DAV International Journal of Science

STUDY OF OPERATION AND FUNCTION OF TWO-PHASE PUMPS

Maryam Khalili[1]*, Akbar Alidadi Shamsabadi[2], Mohammad Mehdi Hajivand[2], Afshin Raeisi Dehkordi[1]
Shahab Taghipour[1], Daryosh Mohammadi Janaki[3]
[1] Islamic Azad University, Shahrekord branch, Faculty of Engineering, Shahrekord, Iran.
[2] Islamic Azad University, Science and Research Branch, Tehran, Faculty of Environment and Energy, Iran.
[3] Shahrekord University, Faculty of Engineering, Iran
(* Corresponding author, alidadi.en2012@gmail.com)

ABSTRACT
In different industries, a lot of money has been paid for separation or matching of two phases of gas and liquid in order to transfer them from one place to another. Therefore, transferring the two-phase flow has always been one of the experts' concerns. To solve this problem in recent decades, the two-phase pumps, which are able to increase the pressure of the two-phase flow, gas and liquid mixture, simultaneously, have been studied. In this paper, at first, kinds of two-phase pumps were introduced and their function method was studied in short as well as each pump's scope, advantages and disadvantages were discussed. Finally, all effective parameters on one kind of two-phase pumps- spiral pump- and their impact how were explained in order to design for intended use based on their application type and effect.

KEY WORDS: Two-phase pump, two-phase fluid, function method, spiral pump.

INTRODUCTION

The two-phase pumps, which increase the pressure of two-phase flow of liquid and gas, have been paid much attention to in recent decades. They enjoy a lot of advantages including the ability to increase the flow pressure in two-phase mode with high volume of gas, work in low speed and separate the two phases of gas and liquid. These benefits lead to high application of these pumps in industry and help them to design stronger and more frugal pumps than the past. If two phases of the flow are of the same kind, the two-phase flow can be change into a one-phase flow and then transferred by changing the temperature and pressure. If not, they can be transfered by seperation from each other. Some people, including Cooper (Cooper, 1967), Murakami and Minemura (Murakami and Minemura, 1974) and so on, tried to superpose the measured information with the obtained parameters but it was futile for finding their effect on pumps functions because they indicated comparison between identical conditions. It does not mean that these findings were useless and, a lot of fruitful information was obtained from them. Therefore, all academic and non-academic research done on two-phase pumps were about identification of the impact of one or more parameters of effective parameters on the pump function.

In this paper, advantages, disadvantages, working and application method of two-phase pumps were introduced completely and the effective parameters on pumps and their impact on flow and head of one kind of pump was investigated.

Types of two-phase pumps

1. Two-phase pumps of Centrifugal (Zuchao *et al.*, 2008)

Centrifugal pump is a most common pump used in industries, agriculture, domestic applications (Shah *et al.*, 2013), extensively fot hydraulic transportation of liquids over short to medium distance through pipelines where the requirements of head and discharge are moderate (Pandey *et al.*, 2012). The main structure of these pumps is formed by a set of blade put on an axis and the flow parallel to it enters it a nd exists vertically. The working base of centrifugal pumps is due to using centrifugal forces. Every substance which is moved in a circular direction, is affected by a centrifugal force. Its orientation always tends to draw the substance of the axis or rotation center. The rotated piece inside the pump's casing leads to movement of flow; as a result, it is affected by centrifugal force and exits from the external channel. As a result of creating a relative vacuum, the atmosphere pressure causes that the flow enter the pump's body. Until the two-phase flow is in the pump, the above order is repeated. The rotated piece inside the centrifugal pumps is named blade. The entrance channel is located in the center of the blade and the exit one around the blade's body. (Figure 1)

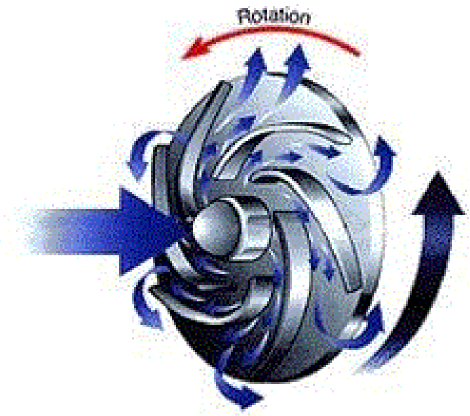

Figure 1. A semi-open blade of the centrifugal pump

The interruption mechanism can be summerized as following:
accumulation of gas in channels of the blade, separation of the fluid, and the asymmetric loop of gas in the loosenes between the blade and casing.

