Pulsation Study Approach 1 Calculations

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Design approach 1 in accordance with API 618

Project: Integrated Methanol and Ammonia Plant
Location: Iran
Equipment: Air Compressor
Purchase order: LIDCO-PO-NEC-278-6019
Airpack reference: 17735-COM

Requirements

Pulsation levels have to meet the limits as per paragraph 7.9.4.2.5.2.2.1as well as the criteria in paragraph 7.9.2 through 7.9.3.

para 7.9.4.2.5.2.5.1

The peak-to-peak cyclic stress range is far below 180 N/mm^2, therefore this paragraph is considered as not applicable.

para 7.9.3.2

$$V_s = 8{,}1 \cdot PD \cdot \left(\frac{k \cdot T_s}{M}\right)^{1/4}$$

$$V_d = 1{,}6 \cdot \left(\frac{V_s}{(R)^{1/k}}\right)$$

$$V_s \geq V_d$$

$$V_s \geq 0{,}03\ m^3$$

$$V_d \geq 0{,}03\ m^3$$

$$\frac{l}{ID} \leq 4.0$$

V_s = minimum required suction surge volume [m^3]
V_d = minimum required discharge surge volume [m^3]
K = isentropic compression exponent at average operating gas pressure and temperature
T_s = absolute suction temperature [K]
M = molecular weight
PD = total net displaced volume per revolution of all compressor cylinders to be manifolded in the surge volume
R = stage pressure ratio at cylinder flanges (= quotient of absolute discharge and suction pressures)
l = surge volume length
ID = surge volume inside diameter

para 7.9.4.2.5.2

$$P_{cf} = 3R\ \%$$

$$P_{cf} \leq 7\ \%$$

P_{cf} = maximum allowable unfiltered peak-to-peak pulsation level, as a percentage of average absolute line pressure at the compressor cylinder flange [%]

para 7.9.4.2.5.3.1

$$\Delta p = \frac{1{,}67 \cdot (R-1)}{R}$$

$$\Delta p \leq 0{,}25\ \%$$

Δp = maximum pressure drop based on steady flow through a pulsation suppression device, as a percentage of the average absolute line pressure at the inlet of the device [%]

R = stage pressure ratio at cylinder flanges (= quotient of absolute discharge and suction pressures)

para 7.9.2

The gas composition, specified in the purchaser datasheet is considered as the basis of this calculation.

para 7.9.4.2.5.2.2.1

$$P_l = \frac{4{,}1}{(P_L)^{1/3}}$$

P_l = maximum allowable peak-to-peak pulsation level at any discrete frequency, as a percentage of average absolute pressure [%]

P_L = average absolute line pressure [bar(a)]

Input

		stage 1	stage 2	
K	isentropic compression exponent	1,4	1,4	
T_s	abs. suction temperature	319,15	333,15	K
M	molecular weight	28,959	28,959	
PD	total net displaced volume per revolution	2,376 E-3 *[note 1]*	9,621 E-4 *[note 2]*	m^3
R	stage pressure ratio	2,314	1,342	
P_L	avg abs. line pressure	17,032	25,742	Bar(a)

Compressor stage data

	1st stage	2nd stage	Unit
Suction pressure	11,5	24,1	Bar(a)
Discharge pressure	24,3	31	Bar(a)
Pressure ratio	2,314	1,342	
Suction temperature	319,15	333,15	K

[note 1]
1st stage

stroke 130 mm
cyl bore 55 mm
rod dia 30 mm
Single acting

$$PD = \frac{1}{4}\pi(0{,}055)^2 \cdot 0{,}13 = 2{,}376 \cdot 10^{-3} m^3$$

[note 2]
2nd stage

stroke 130 mm
cyl bore 35 mm
rod dia 30 mm
Single acting

$$PD = \frac{1}{4}\pi(0{,}035)^2 \cdot 0{,}13 = 9{,}621 \cdot 10^{-4} m^3$$

Output

para 7.9.3.2

1st stage

$$V_s = 8{,}1 \cdot 2{,}376 \cdot 10^{-3} \cdot \left(\frac{1{,}4 \cdot 319{,}15}{28{,}959}\right)^{1/4} = 0{,}0381\ m^3 = 38{,}1\ dm^3$$

$$V_d = 1{,}6 \cdot \left(\frac{0{,}0381}{(2{,}314)^{1/1{,}4}}\right) = 0{,}0322\ m^3 = 33{,}5\ dm^3$$

