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Criterions for the Evaluation of Effectiveness of the Pressure-Pulsation-Damper

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CRITERIONS FOR THE EVALUATION OF THE EFFECTIVENES OF THE PRESSURE-PULSATION-DAMPER

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INTRODUCTION

The effectiveness of damper depends essentially on the place of its location and on characteristics of a pipe-line beyond the damper or, more precisely on the characteristics /impedance/ of technological elements and fitting following the damper. A condition for the choice of a right damper to a given installation is consideration of influence of their parameters on the effectiveness of a damper. It is necessary also to consider the influence of a damper it self which has to be considered as the additional concentrated element build into the homogeneous section of a pipe-line on pressure pulsation before and beyont it. The first step on the way to complete solution of the problem of correct choice of a damper to the installation of reciprocating compressor is working out the way of evaluation of effectiveness of pressure-pulsation-dampers. It should consider all factors having influence on the effectiveness.

REVIEW OF CRITERIONS FOR EVALUATION OF DAMPING

For evaluation of the effect of reduction of pressure pulsation due to the installed damper, some criterions making it possible to express their action in numerical form are necessary. They should also be a ground for comparissons between different dampers applied in the installation and for proving which one would be the best in a given case.

Damping Rate

The most often employed measure of the effect of reducing of pressure pulsation in a pipe-line is the damping rate K_t being the ratio of pressure fluctuation rates in a pipe-line before and beyond the damper.

$$K_t = \frac{\delta_1}{\delta_2} \qquad \text{/1/}$$

For a damper with small hydraulic resistance, the damping rate is simply the ratio of absolute values of pressure pulsation /peak-to-peak/ before and beyond the damper /Fig. 1/.

$$K_t = \frac{\Delta p_{a1}}{\Delta p_{a2}} \qquad \text{/2/}$$

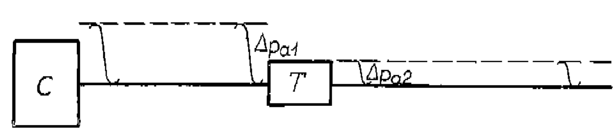

Fig. 1. Sketch illustrating the way of determining the damping rate: C - compressor, T - damper

The damping rate defined as above is appriopriate for applying in experimental investigation of different dampers in order to compare them i. e. the evaluation of influence of different construction elements upon the degree of reducing the pressure pulsation [1], [3] . It must be remembered that the damping rate characterises the effect of damping only in some idealised conditions. It is assumed that in a pipe-line sections preceding and following the damper stretch solely running pressure waves having constant amplitude /Fig. 1/. Such case is very rare in practice. To include a damper into the pipe-line system means to load it with a device reflecting the pressure pulsation waves. Due to resonance, in any section of a pipe-line following the damper pressure pulsation may reach high values although they have been lowered by damper action to permitted level in preceding section.

Rate of Damping of Maximum Values

Some investigators [2] , [4] as a criterion of reduction of pressure pulsation take the rate of damping the maximal values K_{tm} defined as a ratio of maximal absolute values of pressure pulsation in pipe-line sections preceding and following the damper /Fig. 2/.

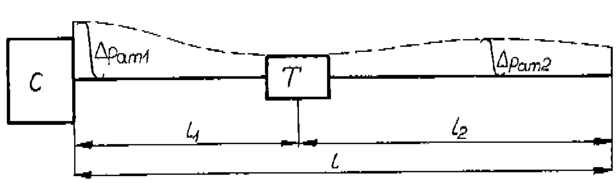

Fig. 2. Sketch illustrating the way of determining the rate of damping of maximum values

$$K_{tm} = \frac{\Delta p_{am1}}{\Delta p_{am2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots /3/$$

Such an approach has been dictated by the necessity of considering the damper action not in an isolated way, but together with the adjacent pipe-line system. It is known that the maximum absolute value of pressure pulsation occurs just by the compressor and beyond the damper this value depends on characteristic of an element placed there or more precisely, on its impedance. So it is possible to obtain the formula for evaluation of the rate of damping of maximum values in a simple pipe-line system, taking into consideration the reflected waves.

