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Research Article

The long term effect of hammer influenced in water pipe line (Case study: pipeline from Azadi to Hor)

Roozbeh Aghamajidi*

*-Assistant Professor, Faculty of Engineering, Islamic Azad University, Sepidan Unit, Fars, Iran

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Abstract

Due to the increase in population as well as the increasing of the human need for water, it is vital for preserving water resource in each area. In the meantime, Iran has been in a state of inaccurate crisis due to the excessive withdrawal of water resources. Therefore, it is important to maintain water resources. And, the traditional methods of water transfer (using open channels and ...) are replaced by new methods such as the use of a water supply pipe. These methods, in addition to cost, have many technical benefits. Including increased transmission efficiency, reduced water waste, as well as saving passive defense principles.

Meanwhile, the use of GRP pipes, in the last 40 years, has led to a dramatic increase. Although the life period of these pipes in the our country will reach 53 years, the efficiency of these engineering pipes has become more and more enriched, reaching its true position in the country.

Due to the great efforts of the responsible and informed management of some manufacturers of these products in the country, the optimal use of this type of pipes is increasing. In this regard, Farassan Co., as the flagship of this industry, has made endless efforts to update and improve the quality of pipes, and has made significant progress. One of the most important points in the use of GRP pipes in comparison with other pipes is the lack of knowledge and awareness of some customers about these pipes and products, which is always a concern for employers and consultants. In this paper, in addition to the proper introduction of GRP Pipes and their use in comparison with other PIPES, it has been tried to discuss the control and monitoring the of the Water hammer in these types of products. In this regard, in the case of a water pipe line project from Azadi dam to the plain of Hor as one of the most important projects of water transportation in Iran, is briefly introduced and analyzed according to the details. Finally, a briefly studying about control and effect of the hammer phenomenon on the GRP pipes in special project is perfectly discussed.

Keywords:

GRP, Hammer, Control, Water Pipe Line, Effect Sand

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*Corresponding author E-mail address: *roozbehaghamajidi1396@gmail.com*

1- Introduction

One of the most important issues in the design of pipes for water supply systems, water transmission and distribution, is the selection of the type of pipe used.

Depending on the need and demand, various industrial factories have produced pipes of various materials, including steel, cast iron, concrete, polyethylene and plastic. In recent years, plastic pipes and especially fiberglass pipes have gained a new place in water engineering projects. The word GRP stands for Glass fiber Reinforced Pipe, which means pipes reinforced with fiber and glass. GRP pipe was first introduced in 1948 in the oil industry. Choosing GRP pipe as a cost-effective, corrosion-resistant material is a better method compared to steel pipes coated with stainless steels and other types of metals. In the late 1950s, pipes with larger diameters entered the market, and GRP pipes were used in the chemical industry. Because this pipe had good resistance to corrosion, it was used in urban water and water applications from 1960 to 1990. One of the strengths of GRP pipe is its useful life, strength and resistance to corrosion. [4].

Another advantage of GRP pipes is the lack of environmental problems. The production and use of GRP pipes in various fields of industry, construction projects, etc., does not have any environmental risks. The reason for this comes from the fact that all the raw materials used in the construction of these pipes are neutral after the chemical reaction and become a product (pipe) and remain in the environment in the same way and do not react with it in any way. [6].

Also, in a water supply or water transmission network, various connections such as tees, elbows, conversions, etc. are used as needed. Therefore, it should be said that in the GRP pipe production industry, it is possible to produce joints in various forms, which in addition to increasing their installation capability, it is possible to reduce the number of joints used and also to produce joints in a way that has the least pressure drop and friction in front of fluid passage.

2- Literature review

Amongst the research works performed in this regard, the followings can be pointed out:

Ali and Fouzi (2001) studied water hammer created in the gravitational piping system due to the sudden shutting off the throttle using two effective numerical methods for separation and problem solving. The finite difference method was examined based on the WHAMO method and the proposed method was analyzed using AFT-Impulse Method [1,5].

Haghigipour, p. (2004). dealt in their studies with the techniques of evaluating water hammer in water distribution systems [9].

Kim et al (2015) investigated water hammer in the pipelines with an air chamber and so forth. [8].

Afshar and Mahjoubi (2008) used two methods of genetic algorithm and mathematical optimization in optimal designing of a pump-bearing transmission system against water hammer and showed it in the simulation process that the increase in the pipes' annulus causes reduction in the effects of the pump's sudden stop, especially the amount of the created negative pressure and the resultant water column separation. Furthermore, optimization was found to prevent the creation of negative wave in the pump location, reverse water movement, increase in the thrust line and reduction in the pressure of the system's suction pipeline [7].

