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# Description and Analysis of a New Air Pump for Agricultural Irrigation

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## ABSTRACT

Different principles have been used to water pumping by compressed air. The one implemented here uses the principles of a simple piston pump except that compressed air is used instead of the mechanical piston. A compressor installed on the ground, sends air flow to a double wall chamber inside the well through a single hose line. Air flow is cut on and off by hydraulic valves which also located on the ground surface. Two necessary check valves for the piston pump to operate, however, are installed in the double wall chamber in the well. Instead of the old metal shaft and tube, a high pressure plastic tube is implemented to carry the water up on to the ground surface from the well. To start modeling, first, the mathematical equations of various sections of the system are presented and then based on those equations, the mathematical model of whole system is derived. To evaluate the model, the results obtained from simulation are compared with experimental results.

**Key Words:** Air Pump; Water wells; Compressed air; Piston pump; Irrigation

## INTRODUCTION

Water pumping from well is historic. The task was first performed by a bucket and a rope. A wooden wheel was used afterwards with animal power replacing human power. Turbine pumps and electric motors are used extensively, today. However, this way has several difficulties particularly in arid and semi-arid areas as for instance: i) the shaft and sleeve can not easily be extended to compensate for the lowering level of under ground water, ii) sediments collected and remained on the turbine may cause the shaft damage (breakage) and iii) maintenance is more time consumption and expensive, since the mechanical parts are to be pulled up to the ground surface for services.

Compressed air may be a way to remedy the turbine pump short comings, but a few mechanical elements are used in the well. This helps in much less maintenance problems and costs. The engine and machine are installed on the ground surface, which are easily in reach for repair and services.

Different methods are used for air pumping water from wells. Fig. 1 shows a very simple one using a double wall tube. No valves or other mechanical parts are used in the well, however, the problem is that at least 40% of the inner tube must be in the water (Cherkassky, 1989). The objective of this research was to introduce and analyze a new air pump which overcomes the problems of the conventional well pumps and can be used in agricultural irrigation.

## MATERIALS AND METHODS

The schematic of proposed air pump is shown in Fig. 2. The pump is divided into two parts; a hydraulic part and a pneumatic one (Nafari-Ghaleh, 2000). The hydraulic part which is held inside the well includes; double wall chamber, water carrying tube, check valves and filter. The pneumatic unit which is installed outside of well (on the ground) includes; a motor driven compressor, 4/2 solenoid directional control valves, air flexible tube, reservoir and air regulator. The double chamber which is held inside well, has connection to the water well through the check valve 1 and a filter. The filter is used to prevent entrance of any small particles to the chamber. Moreover, a second check valve is used to prevent return of water inside carrying tube during suction period. There are some slits around the inner wall of the chamber letting water fill the chamber.

In suction period, the solenoid valve disconnects the flexible tube from compressor port and connects it to the atmosphere to discharge air inside the tube. Therefore, due to the vacuum produced in the chamber, check valve 1 is opened to the well water and thus the chamber is filled.

In discharge period, the solenoid valve connects the compressor port to the flexible tube and compressed air passing through flexible tube, pushes the water inside the chamber and thus the water inside the chamber start to goes up through the carrying tube (the second check valve is open). In this stage, this operation continues till the water level in the chamber reaches a predetermined level and then again the air flow is cut. For next cycle and starting the suction stage, it is necessary to connect the flexible tube to atmosphere. This is done by the directional control valve. The operation of the valve is controlled by a timer automatically. Fig. 3 shows a double stage air pump. This type is used in very deep wells. In this paper, only one stage pump shown in Fig. 2, is discussed. The mathematical model of the proposed air pump and the equations describing the different parts of the system are presented in references (Nafari-Ghaleh, 2000; Mohtasebi *et al.*, 2003).

## RESULTS AND DISCUSSION

To start the analysis of the proposed model, a well with the depth of 30 m (equivalent to 3 bar pressure), flow rate of 36 L sec$^{-1}$, charge and discharge period of 5 seconds were considered in the simulation. The simulation results are explained as follows:

Fig. 4 shows the transient response of compressor output pressure. As it is seen, approximately 0.6 second is necessary for the pressure to reach its steady state value; 3.6 Bar. Moreover, the response is overdamped and there is not any oscillation. The response time is a function of air and water tubes volumes and by decreasing the length of tubes, the response time could be reduced. The response time is fast enough for the system and results are compatible with the experimental results (Nafari-Ghaleh, 2000).

