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Comparison of Pressure Drop in Horizontal Wellbore for 90 and 180 Perforation Phasing

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***Abstract*— In this paper, numerical study was conducted on perforated pipes with phasing angle 180 and 90 respectively. The calculation were carried out with ANSYS FLUENT 15.01 using k- (RNG) model. It concluded from results there is no change in acceleration and frictional wall pressure between 180 and 90 perforation phasing. Total pressure drop in 90 perforation phasing has the highest value compared with 180 phasing angles due to intensified influence of mixing pressure drop. The decreases in additional pressure drop in 90 phasing has the lower value in compared to additional pressure drop at 180 phasing this is due to intensified influence of mixing effects pressure drop.**

Keywords— ***: Horizontal well, perforation, perforation phasing, total pressure drop, additional pressure drop***

1. Introduction

Horizontal Direction Drilling can be define as a trench less method of installing piping underground with other capable systems along predetermined path this system installing by the use of highly specialized drilling equipment. The productivity of a horizontal well is two to five times more than the productivity of a vertical well. This productivity improvement occurs because of the contact area between the reservoir and the well. It usually suitable to drill the horizontal well as long as possible under the assumption of infinite conductivity. Infinite conductivity and uniform flux is the most assumptions used in studying of horizontal well. The infinite conductivity assume no pressure drop along the well in facts (the pressure drop is negligible because is very small), while the uniform influx mean the influx is constant during the well. Dikken, (1990) [1] simple semi-Analytical model was presented on single phase turbulent flow to stabilized reservoir flow. Concluded that flow inside horizontal wellbore non laminar (transition or turbulent). Asheim et al., (1992) [2] developed experimental and numerical model to study the effect of friction factor due to both wall friction and inflow of fluid through perforation on. Since the inflow disturbs the main flow velocity profile in the pipe so that influence on the pressure gradient along the well. The test section that conducted the experiments on it contains one or two inlet ports and taps to measure pressure differences.

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The total pressure loss is explained as the sum of the wall friction loss and inflow effects . The wall friction factor was found by measuring the pressure drop without injection through the perforation. The pressure drop due to fluid inflow was found by subtracting the pressure drop due to wall friction. The wellbore flow resistance developed excellent correspondence was obtained for inflow through ports less than three times the main flow velocity. The equivalent friction factor due to inflow through perforation

where the first term in the right hand represent wall friction factor (with no injection case) and the second term is friction factor due to inflow.