$$K_{tm} = \cos\frac{\omega l}{a} - \frac{Z_f^2}{Z_2 Z_1}\sin\frac{\omega l_1}{a}\sin\frac{\omega l_2}{a} + i\left(\frac{Z_f}{Z_2}\sin\frac{\omega l_1}{a}\cos\frac{\omega l_2}{a} + \frac{Z_f}{Z_1}\sin\frac{\omega l}{a}\right) \ldots\ldots\ldots /4/$$

where: l, l_1, l_2 - lenghts of sections in accordance with Fig. 2, Z_f - wave impedance of a pipe-line, Z_2 - impedance of a damper, Z_1 - impedance of load, a - velocity of sound , ω - circular frequency of pressure changes. It is possible to obtain from the general equations /4/ the series of formulas for different given pipe-line systems. For instance, for a system which consists of pipe-line, vessel having volume V and a second pipe-line closed in an acoustic sense, introducing:

$$Z_f = \frac{\varrho_o a}{A_r} \;, \quad Z_2 = \frac{\varrho_o a}{i\omega V} \;, \quad Z_3 = \infty$$

we get:

$$K_{tm} = \cos\frac{\omega l}{a} - \frac{\omega V}{A_r a}\sin\frac{\omega l_1}{a}\cos\frac{\omega l_2}{a} \quad \ldots /5/$$

where A_r is the cross-section of a pipe-line. The rate of damping of maximum values K_{tm} undoubtedly characterises the effectiveness of a damper, but doesn't allow to estimate the suitability of its installation into the considered pipe-line system. Thus, the evaluation of the effectiveness of the damper, expressed by K_{tm} has small usefullness in practical applications.

Rate of Introduced Damping

Because of shortcoming of the above introduced criterions some authors [5] conclude that it is much more appriopriate to evaluate the effect of reducing of pressure pulsation by the rate of introduced damping W_t. Let the absolute value of pressure pulsation just beyond the compressor be Δp_{a1} and in some another point beyond the proposed damper be Δp_{a2} /Fig. 3a/. After introducing damper T /Fig. 3b/ into the system, absolute values of pressure pulsation will be $\Delta p'_{a1}$ and $\Delta p'_{a2}$ respectively. The rate of introduced damping W_t is defined by following ratios:

In the stretch before the damper:

$$W_{t1} = \frac{\Delta p_{a1}}{\Delta p'_{a1}} \quad \text{........................./6/}$$

In the stretch beyond the damper:

$$W_{t2} = \frac{\Delta p_{a2}}{\Delta p'_{a2}} \quad \text{........................./7/}$$

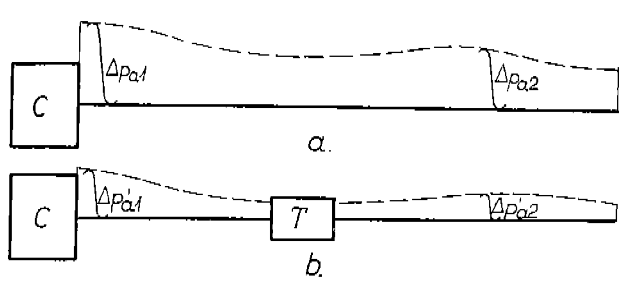

Fig. 3. Sketches for determining the rate of introduced damping

After introducing the rate defined by equations /6/ and /7/ it is possible to assess more precisely the influence of the damper on the pulsating stream of gas in a given pipe-line system. It can be easily shown, that K_{tm} and W_{t2} are related in a following way:

$$\frac{W_{t2}}{K_{tm}} = \left|\frac{Z_l}{Z_c+Z_l}\right| \cdot \left|\frac{Z_w+Z_c}{Z_w}\right| \quad \text{............/8/}$$

where: Z_l - load impedance, Z_c - compressor impedance /source of pulsation/, Z_w - entrance impedance of a system with a damping device. Generally, $0 < W_{t2}/K_{tm} < \infty$. Only, when $Z_c \to 0$ $W_{t2} = K_{tm}$, which means that the rate of introduced damping and the rate of damping of maximal values are the some when damper is installed close to compressor. However, the rate of introduced damping W_t has some substantial disadvantages which may lead in some cases to distortions in evaluating the effectiveness of damping. It is due mainly to the fact, that two arbitrary measure points on the pipe-line don't necessarily describe precisely pressure pulsation in the system as a whole.

To the general imperfections of all used criterions K_t, K_{tm} and W_t one can add one more: it is that none of them can be succesfully applied for evaluation of effectiveness of dampers in pipe-line systems.

