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Effect of Valve Opening on the Performance of a Pumping Station in a Pipeline Transportation System Using Dampers: An Experimental Study

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ABSTRACT

The article examines whether a choke valve opening affects the productivity of a sewerage system with dampers located in the pipe transportation line or not. The work employs a complete setup that determines the role of the valve openings in fluid flow, pressure profiles, and power consumption through experimental evaluation. The study now provides insights concerning the best possible vapor opening configurations, and damper adjustments, which, in turn, further improve the pumping station performance. Studies provide an addition to knowledge on fluid flow characteristics in fluid pipelines and suggest several recommendations on adopting proper procedures, flow rates, and acceptable pressure levels. The results of this research are a valuable contribution to the planning and regulation of safe and stable pipe systems transporting the particles. It is the pump's flow that determines what flow value the valve opening has. Leaving aside very low hydro speeds, the gate's capacity in a momentary instant change from 1.972 L/m to 6.67 L/m through the quickness of flow. The diagram of the pressure chart suggests that there is a marginal increase in the efficiency of the valve opening due to stronger flow disturbances. The stability of the pump is at its highest at speed 1: the servo-valve opening is fully open; and at speed 10, the acceleration values are 0.1297 m/s^2, 0.2848 m/s^2, 0.2017 m/s^2, 0.1876 m/ s^2, and the shaft would produce vibration with an acceleration value in the Z axis during a 10-minute test. It proves that the pump works better than the pump did before.

1. Introduction

Purport to conduct this experimental study and so can find out what an impact of opening valves and adjusting damper settings have on the efficiency of pumping stations in pipeline transport systems. The experimental setup systematically changes valve opening states and damper settings to understand the effect of these function parameters on the flow characteristics, the profile of the pressure, and the energy consumption. Because of that, the results are supposed to be the major impetus for acquiring in-depth knowledge of the workings of the flow pattern systems in the channels and offering practical recommendations for making pumping station operations efficient. The study's

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findings would make the authorities consider the implementation of solid steps to improve the general performance of pipe transporting systems. In addition, the research will not only enrich the field of pipeline engineering, but also enable engineers to effectively and environmentally friendly transport systems to be designed. The study's findings will be given where links between dietary change and health improvement will be presented. Also, the relevance of this study for future academic research and practical applications will be discussed.

Dai, *et al.*, [1] analyzed the vibrations brought about by a vortex of a moving liquid in an explained tube utilizing Galerkin's four-mode approach. Results showed that when the liquid speed is in the subcritical region, the cylinder displays different powerful way of behaving, including upset period multiplying of dendrites. Siba, *et al.*, [2] Stream-instigated vibration is a subject of observational review pointed toward carrying out stream control applications utilizing gap innovation. It inspects the progression of different liquids, including water, oil, gas, and fumes, and makes numerical models for precise estimations. Scientific, mathematical, hypothetical, and exploratory examinations settle on various ways of making, improving, and changing these measurements.

Nosherwan Shoaib, *et al.*, [3] explored the proliferation of electromagnetic waves in oil transport pipelines underground, zeroing in on the engendering of these waves under high temperatures. It makes a model at the lower part of the well for oil pipelines, working out dispersing factors to confirm the pipeline's exhaustive remote capacities. Bhagwat *et al.*, [4] uncovers that line networks changed to deal with liquids like steam, different cycles, and hydrocarbon gases can cause high stream, acoustic vibrations, and mental exhaustion. Carucci and Mueller acquainted a procedure with decide tubules' aversion to AIV stress disappointment quite a while back. This exploration proposes a procedure to diminish acoustic vibrations in channeling frameworks, possibly focusing on countermeasures to lessen tube disappointment brought about by AIV and FIV. Shuai Meng [5] concentrated on zeroed in on the use of the proposition to gather and store carbon dioxide and to show that the cylinder introduced on one side can acquire energy misfortunes because of the inward stream. Fixed toward one side to deplete the fluid [6], the Galerkin differential change approach uncovers nonlinear intensity and stream-prompted vibration in liquid vehicle structures. Enormous contrasts in structure subtleties decline unsteady vibration frequencies, while an expansion in slip coefficient diminishes vibration recurrence and speed. These discoveries are significant for the moved substance and inconsistent.

Talib EH. Elaikh, et al [7] introduced a no-vibrational logical answer for the useful characterization (FG) of a fine material transmission liquid. It uncovers that the material's properties change with microtubule thickness and rely upon the power dispersion regulation and connected pressure. Hamilton's guideline is utilized to find the condition of movement for limit conditions. The concentrate likewise features the effect of liquid stream speed, inclination file, and material length scale boundary on the vibration and dependability of female vaginal liquids. Chenghua Shi *et al.*, [8] featured the significance of underground pipeline networks for giving fundamental necessities like water, gaseous petrol, and oil. Nonetheless, fast urbanization and parkway advancement present critical dangers, including blast burrowing. Pipelines' materials, wall thickness, and stress conditions shift, leaving every pipeline with fluctuating protection from stacking. Hence, unique PPV control rules are required for every pipeline. A strategy ought to be created to decide the PPV control standard for pipelines covered underneath nearby passage impacts, taking into account factors like material, wall thickness, and tension circumstances. This will guarantee pipeline security under impact loads. Enbin Liu, *et al.*, [9] underscored the significance of legitimate treatment of gaseous petrol station pipelines to forestall strange vibrations and possible financial misfortunes. Three vibration decrease frameworks have been proposed and tried, with the principal wellspring of atypical vibration being liquid strain variety ready to go. The review presumes that raising the line breadth and introducing legitimate limitations is the best technique for diminishing vibration in the framework.

