Comparative Study on Water Hammer for Pump Station in High Pressurized Pipes in Kuwait

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Abstract

Because of abrupt changes for velocity in water, transient flow is occurred in practical life. To reduce and avoid the high or low pressure of pipe network system, various surge protection facilities are used to prevent the risk in pipe network system. Especially, we focused on study not only preventing positive and negative pressure but also selecting adequate equipment for high pressurized pipelines. Several critical cases were considered by undertaking a steady state hydraulic study and transient dynamic simulation and we suggested that the surge vessel of various surge protection system was recommended to control high and low pressures on pipeline system in perspective.

Keywords : Water Hammer, Surge Analysis, Surge Vessel, High Pressurized Pipes

1. INTRODUCTION

By extending urban area recently, it's necessary to consider long distance for water supply from water treatment facility to household, so the pressure of pump had a tendency to increase. Generally, there were many solutions to prevent the high pressure in transient such as simplified equation, selection table, graphical method, actual experiment and computer program. In current trend, the review of water hammer was carried out by computer modeling because it was convenient and showed enhanced result for transient flow quickly. The purpose of surge analysis was to estimate the impact of water network system and prevent the unexpected accident of huge transmission pipeline by power failure, valve closing, pump start & stop and etc. In this study, we focused to evaluate the positive and negative pressure using major criteria for Azzour WDC II pump station in Kuwait because of extraordinary case for high pump head (Mina Abdullah : 120 m, Wafra : 180 m) and reviewed the critical condition of water hammer not only conservative solution but also effective selection for surge protection system. The procedure of surge analysis is as Figure 1.

The Azzour WDC II project site was located in southern area of Kuwait and about 70 km distance from Kuwait City. The Figure 2 shows detailed information for project area.

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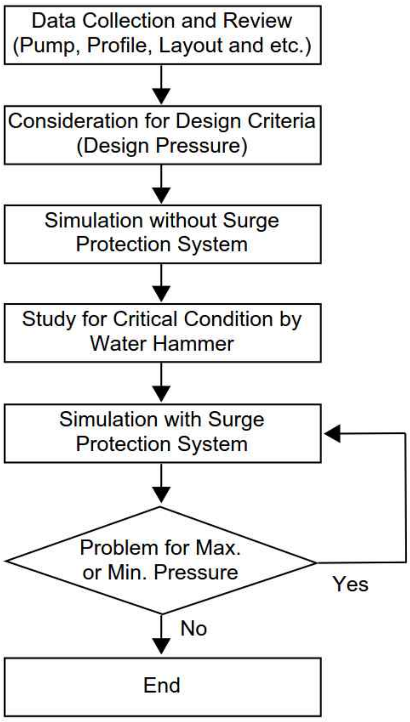

Fig 1. Flow Chart for Surge Analysis

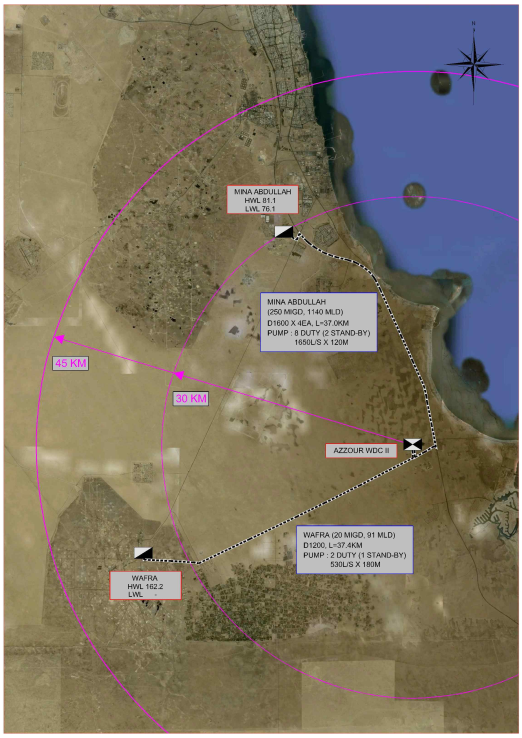

Fig 2. Location Map

2. CASE STUDY

2.1 BASIC INFORMATIONS

To review and calculate the transient flow, the detailed information was required such as pump head, flow rate, pump inertia, pipeline length, profile, pipe diameter, pipe material and etc.