$V_s \geq V_d$ True

$V_s \geq 0{,}03\ m^3$ True, so V_s = 0,0381 m³

$V_d \geq 0{,}03\ m^3$ True, so V_d = 0,0322 m³

2nd stage

$$V_s = 8{,}1 \cdot 9{,}621 \cdot 10^{-4} \cdot \left(\frac{1{,}4 \cdot 333{,}15}{28{,}959}\right)^{1/4} = 0{,}0156\ m^3 = 15{,}6\ dm^3$$

$$V_d = 1{,}6 \cdot \left(\frac{0{,}0156}{(1{,}342)^{1/1{,}4}}\right) = 0{,}0202\ m^3 = 20{,}2\ dm^3$$

Some of the following 3 equations are not true, hence calculated sizes are not acceptable. Sizes are too small for API 618, minimum sizes of 0,03 m³ must be used.

$V_s \geq V_d$ Not True, so V_s = 0,03 m³

$V_s \geq 0{,}03\ m^3$Not True, so V_s = 0,03 m³

$V_d \geq 0{,}03\ m^3$Not True, so V_d = 0,03 m³

summary

Some sizes are too small for API 618, minimum sizes of 0,03 m^3 (30 dm^3) must be used. Therefor the minimum volumes are as per below.

	1st stage	2nd stage	
V_s	38,1	30,0	dm^3
V_d	32,2	30,0	dm^3

To have the final volume of each pulsation dampener, the $V_{suction}$ and $V_{discharge}$ of existing piping is subtracted for each stage. Line volume + Pulsation dampener volume shall met the final volume.

Tag no.	V_{total}	$V_{piping\ line\ (note1)}$	$V_{pulsation\ dampener}$	
KV-020-001	38,1	2,289	35,811	dm^3
KV-020-002	32,2	0,257	31,943	dm^3
KV-020-003	30,0	0,114	29,886	dm^3
KV-020-004	30,0	0,297	29,703	dm^3

Note 1: V_{piping} is extracted from the package 3d model.

para 7.9.4.2.5.2.1

1st stage

$$P_{cf} = 3 \cdot 2{,}314 = 6.942\ \%$$

According to para 7.9.4.2.5.2.1 the cylinder flange pressure pulsation P_{cf} shall be limited ot the lesser of 7% or the value from the above equation.

6.942 % is less than 7%, therefore the pulsation have to be lower then 6.942%, this is acceptable as per compressor information

2nd stage

$$P_{cf} = 3 \cdot 1{,}342 = 4{,}026\ \%$$

According to para 7.9.4.2.5.2.1 the cylinder flange pressure pulsation P_{cf} shall be limited ot the lesser of 7% or the value from the above equation.

4.026 % is less than 7%, therefore the pulsation have to be lower then 4.026%, this is acceptable as per compressor information

para 7.9.4.2.5.3.1

1st stage

$$\Delta p = 1{,}67\left(\frac{2{,}453 - 1}{2{,}453}\right) = 0{,}989\ \%$$

0,989 % of 23,3 bar discharge pressure is 0,23 bar. Which is higher than the calculated differential pressure across the pulsation dampeners. (0.12bar)

2nd stage

$$\Delta p = 1{,}67\left(\frac{1{,}357 - 1}{1{,}357}\right) = 0{,}439\ \%$$

0,439 % of 30 bar discharge pressure is 0,13 bar, Which is higher than the calculated differential pressure across the pulsation dampeners. (0.08bar)

para 7.9.4.2.5.2.2.1

Maximum allowable peak-to-peak pulsation level at any discrete frequency, expressed as a percentage of average mean absolute pressure.

1st stage suction

$$P_l = \frac{4{,}1}{(9{,}500)^{1/3}} = 1{,}936\ \%$$

Maximum allowable peak to peak is 1,936 % is 0.45bar. The calculated peak to peak is significantly lower due to pulsation dampers

1st stage discharge

$$P_l = \frac{4{,}1}{(17{,}368)^{1/3}} = 1{,}583\ \%$$

Maximum allowable peak to peak is 1,583 % is 0.37bar. The calculated peak to peak is significantly lower due to pulsation dampers

2nd stage suction

$$P_l = \frac{4{,}1}{(22{,}100)^{1/3}} = 1{,}461\ \%$$

Maximum allowable peak to peak is 1,461 % is 0.44bar. The calculated peak to peak is significantly lower due to pulsation dampers

2nd stage discharge

$$P_l = \frac{4{,}1}{(26{,}250)^{1/3}} = 1{,}380\ \%$$

Maximum allowable peak to peak is 1,380 % is 0.41bar. The calculated peak to peak is significantly lower due to pulsation dampers