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Кафедра авіаційних двигунів

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д-р техн.наук, проф..
____________ М.С. Кулик
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ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ « МАГІСТР »
ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
“ ГАЗОТУРБІННІ УСТАНОВКИ І КОМПРЕСОРНІ СТАНЦІЇ ”
(Пояснювальна записка)

Тема: Покращення акустичних характеристик газотурбінної установки

Виконав: ____ **Кондратюк Н.О.**

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Нормоконтролер : __________________ /_____________________/

КИЇВ 2020

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

AEROSPACE FACULTY

AEROENGINES DEPARTMENT

PERMISSION FOR DEFENCE

Head of the Department
Doctor of Sciences (Engineering), prof.
___________ M.S. Kulyk
"_____" ______ 2020

MASTER'S THESIS
ON THE EDUCATIONAL PROFESSIONAL PROGRAM "GAS TURBINE PLANTS AND COMPRESSOR STATIONS"

(EXPLANOTARY NOTE)

Theme: "Improvement of gas turbine plant acoustic characteristics"

Performed by: ____ Kondratiuk N.O.

Supervisor:
Doctor of Sciences (Engineering), Associate Professor____________ Doroshenko K.V.

Advisers:

Labor precaution :

Ph.D., Associate Professor______________________________Kovalenko V.V.

Environmental protection :
Ph.D. (Engineering), Assoc. Prof.__________________________Chernyak L. M.

Standards Inspector ________________________ /_______________________/

Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Faculty: *Aerospace Faculty*

Department: *Aeroengine department*

Educational degree: *Master*

Specialty: *142 "Power machinery"*

Educational Professional Program: *«Gas Turbine Plants and Compressor Stations»*

APPROVED BY

Head of the Department

__________M. Kulyk

"__" ____2019

Graduation Work Assignment

Kondratiuk Nikita Oleksandrovych

(surname , name and patronic of graduating student)

1. Theme: "Improvement of gas turbine plant acoustic characteristics"
   Approved by the Rector's order of September 26, 2019 № 2187/ст
2. The project to be performed from 29.10.2019 to 02.02.2020
3. Initial data for the project: Gas turbine plant should be calculated for standard ambient conditions $p_н$ = 101,325 Pa; $T_н$ = 288 K
4. The content of the explanatory note (the list of problems to be considered): Introduction; Analytical part; Project part; Special part; Labor precautions; Environmental protection; General conclusion .
5. The list of mandatory graphic materials: presentation of results. Microsoft office Power Point, should be used to provide graphic support and presentation.

6. Time and Work Schedule

№	Stages of Graduation Project Completion	Stage Completion Dates	Remarks
1.	Literature review of materials concerning theme of diploma work. Analytical part	15.10.19-31.10. 19	
2.	Project part	1.11.19-12.11.19	
3.	Special part	12.11-16.11.19	
4.	Labor precaution	15.12.18- 20.12. 19	
5.	Environmental protection	20.12. 18 - 30.12.19	
6.	Arrangement of graphical part of diploma work	14.01. 18 -20.01.20	
7.	Arrangement of the explanatory note	20. 01.19- 25.01.20	

7. Advisers on individual sections

Section	Adviser	Date, Signature	
		Assignment Delivered	Assignment Accepted
Labor precaution	Ph.D., Associate Professor Kovalenko V.V.		
Environmental protection	Ph.D. (Engineering), Assoc. Prof. Chernyak L.M.		

8. Assignment issue date: «_ _» ________ 2020

Diploma work supervisor: __________________ K.V. Doroshenko
(supervisor signature)

Assignment is accepted for execution: _____________ ______N.O.Kondratiuk
(graduate student's signature) (date)

ABSTRACT

Explanatory note to the diploma work "Improvement of gas turbine plant acoustic characteristics": 82 pages, 11 figures, and 2 tables 23 references.

The object of study is sound-absorbing materials for the hot part of the engine.

Subject of study - acoustic characteristics of sound-absorbing materials.

The aim is to improve the acoustic characteristics of a gas turbine plant by using effective sound-absorbing materials for the hot part of the engine.

Thesis materials are recommended for use in the reconstruction of compressor stations in order to reduce noise.

Key words: GAS TURBINE PLANT (GTP), THERMODYNAMIC CALCULATION, GASDYNAMIC CALCULATION, NOISE, SOUND-ABSORBING MATERIALS.

CONTENT

INTRODUCTION

Currently, gas turbine engines (GTE) are widely used in various transport and energy industries. Decreasing the noise level of a gas turbine engine is an urgent task, and when applied on the ground as a power plant.

Recently, gas turbine engines are widely used as gas pumping units (GPU), as well as in other ground-based power plants.

In connection with the increase in the length of gas transmission pipelines arose the need for compressor stations in close proximity to settlements where the requirements for plague are strictly regulated. In individual In cases, these requirements for compressor stations with typical gas compressor units are no longer are being implemented. The introduction of more powerful gas pumping units makes it is necessary to carry out additional measures to reduce noise to levels not exceeding the values prescribed by sanitary standards (SN), GOST, building codes and regulations (SNiP).

There are two ways to combat the noise of gas turbine engines:

- reduction of noise in the source;
- reduction of propagating noise.

Typically, noise reduction in the source is achieved by degrading other characteristics.

GTE (power reduction, weight gain, etc.), therefore, at present, in the struggle it is often the second approach that is often used with scum. To reduce the spread of soundproofing aircraft gas turbine engines designs. When using the engine on the ground, it is possible to use sound insulation method of the compartment (room) where the gas turbine engine is installed. There is also the opportunity installation of air intake and exhaust gas silencers. In this regard, the work is devoted to the selection of effective in a wide range frequencies of sound absorbing and sound insulating constructions with folded filler to reduce the noise of gas turbine engines and power plants.

CHAPTER 1

GTE NOISE REDUCTION IN GROUND CONDITIONS

When using gas turbine engines in ground conditions, the same methods are used noise reduction, as for aircraft engines (often used on the ground adapted gas turbine engines, originally designed for aviation). There are some natural differences compared with the methods of noise reduction aircraft GTE – with using the engine on the ground there is the possibility of applying the method soundproofing of the compartment (room) where the gas turbine engine is installed, and also there are no restrictions, typical for aviation (light weight, high reliability, etc.) [1-5]. Also there is a need to address issues related to the development of silencers air intake and exhaust gas [4].

Figure 1.1 shows a GPU circuit with a gas turbine drive and smallpox sources of noise.

GPU noise through suction and exhaust channels, piping systems, and also through building envelope penetrates the atmosphere and can spread to significant distances. Protection of residential buildings and the territory of the compressor station from noise can be greatly facilitated by competent and rational, in terms of acoustics, planning the relative position of objects at the station. At the same time, objects requiring protection from noise (administrative buildings, repair and restoration services, canteens, etc.) should be as high as possible remote from noisy installations located both in open areas and in indoors. In addition, a rational layout of the building with hosted noisy equipment.

The machine room should be at the maximum distance from the administrative buildings, production workshops, etc. The exhaust shaft should be oriented in side opposite to the main housing estate so that the blinds the suction chamber grilles and the exhaust shaft were not in line of sight radius residential and public buildings. The piping system should place on the opposite side from the housing estate. Double glazing area Compressor hall housings should be kept to a minimum. External enclosures constructions, doors, gates should have increased sound insulation [4].

When planning a compressor workshop, such an internal an arrangement in which all auxiliary rooms where people should work, would be isolated from the engine room.

The layout of the gas compressor unit must be designed so that the area surfaces emitting sound energy into the engine room was minimal.

The suction and vklopa lines, as well as auxiliary equipment for gas turbines, should be position below the mark of the service site, in the overlap of which leave only the most necessary minimum of openings.

GPA placement density should be the lowest, which will allow to use additional means to reduce the noise - screens or partitions.

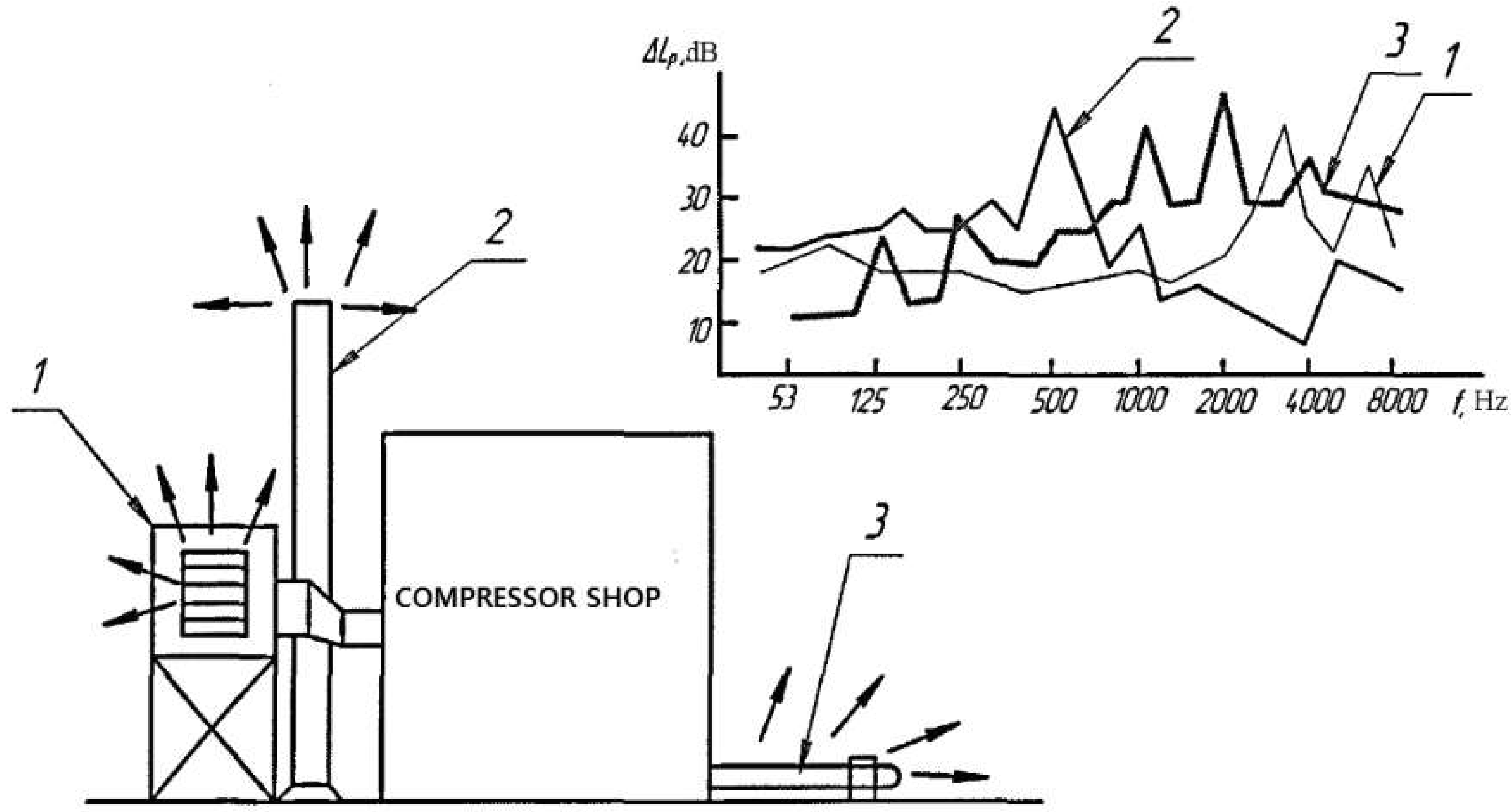


Figure 1.1. – The main sources of noise and typical spectogram of sound pressure levels

1 – suction shaft, 2 – exhaust pipe, 3 – piping technology

When choosing the shape and volume of the rooms of the machine rooms should be given preference for elongated shape and flat sound-absorbing ceiling is minimally necessary height. Decreased room height contributes to increased the effectiveness of the use of sound-absorbing ceiling lining. Noise reduction effect in this case is 5-6 dB.

Silencers are usually divided into active and reactive [4]. Noise reduction in silencers of active tin occurs due to the dissipation of sound energy in absorbent lining, which use special sound-absorbing materials.

Noise absorption in reactive silencers occurs by reflection and scattering of sound energy in acoustic filters, which are formed by a combination acoustic mass and elasticity in the form of chambers and connecting tubes. Characteristic a feature of active type silencers is a rather smooth appearance of the frequency curve silencing, while for jet silencers this curve has some sharp peaks and dips.

The most widely used active silencers are tubular and lamellar type.

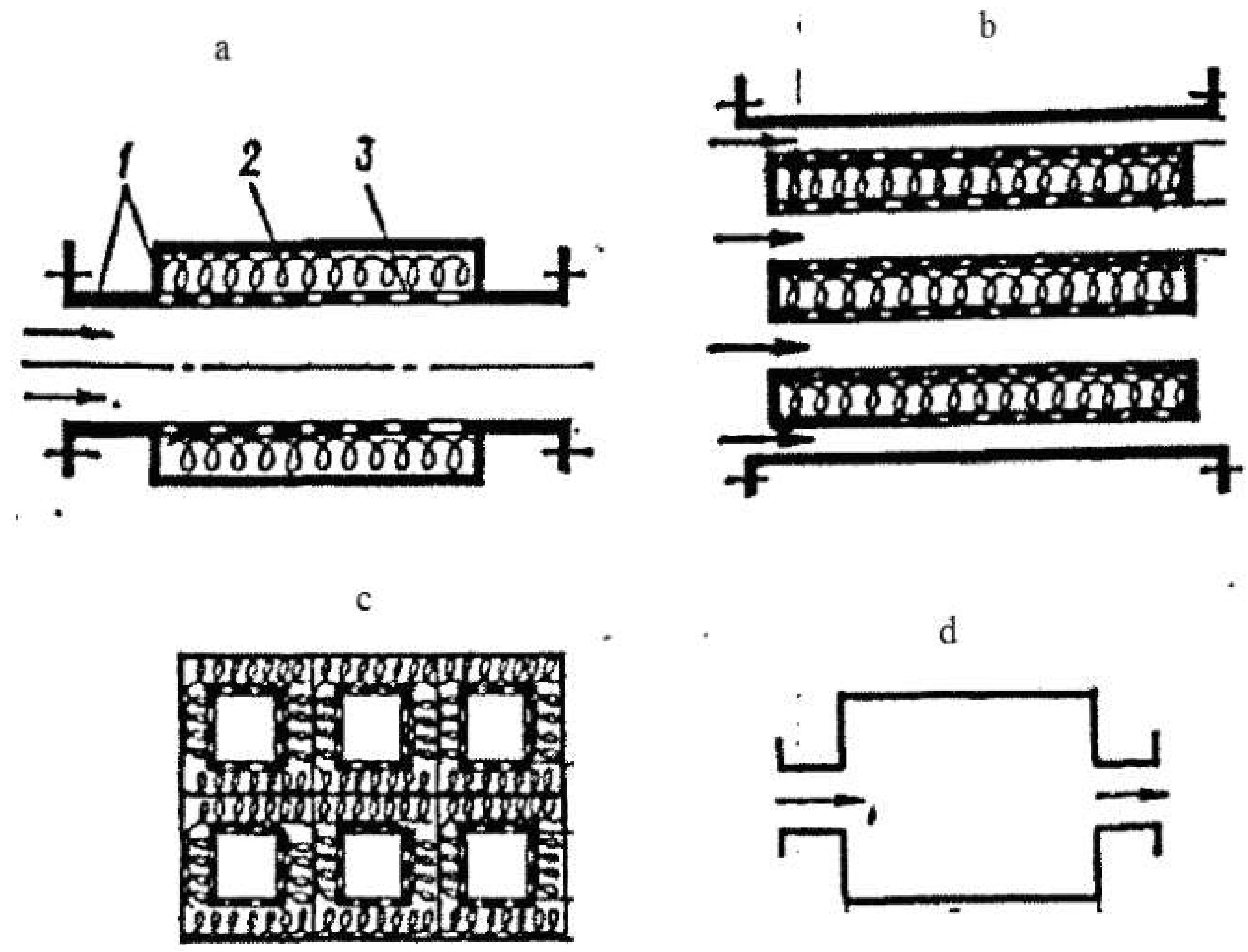


Figure 1.2 – Schemes of various types of silencers

a – tubular, b – panel, c – cellular, d – chamber with a screen;

1 – case, 2 – sound-absorbing material, 3 – perforated coating

A tubular silencer is the simplest (Figure 1.2, a) [6]. It imagines a section of a pipeline of circular or rectangular cross section with lined sound-absorbing material walls. Perforated, transparent coating serves to preserve the shape of the channel and prevent blowing sound-absorbing material flow. The greatest attenuation for tubular silencers takes place at the first three calibers, and then the attenuation decreases. Therefore cost-effective use relatively short tubular silencers with a length of not more than three calibers.

