Journal of Petroleum Science and Engineering 116 (2014) 8–18

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

An approach to evaluate Venturi-device effects on gas wells production

Efraín Quiroz-Pérez [a], Richart Vázquez-Román [a,*], Raúl Lesso-Arroyo [b],
Victor M. Barragán-Hernández [c]

[a] Instituto Tecnológico de Celaya, Departamento de Ingeniería Química, Av. Tecnológico s/n, Celaya, Gto., CP 38010, Mexico
[b] Instituto Tecnológico de Celaya, Departamento de Ingeniería Mecánica, Av. Tecnológico s/n, Celaya, Gto., CP 38010, Mexico
[c] Pemex Exploración y Producción, Activo Integral Burgos, José Barrera 348, Col. Lucha Social, Cd. Miguel Alemán, Tamps., CP 88300, Mexico

ARTICLE INFO

Article history:
Received 11 July 2013
Accepted 2 March 2014
Available online 12 March 2014

Keywords:
CFD modeling
Venturi device
flow pattern
gas production
Eulerian–Eulerian approach
RNG k–ε turbulence model
MUSIG model

ABSTRACT

This paper presents a theoretical analysis of the effect produced by Venturi devices in gas wells. The first part of our methodology consists of performing steady-state simulations to fit experimental and theoretical pressure profiles. These simulations were carried out in Aspen Plus® to reproduce gas production in wells. The results in our case study have indicated that the flow pattern corresponds to a mist type. Then CFD simulations have been used to reproduce the gas–liquid flow through a Venturi device based on ANSYS CFX®. It has been observed that the Venturi increases the gas volume fraction and easy formation of smaller bubbles, which tend to flow in the center of the well. CFD simulations were carried out assuming an Eulerian–Eulerian approach for the bubbles dispersion through the Venturi device. The RNG k–ε model and the homogeneous *MUSIG* model are used to include the turbulence effect and to represent the bubbles population balance, respectively. Thus the numerical evidence indicates that Venturi-devices promote a flow pattern where the pressure drop decreases and hence it can increase the gas production in certain types of gas wells.

1. Introduction

Excessive drag and accumulation of liquids in gas wells affect their productivity. As the drag of liquids to the surface occurs, the flowing mixture became heavier and the production tends to decrease though the reservoir pressure remains almost constant. Similarly, if there were accumulation of fluid in the bottom of the well, then a column of liquid could eventually be formed and the power supplied to overcome the hydrostatic pressure due to the column exerted may become insufficient to flow out (Fanchi, 2006). In gas wells, the production decreases when the flowing mass becomes heavier and, hence, it demands a higher pressure to maintain the same level of production.

Computational fluid dynamics (CFD) has shown high potential to describe gas–liquid flows as expected in wells. Duan et al. (2011) have performed CFD simulations for bubbly flow moving upward through a cylindrical channel. The authors used two approaches based on population balances for bubbles to determine changes in the gas volume fraction and the distribution of bubbles under complex conditions of flow: the Average Bubble Number Density (ABND) model and the non-homogeneous MUSIG model (MUlti-SIze-Group). In their research, the authors manage to largely validate the experimental results reported by Prasser et al. (2007). Hibiki and Mishima (2001) and Das and Das (2010) considered a population balance to determine the gas volume fraction and the corresponding pattern in circular and annular ducts, producing also a good reproducibility of experimental data. Venturi devices receiving a mixture of gas and liquid produce an atomization of the liquid to produce smaller droplets with different sizes. Ahmadvand and Talaie (2010) have used a model to simulate the droplet dispersion through a cylindrical Venturi scrubber based on an Eulerian approach.

In a way, a Venturi devise behaves similar to an ejector when the gas injected achieves the throat in a liquid column. Kim et al. (2007) conducted CFD simulations and experimental studies to determine the hydrodynamics of a gas–liquid ejector horizontally connected at the bottom of a rectangular bubble column. The authors studied the air–water system to evaluate the effect of the ejector geometry in nozzle diameter and mixing chamber as well as the operating conditions such as liquid circulating rate, liquid level in the column, rate of gas suction and volumetric fraction in the column. Li and Li (2011) focused on the ejector performance dependence on the gas–liquid suction. In the petroleum industry, it is well known that production in deposits from low pressure can be improved through the installation of a pump jet (or ejector) in wells (Bailey et al., 2000). It also solves the problem of liquid accumulation in gas wells avoiding the high cost for other lifting techniques (Bailey et al., 2000). The ejector is installed where the

---

* Corresponding author. Tel.: +52(461) 6117575 x 5572.
E-mail address: richart@iqcelaya.itc.mx (R. Vázquez-Román).

http://dx.doi.org/10.1016/j.petrol.2014.03.002
0920-4105/© 2014 Elsevier B.V. All rights reserved.