Dhurgham and Muhannad Al-Waily [10] zeroed in on the vibrations in pipelines used to ship liquids in modern settings. Vibrations can cause framework breakdown and monetary misfortunes. The analyst investigated ways of decreasing vibrations and oversaw them utilizing the Nyquist strategy. The review broke down the powerful way of behaving of moderate and non-moderate liquid shipping tubes without water-driven damping, following each stage's response and steadiness. Differential conditions for lines and obsessions were inferred, and the overall active condition for pipeline transport liquids was addressed utilizing Galerkin innovation. The steadiness was determined utilizing Nyquist procedures. The exploration features the significance of successful control and obsession in pipeline frameworks. Stephanie Rinaldi [11] introduced an insightful model for the enhanced straight elements of a cantilever chamber subject to a hub stream, breaking down powers at its free end. The examination recommends that the chamber might become temperamental at lower stream speed because of vibration. Duha *et al*., [12] dissected the impacts of different elements on pipeline networks introduced in the oceans, including waves, flows, barge development, and cooperation with the ocean bottom. It developed a powerful investigation of a suspended subsurface J-mode pipeline during establishment, taking into account ocean state, wave bearing, and water profundity. The outcomes showed that wave bearing's effect on bowing second beginnings at 2 meters beneath the water's surface, reduces until 100 meters, and wave level's effect starts at 2 meters [13]. The observation aimed to locate the most advantageous conditions for treating palm oil mill effluent (POME) wastewater with microalgae, thinking about retention time as an important parameter. The look at used a significant composite rotatable layout with a second order polynomial model, estimating removal chances of nutrients. The surest conditions were 18 days for ammonia nitrogen and 9.22 pH, and 15 days for Ortho phosphorous with a pH of nine.2. The effects were verified through experiments.

Qusay *et al.*, [14] targeted to optimize the overall performance of hole fiber ultrafiltration (UF) membranes the use of air-liquid-segment float. The Win-QSB approach is used to estimate and optimize working situations, including feed awareness, drift rate, temperature, transmembrane stress, and air float price. Results confirmed that air flow rate substantially affects permeation flux and protein rejection and that air injection with the feed solution complements permeate flux by using zero.37. Mohammed *et al.*, [15] introduced a method for preparing metal-graphite composite brushes in electric-powered vehicles, making sure they've mechanical and electrical houses that align with standards, and remodelling electric energy into mechanical electricity [16]. The have a look at located that adding nanofluid to photovoltaic panels (PV) can improve their efficiency and thermal performance. The use of nanofluid can reduce the temperature of the panels, improving their performance. The thermal model for the proposed cooling technique can assist engineers lessen checking out time and price. They have a look at also showed that the coefficient of heat switch and Nusselt quantity boom with the attention of nanofluid. This shows that nanofluid can considerably improve the performance and performance of PV panels, particularly in high-temperature conditions like Iraq.

Understand how a sort of valve opening affects the performance of a pumping station at transmission line which are equipped with a feeder. Probably the study intends to understand what is the way by which valves interrupted flow rates, pressures efficiency and performance of the system. Besides, it strives for an evaluation of the impact of dampers on stream distribution and a surge of system operation comfortability levels. The approach of the study is to conduct experiments to shed light on the required characteristics and optimal operation of pumping infrastructures in pipeline delivery systems to improve efficiency, reduce energy consumption, and sustain operations.

2. Experimental Work

The actuator valve controls the damper and system to minimize pulsing from the dosing pump. Water is chosen for flow due to 20°C winter conditions in Iraq, calculating Reynold's number .The test configuration for this experiment is in Table 1.

Table 1
Water properties [13]

Temperature (∘ C)	Density, ρ kg/m^3	Dynamic Viscosity, μ (Pa-s)
0	999.9	1.792E – 03
5	1000.0	1.519E – 03
10	999.7	1.308E – 03
15	999.1	1.140E – 03
20	998.2	1.005E – 03
30	995.7	8.010E – 04
40	992.2	6.560E – 04
50	988.1	5.490E – 04
60	983.2	4.690E – 04
70	977.8	4.060E – 03
80	971.8	3.570E – 04
90	965.3	3.170E – 04
100	958.4	2.840E – 04

3. Structural Parts

PVC pipes are a popular choice for piping systems due to their durability, chemical resistance, cost-effectiveness, and ease of installation. They are suitable for indoor and outdoor applications, are lightweight, and have good insulating properties. Available in various sizes and configurations, they are easy to install, recyclable, and non-toxic, meeting safety standards. They work to draw water into systems and push it to glass aquariums. They consist of two tubes, each tube 1 meter long. The first tube connected to the dosing pump has an outside width of 25.4 mm and an inner distance of 18 mm, and the other going to the aquarium has an outer breadth of 25.4 mm and an inside measurement of 16 mm. As shown in Figure 1 and Table 2.

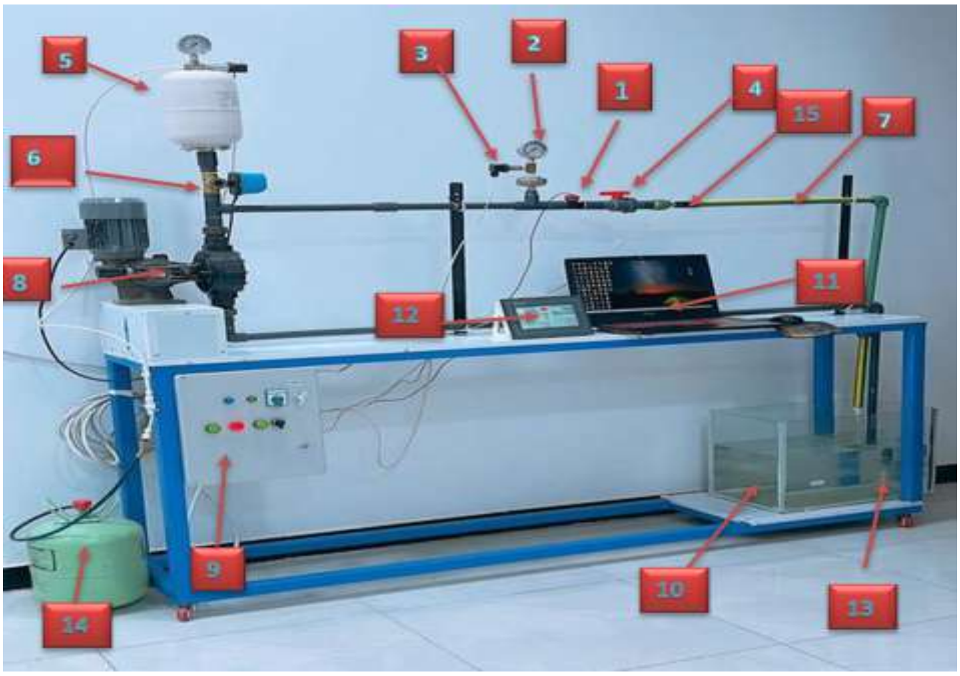

Fig. 1. Present pumping system

Table 2
Part of the system

Tag number	Part name
1	Flow rate sensor
2	Pressure gage sensor
3	Electric pressure sensor
4	Mechanical valve
5	Damper
6	Electric valve
7	PVC pipe
8	Dosing pump
9	Control unit
10	Water pool
11	Computer
12	Display control
13	Filter
14	Gas storage
15	Accelerometer sensor

A ball valve is a quarter valve with a hollow cylindrical ball controlling water or airflow. Commonly used in industries like oil and gas production, chemical manufacturing, pharmaceutical manufacturing, and power generation, it has fast quarter-turn operation, excellent sealing properties, and a wide range of pressures and temperatures. However, they may not be suitable for microcontrollers, are susceptible to cavitation and erosion, and the initial cost is high with an inner diameter of 18mm. As shown in Figure 2.