Tubular silencers can be used effectively to silence sound in pipelines of small diameter [6]. For power plants with oversized ducts do not allow the use of tubular silencers significant effect and is appropriate only for a small amount of required attenuation.

To increase attenuation in large ducts, resort to uniform distribution of sound-absorbing material over the flow area. This The principle is used in a plate silencer. Panel (plate) silencer is a series of parallel panels with sound-absorbing material, breaking the duct into several parallel channels (Figure 1.2.b) [6]. The side walls of the shields (plates) are made of perforated sheets or nets transparent to sound waves. Plate thickness and the distance between them is the same over the entire cross section of the channel. The exception is the distance between the end plates and the silencer body, which is half distance between other plates. In some cases, use a silencer circuit with the location of the extreme lastin close to the walls of the body, but the thickness of the extreme plates should be equal to half the thickness of other plates. Such conditions presented to ensure equal sound attenuation in each channel of the silencer.

Silencers with spatial distribution of the sound absorber in the gas outlet the path are also silencers of the honeycomb type, the cross section of which is shown in Figure 1.2, in [6], but they can be considered as a series of tubular silencers.

Active silencers also include knee and turns. Due changes in the direction of movement of sound waves the effectiveness of rectangular turns compared to a tubular muffler at high frequencies, where "Radiation effect", may increase up to 20 dB. However, for gas-air ducts tend to the use of smooth knees and turns to reduce hydraulic flow resistance. At the same time, acoustic efficiency decreases sharply for smooth rotation by 90 ° with a distance between the walls from 0.3 to 1.6 m, its value is not exceeds 5 - 8 dB even at high frequencies.

Of the considered types of active silencers, the most suitable for reducing noise in the gas-air paths of power equipment are tubular silencers for small duct sizes and plate silencers for large flow sections that combine high acoustic performance with good aerodynamic qualities, manufacturability in production and installation, as well as with relatively low cost.

Active type silencers are especially effective at medium and high frequencies. For damping low-frequency noise, as well as the emission of some aggressive gases more appropriate to use reactive silencers. One of the simplest and common types of jet silencers is a single expansion camera figure 1.7, d [6].

It is advisable to increase the efficiency of measures to reduce noise use a combination of panel and tubular silencers, i.e. panel installation silencing at the suction and exhaust and facing the underwater air and exhaust gas channels soundproofed panels.

It should be noted that the noise characteristics of the exhaust gas compressor differ from parameters on suction. The nature of the noise is low-frequency. In addition, the temperature at GTE exhaust is high, which must be considered when choosing a type of sound absorber.

Facing of sound absorber materials internal surfaces of flow paths of the engine and air intake is one of the most effective passive ways to reduce discrete fan and turbine noise [7].

Sound-absorbing structures (sound absorbers) are called specifically designed designs with the ability to significantly absorb sound energy incident on them [7].

Asto in these designs use special materials called sound absorbing. Often and simple simple sound-absorbing structures they are called, although not entirely correct, sound-absorbing materials.

The sound energy absorbed by the structure, of course, does not disappear, it turns into thermal energy. The physical process of converting sound energy into thermal can occur in many ways. However, this transformation is always occurs due to friction and associated irreversible thermodynamic processes [thirty]. For example, in some cases, sound waves falling on a sound-absorbing structure waves cause air vibrations in the narrow burrows of any porous material.

Due to the viscosity of the air, its vibrations in such pores are accompanied by trepium, and the kinetic energy of the vibrating air goes into thermal energy. In other cases, flexible elements oscillate under the influence of incident sound waves structures, such as thin panels made of wood or plastic materials. Due internal friction in the materials of such flexible structures, transformation occurs kinetic energy of their vibrations in heat [7].

The impedance of the sound-absorbing surface characterizes the movement delay surface boundaries on the magnitude of the effect of pressure force [26.98]. Value the phase difference of these vibrational processes determines the degree of dissipation acoustic energy. In the future, we will call this specific impedance simply impedance. The impedance of this design is a function of frequency and angle of incidence sound waves [7].

Sound-absorbing structures installed in the channels of aircraft engines, must satisfy a number of requirements [7]. They should have a minimum thickness and mass, small hydraulic losses, maintain high pressure and temperature and, of course, have a high sound absorption capacity.

Sound-absorbing structures can be divided into two groups: locally responsive, which allow sound propagation in only one direction, and volume reactive, allowing the propagation of sound in more than one direction [7].

Sound-absorbing structures based on volumetric reactive porous materials consisting of a solid skeleton and pores filled with air [1-7].

The pores of such materials should be in the form of narrow channels, the shape of which can be different with the condition, however, so that the material allows through blowing air note. Airborne sound waves incident on such material cause air fluctuations in holes; due to air viscosity, these oscillations are accompanied by friction, and the kinetic energy of the oscillating air partially goes into heat.

Energy transfer also occurs due to irreversible processes associated with thermal conductivity of air and skeleton. In cases where the skeleton itself also comes in oscillations, additional thermal energy is obtained due to internal friction in the material skeleton. Such PPCs have a more broadband sound absorption characteristic for compared with the resonance claddings discussed below, but inferior to them in efficiency in a narrow frequency band. In addition, low mechanical properties and the ability to absorb oils, fuels and other liquids leads to a decrease sound absorbing ability, as well as the possibility of fire during operation engines. For these reasons, it is currently the most widely used for jamming.

Aircraft engines use cellular acoustic liners. The prototype of a cellular sound absorber materials is the classic Helmholtz resonator consisting of an air cavity connected by a hole or a jaw to ambient air. If the cavity dimensions are small compared to the length of the sound waves, then it can be considered as an oscillatory system with one degree of freedom, which mass is the mass of air in the jaw together with the hovering around it thirty holes with a mass of attached air, and the elastic element is a prisoner in cavity air [26.98]. Such a system has its own frequency:

Helmholtz resonator reduces sound intensity at a specific frequency oscillations (resonant frequency) [1-7]. Due to technological features manufacturing acoustic liners, the characteristic of the active sound absorption of the cladding more wide frequency range, however maximum noise reduction with acoustic liners also observed at a certain frequency of oscillation, which is being tuned.

The noise reduction in the lined channels is due to acoustic scattering energy in closed volumes formed by the honeycomb filler, and in connecting them with channel mouths (perforations), the cost of work on air compression, bringing it into vibrational motion and friction losses during gas motion in numerous the necks [4].

The resonator absorbs part of the energy of the sound waves incident on it, if the neck It provides friction resistance to the passing air flow. Such a resistance can be obtained by making a jaw of small diameter and large length or by placing it in the neck porous material (e.g. fabric stretched across the neck).

Acoustic liners must satisfy a number of requirements: acoustic, aerodynamic, strength. Providing significant absorption of sound energy over a wide band of frequencies lined with HSS channels should have low hydraulic losses (low pressure losses), sufficient rigidity to be used as power shells, considerable strength to withstand significantly acoustic and aerodynamic loads over a long life (equal to the life of the entire engine).

Currently, cellular sound-absorbing cladding is most fully satisfy the requirements of the gas turbine engine [7]. They consist of a perforated sheet or layer.

Porous material, impermeable sheet and honeycomb located between them

filler. Such a design actually represents a set of Helmholtz resonators uniformly located on the surface, i.e. is resonant — very effective in a narrow frequency range [91].

turbofan at the repetition frequency of the blades of the Republic of Kazakhstan or in the landing mode (where the noise of this the source is prevailing), or at a higher oscillation frequency with the aim of ensuring the minimum level of muffled noise by the sum of three control points.

The flow rate in the channel seriously affects the frequency and value (effect of drift flow) of maximum sound absorption [1-7]. With increasing flow velocity in the direction opposite to sound propagation in the channel (M <0), the efficiency of the PPC increases with simultaneously reducing the frequency corresponding to the maximum attenuation of sound (for example, for air intake duct). With the coincidence of the directions (M> 0) of the flow and propagation of sound vibrations (for example, in the outer tract of the engine), with an increase in the flow rate, the efficiency of the PPC decreases somewhat.

In cases of using a gas turbine engine under ground conditions - as a gas compressor unit or as a power unit installation of any ground vehicle - porous is also widely used sound-absorbing material (SAM) to reduce broadband noise character [1-7].

Sound energy losses in porous sound absorbing materials are determined a number of factors [4]. The main one is the viscous friction of air in the narrow pores of the material.

Another is losses due to the thermal conductivity of air and material. In the fall sound wave in the pores is a sequential compression and rarefaction of air. At the air heats up during compression, and energy is lost due to the removal of part of the pore walls the resulting heat. The third factor contributing to energy loss is deformation of the frame of the sound-absorbing porous layer. The frame is characterized high, in comparison with resonant structures, the degree of perforation. Is explained this is due to the fact that it is necessary to provide the maximum possible acoustic transparency of the sheet so that more acoustic energy reaches the SAM.

As SAM, cork, basalt and glass fiber are used, mineral wool plates, various foams, etc. [1-7]. Application of these materials as a filler in a sound-absorbing structure caused by two reasons: SAM provides a wide range of sound absorption and has a relatively low cost.

However, sound absorbing structures with SAM based on basalt and glass fibers have a lot of both technological and operational disadvantages [1-7].

Technology for the production, preparation and installation of structures with SAM environmentally friendly unsafe - it is necessary to protect the skin and respiratory organs of workers from getting fine fibers, which, due to their small size and weight, are easily carried by air.

Often, SAM are pre-sewn into mats, and then inserted into panels in as a placeholder. SAM mats must provide acoustic performance be relatively loose - the specific gravity should be at the level of 25kg / m3. But the problem ensuring uniform distribution of fibers across the mats and the constancy of this time distribution when exposed to atmospheric conditions (humidity, frost, etc.), as well as its own weight effects is a very difficult task. Is known [7] that under its own weight over time SAM based on basalt and glass fibers tend to crumble. This effect is usually enhanced by vibration.

Equipment during its operation. It takes a lot of stitching seams in mats with SAM, creation a complex system of their suspension in the cavities of walls and panel silencers. And even these measures do not guarantee the constancy of the acoustic parameters of the noise reduction system based on acoustic liners with sound-absorbing materials in time.

Sometimes they increase the density of sound-absorbing materials in mats by two to three times, thereby reducing the temporary effect of shedding [7]. This increases the weight and cost.

panels, and its acoustic efficiency is reduced. Sensitivity to dust and soot, which is important for panel mufflers, for example, noise reduction systems gas pumping units. Clogging pores in sound-absorbing materials, dust reduces their acoustic performance.

In case of violation of the integrity of panels, walls of ducts or panel silencers, what happens during burnout (in the exhaust system), during corrosion, or during mechanical damage, thin glass or basalt fibers fall either on the unit, which the consequence may be the cause of failure, or into the environment, which leads to environmental pollution.

One type of porous metal is an elastic damping material. Its elastic damping properties resemble those of rubber.

Hence the name "metashyurezina" (metal analogue of rubber) or abbreviated MP. MP a spetial porous metal structure obtained cold pressing the workpiece from a wire spiral into the final one in shape and sizing detail. Therefore, MR occupies an intermediate position between the material in common understanding and design.

For the manufacture of parts from MR, wire with a diameter of 0.03 to 0.5 mm is used.

The choice of diameter and grade of wire is determined by the working conditions, the possibility the use of high-performance equipment for spiral winding and obtaining required characteristics [5,12,13,14].

Features of the structure of MR, in particular, the absence of hard bonds (hard frame), allow to obtain very large elastic deformations, reaching 30-40% from the height of the part. Having a sufficiently high strength, the material MR is, perhaps the only elastic porous metal material [5].

MR material provides a fairly high coefficient value sound absorption. Aluminum wire structures comparable in weight to honeycombs ZPK, can find application as an acoustic cladding of gas-turbine engine tracts [1]. For now the use of MR as a sound absorber is very limited due to the high material cost.

From the point of view of acoustics, the use of honeycomb structures provides significantly In comparison with ZPM-based panels, the sound absorption efficiency in limited frequency range. Such sound absorber materials have a small weight, if applied non-combustible materials can work effectively in high temperature gas streams [2].

But the use of honeycomb structures is limited in that they have relatively narrow dianazonone effective sound absorption, therefore, to reduce noise having broadband nature, their use is inefficient. Also disadvantage honeycomb based structures is the high cost of honeycombs, due to sophisticated manufacturing technology, as well as low technological flexibility to changes for sound absorption parameters of material properties and geometric parameters of cellular structures [4]. For almost every type of material filler (steel, aluminum, brass, copper, titanium, paper, fiberglass, carbon fiber and other) requires its own technology and its own unique technological equipment.

It is almost impossible to manufacture cellular sound absorber materials from a combination of materials, for example, aluminum - steel, titanium - steel, aluminum - composite material. Exist problems associated with the removal of condensate from honeycomb structures.

Conclusions of chapter 1

One of the problems of gas turbine plants is the problem of noise reduction. Sources of noise are engine elements are compressor, combustion chamber, turbine, power turbine and output device.

Literature analysis showed that the important issue is the use of effective sound-absorbing materials not only in the cold part of the engine (at the engine inlet, in the compressor), but also in the hot part of the engine - the combustion chamber, turbines and the output device.

Therefore, the study of the characteristics of sound-absorbing materials for the hot part of the engine is an urgent issue.

CHAPTER 2

THERMOGASDYNAMIC CALCULATION OF GTE

2.1 Calculation of thermo-dynamic gas turbine plant

The aim of thermodynamic calculation is to determine the parameters of the working fluid flow in specific sections of the installation and power density, specific fuel consumption, the main gas turbine efficiency. For a given power and found specific air flow capacity is determined to install. The results of thermodynamic calculations used in the following gas-dynamic calculation to determine the geometric parameters of gas turbines and in general.

The necessary data for thermodynamic calculation are: gas temperature at the outlet of the combustion chamber Tg * degree increase in air pressure in the compressor π_k^*, shaft horsepower turbine power N_e.

Are established as settlement conditions - pressure and temperature of air at the inlet of gas turbines. If they are not addressed specifically, the calculation is performed to a standard atmospheric conditions: $p_н$ = 101,325 Pa; $T_н$ = 288 K.

Choice constructive scheme and main parameters for the installation process $T_г^*$ and $\pi_к^*$ based on an analysis of parameters performed attitudes and tendencies of their development.

Initial data

Initial data for thermodynamic and gas dynamic calculations:

H=0;

M_H=0 ($p^*_{h.p.}$=p_0=101.3 kPa, $T^*_{h.p.}$=T_0=288 K)

Main parameters of working process:

$T_н^*$=1300 K;

π_c=18;

η^*_c=0.98;

k=1.4; k_g =1.33;

R=287 J/kg*K;

$R_г$=288 J/kg*K;

N_e=10000 kW;

H_u=43000 kJ;

Calculation of low pressure compresor working body

Parameters of air in the station B-B(at the entrance to the GTP)

$p_B^* = \sigma_{BX}^* \, p^*_H$= 0.99*101300=100287 Pa;

$T_H^* = T_0$=288 K

where $\sigma_B = 0.99$ - Coefficient of regeneration of full pressure in air intake.

The definition of what is consumed to compress 1 kg of air in the compressor and options for air-to station K-K(at the outlet of the compressor)

$P_{LPC}^* = p_B^* * \pi^*_{LPC}$=100287*5.67=568600 Pa

$T_{LPC}^* = T_B^* + \frac{L_K}{\frac{k \cdot R}{k-1}}$=508

when η_{LPC}^*=0.84;

$L_{LPC} = \frac{k}{k-1} \times R \times (T_{LPC}^* - T_B^*) = \frac{1.4}{0.4}$*287*(508-288)=221000 J/kg

where k = 1,41, R = 288 J/(kg·К); $\eta^*_{с.к}$ = 0,84 – efficiency of stage of compressor .

