Study on the capacity expansion and energy saving modifications of brine transportation pump station at Huaiyin

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Abstract: Through investigation and study on the brine pipeline from Huaiyin to Lianyungang and on the basis of testing the running of several pumps in parallel connection in the first station. This paper points out that transportation capacity can be increased only when intermediate pump station is set up. The resistance calculation suggests that the modification on the pipeline with transportation capacity of 600×104m3/a and the design of intermediate pump station is an optimal choice, and in the meantime the maximum brine transportation capacity is fixed. In addition, a closed-circuit brine transportation system is more economic and rational based on the analysis on the pros and cons of the transportation process

Key words: Closed-circuit transportation, Running in parallel connection, Brine transportation, Intermediate pump station

INTRODUCTION

Jiangsu Oilfield Huaiyin own the brine pipeline from Huaiyin to Lianyungang is 173.8 kilometers. This pipeline belongs to Jiangsu Oil Field. A pumping station is set in Zhaoji. The original design of the transportation capacity is 365×10^4 m^3/a. Jiangsu Oil Field rebuilds the pipeline and increases the transportation capacity because several salt files increased the requirements of brine including Lianyungang Caustic Soda Plant and some other salt plants near Lianyungang. The scope of underground rock salt mine in Zhaojij Huaiyin Salt Mine is 1.1559 km^2. In addition, mine development corporation explored 3.113 km^3 reserve capacity. These will guarantee the long term and stabilized operation for the brine pipeline. The benefits were brought under the transportation capacity increase. Furthermore, the power consumption was 20 million

yuan/year. This rebuilt can increase the efficiency of the pump station and decrease the energy consumption, and also brings the benefits for the enterprises. According to the brine requirements in Lianyungang district, the objective of the rebuilt is to improve the transportation capacity of the pipeline from Zhaoji Salt Field, Huaiyin to Lianyungang, the target transportation capacity should get 600×10^4 m^3/a or more. The design capacity should be 740 m^3/h.

INVESTIGATION AND REBUILT CONDITIONS

Total pipeline length is 173 kilometers, the diameter of the pipeline is Φ508 × 7.1mm, the design pressure is 5MPa. Pipeline pressure strength is 7.5 mPa. At preliminary design, the working days is 330, transportation capacity is 365×104 m^3/a. The maximum transportation capacity is 400×104 m^3/a. The material is saturated salt water at room temperature (specific gravity is 1.21, viscosity is 2.18 mPa·S, NaCl 300g/L, Na_2SO_4 4.11 g/L, $CaSO_4$ 3.6 g/L).

Pumping station used 5 corrosion resistance pumps made in Dalian, the type of the pump was DMCl00A×6, multi-stage pumps. 3 of them were in use, 2 of them as the alternative. The properties of pump are listed in Table 1. The practical operation showed that parallel connect 3 pumps was suitable to the operation. The transportation capacity can get 465 m^3/h when the pressure was less than 5.0 MPa. After the brine pipeline from Huaiyin to Lianyungang production, calcium sulfite scaled at the inner wall. The thickness of the scale was about 1 cm for 3 years operation. The insider diameter reduced and made the pressure increasing. The closer to the pump station and higher pressure of the pipeline, the thicker of the scaling, and vice versa.

According to the survey and considering the pipeline safety, the outside pressure must be lower than 5.4 MPa (more than the pressure required to conduct a security assessment on the pipeline). It can set up intermediate pump station to solve the insufficient transportation pressure problem.

The selection sites should be considered some basic conditions for the intermediate pump station. Firstly, the site must have the power condition. Generally speaking, it is easy to find 380 V, 3 ph, 50 Hz power. It is a little difficult to find 10000 V or 6000 V power. The project cost will be increased if the new erection power cord was too long. The intermediate pump station can be set at the local valve room for convenient management. 3# Valve room is near the Gaogou alcohol liquor factory, it can use the same line to supply the power. 4-1# valve room is near Xiaoyi 35 kV power substation. 3# and 4-1# valve rooms are the ideal intermediate pump station location.