Fig. 2. Ball valve

A dosing pump is a positive displacement pump used in various industries for precise injection of liquids. They work on the principle of displacement, delivering a constant volume for each stroke. Types include diaphragm, peristaltic, piston, gear, and solenoid-driven pumps. Features include accuracy, pressure, material compatibility, control, maintenance, safety, and installation. Modern dosing pumps can be integrated into control systems or operated remotely. As shown in Figure 3.

Fig. 3. Mechanical diaphragm

The pump calculations were made based on the ten speeds included in changing the pump speeds, and then the amount of flow was calculated using the flow sensor, and then the rest of the details were calculated, such as the speed of the fluid and Reynold number as Table 3.

Table 3
Pump calculations

Dosing pump speed	Flow rate (m^3/s)	Velocity (m/s)	Reynold number
Speed 1	0.0000248	0.097507	1341
Speed 10	0.0001380	0.543563	7478

Dampers as Figure 4 are crucial in various industries for their ability to absorb and dissipate energy, providing vibration reduction, improved comfort, safety, extended equipment life, performance, and mitigation of external forces, energy absorption, and flexibility. They help prolong machinery and equipment life by reducing stresses and strains caused by vibrations, resulting in cost savings. Advancements in technology allow some dampers to adjust their characteristics in real time, providing greater flexibility and adaptability. Overall, dampers are essential for smooth and efficient system operation [14].

Fig. 4. Pressure tank

4. Measurement Device

Mesens MPS300 Pressure Transmitters are heavy-duty, fully welded pressure transmitters with adjustable process size, electrical connection parts, and signal output. They can be customized with brand and type number for high demands, as shown in Figure 5.

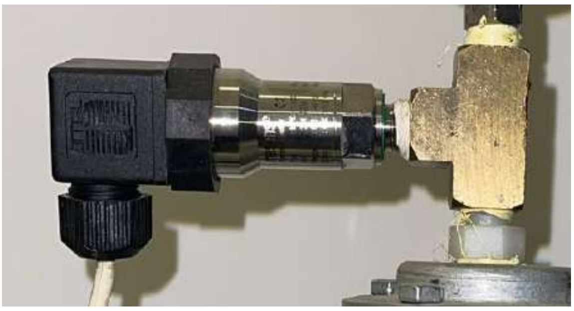

Fig. 5. Electronic pressure sensor

The ADXL335 is a low-power, 3-turn accelerometer that measures speed increase with a full scale of ±3 g. It can measure static speed increase of gravity in slant recognition applications and areas of strength for improvement, shock, or vibration. The accelerometer is available in a small, low-profile, 16-lead, plastic lead outline chip pack [15]. The sensor is installed vertically on the vibrating water pipe, and readings are taken along the z-axis to obtain the vertical vibration of the pipe during the measurement and vibration process.

Fig. 6. Accelerometer sensor

Turbine flow sensors are liquid flow measurement sensors that have convincing accuracy in addition to a wide range. The advantage of this sensor is not deviation. The work includes where the fluid that passes through the sensor is divided equally in rotating turbines and the rotational speed of the rotor and then converted to an electrical impulse signal commensurate with the flow, as shown in Figure 7 [16].

Fig. 7. Electronic pressure sensor

Pulse valves, also known as air shock valves, are used in dust collection. When energized, the valve moves open, creating shock waves that remove dust and particles. To blow, compressed air needs to wait for the valve to close, requiring an on-off signal. Figure (8) shows the solenoid valve [17].

Fig. 8. Solenoid valve

5. Control Unit

The system used for the experimental tests was controlled through a control unit that contains a PLC, power supply, contactor, and safety relay. Through this system, the sensors and devices associated with the system can be controlled, through which the amount of vibration produced through the pipes due to the pulse pump is calculated, which works to divert the flow. Normal to unsteady flow, and it is reduced by the damper in the system. This programming was dealt with through three main programs, the first to operate is DVP022 of the control screen, the second to run the rest of the system, and the last to display Delta WPL soft ladder diagram mode to the results and extract them from the system, which is known as DOP eServer.

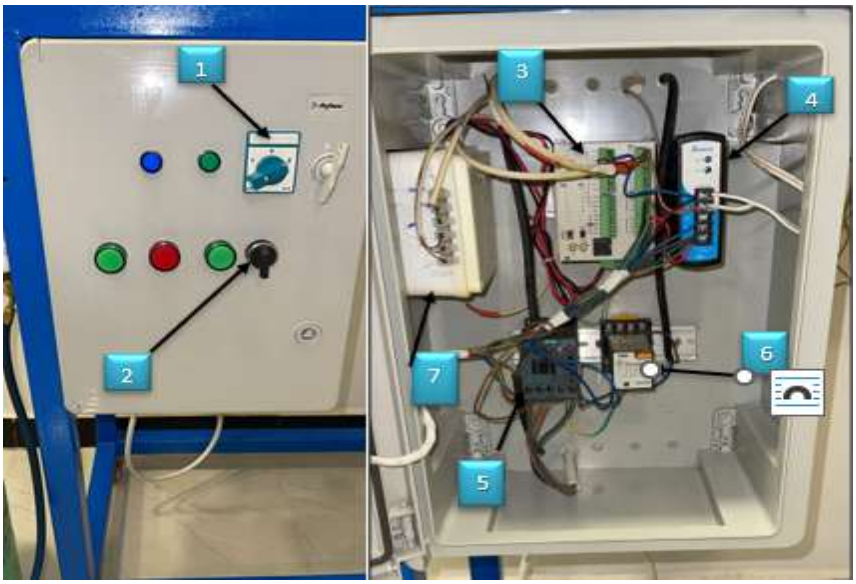

Fig. 9. Control unit

Table 4
Part of a control unit

Tag number	Part name
1	
2	
3	PLC
4	Power supply
5	Contactor
6	Relay safety
7	

6. Control Operation

The system is operated manually, starting from the pump speed value as well as the valve opening on the manual pipe, then waiting a certain time according to the test time, and then operating the electronic valve manually from the control panel, so that the damper begins its work and reduces the amount of vibration resulting in the pipes from the dosing pump. As for automatic operation, it is considered to turn on the system and then give an order through the control panel when a certain value of vibration in the pipe is reached through the acceleration sensor. The system works to instruct the electric valve to open the damping system and reduce the amount of vibration resulting in the pipe, reducing the amount of acceleration that occurs. In the acceleration sensor.

