Journal of Applied Fluid Mechanics, Vol. 5, No. 2, pp. 75-83, 2012.
Available online at www.jafmonline.net, ISSN 1735-3572, EISSN 1735-3645.

Dynamic Analysis of Small Pig through Two and Three-Dimensional Liquid Pipeline

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(Received March 18, 2010; Accepted September 13, 2010)

ABSTRACT

The derivation and solution of the two and three dimensional dynamic equations for a small pipeline inspection gauge (Pig) through a liquid pipeline is the main aim of this work. These equations can be used for synthesis of speed controller of a pig by using a bypass port in Pig. Momentum and energy equations are employed to study the influence of flow field on the Pig's trajectory. The pig is assumed to be a small rigid body with a bypass hole in its body. The variation of the diameter of the bypass port, which is controlled by a valve, is considered in this formulation. The path of the pig or geometry of the pipeline is assumed to be 2D and 3D curve. 2D and 3D simulations of the pig motion are performed individually and a case has been solved and discussed for each of them. The simulation results show that the derived equations are valid and effective for online estimating of the position, velocity and forces acting on the pig at any time of its motion.

Keywords: *Pig, Dynamic equations, Liquid pipeline, Momentum and energy equations.*

NOMENCLATURE

D	pipeline diameter
g	acceleration of gravity
$f(x)$	function of the centerline of the pig in 2D
$sgn(x)$	function of sign
$F_\mu = \mu N$	dry friction force
K_{SC}, K_{SE}, K_V	coefficients of pressure losses
L_{pig}	length of the pig
m	mass of the pig
N	normal force acting on the pig
p	the fluid force acting on the pig in the pipeline direction
P_{tail}	pressure in the tail of the pig
P_{nose}	pressure in the nose of the pig
R	radius of curvature of the pig's path
s	position variable along the pig's path
V_{pig}	velocity of the pig
α	constant value
λ	a time dependent parameter
θ	angle of the tangent to the centerline of the pipeline
ρ	density of fluid
κ	curvature

1. INTRODUCTION

Pipelines are the safest method to transport fluids such as oil and gas products. After several years of the operation, the walls of pipelines suffer deterioration and pipeline conditions get worse. Passing the fluid through pipelines causes some types of corrosions on it. These corrosions can damage the pipeline and reduce its life, hydraulic efficiency, surface softness and so on. All types of pipeline defects increase costs of fluid transportation. For this reason, preventing the pipelines from these defects is always important for oil and gas industries. These damages of pipelines can be monitored only by pigs because there is no access for observing the internal surface of the pipeline. Pigs are devices which are inserted into a pipeline and travels throughout it for inspection. A number of instruments such as MFL(magnetic flux leakage) sensors are carried by a smart pig to detect surface damages of the pipeline and their positions. The more knowledge about the dynamic behavior of the pigs, the more decrease in cost and time of the maintenance. Therefore, pipelines must be pigged regularly. Different kinds of pipe-wall defects that can be detected during pigging were explained by Hopkins (1992). Pigs must be run at constant speeds since the measuring process requires enough time for detecting damages. So, the study of