Examination of pipeline planning in terms of hydraulic criteria

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Abstract. *Transportation of materials with pipelines has a long history. It is a historical fact that materials were transported through pipelines by Chinese and Romans. Presently, this issue has become multidimensional sub ject such as engineering, industry ,economy, security,environment and foreign policy.Therefore, a pipeline cons truction should be evaluated in all aspects. In terms of economy and security, pipelines are more economical and reliable than other types of transport. As Turkey is located at the crossroads of energy lines, it should pay special attention to the design of pipelines. In this article, this issue is considered from an engineering pers pective. However, this will also have an impact on the other fields. These issues are discussed in this article and suggestions are presented.*

Key words: hydraulics, pipeline, gravity, pump

1.Introduction.

The history of the transport of the material through pipelines is quite old. It is known that the first pipeline transportation was implemented by the Chinese and the gas was transmitted through the bamboo canes. Afterwards, it is known that the Romans transported water through lead or soil pipes. Since the transportation of ore between the mine and processing facility is one of the most challenging and expensive works in mining; initially miners were engaged in this field. They have tried the types of transportation such as railway, highway, sea and river. Then they focused on transportation of the ore with pipelines and they applied that. For the first time in the world, miners in California, USA have pumped the gold ore to washing pools and displayed the first example of pipeline transportation. After 1950s, pipeline transportation was improved and became widespread throughout the world.

In general, the amount of material, the physical and chemical properties of the transported material and distance are the factors that determine the most proper transportation system for each case. However, it has been shown that pipelines are safer than all other transport types for materials that have to be transported over a large distance. Pipeline transportation is the most economical and accident-prone transport method. Today, a large number of pipelines are being used and news one are built in various parts of the world.

Pipelines are conveying systems that operate under pressure. There are two methods in transportation through pipelines, mainly hydraulic and pneumatic. Fluid is transmitted by the hydraulic method and air or gas is transmitted by the pneumatic method.

In hydraulic transport, the liquid itself is transported; and water or another liquid can be used as carrier, just like in crude oil lines. Pressure in the system provided by pumps. In the pneumatic transportation system, air or gas is used as a fluid. Solid items may also be transported in capsule . The system pressure is provided with air pumps which are called compressors.

Solid, liquid and gas can be transported in pipelines. Materials such as crude oil, natural gas and water can be transported from long distances and the conveyance is provided in process lines at factories through pipelines. Water supply lines, city networks and wastewater systems in rural areas, rural underground irrigation and drainage systems are also common areas where pipelines are used. As a result, pipelines are used extensively. in fields such as urban life, industry, agriculture and energy. When we consider all of these , the hydraulic bases of the pipelines must be well defined and the projects should be prepared accordingly.

Turkey is an energy corridor which is located on among the produces and consumes country Figure1. and Figure 2.

Fig.1. Pipelines in the Middle East

As known, crude oil and natural gas have different physical and chemical properties. Therefore, pipe materials, fitting elements, valves, operating pressures and safety precautions are also different. In addition, these lines may be under the different external atmospheric conditions such as passing through the mountains with 2500-3000 m height and descend to sea level. It may also pass through under the sea, as can be seen in the fresh water pipeline built between Republic of Turkey and Turkish Republic of Northern Cyprus (TRNC) Figure2.

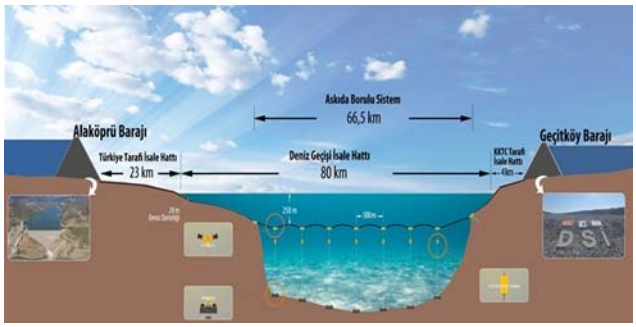


Fig.2. Fresh water pipeline between Turkey and NTRC

However, external atmospheric conditions are as important as internal pressure for these lines. The planning, construction and operation maintenance and repairs of natural gas and crude oil pipelines are subject to the provisions of the regulation published in the official gazette dated 04.07.2014 and numbered 29050 and Petroleum Pipeline Company (BOTAS) is authorized and responsible for them.

Today, considering the advanced stage of material engineering, use of pipes and fitting elements made of suitable materials for the purpose of the project is very important. With no doubt, since the system operates under pressure, the selection of pump or compressor systems to produce this pressure is equally important.

