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Swab – Surge Pressure Investigation, and the Influence Factors, Prediction and Calculation (Review)

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Abstract

Surge pressure is supplemental pressure because of the movement of the pipes downward and the swab pressure is the pressure reduction as a result of the drill string's upward movement. Bottom hole pressure is reduced because of swabbing influence. An Investigation showed that the surge pressure has great importance for the circulation loss problem produced by unstable processes in the management pressure drilling (MPD) actions. Through Trip Margin there is an increase in the hydrostatic pressure of mud that compensates for the reduction of bottom pressure due to stop pumping and/or swabbing effect while pulling the pipe out of the hole. This overview shows suggested mathematical/numerical models for simulating surge pressure problems inside the wellbore with adjustable cross-section parts. The developed models require simple input data that may be gotten from the rig location. Pressure variations due to Swabs and surge has been a major concern in the oil industry for numerous years. If the pressure variations become moreover extraordinary, this leads to formation fracture, and formation influx principal to a kick. In the worst circumstances and situations that kick principal on the blowout and put crew life in hazard. By using theoretical investigation and experimental consequences, it established that the surge pressure is a function of the well depth, the drilling tools combination, the diameter of the wellbore, drilling mud properties, drilling pipe operation speed, and acceleration of the drill pipe movement, etc. This review focuses and investigates the essential theory and on software that computes the pressure variations in different flow conditions to predict surge and swab pressure values.

Keywords: surge, swab, pressure, oil well, drilling operation, trip.

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1- Introduction

Surge pressure is always generated during fluid movement as a result of the devices moving into the well filled with drilling fluid. As for the swab pressure, it is related to the movement of fluids caused by the devices being pulled out of the well filled with drilling fluid. It is generally clear that the process of withdrawing and operating the tube can cause a pressure rise. The process of predicting the rise of that pressure is considered economically important in wells, as maintaining the pressure within the narrow restrictions reduces the loss of mud circulation and reduces the flow of the formed fluids. Mitchell, 1988 [1] suggested a dynamic surge/swab model, the richest technology at that time was with the following: pressures of annulus and pipe are joined of the elasticity of the pipe; The flexibility of longitudinal pipes as well as the viscosity forces of fluids determine the displacement of the pipes; The properties of fluids are different as a function of pressure and temperature. Swab and surge pressure is a recognized matter in the oil industry, Fig. 1 and Fig. 2. show the swab and surge pressure effect and assemblies. In 1934, there was a survey by Cannon that detected as a possible cause of the outflow into the wellbore. Cannon deliberated the problems by way of “a likely reason of fluid influx, and dangerous circumstances of blowouts”. In 1951 Goins linked the increase in pressure with the lost circulation. Surge and swab pressures are the reason for a variation in the value of hole pressure, subsequent in to extraordinary pressure [3]. Approximately studies applied quantitative techniques for predicting the pressure differences downhole accounting for only the drag and viscous motionless pipe wall for the Newtonian fluids for both flow regimes, turbulent and laminar [4]. Lubinski (1977) developed a completely dynamic unsteady-state model related to surge and swab pressure. He demonstrated the transient motion of the drill string and the surge /swab pressure that happens because of the exchange of the drill string [5]. The methods used to quantify these pressures are similar to those used to calculate pressure losses during normal circulation of drilling mud [6].

In order to reduce the problems of calculations, the surge pressure is calculated by determining the swab pressure and assuming that this pressure is equal to the surge pressure when using the same speed of movement of pipes and devices [7]. The value of the surge pressure or swab is very important because more than 25% of the eruption cases are the result of reducing the pressure in the well directly to the state of the swab when withdrawing the pipes, in addition, high swab pressures

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lead to the problems of losing the drilling fluid circulation during the drilling of the well or the process of lowering the lining into the well [8]. The drop in pressure due to the withdrawal of the pipes may result in contamination of the drilling fluid as a result of the entry of the rock formation fluids into the well and this may result in an increase in the costs of treating the drilling fluid [9]. When the pipes move down into the well, the drilling fluids will move up and similarly, when the pipes move up, the fluids will move downwards [10].

The flow pattern of moving fluids can be either laminar or turbulent flow depending on the speed with which the tube moves inside the well, where it is possible to derive the necessary mathematical equations to calculate the pressure of surge or swab in the case of laminar flow, but in the case of turbulent flow, empirical relationships must be used [11].