Aghamajidi et al(2020). investigated the use of pipelines at high working pressure in different projects of Kermanshah and the effect of ram impact, and emphasized the positive result of using fiberglass pipes in search pressure[1].

3- Transient pressures, (blue shock) in GRP pipes

Internal pressures, the most well-known of which is water hammer , are caused by a sudden change in fluid velocity within the system. In certain conditions, this impact force can be so intense that it breaks the system. The transient pressure moves with the speed of the wave in the system and is able to increase or decrease the pressure according to the source and direction of the wave movement. This wave moves through the system and can cause damage far away from its source. [2].

The amount of water hammer depends on the characteristics and speed of the fluid, the modulus of elasticity of the pipe, the thickness of the pipe, the length of the pipeline and the intensity of the change of the fluid complement. The low modulus of elasticity in fiberglass pipes causes high ability, wave force dissipation and reducing the effect of waves in the system. The intensity of the pressure wave in metal pipes is much higher due to their high modulus of elasticity. Thus, the intensity of water hammer in Fratec pipes is about half of its intensity in similar conditions in carbon steel or cast iron pipes[2]..

The pipes of this GRP in any pressure category are able to withstand water hammer up to 40% more than their nominal pressure. For example, a pipe with a working pressure of 10 bar to a pressure of 14 bar is resistant to ram. The following approximate relationship is used to determine the pressure changes at a given point in a straight pipeline, neglecting the small drop due to friction: [4].

$$\Delta H = (w.\Delta V)/g$$

In which :

Pressure variation (m) = ΔH

Surge velocity (m/s) =w

g=acceleration of gravity

The pressure wave speed in GRP pipes can be extracted from the following table:

Image (1) A view of the implementation of GRP pipes in industrial projects

Table (1) pressure wave speed in GRP pipes (m/s)

Diameter	٤٠٠_٣٠٠	٤٥٠_٨٠٠	٢٥٠٠_٩٠٠	
٦atmosphere pressure	٣٦٥	٣٥٠	٣٤٠	٢٥٠٠hardness
١٠atmosphere pressure	٤٣٥	٤٢٠	٤٠٥	
١٦atmosphere pressure	٥٠٠	٤٩٠	٤٨٠	
٦atmosphere pressure	٤٠٥	٣٨٠	٣٧٠	٥٠٠٠hardness
١٠atmosphere pressure	٤٣٥	٤٢٠	٤١٠	
١٦atmosphere pressure	٥٠٥	٤٩٥	٤٨٠	
٢٥atmosphere pressure	٥٧٥	٥٧٠	٥٦٠	
٦atmosphere pressure	٤٢٠	٤١٥	٤١٠	١٠٠٠٠hardness
١٠atmosphere pressure	٤٣٥	٤٢٥	٤١٥	
١٦atmosphere pressure	٥٠٠	٤٩٥	٤٨٥	
٢٥atmosphere pressure	٥٨٠	٥٧٠	٥٦٠	
	٦٢٠	٦١٥	٦١٥	

Table (1) pressure wave speed in GRP pipes (m/s)

Diameter	١٠٠	١٢٥	١٥٠	٢٠٠	٢٥٠	
٦atmosphere pressure	٥٨٠	٥٦٠	٥٤٠	٥٢٠	٥٠٠	**١٠٠٠٠ hardness**
١٠atmosphere pressure	٥٩٠	٥٧٠	٥٦٠	٥٤٠	٥٢٠	
١٦atmosphere pressure	٦٤٠	٦٢٠	٦١٠	٦٠٠	٥٩٠	

4- Comparison of the effect of water hammer in GRP pipes in comparison with steel pipes:

The effect of the water hammer finally appears as an increase or decrease in the local pressure of the fluid inside the pipe, which causes the collapse, destruction or destruction of the pipe. Therefore, knowing this phenomenon is very important. Normally, the surge speed inside GRP pipes is 320-610 m/s, while metal pipes have a water hammer between 1100-1350 m/s, which affects the amount of water hammer pressure. For example, if the general equation of water hammer $\Delta H=\Delta Y/g*a$ should be considered, where:

ΔH: Local pressure caused by water hammer

G: Gravitational acceleration

a: surge speed inside the pipe

It can be concluded that, in general, due to the 2-3 times the surge speed in steel pipes, the creation of local pressure in these pipes is much more and more tolerant than GRP pipes. And the hammer has a greater effect on steel pipes. [11].

Therefore, the time required to control the impact of the ram is expressed in the form of the following equation:

$$\Delta t = \frac{2l}{a}$$

Δt: the time required to close the valve and control the impact of the ram.

l: the return path of the wave along the pipeline path

a: The surge speed is inside the pipe.