7. Results and Discussion

The next part of this last section will summarize experiment results which will be obtained through experimental tests for different valve openings. The tube flow rate and the pressure as a result of vibration will be reviewed in addition to the change in the z-axis leading to the Calculation of vibration.

8. The Effect of Valve Opening on Water Flow Rate

Monitoring and evaluation of this study are based on the investigation of how the valve opening positions affect the water flow rate in the pipe transportation systems. The researchers, in the meantime, use specific valve opening positions to adjust the volume of water that flows from the pipe at different points along the pipeline. They seek to delineate the relationship between the valve opening and the nature of the entire water flow dynamics and the interaction of valves with dampers. This research will explore the best lever positions that offer the highest flow rates yet guarantee complete system stability and performance. It generates data that allows observing the course of the problem and to identify possible trade-offs among the valve positions, the system performance, and the energy consumption. The conclusion will serve as a base for observing the influence on water flow rates implemented with valve opening and suggest measures regarding the operation of a pumping station and pipeline systems efficiency.

The valve opening is dependent on the flow rate as represented in Figure 10. Out of the two water pumps excited, the full-open valve No. 1 reached the maximum flow of 1.972 L/m at the first speed and amount of 6.99 L/m at the tenth speed, and therefore the speed of the pump has the largest effect on the quantity of water received. The flow at the half-closed valve was 1.8 L/m at speed 10, and the flowing volume was 6.67 L/m, but when the valve opened its hole for half, the value of flow at speed 4 reached 1.65 L/m which is lesser compared to the blockage before it. With the rate of flow being set to 10, the flow index came up to 6.56 L/m. The last case, in which the valve is open until 1/4, shows flow rate as 1.081 L/m which is indicatively a minimum value. The flow reached it from fluid dynamic standing in the rest candidates. When speed 10 was set, I observed that the flow rate hit 6.488 L/m.

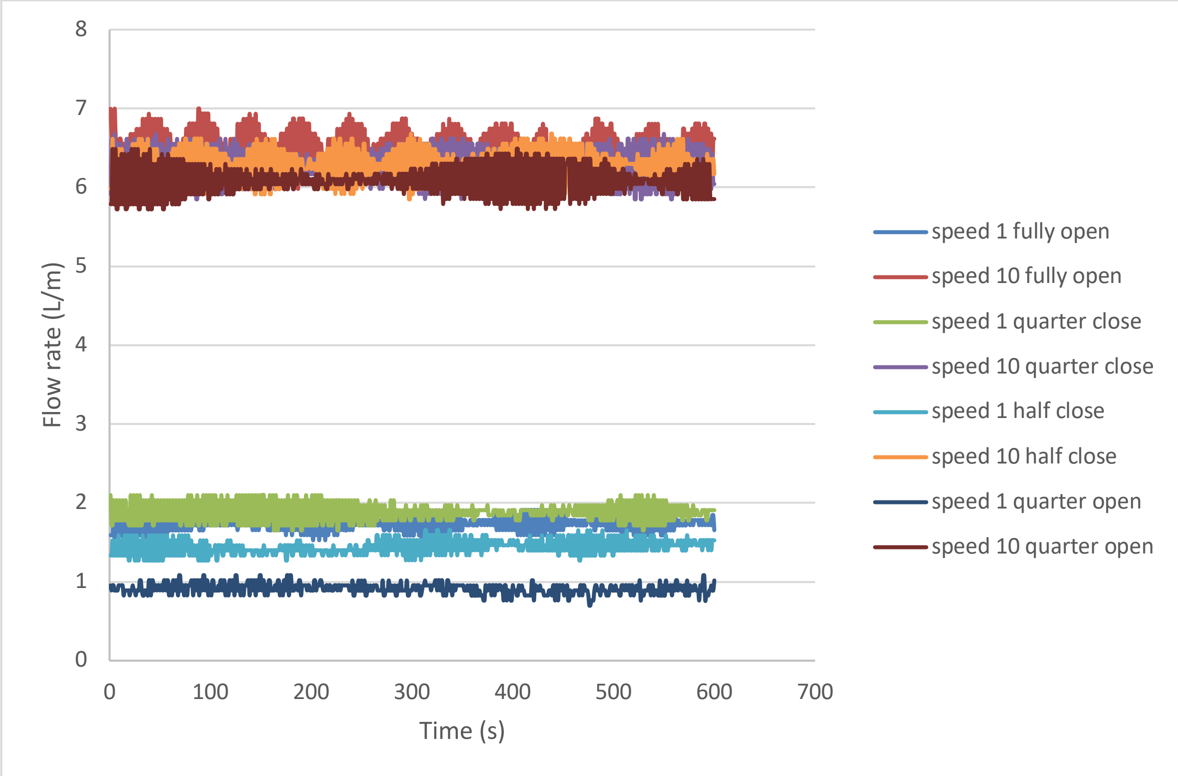

Fig. 10. Flow rate with time for different pump speeds and valve opening

9. The Effect of Valve Opening on Water Pressure

The experimental research in this study describes the role of valving cylinder positions in water pressure in the pipe transportation system. The study proceeds in the form of controlled experiments through monitoring changes in valve opening end-pressure levels and assessing the relationship between dampers and water pressure dynamics. The research employs sensor-based techniques to properly and precisely measure pressure and flow rates, and endeavors to discern how the dampers are influenced by varying valve openings. This becomes a matter of identifying the most effective configuration of valve that open most of the required pressure levels while keeping the system as performant as possible. The outcomes are projected to help in identification of the advantageous valve openings, pressure regulation, and the relation to energy consumption. Such data will allow for a deeper comprehension of valve opening's influence on the water pressure and can also advise about the conception of the pumping systems' operation strategies.