Environmental Impact Assesment(EIA) study and the estimation of the environmental impact are important issues that should be considered during the design step of the pipeline project. In addition, the safety of the pipeline must also be considered during the planning phase.

2. Advantages of Pipeline Transportation

As already mentioned, pipeline transportation has many advantages. These can be ranked as follows;

- It is very economic as compared with other transportation types.
- Prices do not change rapidly.
- The lines are safe because they are often buried under the ground.
- Buried lines do not obscure traffic and other services.
- It is easier to identify the route when compared with railway and highway.
- The accident rates are very low.
- It is possible to increase the transmission rate within certain limits.

3. Disadvantages of Pipelines

Despite the advantages of pipelines, they are also some negative aspects. We can summarized them as follows:

- The initial investment cost is high.

- The cost of filling the line is high.
- Problems such as clogging or breakdown may occur in pipeline.
- Leakage can be obtained from pipelines.
- The possibility of sabotage is very high.
- it is not flexible in capacity and location

4. Pipes materials

In general, pipe material should be strong enough to the forces created by static pressure of fluid, centrifugal forces at bends, momentum forces in section chances and bends, forces due to changes in temperature, water hammer which results sudden stopping of fluid and external loads like soil and traffic loads. Pipes are usually made by using concrete, reinforced concrete, steel,polyvinil clorur (PVC), and poly etilen (PE) pipes. Recently, significant developments occurred in material engineering and a wide variety of synthetic and composite materials have been develop ed. These materials are different in terms of expansion, contraction, shrinkage, tensile strength and roughness. The discharge transmitted from steel and PVC pipes under same pressure and with same diameter can be different, because roufness coefficient is different. For example, according to the William-Hazen formula, which is used extensively world and in Turkey to calculate drinking and utility water; steel and PVC pipes with D=0.250 m diameter and J= 0.0005, the flow rate transmitted is Q=46 lt/s in a steel pipe and Q=63 lt/s in PVC pipe. Materials should be selected in accordance with type and purpose of use of pipe line and also depending on circumstances.

5 Pipeline route determination and safety

Before now, land surwaying was carried out on field with the scale 1/25000 and1/5000 topographic maps. Route selection at land and sea is equally important, however there are differences in terms of material and method in both. Later, by means of developing computer technology and programming it can be carried out more easly. The safety of the pipelines is also very important which should be considered at the planning stage In general, the following points are taken into account for pipelines to be constructed on land;

- Climate,
- Land conditions,
- Environment and safety
- Complying with standards,
- Legal restrictions,
- Economy,
- Technique,
- Maintenance and Repair

The most important problem at sea is the presence of hydrostatic pressure and moving of pipline by earthquake and the waves. However, the pipeline can be constructed to the bottom of the sea, and it could also be suspended. In either case, however, pressure and corrosion resistant material is selected and connected to the floor by anchorage. The choice of route is also important at sea. The maritime traffic, the possibility of sabotage and international agreements should be taken into account when choosing safe routes. According to safety and requirements, pipelines can be installed in more than one line. In this case, cost increases along with the capacity naturally.

6. Evaluation in terms of hydraulic criteria

Planning is based on continuity, energy and momentum equations in fluid mechanics. The fact that the flow is three-dimensional so, it requires the use of the three-dimensional form of these equations which further complicate the calculations. However, where the velocity variation in the section is not important, the three-dimensional flow can be thought of as one-dimensional by using average velocity. It can be neglected if the velocity correction coefficients are around $\alpha = \beta = 1$ However, this value should be taken into account, if it is significantly different from one. These approaches provide great convenience to the projects.The most important factor in designing a water pipeline is determining whether the system will work with gravity or with a pump.

6.1 Systems that work with gravity

The piezometer line should never intersect the land. Otherwise, the pressure drops and free surface flow occurs. The flow rate cannot be transmitted. For this reason, the highest point of the ground and the piezometer line should be designed to give the necassary operating pressure in the system.At the following figure 3, the J_1 piezometer line crosses with the highest point C of the land and free surface current is occurred in the pipeline which is unacceptable. Therefore, J_2 water pipeline is designed at which it is transmitted and the proper operation pressure is provided. Figure 3.

