MINING AND METALLURGY INSTITUTE BOR
UDK: 622
ISSN: 2334-8836 (Štampano izdanje)
ISSN: 2406-1395 (Online)

UDK: 621.967.2:622.272(045)=111
doi:10.5937/MMEB1602055M

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HYDRAULIC ANALYSIS THE STATIONARY PHENOMENA UPON GRAVITATIONAL PIPELINE TRANSPORT OF BRINE

Abstract

This paper will demonstrate the methodology and results of analysis the stationary phenomena upon gravitational pipeline transport of brine from the Salt Mine Tuzla to the ultimate consumer. Moreover, it will provide the analysis of reciprocal effects of flow, change in diameter, speed of hydraulic ascent, loss of pressure and density of brine.

Keywords: *brine, pipeline, stationary phenomena, hydraulic analysis, flow*

1 INTRODUCTION

1.1 Salt Mine Tuzla - Salt Deposit Tetima

Exploitation of salt in Bosnia and Herzegovina is closely linked to the area of Tuzla, namely to the salt deposit in Tuzla, where the industrial exploitation of salt is conducted over a period of more than 100 years. In the last 10 years, the exploitation in the new salt stones deposit Tetima has been more intensified and represents an alternative capacity for the deposit Tuzla.

In research the salt stone deposit Tetima, a multidisciplinary principle was enforced, but the exploration drilling has the main role in deposit exploration, and a geometrization of the salt object is conducted based on it. The level of understanding the certain important deposit characteristic and parameters (geological, hydrogeological, and chemic technological) that were contemporary then, and which have a crucial impact in choosing the manner and method of exploitation of one salt deposit, intruded as an optimal solution in choosing a concept by which the exploitation of this deposit is conducted by controlled leaching the individual boreholes on the field surface.

The Basic Mining Project, made in the end of the eighties, appropriates a phase development ranging from 1 600 000 m^3 over 2 500 000 m^3 to the final 4 500 000 m^3 of salt water per year. All of the mining objects, facilities and devices were sized according to the final capacity and were constructed in the early nineties [5].

In March 1992, the Mine started working in trial period on five exploration boreholes, but after only two months due to the war the trial period ended.

After the revitalization of the mine objects, facilities and devices, which lasted from 1996 to 2000, production was again launched in 2001.

In the last eighties, due to the increased number of salt water consumers, the production of salt water was intensified. Due to this, all of the mining works following the production of salt water were intensified as well. In the period from 2005 to

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2014, fourteen new exploitation boreholes were drilled as the capita; objects. With these fourteen boreholes and five boreholes drilled before the war, nineteen of the designed one hundred are operational. Hence, it can be concluded that in this way the demands of consumers were met.

1.2 Transport System from the Mine to the Consumers

From the reservoir of salt water Tetima, brine is transported to the consumer by gravitational force. Due to a high available energy in the pipelines, and in order to unburden the pressure on sections of the line routing, supporting chambers are provided.

