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Pipe Stress Analysis and Equipment Nozzle Loads Evaluations

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Abstract

This paper discusses several aspects of piping stress analysis and is presented a study case regarding equipment nozzle loads evaluations. Piping stress analysis is made using Caesar II software package version 5.20, developed and released by COADE Inc. Engineering Software, Houston, Texas, USA.

Key words: *stress, analysis, loads, pipe*

Scope of Analysis and System Description

The scope of this analysis is to evaluate the stresses, displacements, forces and moments acting (internally & externally) on the piping under various conditions/cases (e.g. sustained, expansion, operating, occasional and hydro test) due to the combined effect of internal pressure, maximum differential temperature, bending and external loads as applicable. These calculations and analysis have been carried out using CAESAR-II Version 5.20.

The piping flexibility analysis is for Light Naphtha charge pumps (213-G-001A/B) suction lines from Equipment Light Naphtha surge drum (213-D-001) (fig.1).

For piping systems connecting two similar equipment units where one unit is a spare, the stress analysis shall be performed considering the spare equipment unit under stand-by (or out-of-service) conditions while the other equipment unit are considered under service conditions [1]. For the typical piping systems connected to rotating pump pairs (i.e. two identical centrifugal pumps, Pump A and Pump B, each of them being a spare interchangeably), the Design and Operating conditions need to be analysed for three (3) alternatives, as follows:

1) Temperature T1 case – Pump A in service, Pump B out-of-service (stand-by);
2) Temperature T2 case – Pump A out-of-service (stand-by), Pump B in service;
3) Temperature T3 cases – Both pumps (A and B) in service.

Surge drum (213-D-001) nozzles was modelled as flexible piping elements defined by the actual design dimensions (outside diameter, wall thickness and outside height/length) and generally connected to the vessel outside wall surface by full anchor joints [1]. Piping is connected to the equipment nozzle flange face by full anchor restraint. The reference Cartesian coordinates system used for piping stress analysis purpose is the right-hand orthogonal coordinate system, with the Y axis being positive up-ward and the Z axis being negative in the conventional North direction.