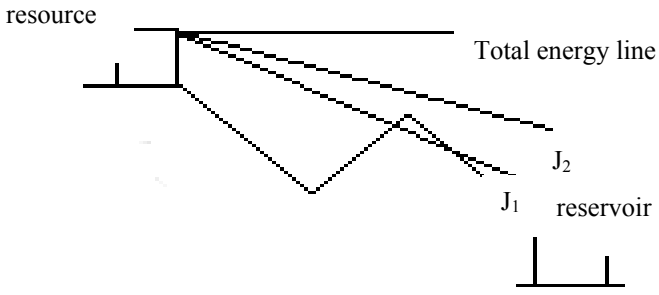


Fig.3.Designing pezometric line

6.2.Reducing excessive pressures

Depending on the static load, excessive pressures may occur in water pipelines which cause pipelines to be damaged and accedents. These overloads must be broken by pressure reducer structure (prs) or high-pressure valves as indicated in the following Figure 4. Energy line 1 is brought to a high pressure and it is broken by pressure reducing structure (prs) and the presssure is brought to the projected level.

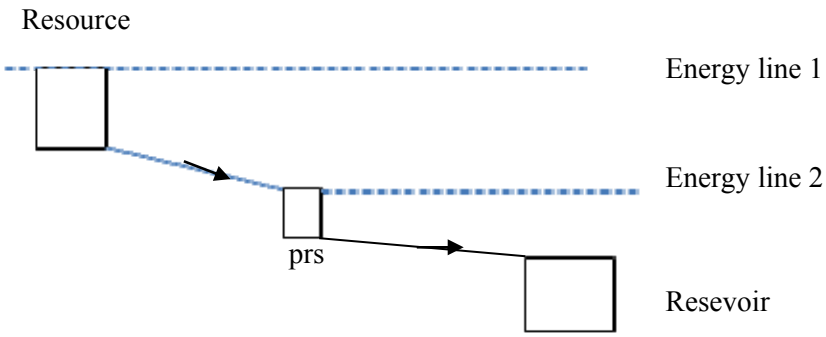


Fig.4. Breakage of excess pressure

6.3 Systems that operate with pump

Pumps are the hydraulic machines that convert the mechanical energy into hydraulic energy. In the design of a pump system; basic concepts such as flow rate, economic pipe diameter, suction and discharge heights, local and continuous load losses, manometric elevation, number of revolutions and pump efficiency must be determined. In a typical pump system, manometric height(Hm), discharge (Q) and is pump power (N) and they can be calculated by the following formulas:

$$Hm = (hse + h_{ke}) + (hsb + hkb) = Hg + \Sigma Hk$$

$$Q = 0{,}279.C.D^{2{,}63}.J^{0{,}54}$$

$$\mathbf{N} = \frac{\gamma\, Q\, Hm}{75\ \eta}\ BG\ = \frac{\gamma\, Q\, Hm}{102\ \eta}\ KW$$

Where;
Hse; static suction height
Hsb; static pressure height
Hg ; geometric height
Hk ; total loss
γ ; specific wight of fluid
Q; discharge

C; coefficient of William – Hazen equation
D; diameter of pipe
J; hydraulic grade line

As known, open air pressure is theoretically 10.33 m. at the coast. This gives out the theoretical suction height (Hse). Depending on the topographic structure, this decreases. The maximum suction heights in the pumps are even lower due to the continuous and local losses in the exhaust pipe. The pumps operate at high efficiency at a certain speed and the efficiency is low at the other speeds. The pump efficiency is a function of the flow rate and manometric height (Hm). For this reason, it is important to determine the pump performances and the number of cycles in comparison. Pumps can be classified in various forms; but mainly, they can be divided into two groups as centrifugal and volumetric pumps**;**

