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Sensitivity Analysis on Surge Analysis of Water Supply System

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Abstract: Present work is similar to sensitivity analysis of surge analysis of water supply mains, which has been done earlier. In initial section a 1000mm DI K-9 water supply rising main has been laid from Narwana Branch to canal water Pump House Ismailpur and up to canal based water works, Ambala city. Out of 14.3 km pipeline, the pipe from Narwana Branch to pump house has been laid under gravity and rest of the pipe has been laid as rising main from canal pump house to canal based work. Previous analysis was carried out for 3 no. of pump with discharge 0.999 cumec and it was found safe in respect of pipe thickness as per IS 8329: 2000 (re-affirmed 2005) Indian Standard for Centrifugally Cast (Spun) Ductile Iron Pressure Pipes for Water, Gas and Sewage – Specification (Third Revision). In this analysis another trial has been made for 4 no of pump with discharge 1.332 cumec, which has been found unsafe. The analysis dealing with pumping mains has been designed as per the design and hydraulic data available and as per the guidelines of Central Public Health and Environmental Engineering Organisation (CPHEEO). Results are available in Microsoft excel sheet.

Keywords: Surge, transmission mains.

1 INTRODUCTION AND LITERATURE

Water hammer (or hydraulic shock) is the momentary increase in pressure inside a pipe caused by a sudden change of direction or velocity of the liquid in the pipe. Water hammer can be particularly dangerous because the increase in pressure can be severe enough to rupture a pipe or cause damage to equipment. A common instance of water hammer could be observed by turning off a shower instantaneously. The action emanating as a result of water hammer or surge sends a loud thud through the house. This can cause loosening of joints and bursting of pipelines if the pressure is high enough.

Lingireddy, et al. [1] carried out the analysis of pressure surge in pipeline system resulting from air releases. In their research, they noted that since air valve are integral parts of a long pipeline passing through elevations. Pressure surge propagation is quite inevitable. Pressure surge will occur due to the release of air accumulated in a pipeline in the course of transmission. But the effect of this would be reduced to a minimum if proper sized surge suppression device like orifice plate is installed in the system. The work specifically considered the pres-sure reduction in a pipeline system when a 12.5 mm orifice was installed in pipeline compared to a 75 mm ori-fice also installed. The pressure surge when a 12.5 mm orifice plate was installed reduced to about 30 meter of water while the pressure when a 75 mm orifice was in-stalled was still as high as 168 meter of water from a surge pressure of 210 meters of water.

2 APPURTENANCES

The rising main is to be designed for surge analysis and location of Zero velocity valve, butterfly valves and air valves is to be mentioned as per CPHEEO manual. These are some essential protection devices used in the analysis, described below:

2.1 Air Valve:

Air valves are fitted to release the air automatically when a pipeline is being filled and also to permit air to enter the pipeline when it is being emptied. Additionally air valves have also to release any entrained air, which might be accumulated at high points in the pipeline during normal operations Without air valves, vacuum may occur at peaks and the pipe could collapse or it may not be possible to drain the pipeline completely.

2.2 Zero Velocity Valve:

Zero velocity valves are special type of spring loaded non-return valves intended for upsurge control. The valve closure occurs gradually with the reduction in velocity following power failure, resulting in full closure at zero velocity. The springs are designed in such a manner that the valve remains full open when 25% of designed velocity is achieved. In case of closure of pump, disc starts closing in relation to decrease of velocity and fully closes when velocity drops near to zero. Thus upstream water column is prevented from creating water hammer wave. The Zero velocity valves are usually provided with bypass which allows a small amount of reverse flow. Bye pass arrangement keeps pressure balance on both sides of disc. It also prevents creation of vacuum in downstream side.

2.3 Butterfly Valve:

Valve shaped like a butterfly. Butterfly valve used to regulate and stop the flow spatially in case of large conduits. Optimal for automated operation with a low operating torque and 90 degree operating angle. These valve have little resistance to flow (allow smooth flow).They are sometime cheaper than sluice valve for large sizes and occupy large space. Butterfly valve with no sliding part have the advantage of ease of operation, compact size, reduced chamber valve house and improve closing and retarding characteristics.

2.4 Check Valve:

Check valves, also called non-return valves or reflux valves, automatically prevent reversal of flow in a pipeline. They are particularly useful in pumping mains when positioned near pumping stations to prevent backflow, when pumps shut down. The closure of the valve should be such that it will not set up excessive shock conditions within the system.