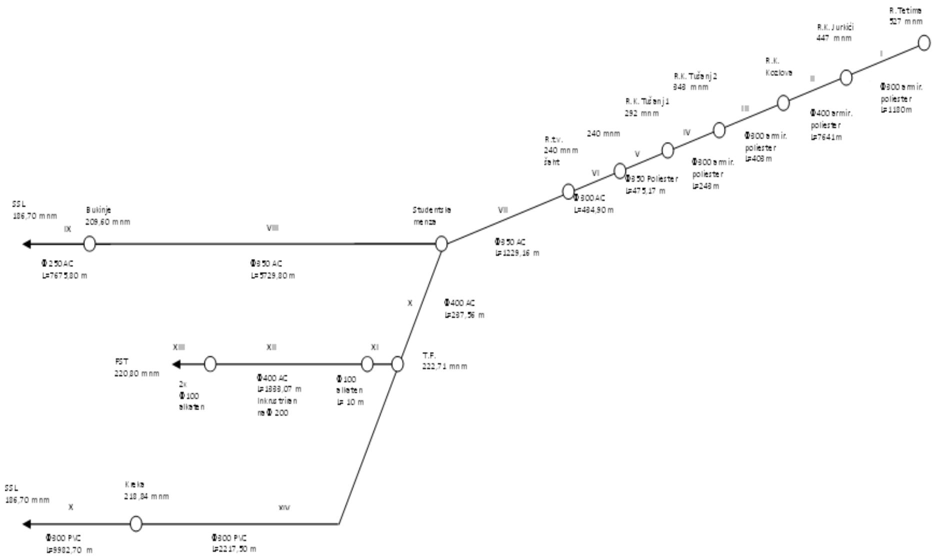

Figure 1 *Schematic view of pipeline from the mine to the consumers*

2 METHODOLOGY OF HYDRAULIC ANALYSIS THE STATIONARY PHENOMENA UPON GRAVITATIONAL PIPELINE TRANSPORT OF BRINE

The line routing for transport of brine is divided into i=15 routes.

The calculation is done for:

- Maximum projected flow Q1= 516,6 m^3/h;
- 2014: minimum flow Q_4= 309 m^3/h; maximum flow Q_3= 331 m^3/h
- 2015: minimum flow Q_4= 309 m^3/h; maximum flow Q_2= 361 m^3/h

For every route, the following data were collected:

- Pipeline type
- Length of pipeline L_i (m)
- Diameter of pipeline D_i (m)

- Flow Q_i (m^3/s)
- Abrasion coefficient k (m)
- Elevation of reservoir bottom H_{i1} (m nm)
- Elevation of supporting chamber overflow H_{i2} (m nm)
- Brine density (kg/m^3)
- Kinematic viscosity ϑ (m^2/s) for temperature up to 30ºC
- i= up to 15

The methodology of analysis the hydraulic parameters for each route:

Available upper – air difference $H_{0i}=H_{i1} - H_{i2}$; (m)

Speed through pipelines:

$$v_i = \frac{4Q_i}{D_i^2 \cdot \pi}; \left(\frac{m}{s}\right)$$

Reynolds' number: $R_{ei} = \frac{v_i \cdot D_i}{\vartheta}$

For calculation of abrasion coefficient, the Swamee-Jain Friction Factor is used (for $10^{-6} \leq \frac{k}{D} \leq 10^{-2}$ i $5000 \leq R_e \leq 10^8$)

$$\lambda_i = \frac{1,325}{\left[l_n\left(\frac{k}{3,7 \cdot D_i} + \frac{5,74}{R_{ei}^{0,9}}\right)\right]^2}$$

Hydraulic slope: $i_i = \frac{\lambda_i \cdot v_i^2}{D_i \cdot 2g}$

Exertion loss: $\Delta h_{ti} = i_i \cdot L_i ; (m)$

In accordance with calculation, the local losses of exertion are frequently not defined, but it is perceived that they range from 5 to 10 % of exertion loss in straight – lined routes of pipelines.

Local loss of exertion (loss of pressure) 10%: $\Delta h_{Li} = \frac{10}{100} \cdot \Delta h_{ti} ; (m)$

Total loss of exertion (loss of pressure) on "i" route are: $\Delta h_i = \Delta h_{ti} + \Delta h_{Li} ; (m)$

Elevation of piesometric line $H_i=H_{i1} - \Delta h_{ti}$; (m)

Loss in pressure:

$\Delta p_i = \Delta h_i \cdot \rho \cdot g ; (Pa)$

Brine volume in pipe on "i" route: $V_i = \frac{D_i^2 \cdot \pi}{4} \cdot L_i;\ (m^3)$

Brine mass in pipe on "i" route:

- for ρ_1=1200 kg/m^3 $\rightarrow$ $m_{1i} = V_i \cdot \rho_1; (kg)$
- for ρ_2=1201 kg/m^3 $\rightarrow$ $m_{2i} = V_i \cdot \rho_2 ; (kg)$
- for ρ_3=1202 kg/m^3 $\rightarrow$ $m_{3i} = V_i \cdot \rho_3; (kg)$

Each route is calculated.