The time required to close the valve and reduce the negative effects of hammer impact in the pipeline route is 2 to 3 times more than regular pipes. Because of this, it is very important to control the pipeline in steep routes and water supply lines under pressure, and it causes the costs of controlling the impact in the water supply line to cause changes in the cost reduction. [13].

5- case study of water supply project from Azadi dam to Dasht Har

This project is called the water supply project from the Azadi Reservoir Dam to Har Plain, about 500 meters below the Shahgoz Bridge Plain, about 90 km from the town of Javanmard at the coordinates of 46-21 degrees north longitude and 33-34 degrees north latitude downstream of the Azadi Reservoir Dam and adjacent to it. The river is located, the specifications of the place of implementation are presented in the following forms. [16].

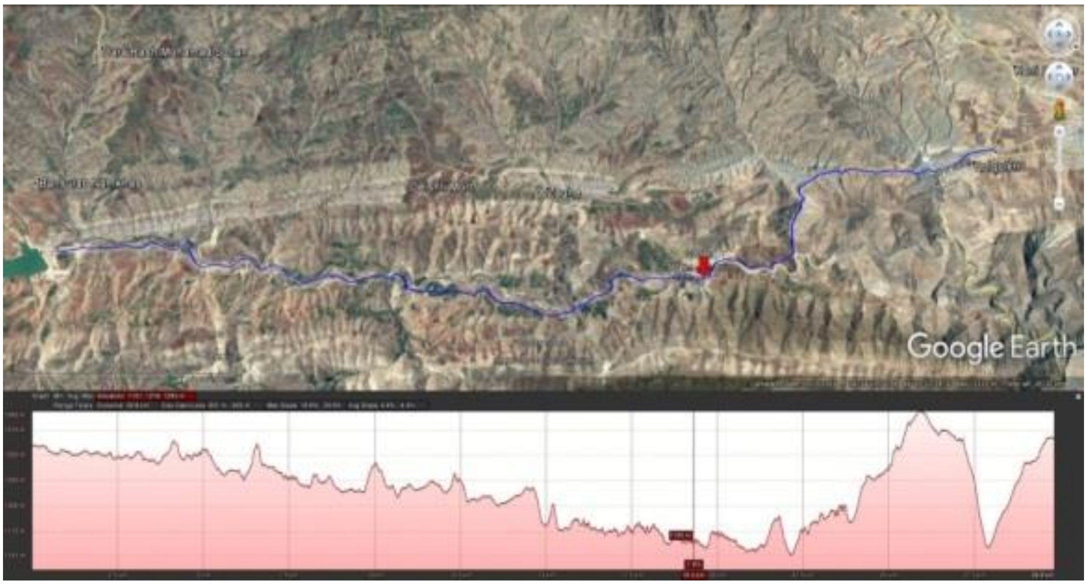


Image (2) of the Azadi Dam location on the route

Image (3) of the route profile of the water transmission line from Soy to Har Plain

The specifications related to the pipeline route are as follows:

Diamerer (mm)	Discharge (litr/s)	Elevation of end of water pipe line	Elevation of start	Length
1700-1400	2500	۱۲۶۹	۱۲۵۶	30 (km)

From the whole Of the 30 km, about 6 km of the route of metal (steel) pipes have been used and about 24 km of the route have been used of GRP pipes, the specifications of the pipes in the transmission line are presented as follows:

Table (2) specifications of GRP pipes in this water supply plan

no	diameter	presuure	length
۱	۱۷۰۰	۱۰	۶۲۷۰
۲	۱۷۰۰	۱۶	۳۲۴۰
۳	۱۶۰۰	۱۶	۶۴۸۰
۴	۱۵۰۰	۱۶	۲۹۷۰
۵	۱۵۰۰	۱۰	۵۲۰۰

5- Hydraulic simulation of the path of the water transmission line

5-1- Hydrodynamic analysis

As shown in picture (2). The topography of the water transmission line route along the route and the pipe has many elevations and elevations, therefore, maximum changes in failures have been considered for modeling, and finally, the following assumptions have been used:

1- Water Gems, 8c software is used.

2- Hazen-Williams coefficient equal to 145 for GRP pipes and 120 for steel pipes has been used.

3- The length of the route is equal to 29.8 km.

4- The diameter of the pipes in the route is considered from 1700 mm to 1400 mm according to the table below.

5- It is assumed that the flow rate of the transmission line is equal to 2.2 m/s, and the results are as follows.

