Pulsation Study Approach 1 Calculations

Code 2
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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)]

Isentropic exponent is ratio of Cp/Cv and always more than 1. For cuurent project it is approximately equal to 1.4

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

change unit to bar

Please recheck. these values are differ from note 1 and 2.

[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

k is approximately is equal to 1.4. therefore, volume is 38 dm3.

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

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

recalculate based on the above comment.

Some of the following 3 equations are not true, hence calculated sizes are not ac[...]o 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

k is approximately is equal to 1.4. therefore, volume is 38 dm3.

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

To be recalculated based on the comments on previous pages.

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.

It seems that you do not understand this clu. of API well. It means that pressure pulsation at compressor flange shall be less than calculated value or 7% whichever is less. As per calculated value acceptable pulsation at compressor flange are 7 and 4.07 accordingly. Please recheck and update the description.

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.

It seems that you do not undrestand this clu. of API well. It meens that pressure pulsation after pulsation damper shall be less than calulated value. Please be noted that pressure pulsation is differ from pressure drop.