2.5 Gate Valve:

Gate valves are the normal type of valves used for isolating or scouring. They seal well under high pressure and when fully open, offer little resistance to fluid flow. Long stroke requires time to open and close, not suitable for quick operation.

3 STUDY AREA

The present work is surge analysis of water transmission main in the city of Ambala. The pipe line had been designed for providing water from Narwana Branch to canal water Pump House Ismailpur and up to canal based water works, Ambala city.
The raw water outlet connection of canal based water supply scheme Ambala city was from Pinjokhra minor which generally runs for 15 days during running period of canal and remains closed for next 15 days of the month due to which a great problem was faced by Public Health Engineering Department to provide sufficient water supply to the inhabitants of Ambala city during the closer period of canal. The NSL at Ismailpur is 256.79m whereas at canal based water works is 268.64m. The inlet pipe to receiving chamber is approximately 3.5m.

Figure 1. Location of Ambala city

3.1 Existing Coveyance System:

The pipe parameters are as follows

i. Total length of the total pipeline = 14 km
ii. Diameter of pipe = 1000 mm
iii. Material of the pipes = Ductile Iron (DI) Pipes
iv. Specification of pipes = K9 pressure pipe

3.2 Longitudinal Profile:

Figure given below has been drawn from the data given in the level book, source: PWD PHE Division, Haryana, Ambala City.

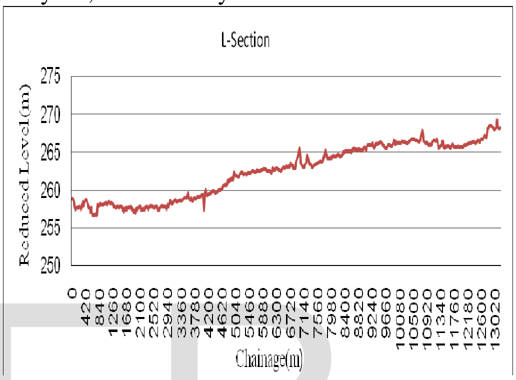

Figure 2. Topographical detail of the pumping main area

4 METHODLOGY

The calculation has been done manually and with the help of Hazen Williams Formula, taken from CPHEEO Manual. All the data is given by PWD PHE Division, Haryana, Ambala City.

4.1 Data Given:

Discharge of Single Pump (40m Head)

Q_1 = 20,000LPM
= 0.333 cumec

Earlier analysis has been done for 3 no. of pump and in this analysis we have increase one no. of pump, so
No. of Pumps running at a time = 4
Total discharge (Q) = 4 x 0.333
= 1.332 cumec

Internal Diameter of DI K9 Pipe =1.009m
Area of cross section of DI K9 Pipe (A)
= 0.799m^2
Normal Velocity of flow (V_o) = Q/A
= **1.66708 m/s**

4.2 Calculation:

As per Central Public Health and Environmental

Engineering Organization (CPHEEO) Velocity of pressure wave (C) = $1425/\sqrt{1+(kd/EC_t)}$

Where, k = bulk modulus of water= 2.07×10^8 kg/m^2

D = diameter of pipe
= 1.009m (given)

C_t =Wall thickness of pipe
= 0.0135m (As per IS 8329:2000)

E = Modulus of Elasticity of Pipe Material
= 1.7×10^{10} kg/m^2

Velocity of pressure wave (C) = **1031.073m/s**

4.3 Internal Pressures:

Maximum Pressure rise in the closed conduit above the normal pressure (in m) as per CPHEEO Manual:

$H_{max} = C\, V_o/g$
= (1031.073 x 0.8335)/9.81
= **87.68 m**

Static Head = **11.85 m**
Residual Head = **3.5 m**
C_f value = 140

C values ranges from 90 to 140 depending on the diameter and velocity.
By Hazen Williams formula for frictional head

Frictional Head (H_f)
= $[Q \times 10^9/(7.436 \times C_f \times d^{2.63})]^{1.852} \times L$
= 7.16 m

Total Head H = 87.68 + 11.85 + 3.5 + 7.10
= **110.13**

5 RESULTS

Following results has been drawn in tabular form.