The specifications related to piping along the transmission line are as follows:

Table (3) specifications of pipe laying in the water transmission line from Azadi Dam to Dasht Har

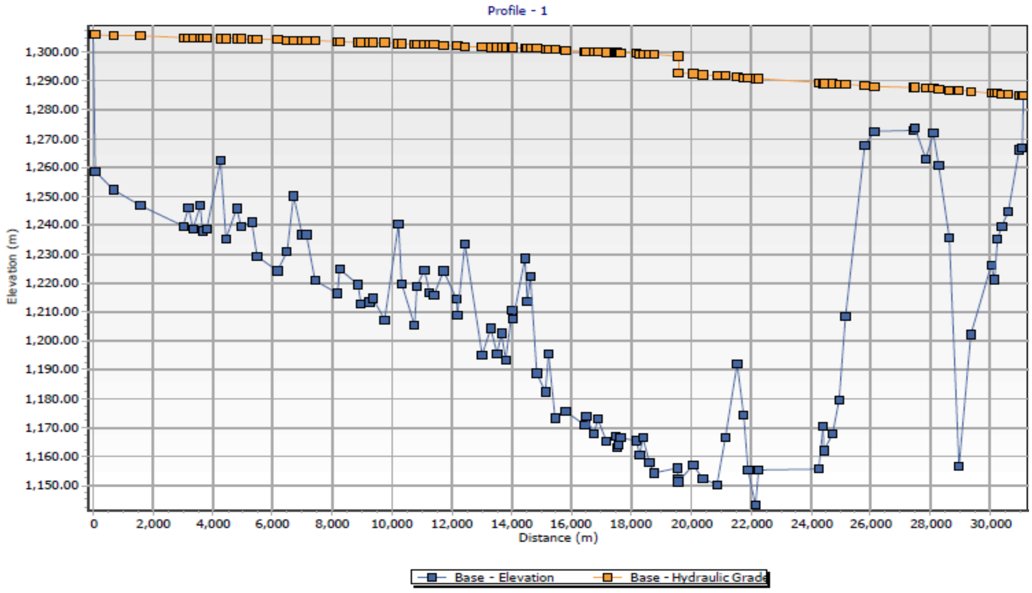
Row	Kilometer first	end kilometer	Diameter pipe	The working pressure of the load pipe	Size|	Pipe type
١	٠	٦+١٠٧	١٧٠٠	١٠	٦١٠٧	GRP
٢	٦+١٠٧	٩+١٧١	١٧٠٠	١٦	٣٠٦٤	GRP
٣	٩+١٧١	١٥+٠٥٨	١٦٠٠	١٦	٥٨٨٧	GRP
٤	١٥+٠٥٨	٠٢٨+٢٠	١٥٠٠	١٦	٤٩٧٠	GRP
٥	٠٢٨+٢٠	٠٠١+٢١	١٥٠٠	٢٠	٩٧٣	GRP
٦	٠٠١+٢١	٠٨٥+٢١	١٤٠٠	-	٨٤	?
٧	٠٨٥+٢١	٦٤١+٢٢	١٥٠٠	-	١٥٥٦	STEEL
٨	٦٤١+٢٢	٦١٤+٢٥	١٥٠٠		٢٩٧٣	STEEL
٩	٦١٤+٢٥	٠٢٢+٢٦	١٧٠٠	١٠	٤٠٨	GRP
١٠	٠٢٢+٢٦	٢٦+٢٥٢	١٦٠٠	١٠	٢٣٠	GRP
١١	٢٦+٢٥٢	١٦٧+٢٩	١٥٠٠	-	٢٩١٥	STEEL
١٢	١٦٧+٢٩	٨١٥+٢٩	١٤٠٠		٦٤٨	GRP

Table (4) hydraulic characteristics of the water transmission line route from Azadi Dam to Dasht HOR