The above diagram, which is the pressure curve at full flow of valve, indicated that for the 1st of chosen speed, 0.1 bar successfully achieved pressure value however this was not limited it always continued to rise until 21 times during the first 10 minutes of the test period. When the pump operated at a speed of 10, the pressure caused more than three times increase when compared to a lower pressure of 0.8 bar.

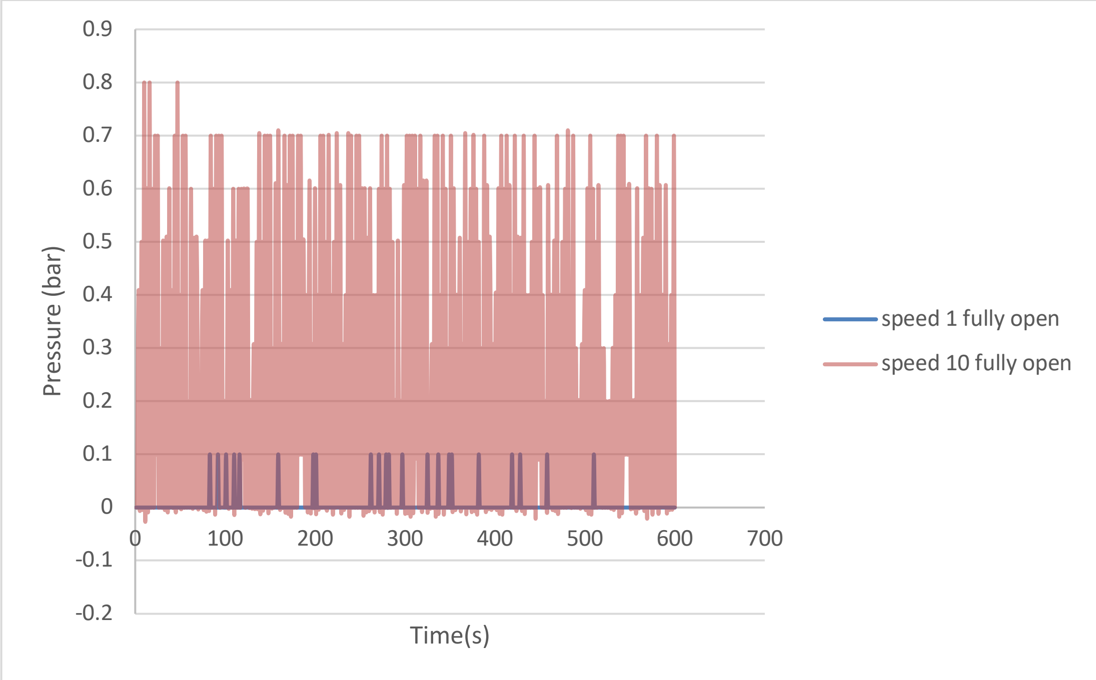

Fig. 11. Pressure with time for different pump speeds at a fully open valve

From Figure 12 which shows the burst pressure diagram at one quarter to the valve opening, one can see that the pressure shot up to 0.1 bar at speed 1, but numerous times, the pressure was recorded to have risen to 0.1 bar before finally settling at a pressure value of 0.1 bar within 10 minutes of the test duration. The pressure of gases at speed pump 10 was 0.6 bar, which is about the full opening of the gas valve.

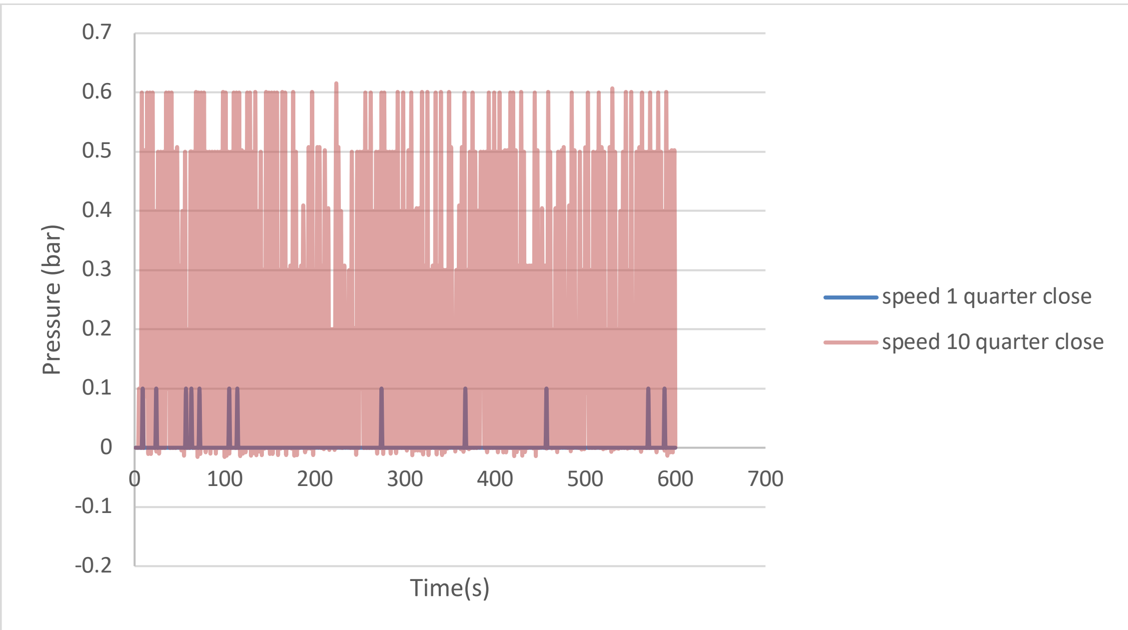

Fig. 12. Pressure with time for different pump speeds at the quarter close valve

From Figure 13, which shows the pressure diagram at the half-closed valve opening, it is noted that the pressure value reached 0.1 bar at speed one, but many times due to flow disturbance, it continued to rise to 0.1 bar up to 2 times within 10 minutes of the test time. When the pump speed was 10, the pressure reached 0.6 bar, but not for a large number of times, and this indicates the effectiveness of the pump opening in making the system stable.

