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EXPERIMENTAL INVESTIGATION OF DYNAMIC CHARACTERISTIC OF FLAT DIFFUSER CHANNELS

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The results of the investigation of vibrating state of diffusers at different opening angles of its blading section in different starting conditions are given.

Keywords: diffuser, dynamic loads, turbomachine

Introduction

Virtually diffusers are an essential part of all turbine machines. At the same time diffusers are the source of higher energy loss, higher noise and the weakest component in the context of vibrating reliability in both gas and steam turbines.

Comparing known experimental data it is very easy to arrive at the conclusion that there is a direct relation between the flow regime in one or another channels and its vibrating state. The most distinct relation is observed in diffuser channels where in some cases the flow of medium is accompanied with a flow separation from a channel border.

The studied relation is quite obvious if a flow separation appears, but the presence of this relation in nonstalling flow requires experiments.

In order to study both two-dimensional and axially symmetrical diffusers specially-made installations are shown in this work and this work presents how the forces are changing on the walls of two-dimensional diffusers if its geometry varies and how pressure fluctuations change after axially symmetrical diffusers if starting conditions change.

2. Short description of experimental installation

The simplest experimental installation shown on fig.1 was used in order to study two-dimensional diffusers.

The two-dimensional diffuser consists of two plates 1 coupled tight with cylinders 2. These cylinders provide identical velocity fields before inlet section of the diffuser at different angles of plates 1. Cylinders come into support bearings, placed on side walls 4. It gives the opportunity to change the expansion angle of the diffuser. Connectors 3, connected with upper and low walls 5 don't allow the working medium to go past the diffuser's channel. The installation is fixed with flanges 6 to the flange of air receiver.

In order to evaluate an efficiency of pressure recovery in diffuser in the channels and dynamic force acting on its walls plates 1 are joined resistive-strain dynamometer 7.

As air is released to atmosphere the pressure inside the channel was always lower than atmospheric pressure and the force appearing on the plates directed towards canal centerline if there was a pressure recovery. According to it tensile stress appeared on the load-bearing element 7 and if the efficiency of pressure recovery was high, tensile stress became higher, and if the efficiency of pressure recovery was lower, the measuring force was lower too The meter is a standard device "Handyscope HS2" made by "TiePie engineering" and this device gave a possibility to monitor forces acted to the plates 1.

In order to investigate axially symmetrical conical diffusers the installation shown on Fig. 2 was used. Diffusers 1 were placed behind the turn of flow at 90^o in turning elbow 2 which were mounted on the receiver tank 3.

In order to change conditions of inlet of working medium behind turning elbow 2 the leveling device 4 can be placed. A punched diaphragm, a slit diaphragm and matched slit diaphragm is used as a leveling device.

The investigations are carried out with the curvilinear elbow and the turning elbow. The turning elbow was two pipes welded at 90 ^{o}. This measuring system gave possibility to determine all integral characteristics of diffusers (coefficient of power loss, pressure recovery, efficiency), its vibrating state (vibrating velocity and vibratory displacemen), pressure fluctuations in outlet section of the diffusers.

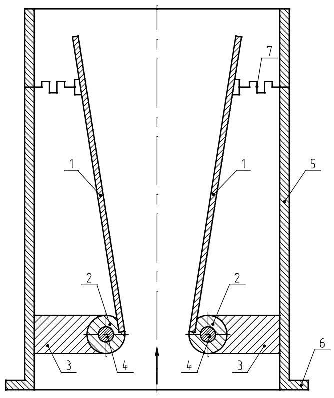

Fig. 1: Scheme of installation to study two-dimensional diffusers

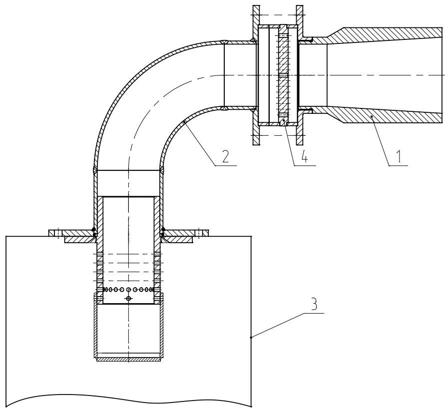

Fig. 2: Scheme of installation to study conical, placed behind turning elbows

3. Influence of expansion angle of two-dimensional diffuser on dynamic force acted to its walls

It is well-known that that flow regime in conical diffuser depends on expansion angle of its blading section.