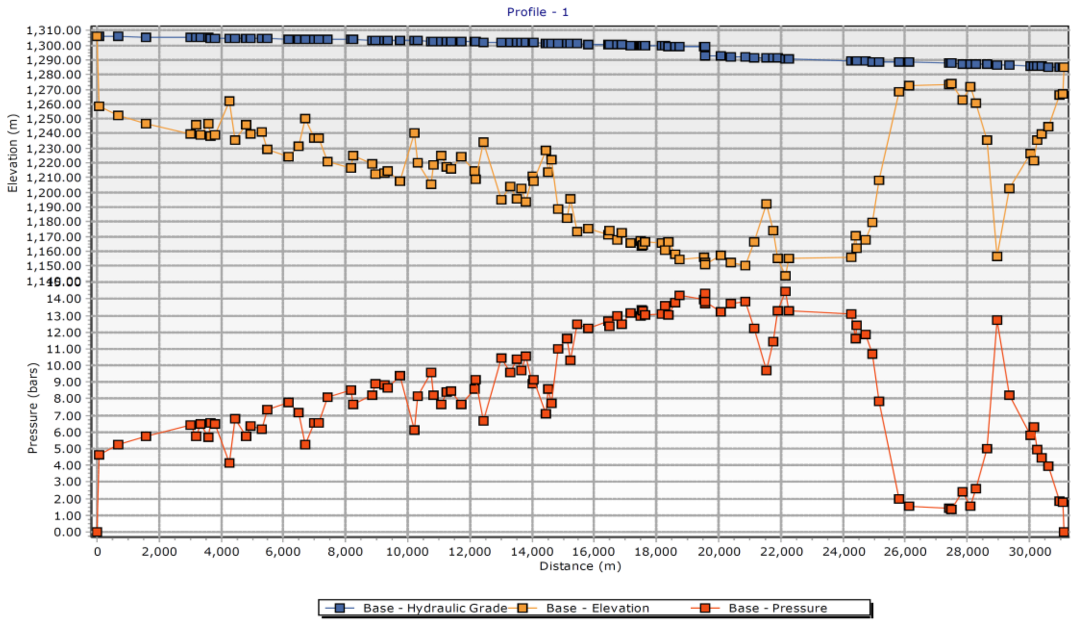
Row	Description	the amount of	the unit
۱	path length	۲۹۸۰۰	Meter
۲	Transfer flow	۲.۲	cubic meters per second
۳	Pipe type	GRP-steel	–
۴	Diameter pipe	1700-1400	millimeter
۵	The speed of water in the pipe	۲۰۰۱/۰۵/۰۱	meters per second
۶	The number of pipelines	۱	number
۷	Working pressure of pipes	۲۰-أكتوبر	Kilopascal
۸	Hazen-Williams coefficient	۱۴۵–۱۲۰	–
۹	Number of pumping stations	In transit	۰
۱۰	Maximum height along the route	۱۲۷۶	meters above sea level
۱۱	Minimum height along the route	۱۱۴۶	meters above sea level
۱۲	The number of balance tanks at the beginning of the route	۰	number
۱۳	Maximum water height in the dam	۱۳۰۶	meters above sea level

It is necessary to explain that the specifications of the transmission line are presented in table (4).

There are different heights and lengths of the post route, and also the pressure difference varies from 1 to 16 bar, so it is presented based on the hydrodynamic conditions of the pipes and the hydrostatic state of the working pressure of the pipes. The water speed inside the line is 8/m/s. It varies up to 1.4 m/s. Therefore, in terms of pressure, there is no problem in the route of the line, and as a rule, the proper use of the pipes should be observed. It should be noted that according to the management organization's 3-117 standard, for water transfer, the operation and working pressure of the pipes must be at least 90% of the nominal pressure of the pipes. Therefore, in this sense, part of the route should be reviewed.



Graph (1) hydraulic gradient of the water transmission line route from Azadi Dam to Dasht Har



Graph (2) gradient of pressure changes along the route of the water transmission line from Azadi Dam to Dasht Har

6- Hydrostatic analysis:

If the fluid inside the line is still or the valve is closed, hydrostatic analysis is done, and its specifications are as follows:

- Checking the impact control of the Hammer in the water transmission line:
- Investigating the effects of hammer effect on the entire route of the transmission line

In order to check the route of the water transmission line and to check the water transmission line more optimally, water hammer seri 8i software has been used to check the impact of the ram. The details are as follows:

1- The search speed for fiberglass pipes is 405 to 485 m/s.

2- The search speed for metal pipes is between 1200 and 1100 meters per second for each transmission line route.

3- The Williams coefficient is considered equal to 145 for GRP pipes and equal to 120 meters for steel pipes.