Determination of high pressure compressor

Temperature and air pressure at the outlet of the compressor calculated as follows:

$p_{BBT}^* = \sigma_{ПД}^* \times p^*_{LPC}$=0.99*568600=562900 Pa;

$p_K^* = p_{BBT}^* \times \pi^*_{HPC}$=562900*3.18=1884000 Pa;

T_K^*=744.2 K;

$L_{LPC} = L_{HPC}$=221000 J/kg;

Calculation of combustion chamber:

Defining the working fluid in the station r-r (before the turbine)

$p_H^* = \sigma_{KC}^* \times p^*_K$=0.96×1884000=1813000 Pa;

The relative fuel in the combustion chamber is calculated as follows:

$$g_f = \frac{G_П}{G_{ВКЗ}} = \frac{C_П \times (T_B^* - T_K^*)}{\eta_Г \times H_U} = \frac{1280 \times (1300 - 744.2)}{0.97 * 43000} = 0.017;$$

where H_u – lower heat of combustion; $\eta_г$ – factor taking into account incompleteness of combustion and heat loss through the walls of the combustion chamber. $\eta_H = 0,97$.

For gaseous hydrocarbon fuels $H_u = 43 \cdot 10^6$ J/kg.

High pressure turbine:

The pressure at the outlet of the combustion chamber:

$p_H^* = 1813000$ Pa;

$T_H^* = 1300$ K;

$$T_{HPT}^* = T_H^* - \frac{L_{HPC}}{\frac{1.33}{0.33} \times R_Г \times (1 - g_{охл} - g_{вídв}) \times (1 + g_П) \times \eta_{mвт}};$$

$$T_{HPT}^* = 1300 - \frac{221000}{\frac{1.33}{0.33} \times 288 \times (1 - 0.035 - 0.02) \times (1 + 0.017) \times 0.99} = 1100\,K;$$

$g_{cool} = 0.035$;

where $g_{cooling}$ – the relative cost of air shown at the outlet of the compressor for cooling turbine parts; $g_s = 0.02$ - relative air flow that is selected for the technological needs of GTP; $\eta_{mc} = 0.99$ – mechanical efficiency turbocharger compressor.

Size $g_{cooling}$ established depending on the temperature at the outlet of the combustion chamber and the chosen method of cooling.

$$\Pi_{HPT}^* = \left[\frac{\eta_{ТВТ}^*}{\eta_{ТВТ}^* - (1 - \frac{T_{ТВТ}^*}{T_Г^*})}\right]^{\frac{1.33}{0.33}} = \left[\frac{0.9}{0.9 - (1 - \frac{1101}{1300})}\right]^{\frac{1.33}{0.33}} = 2.12$$

$$p_{HPT}^* = \frac{p_H^*}{\pi_{ТВТ}^*} = \frac{1713000}{2.13} = 804200\,Pa;$$

Determination of low pressure turbine

$$T_{LPT}^* = 1101 - \frac{221000}{\frac{1.33}{0.33} \times 288 \times (1 - 0.4 - 0.035 - 0.02) \times (1 + 0.017) * 0.99} = 900\,K;$$

$\pi_{LPT}^* = 2.46$;

$$p_{LPT}^* = \frac{p_{HPT}^*}{p_{THTLPT}^*} = \frac{804200}{2.46} = 326900\,Pa;$$

Determination of power turbine

Determination of the expansion of gas in the power turbine and gas parameters at the exit from it

$$L_e=\frac{к_г}{к_г-1}\times R_г\times T_{ТК}^*\times\left[1-\left(\frac{1}{\pi_{ТВЛ}^*}\right)^{\frac{0.33}{1.33}}\right]\times\eta_{ТВЛ}^*;$$

$$L_e=\frac{1.33}{0.33}\times 288\times 900\times\left[1-\left(\frac{1}{2.93}\right)^{\frac{0.33}{1.33}}\right]\times 0.92=225000\ J/kg;$$

where efficiency power turbine $\eta^*_{c.т}$ = 0,9 in the transition channel; σ_g = 0,99 pressure loss coefficient.

$$\pi_{ТВЛ}^*=\frac{p_{ТК}^*}{p_Т^*}=\frac{326900}{111430}=2.93;$$

$$p_Т^*=1.1\times p_Н=1.1\times 101300=1114300\ Pa;$$

The gas temperature at the outlet of the turbine:

$$T_Т^*=T_{ТК}^*-\frac{L_e}{\frac{1.33}{0.33}\times 288}=900-\frac{225000}{\frac{1.33}{0.33}\times 288}=706.2\ К;$$

Setting the value of the reduced rate within $\lambda_т$ = 0,625 determine the velocity of the gas at the outlet of the turbine, static temperature and pressure:

$$p_Т^*=p_{ТК}^*\times\left[1-\frac{1-\frac{T_Т^*}{T_{ТК}^*}}{\eta_{ТВЛ}^*}\right]^{\frac{1.33}{0.33}};$$

$$p_Т^*=326900\times\left[1-\frac{1-\frac{706.2}{900}}{0.92}\right]^{\frac{1.33}{0.33}}=111600\ Pa;$$

Calculation of basic parameters of gas turbine

Output device

$$C_C=\varphi\times\sqrt{2\times\frac{1.33}{0.33}\times 288\times 706.2\times\left[1-\left(\frac{101300}{111600}\right)^{\frac{0.33}{1.33}}\right]}=195.3\ m/s$$

where φ=0.99;

$$T_C^* = T_T^* - \frac{C_C}{\frac{1.33}{0.33} \times R_\Gamma} = 706.2 - \frac{195.3^2}{\frac{1.33}{0.33} \times 288} = 673.4 \text{ K};$$

Nominal hourly flow of gas consumption (Nm3 / h) for the current density of the gas

$$\rho_C = \frac{p_H}{R_\Gamma \times T_C} = \frac{101300}{288 \times 673.4} = 0.522;$$

$$N_{EKB} = N_e + {}^1/_\beta\,(C_C - V) = 10500 + {}^1/_{15} \times 195.3 = 10513\ kW;$$

$$C_C = \frac{G_\Pi}{N_{EKB}} = \frac{2082}{10513} = 0.198\ \text{кг}/(kW * h);$$

$$G_\Pi = 3600 \times g_f \times G_B \times (1 - g_{ОХЛ} - g_{ВІДБ}) = 3600 \times 0.017 \times 36 \times (1 - 0.035 - 0.02) = 2082\ kg/hour;$$

For a given air flow capacity of the installation of a compressor is determined by the expression: $G_B = \frac{N_e}{L_e} = \frac{10500 \times 10^3}{225000} = 46.7$ kg/s;

2.2 Calculation of gas-dynamic gas turbine plant

The aim is to determine gas-dynamic calculation diametric sizes in specific sections of flow of the installation, the number and frequency of rotor rotation, the number of stages of the compressor and turbine distribution of compression (expansion) between the stages and steps, refine your GTU.

As a result of input data used thermodynamic cycle calculation of the actual installation.

During the gas-dynamic calculation based on statistics made designs GTP selected axial velocity component in the air inlet compressor - CBA and angular velocity at the outer diameter of the impeller first stage compressor . These parameters largely determine the diametrical dimensions of the gas turbine, the number of degrees of compressor and turbine and axial dimensions and weight of the installation.

Definition of diametric size inlet compressor

Determination of low pressure compressor

Find the area of the flow at the inlet to the compressor

$F_B = \frac{G_B}{\rho \times C_{1a}} = \frac{46.7}{1.051 \times 180} = 0.247\, m^3$;

Where: $C_{1a} = C_{aв} = 180 \frac{m}{s}$;

$T_B = T_B{}^* - \frac{C_{aв}}{2 \times \frac{1.4}{0.4} \times 287} = 272$ K;

p_B=82104 Pa;

ρ_B=1.051 kg/m^3;

Choose relative diameter impeller hub $\bar{d}_в = 0.4$ and determine the outer diameter of the impeller inlet compressor.

Rounding the value found D_{shroud}, calculate the diameter of the sleeve and the average diameter:

$D_{B.K.} = \sqrt{\frac{4 \times F_B}{\pi \times (1 - d_{BTB}{}^2)}} = \sqrt{\frac{4 \times 0.247}{\pi \times (1 - 0.4^2)}} = 0.612\, m$;

$h_B = \frac{D_{B.K.} \times (1 - d_{BTB}{}^2)}{2} = \frac{0.612 \times (1 - 0.4)}{2} = 0.184\, m$;

$D_{B.BT.} = D_{B.K.} \times d_{BT.B.} = 0.612 \times 0.4 = 0.245\, m$;

Parameters flow at the outlet of LPC:

$T_{LPC} = T_{LPC}{}^* - \frac{C_{LPC}{}^2}{2 \times \frac{1.4}{0.4} \times R} = 508 - \frac{130^2}{2 \times \frac{1.4}{0.4} \times 287} = 500$ K;

$P_{LPC} = p_{LPC}{}^* \times (\frac{T_{KHT}}{T_{KHT}{}^*})^{\frac{1.4}{0.4}} = 568600 \times (\frac{500}{508})^{\frac{1.4}{0.4}} = 537900\, Pa$;

$P_{LPC} = \frac{p_{LPC}}{R \times T_{LPC}} = \frac{537900}{287 \times 500} = 3.75\, kg/m^3$;

$F_{LPC} = \frac{G_B}{\rho_{LPC} \times C_{LPC}} = \frac{46.7}{3.75 \times 130} = 0.096\, m^2$;

Scheme D_{BT}=const:

$D_{LPC.K.} = \sqrt{D_{B.BT.}{}^2 + \frac{4 \times F_{LPC}}{\pi}} = \sqrt{0.245^2 + \frac{4 \times 0.096}{3.14}} = 0.427\, m$;

Number of stages of LPC:

$L_{CT} = \Delta$

$W_{u\,BT} \times U_{BT1} = \Delta W \times U_{BT} \times (U_{K1} \times d_{BT1}) = 140 \times (370 \times 0.4) = 20650 \frac{J}{kg}$;

$\Delta W_{u\,BT}$=140 м/с;

$L_{CP.CT.}=1.35\times L_{CT1} = 1.35\times 20650 = 27877.5\frac{J}{kg}$;

$Z_{LPC}=1+\frac{L_{LPC}-L_{CT1}}{L_{CT.CP.}} = 1+\frac{221100-20650}{27877.5} = 7.187\approx 7$;

$N_{LPC}=G_a\times L_{LPC} = 46.7\times 221000 = 10320700\ W$;

Calculation of high pressure compressor:

$p_{BBT}=p_{LPC}{}^{*}\times\sigma_{C-B}\times(\frac{T_{LPC}}{T_{LPC}{}^{*}})^{\frac{1.4}{0.4}} = 568600\times 0.99\times(\frac{500}{508})^{\frac{1.4}{0.4}} = 532500\ Pa$;

$T_{BBT}=T_{LPC}=500$ K;

$P_{LPC}=\frac{p_{BBT}}{R\times T_{BBT}} = \frac{532500}{287\times 500} = 3.71\frac{kg}{m^3}$;

We set $F_{BBT}=F_{LPC}=0.096\ m^2$;

$D_{BBT.BT.}=\sqrt{\frac{4\times F_{BBT}}{\pi\times(1-d_{BT.BBT.}{}^2)}} = \sqrt{\frac{4\times 0.096}{\pi\times(1-0.7^2)}} = 0.49\ m$;

$D_{BBT.K.}=\frac{D_{BBT.BT.}}{d_{BT.BBT.}} = \frac{0.49}{0.7} = 0.7\ m$;

$h_{BBT}=\frac{D_{BBT.K.}-D_{BBT.BT.}}{2} = \frac{0.7-0.49}{2} = 0.105\ m$;

On output from HPC:

$c_C=100$ m/s;

$T_K= T_K{}^{*}-\frac{C_K{}^2}{2\times\frac{1.4}{0.4}\times R} = 744.2-\frac{100^2}{2\times\frac{1.4}{0.4}\times 287} = 739.2$ K;

$p_K= p_K{}^{*}\times\left(\frac{T_K}{T_K{}^{*}}\right)^{\frac{1.4}{0.4}} = 1784000\times\left(\frac{739.2}{744.2}\right)^{\frac{1.4}{0.4}} = 1742000\ Pa$;

$\rho_K=\frac{p_K}{R\times T_K} = \frac{1742000}{287\times 739.2} = 8.21\ kg/m^3$;

For scheme D_{BT}=const:

$D_{HPC}=\sqrt{D_{KBT.K.}{}^2+\frac{4\times F_K}{\pi}} = \sqrt{0.7^2+\frac{4\times 0.057}{3.14}} = 0.646\ m$;

$h_{BBT}=\frac{D_{K.K.}-D_{KBT.}}{2} = \frac{0.7-0.646}{2} = 0.027\ m$;

$c_{HPC}=130$ m/s;

$U_{BBT.K.} = 480\frac{m}{s}$;

$U_{BBT.BT.} = U_{BBT.K.}\times d_{BT.BBT.} = U_{BBT.K.}\times\frac{D_{BT.BBT.}}{D_{BBT.K.}} = 480\times\frac{0.49}{0.7} = 336\frac{m}{s}$;

In case D_{BT}=const:

$U_{ВВТ.ВТ.} = U_{К.ВТ.}$

$$L_{еф.1ст.HPC.} = \Delta W_{u\,ВТ} \times U_{ВВТ.ВТ.} = 100.75 \times 336 = 33850 \frac{L}{kg};$$

$$\Delta W_{u\,ВТ} = 100.75 \frac{m}{s};$$

$$L_{ср.ст.HPC.} = \Delta W_{u\,ВТ} \times U_{К.ВТ.} = 77 \times 443 = 34110 \frac{J}{kg};$$

where $\Delta W_{u\,ВТ} = 77 \frac{m}{s}$;

$$U_{К.ВТ.} = U_{ВВТ.К.} \times \frac{D_{К.ВТ.}}{D_{ВВТ.К.}} = 480 \times \frac{0.646}{0.7} = 443 \frac{m}{s};$$

$$L_{еф.ср.ст.HPC.} = 0.5 \times (33850 + 34110) = 33980 \frac{J}{kg};$$

$$Z_{HPC} = \frac{L_{HPC}}{L_{еф.ср.ст.HPC.}} = \frac{221000}{33980} = 7.504 \approx 8;$$

$$n_{HPC} = \frac{60 \times U_{HPC}}{\pi \times D_{К.ВТ.}} = \frac{60 \times 480}{3.14 \times 0.7} = 13100\, rpm;$$

Calculation of combustion chamber:

$$V_{CC} = \frac{G_{П.ГОД.} \times \eta_Г \times H_U}{q_{CC} \times p_К^*} = \frac{2082 \times 0.97 \times 43 \times 10^7}{4.3 \times 10^6 \times 1784000} = 0.011\, m^3;$$

$$V_{CC\,max} = \frac{G_В}{c_{CP} \times \rho_К} = \frac{46.7}{8.21 \times 40} = 0.142\, m^2;$$

$G_{П.ГОД.} = 2082$

when $D_{зовн.CC} = 1.1 \times D_{К.К.} = 1.1 \times 0.7 = 0.77\, m$;

$$D_{ВН.CC} = \sqrt{0.77^2 - \frac{4 \times 0.142}{3.14}} = 0.642\, m;$$

$$h = \frac{0.77 - 0.642}{2} = 0.064\, m;$$

Definition of diametric size inlet turbine compressor and the number of stages

Square the previous section of the flow at the outlet of the first nozzle device are as follows:

where $G_г$ – flow gas turbine; $\sigma_{к.з} = 0{,}87$; $\sigma_{c.a} = 0{,}985$– loss factor full pressure nozzle apparatus; $m_г = 0{,}0396$; $q(\lambda_г)$ – feature flux density, $\alpha_1 = 15°$.

As a first stage turbine always supercritical pressure drop, the $\lambda_г = 1$, $q(\lambda_г) = 1$.

Consumption of gas turbine

$$G_T = G_K \cdot (1 + g_{combution}) \cdot (1 - g_{cooling} - g_s) = 36 \cdot (1 + 0.017) \cdot (1 - 0.035 - 0.02) = 34.598$$

$$F_{r.ca} = \frac{G_T \cdot \sqrt{T_r^*}}{p_r^* \cdot \sigma_{ca} \cdot \sigma_{kz} \cdot q(\lambda_r) \cdot m_r \cdot sin(\alpha)} = \frac{34.598 \cdot \sqrt{1300}}{1713000 \cdot 0.99 \cdot 0.96 \cdot 0.0396 \cdot 0.259} = 0.075 m^2$$

$$D_{r.av} = 1.1 \cdot D_{shroud} = 0.595\, m;$$

$$h_T = \frac{F_{r.ca}}{3.14 \cdot D_{r.av}} = \frac{0.075}{3.14 \cdot 0.595} = 0.040\, m;$$

$$D_{r.shroud} = D_{r.av} + h_T = 0.595 + 0.040 = 0.635\, m;$$

$$D_{r.shroud} = 0.7\, m;$$

$$D_{r.hub} = D_{r.av} - h_T = 0.595 - 0.040 = 0.555\, m.$$

$$u_{r.av} = u_{hub} \cdot \frac{D_{r.av}}{D_{r.shroud}} = 300 \cdot \frac{0.595}{0.635} = 297.500 \frac{m}{s}.$$

Number of steps turbines:

y=0.6

$$z_{turbine} = \frac{2 \cdot y^{*2} \cdot L_{TK}}{\eta_{TK}^* \cdot u_{r.av}{}^2} = \frac{2 \cdot 0.6^2 \cdot 464551.978}{0.99 \cdot 297^2} = 4.153 => 4.$$

The definition of Diametric sizes and number of stages of turbines of high and low pressure.