Table 1. Pump Specification in Mina Abdullah & Wafra

Location	Mina Abdullah	Wafra
Type	Double Suction Volute	Double Suction Volute
Size	Suction D800 Discharge D600	Suction D500 Discharge D400
Nos. of Rotation	745 rpm	990 rpm
Efficiency	90.6%	85.3%
Nos. of Pumps	10 (8 Duty, 2 Stand-by)	3 (2 Duty, 1 Stand-by)
Inertia	Pump GD^2 = 74.4 kg-m^2 Motor GD^2 = 384 kg-m^2 Total GD^2 = 458.4 kg-m^2	Pump GD^2 = 24.4 kg-m^2 Motor GD^2 = 131 kg-m^2 Total GD^2 = 155.4 kg-m^2
Pump Head	120 m	180 m
Flow	1650 L/s	530 L/s
Power	2750 kW	1420 kW

The material of pipe was carbon steel with cement linings, so we applied Hazen-Williams equation (1) for the head loss of dynamic simulation in initial condition and a roughness coefficient was used to from 110 to 130 by pipe diameter. (~ D600mm : 110, D700 ~ 900mm : 120, D1000mm ~ : 130)

$$H \quad 10.666 \times C^{\;1.85} \times D^{-4.87} \times Q^{1.85} \times L \qquad (1)$$

Where, H=Pressure loss in pipeline (m), C=Roughness coefficient (110~130), Q=Volumetric flow rate (m^3/s), D=Pipe diameter (mm) and L=Pipe Length (m).

The fundamental equation (2) of transient flow was suggested by Joukowsky.

$$\triangle P = \pm \rho a \triangle V \text{ or } \triangle \quad = \pm \frac{a \triangle V}{g} \qquad (2)$$

Where, P=Piezometric pressure, ρ=Fluid density, V=Average velocity, a=Acoustic(Water hammer) wave speed and g=Gravitational acceleration.

Because of huge amount weight by simulation, flywheel was not considered in surge protection system, and we focused on surge vessel and closing time of check valve.

2.2 MINA ABDULLAH

The maximum pressure was 178 m, and this was within the allowable pressure of PN16 in transmission lines. The result of water hammer and closing time for check valve showed as Figure 3 and Table 2. Based on simulation, rapid closing type was recommended by check valve.

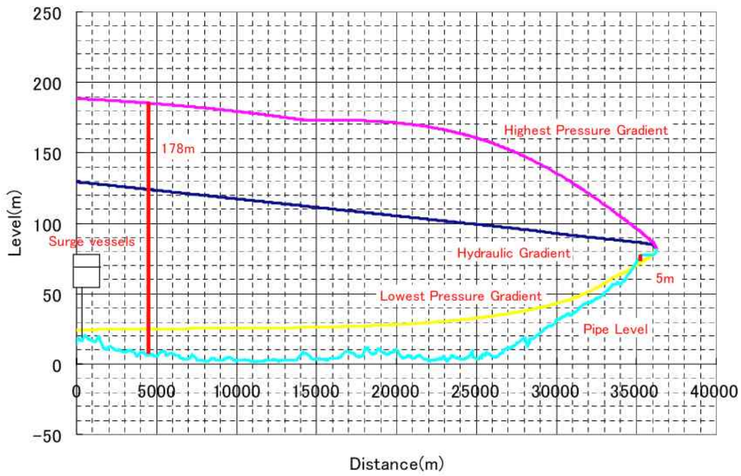

Fig 3. Pressure Diagram of Mina Abdullah with Surge Vessel

Specification of Surge Vessel	
Size	D4.8m×H7.0m
Number	5EA (4 Duty, 1 Stand-by)
Initial Condition	Water Depth : 5.5 m Water Level : 26.0 m Air : 24.0 m^3 Water : 102.7 m^3 Total : 126.7 m^3
Section	18.09 m^2
Pipe	L: 81 m D: 1000 mm

Table 2. Result of Closing Time for Check Valve in Mina Abdullah

Case	Description	Case	Description
Case 1	Rapid Closing C.V Maximum Pressure : 178 m Minimum Pressure : -5 m	Case 4	Slow Closing C.V (20 sec.) Maximum Pressure : 181 m Minimum Pressure : -10 m
Case 2	Slow Closing C.V (5 sec.) Maximum Pressure : 179 m Minimum Pressure : -9 m	Case 5	Slow Closing C.V (40 sec.) Maximum Pressure : 185 m Minimum Pressure : -10 m
Case 3	Slow Closing C.V (10 sec.) Maximum Pressure : 178 m Minimum Pressure : -5 m	Case 6	Slow Closing C.V (80 sec.) Maximum Pressure : 188 m Minimum Pressure : -10 m

2.3 WAFRA

The maximum pressure was 219 m, and this was within the allowable pressure of PN25 in transmission lines. The result of water hammer and closing time for check valve showed as Figure 4 and Table 3. Based on simulation, rapid closing type was recommended by check valve.