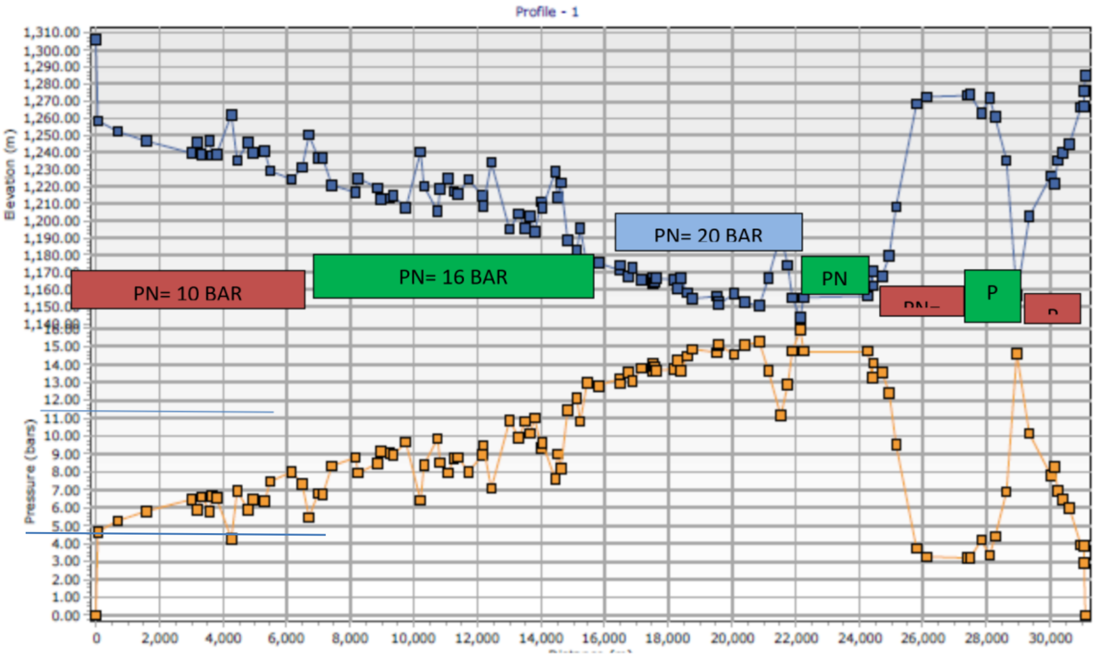
4- The duration of the project is considered equal to 1400 seconds. (This value is considered according to the value of t=l/a20 for GRP pipes.

5- The current is implemented for unsteady and quasi-steady mode.

6- Due to the change in the type of two pipes in the water transmission line, for each section of GRP pipes, according to the pressure, ratio and diameter, the search speed has been aded according to table (1) and for steel pipes, this is 1100 m/s in opnions have been asked.

7- The non-steady-like flow mode has also been investigated in the calculations.

8- The duration of closing the valve at km 21+250, which is the most dangerous part of the route. About 240 seconds, which is the appropriate number for milk conditions.

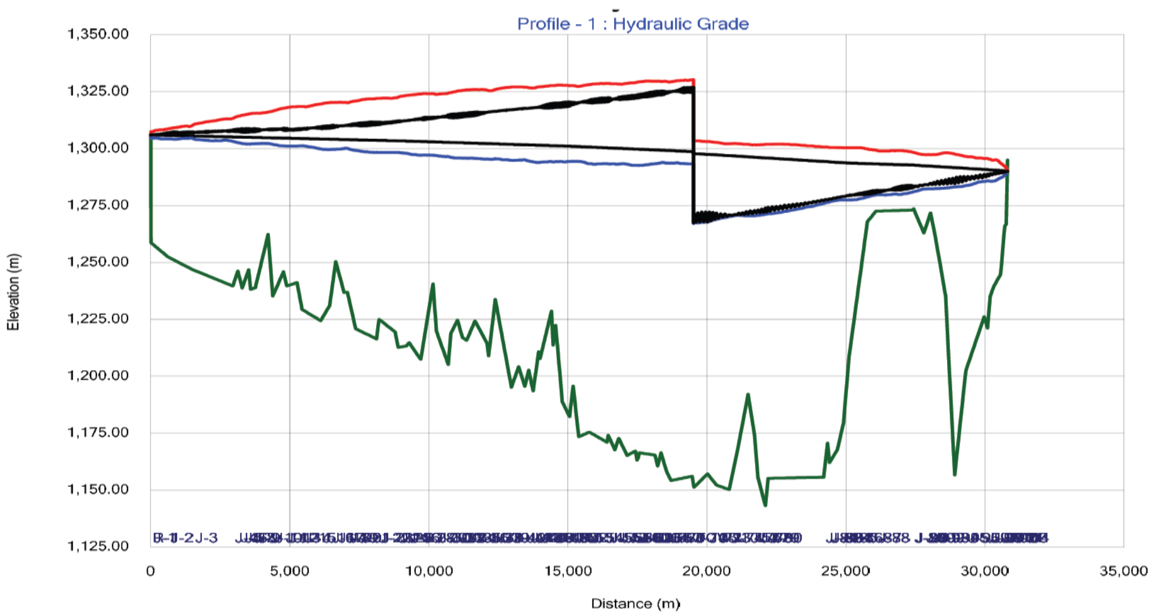


Graph (3) gradient of pressure changes along the route of the water transmission line from Azadi Dam to Dasht Har (in hydrostatic mode)

In the following, the results of the tables and pictures related to the ram impact analysis are presented.