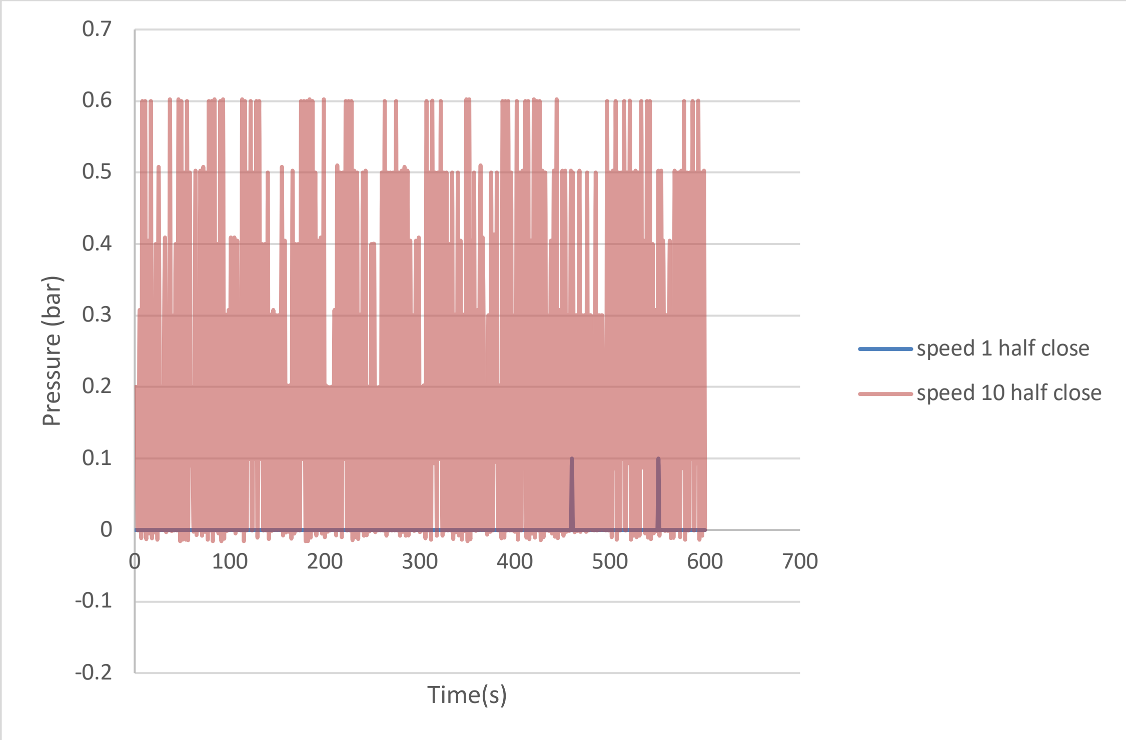

Fig. 13. Pressure with time for different pump speeds at half-close valve

From Figure 14, which shows the pressure diagram at the quarter-hole valve opening, it is noted that the pressure value stabilized at zero within 10 minutes at the time of the test. When the pump speed was 10, the pressure reached 0.9 bar, but not for a large number of times, and this indicates the effectiveness of the pump opening in making the system stable.

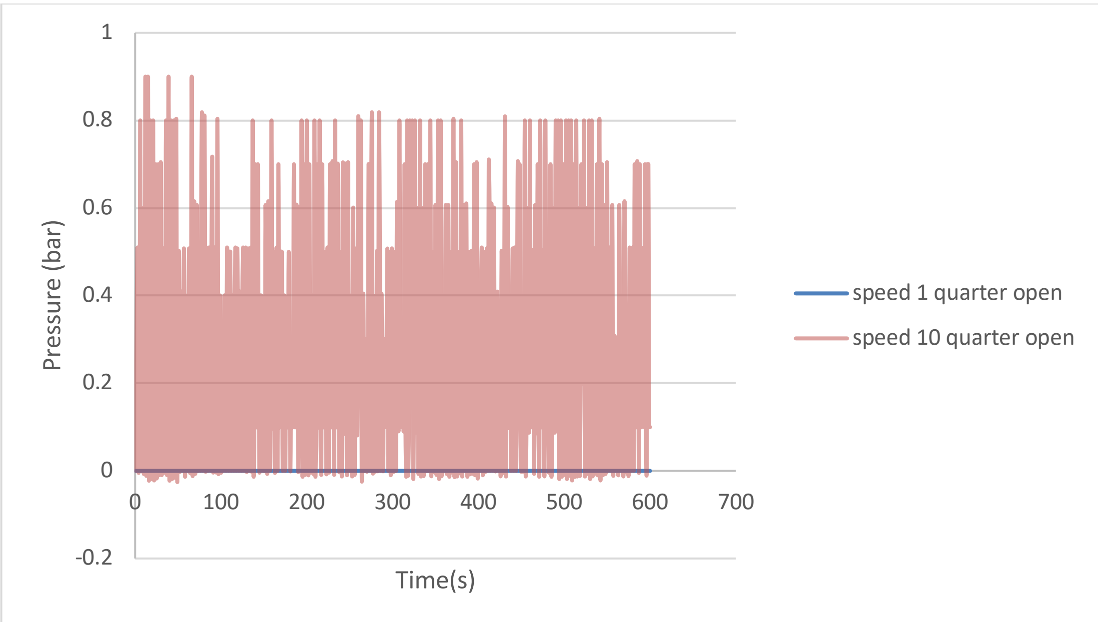

Fig. 14. Pressure with time for different pump speeds at quarter open valve

10. The Effect of Valve Opening on Acceleration

This experimental study investigates the impact of valve opening positions on fluid flow acceleration in pipe transportation systems. The researchers systematically adjust valve opening positions and monitor the corresponding acceleration at different points along the pipeline. From an experimental aspect, their target is to examine the relationship between valve opening and hydrodynamic flow characteristics, as well as the response of valves to dampers. The main goal of the study is to determine the perfect valve opening settings that will cause uniform quickening of the moving fluid and ensure system stability and safety. The discovered facts will deepen our knowledge of such effects in the field of fluid acceleration and they will remind us about the proper ways of improving pumping station operations and saving pipeline network performance. The results will also inform practical strategies for optimizing pumping station operation.

