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	0,9991	0,9982	
T_s	abs. suction temperature	313,15	313,15	K
M	molecular weight	28,959	28,959	
PD	total net displaced volume per revolution	2,259 E-3 *[note 1]*	8,451 E-4 *[note 2]*	m^3
R	stage pressure ratio	2,453	1,357	
P_L	avg abs. line pressure	17,368	26,250	$kg/cm^2(a)$

Compressor stage data

	1st stage	2nd stage	Unit
Suction pressure	9,5	22,1	Bar
Discharge pressure	23,3	30	Bar
Pressure ratio	2,453	1,357	
Suction temperature	313,15	313,15	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

$$V_s = 8{,}1 \cdot 2{,}376 \cdot 10^{-3} \cdot \left(\frac{0{,}9991 \cdot 313{,}15}{28{,}959}\right)^{1/4} = 0{,}035\ m^3 = 35\ dm^3$$

$$V_d = 1{,}6 \cdot \left(\frac{0{,}035}{(2{,}453)^{1/0{,}9991}}\right) = 0{,}023\ m^3 = 23\ dm^3$$

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 m^3 must be used.

$V_s \geq V_d$ True

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

$V_d \geq 0{,}03\ m^3$ not true! V_d = 0,023 m^3, according to API 618 → V_d = 0,03m^3.

2nd stage

$$V_s = 8{,}1 \cdot 9{,}621 \cdot 10^{-4} \cdot \left(\frac{0{,}9982 \cdot 313{,}15}{28{,}959}\right)^{1/4} = 0{,}0141\ m^3 = 14{,}1\ dm^3$$

$$V_d = 1{,}6 \cdot \left(\frac{0{,}0141}{(1{,}357)^{1/0{,}9982}}\right) = 0{,}0166\ m^3 = 16{,}6\ dm^3$$

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 m^3 must be used.

$V_s \geq V_d$ Not True, so V_s = 0,03 m^3

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

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

summary

	1st stage	2nd stage	
V_s	35,0	14,1	dm^3
V_d	23,0	16,6	dm^3

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

	1st stage	2nd stage	
V_s	35,0	30,0	dm^3
V_d	30,0	30,0	dm^3

para 7.9.4.2.5.2

1st stage

$$P_{cf} = 3 \cdot 2{,}453 = 7{,}358\ \%$$

According to para 7.9.4.2.5.2 $P_{cf} \leq 7\ \%$

7,358 % is slightly more than 7%, but acceptable according to 7.9.4.2.5.2.1. with the following note;

Pulsation dampener will be sized as per API 618 0,03m^3 the remaining volume is from the inlet piping since there is no check valve.

2nd stage

$$P_{cf} = 3 \cdot 1{,}357 = 4{,}072\ \%$$

According to para 7.9.4.2.5.2 $P_{cf} \leq 7\ \%$

4,072 % is less than 7%, therefor accepted.

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 differential pressure is 0.12bar is within this range.

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 differential pressure is 0.12bar is within this range.

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 differential pressure is 0.08bar is within this range.

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 differential pressure is 0.08bar is within this range.