inlet volume recovery values are entered on this window. When the required information for creating the well control form is entered and click the create well control form button, the well control window shown in Fig. 4 appears. This is the window where transactions are performed and account results are requested.

Fig. 3. Window for entering the well control data of the software

Fig. 4. Well control menu

This window is divided into three main sections: the well control form where the actual data results of the well control form are shown, the form where the revival data are shown and the form where the analysis graphs are generated according to the results of the calculated data. Fig. 5 shows the example of the window by creating the well control form.

In the form of recovery data, the balancing sludge weight, the first circulation pressure, the last circulation pressure, the pressure difference between the first and last circulation and the amount of pressure that must be reduced every 100 strokes can be seen. Drilling pipe closing pressure, casing closing pressure and inlet volume values are transferred as data input. In this well control form, there are the number of current date and time of the formation strength data and the data of the existing well data. An example of the revival form with the results of the revival data is given in Fig. 6.

Another window is the graph window that changes depending on the stroke and drill pipe pressure. The first and last circulation pressure is used when creating the graph. Appropriate graphics are created based on the results of this data. With these graphs, necessary analyzes can be made and an example graph is shown in Fig. 7.

4. Result and Discussion for an Application

The transactions made with the developed software shortens the account time and prevents the user from making mistakes. In order to investigate the accuracy of the developed software, many samples were experimented and well control forms were created for all of them. The results of the software developed with a sample taken from Akman (2019b) were checked.
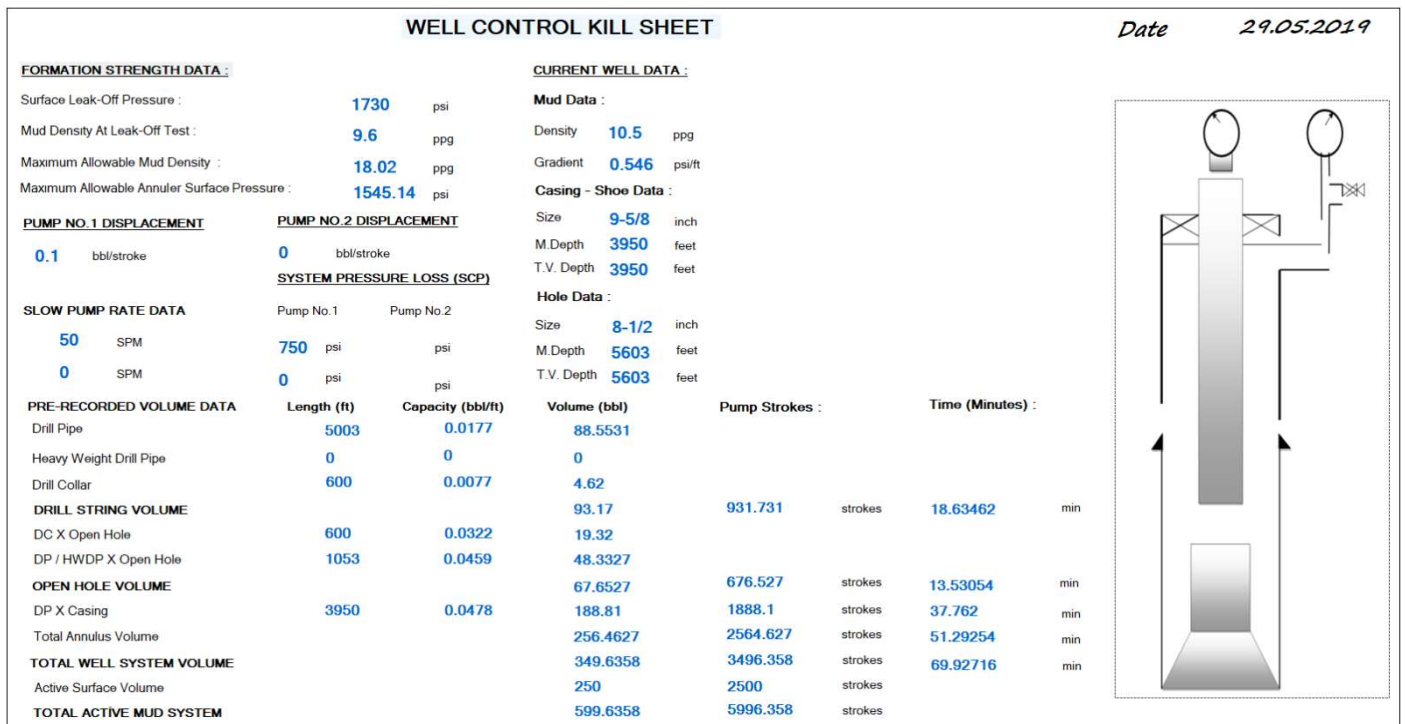
WELL CONTROL KILL SHEET

Date 29.05.2019

FORMATION STRENGTH DATA :

Surface Leak-Off Pressure :	1730	psi
Mud Density At Leak-Off Test :	9.6	ppg
Maximum Allowable Mud Density :	18.02	ppg
Maximum Allowable Annuler Surface Pressure :	1545.14	psi

