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
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 $Q_1= 516.6 \, m^3/h$;
- 2014: minimum flow $Q_2= 309 \, m^3/h$;
- maximum flow $Q_3= 331 \, m^3/h$;
- 2015: minimum flow $Q_4= 309 \, m^3/h$;
- maximum flow $Q_5= 361 \, m^3/h$

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_1 (m)
- Elevation of supporting chamber overflow H_2 (m)
- Brine density (kg/m^3)
- Kinematic viscosity \( \nu \) (m^2/s) for temperature up to 30°C
- 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:

\[ \nu_i = \frac{4Q_i}{D_i^2 \cdot \pi} \left( \frac{m}{s} \right) \]

Reynolds’ number: \( R_{ei} = \frac{\nu_i D_i}{\delta} \)

For calculation of abrasion coefficient, the Swamee-Jain Friction Factor is used (for \( 10^{-6} \leq \frac{k}{D} \leq 10^{-2} \) 5 000 \( \leq R_{ei} \leq 10^8 \))

\[ \lambda_i = \frac{1.325}{\left[ \frac{k}{3.74 \cdot D_i} + \frac{5.74}{R_{ei}} \right]^2} \]

Hydraulic slope: \( i_i = \frac{\lambda_i \nu_i^2}{2g} \)

Exertion loss: \( \Delta h_{it} = i_i \cdot L_i \) (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%:

\[ \Delta p_i = \frac{\Delta h_{it}}{100} \cdot \Delta h_{it} \] (m)

Total loss of exertion (loss of pressure) on “i” route are:

\[ \Delta h_i = \Delta h_{it} + \Delta h_{it} \] (m)

Elevation of piesometric line H_i = H_{i1} - \Delta h_i (m)

Loss in pressure:

\[ \Delta p_i = \Delta h_i \cdot \rho \cdot g \] (Pa)

Brine volume in pipe on “i” route:

\[ V_i = \frac{\pi \cdot D_i^2}{4} \cdot L_i \] (m^3)

Brine mass in pipe on “i” route:

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

<table>
<thead>
<tr>
<th>Route I</th>
<th>Elevation of bottom m of altitude</th>
<th>L_i (m)</th>
<th>Q (m^3/year)</th>
<th>Q (l/s)</th>
<th>D_i (m)</th>
<th>( \nu_i ) (m/s)</th>
<th>k</th>
<th>Re_i</th>
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<td>R Tetima RK Jurkići</td>
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<tr>
<th></th>
<th>( \lambda_i )</th>
<th>( I_i )</th>
<th>( \Delta h_{it} ) (m)</th>
<th>( \Delta h_i ) (m)</th>
<th>( \Delta h_{it} ) 10%</th>
<th>( \Delta h_{it} ) (m)</th>
<th>Elevation pij.lin. (m)</th>
<th>( \Delta p ) (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
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The following diagrams will demonstrate the interdependency between some calculated parameters specified in Table 1.

**Figure 2** Abrasion coefficient in the function from speed “v” 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
Increasing the brine density from 1,200 to 1,202 kg/m³ 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/m³ 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 values v, i, Δh, Δp and Re are increased, and the abrasion coefficient L, D, decreases for the exact same value.

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