Graph (4) pressure changes related to the route of Azadi Dam transmission line due to hammer effect

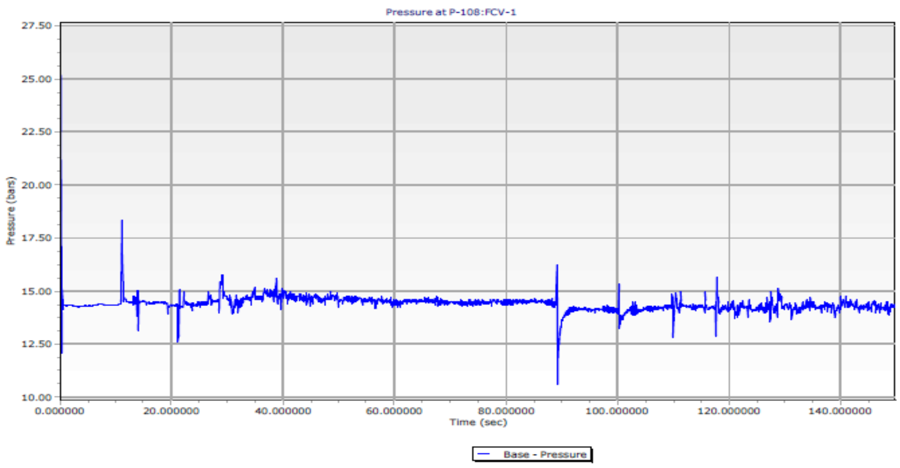
Graph (4) pressure changes related to the route of Azadi Dam transmission line due to hammer effect



Graph (5.) The gradient of speed changes along the route of the water transmission line from Azadi Dam to Dasht Har

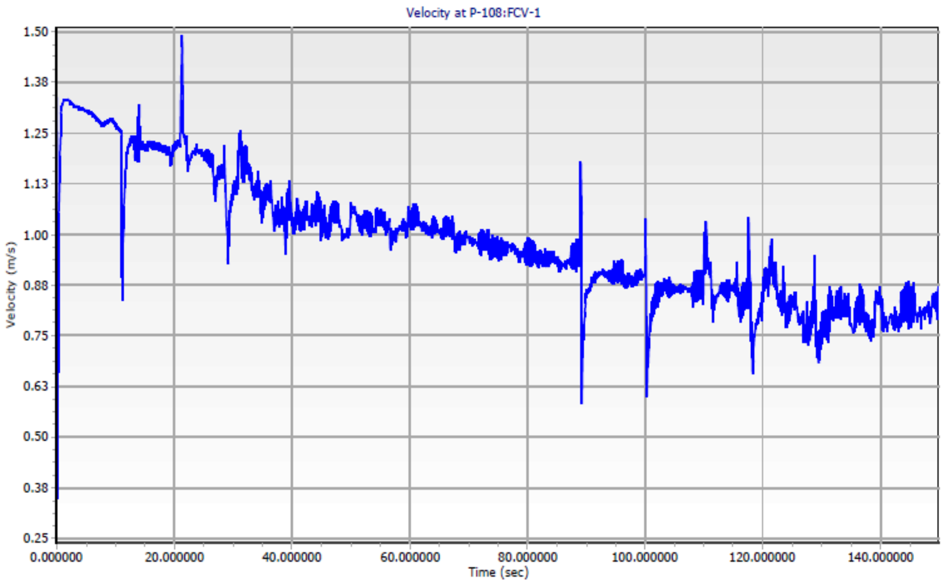
-Investigating the amount of changes in atmospheric pressure due to the impact of the ram at 21+250 km (high risk area):

2- During the investigations carried out in this area of 21+250 km (which has high pressure and is considered one of the high-risk areas), the ram impact analysis was carried out using the water hammer software model, which shows the following changes in pressure and flow according to Close and open and close valves are provided.



