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# A New Method of Plunger Lift Dynamic Analysis and Optimal Design for Gas Well Deliquification

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## Abstract

This work presents a new dynamic model to describe the plunger motion by considering the changes of the tubing and casing pressures, liquid accumulation, liquid fallback, and the resistance force to the plunger. The characteristics of the tubing and casing pressures in plunger-lifted gas well are described quantitatively according to a field test data set. A better liquid accumulation mechanism is proposed. The effect of liquid falling back and liquid transfer from the tubing into the annulus during shutting-in period is specially considered for liquid accumulation and slug height modeling. The new method improves the prediction precision compared to the conventional methods that assume the constant tubing pressure for the entire process. The resistance coefficients of the plunge motion in four different phases are determined by combining the dynamic model with field test data. An example is given to illustrate the dynamic performance of plunger lift and the optimal design. The principle and approach to optimize plunger lift for dewatering gas well are proposed and discussed.

## Introduction

Plunger lift is a particular form of intermittent lift which makes use of a metal plunger to supply a solid interface between gas and lifted liquid load. Plunger lift has several advantages over other artificial lift techniques. It is especially suitable for dewatering loaded gas well that has low to medium water influx. For this case, a plunger is held in the lubricator for certain time to maximize gas production. If there is sufficient gas supply from reservoir, no packer is used in the well. This paper will focus on natural plunger lift with no additional gas injected from the surface.

Foss and Goal[1] presented the first static force balance analysis on plunger lift based on the experimental work in Ventura oil field in the middle of 1960s. Hacksma[2] applied nodal analysis to the plunger lift design for oil well with Foss and Goal's plunger performance charts in 1972. In 1982, Lea[3] developed the first dynamic plunger lift model and built the liquid accumulation equations. Later in 1988, Avery and Evans[4] presented a general dynamic plunger lift model by coupling reservoir's capability IPR relationship. In 1992, Chacin and Schmidt et al.[5] studied the design of plunger assisted intermittent gas lift installations with mass and momentum balance equations of the entire system.

On the plunger lift characteristics and performance, White[6] studied experimentally intermittent gas lift with and without a plunger in 1982. A surprising result from his study is that the plunger with a hole through its center produced the lowest fallback value. From this work one can conclude that the classic picture of a plunger being a moving partition between liquid slug above and gas below is neither correct nor desirable. In 1985, Mower and Lea et al.[7] conducted a laboratory measurement study with a 735-ft (224-m) test well. It provided information on gas slippage, liquid fallback, and plunger rise and fall velocities during the rise and fall of 13 different commercial plungers.

Among previous studies, there exist the following limitations. (1) Constant tubing pressure is assumed; (2) No vigorous dynamic model for plunger falling process. Normally, an average falling velocity of plunger is assumed; (3) No particular model on gas production and liquid accumulation is built for plunger lift to unload liquid from gas well; (4) Therefore, the optimal design for plunger lift in gas well is not reliable.

This study describes a generalized dynamic model for the plunger lift in gas well and presents optimal design approach.