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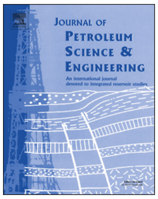

# Experimental investigation of the flow at the entrance of a rotodynamic multiphase pump by visualization

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In order to minimize the negative influence of mixed conditions at the entrance of a rotodynamic multiphase pump (MPP), a buffer tank was designed and installed in front of the pump. The structure of the buffer tank and the scheme of openings on the central porous pipe were designed and presented in this study. Visualization tests were conducted under different conditions to verify the rationality of the design buffer tank. Two indexes, i.e. the flow pattern for the gas–liquid two-phase flow and the distribution law for the bubble size, were used to evaluate the performance of the device. The test results showed that uniform bubble flow was presented after the mixture passes through the buffer tank and no aggregations of big bubbles were observed. It indicated that the flow pattern of the mixture was optimized with the designed structure of the buffer tank and the opening scheme on the central porous pipe. It can be concluded that the buffer tank enables the perfect mixture of the gas and liquid fluid. A set of experiments were also conducted to study the distribution of the bubble sizes and bubble numbers with the inlet gas volume fraction and rotation speed. The variations of bubble size with inlet gas volume fraction (IGVF) and rotation speed were plotted. It was shown that bubble sizes grew up with the increase of the IGVF but decreased with the increasing rotation speed. In addition, curves are drawn to express the relationship of bubble size with IGVF and rotation speed.

## 1. Introduction

Multiphase pumping is a new technology method for transporting offshore and onshore crude well fluid. This system has a number of advantages over the traditional methods for oil–gas separation and conventional oil production technologies, such as: simple structure, convenient operation, cost savings, enhanced recovery and so on (Saadawi, 2007a; Hua et al., 2011; Lafaille, 1990). The use of MPPs in oil fields has attracted world-wide attention since it was proposed due to considerable economic benefits to the investor. Nowadays, hundreds of MPPs have been applied in onshore, offshore and submarine oilfields all over the word (Hamoud and Al-Ghamdi, 2008; Humoud et al., 2008).

Multiple flow patterns are presented in the multiphase flow of gas and liquid produced from the oil wells, such as bubble flow, annular flow, fog flow, slug flow and so on. As a result, the incoming flow pattern of the MPP could be as one kind or mixture of them (Gié et al., 1992). Meanwhile, it is likely to appear the condition of slug flow and a sudden change of gas volume fraction (GVF), leading to dramatic drop of hydraulic efficiency and head, as well as sharp fluctuation of torque. More seriously, unsteady operation of the pump will probably cause mechanical failure (Bratu, 1995). Barrios analyzed the flow patterns of gas and liquid two-phase within an electric submersible pump to investigate the stability of gas pocket and its impact on pump performance by visualization (Barrios, 2007; Gamboa, 2009, Pessoa, 2001). Thum et al. (2006) conducted sets of visualization tests and believed that a close link can be found between the formation of gas pocket and the flow pattern at the entrance of a centrifugal pump. Wu Yanlan used the sampling test and photographic method to get the range of bubble diameters of the diffuser in a liquid jet gas pump. He got the internal two-phase flow and the distribution of bubble sizes under the working pressure of 500 kPa (Wu et al., 2012).

Given the above background, in order to improve the performance of the pump, it is necessary to use a specialized buffer and mixing equipment in front of the MPP. The equipment should be able to buffer the shock caused by a sudden change of GVF and slug flow. In addition, it should well mix the liquid and gas to improve the operation conditions at the entrance of the MPP.

At the same rotation speed, liquid and gas flow rates change periodically but present as more stable after buffered and mixed by the buffer tank (Pierre Gié et al., 1992). Abu Dhabi Oil Company, the first oilfield with two stages of pump connected in series, exploited a satellite oilfield that transported the oil–gas by MPP (Saadawi, 2007b). Since the satellite oilfield is located in deserts, it

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is a long distance between the well and MPP with rolling dunes, so the pattern of slug flow is easy to appear. In order to buffer the incoming flow, it is required to install a buffer tank in front of the MPP to improve the transportation efficiency. The incoming flow of oil–gas two-phase was slug flow and the IGVF fluctuated from 0% to 100% with a frequency of 0.5 s, so the FRAMO Company designed a slug suppressor with a vertical import. After it was buffered and mixed by the buffer tank, the GVF was controlled from 30% to 50% and the condition at the entrance of the pump was significantly improved.

A buffer tank can buffer the slug flow and provide bubble flow for the entrance of the MPP. However, the bubble size has a great impact on the performance of the pump. Caridad et al. (2008) analyzed the influence of bubble size (0.1 mm, 0.3 mm and 0.5 mm) on the performance of an electric submersible pump when transporting the gas–liquid two-phase fluid. The CFD results showed that the performance of the pump declined dramatically with the increase of bubble size when other variables were assumed to be constant. So, not only can the buffer tank ease the slug flow and well mix the gas–liquid two-phase fluid, but it can also reduce the bubble size to improve the performance of the MPP.

This paper aims to investigate the buffer efficiency of the designed buffer tank using high speed camera. The flow pattern and bubble size were analyzed to evaluate the performance of the new design. The results can provide the setting of inlet boundary conditions for simulating the inner flow field of a MPP.