If $\alpha \leq 10°$ and entering velocity field is comparatively uniform nonstalling flow is kept in theses diffusers and if n – expansion rate is constant the coefficient of pressure recovery reaches maximum.

At $10° < \alpha \leq 25°$ flow separation appears in the diffusers, pressure fluctuations in flow increase dramatically and the decrease of the efficiency of pressure recovery in diffusers takes place. At last at $\alpha > 30°$ a developed separated flow is coming, the pressure recovery doesn’t occur after the flow separation from the walls.

It is clear that all changes taking place in flow pattern if α also changes have to influence dynamic forces which are acting on the walls of diffuser’s channels. This relation is traced on the force oscillogram; forces have been measured on the wall of the studied two dimensional diffuser.

At $\alpha=0$ it was expected (Fig. 4a) (two-dimensional channel) the dynamic component of the measured force was next to zero, the force itself was directed from the canal centerline, constraining measuring transducer of Handyscope HS2”.

There are several changes if it is a diffuser channel with angle $\alpha=7°$ (Fig. 3b).

First of all the great steady-state forces directed towards the canal centerline appear on two-dimensional walls because intrinsical pressure is lower than atmospheric pressure.

The second, in spite of nonstalling flow, the great increase of pressure fluctuation takes place at wall zone and on the oscilogramm the sharp increase of the dynamic component of measured forces appears.

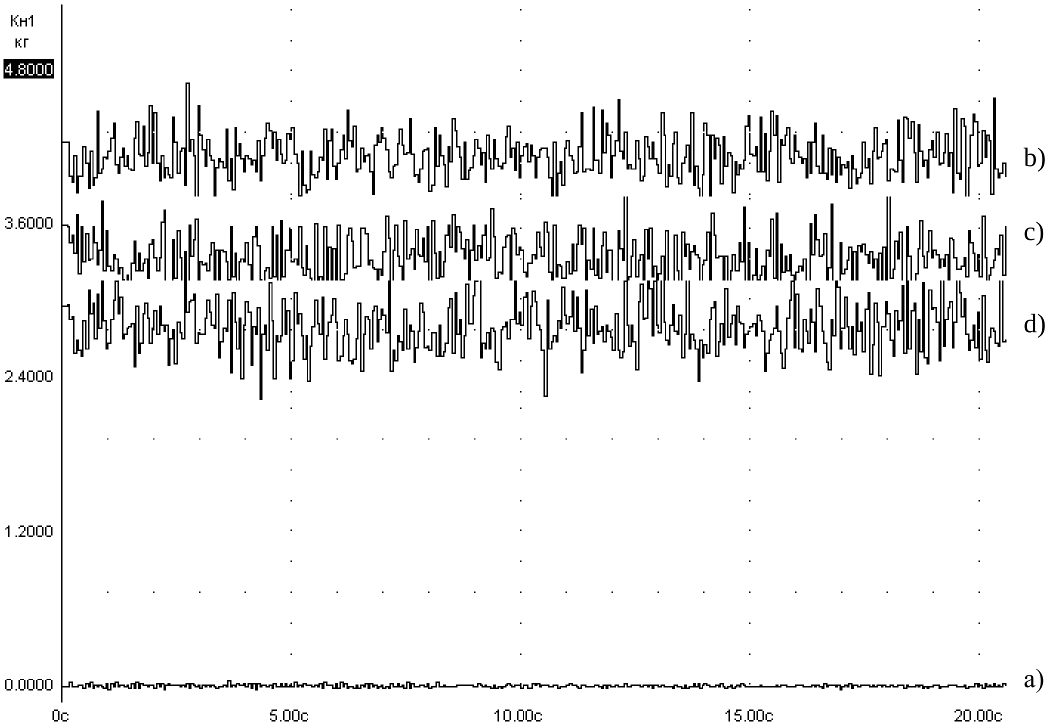

Fig. 3: Oscilogramm of forces on the wall of two-dimensional diffusers
a) of two-dimensional channel; b) diffuser with expansion angle α=7º;
c) diffuser with expansion angle α=10º; d) diffuser with expansion angle α=20º;

