inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 4.6

ABOUT THE EXPERIENCE OF LOW-ROTATED PISTON COMPRESSOR UNITS VIBRATION REDUCTION

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Keywords:
VIBRATION, PIPELINES, DAMPER

ABSTRACT
Main sources of low-rotated piston compressors vibration are analyzed. The results of experimental investigations of vibration levels for different kinds of compressors are discussed. The ways of vibration reduction including compressor mount and the elements are suggested. The experimental results of various supports types installation are provided. The efficiency of vibration reduction achieves 2 and more times. Different kinds of pulsations damper constructions are considered. Preliminary evaluation of dampers parameters was carried out using mathematical models and software developed by authors. The results of calculated and experimental investigations shows a good effect of vibration attenuation.

1 - INTRODUCTION

Piston compressors are used in different industry branches: chemical, machine-building etc. Serious problem of compressors practical usage is vibration of compressor mounts and pipelines leading to the fatigue breakdown of pipeline and apparatus junction, workers health damage, decreasing of compressor operating characteristics, their reliability and durability. The problem of piston compressor vibration sources investigation and the ways of vibration reduction determination is well-known and studied by many authors. Let us point out here main sources of low-rotated piston compressors units vibration:

- Inertia forces of reciprocating and rotating masses;
- Forces from the cylinder gas pressure;
- Crankshaft torsional oscillations etc.

For every frequency value the most strong vibration source (or the main source) can be determined. For low-rotated piston compressors the main vibration source is compressor units external disbalance (periodical forces and inertia moments transmitted to compressor foundation). One of the main vibration sources of piston machine pipelines are low-frequency gas pressure oscillations (pulsations).

2 - METHODICS OF COMPRESSORS PIPELINES VIBRATION EVALUATION. EXPERIMENTAL RESULTS DISCUSSION

Vibration spectra levels can be expressed as the sum of components:

$$\sum L_n = L\left(F_v\right) + L\left(F_h\right) + L\left(M_h\right) + L\left(M_t\right) \tag{1}$$

Here $L(F_v)$ and $L(F_h)$ are vertical and horizontal components of inertia forces; $L(M_h)$ and $L(M_t)$ are horizontal inertia force and tipping moments.
Analysis of compression plants pipelines destructions shows that destructions are mainly caused by pipes material fatigue. Therefore for the evaluation of vibration influence to the compressor pipeline elements stress parameter it is very convenient to use, [1]. Admitted stress value in the most dangerous pipeline section may be accepted as pipeline safety criterion. Exploitation experience shows that pipelines

destructions are mainly caused by longitudinal stress affection. For this case as parameter for vibration standard vibrodisplacement it is better to use. Amplitude of vibrodisplacement is determined by the following equation:

$$A = \frac{k}{n^2}\sigma_a\frac{l^2}{r}, \quad \text{mm} \tag{2}$$

where

- k – coefficient depending on the conditions of pipeline ends fastening;
- n – oscillations form;
- σ_a – admitted amplitude of longitudinal stress;
- l – span length;
- r – pipeline mean radius.

While determining pipelines vibration points it is necessary taking into account the places of flanges supports connection to the pipe. It is also necessary to bear in mind that pipelines vibrations are transmitted through the supports to foundation and to connected assemblies (cooler, separator etc.). For low-rotated piston compressors investigations should begin from the 2 Hz octave.
According to the authors methodics and to existing requirements the cycle of vibration level experimental investigations of different types of low-rotated piston compressors (two-stage, four-stage opposite, four-stage vertical etc.) and the elements was carried out. Measurements were provided in the distinctive point of compressor pipelines (suctioning and charging), on the pipelines supports, foundation, compressor body, cooler etc. in 3 dimensions. Vibrodisplacement, vibrovelocity and vibroacceleration were measured.
As an example of experimental results investigation let us describe four-stage low-rotated opposite piston compressor installed in shop N27 of "Kuibyshevazot" Joint Stock Company. The most high vibration levels for this compressor were measured in the charging pipeline installed in the output from 2-stage. Terz-octave spectrum of vibrodisplacement levels measured in this point of the compressor in vertical direction is shown on the fig. 1 (with full load and without load). We may see here vibration peak for the frequency 12,5 Hz (the main frequency of compressor operation), the value of which significantly exceeds normative data.

3 - THE WAYS OF LOW-ROTATED COMPRESSORS PIPELINES VIBRATION REDUCTION

The ways of different kinds of low-rotated piston compressors vibration reduction (including compressor mount, connecting elements and pipelines) in general may be the following:

1. Installation of the different types of pipelines fixtures, strengthening of pipelines bearings (supports). There are different types of supports: moving and fixed, slipping, roller, suspended etc. Despite on different well-known sophisticated measures of vibration reduction for the number of cases using of supports of pipelines remains the most simple and efficient decision.
   The experimental results of various supports types installation achieved by the authors are proving it again. For example, additional fixed supports were installed down to the charging pipeline of four-stroke piston compressor in shop N4 of "Kuibyshevazot". For the points with the most high vibration level the efficiency of vibration reduction achieves 2 and more times.
2. Reducing of a number of pipeline bends.
3. Installation of the damping packings.
4. Alteration of pipeline mass and rigidity, increasing of pipelines geometrical dimensions.
5. Installation of throttle washers in pipeline flange connections.
6. Installation of narrowing diaphragms for pulsations reduction.
7. Vibration damping methods using (e.g. dynamic dampers).