Table 1 *Calculation results for individual hydraulic parameters on route I*

Route I	**Elevation of bottom m of altitude**	**L_1 (m)**	**Q (m^3/year)**	**Q (l/s)**	**D_1 (m)**	**v_1 (m/s)**	**k_1**	**Re_1**
R Tetima RK Jurkići	527	1180	4525416	143.50	0.3	2.03	0.4	319027
			3162360	100.28		1.42		222936
			2899560	91.94		1.30		204410
			2706840	85.83		1.21		190823
		Λ_1	**I_1**	**Δh_{t1} (m)**	**Δh_{l1} (m) 10%**	**Δh (m)**	**Elevation pij.lin. (m)**	**Δp (Pa)**
		0.02197	0.015402	18.17417	1.817417	19.99159	507.01	235340.97
		0.02229	0.00763	9.003639	0.900364	9.904003	517.10	116589.93
		0.02239	0.006441	7.600579	0.760058	8.360637	518.64	98421.42
		0.02246	0.005633	6.646726	0.664673	7.311398	519.69	86069.78

The following diagrams will demonstrate the interdependency between some calculated parameters specified in Table 1.

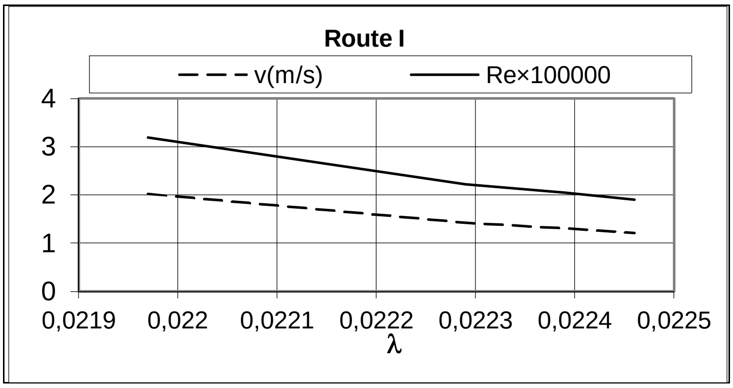

Figure 2 *Abrasion coefficient in the function from speed "i" to the Re number on the route I*

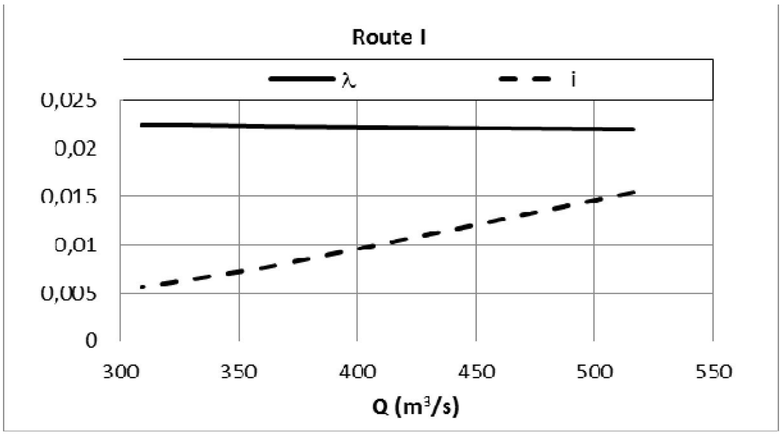

Figure 3 *Hydraulic elevation on the route I of pipeline in the function form of abrasion coefficient*

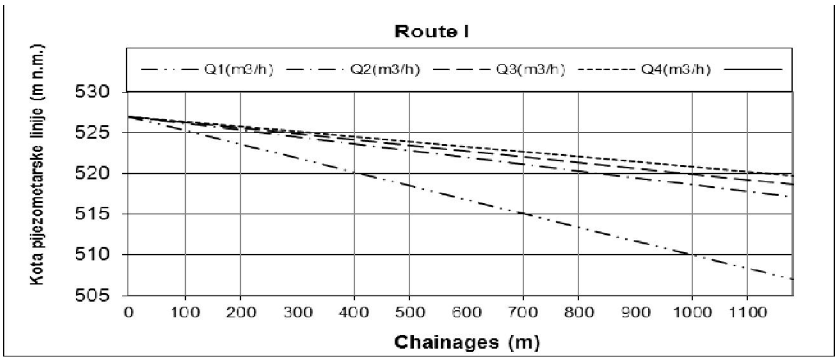

Figure 4 *Piesometric line on the route I in dependency to the size of brine flow through pipeline*