To determine the geometric dimensions between HPT and LPT firstly determine their L_{HPT} i L_{LPT} :

$$L_{HPT} = \frac{L_{HPC}}{[(1+g_{combution})\cdot(1-g_{cooling}-g_s)]} = \frac{221000}{[(1+0.02)\cdot(1-0.035-0.02)]} = 2.323*10^5 J/kg;$$

$L_{LPT} = L_{TK} - L_{THP} = 2.323*10^5$ J/kg;

Temperature $T^*_{гн}$ and pressure $p^*_{гн}$ after LPT determine by formula:

$$T^*_{ГН} = T^*_r - L_{HPT}\cdot\frac{k_r-1}{k_r\cdot R_r} = 1300 - 2.323*10^5\cdot\frac{1.33-1}{1.33\cdot 288} = 1.1*10^3 K;$$

$$P^*_{ГН} = P^*_r\cdot\left[1-\frac{(T^*_r - T^*_{ГН})}{\eta^*_{т.в}\cdot T^*_r}\right]^{\frac{k_r}{k_r-1}} = 8.401*10^5 Pa$$

The cross-sectional area of the nozzle cascade inlet LPT determine by formula:

$$F^*_{ГН} = \frac{G_T\cdot\sqrt{T^*_{ГН}}}{m_r\cdot\sigma_p\cdot P^*_{ГН}\cdot q(\lambda_{ГН})\cdot sin\alpha_1} = \frac{81.54\cdot\sqrt{1.1*10^3}}{0.0396\cdot 0.98\cdot 8.401*10^5\cdot sin20^\circ} = 0.136\ m^2;$$

where $m_r = 0{,}0396$; $\sigma_p = 0{,}98$; $q(\lambda_{гн}) = 1$; $\alpha_1 = 20^\circ$.

The height of the blades at the turbine inlet of a high pressure

$h_т = F_{гн}/(3{,}14 D_{г.сер})=0{,}073$ m;

Outer diameter at the entrance to high pressure turbine

$D_{г.shroud} = D_{г.midle} + h_г=0{,}595+0{,}073=0{,}668$ m;

Hub diameter at the entrance to high pressure turbine

$D_{т.hub} = D_{г.midle} - h_г$=0,595-0,073=0,522 m;

Determined the approximate number of steps

$$Z_{HPT} = \frac{2 \cdot Y^{*2} \cdot L_{тв}}{\eta^*_{тв} \cdot U^2_{твсер}} = \frac{2 \cdot 0{,}6^2 \cdot 2.323*10^5}{0{,}95 \cdot 297.5^2} = 1{,}989;$$

$$Z_{LPT} = \frac{2 \cdot Y^{*2} \cdot L_{тн}}{\eta^*_{тн} \cdot U^2_{тнсер}} = \frac{2 \cdot 0{,}6^2 \cdot 2.323*10^5}{0{,}92 \cdot 350^2} = 2{,}054.$$

Determination of power turbine

$$T_T = \frac{T_T^*}{\left(1 + \frac{K_Г - 1}{2} \times M_T^2\right)} = \frac{706.2}{\left(1 + \frac{0.33}{2} \times 0.3^2\right)} = 696\,К;$$

$$p_T = p_T^* \times \left(\frac{T_T}{T_T^*}\right)^{\frac{1.33}{0.33}} = 111600 \times \left(\frac{696}{706.2}\right)^{\frac{1.33}{0.33}} = 105200\,Pa;$$

$$\rho_T = \frac{p_T}{R_Г \times T_Г} = \frac{105200}{288 \times 696} = 0.525\,kg/m^3;$$

$$c_T = M_T \times \sqrt{K_Г \times R_Г \times T_T} = 0.3 \times \sqrt{1.33 \times 288 \times 696} = 155\frac{m}{s};$$

$$F_T = \frac{G_{В.Р.} \times (1 + g_a) \times (1 - g_{відб})}{c_T \times \rho_T} = \frac{68.49 \times (1 + 0.017) \times (1 - 0.02)}{155 \times 0.525} = 0.572\,m^2;$$

when $D_{Т.ВТ.} = 1.05 \times D_{К.К.} = 0.735\,m$;

$$D_{Т.К.} = \sqrt{D_{Т.ВТ.}^2 + \frac{4 \times F_{Т.}}{\pi}} = \sqrt{0.735^2 + \frac{4 \times 0.572}{3.14}} = 1.126\,m;$$

$$h_T = 0.5 \times (1.126 + 0.735) = 0.195\,m;$$

$$U_{ТВ.СР.} = 250\frac{m}{s};$$

$$H_{ТВЛ} = \frac{L_e}{U_{ТВ.СР.}^2} = \frac{225000}{250^2} = 3.6$$

We set $H_{СТ} = 1.5$:

$$Z_{\text{т.вл.}} = \frac{3.6}{1.5} = 2.4 \approx 2;$$

Table 2.1- Results of thermodynamic and gas-dynamic calculation are represented in table

Elements of GTE	G , kg/s	N , kW	Section	P^*, kPa	T^*, K	D, m	D_{sl}, m	h_{bl}, m
LPC	46.7	1032.7	In	100.287	288	0.612	0.245	0.184
			Out	568.6	508	-	0.427	0.105
HPC	46.7	1032.7	In	562.9	508	0.49	0.7	0.105
			Out	1884	744.2	0.49	0.646	0.027
HPT	34.59	8037.115	In	1813	1300	0.635	0.555	0.04
			Out	804	1100	0.635	0.555	0.04
LPT	81.54	8037.115	In	804	1100	0.668	0.522	0.073
			Out	326.9	900	0.668	0.522	0.073
PT	68.49	15410.25	In	326.9	900	0.668	0.522	0.073
			Out	111.6	706.2	0.735	1.126	0.195

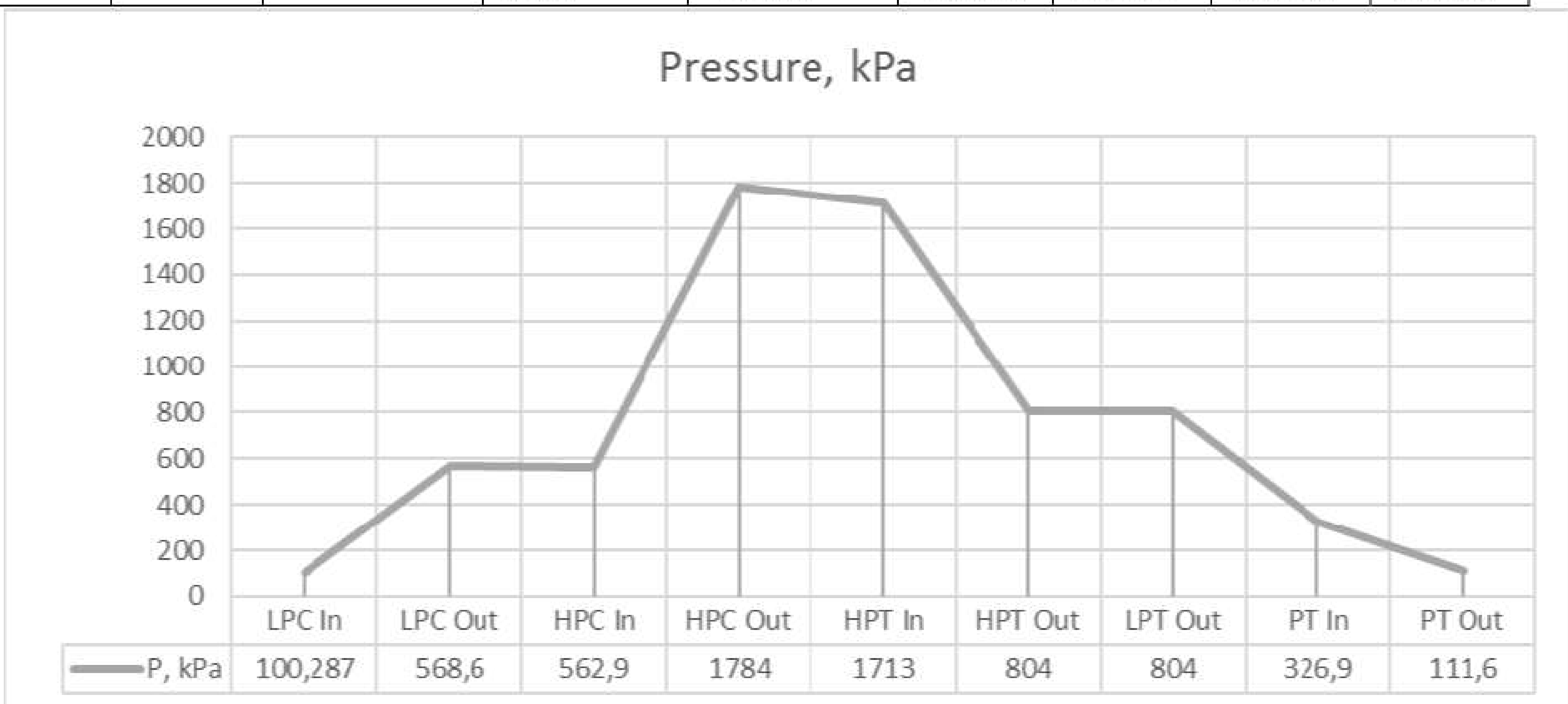


Figure 2.1 - Results of thermodynamic and gas-dynamic are represented in the graph

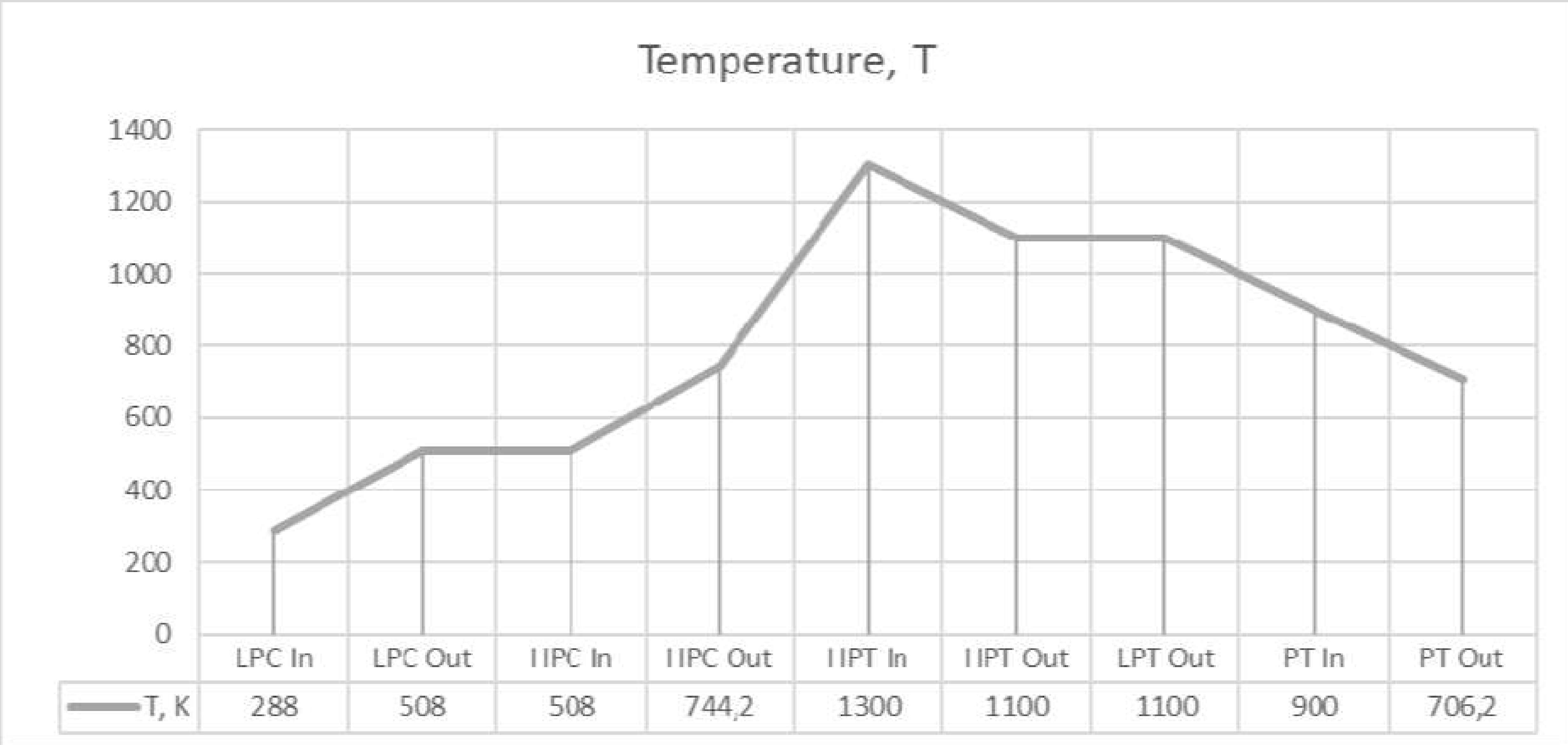


Figure 2.2 - Results of thermodynamic and gas-dynamic are represented in the graph

Strength calculation of basic elements of power turbine

The aim of gas dynamic calculation of turbine stage is to determine geometrical characteristics of turbine blades in 3 sections (root, middle and tip section).

Gas-dynamic calculation of power turbine stage.

Gas temperature before the turbine: $T^*_{hpt} = T^*_g = 1000\,K$

Gas pressure at rotor inlet: $p^*_{hpt} = 105.2\,kPa$

Gas flow rate: $G_g = 68.49\,kg/s$

Middle section circumferential velocity: $u_{hpt.mean} = 250\,m/s$

Reduced velocity at the exit of nozzle diaphragm: $\lambda_1 = 1.103$

Angle of gas flow at the exit of nozzle diaphragm: $\alpha_1 = 14°$

Mean diameter before the rotor: $D_{t.mean} = 1.126\,m$

Geometrical dimension of stage at the inlet

$$q_{\lambda_1} = \left(\frac{k_g+1}{2}\right)^{\frac{1}{k_g-1}} \cdot \lambda_1 \cdot \left(1 - \frac{k_g-1}{k_g+1} \cdot {\lambda_1}^2\right)^{\frac{1}{k_g-1}} = 0.9878$$

$$F_1 = \frac{G_g \cdot \sqrt{T_g^*}}{m_g \cdot p_{hpt}^* \cdot q_{\lambda_1} \cdot sin\alpha_1} = 0.572\, m^2$$

Blade height:

$$h_1 = \frac{F_1}{\pi \cdot D_{t.mean}} = 0.195\, m$$

Outer diameter of the rotor:

$$D_{1.rotor} = D_{t.mean} + h_1 = 1.321\, m$$

Sleeve diameter:

$$D_{1.sl} = D_{t.mean} - h_1 = 0.931\, m$$

Relative sleeve diameter:

$$d_{1.sl} = \frac{D_{1.sl}}{D_{1.rotor}} = 0.9114$$

Temperature and pressure in the section:

$$T_2^* = T_g^* + \frac{k_g - 1}{k_g} \cdot \frac{L_{hpt}}{R_g} = 806.1\, K$$

$$p_2^* = p_c^* \cdot \sigma_{cc} \cdot \left(1 - \frac{T_g^* - T_2^*}{T_g^* \cdot \eta_{hpt}^*}\right)^{\frac{k_g}{k_g - 1}} = 95407.364\, Pa$$

Axial velocity at the exit from the rotor:

$$\Delta C_a = 40\, m/s$$

$$C_{1a} = 196.59\, m/s$$

$$C_{2a} = 230\, m/s$$

$$C_{2u} = 0\, m/s$$

Reduced velocity:

$$\lambda_{C_{2a}} = \frac{C_{2a}}{\sqrt{2 \cdot \frac{k_g}{k_g + 1} \cdot R_g \cdot T_2^*}} = 0.3502$$

Relative density of flow:

$$q_{\lambda_{C_{2a}}} = \left(\frac{k_g + 1}{2}\right)^{\frac{1}{k_g - 1}} \cdot \lambda_{C_{2a}} \cdot \left(1 - \frac{k_g - 1}{k_g + 1} \cdot \lambda_{C_{2a}}{}^2\right)^{\frac{1}{k_g - 1}} = 0.5275$$

Area of gas channel at the rotor exit:

$$F_2 = \frac{G_g \cdot \sqrt{T_2^*}}{m_g \cdot p_2^* \cdot q_{\lambda_{c_{2a}}}} = 0.593\, m^2$$

According to chosen law of profiling, find the characteristic sectional dimensions.