q is pipe flow rate and is inflow rate per unit length

Su and Gudmundsson, (1993) [3] experimental Study made to analyze the friction factor of perforation roughness of perforated pipe. It was concluded from the results that friction factor of perforation phasing increases linearly with perforation density where there is no overlap between two adjacent perforations and the friction factor decreases while the Reynolds number increase. Whenever perforation diameter increase lead to increase friction factor. Ihara and Shimizu, (1993) [4] an experimental and computer model was developed to study the effect of acceleration pressure drop in horizontal wellbore. The computer model including the accelerational pressure drop as well as the frictional pressure drop. The relative magnitude of pressure drop due to acceleration is estimated to know what that condition the acceleration pressure drop became important in horizontal wellbore. Arshad et al., (1994) [5] A computer model was developed to Study the effect of well pressure drop in horizontal well production performance. Arshad was developed correlation and that correlation results of two phase experimental studies and mathematical modeling used to study the effect of single and multiple perforation pressure drop along the pipe and used air and water as fluid. The pressure drop in horizontal wellbore that causes by frictional and fluid inflow don't change frequently the overall production rate in compared to constant well pressure in the well. Su and Gudmundsson, (1994) [6] experimental study made on perforated pipe. Concluded from the result the total pressure drop in horizontal wellbore consist of reversible (acceleration) pressure drop due to momentum change from velocity and irreversible pressure drop is due to wall friction ,perforation roughness and mixing effect. Yuan et al., (1996) [7] studied the flow behavior in horizontal wells with single perforation and with multi perforation with densities 1, 2and 4 SPF the flow considered to be single phase liquid flow. It was concluded that the friction factor for perforated pipe with inflow can be either smaller or greater than for smooth pipe depending on the ratio of inflow to main flow rate. Perforation density also affected influx to main flow rate ratio directly so affected the velocity field. Ouyang et al., (1997) [8] developed single phase wellbore model to study the importance of frictional and accelerational on pressure drop in horizontal wellbore. The results show accelerational pressure gradient may or may not be important compared to frictional pressure dependent to the properties of the fluid, specific geometry of the pipe and conditions of the fluid. Yuan et al., (1997) [9] an experimental and theoretical model was conducted to predict horizontal well friction factor for single injection point. From results of experimental data new correlation friction factor was developed by applying it in expression of apparent friction factor. The friction factor correlation that was developed compared with Asheim et al (1992) data and model and found that new correlation is better than Asheim et al (1992) model. Yalniz and Ozkan, (1998) [10] developed an experimental and theoretical model to study the effect of inflow through perforation in horizontal well and correlates this effect in apparent friction factor. From result can be concluded that when there is no flow through perforation the friction factor reduced compared to un perforated section of pipe and the inflow through perforation caused additional pressure drop. The results of this study developed friction factor that is function of inflow to main pipe flow rate ratio and perforation to well diameter. M. Abdulwahid 2013 [11] numerical studied by using ANSYS FLUENT on pipe the physical model of that pipe is partly perforated and regular pipe without perforation the length of pipe 1300 mm and ID=22 mm with 60 perforation phasing, 6 SPF perforation density and Reynolds number ranged from 28773 to 90153. It was concluded that total pressure increases according to larger acceleration pressure drop for higher flow rate through perforations and the increases in perforations number increase total pressure drop and vice versa. Total pressure drop in whole pipe was greater than the value in perforated suction. Azadi et al., 2017 [12] 3D CFD model was developed to steady the fluid flow through perforated pipe wellbore surrounded by porous media. The model that used to observation the influence of perforation density, diameter and phasing angle on the friction factor on the wall of the pipe and pressure drop along the perforated pipe. The results show that increase of number of perforation give rise to higher friction factor and shear stress as well as greater pressure drop along the pipe. The wall friction factor independent the perforation density. It is also spotted that the overall pressure drop has the highest value for 90 perforation phasing angle comparing to other phasing. The pressure drop grows with increasing with velocity for turbulent flow with higher Reynolds number.

2. Model Description

The calculation were carried out with ANSYS FLUENT 15.01 using k- (RNG) model. Two test pipe developed, first pipe with 400 perforations sets in two lines with phasing 180 each line have 200 perforations the length of pipe that drawing in ANSYS WORKBENCH is 1.02 meter with 24 mm

Table 1-Parameters of perforated pipe

Item	Pipe 1	Pipe 2
I. D	24 mm	24 mm
Perfo. D	3 mm	3 mm
No. Perf	400	800
Perf. Phasing	180◦	90◦
Perf. Density	122	122
Length of pipe	1.02 m	1.02 m

3. Simulation Parameters

The working fluid that used is water with constant density 998.2 kg/m^3 and viscosity of 0.001003 kg/m s as table 2. This results that conducted for several flow rates to observe the flow in perforated pipe in all these models. The pipe has 0.03 mm roughness. Table 3 represents the case study.

Table 2- The properties of working fluid (Water) used in simulation

Fluid	Density	Viscosity
water	998.2	0.001003

Table 3- case study

Flow Tests	Inlet Flow Rate lit/hr	Perforation Inlet Flow Rate lit/hr	Outlet Flow (Re)
Test 1	5540	0-685	81211.4-91182.9
Test 2	4533	0-798	66473.6-78115.5
Test 3	3843	0-760	56370-67447.8
Test 4	1627	0-663	23885.8-33552.5

4. The assumption of the study

1. The flow is to be a single phase.
2. The flow is steady state.
3. The fluid to be an incompressible Newtonian fluid (used water as working fluid through pipe).
4. The flow is isothermal .
5. The flow is turbulent.
6. No heat transfer between the system and surrounding.
7. No mechanical work done by or on the fluid (passage of water through pipe).