THE PRELIMINARY TESTS FOR CAPACITY EXPANSION

Lianyungang Soda Plant expanded its capacity in 2007. The brine transportation capacity of the pipeline form Huaiyin to Lianyungang must be increased. 4# and 5# pumps updated to ZYWD200-70×6, which was made in Zhongyi Pump, Jiangsu. The properties of the pump are listed in Table 1.

2 Zhongyi pumps and 4 Dalian pumps parallel connected in practical operation. Or 3 Dalian pumps and one Zhongyi pump connected, or one Zhongyi pump operated alone. The inlet pressure of the pump was kept at 0.07-0.094 MPa, the operation results is shown in Table 2.

Table 1 Parameters of the pumps operated presently

Number	Pump Type	Rated Flow m^3/h	Head m	Speed r/min	NPSH m	Electric machine Rating Power kW	Current
1# 2# 3#	DMC100A	155	430	2970	5	400	47.8
4# 5#	ZYWD200-70×	210	430	2970		500	57.9

Table 2 Records of parallel connected operation for outlet transportation pump

Date	Operation Mode	Operation current (A) 1# pump	2# pump	3# pump	4# pump	5# pump	Total current	Outlet pressure (MPa)	Outlet transportation (m^3/h)
5.27	2 big 2 small		38.5	41.6	50.7	49.2	180	5.39	569
5.27	2 big 2 small		38.6	41.8	50.7	49.4	180.5	5.39	569
5.28	1 big 3 small	37.6	37.5	42.2		53.9	171.2	5.37	569
5.28	1 big 3 small	37.5	37.5	42		54	171	5.38	570
5.28	1 big 3 small	37.4	38.1	41.8		53.3	171.6	5.4	571
6.18	1 big 3 small	38.2	37.8	41.6	56.3		174.8	5.4	570
6.18	1 big	40.2			61.7	55.2	157.1	5.24	562
6.19	1 big 3 small	40.2		43.3	61.9		146	5.13	159
6.19	1 big 3 small				63		63	1.07	258
6.30	1 big 3 small	37	36.2	39.8	53.6		167.4	5.43	571
6.30	1 big 3 small	36.6	36.3	39.9	53.2			5.4	568
7.4	1 big 3 small	36.5		39	51.6	49.8	177.6	5.34	568
7.4	1 big 3 small	37		40	52	47	178	5.34	565

4# and 5# pumps increased rating flow, and 2 big and 2 small pumps parallel connected can get 730 m^3/h. 1 big and 3 small pumps parallel connected can get 675 m^3/h. Actually the flow capacity just can get 570 m^3/h. Zhongyi pumps were rebuilt, and increased the rating capacity to 250 m^3/h, the flow capacity still was 570 m^3/h after parallel connection.

The reason is that the properties of the pump and the pipeline did not match each other, which means the head of the pump was not enough. That is to say, the head of the pump cannot overcome flow resistance of target flow. It can not get the target flow even if the types of pump changed and rating flow increased. The flow capacity can be increased by improving head of pump and matching the head and flow resistance of the pipeline.

PARALLEL CONNECTION OF THE PUMP

Parallel connection of the pump is very universal in the long transportation pipeline. In Fig.1, the matching relationship of pump properties and pipeline resistance is shown for the parallel connection pump. H0 is stop head of pump, H1 is sea level head, HA and HB is valve resistance. Curve 1 is pipeline resistance, curve 2 is 2 or more pumps parallel connected properties, curve 3 is one pump property.