Basic differential equations that describe laminar flow through circular tubes are used to predict the motion of tubes within fluids, in addition to their use for fluid motion within tubes, but there is, however, a difference in boundary conditions between the two cases [12]. It is possible to derive the surge pressure equation for non-Newtonian fluids using the power law model or the plastic Bingham model, where the equations can be obtained by changing the boundary conditions on the well wall. Since there are no specially developed equations for calculating surge pressure in turbulent flow, Barrdhard [13] gave a relationship to the adhesion constant of clay K, which helped to derive all these annular space equations for surrounding circular pipes.

The pressure required to break the gel texture of the clay and the circulation of the drilling fluid began to be called the pressure of surge due to the cracking of the gel resistance, and it was explained by Melros [14].

2- Surge and Swab Pressure Calculation and Prediction

The effects of swab pressure and surge have been known since an early age, i.e. since 1934, when Cannon was interested in the eruptions that may occur in normal pressure wells. Although the density of the used drilling fluid gives hydrostatic pressures greater than the measured pore pressures of rock formations, yet the phenomenon of eruption occurs in the well [16]. In order to examine this problem, Cannon conducted a series of experiments in order to measure the real pressures of extraction and dates. Table 1 shows the results of the Cannon experiments.

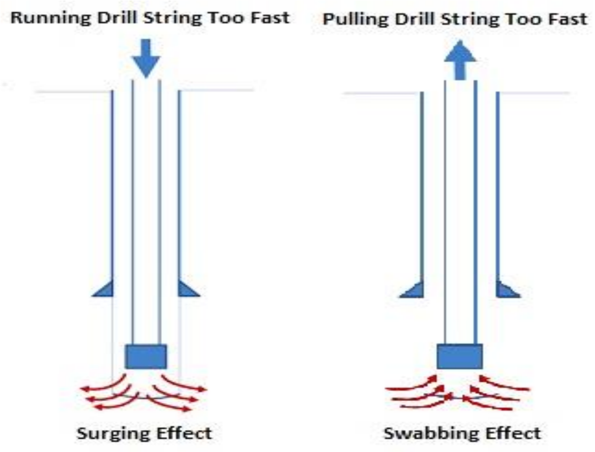

Fig. 1. Surge and Swab Pressure Effect [2]

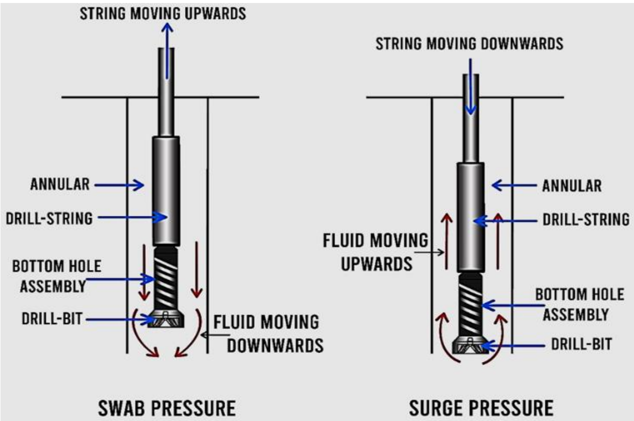

Fig. 2. Swab and Surge Pressure with Drill String Assemblies

Table 1. Cannon's Experiment and His Results [2]

Annulus size inch	Depth ft.	Gel Strength lb./100ft^2	Surge pressure psi
10^3/4 casing size ,4^1/2 drilling pipe size	7000	36	275
	7000	12	125
	3000	36	125
	3000	12	62
7 casing size ,3^1/2 drilling pipe size	7000	60	487
	7000	36	462
	7000	6	362
	3000	60	212
	3000	36	200
	3000	6	160

His tests were conducted at various depths and for different diameters of wells, and the cohesion of mud measured in terms of the resistance of the gel. It was found that the pressure of surge at a depth of 7000 feet using a drilling fluid with a resistance of 36 inside the annular space with a liner diameter of 7 equals 462

pounds per square inch. His examinations showed that the value of surge pressure is directly proportional to the depth. For example, the surge pressure value at a depth of 3000 feet equals 200, while at a depth of 7000 feet, it equals 462 pounds per square inch for a drilling fluid with 36 gel resistance [2].
insufficient studies tried to clarify the quantitative techniques for predicting pressure differences downhole related to the viscous drag and motionless pipe wall for the Newtonian fluids for both turbulent and laminar flow regimes [17]. Field or documented pressure is frequently unobtainable; nevertheless, few analyses have collected relevant [18]. Fig. 3 contains information for confirming the downhole pressure differences. Where the figure below shows a schematic diagram of the pressure change measurements inside the well during the lowering of one pipe connection at a depth of about 1850 feet [19].