Fig.1 represents the type of the mesh methods
Table 4 represents mesh properties.

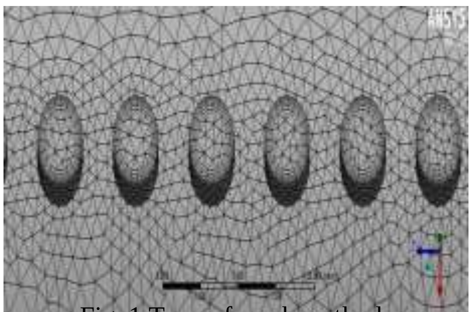

Fig .1 Type of mesh methods

Table 4- Mesh properties

No.P	Nodes	Elements	Mesh metric
400	731927	2207569	Skewness
800	1374887	4149594	Skewness

5. Mathematical Modeling

5.1 Governing Equation Of Fluid Flow

5.1.1 Thecontinuityequation

(1)

The continuity equation for flow in Cartesian coordinates in three dimensions is:

$$- \quad - \quad - \qquad (2)$$

5.1.2 The Momentum Equation

(3)

5.1.3 Classification of pressure drop in perforated pipe

Total pressure drop in perforated pipe can be calculated from

(4)

The total pressure drop can be divided into acceleration pressure drop (momentum change), wall friction pressure drop and additional pressure drop (which is the sum of perforation roughness and mixing pressure drop). The first term in RHS is the pressure drop caused by axial velocity change (net momentum increase).

(5)

Where the mean velocity at the inlet and outlet of wellbore. The second term in RHS is the pressure drop caused by wall friction. The pressure drop due friction of pipe wall for all types of fully developed in wellbore internal flows (laminar or turbulent flow) and for smooth or rough surface is based on mean velocity at the out left of wellbore calculated from Darcy_weisbach equation 1986.

$$- \; - \qquad (6)$$

: length of the pipe, D is the diameter of the pipe,
The friction factor in turbulent pipe flow is Haaland (1983) equation

$$[\; [- \quad -] \;] \qquad (7)$$

6. Results and Discussion

In this paper, numerical study was conducted on perforated pipes to calculate the influence of perforation phasing on acceleration, frictional, additional and total pressure drop. The study conducted for several flow rates.

Fig.2 represents the relationship between acceleration pressure drop and total flow rate ratio. The acceleration pressure drop calculated from eq (5) for several flow rates. The acceleration pressure drop increase with increasing total flow rate ratio so there is directly relationship. It show from figure there is no obvious change in acceleration pressure drop between 180 and 90.

Fig.3 represents the relation between the frictional pressure drop and total flow rate ratio. The wall pressure drop calculated from eq (6) for several flow rates. The frictional pressure drop increase with increasing total flow rate ratio so the relation is directly. It show from figure there is no obvious change in frictional pressure drop between 180 and 90 phasing.

Fig.4 represents the relation between the total pressure drop and total flow rate ratio. The total pressure drop consist of four parts (acceleration, wall friction, perforation roughness and mixing effect) and all these parts contributed in total pressure drop. The total pressure drop increase with increasing

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flow rate ratio (inflow through perforation to total flow rate) for all four tests. This rising in total pressure drop is caused by increase of acceleration pressure drop velocity increases) due to flow rate ratio increased. Increase in Reynolds number also lead to increase in total pressure drop. The figure shows the total pressure drop in 90 phasing has the highest value compared to total pressure drop in 180 phasing this is due to intensified influence of mixing effects pressure drop which leads to increase the total pressure drop.

Fig.5 represents total pressure along pipe length. The figure shown the total pressure at the heel end of the well will be the lowest compared with total pressure in the toe and any location in the well this is due to the pressure drop in the well.