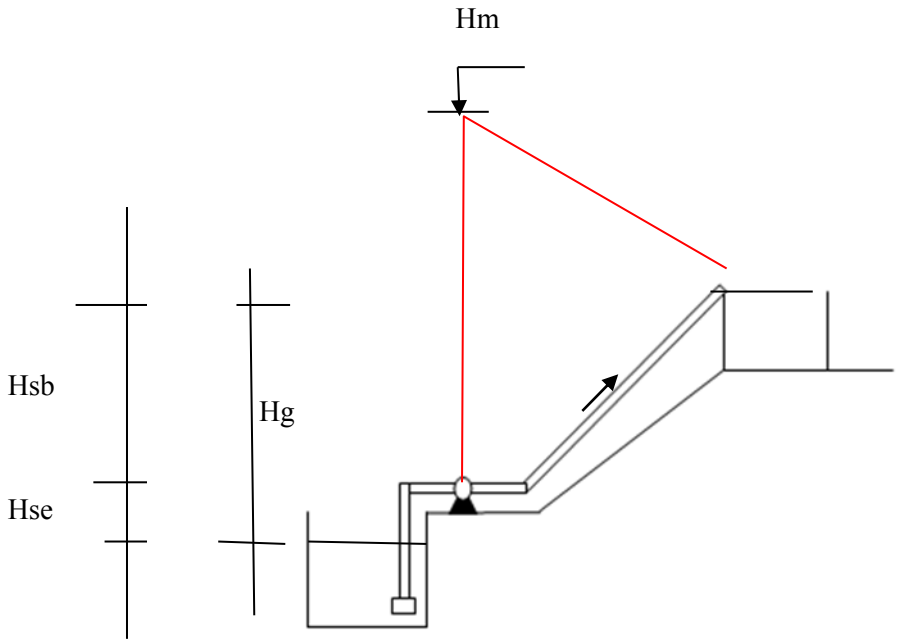


Fig. 5. Schematic heads of a pumping system

6.2.1 Pump selection criteria

Pumps are selected some cretain criteria which are summerized at the following;

- Flow rate to be transmitted
- Manometric height
- Turn rate of pump shaft
- Pump efficiency
- Silent and non-vibration operation of pump

- Pump dimensions
- Pump price
- Spare Part
- Easy maintenance and repair of the pump

6.2.2 Connection types of pump When a pump is not adequate, then the pumps can be connected in series or parallel to increase the flow or manometric heights.

Serial Connection It is used when it is necessary to increase the pressure load without increasing the load

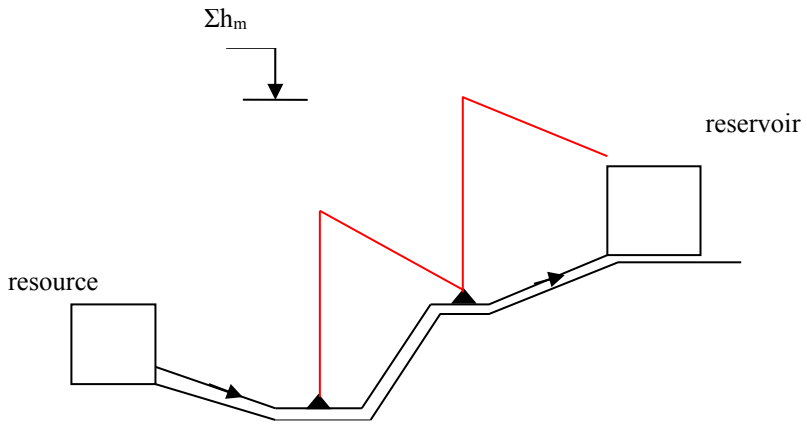
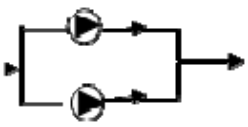


Fig.6.Serial connection

Parallel Connection In this type of connection the flow rate increases, but the manometric height does not change.



$$Q = Q_1 + Q_2$$

$$Hm = Hm_1 = Hm_2$$

Fig.7.Paralel connection

Specific Speed By definition, it is the number of cycles of the pump that presses 1m3/sec flow to 1 m height. In other words, it is the number of revolutions per minute(rpm) required to turn the pump that presses 1m3/sec flow to 1 unit height. It can be calculated by the following formula;

$n_s = n. Q^{\frac{1}{2}} H_m^{-\frac{3}{4}}$

where;

n_s ;specific speed (rpm)

n : number of pump cycle

H_m ; manıometric height

Q; discharge

Pump efficiency The pump that completes thminute e same tas with the lowest specific speed or number of cycles is considered as the most efficient pump. The efficiency of the pumps is around η =70 -75% practically.

6.2.3Head losses

Head loss is loss of energy which occures due to frictional forces between a flowing fluid and the pipe or channel at which the fluid moves. There are two types of head losses;

Continuous head losses The loss due to frictional forces between fluid and pipe is called continuous head losses and which is calculated by the Darcy-Waisbach formula

$h_{ks} = f \times \frac{l}{d} \times \frac{v^2}{2g}$

Where;

h_{ks} ; continuous head loss

f; frictional factor

d;diameter of pipe

v; velocity

g;gravitataional accereation

Local head losses This type of energy losses occure at the the places where the direction of strimline changes such as horizontal and vertical bends, diameter changes, tee, valve on the line, backfire block. Each element has differrent local coefficients (k) which can be taken from charts and can be calculated with the following general formula;