2. Positive displacement pumps

2.1. Screw pump

The screw pump has been used as a two-phase pump for a long time, especially for transferring the two-phase flow with high amount of gas and in variable entrance conditions. In particular conditions, this pump works up to 100%. Fig. 2, shows a profile of the screw pump. The multiple-phase mixture enter the pump from one side and is divided into two fluids and enter the entrances put in two sides of the pump. The volume flow depends on the pitch and diameter of the screws and the rotation velocity. When the gas is compacted, a little amount of the liquid returns to the back from the empty spaces between the screws and the shield wall which leads to reduction of the voluminous yield of the pump.The double-flow screw pump (up to about 30 bar (450 psig)) is available as a low-pressure pump and up to pressure difference about 90 bar (1300 psig) as a high pressure pump. According the parameters, it can have flow up to 2000 m3/ h.

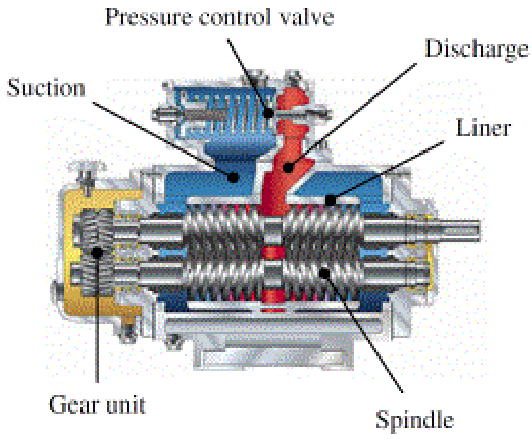

Figure 2. Sectional drawing of a double-flow screw pump (Räbiger *et al.*, 2008)

2.2. Progressing Cavity Pump (PCP)

The PCP is made of a rubber stator and a metal rotating rotor (Fig. 3). This pump, for low flow (less than 200 m3/h) and the low pressure of the outlet up to 400 psig has a special ability for bearing the considerable amounts of the solid particles (sand).

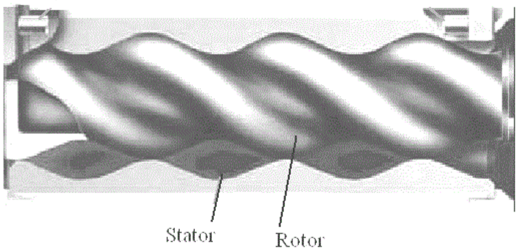

Figure 3. Rotor and stator of the PCP

The two spiral interior stators are made of a hard material resistant to erosion. When the rotor rotates in the stator, some holes are made which move from the suction part to the end of propulsion part and transfer the pumping materials (Fig. 4). Progressing Cavity Pumping is being more and more used in oil production, mainly in (heavy oil) fields, due to its numerous technical advantages (Paladino *et al.*, 2011).

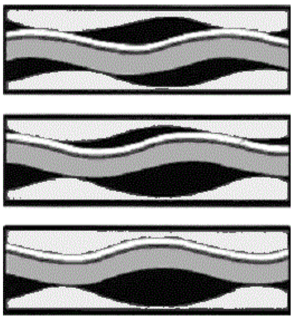

Figure 4. Working method of PCP

Continual seal off between the spirals of rotor and stator keeps the flow stable movement in a fix flow proportionate with the pump rotative velocity. However, PCP has a low ability to transfer the high amount of gas in liquid which is resulted from the limitations of the stator elastomeric materials .In Fig. 5, a model of a complete system of PCP is shown.