The Total Rate of Damping of Pressure Pulsation

The most general criterion for evaluation of effectiveness of dampers is the total rate of damping of pressure pulsation K_g which determines the reduction of the general pressure pulsation level along the whole lenght of a pipe-equipment. It takes into consideration the effect of reduction of absolute values of pressure pulsation before as well as beyond the damper. Let in an installation without damper the maximum of an absolute value of pressure pulsation along the pipe-line be Δp_{am} /Fig. 4a/. After introducing the damper let such maximum be Δp_{amt} /Fig. 4b/. The total rate of damping of pressure pulsation will then be defined as the following ratio:

$$K_g = \frac{\Delta p_{am}}{\Delta p_{amt}} \quad \text{........................./9/}$$

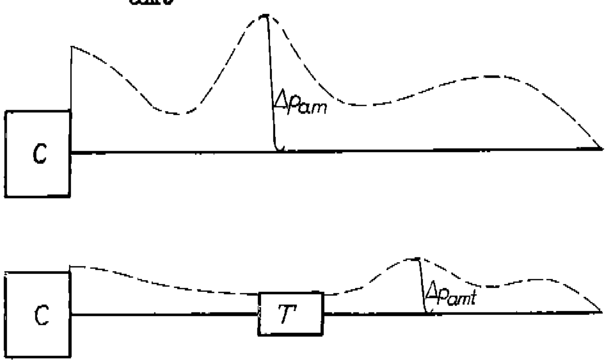

Fig. 4. Sketches for determining the total rate of damping of pressure pulsation

The ground for evaluation of effectiveness of dampers by the total rate of damping of pressure pulsation K_g is the knowledge of the change of absolute values of pressure pulsation along the pipe-line. First, one has to determine this without damper but with all elements of technological equipment and fitting. Then similiar evaluation has to be performed on the system with a build-in proposed damper. Mastering of determining these changes in any installation as early as in the phase of its design makes it possible to select in the most optimal way pressure dampers for both, compression stations and single reciprocating compressors.

EXAMPLE OF EVALUATION OF EFFECTIVENESS OF A DAMPING VESSEL

Fig. 5 shows diagrams of Δp_a = f/l/ obtained by experimental investigations of influence of place of installation of a damper on its effectiveness, at 1100 rev/min. The experiments were carried out on an electric model of laboratory installation of compressed air, at the end of which was placed a strongly throttling valve /$Z_1 \cong \infty$/. The volume of a damping vessel was V = 0,0956 m^3. The vessel was placed at following distances from a compressor: 0,3 , 1,875 and 5,325 m. Table 1 contains the total rate of damping of pressure pulsation K_g, the rate of damping K_t, the rate of damping of maximal values K_{tm} and maximal rates of pressure fluctuation in a pipe-line beyond the vessel δ_m.

Table 1

Distance of damping vessel from compressor /m/	K_g	K_t	K_{tm}	δ_m
0,3	2,90	3,54	5,0	0,027
1,875	1,57	0,95	3,52	0,07
5,325	0,436	0,70	3,02	0,293

From the curves of Δp_a = f/l/ it can be easily seen how important influence on the effectiveness has the place of installation of a damping vessel. Evaluation of effectiveness of a damping vessel using rate of damping loses its sense in case of the greatest distance of a vessel from compressor. Absolute values of pressure pulsation measured 0,15 m before and beyond the damping vessel are 0,24 and 0,345 bar respectively. Their absolute values don't give the proper idea about the level of pressure pulsation in a pipeline consequently, the value of K_t = 0,70 means, that between these two sections an amplification almost doubles. It can be easily checked that the measurement of absolute values of pressure pulsation at different distances before and beyond the damper gives completely different results. The rate of damping of maximum values K_{tm} = 3,02 means that damping vessel damps maximal pressure pulsation. But it says nothing about their absolute values and reasonableness of applying the damping vessel. On the other hand the total rate of damping of pressure pulsation