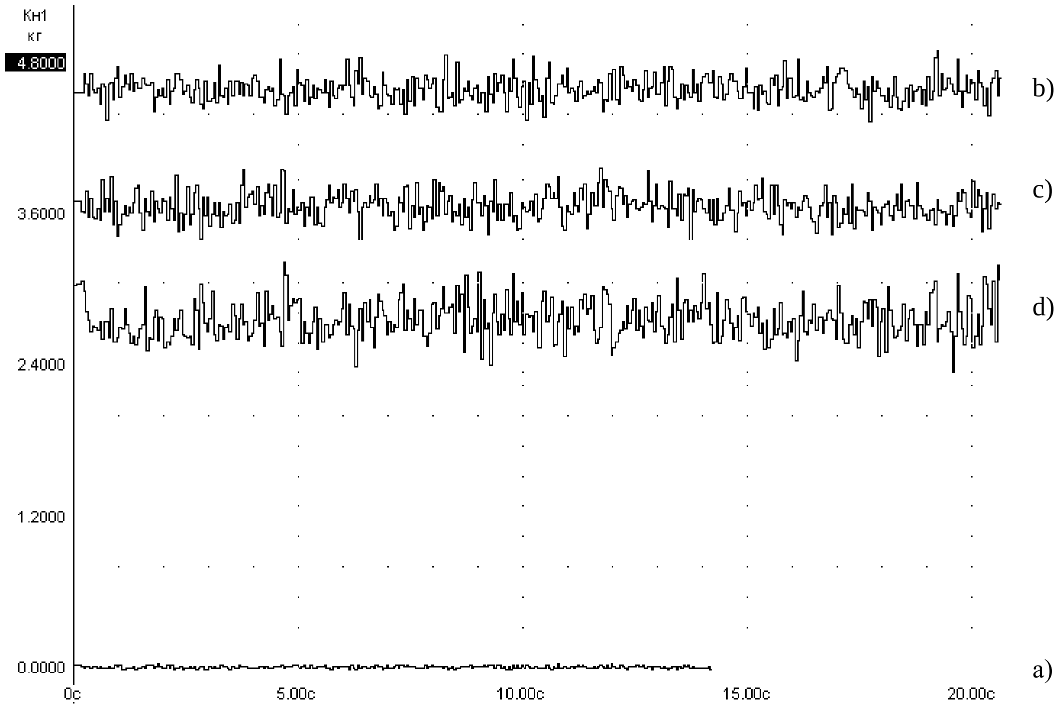

Fig. 4: Oscilogramm of forces on the diffuser wall with longitudinal groove
a) two-dimensional channel; b) diffuser with expansion angle α=7º;
c) diffuser with expansion angle α=10º; d) diffuser with expansion angle α=20º;

The increase of the dynamic forces on the side walls of two-dimentional diffuser is connected probably with intensification of low-frequency turbulent fluctuations, carring the bigger share of turbulent energy flow.

While increasing the expansion angle of the diffuser to α=10° there is a following increase of dynamic components of the integral force on the streamlined wall and a decrease of it by 40-45% (Fig. 3b). It happens in spite of the increase in compare with previous case with expansion angle of the channel.

This decrease of load points to the decrease of efficiency of pressure recovery in the diffuser and it is connected with the beginning of flow separation from the walls of diffuser.

If expansion angle α=20° (Fig. 3g) amplitude value of force fluctuation on the wall rises, and its magnitude decreases.

Everything will be changing if naked walls of two-dimensional diffuser are substituted with walls with profiled walls with longitudinal rectangular groove.

In this case the oscilogramm with $\alpha=0^o$;7°;10^o;20°, given on Fig. 4 shows that there is an increase of dynamic forces on the walls of the diffusers and indirectly points to the changes in flow profile while profiled walls are used in diffuser channels.

Given results (Fig. 5) give a possibility to influence dynamic forces, which set up vibrations of the wall of the diffusers.

The next set of experiment was carried out with two-dimensional diffuser. To make channel wider only one wall was deviated at α. In this case on the vertical wall at all α a nonstalling flow is kept, but the flow always separates from the opposite wall, which was placed at α to a vertical centerline of channel.