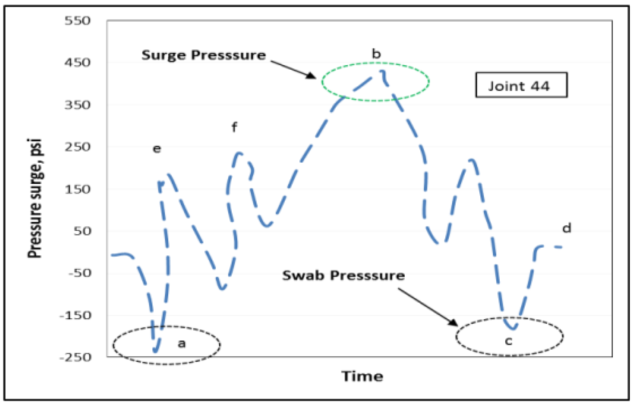

Fig. 3. Swab and Surge Pressures through Landing a Casing Joint with Time [19]

The basic differential equations that describe laminar flow through circular pipes are used to predict the movement of pipes within fluids and vice versa. The following equation can be used that represent fluid flow inside pipes [20].

$$dpf/dL = -\mu V/1500d2 \quad (1)$$

Where: μ= fluid viscosity, cp. V= The average velocity of the fluid in the pipe, m/min. d= The inner diameter of the pipe, inch.

The effect of the velocity of the drill string on the values of surge and swab pressures is studied by Burgoyne [21] and as shown in Fig. 4. It is gotten that the high the trip speed means high pressure alteration in the well. Furthermore, pressure variations become less sensitive to the tripping speed when the fluid works as shear thinning with lessening the flow behavior index.

Surge pressure due to the inertia of the mud is due to the resistance of the drilling mud shaft to changes in motion as is evident from Newton's law of motion [22] as in Eq. 2:

$$F = ma = \rho va \quad (2)$$

Where: ρ=fluid density, v=fluid volume, a=acceleration, and the pressure of surge caused by force F is calculated from Eq. 3:

$$dp = F/Da = \rho va/Da = \rho adL \quad (3)$$

Where for open-ended pipes, fluid acceleration occurs both inside and outside the pipes, as in Eq. 4:

$$dpa/dl = 0.00162\rho\,(D1 - D2)/(D1 - D2) \quad (4)$$

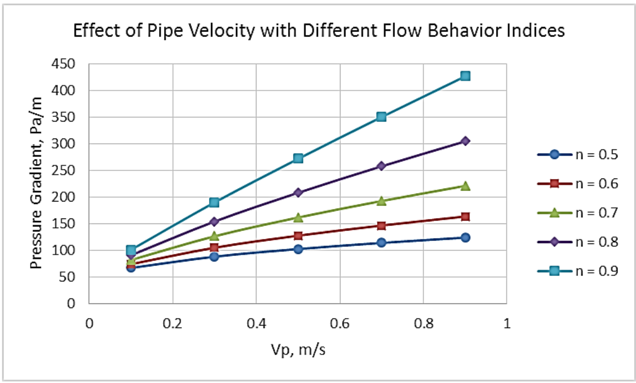

Fig. 4. Effect of the Velocity and Flow Behavior Index [21]

There is an approximation method for calculating the pressure of viscous swabs, and its basic idea is to simplify to obtain approximate equations, and then simplify the equation and put it in terms of pipe velocity, properties of drilling fluid, well diameter, and drilling pipe dimensions [23]. Using an efficient electronic calculator, and by performing calculations on more than 500 wells using a range of different diameters and clay properties, Eqs. 5, 6, 7, and 8 were obtained [24].
Eq. 5 is used for laminar flow for the closed ended pipes.

$$ps = B\mu pVp + \tau y/(0.3\,(D2 - D1)) \quad (5)$$

Eq. 6 is used for the turbulent flow of the closed ended pipes.

$$Ps = A\mu p\text{^}0.21Vp\text{^}1.8 \quad (6)$$

Eq. 7 is used for the laminar flow of the open ended pipes.

$$Ps = \beta\mu pVp + \left(\frac{\tau y}{0.3(D2-D1)}\right) \quad (7)$$

Eq. 8 is used for the laminar flow the open ended pipes.

$$Ps = \alpha A\mu pP\text{^}0.21\rho\text{^}0.806Vp\text{^}1.8 \quad (8)$$

Where: Ps: swab pressure, psi. A, B, α and ß: constant. D1and D2: pipes diameter, inch. $\mu_{p:}$ fluid viscosity, cp. τy: shear stress lb./100ft^2. Vp: pipe velocity ft./sec. ρ: fluid density, ppg.