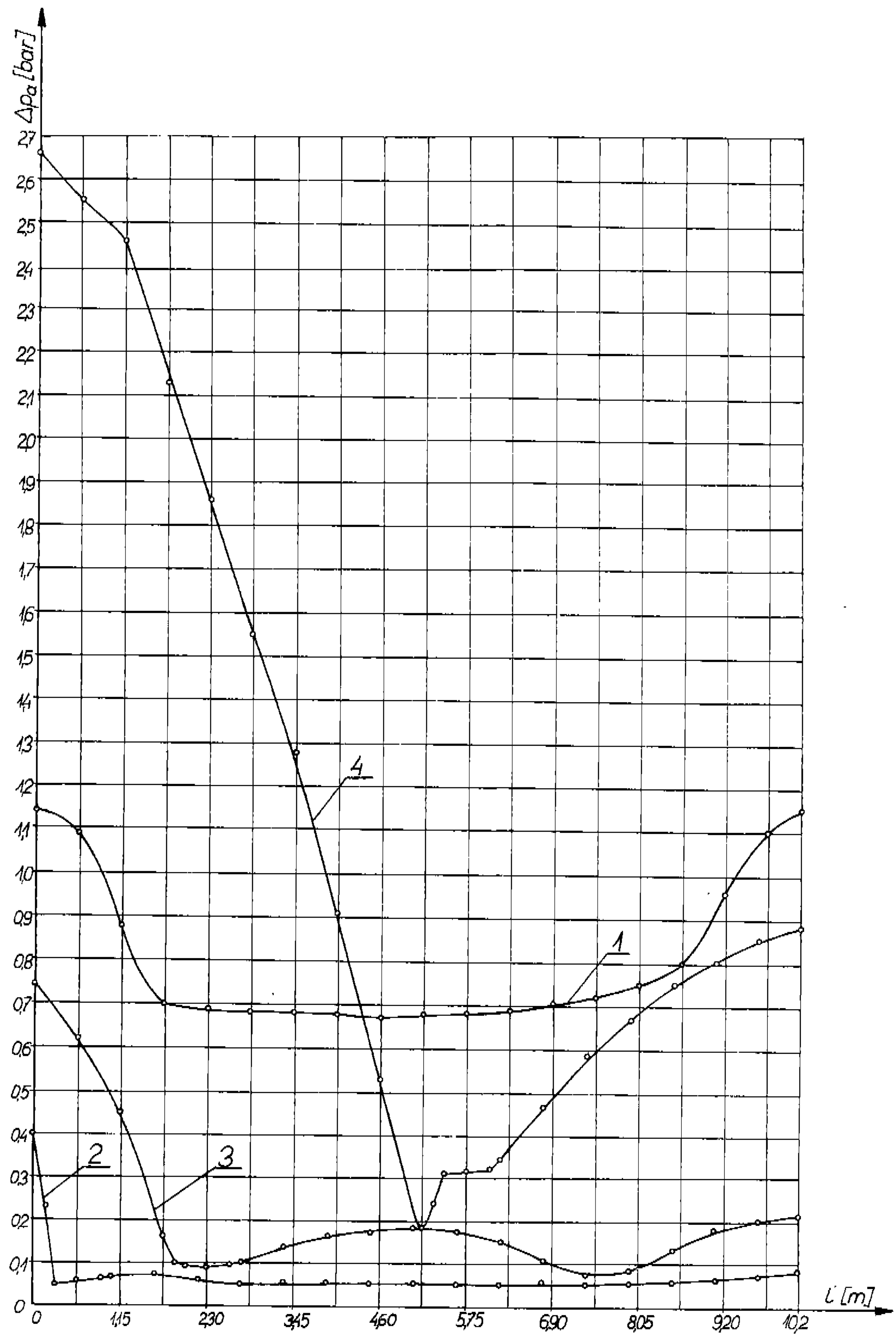

Fig. 5. Diagrams of $\Delta p_a = f/l/$ for different distances of a damping vessel from compressor at 1100 rev/min: 1 - outlet pipe-line without damping vessel, 2 - damping vessel at 0,3 m, 3 - damping vessel at 1,875 m, 4 - damping vessel at 5,325 m

K_g = 0,436 indicates that installing the damping vessel at 5,325 m from compressor has caused 2,29 fold increase of absolute values of pressure pulsation in comparison with a pipe-line without the vessel.

CONCLUSION

On the ground of above considerations and the example it can be stated that the total rate of damping of pressure pulsation K_g is the nost suitable criterion of evaluation of effectiveness of dampers. It gives the whole idea of general reduction of pressure pulsation in a system due to installation of a damper. The answer on the question whether the damper damps the pressure pulsation sufficiently we can get after veryfying if the maximal pressure fluctuation rate in a pipe-line beyond the damper is smaller than permitted.

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