The oscilogramms taken from the vertical wall at different digression of the opposite wall given on Fig. 5 says that α influences the amplitude of fluctuation of the measured forces slightly. While the increase of α. To 15^o the amplitude is practically constant. However it rises little further. Only at $\alpha.=30^o$ if there is developed separate flow in the channel on the vertical wall with boundary layer amplitude of dynamic forces increases in average by 20-25%.

On the deviated wall there is another case. If α=7°(Fig. 6) the oscilogramm on the wall is practically the same to the oscilogramm on the vertical wall, but at α=10° amplitude of dynamic component increases 2-2,5 time much, but at α=15°the studied amplitude icreases 3 times much.

Given results point to the sharp increase of dynamic forces on the surfaces, where separation of working medium takes place. It is a place which give contribution to the vibration state of diffuser channels.

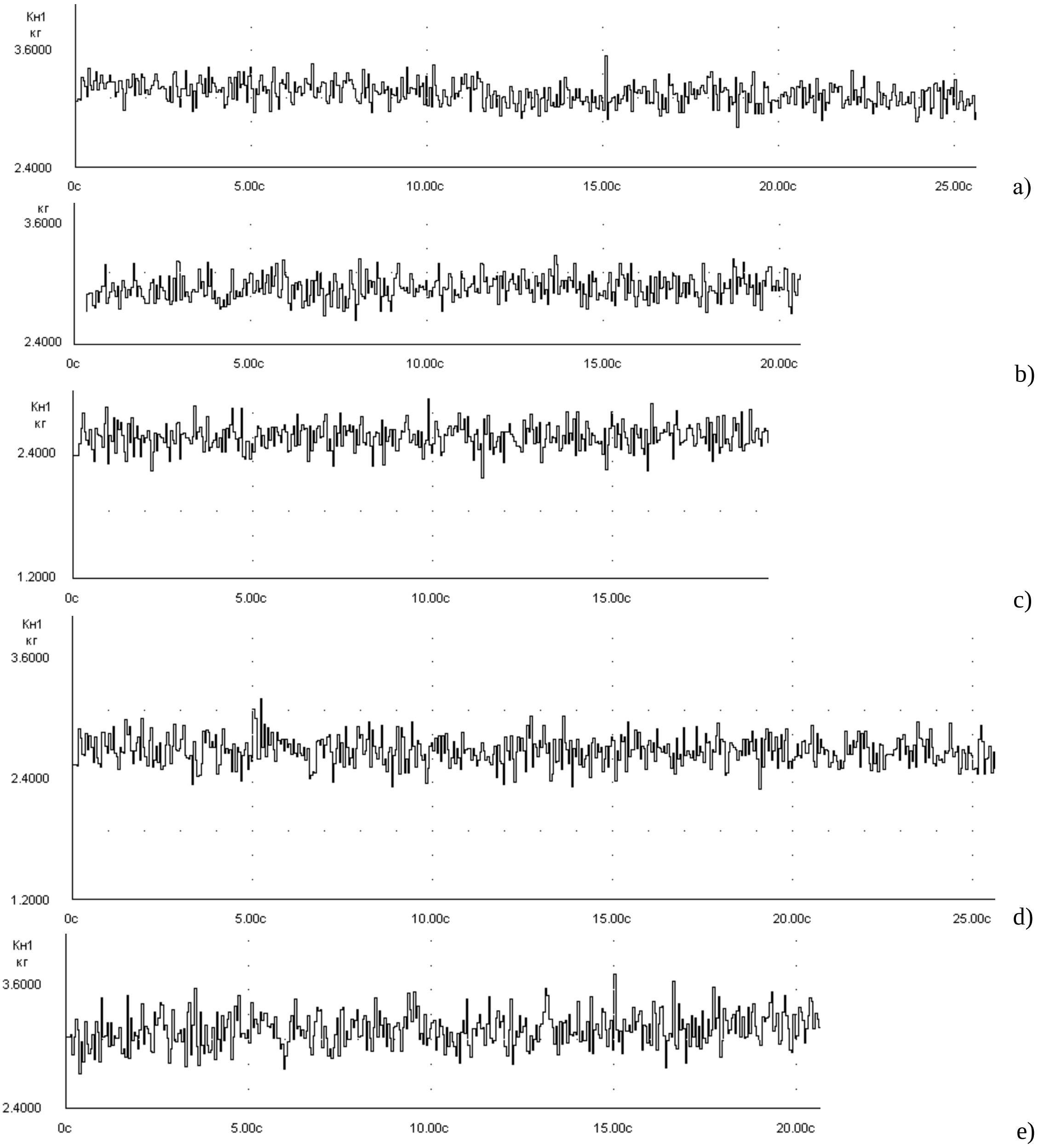

Fig. 5: Oscilogramm of forces on the vertical walls of asymmetrical diffusers
a) diffuser with expansion angle α=7º; b) diffuser with expansion angle α=10º;
c) diffuser with expansion angle α=15º; d) diffuser with expansion angle α=20º;
e) diffuser with expansion angle α=30º;

