Different an Approach About Determination of Critical Submergence and Preventing Vortex in Deep Well Pumps

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Abstract: *This study was conducted on a deep well simulator for typical irrigation purposes. In this article the changes of the critical submergence (Sc) for deep well pumps was determined by taking into account the vacuum pressure measured at the pump inlet axis for a specific criterion. Pump vacuum pressure was determined with the aid of U-pipe differential monometer. When the pump is running, the is generated drawdown and vacuum pressure as depending flow rate. When the pump is run constantly flow rate and the submergence is reduced, the vacuum pressure is increased due to the decreasing water load. When the submergence continues to decrease, in the manometer mercury level is equalized. When the mercury levels in the right and left arms were equal, it determined as the critical submergence of dynamic level the pump at this flow rate.*

The possibility of vortex in the water at low submergence of the pump is very high. Vortex is an undesirable condition for the pump. The vortexes formed at different submergence of the pumps were imaged by camera. Vortexes were determined to occur at lower submergence. The submergence was called as vortex submergence (Sv). All vortex submergence levels were determined below the critical submergence level. The operation of the pumps above the critical submergence levels determined by measuring the vacuum pressure were prevents the formation of vortex.

Keywords — *Vortex, Critical Submergence, Submergence, Deep Well Pumps*

I. INTRODUCTION

The vertical distance between pump water inlet and dynamic water surface is defined as “submergence” (S). If the submergence is less than critical submergence (Sc), then a vortex is generated. If air enters in the vortex result, the pump loses suction and the efficiency decreases[1, 2]. Some researchers have explained the critical submergence with equations based on Froude number [1-7]. However, the critical submergence calculation based on the Froude number is generally used in open channels or tanks. The water inlet diameter is the most important factor influencing the critical submergence in open channels or tanks [1, 8, 9]. The critical submergence is often used to take measures against vortexes [4, 10].

In deep well pumps, the submergence calculation is generally associated with the net positive suction height (NPSH) required of the pump [11]. Pump manufacturers generally take into account the NPSHR of the pump at the stage of placing deep well pumps in the well. However, many manufacturers or assemblers place deep well pumps under the water to deep distances by taking into the well level changes that occur during the year. In addition, manufacturers are measuring the NPSH of deep well pumps in tanks or ponds instead of wells. In the deep well, the hydraulic condition applied by the water to the pump is different, the hydraulic situation applied in the tank or the pool is different. Institute [4] stated that the minimum submergence for the submersible pump in the sewage pit would be as high as the diameter of the motor cooling shroud. In this study, it is aimed to try a new method during the placement in the well of deep well pumps.

In this context, new methods have been tried to calculate the critical submergence (with vacuum pressure measurement) and accuracy (with vortex formation depth). One important aspect of this study is that the measurements made for the submergence of the deep well pump are done in test tower designed as an irrigation well.

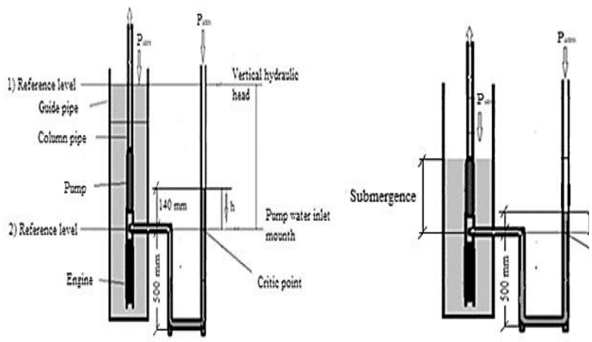
II. MATERIAL AND METHODS

In this study was used in irrigation deep well pump type submersible. Pump vacuum pressure was determined with the aid of U-pipe differential monometer installed at pump inlet. As can be seen in Figure 1 and 2, the height h between the mercury level at the right arm of U-pipe differential monometer and number 2 reference level was measured and recorded. Before the operation of the pump, the height h is equal to vertical hydraulic head and submergence is at the maximum level. By operating the pump, the vacuum pressure was measured at different submergence at constant flow rate. Lowering the submergence at the fixed flow rate have increased the vacuum pressure. In other words, increase in vacuum pressure caused decrease in height h. The decrease of h height means that the pressure in the positive (to the right of the mercury U manometer) direction goes to the negative (to the left of the mercury U manometer) pressure. Excessive reduced submergence will cause vortex formation and even air into the pump. In this case, the point where the h value is zero, ie of the pump vacuum pressure is equal the positive hydraulic load, is determined as the critical submergence. In this way, vortex formation is prevented by determining the critical submergence. The h values were measured in mm. With these h values, pressure at pump inlet was calculated by suing the following equation;

$$P_e = [\rho * g * (h/1000)]/1000 \text{ (kPa)} \quad (1)$$

Where; mercury density ρ =13600 kg m^{-3} and gravitational accelerationg= 9.81 m s^{-2}.

Then at constant flow rates, from the regression equations obtained from Pe equation as a function of submergence, the submergence (S) making the Pe value zero were determined and they were taken as critical submergence (Sc) (Figure 3).



a) b)

Fig.1. View of U tube differential manometer in different operating situations (a) state at the time the pump is not running b) state at the time the pump is running).

Fig. 2. U-tube differential manometer

The camera was used to view the formation of vortex. Side camera was connected to outside of the transparent pipe in order to track the pump-inlet and the formation of vortex.(Figure 3).The submergence level in which vortexes were visualized was named as vortex submergence (Sv).