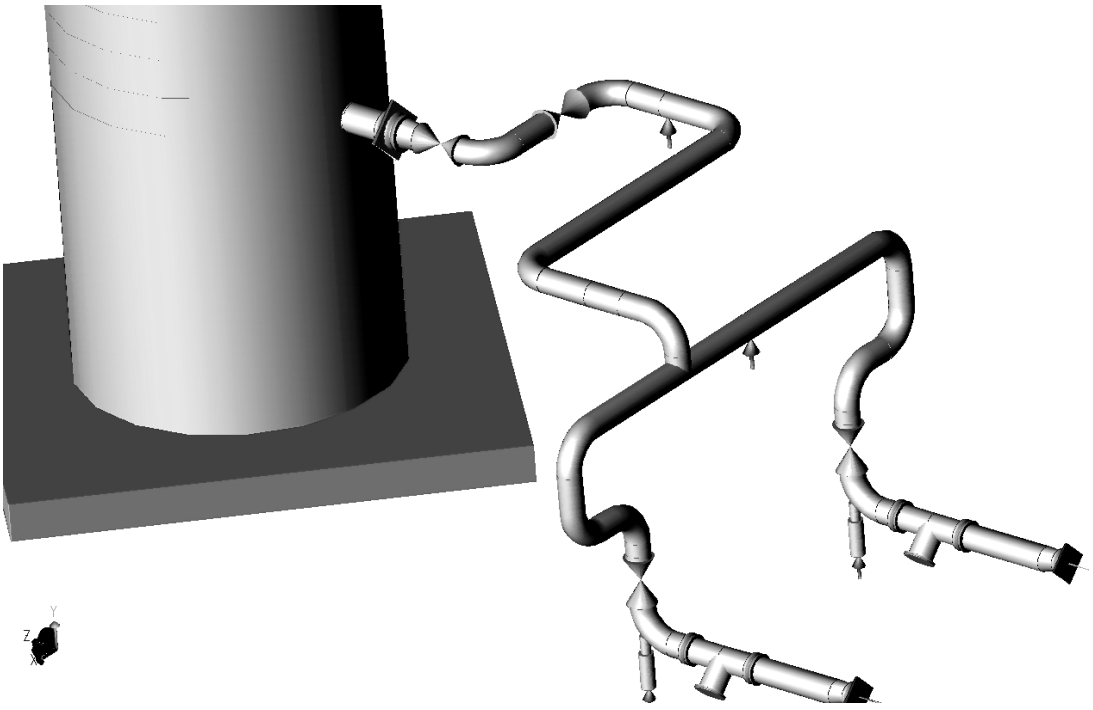

Fig. 1. Light Naphtha charge pumps (213-G-001A/B) suction lines from Equipment Light Naphtha surge drum (213-D-001).

Loading Cases and Calculation Parameters

The piping systems connected to rotating pump pairs (213-G-001A/B, Pump A and Pump B,) was analysed in agreement with the next loading cases.

Case No.	Combination	Load	Importance
Loading Cases for Equipment Nozzle Loading evaluation			
L1	L1 = WW+HP	HYD	Hydro-Test Loading Case
L2	L2 = W+P1	SUS	Sustained Loading Case
L3	L3 = W+T1+P1	OPE	Maximum Operating Temperature Loading Case, Pump A active
L4	L4 = W+T2+P1	OPE	Maximum Operating Temperature Loading Case, Pump B active
L5	L5 = W+T3+P1	OPE	Maximum Operating Temperature Loading Case, Pumps A&B active
L6	L6 = W+T4+P1	OPE	Design Temperature Loading Case, Pumps A&B active
L7	L7 = W+T5+P1	OPE	Steam out Operating Temperature Loading Case, Pumps A&B active
L8	L8 = WNC+T6	OPE	Stand-By Case corresponding to the Maximum Out-of-Service Temperature
L9	L9 = WNC+T7	OPE	Stand-By Case corresponding to the Minimum Out-of-Service Temperature

L10	L11 = W+T4+P1+WIN1	OPE	Wind load along ± X directions superposed Design Temperature ,Pumps A&B active
L11	L11 = W+T4+P1-WIN1	OPE	
L12	L12 = W+T4+P1+WIN2	OPE	Wind load along ± Z directions superposed Design Conditions, Pumps A&B active
L13	L13 = W+T4+P1-WIN2	OPE	
L14	L14 = W+T4+P1+U	OPE	Seismic load along ± X directions superposed over Design Conditions, Pumps A&B active
L15	L15 = W+T4+P1-U1	OPE	
L16	L16 = W+T4+P1+U2	OPE	Seismic load along ± Z directions superposed over Design Conditions, Pumps A&B active
L17	L17 = W+T4+P1-U2	OPE	
L18	L18 = W+T5+P1+WIN1	OPE	Wind load along ± X directions superposed over Steam out Operating Conditions , Pumps A&B active
L19	L19 = W+T5+P1-WIN1	OPE	
L20	L20 = W+T5+P1+WIN2	OPE	Wind load along ± Z directions superposed over Steam out Conditions , Pumps A&B active
L21	L21 = W+T5+P1-WIN2	OPE	
L22	L22 = W+T5+P1+U1	OPE	Seismic load along ± X directions superposed over Steam out Conditions , Pumps A&B active
L23	L23 = W+T5+P1-U1	OPE	
L24	L24 = W+T5+P1+U2	OPE	Seismic load along ± Z directions superposed over Steam out Conditions , Pumps A&B active
L25	L25 = W+T5+P1-U2	OPE	

