Numerical Simulation of Mud Discharge after Drilling Riser Emergency Disconnection

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ABSTRACT

After emergency disconnection of a drilling riser, drilling mud mostly discharges directly from riser bottom and generates a fast-opening waterhammer. A new numerical procedure is developed to simulate the flow of mud discharge, in which WENO scheme and TVD Runge-Kutta scheme are applied to discrete the governing equation, and Level Set method is adopted to track the top level of mud column during mud falling and seawater refilling. Also, a whole fluid column model is introduced as a contrast. Case calculation shows variations of flow velocity, acceleration, fluid pressure and flow friction force of drilling mud during discharging.

KEY WORDS: mud discharge; drilling riser; emergency disconnection; WENO scheme; TVD Runge-Kutta scheme; Level Set method

NOMENCLATURE

BOP: blowout preventer
CFD: computational fluid dynamics
CFL: Courant-Friedrichs-Lewy
FVM: finite volume method
LMRP: lower marine riser package
LMF: laminar flow
MOC: method of characteristics
TBF: turbulent flow
TSF: transition flow
TVD: total variation diminishing
WFC: whole fluid column
WENO: weighted essentially non-oscillatory

INTRODUCTION

In offshore drilling, emergency disconnection of a drilling riser is occasionally required to protect subsea wellhead, pipe system and floating platform in harsh environments or loss of dynamic positioning control. During an emergency disconnection sequence, drill pipe is sheared off instantly by a subsea BOP while drilling riser disconnected at LMRP(Paula Jr and Fonseca, 2013). Because retaining drilling mud in a riser would magnify the riser dynamic response and time is limited to replace all mud with seawater before a sudden disconnection, drilling mud mostly releases freely from the riser bottom whilst the riser recoiling upwards(Miller, et al., 1998). Mud discharge during riser recoil is neither feasible to measure exactly in any real situation, nor easy to do experimental simulation. Hence, numerical simulation is an indispensable choice to obtain required parameters after disconnection for riser recoil response analysis and structural dynamic analysis of a riser in hanging state.

Actually, efforts have been continuously made to achieve a more precise prediction of this unsteady flow. Yong, et al.(1992) calculated falling velocity and column length for the first time during mud column falling from an open ended riser, and they done this via an initial slug column model without any water refill. Miller, et al.(1998) simulated the flow process by a time-domain MOC program named "STARR". Lang, et al.(2009) simulated mud release through the one-dimensional Euler equations and a FVM model, but did not provide enough description of this FVM program for reference. Grytoyr, et al.(2011) emphasized the influence of mud column on total weight and friction loads during riser recoil, and introduced a modified slug column model with considering a refill valve at riser top. Li, et al.(2012) discussed the effect of mud shedding on riser recoil response and utilized Herschel-Bulkley rheology model for flow friction computation.

Although the "slug column model" is easy to calculate a rough trend of mud release in a whole discharge period, it only adopts constant velocity and acceleration of a single mud column in each time step and thus can not provide fluctuation details in the first few seconds after disconnection. MOC can simulate some detailed variation of flow velocity and fluid pressure, but its fixed marginal grids are difficult to fit the boundary change and hard to capture the moving of top mud level during mud release. Moreover, the previous papers often considered a simplified pipe flow without a drilling pipe in riser rather than a more practical annular flow.

This paper develops two procedures. The first one is a WFC model and solved by a cubic equation. The second one is a CFD procedure in which the WENO scheme and the TVD Runge-Kutta scheme are applied to discrete a special governing equation for the first time, and Level Set method is utilized to track the top mud level during fluid falling. Especially, this paper considers an annular flow and treats friction coefficients in a serious way. A case calculation exhibits the fluctuations of flow velocity, fluid pressure and whole fluid weight, and emphasizes the risk of pressure attenuation as well as the influence of friction force and column weightlessness induced by falling acceleration.