The numerical model was developed by Chukwu [25] for predicting the surge and swab pressures by simulating the downhole pressure variations happening through tripping in wells. Their model uses the current variable narrow-slot guesstimate technique for accounting for the pipe eccentric for surge pressure control. The program was created by using EXCEL, based program which computes the pressure variations in the well because of surge and swab. The processes of programming the input data for checking if the flow is turbulent or laminar [26].

It is desirable to know the calculations carried out by the program, for example, it is possible to observe the pressure change at the lower orifice assembly. or the entire system, as shown in Table 2. Where the change of positive or negative pressure is given by the pressure of the new bottom hole [27]. It can be observed that if the new bottom hole pressure is greater than the formation fracture pressure, the following statement will appear that "The wellbore pressure is higher than the formation fracturing pressure". But in the event that the pressure was within the limits of the fraction, no statement or warning will appear [28], as shown in Table 3.

Table 2. Input Fragment for Calculating Surge and Swab Pressure [27]

surge and swab q1pressure (input data), general information		
Diameter drill string	0,1397	m
mud density	1200	kg/m^3
formation pressure	320	bar
wellbore pressure	350	bar
borehole diameter	0.3048	m
velocity drill string	0.4673	m/s
dynamic viscosity	0.0042	pa*s
length of section	50	m
flow	0.01	m^3/s
area wellbore	0,072928	m^2
area drill string	0.01532	m^3
power law constant	1	
flow behavior index	0.33	
fanning friction factor	0.102397	
fluid velocity	0.1	m/sec

Table 3. The Output of the Program that Calculates Surge and Swab Pressure [28]

OUTPUT FOR THE CALCULATION SHEET			
Surge and swab pressure change			
pressure loss over BHA	YES	31,114	Bar
Pressure loss over the drill string	YES	66,039	Bar
total pressure change due to surge and swab pressures	YES	97,153	Bar
New pressure in a well pore, when the pressure change is added			
bottom hole pressure	350		Bar
total pressure change due to surge and swab pressures	297,153		Bar
new bottom hole pressure	379,715		Bar
wellbore pressure is higher than formation pressure !!!!			

Surge and swab is a recognized problem for the drilling operations. Investigators have been examining this problem in many researches [29]. Surge and swab pressures mention to pressure variations because of dropping or retreating the assembly from the hole [30]. Surge and swab pressure variations are may be negative or positive [31]. positive when dropping the pipe down and negative when retreating the pipe up [32]. The strength of those pressure variations be contingent on the lowering the speed in other words, (tripping in) or retreating of the pipe out in other words, (tripping out). When the speed of the tripping is too high, the equivalent pressure variation is also high and will be higher than the formation fracture pressure [33]. High surge pressure reason for the formation fracturing, but high swab pressure leads to partial or in approximately cases full fluid losses, however for the worst-case situation well collapse may occur when the speed is very low, which will lead to a sluggish tripping operation, and that is reflected to the non-productive time (NPT) [34].

Dewitte, [35]. presented a work to predict the maximum surge and swab pressures, the differences of surge and swab in the time domain at the bottom of the wellbore as in Eqs. 9 to 12. The computer program correspondingly makes caution influx for the swab or lost circulation for the surge.

$$\partial p/\partial z+ p*A*g*\partial t+hf\,(q, vp) =0 \tag{9}$$

$$\partial p/\partial t+s*\partial q/\partial z=0 \tag{10}$$

$$S=Pc/A \tag{11}$$

$$c=g/\rho(\alpha+\beta) \tag{12}$$

Where: q: flow rate bbl./s. A: cross section area in2. S: force lb./ft2. C: constant. g: acceleration. ρ: density ppg. t: time min. α, β: constant. ∂p: pressure change. ∂z: depth change. ∂t: time change. Pc: predicted pressure.

3- Discussion and Conclusions

Aspects that affect surge and swab pressures should be exactly designated with the intention of control kicks or blowouts and to prevent loss of circulation. In this review a sensitivity investigation is done to examine the effect of some parameters on the values of swab and surge pressures.