**Fig. 1. Simple Air Pump**

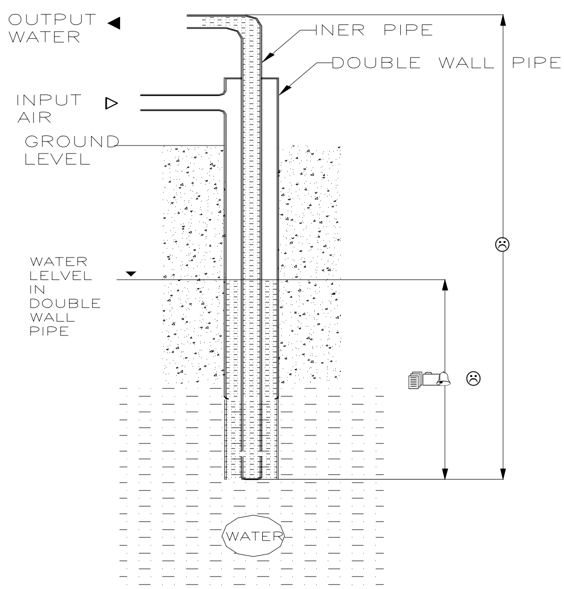



**Fig. 2. The Proposed Air Pump**

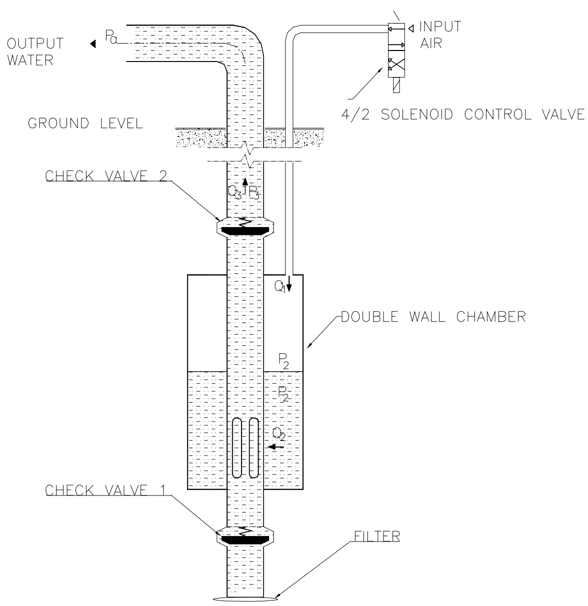



Fig. 5 shows relation between time and compressor output flow. As it is seen, at the start, the maximum output flow of compressor is about 120 L sec$^{-1}$ and by filling gradually the flexible tube and also the upper volume of double wall chamber, pressure increases and thus the flow is decreased and finally the flow is set on 36 L sec$^{-1}$ (Brown, 1986). This means that the required time for filling the air tube and compressing air to transmit the force is about 0.6 seconds. The results are also compatible with experiment results.

Fig. 6 shows the relations between output flow and pressure of the compressor. It shows that by increasing pressure, the flow decreases. This is specification of screw compressor.

Fig. 7 shows variation of the output flow from carrying tube. As it is seen, whenever, the pressure of the double wall chamber is less than 3 Bar, (t = 0.4 S), the water pressure is not enough to carry water. However, by reaching 3 Bar pressure, the exit of water from carrying tube is started. It should be mentioned that before reaching the 3 Bar pressure, the height of water in transmission tube gradually increases and then the exit of water is started.

Fig. 8 shows the total flow produced by this pump during 5 second. As it is seen, before 0.6 second the output