Nomenclature

B_B	birth rate due to breakup of larger bubbles
B_C	birth rate due to coalescence of smaller bubbles
D_B	death rate due to breakup into larger bubbles
D_C	death rate due to coalescence with other bubbles
C_D	drag coefficient
C_L	lift coefficient
C_{TD}	turbulent dispersion coefficient
C_{WL}	wall lubrication coefficient
d	diameter
d_i	diameter of bubbles of size i
D	pipe diameter
Eo	Eotvos number
Eo′, d_H	parameters in the Legendre and Magnaudet model (1998)
f_i	size fraction of the bubbles of diameter i
f_η	parameter in the RNG k–ε turbulence model
f_μ	constant in the zero-equation turbulence model
$\vec{F}_{l-g}$	total force acting on the liquid phase due to interaction with the gas phase
F_B	calibration factor in the Luo and Svendsen (1996) model
F_{CT}	calibration factor in the Prince and Blanch (1990) model
$g(m_i, m_j)$	breakup rate of bubbles of mass i that originate bubbles of mass j
$\vec{g}$	gravitational force
g	gravity constant
h_0	initial liquid film thickness between two bubbles
h_f	critical liquid film thickness between two bubbles when rupture occurs
H, J	dimensionless parameters in the Grace model described in Clift et al. (1978)
k	turbulence kinetic energy
l_t	turbulence length scale
m_i	mass of bubbles of size i
M	Morton number
n_i	number density of particles of diameter i
$\vec{n}_W$	unit normal vector pointing away from the wall
P	pressure
P	production of turbulence due to viscous stresses
$Q_{ij}(m_i, m_j)$	coalescence rate of two bubbles of mass i and j
r_{ij}	equivalent radius of two bubbles of size i and j
r_i	radius of a bubble of size i
Re	Reynolds number
S	source term in the continuity equations
S_{ij}	cross-sectional area of two colliding bubbles of size i and j
t	time
t_{ij}	time required for the coalescence between two bubbles of size i and j
$\vec{\upsilon}$	velocity vector
υ_t	turbulent velocity
υ_T	terminal velocity
V_i	volume of the bubbles of diameter i
V_D	fluid domain volume
y	height of the water column
y_W	distance to the nearest wall

Subindex

eff	effective
g	gas
l	liquid
l–g	liquid–gas
P	particle
ref	reference conditions
t	turbulent

Superindex

D	interphase drag
L	lift
TD	turbulent dispersion
VM	virtual mass
WL	wall lubrication

Greek letters

α	volume fraction
β	parameter in the Luo and Svendsen (1996) model
φ	parameter in the RNG k–ε turbulence model
ε	turbulence kinetic energy dissipation rate
ξ	dimensionless size of eddies in the subrange of isotropic turbulence
η	parameter in the Luo and Svendsen (1996) model
η_{ij}	collision efficiency between two bubbles of size i and j
μ	viscosity
μ_t	Eddy viscosity
θ_{ij}^{T}	turbulent contributions to the collision frequency
θ_{ij}^{LS}	laminar shear contributions to the collision frequency
θ_{ij}^{B}	buoyancy contributions to the collision frequency
ρ	density
σ	surface tension coefficient
σ_t	turbulence Schmidt number
σ_k, σ_ε, $C_{\varepsilon 2}$, β_{RNG}, $C_{\varepsilon 1}$, C_μ	parameters in the RNG k–ε turbulence model
τ_{ij}	time of contact for between two colliding bubbles of size i and j
χ	dimensionless critical energy for the bubble breakup
ω	vorticity
ν	dynamic viscosity
ν_t	kinematic eddy viscosity
∇	gradient

liquid accumulation appears and then gas is injected into the convergent zone to produce an ascendant flow, which generates a decrement in the pressure at the throat and a consequently liquids suction (Sherwood and Atkinson, 2005).

Paladino and Maliska (2011) have analyzed bubbly flow within Venturi tubes and nozzles using the two-fluid model. The authors considered the effect of non-drag forces, wall lubrication under turbulent dispersion and lift forces, based on Antal et al. (1991), Lopez de Bertodano et al. (1994), and Tomiyama (1998). It is concluded that such forces have great influence on the calculations of the pressure drop and the gas volume fraction through the contraction. The authors also suggest using the RNG k–ε turbulence model, since it seems to have better performance in zones of contraction than the k–ε model.

Some experimental data have appeared in the literature to validate CFD results. Couët et al. (1991) conducted a series of