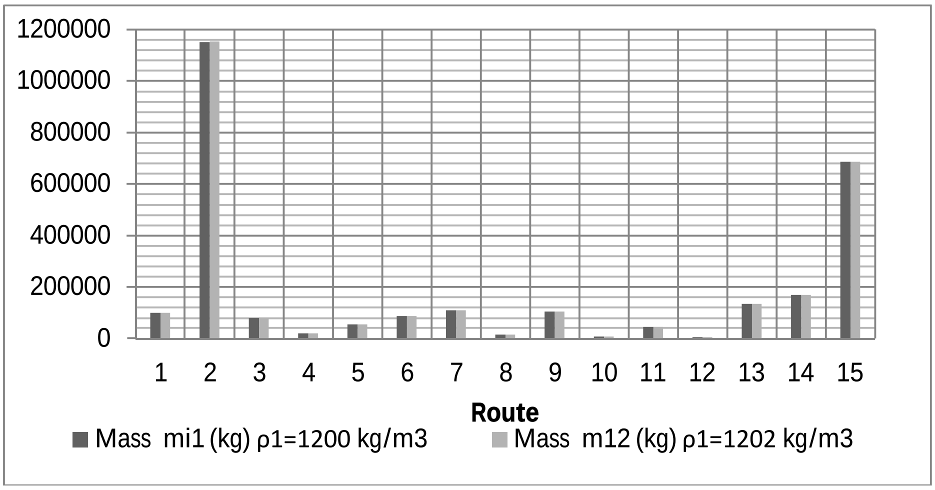

Figure 5 *Diagram of mass dependency from brine density in pipeline on all routes*

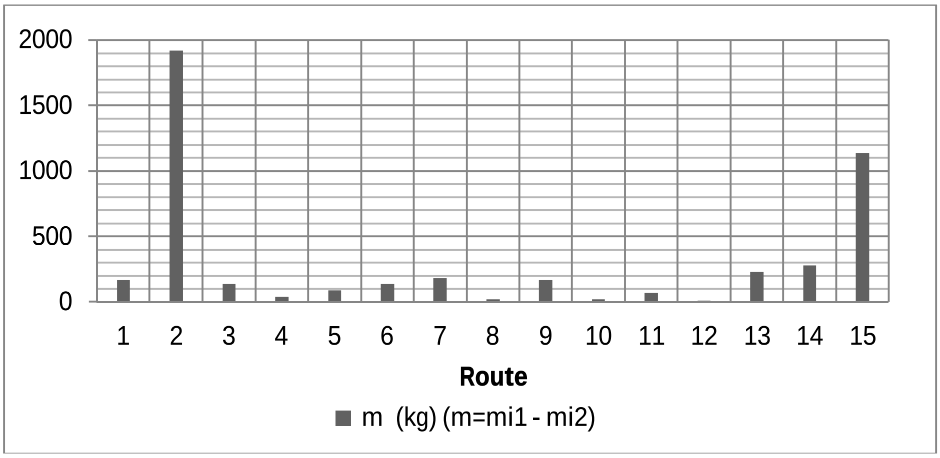

Figure 6 *Diagram of difference in brine masses upon density increase on some routes*

Increasing the brine density from 1,200 to 1,202 kg/m^3 on the first route, the brine mass in pipeline is increased from 100.04 t to 100.21 t (for 170 kg). On some routes, the value of difference in brine masses is not only influenced by increase in density, but by the length and diameter of pipeline as well.

Diagrams in Figures 7, 8 and 9 show the change in diameters along the line routing.