1-The analysis is established on the theory of hydrostatic drilling fluid mechanics, taking the effect of drilling mud model and flow type. Also, investigating the developed equations for computing and predicting the surge and swab pressures. In addition to discussing the output of the used program to get graphical form from which effects of drilling fluid properties, drill string tripping velocity, and hole diameter; on swab and surge pressures.

2-Good speeds of tripping are significantly prejudiced by size of the hole. In other words, the value of tripping speed is the individual controlling factor with reverence for controlling swab and surge pressures.

3-Substantial swab and surge pressures happen though moving the drill string.

4-Swab and surge pressures have high values when the diameter ratio upsurges.in other words, for slight annulus the pressure is extra noticeable likened to the surge and swab pressures at an extensive annulus.

5-The optimization of tripping limitations and assurance the wellbore stability is an important factor. Many models, programs, and equations are used for this. For an

open-ended pipe, there is an increase in the difficulty of the calculations significantly.
6-The pressure drops in the annulus and drill string are preferred to be equal. Meanwhile, different geometries occur, though, flow rates in the annulus and pipe will not be identical. Furthermore, it is preferred that the flow in the pipe will be turbulent while in the annulus is preferred to be laminar
7- Many steps may be used to minimize the swab and surge effect for instance, preparing good drilling fluid conditions, withdrawing of hole with sensible speed, using lubricant additives to keep good hydraulic for preventing bit or bottom hole assembly from balled up, and finally, using chemicals for preventing the clay swellings.
8-. Finally, it can be said that most instability well problems happen through tripping in/out operations, because of surge-swab pressures produced by the movement of the pipe string.

Nomenclature

µ: fluid viscosity
ty: shear stress
MPD: management pressure drilling
ρ: fluid density
v: fluid volume
Ps: swab pressure
D: Pipe diameters
a: acceleration
A, B, α, and ß: Constant
NPT: productive time

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الخلاصة

يمكن تعريف ضغط الاندفاع بانه ضغط يحدث نتيجه حركة الأنابيب للأسفل اما ضغط السفط يحدث بسبب انخفاض الضغط نتيجة لحركة انابيب الحفر للأعلى. تعتبر دراسة والتحقق في زيادة ضغطي الاندفاع والسفط ذات أهمية كبيرة لمعالجة مشكلة فقدان دورة سائل الحفرالناتجة عن العمليات غير المستقرة اثناءعمليات الحفر. خلال ادخال انابيب الحفر توجد زيادة في الضغط الهيدروستاتيكي للطين الذي يعوض عن انخفاض ضغط القاع بسبب توقف الضخ و / أو تأثير المسح والعكس صحيح اثناء عملية سحب الأنابيب من البئر. ان هذه المراجعه ركزت على معادلات للتنبؤ بزيادة الضغط الناتج عن عمليات ادخال واخراج الانابيب وذلك باستخدام الاستقصاء النظري والنتائج التجريبية لباحثين بحثوا في هذا المجال. ثبت أن ضغطي الاندفاع والسفط هما دالة لعمق البئر، ومجموعة أدوات الحفر، وقطر البئر، وخصائص طين الحفر، وسرعة سحب وادخال أنابيب الحفر، وسرعة حركة أنبوب الحفر. يمكن القول أن بعض مشاكل البئر غير المستقرة تحدث من خلال عمليات الدخول / الخروج للانابيب، بسبب ضغوط السفط والاندفاع الناتجة عن حركة سلسلة الأنبوب بالاضافه لذلك يجب اجراء حسابات خاصه بسرعه انزال الانابيب واخراجها وذلك للتقليل من مشاكل الابار اثناء سحب واخراج الانابيب. تتضمن هذه المراجعه العامة نماذج رياضية / رقمية لمحاكاة مشكلة ارتفاع او انخفاض الضغط داخل حفرة البئراثناء انزال او اخراج الانابيب حيث يكون تدفق السوائل الناتج عن حركة أنبوب الحفر له تاثير كبيروقابل للضغط. ركزت هذه المراجعة على النظرية الأساسية لضغطي الاندفاع والسفط والتحقيق فيها وعلى البرامج التي تقوم بالتنبأ بتغيرات الضغط في ظروف التدفق المختلفة للتنبؤ بقيم ضغطي الاندفاع والسفط.

الكلمات الدالة: الاندفاع، السفط، ضغط، بئر نفطي، عمليات حفر، رحلة.