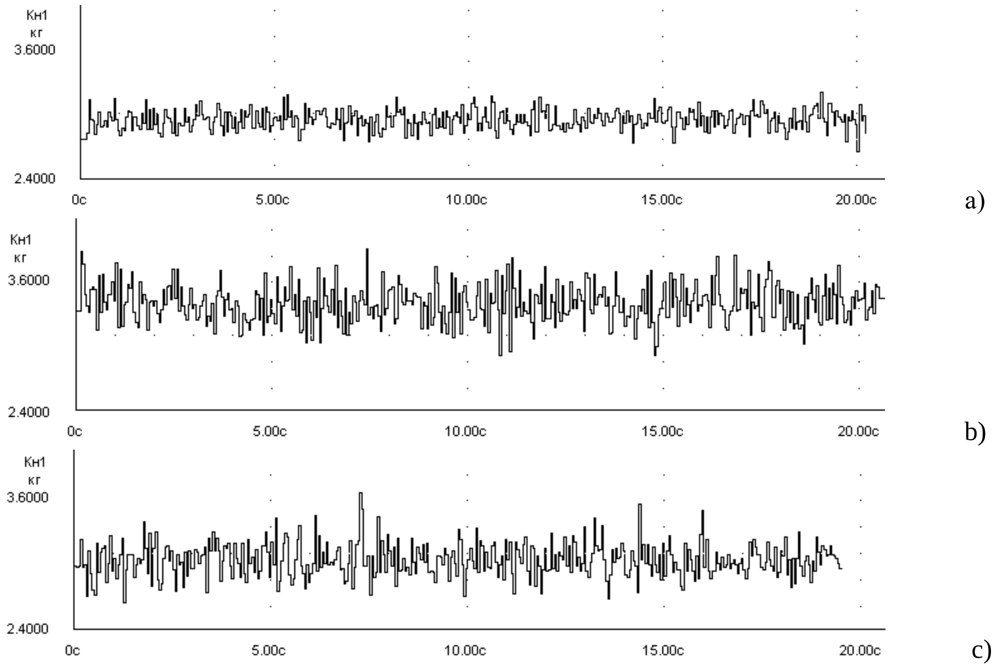

Fig. 6: Oscilogramms of forces on the deviated wall of asymmetrical diffusers
a) diffuser with expansion angle α=7º; b) diffuser with expansion angle α=10º; c) diffuser with expansion angle α=15º;

4. The results of investigation of conical diffusers placed after 90º turn of flow

Investigating conical diffuser the profile flow in its blading section has been changed. And the reason of it is the change of opening angle α if the expansion angle is constant and the change of entering velocity field. The installation shown on the Fig. 2 was used.

After these turns very complicated velocity field with two whirl cords appears, these whirls are rotating in the opposite direction. In this case in conical diffusers practically at all opening angles α downstream the flow of working medium is unstable and in outlet cross-section the maximum amplitude of pressure fluctuation reaches. The external manifestation of high pressure fluctuation is vibratory displacement of surface in studied diffusers. The sensor point was in inlet cross-section of the diffusers. All measurements were carried out at $\varepsilon_a = \frac{B}{P_0}$,

$\varepsilon_a = 0{,}87$ P_o – air pressure in receiver (Fig. 2), B - atmospheric pressure.

