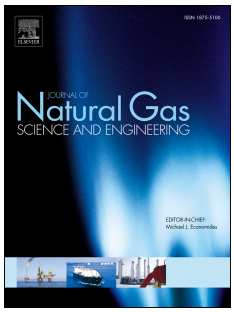
Accepted Manuscript



Numerical simulation of pipeline hydrate particle agglomeration based on population balance theory

GuangChun Song, YuXing Li, WuChang Wang, Kai Jiang, Zhengzhuo Shi, Shupeng Yao

PII: S1875-5100(18)30014-3

DOI: 10.1016/j.jngse.2018.01.009

Reference: JNGSE 2416

To appear in: *Journal of Natural Gas Science and Engineering*

Received Date: 15 May 2017

Revised Date: 4 January 2018

Accepted Date: 6 January 2018

Please cite this article as: Song, G., Li, Y., Wang, W., Jiang, K., Shi, Z., Yao, S., Numerical simulation of pipeline hydrate particle agglomeration based on population balance theory, *Journal of Natural Gas Science & Engineering* (2018), doi: 10.1016/j.jngse.2018.01.009.

Numerical simulation of pipeline hydrate particle agglomeration based on population balance theory

GuangChun Song , YuXing Li , WuChang Wang *, Kai Jiang , Zhengzhuo Shi , Shupeng Yao

Shandong Key Laboratory of Oil-Gas Storage and Transportation Safety, College of Pipeline and Civil Engineering, China University of Petroleum, Qingdao 266580, Shandong, PR China

Abstract

In offshore operations, the agglomeration between hydrate particles is a significant reason that could lead to pipeline hydrate plugging. Dynamic modeling and numerical simulation of pipeline hydrate particle agglomeration are of great importance to offshore hydrate management. For this purpose, a dynamic model of hydrate agglomeration was proposed and then used to simulate pipeline hydrate particle agglomeration in this paper. The dynamic model was established based on population balance equation, which took both hydrate agglomeration and hydrate breakage into consideration. Collision frequency, agglomeration efficiency, breakage frequency and size distribution of the sub particles resulting from particle breakage are four key parameters that involved in the dynamic model. Combined with several traditional solid-liquid flow models, the dynamic model was solved by the CFD software FLUENT 14.5 to simulate the agglomeration process of hydrate particles in the pipeline at different conditions. The influences of flow rate and hydrate volume fraction on the agglomeration process were analyzed emphatically. The simulation results were also compared with the calculation results of hydrate particle growth model and hydrate rheological model. The conclusions of this paper can provide guidance for the development of deep water flow assurance.

Keywords:

Hydrate, Agglomeration, Population balance, Dynamic model, Numerical simulation

Nomenclature

a	agglomeration efficiency	
b	particle size distribution function	
c_b	molar concentration of hydrate former in the bulk liquid	$mol \cdot m^{-3}$
c_{eq}	molar concentration of hydrate former at the bulk/hydrate particle interface	$mol \cdot m^{-3}$
c_{in}	initial molar concentration of hydrate former in the bulk liquid	$mol \cdot m^{-3}$
C_D	drag coefficient	
$C_{\varepsilon 1}$ and $C_{\varepsilon 1}$	constants	
e	parameter represents for the ratio between van der Waals force and flow shear force	
E	empirical constant	
f	fractal dimension of hydrate particles	
F	cohesion force acting on hydrate particles	N
$\vec{g}$	acceleration of gravity	$m \cdot s^{-2}$
G	absolute velocity gradient	s^{-1}
H	Hamaker constant	J
k	turbulent kinetic energy	$m^2 \cdot s^{-2}$
k_B	Boltzmann constant	$J \cdot K^{-1}$
k_f	parameter related to fluid properties	
k_{ls}	momentum transfer coefficient	
k_r	growth rate constant	$m^4 \cdot s^{-1} \cdot mol^{-1}$
K	parameter represents for the possibility of breakage after particle collision	
L and L'	hydrate particle size	m
L_0 and L_{max}	initial diameter and maximum diameter of hydrate particles, respectively	m
m	empirical constant	
$\overrightarrow{M}$	interphase momentum exchange	