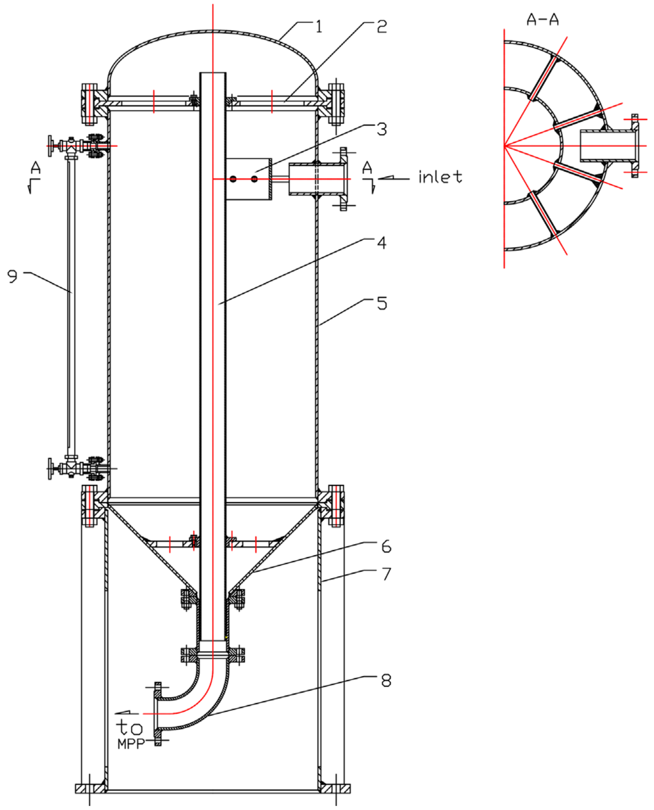

**Fig. 1.** Structure of buffer tank. (1) Cover of the upper part. (2) Upper inner cover. (3) Lower inner cover. (4) Central perforated tube. (5) Barrel. (6) Cover of the lower part. (7) Base. (8) Elbow pipe. (9) Liquid-level meter.

## 2. Structure design of the buffer tank

The purposes of installing a buffer tank in front of a MPP are to provide well mixed fluid for the MPP, reduce the fluctuation of power caused by sudden change of IGVF, improve the conditions at the entrance and as such improve the performance of the pump. The buffer tank, which was designed by the authors based on the idea from Salis et al. (1996), is shown in Fig. 1. It consists of barrel, cover of the upper part and lower part, circle baffle, central perforated tubes, liquid-level meter and so on.

The liquid sinks to the bottom and enters the central perforated tubes by the openings on them. The air masses breaks and mixes uniformly with the liquid. Finally, the well mixed mixture enters the MPP from the buffer tank. When the slug flow happens, the liquid in the buffer tank integrates with the large gas masses and the IGVF is reduced.

A number of key parameters of the buffer tank are considered in this novel design, such as internal volume, distribution of openings on central perforated tubes and height of residual water in the buffer tank (Zhao and Xue, 2000). Among these parameters, the distribution of openings on the central perforated tubes plays a key role in determining the mix efficiency of gas with liquid.

The design of central perforated tubes utilizes the method of porous muffler design which is normally used for compressors. The sum of its cross sectional area is no less than the cross sectional area of inlet pipe. The distance between holes and the average opening diameter are half and one-eighth of the central perforated tubes diameters, respectively. There are eight holes distributed uniformly in every cross section along the circumferential direction with the location of holes in adjacent cross sections staggered.

The opening condition of central perforated tubes is determined as 24 cross sections for opening with 8 openings in each cross section uniformly distributed along the circumferential direction. Considering the variable pressure in the buffer tank, the opening diameters of central perforated tubes are different at the top and bottom. The upper 12 cross sections have larger openings with a diameter of 10 mm, while the lower 12 cross sections have smaller openings with a diameter of 8 mm. The axial distances between two openings cross sections are 40 cm with a stagger angle of 22.5° along the circumferential direction between neighboring cross sections. The opening method of central perforated tubes is shown in Fig. 2.

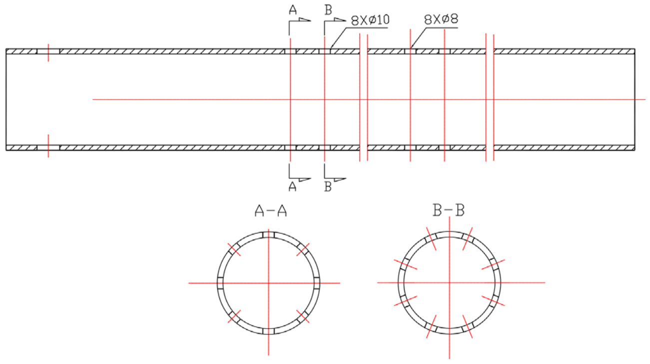

**Fig. 2.** Opening schematic diagram of central perforated tube.

## 3. Visualization experiment

### 3.1. Test bench

A layout of the test bench, as shown in Fig. 3, consists mainly of a liquid pipeline and a gas pipeline. The gas is taken from a compressor, mixed with liquid phase in the buffer tank before they enter the pump, conveyed by the MPP and released back to

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