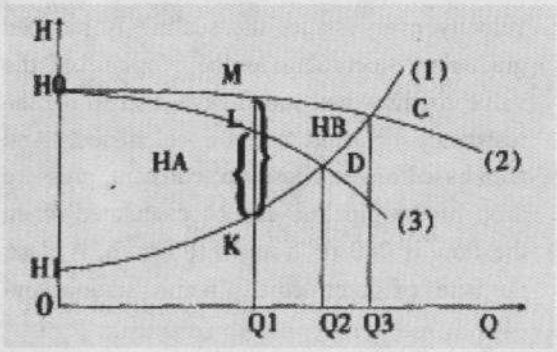

Fig.1 Matching of parallel connection of pump group and pipeline properties

From Fig.1, (1) when outlet transportation capacity is Q1, the outlet valve need turn down for one pump, the resistance gets HA. The each outlet valve need turn down for many pump parallel connection, the resistance gets HB, at that time, one pump can save more energy than many pumps parallel connection. (2) the maximum transportation capacity is Q2 for one pump. The head and pipeline resistance are matched each other, single pump efficiency shows completely. (3)Several pumps connection, the maximum transportation capacity is Q3, the head of the pump is the same and the resistance of the pipeline is the same. (4) the outlet pressure corresponds certain of outlet capacity for the pipeline transportation. The outlet capacity is constant when the outlet pressure is constant. That is to say, whatever increasing pumps numbers, the transportation capacity of the pipeline will not be changed if the head of the pump is constant. The transportation capacity can be improved by increasing rating flow and head of pump together.

RESISTANCE CALCULATIONS

The density of brine is 1210 kg/cm^3, viscosity is 2.18 mPas. The diameter of the pipeline isΦ508×7.1, the distance of the valve rooms along the pipeline. The pressure of the valve rooms when the flow is 565 m^3/h.

Calculation: firstly calculates the flow velocity every stage, the scaling is reduced gradually. According to the pressure of the valve rooms when the flow is 565 m^3/h, the resistance constant can be calculated. And then based on the resistance constant, pressure drop of the pipeline can be calculated when the flow is 740 m^3/h and 1100 m^3/h. At last, the site of intermediate pump station and pressure increasing can be determined according to pressure drop.

The flow is 600×104 m^3/a (740m^3/h), 3# valve room must set pressure adding pump station.

The maximum transportation capacity of the pipeline is 1100 m^3/h. the main limited conditions are: the flow velocity has been 1.732 m/s. The velocity gets the highest to the brine. From the investment benefits point view, it must set 3 intermediate pump stations at 1#, 3#, and 4-1 #valve rooms if the flow reaches 1100 m^3/h. One station will be needed at 2# valve room if the flow is over 1100 m^3/h.

COMPARISON OF REBUILT SCHEME OF HUAIYIN PUMP STATION

The outlet flow is 740 m^3/h and the pressure is 5.4 MPa for Huaiyin pump station.

(1) Two in use and one stand by

The flow of each pump is 370 m^3/h, head 450 m, 3 pumps parallel connected operation, two in use and one stand by. The speed of pump is 1480 r/min. The efficiency of pump is 75%. The power of draft is 727 kW. The electric machine is 800 kW (6000V, 3hp, 50Hz). The DH370-60X 8 pumps is recommended. This pump had 8 impellers, 4 left and 4 right symmetrically. It just need add one pump if the capacity expansion to 1100 m^3/h. It will change 3 in use and 1 stand by, or add 2 pumps, 3 in use and 2 stand by.

(2) 3 in use and 2 stand by

The flow rate of single pump is 250 m^3/h, head 450 m. 5 pumps parallel connected operation. This is 3 in use and 2 stand by. The speed of pump is 1480 r/min. The efficiency of pump is 70%. The power of draft is 527 kW. The electric machine is 630 kW (6000V, 3hp, 50Hz). The DH250-60X 8 pumps is recommended. This pump had 8 impellers, 4 left and 4 right symmetrically.

(3) Add some new pumps based on the old pumps

At present, the station has 5 pumps, including 3 Dalian pumps (flow rate is 155 m^3/h, head is 430 m), 3 Zhongyi pumps (flow rate is 210 m^3/h, head is 430 m, one is stand by). 3 Dalian pumps have been in use for several years, spare parts consumed too much. 3 Zhongyi pumps will be added. This scheme need rebuilt the pumps and improve the head to 450 m. The flow rate is 265 m^3/h, head 450 m; speed is 1450 r/min. The DH265-60X 8 pumps is recommended. This pump had 8 impellers, 4 left and 4 right symmetrically. 2 new pumps and one old pump were operated at the beginning. One new and two old were as stand by. This scheme considers the capacity expansion in the future.

COMPARISON OF INTERMEDIATE PUMP STATION

There is no intermediate pump station in the brine pipeline. The outlet pressure is 5.4 MPa, the maximum transportation capacity is 565-570 m^3/h. According to the pipeline resistance calculation results, it must set different parameters and different intermediate pump stations to the different outlet transportation.