In Figure 15, which shows the vibration with the acceleration value in the Z axis on the shaft during 10 minutes at the time of the test, it is noted that its value reached 0.1859 m/s^2 at pump speed 1 and the valve opening is fully open, but at pump speed 10, the acceleration value reached 0.1297 m/s^2 This indicates the stability of the pump compared to the speed of the first pump.

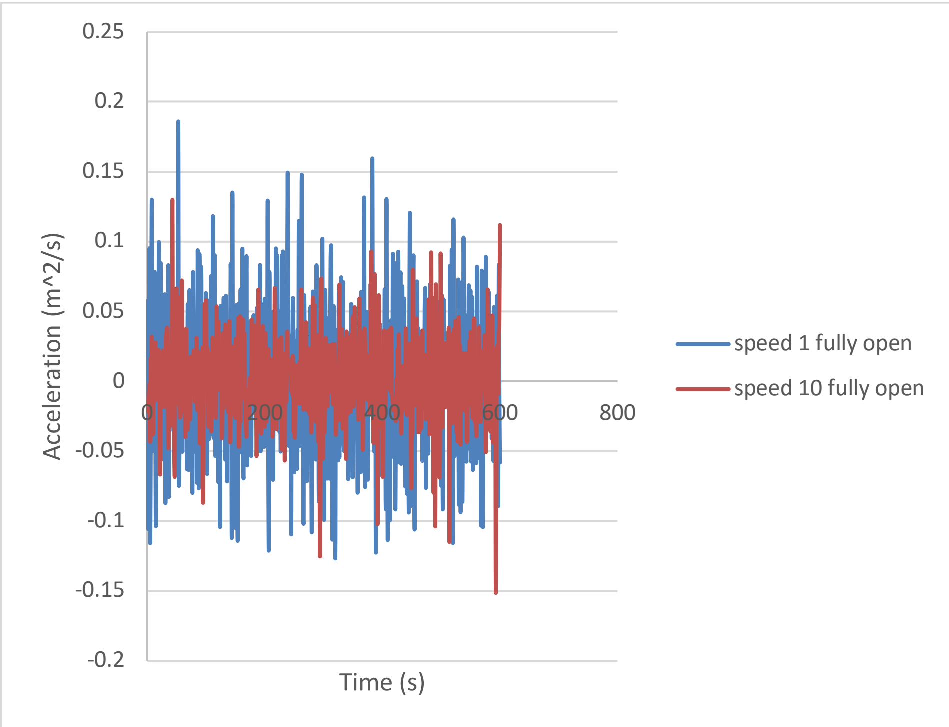

Fig. 15. Acceleration with time for different pump speeds at a fully open valve

In Figure 16, which shows the vibration with the acceleration value in the Z axis on the shaft during 10 minutes at the time of the test, it is noted that its value reached 0.2848 m/s^2 at pump speed 1 and the valve opening is a quarter closed, but at pump speed 10, the acceleration value reached 0.2017 m/s^2 This indicates the stability of the pump compared to the speed of the first pump.

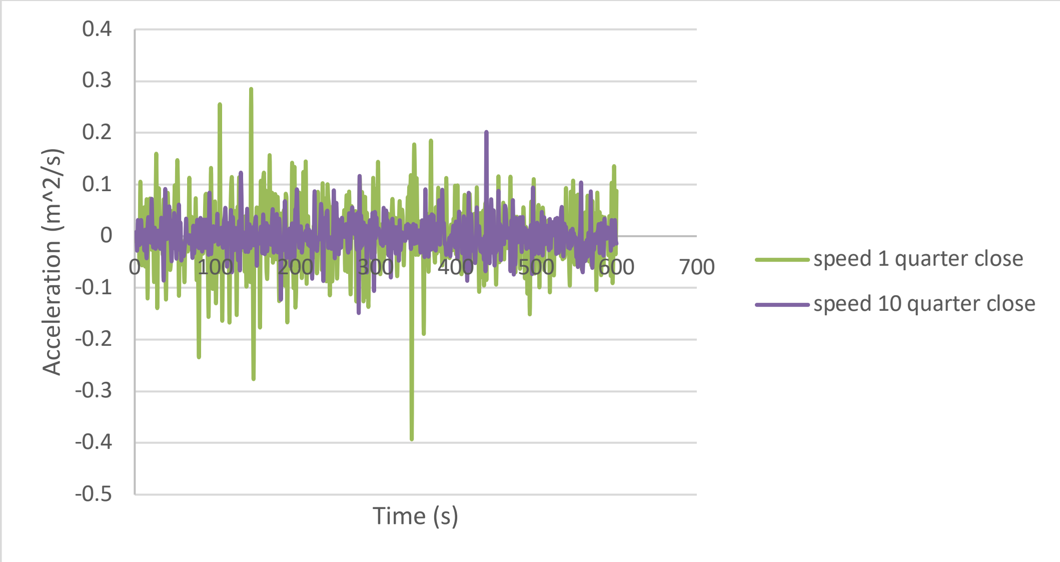

Fig. 16. Acceleration with time for different pump speeds at the quarter-close valve

In Figure 17, which shows the vibration with the acceleration value in the Z axis on the shaft during 10 minutes at the time of the test, it is noted that its value reached 0.148 m/s2 at pump speed 1 and the valve opening is half closed, but at pump speed 10, the acceleration value reached 0.11639 m/s2 This indicates the stability of the pump compared to the speed of the first pump.