**Fig. 3. Two Stages of the Proposed Air Pump**

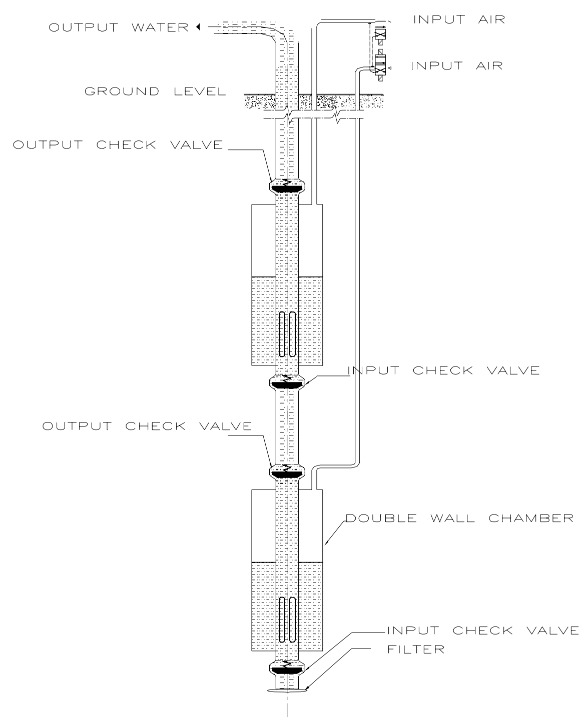


**Fig. 4. Transient Response of Compressor Pressure**

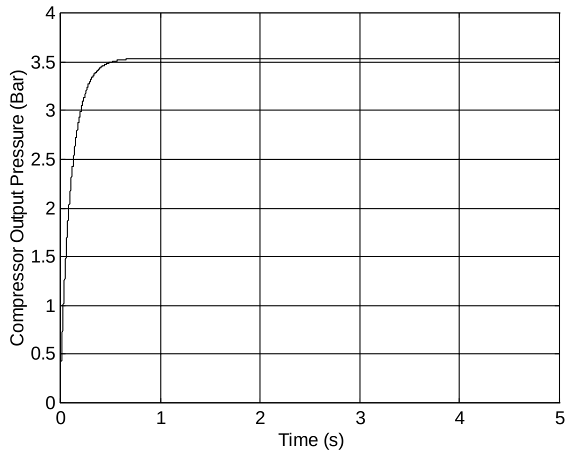



**Fig. 5. Transient Response of Compressor Flow**

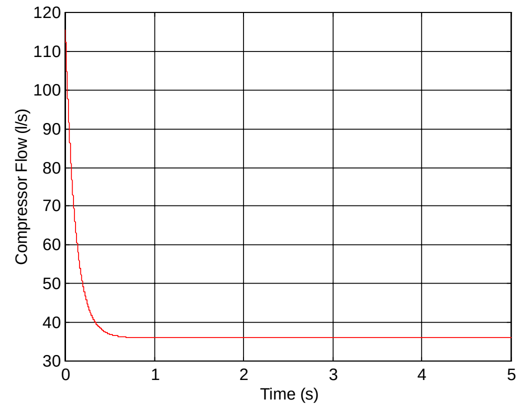



**Fig. 6. Relation Between Compressor Pressure & Flow**

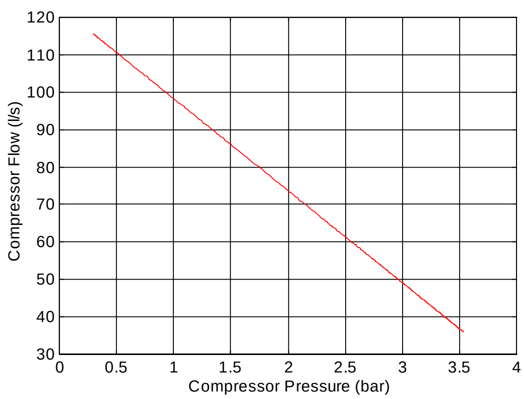



**Fig. 7. Carrying Tube Pressure Versus Time**

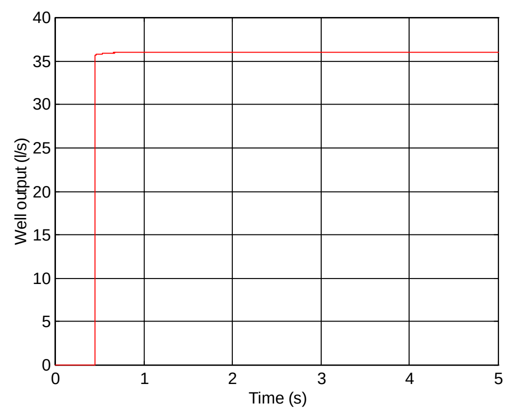
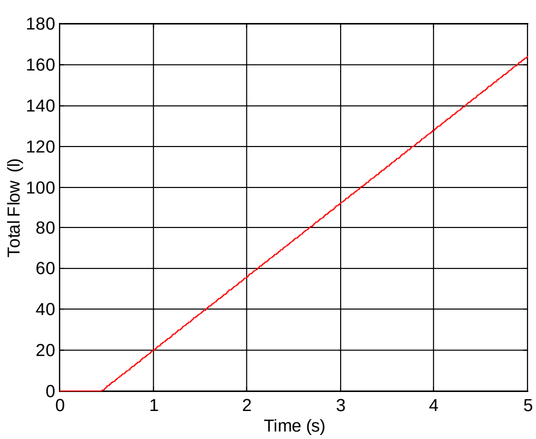



**Fig. 8. Air Pump Flow Delivery Versus Time**




flow is zero, however, after 5 second the total is 165 L. To increase this value, the volume of the double wall chamber should be increased and also the cycle time should be considered larger.

## CONCLUSION

The feasibility of a new air pump was investigated in this paper. This air pump is more simple and needs less maintenance in comparison with the other well pumps. A prototype was manufactured and then based on the simulation results, the response time of 0.6 second was achieved. The results showed that for each cycle of 5 seconds, 165 L is delivered by this system. Moreover, due to verifying the air pump model, it is possible to design air pumps with different cycle times and also capacities to be used in various wells.

## REFERENCES

Brown, R.N., 1986. *Compressors and Selection Sizing,* p. 788. Gulf Publishing, Housten Texas, USA

Cherkassky, V.M., 1989. *Pumps, Fans and Compressors,* p. 388. Mir Publishers, Moscow, Russia

Mohtasebi, S.S., M. Behroozi Lar and A. Nafari Ghaleh, 2003. *Modeling, Simulation and Analysis of an Air Pump.* Annual Conference of CSAE/ SCGR, Annual Conference of CSAE/SCGR, Montreal, Quebec, July 6-9, 2003, Canada

Nafari–Ghaleh, A., 2000. Optimization of a new air pump, *M.Sc. Thesis,* Department of Power and Machinery, Tehran University, Tehran,

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