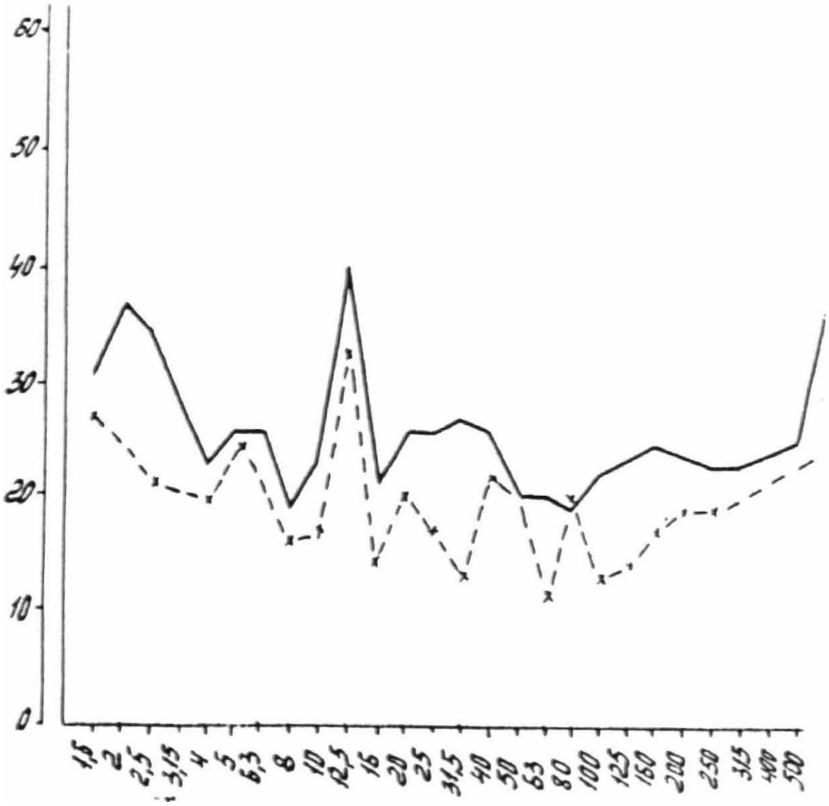

Figure 1: Terz-octave spectrum of vibrodisplacement levels on the output of 2-stage (vertical direction, full load and without load).

8. Installation of low-frequency pulsations dampers. It is well-known, that the main reason of another problem is low-frequency gas pressure pulsations reduction in compressor pipeline main. Traditional way of low-frequency gas pressure pulsations amplitude reduction is using of empty chamber mufflers, or dampers. However for low-rotated piston compressors very large overall dampers dimensions are required. These dimensions can be sufficiently reduced if at least one of the damper walls is pliable. In this case oscillatory gas movement will extend the walls and all variable flow consumption through the compressor pipeline will be locked within the damper. There are constructions of dampers with pliable walls, e.g. intake manifold oscillations damper of internal combustion engine, [2]. However this construction cannot provide maximal efficiency of oscillations attenuation. Improved constructions of dampers containing pliable capacity were developed by the authors, [3-5]. For example, pulsations damper for suction system contains variable volume capacity supplied with rigid walls, for one of which at least one input manifold is mounted to connect capacity cavity with piston machine cylinder. Such construction allow to achieve effective pressure impulses compensation in the intake system due to exclusion of casing elastic characteristics. Insignificant casing mass (comparatively with rubber casing) leads to insignificant damper's inertia providing improvement of volume sensitivity to track pressure impulses in the system and increasing pulsations damping efficiency under dynamic loads.

9. Using of resonant pulsations dampers. Such dampers are efficient only for very restricted frequency range, but for some cases such constructions are reasonable to use. Resonant damper have significantly lesser volume comparing with usual empty dampers. For four-stage opposite compressor, as it shown in fig. 1, we have such resonant frequency. For this case different resonator constructions were designed, [6].

10. Using of active and active-adaptive pulsations compensators. Active noise and vibration control method has a lot of practical usage opportunities in the different branches of industry. One of them is low-frequency pulsations attenuation. For such application active compensator construction was developed. Compensator has a form of chamber and connected with compressor pipeline. Chamber contains a piston drived by implemented mechanism, e.g. by crankshaft. Movement of compressor

and compensator pistons is synchronized in order to anti-phase waves generate. Construction of compensator is patented.