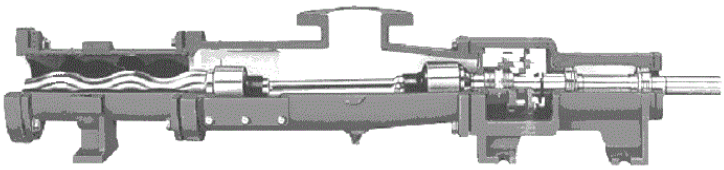

Figure 5. A model of a complete system of PCP

2.3. Piston pumps

One on the simplest forms of the multi-phase pumps is using a big two-phase piston for compacting the mixture of gas-liquid. This method is used for the scopes of low and average flow having the maximum capacity about 110000 bbl/d (the total volume of gas and liquid) and the most outlet pressure about 1400 psig. Some models of piston pomps are shown is Figure 6 and 7.

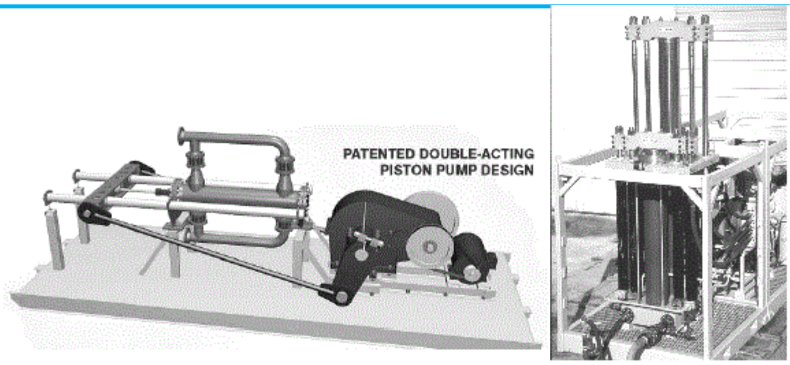

Figure 6 and 7. Two models of a two-phase piston pump

3. Rotary Pump

3.1. Helicon-axial pump

In this pump, the flow runs in a set of pump's layer vertically. Every layer includes a helically-like rotating blade and a fix diffuser (Zhang *et al.*, 2010). (Fig. 8)

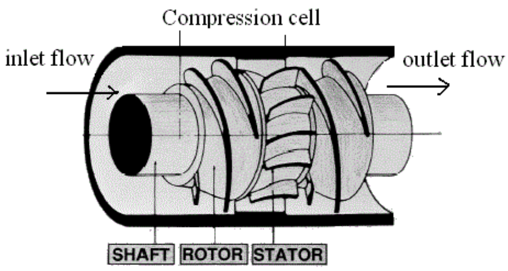

Figure 8. Inner structure of the Helicon-axial pump

Compacting of gas in consecutive layers leads to changing the geometry of the diffuser blade to be compatible with flow reduction (Fig. 9).

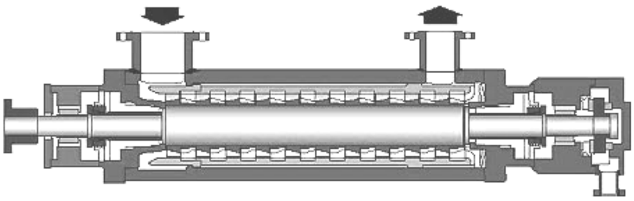

Figure 9. A complete model of a Helicon-axial pump

The advantage and disadvantages of Helicon-axial pump are listed in table 1.

Table 1. The advantage and disadvantages of Helicon-axial pump

Helico-Axial pumps	
advantages	disadvantages
High capacity (50,000 bbl/d to 450,000 bbl /d) and	High shear
Good operational range and flexibility due to high speed range	Slugging problem
High differential pressure (< 2900 psig) and high pressure rise	Not a good choice for viscous fluids
Self-adapting to flow changes	Not a good choice for low flow rates
Series and parallel operation is possible	Not able to operate in low suction pressure
70 mm <Impeller diameter< 400 mm	
Low potential for erosion in case of solid handling	

3.2. The spiral two-phase pump

The different parts of this pump are shown in the Fig.10.