Blade height:

$$h_2 = \frac{F_2}{\pi \cdot D_{t.mean}} = 0.203\, m$$

Inner diameter:

$$D_{2.sl} = D_{1.sl} = 0.931\ m$$

Outer diameter:

$$D_{2.rotor} = D_{2.sl} + 2 \cdot h_2 = 1.337\, m$$

Relative sleeve diameter:

$$d_{2.sl} = \frac{D_{2.sl}}{D_{2.rotor}} = 0.901$$

Circumferential velocity on three radii is equal to:

$$u_i = u_{hpt.mean} \cdot \frac{D_i}{D_{t.mean}} = \begin{bmatrix} 474.639 \\ 497.717 \\ 523.781 \end{bmatrix} m/s$$

Stage loading coefficient:

$$\mu_i = \frac{L_{hpt}}{u_i^{\,2}} = \begin{bmatrix} 1.7 \\ 1.6 \\ 1.4 \end{bmatrix}$$

Absolute and reduced velocity at the exit of ND is found at condition of gas axial exit (on the mean radius):

$$c_{1.mean} = \frac{L_{hpt}}{u_1 \cdot cos\,\alpha_1} = 812.619\, m/s$$

$$\lambda_{c_{1.mean}} = \frac{c_{1.mean}}{\sqrt{2 \cdot \frac{k_g}{k_g + 1} \cdot R_g \cdot T_g^*}} = 1.1033$$

Axial component of absolute velocity before rotor (on the mean radius):

$$c_{1a.mean} = c_{1.mean} \cdot sin\,\alpha_1 = 196.59\, m/s$$

$$c_{1a.mean} = \frac{c_{1a.mean}}{u_1} = 0.395$$

$$c_{1ai} = c_{1a.mean} = \begin{bmatrix} 196.59 \\ 196.59 \\ 196.59 \end{bmatrix} m/s$$

Circumferential components of absolute velocity at the entrance and exit of rotor (on the mean radius):

$$c_{1u.mean} = c_{1.mean} \cdot cos\, \alpha_1 = 788.481\, m/s$$

$$c_{1ui} = c_{1u.mean} \cdot \frac{D_{t.mean}}{D_i} = \begin{bmatrix} 826.82 \\ 788.48 \\ 749.24 \end{bmatrix} m/s$$

$$c_{um} = \frac{c_{1u.mean} - c_{2u}}{2} = 394.24\, m/s$$

Absolute and reduced velocity at the exit of ND:

$$c_{1i} = \sqrt{c_{1ai}^2 + c_{1ui}^2} = \begin{bmatrix} 849.87 \\ 812.62 \\ 774.61 \end{bmatrix} m/s$$

$$\lambda_{c_{1i}} = \frac{c_{1i}}{\sqrt{2 \cdot \frac{k_g}{k_g + 1} \cdot R_g \cdot T_g^*}} = \begin{bmatrix} 1.1539 \\ 1.1033 \\ 1.0517 \end{bmatrix}$$

Relative gas velocity and its circumferential component before the rotor:

$$W_{1ui} = c_{1ui} - u_i = \begin{bmatrix} 352.18 \\ 290.76 \\ 225.46 \end{bmatrix} m/s$$

$$W_{1i} = \sqrt{c_{1ai}^2 + W_{1ui}^2} = \begin{bmatrix} 403.334 \\ 350.986 \\ 299.135 \end{bmatrix} m/s$$

$$\alpha_{1i} = tan^{-1}\left(\frac{c_{1ai}}{c_{1ui}}\right) = \begin{bmatrix} 13.375 \\ 14 \\ 14.702 \end{bmatrix} deg$$

Angle of gas entrance into rotor in relative motion:

$$\beta_{1i} = tan^{-1}\left(\frac{c_{1ai}}{W_{1ui}}\right) = \begin{bmatrix} 26.98 \\ 30.73 \\ 35.64 \end{bmatrix} deg$$

Reduced velocity of gas at the exit of rotor:

$$\lambda_{c_2} = \frac{c_{2a}}{\sqrt{2 \cdot \frac{k_g}{k_g + 1} \cdot R_g \cdot T_2^*}} = 0.3502$$

Angle of gas discharge from rotor in relative motion:

$$\beta_{2i} = tan^{-1}\left(\frac{c_{2a}}{c_{2u} + u_i}\right) = \begin{bmatrix} 25.85 \\ 24.8 \\ 23.71 \end{bmatrix} deg$$

Determine absolute and relative velocities at the exit from rotor and its circumferential component:

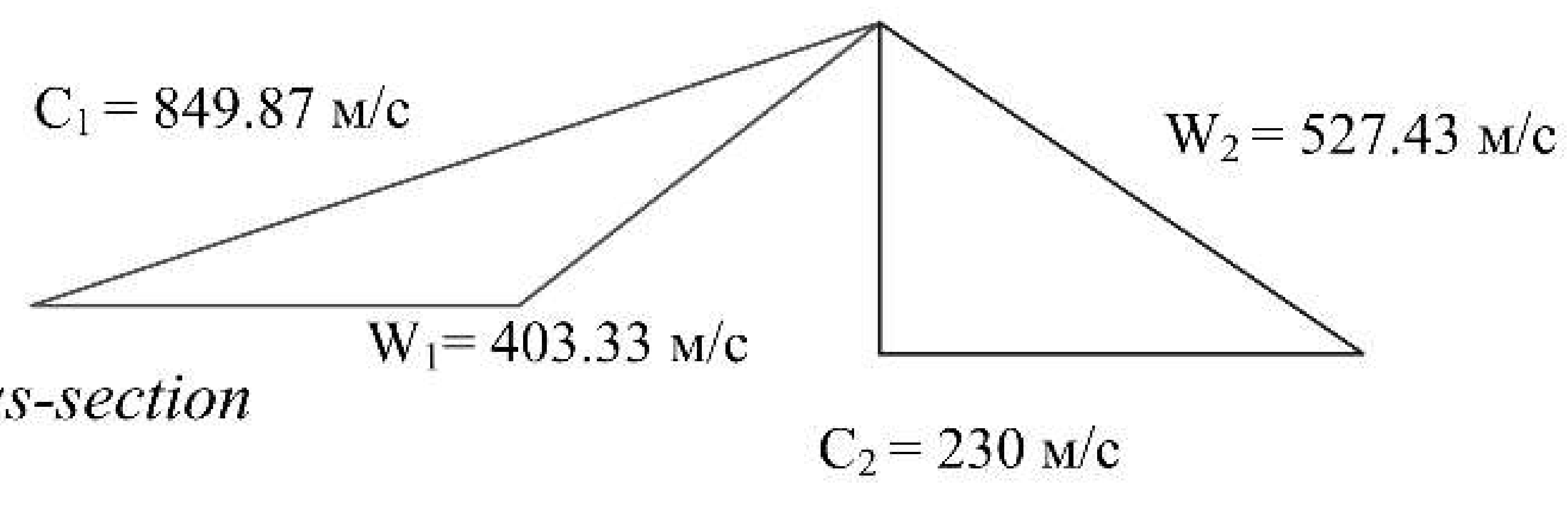
$$c_{2i} = \sqrt{c_{2a}^2 + c_{2u}^2} = 230\, m/s$$

$$\alpha_{2i} = 90°$$

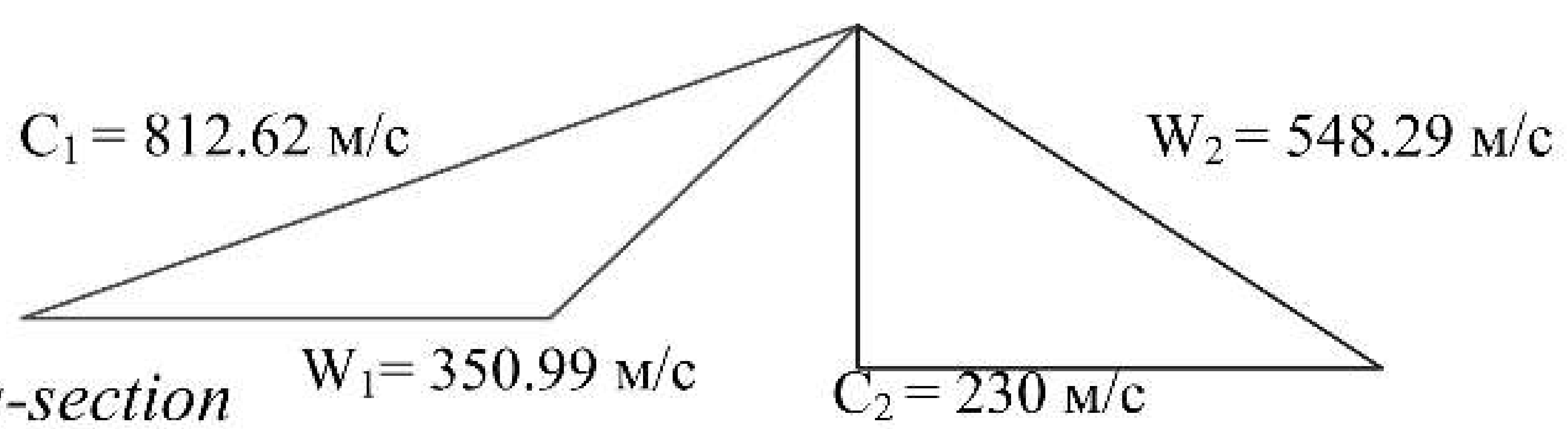
$$W_{2i} = \frac{c_{2a}}{sin\,\beta_{2i}} = \begin{bmatrix} 527.43 \\ 548.29 \\ 572.05 \end{bmatrix} m/s$$

$$W_{2ui} = W_{2i} \cdot cos\,\beta_{2i} = \begin{bmatrix} 474.639 \\ 497.717 \\ 523.781 \end{bmatrix} m/s$$

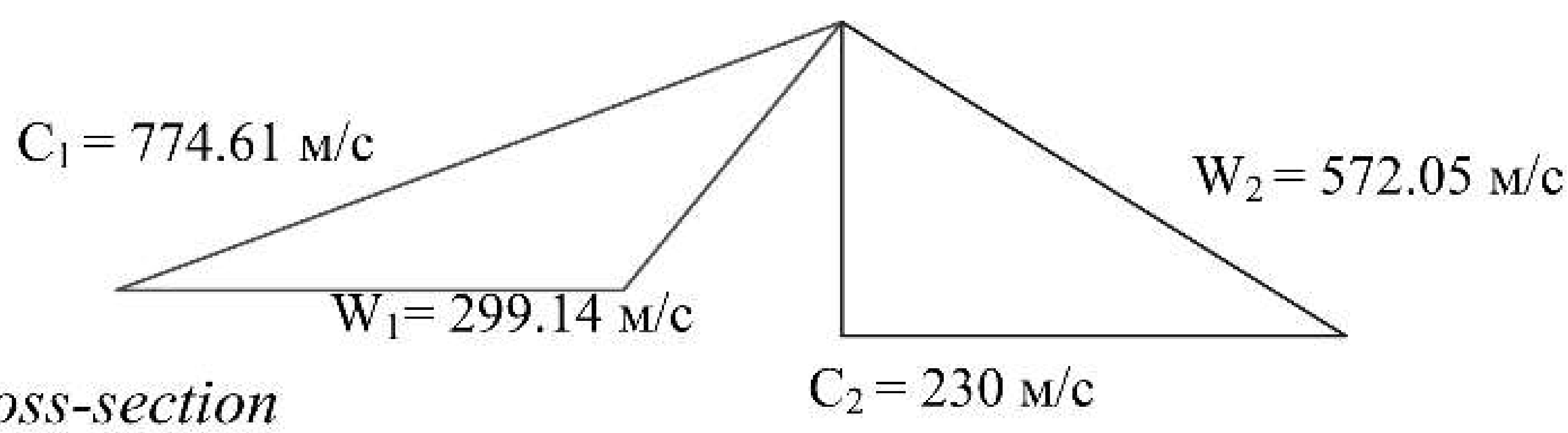
Constructing the triangles of velocity in the considered cross-sections on the PT blade height:



Root cross-section



Mean cross-section



Outer cross-section

Static temperature of flow:

$$T_{W_i} = T_g^* + \frac{k_g - 1}{2 \cdot k_g \cdot R_g} \cdot \left(c_{1i}^2 + W_{1i}^2\right) = \begin{bmatrix} 1408.9 \\ 1418.6 \\ 1430.1 \end{bmatrix} K$$

Air swirl in the rotor:

$$\Delta W_{u_i} = W_{1u_i} + W_{2u_i} = \begin{bmatrix} 826.82 \\ 788.48 \\ 749.24 \end{bmatrix} m/s$$

Reduced velocities at the entrance and exit of the rotor:

$$\lambda_{W_{1i}} = \frac{W_{1_i}}{\sqrt{2 \cdot \frac{k_g}{k_g + 1} \cdot R_g \cdot T_{W_i}}} = \begin{bmatrix} 0.592 \\ 0.5134 \\ 0.4358 \end{bmatrix}$$

$$\lambda_{W_{2i}} = \frac{W_{2_i}}{\sqrt{2 \cdot \frac{k_g}{k_g + 1} \cdot R_g \cdot T_{W_i}}} = \begin{bmatrix} 0.7742 \\ 0.8021 \\ 0.8335 \end{bmatrix}$$

Degree of kinematic reactivity is found by the formula:

$$\rho_{k_i} = 1 - \frac{c_{1ui}}{u_i} + \frac{\Delta W_{u_i}}{2 \cdot u_i} = \begin{bmatrix} 0.129 \\ 0.208 \\ 0.285 \end{bmatrix}$$

The stage work can be checked by the formula:

$$L_{st_i} = \frac{1}{2} \cdot \left(c_{1i}^2 - c_{2a}^2 + W_{2i}^2 - W_{1i}^2\right) = 392.4406\, kJ/kg$$

Take relative lattice density of rotor on the mean radius $z_{rotor} = 0.9$, parameter $h_{bl1.rel} = 2$ and determine profile chord and lattice density of the rotor:

$$b_{rotor} = \frac{h_1}{h_{bl1.rel}} = 0.01801\, m$$

$$t_{rotor.mean} = b_{rotor} \cdot z_{rotor} = 0.01621\, m$$

Determine blade quantity of the rotor:

$$z_{rotor} = \pi \cdot \frac{D_{t.mean}}{t_{rotor.mean}} = 150.5615$$

The number of blades is approximated to closest integer z and recalculate:

$$t_{rotor.mean} = \pi \cdot \frac{D_{t.mean}}{z_{rotor}} = 0.01621\, m$$

Determine the angle of curvature of leading edge, by setting the flow lag angle to $\delta = -4°$:

$$\beta_2' = \beta_{21} + \delta = 20.8021°$$

Determine the angle of incidence of leading edge, by setting the angle of attack to $i' = -2°$:

$$\beta_1' = \beta_{11} + i' = 32.0633°$$

Angle of profile curvature is calculated by the formula:

$$\Theta' = 180 - (\beta_1' + \beta_2') = 127.1346°$$

Determine angles of curvature of leading (χ_1) and trailing edges (χ_2), by setting the value of $\frac{a}{b}$:

$$a = 0.45\ and\ b = 1$$

$$\chi_1 = \frac{\Theta'}{2} \cdot \left[1 + 2 \cdot \left(1 - 2 \cdot \frac{a}{b}\right)\right] = 76.2807°$$

$$\chi_2 = \Theta' - \chi_1 = 50.8538°$$

Determine the angle of profile incidence:

$$\upsilon = 180 - (\beta_1' + \chi_1) = 71.6559°$$

Determine the blade width:

$$S' = b_{rotor} \cdot sin\,\upsilon = 0.01709\, m$$

The maximum profile thickness:

$$C_{max} = C_{max.rel} \cdot b_{rotor} = 0.0036\, m$$

Conclusion of chapter 2

This section presents the results of thermogasdynamic calculation of a gas turbine plant.