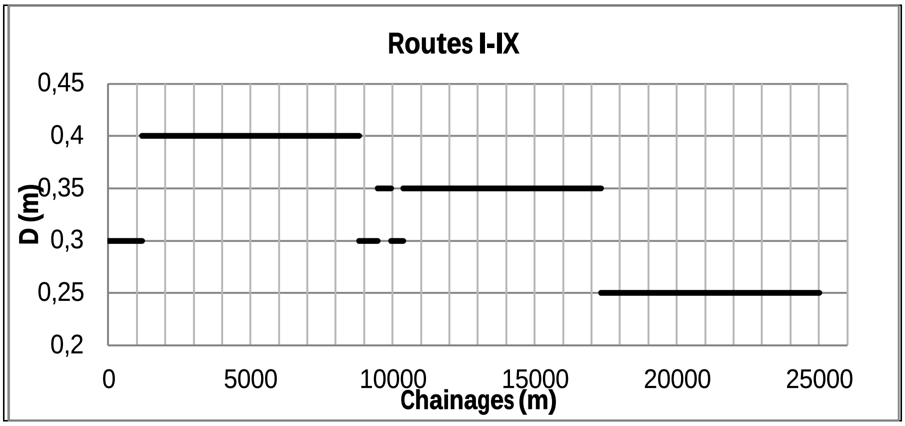

Figure 7 *Change in pipeline diameter on the routes I to IX*

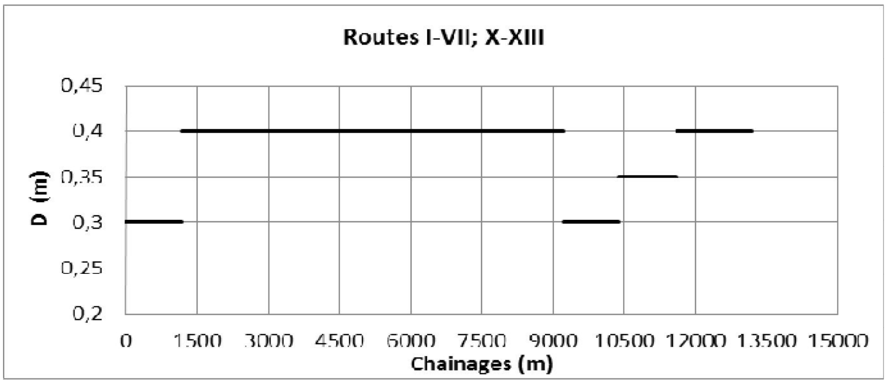

Figure 8 *Change in pipeline diameters on the routes I –VII, X-XIII*

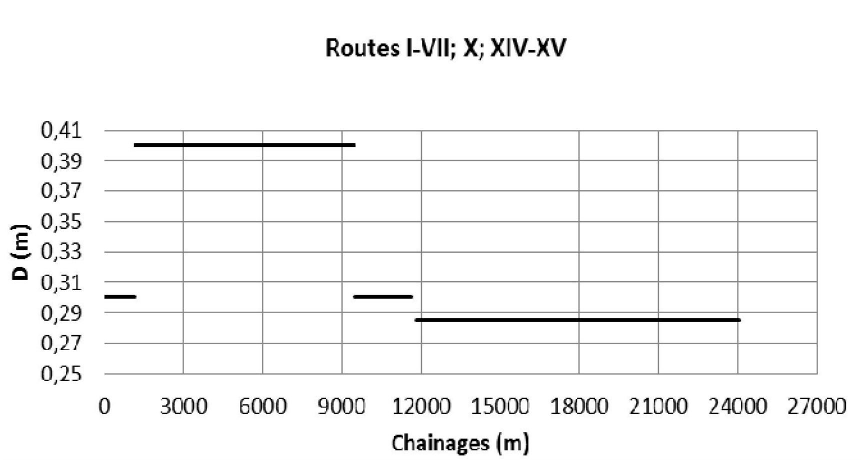

Figure 9 *Change in pipeline diameters on the routes I –VII, X, XIV-XV*

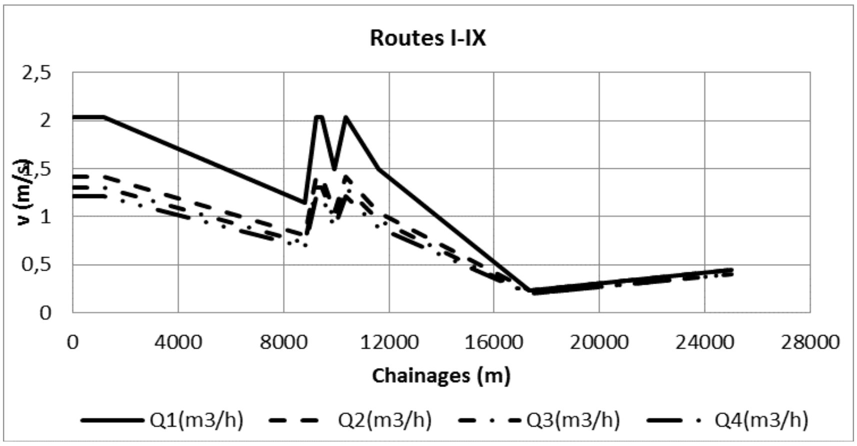

Figure 10 *Change in flow speed in pipeline on the routes I to IX depending to the flow size*