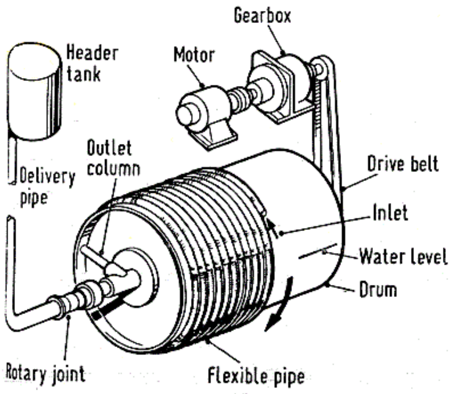

Figure 10. Shematic picture of the spiral pump

Benefits:

-The two-phase flow (gas-liquid) pumping

The spiral pump has the ability of pumping the two-phase flow with density coefficient of gas in liquid up tp 95%.

-It can used as a device to separate the gas phase from liquid one

-using wind energy

The spiral pump can also work with low rotating speed and provide the least flow for a specific height. Therefore, it is a very suitable device for coupling with wind turbine in order to transfer water.

-Pumping the river water

Using the spiral pump beside the rivers to transfer the water to the higher hights is very suitable.

-The cheap and easy constructing, installation and launching

-The plastic materials used in making this pump

When the passing flow leads to corrosion of metals, all of pieces used in this pump which are in contact with the flow can be made by plastic materials..

Effective parameters on performance of screw biphasic pump

The carried out experiments and examination of the theoretical relations of the two-phase flow revealed that the effective parameters on this pump function are as following

1. The ratio of liquid to the inlet gas (γ)

The ratio of liquid to the inlet gas in every rotation depends on the amount of the angle upon which the head of the spiral pipe moves in liquid or gas.

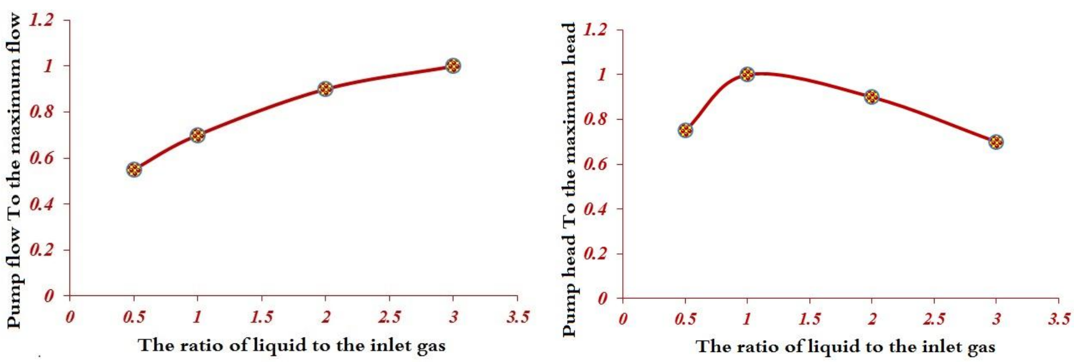

Figure 11 and 12. effect of the ratio of liquid to the inlet gas on the head of the pump and flow

Effect γ of on the flow of the fluid: as it is shown in Fig. 11, increasing the amount of liquid leads to increasing the outlet flow of the pump.

Effect of γ on the head: in Fig. 12, the effect of ratio of liquid to the inlet gas on the head is shown. Until the ratio of liquid to the inlet gas equals one, the pump head will be increased and, when this ratio is increased, the head ratio will be reduced.

2. Effect of the rotative velocity (N)

Effect of the rotative velocity on flow: as it is shown in Fig. 13, the increase of the rotative velocity has a direct relationship with the pump flow.