Where: HP – Hydro-Test Gauge Pressure; P1 – Design Gauge Pressure, 715KPa; T1 – Maximum Operating Temperature (43° C), MAXOT, Pump A active; T2 – Maximum Operating Temperature (MAXOT), Pump B active (43° C); T3 – Maximum Operating Temperature (MAXOT), Both Pumps A&B active (43° C); T4 – Design Temperature(170 °C); T5 – Steam out Temperature (150 °C); T6 – Winter Temperature (4° C); T7 – Solar Temperature (85° C); WIN1 – Wind load along horizontal +X direction; WIN2 – Wind load along horizontal +Z direction; U1 – Seismic Acceleration along horizontal +X direction; U2 – Seismic Acceleration along horizontal +Z direction; SUS – Sustained; OPE – Operating.

Loads on Equipment Nozzles

The nozzle loadings of pressure vessels shall be assessed for the basic loading cases only and shall be referred to the full anchor or flexible joint between nozzle and vessel outside wall surface[1]. When the actual external loads applied by piping on the connected vessel nozzle exceed the corresponding allowable limits, a local stress analysis shall be performed, in accordance with WRC Bulletins No. 107 and/or 297 [2,3]. For the nozzle loadings of pumps, the following relevant standards should be taken into account for typical machinery equipment: API Centrifugal Pumps – API 610 Std., par. 5.5, Table 4, and Annex F, par. F.1.1, F.1.2 and F.1.3 (horizontal pumps) or par.F.2 (vertical in-line pumps).

The following tables are the brief results from the CAESAR-II output:

Table 1. Maximum loads on pump nozzle from all load cases (6”-150#)

Loads in Design case	Node	FORCES (N)			MOMENTS (N-m)		
		Fx	*Fy*	*Fz*	*Mx*	*My*	*Mz*
	220	467	-1940	-1598	636	739	1275
	420	96	-1220	-594	-255	-19	-2303
Allowable as per API 610 Annex F, Par. F.1.2		*4980*	*4100*	*6220*	*2360*	*3520*	*4600*

Table 2. Maximum loads on 213-D-001 nozzle from all load cases (12"-150#)

Max. Loads at equipment nozzle	Node	FORCES (N)			MOMENTS (N-m)		
		Fx	*Fy*	*Fz*	*Mx*	*My*	*Mz*
	1040	-1462	-4495	3324	5001	3803	-2268
	Allowable	-	-	-	-	-	-

Conclusions

Piping systems shall have sufficient inherent flexibility to allow for thermal expansion and/or contraction due to operating the piping system and connected equipment at the required temperature conditions without leading to [1]:

- Overstressed piping (above ASME B31 Piping Codes allowable limits);
- Leakage of joints;
- Excessive loading on equipment (above vendor/manufacturer's allowable limits);
- Excessive loading on piping supports and sustaining steel/structure.

Regarding the Light Naphtha charge pumps (213-G-001A/B) suction lines from Equipment Light Naphtha surge drum (213-D-001) we can say:

- The stresses (in sustained, expansion, occasional and hydro test) are all within respective allowable limits as per ASME B31.3.
- The lateral movements of piping are safe.
- Pump nozzle loads are with in the allowable.

References

1. * * * – *Specification for Piping Stress Analyses*, SPG (Steiner-Prematechnik-Gastec GmbH), Doc. No. MHS-E000-PI-SP-006-02.
2. * * * – API 610 Standard – *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*, 10th Edition, 2004
3. * * * – BS PD 5500 – *Specification for Unfired Fusion Welded Pressure Vessels*, 2000 Edition with 2001 & 2002 Amendments and Corrigenda.

Analiza sistemelor de conducte şi evaluarea încărcărilor pe racordurile echipamentelor

Rezumat

În lucrare se prezintă analiza stării de tensiuni în cazul unui sistem de conducte cu evaluarea încărcărilor pe racordurile echipamentelor aferente. Analiza este efectuata utilizând Caesar II, versiunea 5.20.