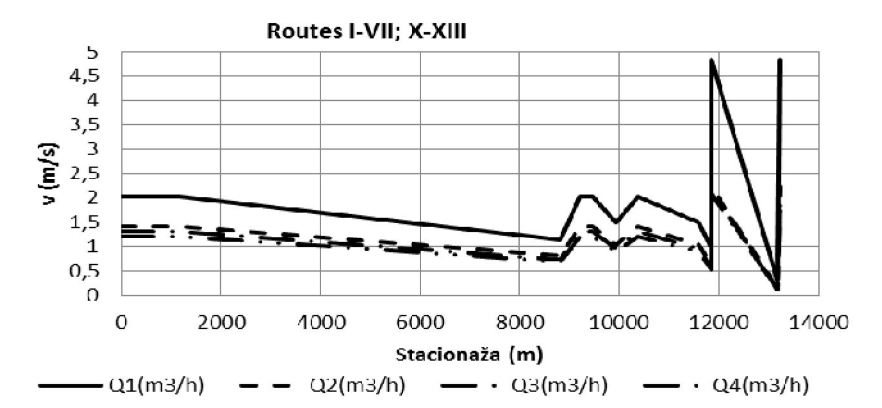

Figure 11 *Change in flow speed in pipeline on the routes I-VII, X-XIII depending to the flow size*

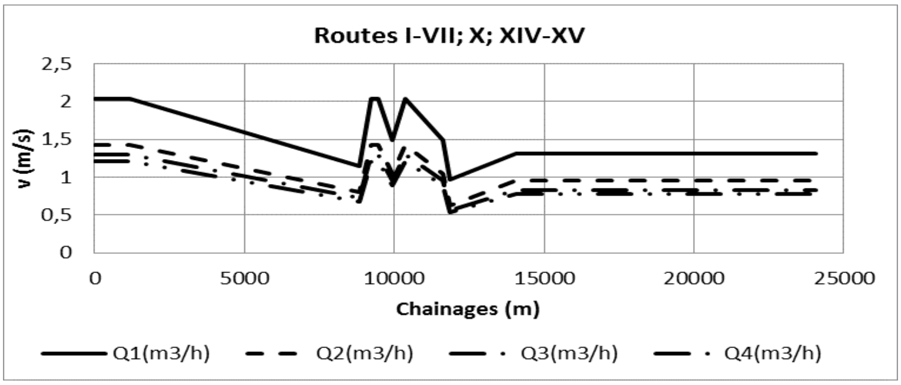

Figure 12 *Change in flow speed in pipeline on the routes I-VII, X, XIV-XV depending to the flow size*

3 DISCUSSION

Based on the conducted research and analysis, the following can be concluded:

- With increase of brine flow “Q”, the speed in pipeline “v” increases (at D=const.).
- With increase of flow, the values v, i, Δh, Δp increase, the Re (at D=const. L=const.) increases, but the abrasion coefficient λ slightly reduces and vice versa.
- At D=const. by reduction the flow, the value of speed “vi” of the number Re on the route reduces, and the value of abrasion coefficient λ rises.
- Length of the route does not affect the value of abrasion coefficient.
- With increase in the flow Q, the piesometric elevation reduces.
- Change in brine density for 2 kg/m^3 influences the change in brine mass in pipeline on some routes.
- If pipe length and diameter are larger, the mass change is more significant.
- Length of pipeline influences the overall increase in brine mass in pipeline by increase in density.

CONCLUSION

In conclusion, based on the analysis provided in this work it is possible to mathematically calculate the gravitational transport of brine through pipeline, and hence, it can be used to calculate the gravitational transport of colloid hydro – mixtures.

Upon calculations based on this model, the entry data must be accurately defined. Therefore, the analysis of obtained data for a specific instance leads to a conclusion that by increasing the flow, the vales v, i, Δh, Δp and Re are increased, and the abrasion coefficient L_i, $D_{i,}$ decreases for the exact same value.

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