Dimensions of this paper do not allows to authors to describe some other methods and constructions.

4 - EVALUATION OF COMPRESSOR PIPELINES VIBRATION REDUCTION EFFICIENCY

For the preliminary evaluation of piston compressor mount parameters, the forecast of pipelines vibration characteristic and evaluation of vibration reduction the mathematical model of spreading of low-frequency gas pressure pulsations in the compressor pipeline and software "PIPELINE" have been developed. Software allows to carry out an analytical evaluation of delivery and suction pipelines. Calculated scheme of pipeline includes an assembly of consequently connected links imitating pipeline real elements. The different data are inputted: links parameters, compressor rotating frequency, temperature etc. Computations are provided by using of solution of system of differential equations describing system elements during harmonic excitation with different frequencies.

An illustration of the software using for pliable damper necessary parameters evaluation is shown in [4]. The software was also used for resonators constructions efficiency evaluation. Different resonator characteristics and possibilities of installation were evaluated. It was decided that the best variant is when connecting pipe is partly inside in the resonator. Fig. 2 shows the results of vibration attenuation using this variant of resonator installation.

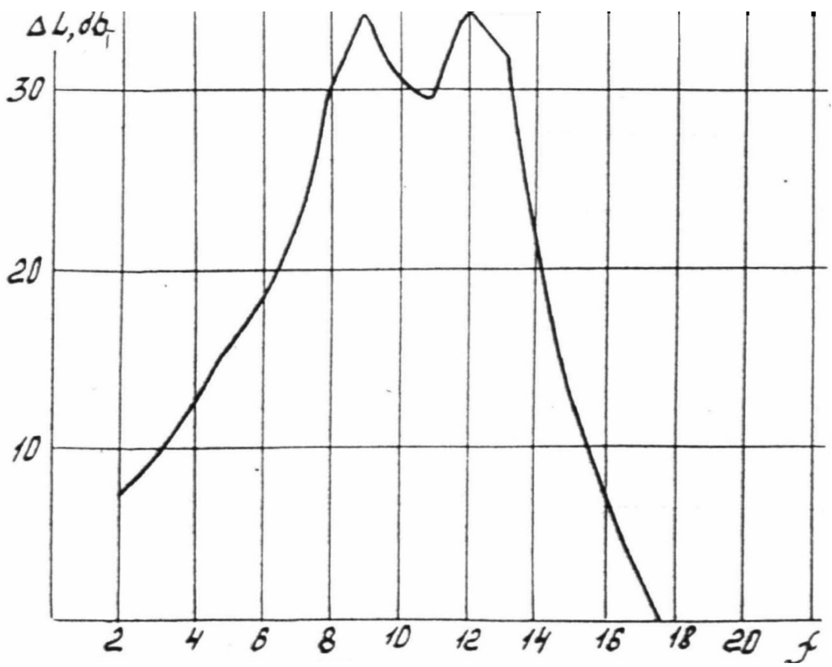

Figure 2: Evaluation of pipeline vibration attenuation efficiency using resonator construction.

5 - CONCLUSIONS

The results of calculated and experimental investigations are discussed. The efficiency of different measures of vibration reduction is discussed, including the constructions of pulsation dampers developed by authors. Good effect of vibration attenuation was achieved. Suggested measures and constructions of low-frequency pulsations reduction may be used in different branches of mechanical engineering, for example, in force devices of vehicles, pneumatic systems of industrial plants, etc.

ACKNOWLEDGEMENTS

Dr. M.Yu.Nadtochy for his kind advices.

REFERENCES

1. **A.S.Vladislavlev, A.A.Kozobkov, V.A.Malyshev, A.S.Messerman, V.M.Pisarevsky**, *Pipelines of piston compressor machines*, Moscow, "Mashinostroenie" (rus, pp. 288, 1972

2. **C.Cortemiglio et M.Piron**, Absorbeur de pulsations pour le collecteur d'alimentation d'un moteur à combustion interne, *Appl. Patent France N 2579667*, 1986

3. **R.N.Starobinsky, A.V.Vassiliev, V.I.Voltchonkov et al**, Pressure oscillations damper for the suction system of piston machine, *Invention certificate N 1789748 A1, Russia*, 1993

4. **A.V.Vassiliev, R.N.Starobinski, V.M.Ryabov** , Piston machine pipelines vibration attenuation using compact low-frequency pulsations damper, In *Proc. of "Inter-Noise 97" Int. Congress, Budapest, Hungary*, pp. 639-642, 1997

5. **A.V.Vassiliev**, Membrane-Spring Damper of Low-Frequency Gas Dynamic Pulsations Proc. of "Transport Noise and Vibration, In *Int. Symp. Tallinn, Estonia*, pp. 43-46, 1998

6. **A.V.Vassiliev**, *Piston machines pressure oscillations and suction noise reduction using low-frequency mufflers* , Dissertation of Cand. of Techn. Sc. MADI, Moscow (rus)., pp. 242, 1994