The aim of thermodynamic calculation is to determine the parameters of the working fluid flow in specific sections of the installation and power density, specific fuel consumption, the main gas turbine efficiency. For a given power and found specific air flow capacity is determined to install. The results of thermodynamic calculations used in the following gas-dynamic calculation to determine the geometric parameters of gas turbines and in general.

The aim is to determine gas-dynamic calculation diametric sizes in specific sections of flow of the installation, the number and frequency of rotor rotation, the number of stages of the compressor and turbine distribution of compression (expansion) between the stages and steps, refine your GTU.

CHAPTER 3

POROUS FIBROUS METAL MATERIAL FOR SOUND-ABSORBING STRUCTURES OF AERONAUS TEC

3.1 Introduction

In order to reduce the noise of the hot part of the engine, it is proposed to install porous fiber metal material in the engine under design as sound-absorbing structures. The results show the promise of using this material to effectively reduce noise in the combustion chamber, turbine, free turbine and exhaust device [8].

The problem of reducing aircraft noise is one of the main environmental problems of protecting the environment from aviation. The main source of noise during takeoff and landing is an aircraft engine. The development of effective sound-absorbing materials and sound-absorbing structures to reduce the noise level from aircraft engines is the subject of a number of works [9–11].

Porous metallic materials have long been widely used in power engineering, aviation, chemical, petroleum, food, metallurgy and other industries. Due to their absorbing properties due to the permeable structure, they are actively used as noise suppressors. In sound-absorbing structures, porous layers of perforated sheets with dense metal grids tightly adjacent to them are widely used. However, in acoustic terms, such porous layers are inferior to porous materials made of metal fibers with high absorbing properties, which are practically independent of the sound pressure level in the flow and provide noise reduction over a wide frequency range due to the effect of viscous friction.

Due to the attractiveness of porous fiber materials in terms of sound-absorbing properties, repeated attempts have been made to introduce them into the aircraft engine's sound attenuation system. Their practical application, however, encounters difficulties in ensuring the required operational characteristics - temperature, strength, corrosion resistance, etc. In addition, the density of the sound absorber materials for an aircraft engine is of great importance, which also imposes certain requirements when choosing a sound-absorbing material. Due to these reasons, in order to reduce noise propagating through the channels of an engine, sound-absorbing constructions are mainly used, including a perforated sheet and an air cavity behind it with a honeycomb core. Such designs belong to the resonant type of silencers. Usually they have high acoustic efficiency in a rather narrow frequency range not exceeding one octave, in contrast to porous homogeneous materials [12, 13].

The operational properties of a porous fiber metal material largely depend on the material from which the fibers are made. To ensure the operability of the FDA in the conditions of the hot section of aviation gas turbine engines, the fibers must be resistant to high-temperature oxidation and corrosion.

The most progressive method for producing metal fibers from heat-resistant and corrosion-resistant alloys is the metal-free casting of metal on a cooled surface. Its variety is the method of extraction of a hanging drop of melt, which makes it possible to produce fibers with specified sizes from most alloys, including refractory and chemically active metals.

At the same time as high heat resistance and corrosion resistance, the fibers for obtaining highly porous sound-absorbing materials must have strength and ductility, which allows pressing and rolling of porous fiber metal material and ensure the resistance of the material to the effects of high-speed gas flows.

Many well-known heat-resistant alloys containing a large amount of aluminum in their composition do not allow obtaining fibers with the necessary ductility. For example, VKNA-type alloys developed at based on NiAl and Ni3Al intermetallic compounds are characterized by high heat resistance and exceptional oxidation resistance at temperatures up to 1200 ° C, which made it possible to use them to obtain aviation gas-turbine engine parts operating at maximum temperatures [8, 14–16] . However, the fibers obtained from these alloys have practically zero ductility, which does not allow for change them as a starting material for the manufacture of porous fiber metal material [17].

The most widely used plastic fibers and high-temperature porous materials from them are alloys based on the Me – Cr – Al system, where Me: Fe, Ni, or Co. Such alloys with their additional alloying with rare-earth metals make it possible to produce fibers with a thickness of 15 microns or more, capable of withstanding temperatures up to 900 ° C and higher.

The main directions of the development of high-temperature porous fiber metal material in the world are: the development of new technologies for the production of fibers and porous materials from them with a high level of performance and low cost, as well as the search for alloys and protective coatings that increase the operating temperature of the porous fiber metal material [17–22].

3.2 Materials and methods

The heat resistance of thin metal fibers is the main factor determining the possibility of using porous fiber metal material in high temperature conditions. Due to the fact that the fibers for the manufacture of highly porous material with the highest acoustic efficiency and low density have a thickness of not more than 50 μm, they should be made of alloys with the highest heat resistance, combined with ductility and corrosion resistance.

When developing sound-absorbing porous fiber metal material, fibers were obtained using the method of extraction of a hanging melt drop. The essence of the method consists in melting the end face of a vertically arranged material rod and bringing the formed melt drop into contact with a rotating heat receiver. On the working edge of the latter, the material is cooled at a speed of up to a million degrees per second and solidifies in the form of a fiber 30–150 μm thick with the formation of a microcrystalline and amorphous structure.

Due to the ultra-high cooling rates, the resulting materials have improved mechanical characteristics and exceptional structural uniformity. Melting the material in a non-contact way, along with the possibility of using an inert atmosphere or vacuum, ensures the purity of the resulting material and the stability of its chemical composition.

By the extraction of a hanging drop of melt method, MATI obtained fibers from corrosion-resistant steel, nichrome and other heat-resistant alloys, which made it possible to develop materials with operating temperatures up to 750 ° C.

A characteristic feature of porous fiber materials is their highly developed surface. It is difficult to accurately determine the specific surface area of these materials; therefore, existing methods for evaluating the heat resistance of these materials are not applicable [23].

The method for determining the heat resistance of porous fiber materials is based on determining the relative change in the mass of a sample when exposed to temperature for a certain period of time in an air atmosphere. In the development of sound-absorbing porous fiber metal material, in addition to heat resistance, laboratory studies of their sound absorption coefficient, corrosion resistance, density and porosity were carried out.

Studies of the corrosion properties of porous fiber metal materials included tests in salt spray chambers and tropical climates, tests for sulfide-oxide, chloride corrosion, etc.

The sound absorption coefficient (α) was determined by the two-microphone method, also called the transfer function method, using an impedance pipe in the frequency ranges from 100 to 10,000 Hz.

3.3 Results

As a result of work on the creation of a porous fiber metal material for high-temperature acoustic liners, a number of materials made of metal fibers were developed [1]. Materials with conventional marks ShV-1, ShV-2 and ShV-3 are distinguished by technologies for their preparation, density, porosity, and operating temperatures. All materials have passed bench tests and are ready for testing as part of full-scale products.

Initially, when creating a porous fiber-absorbing sound-absorbing material, they developed a technology for producing material of the ShV-1 brand using the methods used in powder metallurgy. From the fibers of corrosion-resistant steel with a thickness of 20–40 μm and a length of 200–1500 mm, manufactured by the extraction of a hanging drop of melt method, we obtained a porous material for sound absorber materials at operating temperatures of 400–500 ° C.

The technological scheme for obtaining porous fiber metal material included:

- manufacture of metal fiber;
- the formation of blanks in molds;
- sintering of billets in vacuum furnaces;
- cutting blanks;
- soldering of blanks to a metal base.

According to the above scheme, porous fiber metal material panels were manufactured with a size of 250 × 400 mm, a thickness of 2, 6, and 10 mm and a porosity of 70 and 90%.

To study the acoustic efficiency of porous fiber metal material -based panels made of corrosion-resistant steel fibers, in the frequency range 800–10000 Hz with the number M = 0.35–0.4 (h) Mach islo - the ratio of the flow velocity to the speed of sound) and the sound pressure level of 110–150 dB. As a result of studies, it was found that porous fiber metal material panels based on fibers of corrosion-resistant steel are quite broadband with a uniform absorption spectrum. So, in the frequency range of three octaves wide (1000–6300 Hz), the average efficiency of a two-sided cladding is 1.1–2.2 dB.

In the future, for working temperatures up to 600 ° C and above, a porous fiber metal material was developed for acoustic liners of the ShV-2 brand based on nichrome (X20H80) fibers with a thickness of 20–40 μm and a length of at least 500 mm.

To obtain porous fiber metal material from nichrome fibers, a technology for producing panels using combing methods, needle-punched processing of fiber mass and subsequent sintering has been developed in conjunction with the Scientific Center for Powder Materials Science.

The proposed technology allows to obtain permeable materials with a given porosity and parameters of the pore structure, eliminating the pressing process, and the use of needle-punched processing carried out on a needle-punching device, provides high mechanical strength of the finished material by additional bonding of the FDA to the individual fibers constituting it, and also allows fixing one canvas to another, thereby increasing the thickness of the final sheet, and change its density layer by layer.

Porous fiber metal material panels made of X20H80 alloy fibers are shown in Fig. 1.

The material obtained by this technology can be machined and calibrated on a press to the required dimensions while maintaining a uniform structure, and can also be attached to metal sheets by soldering.

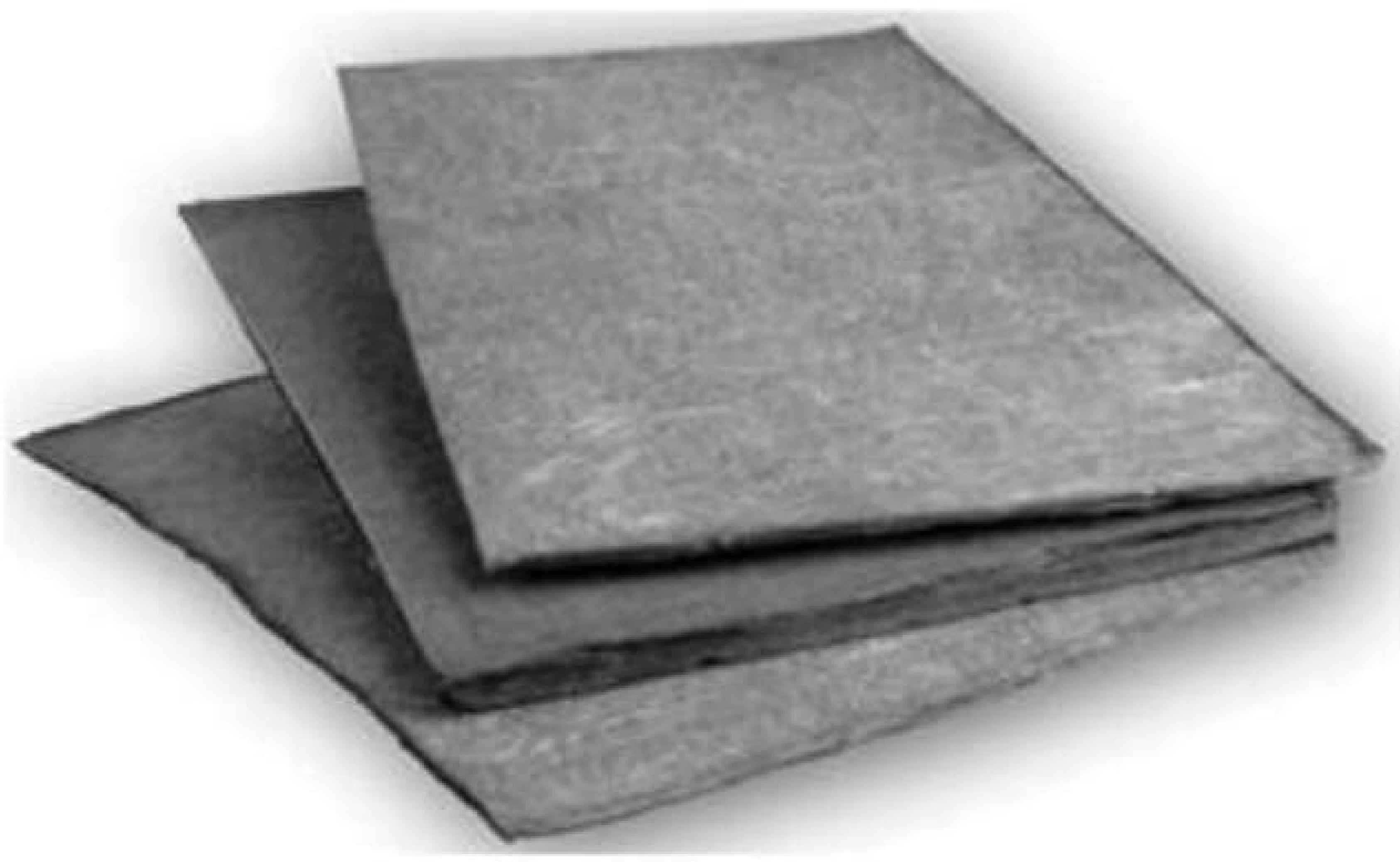


Figure 3.1. - Panels of porous fiber metal material (FDM) of fibers X20H80 alloy

In addition, using the above technology, experimental samples of material in the form of half rings up to 20 mm thick were obtained (Fig. 2), intended for use in the silencer of auxiliary power units (APU). Comprehensive studies of the physical and acoustic properties of samples of such a material with porosity from 85 to 95%, including gradient porosity and in combination with metal honeycombs, have been carried out.

Figure 3.2. - ShV-2 porous fibrous metal material for use in the sound-absorbing structure of an auxiliary power unit silencer

Based on the results of tests of various types of structural samples for heat resistance, hardness, density, porosity and sound absorption coefficient, it was concluded that samples based on homogeneous single-layer porous fiber metal material have the best properties, which have the highest sound absorption coefficient, the highest heat resistance, the lowest density and maximum porosity (95%).

In fig. 3 shows the frequency dependences of the sound absorption of three types of sound absorber materials structural samples based on porous fiber metal material from nichrome fibers. The sound absorption coefficient α of the structural samples was determined on an interferometer when the sample was positioned relative to a rigid wall without an air gap.

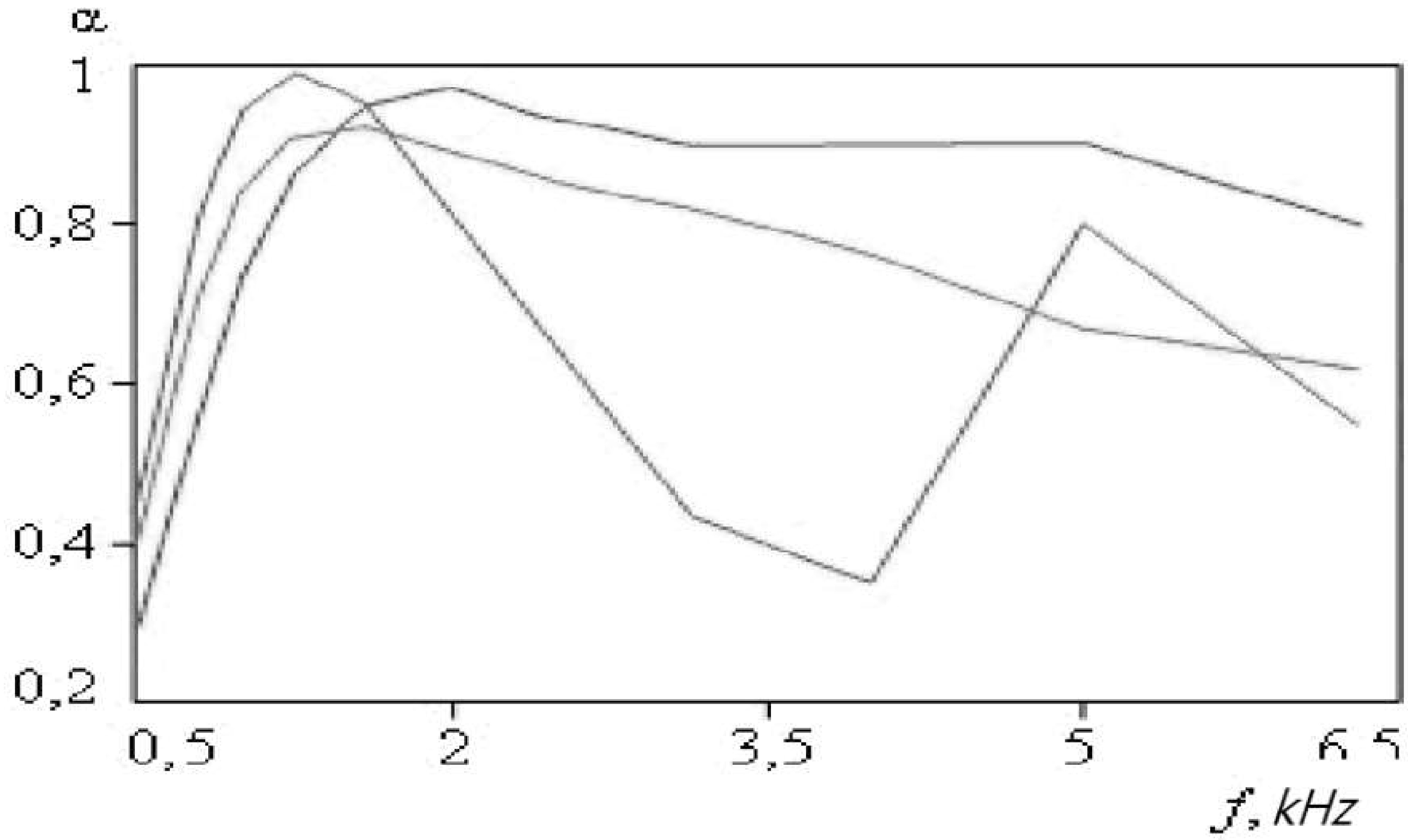


Figure 3.3 - Sound absorption coefficient α of samples of a sound-absorbing structure based on porous fiber metal material:

— porous fiber metal material (thickness 3 mm, porosity 85%) + honeycomb core (thickness 40 mm);

— porous fiber metal material 22 mm thick with porosity of 90%; — gradient FDMM 26 mm thick with porosity of 85, 90 and 95%

Based on the results of comparative studies of acoustic characteristics at the U-96T test bench? it was found that acoustic liners based on porous fiber metal material are significantly wider than resonant structures and are characterized by a uniform absorption spectrum at frequencies above 1 , 6 kHz with an efficiency of 6–8 dB.