PUMP NO.1 DISPLACEMENT

0.1 bbl/stroke

PUMP NO.2 DISPLACEMENT

0 bbl/stroke

SYSTEM PRESSURE LOSS (SCP)

SLOW PUMP RATE DATA

		Pump No.1	Pump No.2
50	SPM	750 psi	psi
0	SPM	0 psi	psi

CURRENT WELL DATA :

Mud Data :

Density	10.5	ppg
Gradient	0.546	psi/ft

Casing - Shoe Data :

Size	9-5/8	inch
M.Depth	3950	feet
T.V. Depth	3950	feet

Hole Data :

Size	8-1/2	inch
M.Depth	5603	feet
T.V. Depth	5603	feet

PRE-RECORDED VOLUME DATA	Length (ft)	Capacity (bbl/ft)	Volume (bbl)	Pump Strokes :		Time (Minutes) :	
Drill Pipe	5003	0.0177	88.5531				
Heavy Weight Drill Pipe	0	0	0				
Drill Collar	600	0.0077	4.62				
DRILL STRING VOLUME			93.17	931.731	strokes	18.63462	min
DC X Open Hole	600	0.0322	19.32				
DP / HWDP X Open Hole	1053	0.0459	48.3327				
OPEN HOLE VOLUME			67.6527	676.527	strokes	13.53054	min
DP X Casing	3950	0.0478	188.81	1888.1	strokes	37.762	min
Total Annulus Volume			256.4627	2564.627	strokes	51.29254	min
TOTAL WELL SYSTEM VOLUME			349.6358	3496.358	strokes	69.92716	min
Active Surface Volume			250	2500	strokes		
TOTAL ACTIVE MUD SYSTEM			599.6358	5996.358	strokes		

Fig. 5. Well control kill sheet

KILL MUD DENSITY (KMD)	INNITIAL CIRCULATING PRESSURE (ICP)	FINAL CIRCULATING PRESSURE (FCP)
12.59 ppg	1560 psi	899.54 psi

SIDPP	:	610	psi
SICP	:	775	psi
Pit Gain	:	12	bbl
Pressure Drop	:	460.45	psi

100 strokes need a reduction : 49.41 psi/100 strok
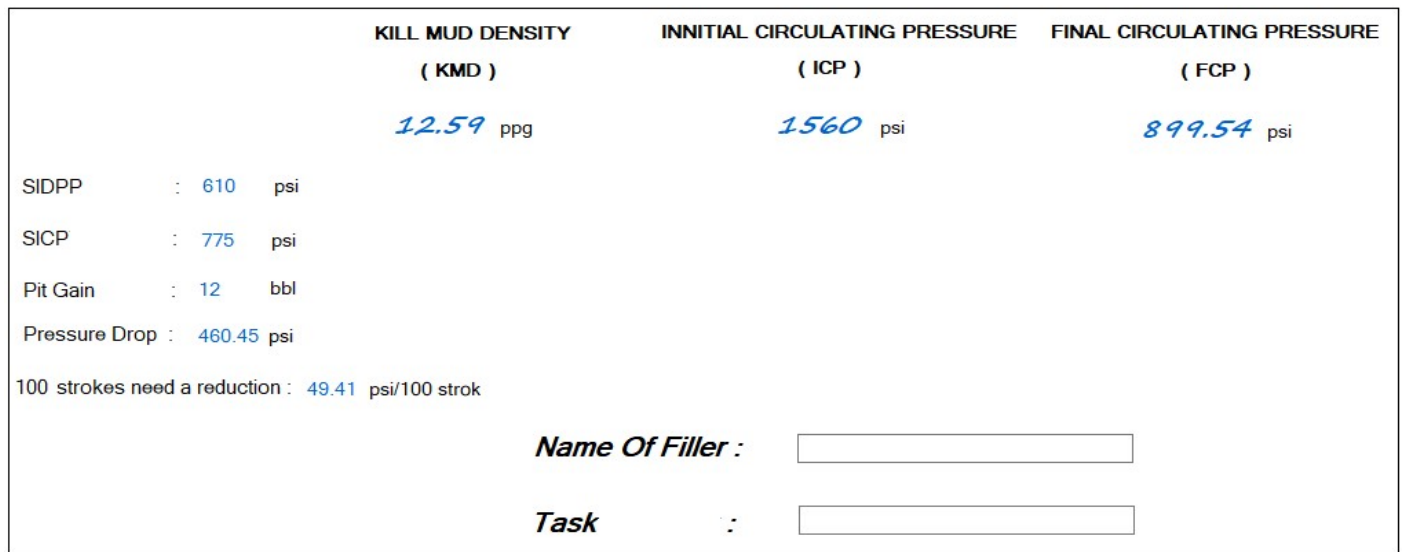
Name Of Filler :

Task :