The principles of the intermediate pump station: it must set intermediate pump station (incoming flow pressure should be controlled at 0.1-0.5 MPa) when the pipeline pressure can not transport the brine to the next valve room. The outlet pressure should be less than 5.4 MPa after adding pressure at intermediate pump station.

The intermediate pump station is built at valve room. It can add pressure in series connection way in pipeline. For the pump, one in use and one stand by. If the power is too large, the type should change to 2 in use and one stand by or 3 in use and 2 stand by, see Fig.1-Fig.4. The pump type should use the same one for convenient change and reduce the maintaining service. Considering the system security, simple watch pump room can be built. Hoisting equipments is equipped. The shaft seal and bearing changing can be finished at spot.

The necessary of building intermediate pump station and scheme of station based on different outlet transportation capacity

(1) Outlet transportation capacity 600×104 m^3/a (740 m^3/h)

The actual transportation capacity should reach 621×104 m^3/a if the station operates for all hour in 350 days. There are two schemes to reach this transportation capacity.

Scheme 1: 3 pumps at a station (2 in use and 1 stand by)

Pressuring adding station is built in 3# valve room. 3 pumps are equipped at the station, 2 in use and 1 stand by. The flow of single pump is 370 m^3/h, 320 m head. The 6 class DH370-60X 8 pumps is recommended. The speed of pump is 1470 r/min. The efficiency of pump is 75%. The power of draft is 518 kW. The electric machine is 630 kW(6000V, 3hp, 50Hz), the material is CD4-MCu.

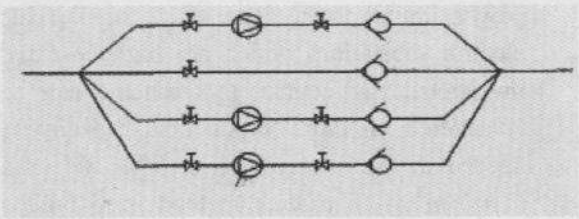

Fig. 2 Pipeline configuration of 2 in use and one stand by

Scheme 2: 4 pumps at two stations (1 in use and 1 stand by)

Pressuring adding station is built in 3# and 4-1# valve room. 2 pumps are equipped at each station, 1 in use and 1 stand by. The flow of single pump is 740 m^3/h, 160 m head. The single class 350SH-160 pump is recommended. The speed of pump is 1470 r/min. The efficiency of pump is 80%. The power of draft is 485 kW. The electric machine is 560 kW(6000V, 3hp, 50Hz), the material is CD4-MCu.

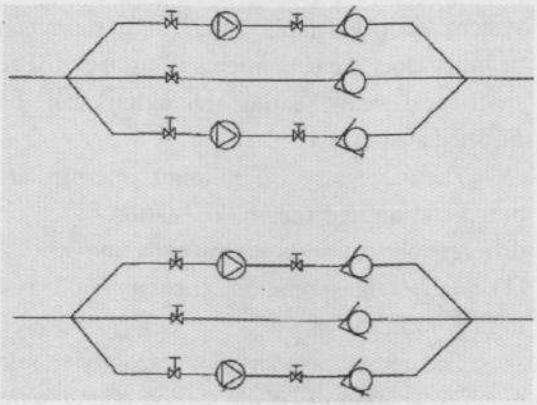

Fig.3 A pump station was built in 3# and 4-1# valve room (1 in use and 1 stand by)

Scheme 2 has one more pump and one more pump station than scheme 1. The investments of two schemes are essentially the same. From the reliability of the pump, the pump structure of scheme 2 is simple and less parts, lower service fee, more important one is to save electricity for scheme 2. The other two reasons also were considered. One is pump operation is safe because of watch by workers. It needs 4 persons to watch the pump station according to usual shift system. It will take 150000-160000 yuan per year. The other is power limitation, it need set 2 small scale electric substations which are high cost and investment. Of course, this scheme can be considered if more production capacity is needed in the future, such as 990×104 m^3/a (1100 m^3/h). The ideal method is to built a new pump station, that is, scheme 1, a new pump station, 2 in use and 1 stand by mode.