By weight characteristics, the porous fiber metal material of nichrome fibers (Fig. 4) corresponds to a metal honeycomb core - a mass of 1 m2 of such a material with a porosity of 95% with a thickness of 10 mm is 4 kg.

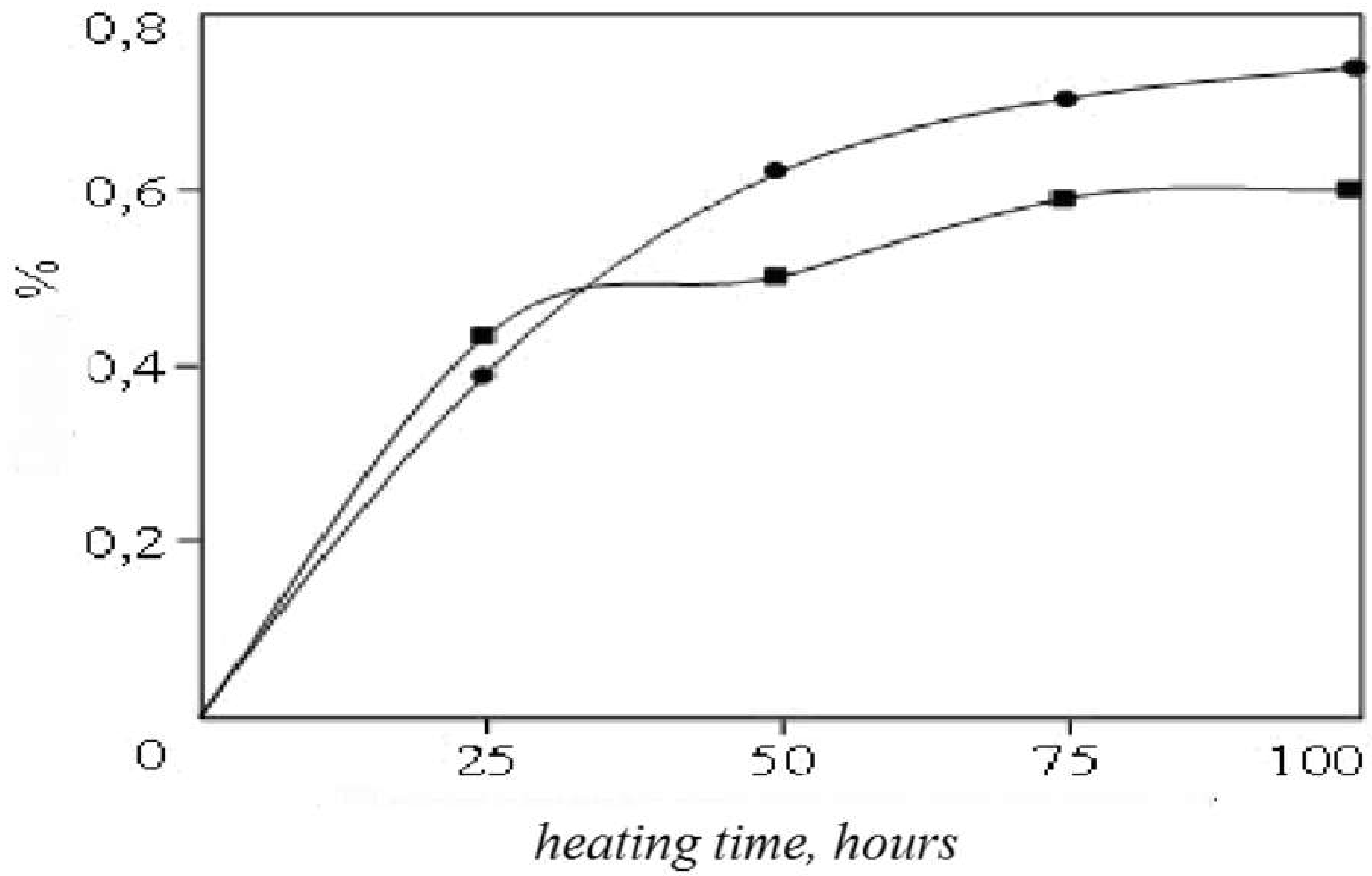
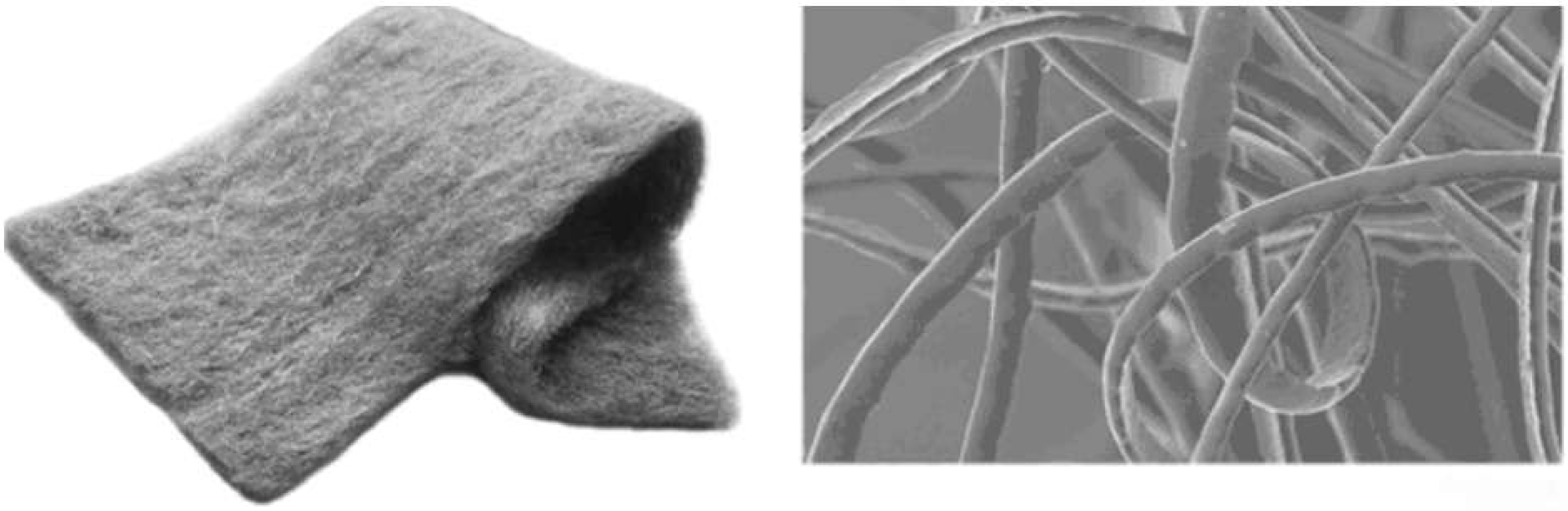


Figure 3.4. - The test results of material grade ShV -2 with porosity of 85 (and 95% on heat resistance at a temperature of 600 ° C

Investigations of the corrosion resistance of material with the conventional brand ShV-2 based on nichrome fibers, carried out on samples cut from 10 mm thick panels at temperatures of 450 and 600 ° C by the method of accelerated cyclic tests with the spraying of a 3% NaCl solution, showed that the corrosion the resistance of samples with an increase in porosity decreases slightly, remaining at a satisfactory level. When tested in a tropical climate chamber and in conditions of high humidity and temperature (450 and 600 ° C), the material also has satisfactory corrosion resistance.

As further studies have shown, using the technology of obtaining fibers by the extraction of a hanging drop of melt method it is possible to create a porous fiber metal material from fibers of heat-resistant alloys with an even lower density and the necessary properties for its use as a filler for high-temperature sound absorber materials aircraft engines.

The extraction of a hanging drop of melt method allows to obtain a continuous fiber from which the canvas can be formed immediately after it is detached from the working surface of the heat sink disk. At the same time, a porous material formed on the receiving surface (with optimally selected process parameters) has a uniform fibrous structure with an average density of ~ 0.05 g / cm3 and mechanical strength sufficient for its further processing, which is ensured by mechanical adhesion of the fibers due to their bending and formation of foci sintering of fibers due to the presence of a melt on their surface (Fig. 5).



a b

Figure 3.5. - Porous material from alloy fibers of the type X23U5 obtained by the extraction method

a - hanging drop of the melt, b - structure

From fibers of an alloy of type X23YU5 (Fe – Cr – Al system), canvases were obtained by the extraction of a hanging drop of melt method, which are used for the development and manufacture of an experimental batch of ultra low-density filler material ShV-3. Together with the Scientific Research Institute of Nonwoven Materials, an experimental batch of mats up to 20 mm thick with a density of 0.2–0.3 g / cm3 and >95% porosity from blanks (canvases) obtained extraction of a hanging drop of melt method.

According to the results of tests of corrosion resistance and heat resistance, the ShV-3 porous fiber metal material can be operated at a working temperature of up to 700 ° C and higher - the weight gain of samples of this material does not exceed 1.1% per 100 hours at a temperature of 700 ° C.

According to the results of tests for general corrosion resistance in the conditions of a salt spray chamber and industrial atmosphere, it was established that the ShV-3 porous fiber metal material in its initial state and after heating at a temperature of 700 ° C has satisfactory corrosion resistance. It should be noted that the corrosion resistance of porous fiber metal material samples in the salt spray chamber and in an industrial atmosphere increases with preliminary temperature control of the samples (short exposure at 700 ° C), which can be explained by the protective properties of the oxides formed on the fiber surface (Fig. 3.6).

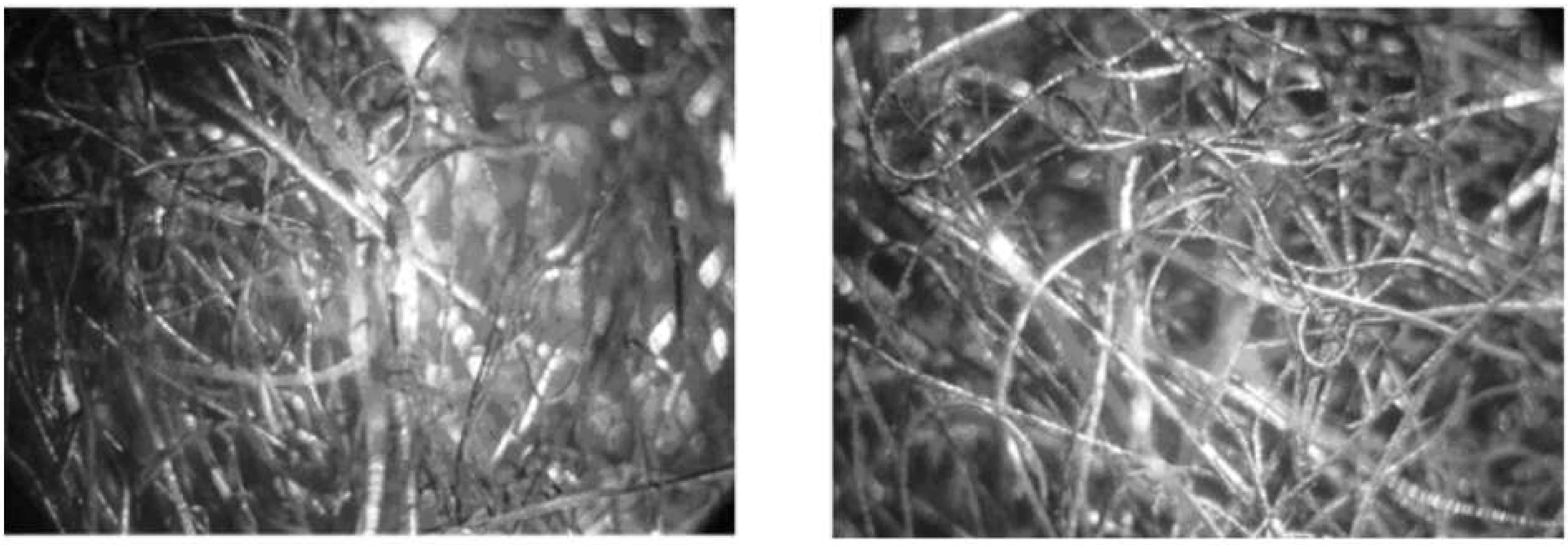


Figure 3.6. - Type of samples (× 16) of porous fiber-metal material after 6 months of testing in an industrial atmosphere - view of individual fibers of porous fiber-metal material without heating and after temperature control at 700 ° C

Such a material at low density has sufficient strength and elasticity - it is used as a filler for high-temperature sound absorber materials for aircraft engines. The material is easily processed, and its high ductility and elasticity provide the ability to fill the working space of the sound absorber materials of any configuration and radius, which eliminates the need for soldering or attaching the filler to a metal base.

In fig. 3.7 presents the results of comparative tests of samples made of material of the ShV-3 brand to determine the sound absorption coefficient in the frequency range 500–6400 Hz. Samples of a thickness of 15 mm were tested from a material with porosity of 95–97% and combined samples from material of the ШВ-3 brand with an input layer of a thin metal mesh.