Fig.6 represents the pressure drop along pipe length, the total pressure drop is decrease from the toe to the heel while the acceleration pressure drop and wall pressure drop increase.

Fig.7 shows the relation between the additional pressure drop and total flow rate ratio. The additional pressure drop consist of (perforation roughness and mixing effect) calculated by subtracting the acceleration and wall friction pressure drop from total pressure drop. There is inverse relationship between the addition pressure drop and total flow rate ratio, as total flow rate increase the addition pressure drop decrease. The figure shows the decreases in additional pressure drop in 90 phasing has the lower value in compared to additional pressure drop in 180 phasing this is due to intensified influence of mixing effects pressure drop.

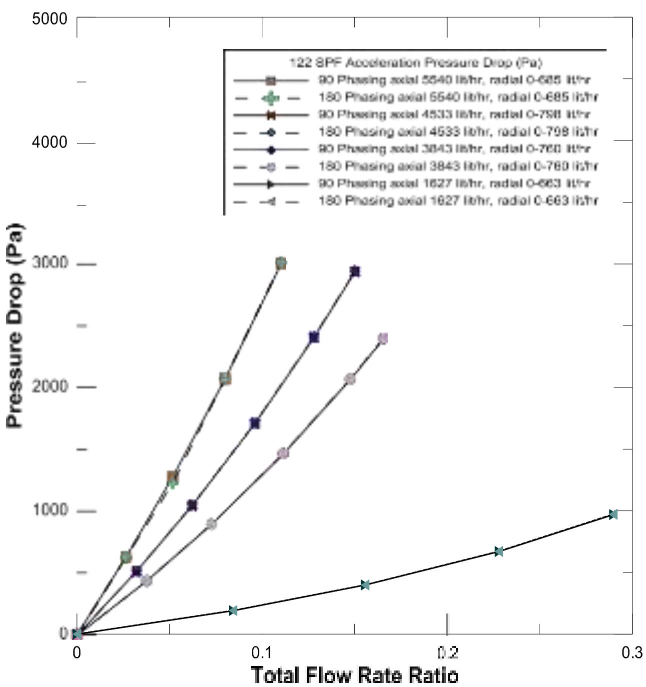

Fig.2 Acceleration pressure drop in 122 SPF 90 And 180 phasing

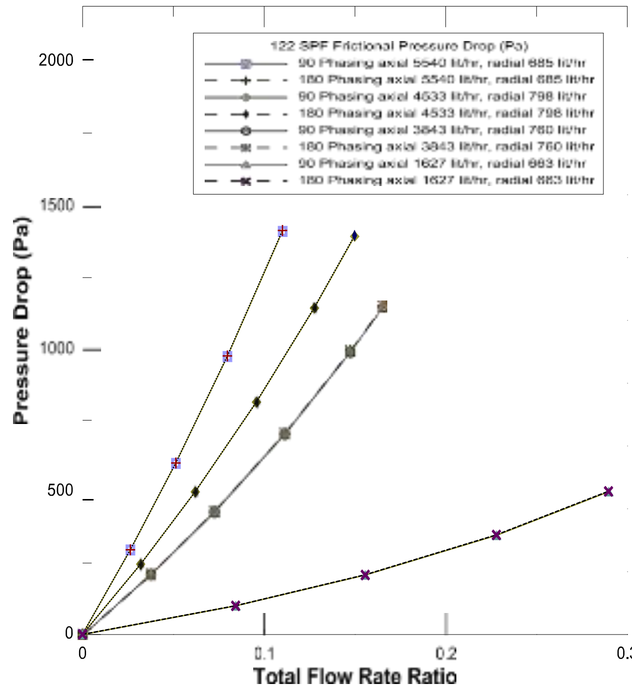

Fig.3 Frictional pressure drop in 122 SPF 90 and 180 phasing

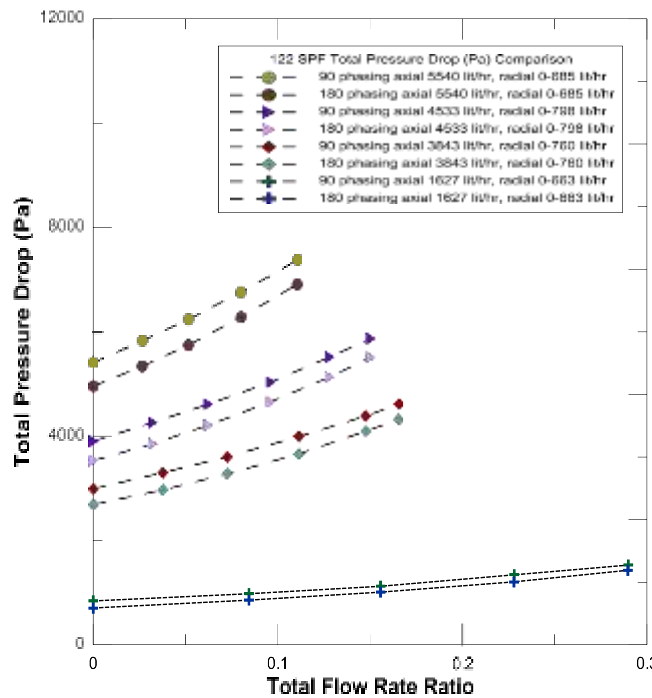

Fig.4 Total pressure drop in 122 SPF 90 and 180 phasing

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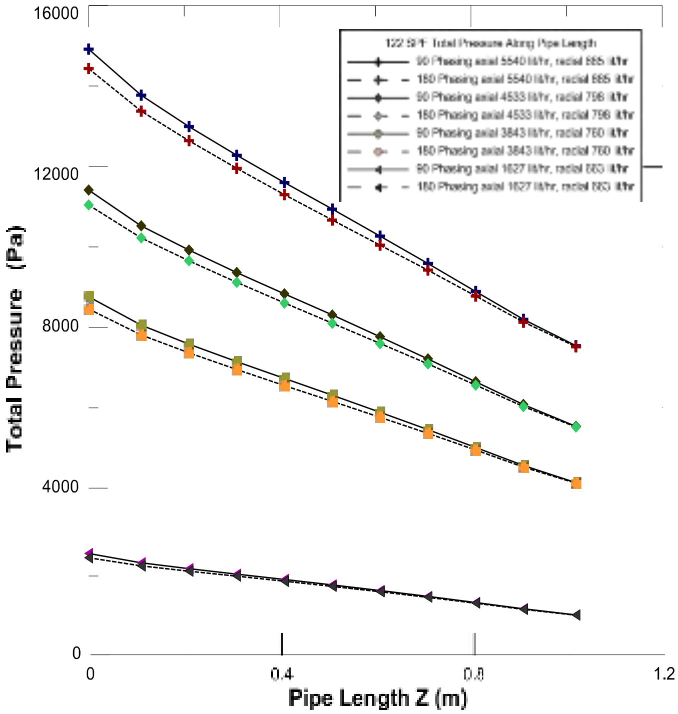