Fig. 6. The kick and drill pipe pressure data

The well information of an application made as an example and measurement data obtained from the closed well after revitalization is given in Table 1 and 2, respectively. The leak-off test (9.625 inch) was performed with a test sludge of 9.6 ppg in the depth of the casing shoe and the surface leak-off pressure (LOP) = 1730 psi. The well control form was created and values to help in production stage were calculated with the software. These results are indicated in the well control form through the software. Many time-consuming operations that are difficult to do by hand can be performed easily with the software. Well control form and revival data form created by using software and given in Table 3.
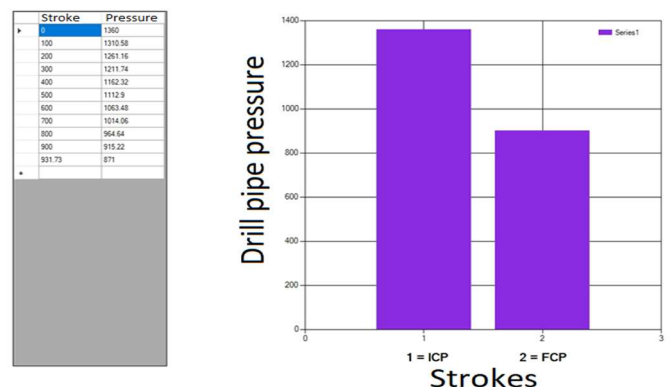
Stroke	Pressure
0	1360
100	1310.58
200	1261.16
300	1211.74
400	1162.32
500	1112.9
600	1063.48
700	1014.06
800	964.64
900	915.22
931.73	871

Fig. 7. Drilling pipe pressure graph for 2 different strokes

Table 1. Well information (Akman, 2019b)

Well Information	Value
Well diameter	8,5 inch
Depth of well	5603 feet MD=TVD
Casing	9,625 inch MD=TVD 3950 ft
Drilling pipe	5 inch
Internal cap. of the drill pipe	0.0177 bbl/ft
Heavy drill pipe	Unconnected, none
Drill collar	6,25 inch
Drill collar length	5003 feet
Mud weight	10.5 ppg
Active surface volume	250 bbl
Casing-Open well	0.0322 bbl/ft
DP/HWDP-Open well	0.0459 bbl/ft
DP/ Casing	0.0478 bbl/ft

applicable maximum mud weight = (*) calculated

Table 2. Measurement data taken from closed well after revitalization

Measurement	Values
Shut in drill pipe pressure (SIDPP)	610 psi
Shut in casing pressure (SICP)	775 psi
Input volume	12 bbl

Table 3. Well control and revival data obtained from software

Result	Value
Maximum allowable mud weight	18.02 ppg
Maximum allowable annular surface pressure	1514.14 psi
Mud gradient	0.546 psi/ft
Drill pipe volume	88.5531 bbl
Casing volume	4.62 bbl
Internal volume of drilling sequence	93.1731 bbl
Internal volume of stroke number of stroke	931.731 str
Internal volume of drilling sequence time	18.63 min
The drill collar volume in open hole (V_{dc}^{oh})	19.32 bbl
The drill pipe volume in open hole (V_{dp}^{oh})	48.3327 bbl
Open well volume	67.6527 bbl
Number of open well volume strokes	676.527 str
Open well volume time	13.53054 min
The casing drill pipe annulus volume	188.81 bbl
The casing drill pipe annulus stroke	1888.1 str
The casing drill pipe annulus time	37.762 min
Total annulus volume	256.4627 bbl
Total annulus volume strokes	2564.627 str
Total annulus volume time	51.29254 min
Total well system volume	349.6358 bbl
Total well system volume strokes	3496.358 str
Total well system volume time	69.92716 min
Active surface volume	250 bbl
Active surface volume strokes	2500 str
Total activated sludge volume	599.6358 bbl
Total active sludge volume strokes	5996.358 str
Pressure drop (K)	460.452 psi
Pressure to be reduced at 100 strokes	49.42 psi/str
Balancing mud weight (KMW)	12.593 ppg
Initial circulation pressure (ICP)	1360 psi
Final circulation pressure (FCP)	899.547 psi

5. Conclusion

Well control is applied in order to keep the well under control safely and to keep the intra-well annulus pressures at the lowest value during well control. An appropriate drilling program is prepared to ensure well control based on the available field data. The most important stage of the drilling program is the preparation of the well control form. The well control form is a separate time-consuming workload.

In this study, a software has been developed which can reduce this workload and create well control form easily. With the software, the drilling program can be controlled more easily. This developed software has been tested on many samples and confirmed to be accurate. A sample evaluation is presented in the study. The results of the study are listed below.

- Software developed in the field of oil and well control was investigated. Lack of such software has been seen.

- As a result of the research, a computer software which forms the well control form has been developed in order to eliminate the deficiency in this area.

- Simple interfaces, this software is very easy to use because of the visual.

- Well control form is formed after calculation by entering some data in the software.

- In addition, a revival data form is created.

- Thanks to the software, the graphs are easily analyzed.

- The development of these and similar software in drilling activities will facilitate drilling activities.

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