Fig. 3. Submersible pump and connection of thecamera

III. RESULT

On the 6" and 7" diameter pump, obtained relationship at the submergence and the vacuum pressure are given in Table 1. The regression equation obtained from these values is given in Fig 4. and Fig 5. According to the 6" pump regression equation result, 40 m^3 h^{-1} and 60 m^3 h^{-1} flow the level of submergence is found to be respectively 262.7 mm and 594 mm when the vacuum pressure is zero. Similarly calculated 7" pump 50 $m^3h^{-1}$and 80m^3 h^{-1}flow rates of the have been found 104.4 mm and 292.4 mm respectively.This value is called as critical submergence (S_C). As the flow increased, the critical submergence increased [4-12].

Vortices were determined according to video camera images recorded at different submergence. Vortex submergence (S_V) of 40 and 60 m^3 h^{-1} flow of the 6" pump were determined respectively as 25 and 50 mm. Vortex images are shown in Figure 6. The vortex submergence of the 7" pump at 50 and 80m^3 h^{-1}flow rates has been identified 40 mm and 140 mm respectively (Fig. 7). The critical submergence of both pumps are high than the vortex submergence.

In the low submergence, continuous air inlet vortex was formed (Figure 6a and 7a). However, discontinuous type vortex formation was observed in the slightly higher submergence (Figure 6b and 7b).

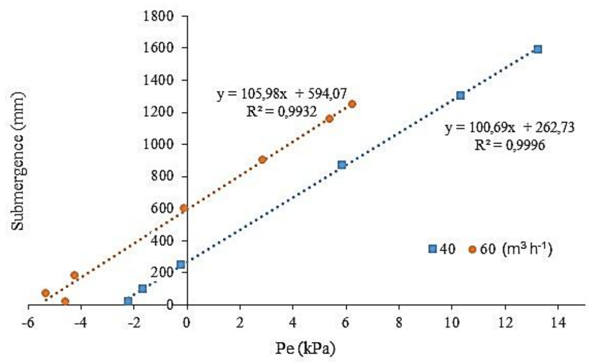


Fig. 4. The 6" pump constant flow rate obtained in the regression equation

Table 1. The 6" and 7" pumps different flow relationship submergence (S) and vacuum pressure (Pe)

Pump type	Q ($m^3 h^{-1}$)	S (mm)	Pe (kPa)
6"	40.02±0.008	1590±1.3	13.28±0.013
	40.10±0.01	1305±0.8	10.35±0.008
	40.07±0.009	870±2	5.87±0.02
	40.14±0.009	250±1	-0.22±0.01
	40.06±0.008	100±1.2	-1.68±0.012
	37.78±0.05	20±1.7	-2.19±0.017
	60.11±0.011	1250±3.4	6.26±0.03
	60.09±0.01	1160±4.1	5.38±0.04
	60.20±0.01	905±2.3	2.86±0.02
	60.12±0.02	600±2	-0.12±0.018
	60.08±0.01	180±1.8	-4.23±0.017
	60.12±0.01	70±2.6	-5.32±0.026
	53.63±0.002	20±0.9	-4.58±0.008
7"	**49.23±0.02**	**1350±1.1**	**12.13±0.007**
	49.28±0.02	**1000±1.7**	**8.7±0.006**
	49.01±0.02	**120±1.1**	**0.08±0.004**
	48.91±0.02	**50±1**	**-0.6±0.004**
	43.76±0.09	**20±0.4**	**-0.68±0.004**
	79.11±0.012	580±2.5	2.82±0.01
	79.24±0.025	310±3.4	0.17±0.01
	79.52±0.027	220±2.8	-0.74±0.01
	79.26±0.021	170±0.8	-1.21±0.02
	79.17±0.019	110±2.1	-1.79±0.02
	79.10±0.028	60±1.5	-2.28±0.03
	78.10±0.027	30±1.2	-2.49±0.02

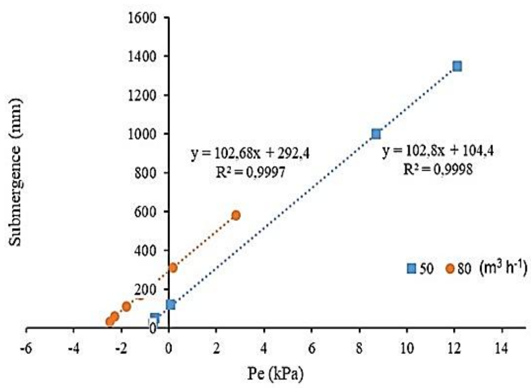


Fig. 5. The 7" pump constant flow rate obtained in the regression equation

a) b)

Fig. 6. In the 6 " pump vortex images at 40 (a) and 60(b) $m^3 h^{-1}$ flow

a) b)

Fig. 7. In the 7" vortex images at 50 (a) and 80(b) $m^3 h^{-1}$ flow

IV. DISCUSSION

Vortexes occurred at low levels in critical submergence level. If the pump is operating at above the critical submergence level, vortex will not occur and air will be prevented from entering the pump. It was detected that this method could be used to prevent the vortex.

The operation of the pumps above the critical submergence levels determined by measuring the vacuum pressure were prevents the formation of vortex.

In the deep well pumps by determining the critical submergence this critical value can be taken into account when placing into the wells of pumps. Critical submergence can be determined in deep well pumps of different nominal diameters.

ACKNOWLEDGMENT

This paper was derived from of method in Ph.D. Thesis of Nuri ORHAN. This study was supported by Turkish Scientific and Technical Research Council of Turkey (TUBİTAK, Project No: 213O140). I thank in Prof.Dr. Sedat ÇALIŞIR who has contributed to this study and decedent.

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