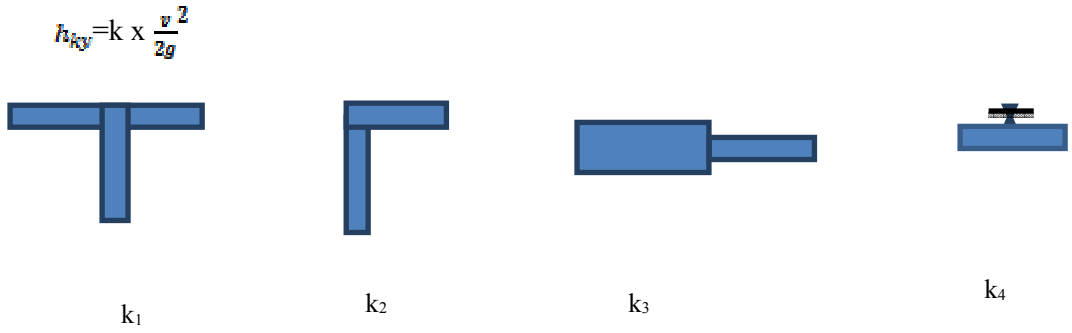


Fig.7. Local losses

Suppression and depression lines A running pump may stop in cases of a sudden failure or power surge. In this case, the upward mass of water slows down first and then returns. If the pump stops, the mass of water continues to move for a while due to the inertia force, which causes excessive pressure drop in the pipe and this is defined as depression. The returning water accelerates by gravitational force and moves towards the pump and creates an excessive pressure on the pump and pipelines, which is called the suppression. It can be calculated by the following formula

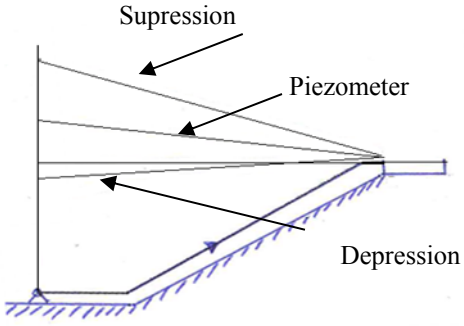


Fig.8. Supression and depression lines

$$a = \frac{9900}{\sqrt{48.3 + \frac{kd}{\varepsilon}}} \qquad \Delta h = \pm \frac{a \cdot v}{g}$$

Where;

a; wave diffusion speed
k; modulus of elasticity of fluid
Δh;high or low pressure head
d;pie diameter
ε; modulus of elasticity of material
g; acceleration of gravity

Conclusion

While planning the pipeline, it is necessary to comply with the law, regulations, technical specifications and sales plans in the project and the construction.Another important issue is that environmental impact assessment (EIA should be undertaken and foreseen possible impacts on environment at the planning stage, not after the project. If required, expropriation can be conducted in the route of pipeline. If there

may be obstacles such as roads, railways, rivers, swamps, the necessary transition structures should be designed. After the route is determined, if there are some underground facilities or infrastructures should be investigated. One should have sufficient knowledge about geological structure, fault lines and ground structure.

It is very important to determine the lowest and highest pressure points on the route by determining the energy and piezometer levels in pipeline design. The pressure in lines must be kept within acceptable limits. The lines should not be laid entirely parallel to the ground. Otherwise,this increases the number of top and bottom points. In this case, while at low points increase the drainage valves requirements and the high points make necassary air discharge valves. After the internal pressure and external pressure or conditions are determined, strong enough pipe material must be selected. Price out should be implemented according to current market conditions.

Once the energy levels have been determined, it should be decided whether the system will operate with gravity or with the pump; and if it will operate with gravity, the most economical pipe diameter that can carry the flow should be calculated. Then,it should be checked whether the flow rate and manometric height meet the requirement. If not, the pumps must be operated in serial, parallel or gradually. In addition, the system should be run and tested after the pipeline has been installed in the ditches, and then the ditches must be covered.

References

[1] Ağıralioğlu N. ve Erkek C. „Su kaynakları Mühendisliği”,Birsen yayınevi, Istanbul, 2000.
[2] BOTAŞ,,Ham petrol ve doğalgaz tesisleri emniyet ve çevre yönetmeliği”, Resmi Gazete, sayı :29050, tarih 04.07.2014.
[3] Deniz V. „Boru hatları yapımında teknik esaslar ve tedarikte güvenlik”, İstanbul.
[4] Güner A. „İçmesuyu İsale hatlarında Boru tipleri”, 2012
[4] Karadoğan H. „Boru hatları tasarımı”,IX.Ulusal tesisat mühendisiliği kongresi,İzmir,2009
[5] Muslu Y. „Su ve atık su teknolojisi”, Seç yayın dağıtım,İstanbul,2000
[6] Muslu Y. „Su temini ve çevre sağlığı”2000
[7] Samsunlu A. „Su Getirme ve kanalizasyon”, Çevre teknolojileri merkezi,İstanbul,1997
[8] Sümer M.B.Ünsal İ, Bayazıt M. „Hidrolik”, Birsen yayınevi, İstanbul,2007