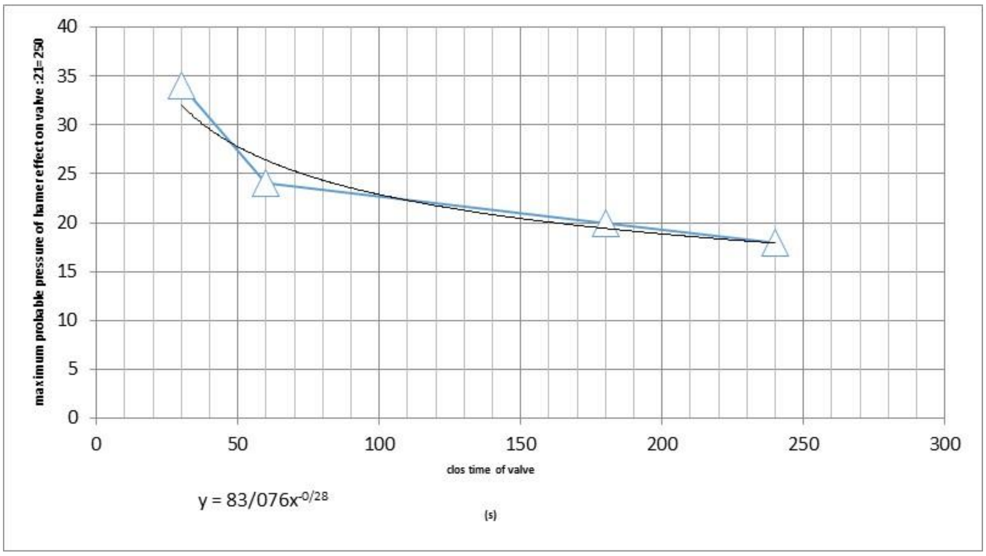
Graph (6.) The gradient of pressure changes in the pipe path at the installation location of the shut-off valve at km 21+250

3- In this analysis, it is determined that the maximum amount of pressure changes at the fracture site of the pipe has a pressure of more than 16 bar (18 bar), which at the time of the beginning of the flow, the amount of pressure change can be observed up to 20 bar and gradually decreases. Therefore, a pipe with a nominal pressure of 20 bar should have been used in this range, which has not been taken into account.



Graph (7) of the gradient of flow rate changes in the pipeline route before the shut-off valve in the transmission line route (km 21+250)

4- As it is clear in the figure above, at the beginning of the flow through the valve, the maximum possible speed is equal to 1.5 meters per second. But after a few seconds, it stabilizes at about 1.13 liters per second and the pressure gradient fluctuation decreases, then the flow passes through the pipe in the value of m/s1 with very little changes. The changes related to the pressure in this whole according to the opening and closing times are presented as follows. Finally, in connection with the effect of the opening and closing time of the valve at 21+250 km and its effect on the maximum possible pressure, a graph is shown as follows It is presented below. Based on this diagram, the longer the opening and closing time of the valve (reasonably) is considered, the more appropriate the maximum possible local pressure caused by the impact of the ram.



Graph (8) of the gradient of pressure changes along the pipeline route at the valve location according to the opening and closing time of the shut-off and connect valve (km 21+250)

7- Discussion and conclusion

- According to the presented materials, it can be concluded that:
- The effect of creating ram impact phenomenon in GRP pipes has much less effects than steel pipes.
- After the implementation of the transmission line route, the ram impact control in the transmission line route is very important and must be saved.
- Pipes should be used according to standard 117-3. (The selection of pipes should be done according to page 37 of this publication and the pipe should be selected with a nominal pressure that the operating pressure and use of the pipes should be considered at most 90% of the nominal pressure of the pipes).
- In high-risk areas, in relation to the impact of the battering ram, studies should be carried out in an appropriate time frame.
- In the analysis of ram impact in valves, the opening and closing time of the valves should be considered equal to 4 to 5 minutes according to the manufacturer's recommendations.
- In the analysis of the non-permanent flow and the execution time of the relevant software, if two types of pipes (with different materials) are used, the minimum execution time based on the recommendation of publication 517 of the management organization should be considered equal to T=20L/A. (which is better if the search speed is calculated for two different types of pipes and performed in two calculation times) and the results in the first second of execution and the intermediate times are carefully examined.

- Examining the water supply plan to transfer water from Azadi Dam to Dasht Har, the following points are important:
- There are many differences between the initial design of the route and the implementation project, and it is necessary that after the implementation of the double-span transmission line route, the impact of the ram should be properly and accurately investigated.
- Changing the diameter of the pipe in 60 meters before the implementation of the above-mentioned shut-off valve caused a local increase in speed equal to 0.25 m/s and as a result, the pressure before the valve increased by 1.2 bar.
- The best time to open the lower valve of the dam to start the discharge in the path of the Beistasi pipeline, according to the opening and closing time of the butterfly valve of km 21+250, should be considered at least equal to 240 to 300 seconds, so that it is possible The return of water along the pipeline route will be greatly reduced.
- If the opening and closing time of the shut-off valve is reduced by 50%, it will be possible to increase the maximum possible local pressure by 75%..

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