The results of measurement of pressure fluctuation in outlet cross-section of investigated diffusers if curvilinear elbow is used are shown on Fig. 7a and the diffusers were placed after square elbow is shown on Fig. 7b. On these figures abscissa is α, the opening angle of diffuser and ordinate axis is relational pressure fluctuation that is ratio of average pressure fluctuation $\overline{p} = \frac{\Delta p}{P_0}$, and excess air pressure in the receiver of the experimental installation.

These curves show that pressure fluctuation at α=10^o reaches 10% of starting pressure of working medium (air). Then if α increases to 7^o the value $\overline{\Delta p}$ decreases to 8% then it is steadily increasing and reaches 15% at α=30^o . The similar relation is observed if rotary elbow is used (Fig. 10), but in this case the value of relational pressure fluctuation in outlet cross-section is higher and it is 18% at α=30^o.
These high pressure fluctuations in flow, leaving diffusers stimulates high vibration of the installation. The presented measurements of vibratory displacement demonstrated that the vibratory displacement on the outer surface of the studied diffusers in the inlet cross-section increases strongly from 15 micron to 25 micron if expansion angle α is increasing. (To compare in steam turbine if there is rotor balancing vibratory displacement on bearings is 3÷5 micron).
The changes of starting condition in conical diffusers with the help of vibration suppressor (Fig. 3) allow to decrease pressure fluctuation at 3 times in blading section of diffusers and to decrease vibratory displacement in check point of experimental installation at 2.5.

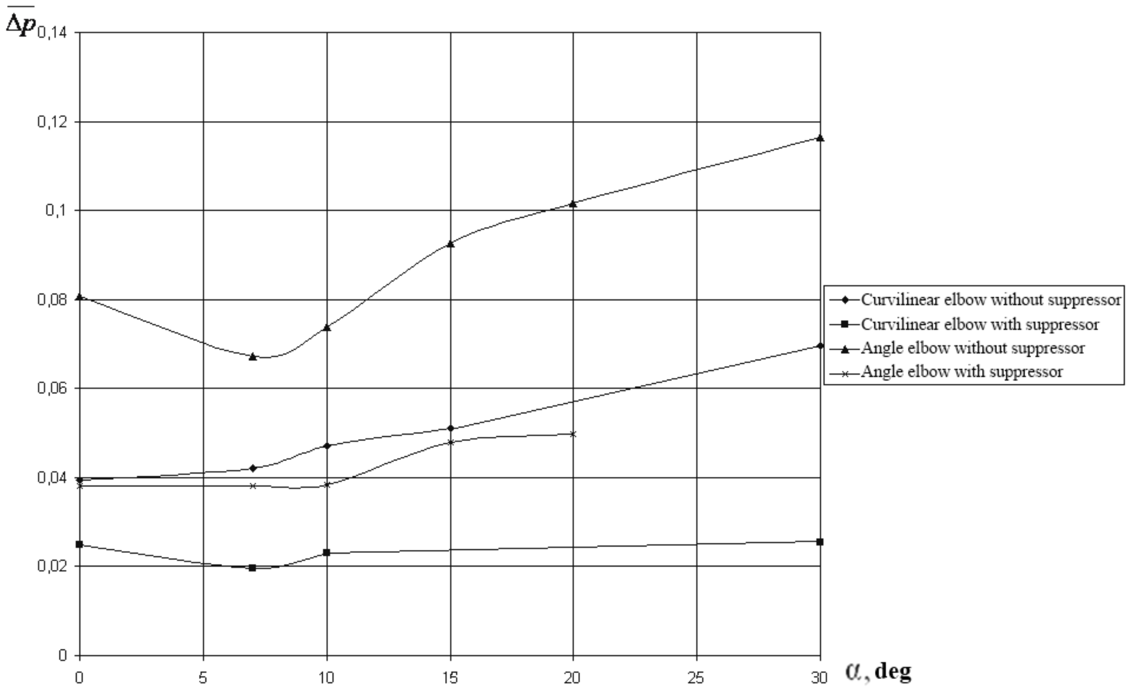

Fig. 7: Relation of average pressure fluctuation in outlet cross section of conical diffusers in relation to α while curvilinear elbow (a) and tuning angle elbow (b) used

Conclusion

The examined investigations demonstrate interdependence of flow regime in diffusers with its vibrating state and methods of increasing vibratory reliability of installations, which have diffusers channels in its blading sections.

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