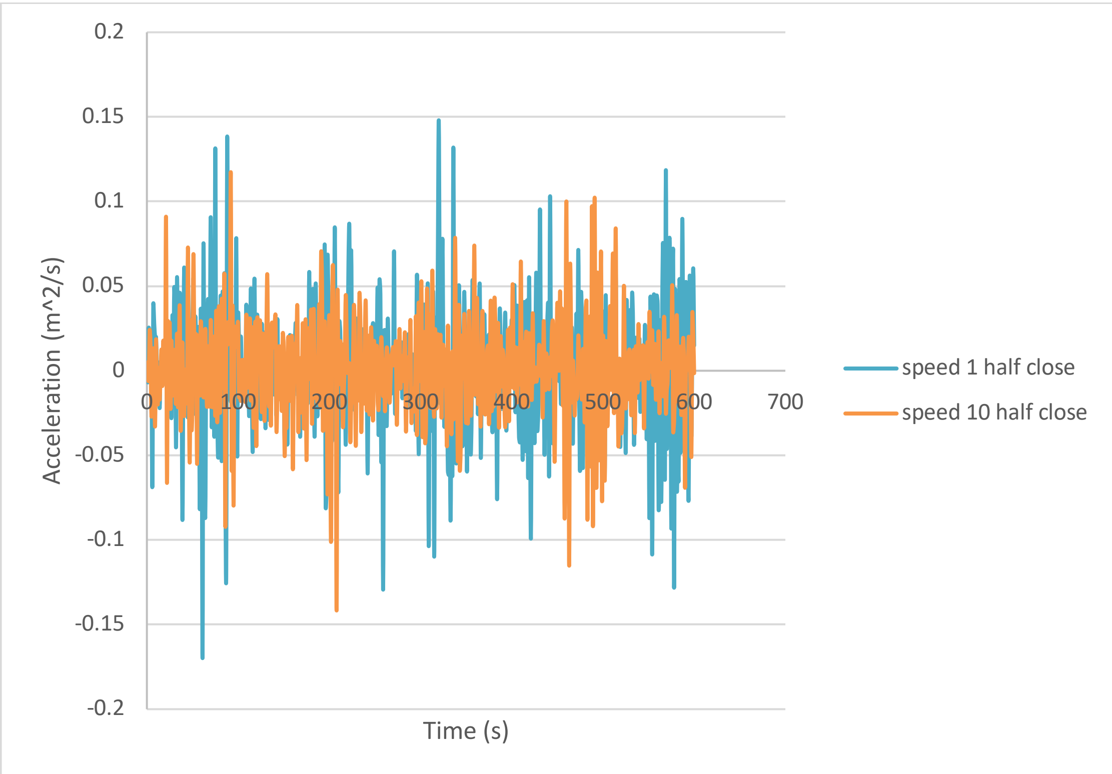

Fig. 17. Acceleration with time for different pump speeds at half-close valve

In Figure 18, which shows the vibration with the acceleration value in the Z axis on the shaft during 10 minutes at the time of the test, it is noted that its value reached 0.1876 m/s2 at pump speed 1 and the valve opening is a quarter opening, but at pump speed 10, the acceleration value reached 0.134 m/s2 This indicates the stability of the pump compared to the speed of the first pump.

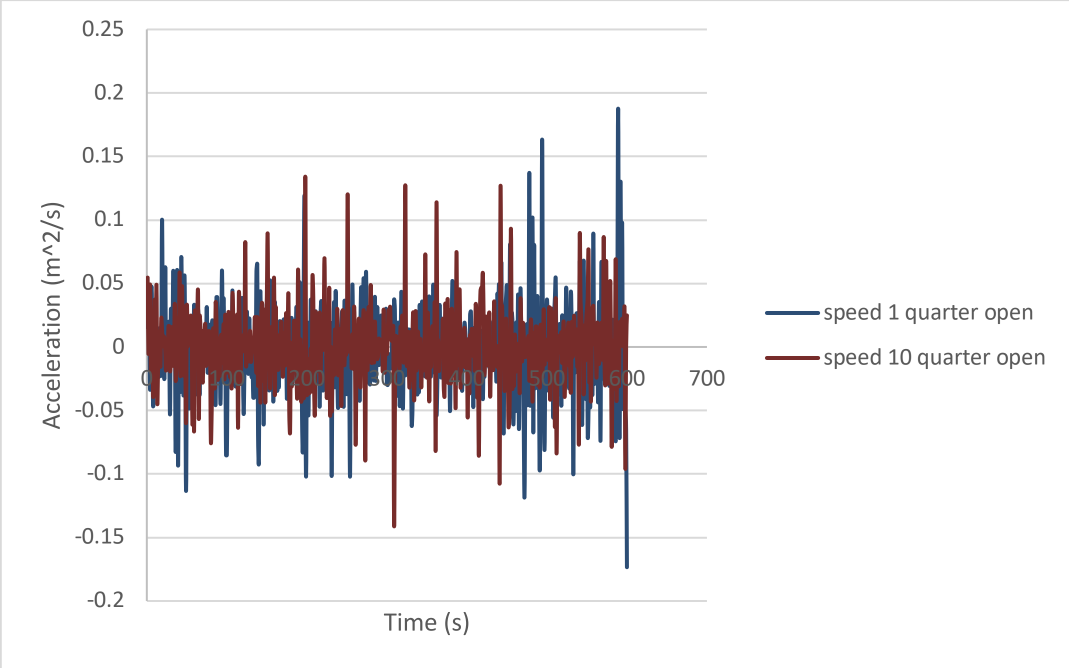

Fig. 18. Pressure with time for different pump speeds at the quarter-open valve

11. Conclusion

The flow rate affects the valve opening's flow value. At the first pump speed, the valve reached 1.972 L/m, reaching its highest at 6.99 L/m. At speed 10, the valve reached 6.67 L/m. However, at speed 1, the valve reached 1.8 L/m, reduced to 6.67 L/m. At speed 10, the valve reached 6.56 L/m, and at speed 10, the valve reached 1.081 L/m. The lowest flow value was reached at speed 10, reaching 6.488 L/m. The pressure diagram at the full valve opening showed a pressure value of 0.1 bar at speed one but increased due to flow disturbances up to 21 times within 10 minutes. At pump speed 10, the pressure reached 0.8 bar more than three times. At the quarter-closed valve opening, the pressure reached 0.6 bar but increased to 2 times within 10 minutes. At pump speed 10, the pressure reached 0.6 bar but not for a large number of times, indicating the pump opening's effectiveness in stabilizing the system. At the quarter-hole valve opening, the pressure stabilized at zero within 10 minutes, and at speed 10, the pressure reached 0.9 bar but not for a large number of times. The vibration with acceleration value in the Z axis on the shaft during a 10-minute test showed that the pump's stability was highest at pump speed 1 with a fully open valve opening. However, at pump speed 10, the acceleration value increased to 0.1297 m/s^2, indicating the pump's stability compared to the first pump. The vibration also reached 0.2848 m/s^2 at pump speed 1 with a quarter-closed valve opening. At pump speed 10, the acceleration value increased to 0.2017 m/s^2, indicating the pump's stability compared to the first pump. The vibration also reached 0.1876 m/s^2 at pump speed 1 with a quarter-closed valve opening. Lastly, at pump speed 10, the acceleration value reached 0.134 m/s^2, indicating the pump's stability compared to the first pump.

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