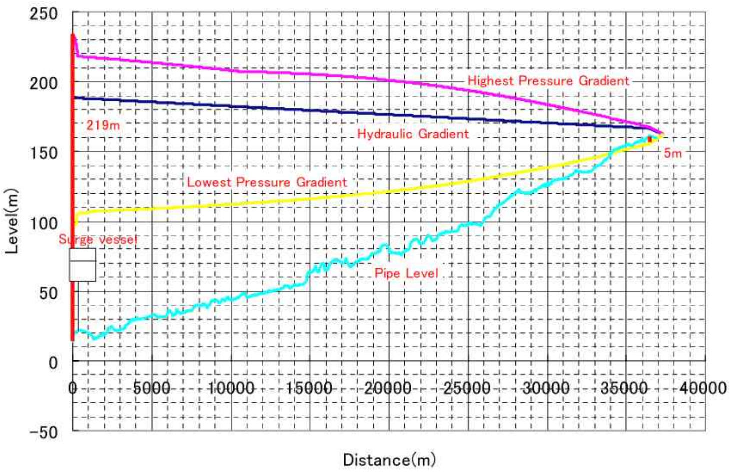

Fig 4. Pressure Diagram of Wafra with Surge Vessel

Specification of Surge Vessel	
Size	D4.3m×H7.2m
Number	2EA (1 Duty, 1 Stand-by)
Initial Condition	Water Depth : 4.2 m Water Level : 24.7 m Air : 44.0 m^3 Water : 60.3 m^3 Total : 104.3 m^3
Section	14.52 m^2
Pipe	L : 97 m D : 800 mm

Table 3. Result of Closing Time for Check Valve in Wafra

Case	Description	Case	Description
Case 1	Rapid Closing C.V Maximum Pressure : 219 m Minimum Pressure : -5 m	Case 4	Slow Closing C.V (20 sec.) Maximum Pressure : 207 m Minimum Pressure : -9 m
Case 2	Slow Closing C.V (5 sec.) Maximum Pressure : 204 m Minimum Pressure : -7 m	Case 5	Slow Closing C.V (40 sec.) Maximum Pressure : 213 m Minimum Pressure : -9 m
Case 3	Slow Closing C.V (10 sec.) Maximum Pressure : 205 m Minimum Pressure : -8 m	Case 6	Slow Closing C.V (80 sec.) Maximum Pressure : 223 m Minimum Pressure : -9 m

2.3 Pipe Material

Because allowable maximum operating pressure (PMA) was 20 bar for PN16 & 30 bar for PN25 based on BS EN 545, the pressure rating of flange was applied in PN16 for Mina Abdullah & PN25 for Wafra and the maximum working pressure (PFA) was 18 bar for Mina Abdullah & 22 bar for Wafra.

Where, PFA : Allowable operating pressure (i.e. maximum internal pressure, exclusive of surge that a component can stand in permanent service). PMA : Allowable maximum operating pressure (i.e. maximum internal pressure, inclusive of surge, that a component can safely withstand in service). PEA : Allowable test pressure (i.e. maximum hydrostatic pressure which can be applied on-site to a component in a newly-installed pipeline).

Table 1. Maximum Values of PFA, PMA and PEA

DN	Flange Pressure Limits (bar)					
	PN16			PN25		
	PFA	PMA	PEA	PFA	PMA	PEA
0 to 50	40	48	53	40	48	53
60 to 80	16	20	25	40	48	53
100 to 150	16	20	25	25	30	35
200 to 600	16	20	25	25	30	35
700 to 1200	16	20	25	25	30	35
1400 to 2000	16	20	25	-	-	-

3. CONCLUSION

We studied the impact of water hammer for transmission pipelines in Mina Abdullah & Wafra and it's required to consider positive & negative pressure in pipes. To prevent the surge pressure in water supply facilities, we carried out the several cases of surge protection system such as flywheel, surge vessel, surge tank and air valve. By dynamic simulation, the negative pressure was –5 m in Mina Abdullah & Wafra and positive pressure was 18 barg in Mina Abdullah and 22 barg in Wafra.

Based on mentioned results for surge analysis, we suggested the surge vessel to protect the critical condition of water hammer as below,

1) For Mina Abdullah transmission pipeline : 5 surge vessels (D4.8m×H7.0m, 4 duty 1 stand-by)

2) For Wafra transmission pipeline : 2 surge vessels (D4.3m×H7.2m, 1 duty 1 stand-by)

3) For check valve : Rapid closing type

Lastly, to show enhanced result in surge protection system, the detailed information should be considered and reflected during the project period.

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