Table-1: Detailed Calculation Sheet including Design Pressure Conditions

Surge Analysis for DI K9 Pipe		
Discharge of Single pump	0.333333333	Cumec
No. of pumps	**4**	Nos
Total discharge (Q)	1.33332	Cumec
Length of Pipe (L)	14	Km
Internal dia of DI K9 pipe (as per IS 8329:2000)	1.009	m
Outside diameter of DI K9 pipe (as per IS 8329:2000)	1.048	m
Wall thickness of pipe as per IS 8329:2000 (C_t)	0.0135	m
Area of cross section (A)	0.799193585	Sqm
Normal velocity in pipe line before sudden closure (V_0) as per CPHEEO manual	**1.25**	**m/s**
Velocity of pressure wave, C = 1425 / $\sqrt{1+(kd/EC_t)}$		
Bulk Modulus of Water (k)	2.07E+08	kg/m^2
Internal Diameter of pipe (d)	1.009	m
Wall Thickness (C_t)	0.0135	m
Modulus of Elasticity of Pipe Material (E)	1.70E+10	kg/m^2
Velocity of pressure wave (C)	**1031.072643**	**m/s**
Internal Pressure		
Maximum rise in pressure in the closed conduit above normal pressure (as per CPHEEO manual)= $V_0 x C / g$	**131.5128735**	m
Static Head	**12.85**	m
Residual Head	**3.5**	m

Table-2: fourth trial when total discharge is 1.332 cumec

Frictional Head, H_f = $[Qx10^9/(7.436xC_fxd^{2.63})]^{1.852}xL$ when 4 pump is working		
Q x 10^9	1.152E+11	
C_f	140	
$d^{2.63}$	79475591.2	
L	14	km
Frictional Head	**25.88240831**	m
Friction due to fixtures (10% of Frictional Head)	**2.588240831**	
Total Head	176.3335226	m
Design Pressure Conditions as per CPHEEO Guidelines		

1.5 times maximum sustained operating head	67.23097371	m
1.5 times maximum pipeline static head	24.525	m
Sum of maximum sustained operating head and maximum surge head	176.3335226	m
Sum of maximum pipeline static head and maximum surge head	147.8628735	m
Design Pressure (Maximum of above)	**176.3335226**	**m**
rounded up value	177	m
in kg/cm^2	17.7	kg/cm^2
in Mpa	**1.73637**	**Mpa**
Design Equation as per ISO 10803 for thickness calculation of DI pipes		
t_1=[p(D-t_1)SF]/(2R_m)		
Internal Pressure (p in Mpa)	1.48131	Mpa
Safety Factor (SF)	2.5	
Minimum tensile strength (R_m)	420	MPa
Outside Diameter of pipe (D)	1048	mm
Minimum thickness required (t_1)	**4.599996604**	**mm**
Check with Ct	Unsafe	>13.5mm

After three trials fourth trial has been made for 4 no. of pump and minimum thickness has been unsafe for 1.332 cumec discharge, while it is safe for 0.999 cumec discharge.

6 RECOMMENDATIONS

i) One number surge relief valve is to be placed on the headed pipe just after the pump house. More than one valve may be provided on the same line to improve the reliability of arrangement.

ii) The air relief valves are recommended to be provided at every one KM of the pipe alignment and in addition to this also at all the location where the pipe gradient changes.

As per the guidelines of CPHEEO Manual, The following ratios of air valves to conduit diameter provide common but rough estimate of needed sizes:

For release of air only	1:12
For admission as well as release of air	1:8

Recommended sizes as per this criteria fall between 80mm and 125mm. an optimum 100mm size may be adopted.

iii) One number zero velocity valve is to be placed on the headed pipe just after the pump house. More than one valve may be provided on the same line to improve the reliability of arrangement.

iv) Butterfly valves are required for isolating or regulating flow in a pipeline. Since in this case, it is a single rising main with no branches, the decision to provide this (these) valve(s) is left to the Engineer-in-Charge. However, if these valves are to be provided, the following factors may be duly considered.

a. The valve(s) should divide the total pipeline into appropriate segments.

b. Ease of approach for operation.

7 CONCLUSIONS

In earlier analysis a DI 1000 K9 pipe has been designed as per the design and hydraulic data available. The 1000mm pipe line has been found safe at 0.999 cumec discharges and after sensitivity analysis it was not safe for discharge 1.332 cumec while using 4 no. of pump at a time .The calculated pressures at the discharge of the pumps while running one, two, three and four pumps including the surge pressure is about 15 kg/cm^2, 15.6 kg/cm^2, 16.5 kg/cm^2 and 17.7 kg/cm^2 respectively, less than the 36 kg/cm^2 pressure (Maximum allowable pressure including surge) as recommended by IS 8329:2000.

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