(2) Outlet transportation 900×104 m^3/a (1100 m^3/h)

The actual transportation capacity can get 924×104 m^3/a if it operates in all the time for 350 days. It must set 3 pump stations to reach this transportation capacity. It need add a pressure adding pump station in 1# , 3# and 4-1# valve room (designated as 1# ,3#, 4-1# pressure adding pump station), pressure increasing is 4.88 MPa, 5.175 MPa, 4.068 MPa respectively.

1# pressure increasing pump station: the total flow rate of pressure increasing pump station is 1100 m^3/h, 415 m head (differential pressure is 4.88 MPa). Considering the generality and interchangeability of the pump, pump parts stock, it is recommended to use 5 pumps, 3 in use and 2 stand by. The parts of pump of this station can interchange with the first station. The flow of single pump is 370 m^3/h, 415 m head. 8 class DH370-60X8 pump is recommended. The speed of pump is 1470 r/min. The efficiency of pump is 75%. The power of draft is 671 kW. The electric machine is 800 kW (6000V, 3hp, 50Hz). The pump material is CD4-MCu.

It need add a pressure adding pump station in 3# valve room (designated as 3# pressure adding pump station), pressure increasing is 4.88 MPa.

3# pressure increasing pump station: the total flow rate of pressure increasing pump station is 1100 m^3/h, 440 m head (differential pressure is 5.175 MPa). Considering the generality and interchangeability of the pump, pump parts stock, it is recommended to use 5 pumps, 3 in use and 2 stand by. The parts of pump of this station can interchange with the first station. The flow of single pump is 370 m^3/h, 440 m head. 8 class DH370-60X8 pump is recommended. The speed of pump is 1470 r/min. The efficiency of pump is 75%. The power of draft is 711 kW. The electric machine is 800 kW (6000V, 3hp, 50Hz). The pump material is CD4-MCu.

4-1# pressure increasing pump station: the total flow rate of pressure increasing pump station is 1100 m^3/h, 345 m head (differential pressure is 4.068 MPa). Considering the generality and interchangeability of the pump, pump parts stock, it is recommended to use 5 pumps, 3 in use and 2 stand by. The parts of pump of this station can interchange with the first station. The flow of single pump is 370 m^3/h, 345 m head. 6 class DH370-60X8 pump is recommended. The speed of pump is 1470 r/min. The efficiency of pump is 75%. The power of draft is 558 kW. The electric

machine is 630 kW (6000V, 3hp, 50Hz). The pump material is CD4-MCu.

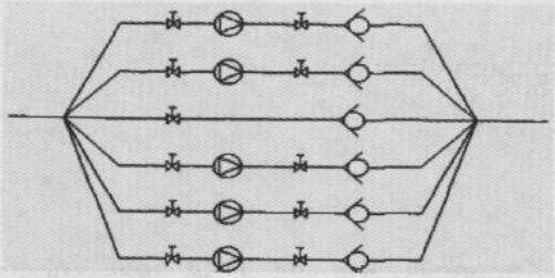

Fig.5 3 in use and 2 stand by scheme

CONCLUSIONS

This paper analyzed and calculated the brine transportation pipeline from Huaiyin to Lianyungang. It was proposed the technical scheme to expand the production to 600×104 m^3/a, 900×104 m^3/a and compared the schemes. The conclusions are: (1) it is feasible to expand the capacity to 600×104 m^3/a for brine pipeline from Huaiyin to Lianyungang. The maximum transportation capacity is 900×104 m^3/a. (2) the best scheme is as follows after the expansion. The first station changed 3 pumps (operation mode is 2 in use and 1 stand by, the single pump flow is 370 m^3/h and 450 head). The intermediate pump station was set in 3# valve room. 3 new pumps were installed at the intermediate pump station (operation mode is 2 in use and 1 stand by, the single pump flow is 370 m^3/h and 450 head). In addition, a 35 kV/6kV electric substation need set at intermediate pump station to provide the electric to 3 brine transportation pump. (3) The production capacity is further expanded to 900×104 m^3/a, it need set a pump station for 1#,3#,4-1# each valve room, the operation mode can use 3 in use and 2 stand by mode. (4) The transportation technology should adopt the obturation mode.

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