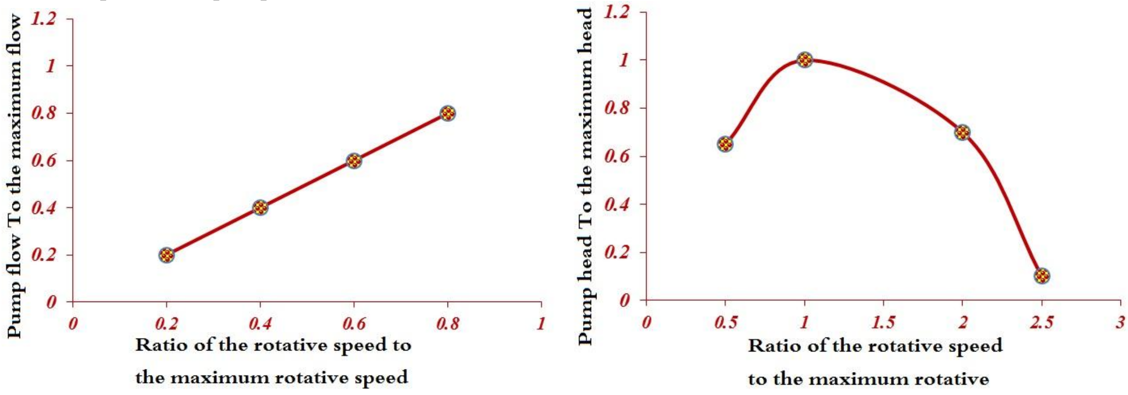

Figure 13 and 14. Effect of the rotative velocity on the pump flow and head

Effect of the rotative velocity on the head: according to Fig. 14, when the rotative velocity is increased, at first the amount of head is increased and when the rotative velocity reaches to maximum 1, it is reduced.

3. Effect of the angle of the pump cylinder pivot with the horizontal

The findings of Fig. 15 reveal that when the angle of the pump cylinder pivot with the horizon is changed, the change of the flow is not tangible.

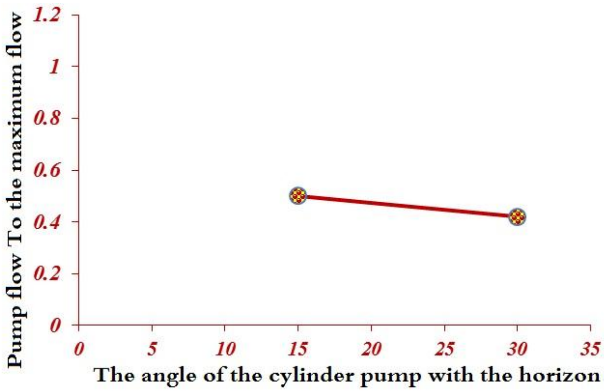

Figure 15. Effect of the angle of the cylinder pump with the horizon on the pump flow

4. The pitch of the spiral pipe

Changing the pitch of the spiral pipe has no remarkable effect on the pump function because the changes of the parameter of rotation in the spiral pump are not tangible.

5. Number of the rotations of the spiral pipe

Number of the coils has no significant effect on the outlet flow of the pump in a specified height, but this parameter is a decisive factor for the maximum amount of the pump head because increasing the number of the coils leads to increasing the maximum amount of the head as it is shown in Fig. 16.

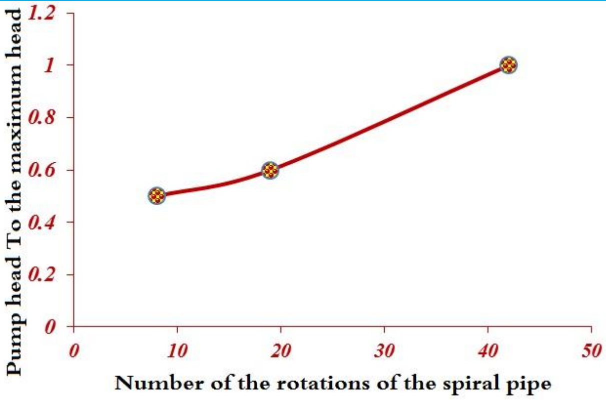

Figure 16. Effect of the number of the rotations of the spiral pipe on the pump head

6. Diameter of the spiral pipe (d)

Diameter of the spiral pipe is the determinant of the inlet flow amount to the pipe. The more the pipe diameter, the big the inlet mouth of liquid to the pipe .As a result, increasing the diameter of the spiral pipe leads to increasing the amount of the pump flow, in addition, increasing the diameter of the spiral pipe lead to reduction of the maximum amount of the head. (Figure 17 and 18).