Fig.5 Total pressure along pipe length

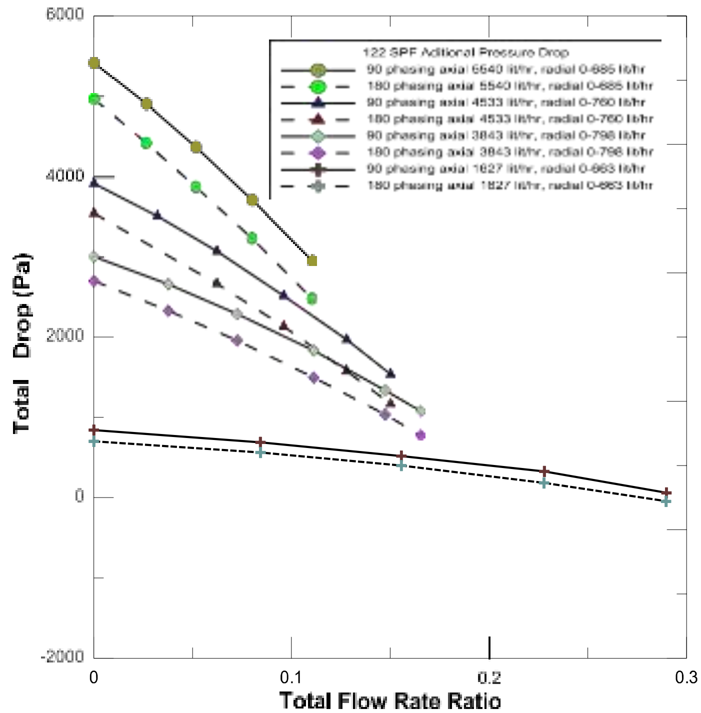

Fig.7 Additional pressure drop in 122 SPF 90 and 180 phasing

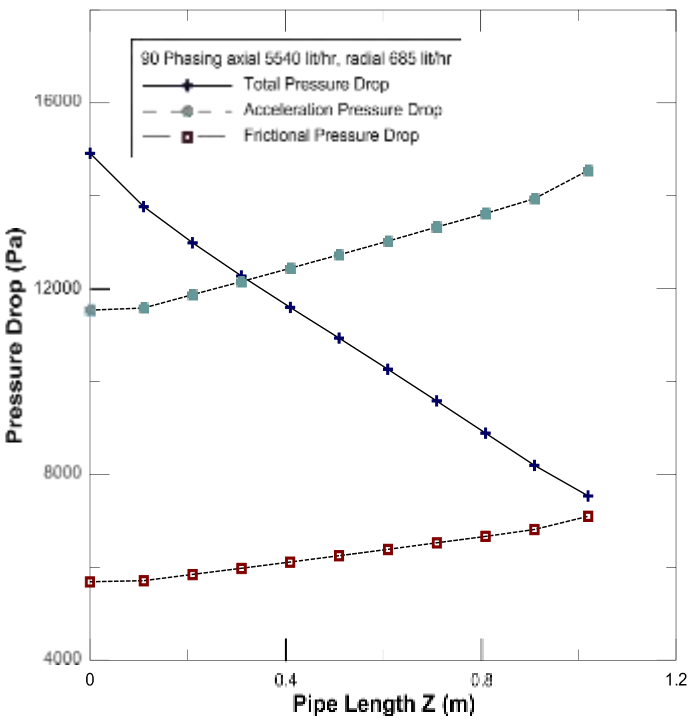

Fig.6 Pressure drop along pipe length

7. Conclusion

Numerical study was conducted on perforated pipe with inflow through perforation. The models that developed have length 1.02 m with 24 mm inner diameter, 3mm perforation diameter,122 perforation density with 180 and 90 phasing angle respectively. There is no obvious change in acceleration pressure drop and wall pressure drop between the phasing 180 and 90 so the acceleration and wall pressure remain at the same. There is directly relationship between the total pressure drop and acceleration pressure drop so the increase in total flow rate ratio leads to increase in total pressure drop. The total pressure drop in 90 phasing has the highest value compared to total pressure drop in 180 phasing. The relationship is inverse between the additional pressure drop and total flow rate ratio whenever the increase in total flow rate ratio leads to decrease in additional pressure drop. the decreases in additional pressure drop in 90 phasing has the lower value in compared to additional pressure drop in 180 phasing

Nomenclature

L: Length of pipe (m)
Q: Main Flow Rate ( )
: Inflow Rate from Perforation ( )
u, v, w: velocity component
n: perforation density SPF (SPM)
μ: Fluid Viscosity (kg/m.s)
ρ: Density (kg/)

: Total Pressure drop (pa)
: Acceleration pressure drop (pa)
: Additional pressure drop (pa)
: inlet pressure of pipe (pa)
: outlet pressure of pipe (pa)
: Roughness (m)
: inlet and outlet velocity of pipe
: friction factor

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