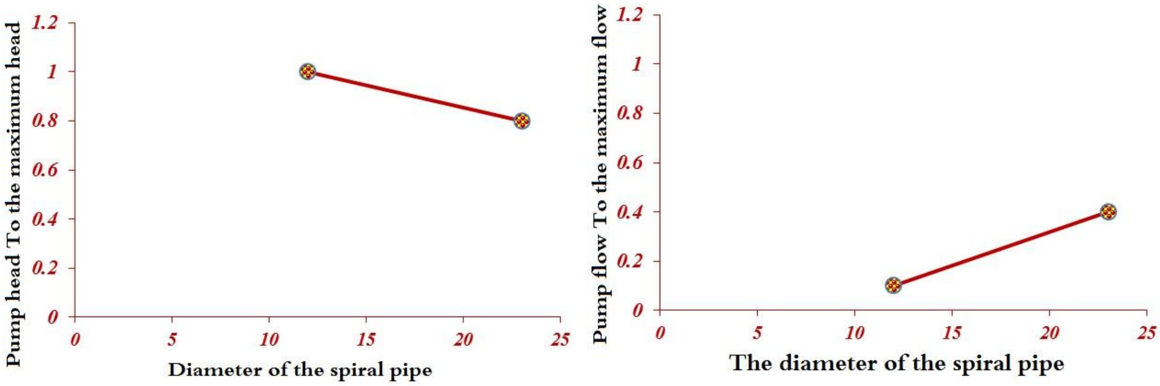

Figure 17 and 18. Effect of the diameter of the spiral pipe on the pump flow and head.

7. The cylinder diameter

Increasing the cylinder diameter leads to increasing the amount of the inlet liquid in every rotation. In a fix rotation speed, when the cylinder diameter is increased, the distance which passed by the spiral pipe in liquid is increased too. In every rotation, a more volume liquid enters to the pipe and moves toward the outlet part.

CONCLUSION

According to the observations of this study, the following results will be obtained:

- The two-phase pumps work in the scope of rotation velocity and special pressures and, according to the intended application, the kind of pump is selected.
- Different parameters including D, d, n, P, γ and so on have effect on designing the pump
- When the rotation velocity is increased, the amount of outlet flow is decreased but it has no effect on the amount of pump head.
- When the ratio of inlet liquid is more than that of gas, the flow rate amount is increased while the head amount decreased.
- The amount of angle of the cylinder pivot with horizon has no effect on flow but when the angle is increased, the head amount decreased.
-The spiral pitch has no effect on flow and head.

-The number of the pump coils has no effect on flow but when they are increased, the head increased too .
-When diameter of the spiral pipe is increased, the flow is increased and the head decreased.
- Increasing the diameter of the cylinder leads to increasing the flow and head.

REFERENCES

Cooper P. (1967). Analysis of single and two-phase flows in turbopump inducers. *J. Eng Power*. **89**: 577–588.

Murakami M. and Minemura K. (1974). Effect of Entrained Air on the Performance of Centrifugal Pumps. *Bull. J.S.M.E.* **117**: 1286-1295.

Paladino E.E., Lima J.A., Pessoa P.A.S. and Almeida R.F.C. (2011). A computational model for the flow within rigid stator progressing cavity pumps. *J. Petrol Sci Eng.* **78**(1): 178–192.

Pandey K M., Singh A.P. and Chakrabotry S. (2012). Numerical studies on effects of blade number variations on performance of centrifugal pumps AT 2500 rpm. *J. Environ Res. Dev*. **6**(3A): 863-868.

Räbiger K., Maksoud T.M.A., Ward J. and Hausmann G. (2008). Theoretical and experimental analysis of a multiphase screw pump, handling gas–liquid mixtures with very high gas volume fractions. *Exp Therm Fluid Sci*. **32**(8): 1694–1701.

Shah S.R., Jain S.V., Patel R.N. and Lakhera V.J. (2013). CFD for centrifugal pumps: a review of the state-of-the-art. *Procedia Eng.* **51**: 715–720.

Zhang J., Zhu H., Yang C., Yan L. and Wei H. (2010). Multi-objective shape optimization of helico-axial multiphase pump impeller based on NSGA-II and ANN. *Energ Convers Manage*. **52**(1): 538–546.

Zuchao Z., Peng X., Guofu O., Baoling C. and Yi L. (2008). Design and Experimental Analyses of Small-flow High-head Centrifugal-vortex Pump for Gas-Liquid Two-phase Mixture. *Chinese J. Chem Eng*. **16**(4): 528-534.