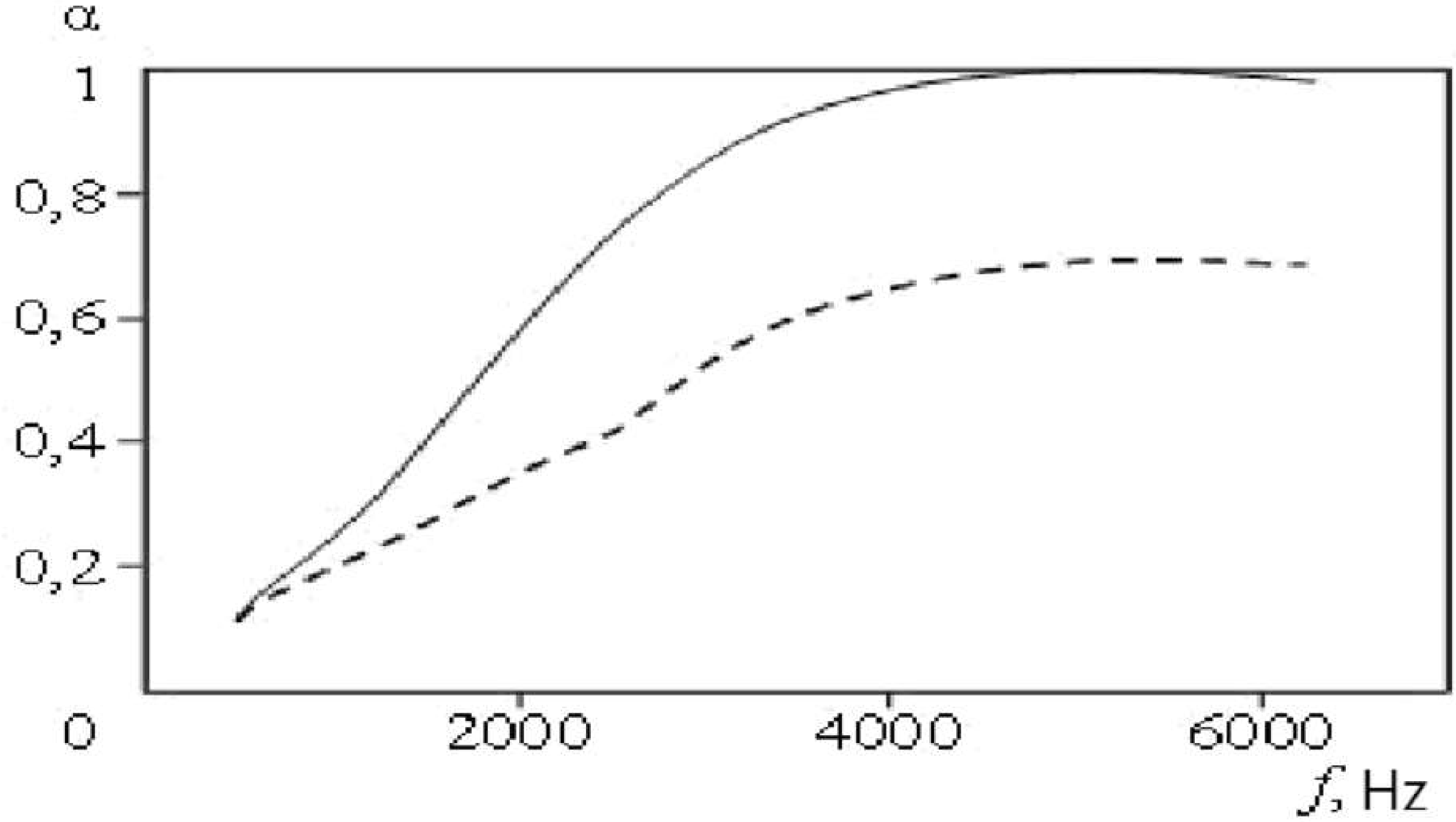


Figure 3.7. - Sound absorption coefficient α of samples from homogeneous porous fibrous metal material (PFMM) (- - -) and from PFMM in combination with one layer of a thick metal mesh of grade C450 (—) in the frequency range 500–6400 Hz

The results of subsequent tests on the acoustic efficiency of sound absorber materials samples based on ultra-low density mats using perforated and mesh layers, showed that the use of a metal mesh in most cases does not lead to any noticeable change in the effectiveness of the acoustic liners. At the same time, the effect of the input perforated coating even with a high percentage of perforation in the presence of a high-speed flow has a noticeable effect on the input resistance of structures, especially at frequencies near the attenuation maximum, and it must be taken into account when designing a silencer using porous fiber metal material. Designs based on ultra-low density mats with an input perforated layer provide noise reduction in the frequency range from 500 to 10,000 Hz with a maximum attenuation of 14-17 dB at frequencies of 2000-2500 Hz. In the frequency range

<1000 Hz, the attenuation does not exceed 4 dB. At high frequencies >5000 Hz, the attenuation is 5–6 dB.

Conclusions of the chapter 3

Porous fiber metal material grades ShV-1, ShV-2 and ShV -3 and acoustic liners based on these porous fiber metal materials have high acoustic efficiency in a wide frequency range and outperform traditional structures based on honeycomb core and active-resonance structures combining layers of porous material with metal honeycombs;

- structures based on homogeneous single-layer porous fiber metal materials with a porosity of 95% and a density of 0.4 g / cm^3 possess the optimum combination of properties;

- according to the level of corrosion resistance and heat resistance, porous fiber metal material can be used in air conditioning complexes of aviation gas turbine engines with operating temperatures up to 700–750 ° C;

- the use of the extraction of a hanging drop of melt method for the production of metal fibers makes it possible to fabricate porous fiber metal material with an ultra-low density - from 0.3 g / cm3 and lower, which have the necessary set of properties to create effective sound-absorbing constructions.

Compared to other porous materials (from metal powders, ceramics, mineral wool, polymer and metal foams, etc.), porous fibrous metal materials have the optimal combination of properties required for a homogeneous silencer of the airborne aircraft engine. In addition to high acoustic efficiency, they are characterized by high strength combined with ductility, high porosity (up to 98%), and low density. Due to the use of fibers made of heat-resistant and corrosion-resistant alloys, porous fiber metal materials can be used for a long time at temperatures up to 700 ° C and above.

CHAPTER 4
ENVIRONMENTAL PROTECTION

4.1 Analysis of the impact of man-made factors on the environment

At the end of XX century. humanity is trapped by acute environmental problems of its own socio-economic development. Quantitative and qualitative increase of volumes of energy-material exchange between society and the environment through acceleration of the rates of scientific and technological progress, attraction to the economic turnover of an increasing mass of natural resources, increase of the scale of nature management and strengthening of anthropo-technogenic pressure on the environment given the assimilation and restoration capabilities of the biosphere.

As the environment is not only a natural basis, a source of human production and transformative activity, but also plays an important outside the production function of the physical, mental, aesthetic environment of human being, it is understandable that degraded, polluted nature objectively impedes the processes of social reproduction. This nature is a direct threat to human health and life.

Serious concern in almost all countries of the world causes excessive pollution by atmospheric emissions. Ideally pure air environment now exists only theoretically, the intensity of industrial, especially industrial, human activity has led to its significant pollution, that is, to a distinct difference of its properties and composition from the indicators of the natural atmosphere.

Moreover, the dynamic equilibrium that existed in nature with respect to the release and absorption of oxygen, carbon dioxide and nitrogen is constantly disrupted along with the development of the motorization, urbanization, electrification and industrial activity of mankind. It has been estimated that oxygen has been used in the last 50 years about the same amount as in the previous million years, or 0.02% of its atmospheric reserve.

Atmospheric pollution has a negative impact on people's health: pneumonia, bronchitis, asthma and other respiratory diseases develop during prolonged exposure to dusty and pollutant-rich air. The polluted air damages the skin, reduces the body's resistance and leads to poor health, the growth of bridge diseases and mortality.

Ukraine is also recognized as a zone of environmental disaster. In general, among the European countries, our country has the highest integrated indicator of anthropogenic loads on the natural environment in almost all territories. At the same time, agricultural development of the land fund (as of 2009) reached 72% of the country, of which 56% was arable land. For comparison, in the US, the plowed area is 19%, in France and Germany - 38%, in Italy - 31%.

The pollution of the air basin, water and land resources, as well as the degradation of soils and reservoirs have become enormous in Ukraine. Thus, almost 40 million tonnes of land, water and land resources are supplied annually to the air pool. hazardous substances, of which 90% is toxic industrial waste. The total area of land used for waste accumulation is 160 thousand hectares. The area of eroded land is estimated at almost 50% of the total farmland.

In Ukraine there are no unpolluted soils: there is a slight degradation of 38%, moderate - 46%, strong -%, extreme - 1% pounds. One hectare of Ukrainian territory emits 19.6 m3 of sewage, while in Russia - 6.6 m3, Belarus - 3.9 m3.

herefore, environmental problems have a socio-economic basis. In other words, environmental degradation is caused by interrelated social (anthropogenic) and natural (environmental) factors. Therefore, the genesis of environmental problems should be viewed through the prism of the development of precisely social relations, which, of course, is a hierarchical multicomponent system of human-nature relations.

4.2. The principle of operation of the compressor station and the impact of its operation on the environment

The main task of the compressor station (COP) is to ensure the design or planned performance of the gas pipeline by increasing the gas pressure, and further transporting it during the following basic technological processes:

- purification of gas from liquid and solid impurities;
- gas compression;
- gas cooling;
- measurement, control and control of technological parameters of operation of the COP and gas pipeline before and after the COP

Also one of the integral components of the gas transmission system are gas distribution stations (GDS), which are designed to supply gas to settlements and industrial enterprises with a given pressure and the required degree of purification and odorization.

At GDS, the high gas pressure at the flow from the COP is reduced, and at a pressure of 0.3, 0.6 or 1.2 MPa (depending on the needs of consumers) enters the distribution networks and gas distribution points of consumers.

The technological process of work is connected with the emissions into the atmosphere of natural gas at start-up and shutdown of gas-pumping units (GPA), in connection with carrying out repair and preventive works on communications of the COP and GDS and other equipment, in case of complete shutdown of the COP and GDS.

Nowadays, more and more are beginning to worry about the fate of our planet, paying attention to even minor emissions of harmful substances into the atmosphere and aquatic environment.

The main document in addressing the issues of protection and preservation of atmospheric air purity is the law of Ukraine on the protection of the atmosphere and the decree of the Cabinet of Ministers, which defines the responsibility of departments, enterprises and organizations for the development of standards for maximum permissible concentrations of harmful substances into the atmosphere.

The main pollutants of the environment are the following emissions: nitrogen dioxide, nitric oxide, carbon monoxide, sulfur dioxide, hydrogen sulfide, soot, dust non-toxic, 3,4-benzoprene, ozone.

The source of emissions at the COP is:

- supercharger discharge candles;
- Methane bleeding candles;
- degasser tube;
- Methane bleeding candle from the CS circuit;
- pipe of exhaust fan of welding post;
- motor transport;
- boiler room chimney;
- pipes of storage tanks of oil-lubricating gas-pumping apparatus
- automatic gas heater tube (PGA);
- high-frequency oscillations of the GPA nodes;
- gas losses through the connection of gas pipelines and gas pipelines;
- explosion of gas-air mixture due to dangerous concentration (5-15%) with air.

ll these factors adversely affect the environment.

According to environmental criteria, natural gas is the most optimal fuel.

The products of combustion do not contain ash, soot and carcinogens such as benzopyrene.

When burning gas, the only significant pollutant of the atmosphere are nitrogen oxides. However, the emissions of nitrogen oxides when combusted at a natural gas compressor station are on average 20 percent lower than when combusted with other fuels. This is not due to the properties of the fuel itself, but to the peculiarities of their combustion processes.

The coefficient of excess air when burning coal is lower than when burning natural gas. Thus, natural gas is the most environmentally friendly type of energy fuel and for the release of nitrogen oxides in the combustion process.

Changes in the environment during gas transportation. The modern backbone pipeline is a complex engineering equipment that, in addition to the linear part (the pipeline itself) includes installations for the preparation of oil or gas for pumping, pumping and compressor stations, reservoir parks, communication lines, electrochemical protection system, roads, trails running along , and entrances to them, as well as temporary residential settlements of operators.

For example, the total length of gas pipelines in Ukraine is approximately 20.9 thousand km. Emissions, mainly methane, are distributed along gas pipelines, mainly outside settlements.

Atmospheric air is exposed to significant pollution due to losses from large and small "breathes" of tanks, gas leaks and so on.

Atmospheric pollution caused by an accidental release of gas or combustion of oil and petroleum products different on the surface during an accident is characterized by a much shorter period of action, and can be attributed to short-term.

Atmospheric air is also polluted as a result of gas leakage through leaky pipeline connections, leakage and evaporation during storage and discharge operations, losses on gas and oil pipelines, etc. As a result, vegetation growth may be suppressed and concentration limits may increase and concentrations may increase. .

Calculation of the concentration of gas emissions during depressurization of the piston receiving chamber.

The maximum value of the ground-level concentration of the harmful substance (mg / m3) at the ejection of a gas-air mixture from a single source with a rectangular mouth (the appearance of a crack 0.3x0.02 m).

where - coefficient dependent on the temperature stratification of the atmosphere, A = 180;

(g / s) is the mass of the pollutant emitted per unit time;

- dimensionless factor that takes into account the rate of sedimentation of harmful substances in atmospheric air;

and - coefficients that take into account the conditions of exit of the gas-air mixture from the mouth of the source of emission;

(m) is the height of the emission source above ground level (for terrestrial sources, calculations = 2 m;

- dimensionless coefficient that takes into account the influence of terrain, in the case of flat or underserved terrain with a height difference not exceeding 50 m per 1 km = 1;

(° C) is the difference between the temperature of the ejected gas mixture and the ambient air temperature;

(m3 / s) - gas-air flow rate, determined by the formula

where (m) is the diameter of the discharge source mouth; (m / s) is the average exit velocity of the gas-air mixture from the discharge source.

When calculating a rectangular mouth, (m) and (m3 / c) are taken.

The effective diameter of the mouth (m) is determined by the formula

The effective flow rate into the atmosphere per unit time of gas-air mixture (m3 / s) is determined by the formula

The values of the coefficients and are determined depending on the parameters,, and:

$$\upsilon'_M = 1{,}3\frac{\omega_0 D}{H};$$

$$f_e = 800(\upsilon'_M)^3$$

$$f = 1000\cdot\frac{10^2\cdot 0{,}0375}{2^2\cdot 4} = 234{,}4;$$

$$\upsilon_M = 0{,}65\cdot\sqrt[3]{\frac{0{,}011\cdot 4}{2}} = 0{,}182;$$

$$\upsilon'_M = 1{,}3\cdot\frac{10\cdot 0{,}0375}{2} = 0{,}244;$$

$$f_e = 800\cdot 0{,}244^3 = 11{,}586$$

;

;

;

The coefficient is determined depending on the formula:

at 100.

$$m = \frac{1{,}47}{\sqrt[3]{f}} \text{ при } f \geq 100.$$

$$m = \frac{1{,}47}{\sqrt[3]{234{,}4}} = 0{,}238\,.$$

.

For 100, the formula uses the formula

where

$$C_M = \frac{AMFn\eta}{H^{4/3}}K,$$

$$K = \frac{D}{8V_1} = \frac{1}{7{,}1\sqrt{\omega_0 V_1}}$$

and it is determined by the following formula for.

at;

Determine the mass of the harmful substance released into the atmosphere per unit time.

$n = 4{,}4\upsilon_M$ при $\upsilon_M < 0{,}5$;

$$n = 4{,}4 \cdot 0{,}244 = 1{,}07$$

,

Accordingly, the concentration will be equal

$$. \ M = S \cdot \mu \sqrt{k \cdot \left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \cdot \frac{P}{\sqrt{T \cdot R}}.$$

$$M = 0{,}0375 \cdot 0{,}62 \sqrt{1{,}31 \cdot \left(\frac{2}{1{,}31+1}\right)^{\frac{1{,}31+1}{1{,}31-1}}} \cdot \frac{50 \cdot 9{,}81 \cdot 10^4}{\sqrt{303 \cdot 519}} = 192{,}4 \ г/с.$$

$$K = \frac{0{,}0375}{8 \cdot 0{,}011} = 0{,}426,$$

According to the internal documentation of the enterprise, the concentration of gas emitted into the atmosphere should not exceed 5980,0 mg / m³. As can be seen from the calculations, the emission rate is exceeded, and therefore measures should be taken to reduce it.

4.3. Measures to reduce the environmental impact of the COP and GDS

In order to reduce the negative impact of the COP and GDS on the environment, the following measures should be implemented on stationary and salvo sources.

According to stationary sources:

- modes of PGA operation at GDS have been developed with the purpose of preventing gas overheating before the heaters and maintaining the gas temperature at the output of GDS at a minimum level;

PGAs are switched off when gas temperatures at the GDS inlet are reached;

- the hot water unit (AGV) is switched off at the GDS with supra-bottom service when the positive ambient air temperatures are reached;

- carry out ecological and technical tests of PGA, AGV, steam boilers with subsequent repair works;

- tanks for collecting, settling oil, technical liquids, pallets for eliminating the spillage of liquids during the replacement of assemblies and units are provided at the sites of the GPA installation, which allows to prevent soil contamination during technical operation, repair, as well as during the regular works on the GPA;

- Provision of washing places on the sites of periodic maintenance, and repair with the necessary communications.

- felling is used around the perimeter of the compressor station to compensate for the noise, preventing it from spreading further.

- technical personnel strictly adhere to the rules of maintenance in accordance with environmental requirements for the protection of nature from production factors.

These measures are aimed at reducing the consumption of fuel gas and reducing the emission of harmful substances into the atmosphere.

According to volley sources:

- triggering of GDS gas, CS, comparison of various types of repair;

- streamlining of purges, reduction of purging times;

Reduction of the rate of gas odorization on GDS.

The use of a cogeneration-type GTU allows replacing part of the capacity of a stationary GTU for fuel economy, which reduces the gross emissions of combustion products and pollutants into the atmosphere.

During operation, the GPU actuator, regardless of its type, emit noise and vibration. The fight against these negative factors of the units is ongoing throughout the design of the CS and the operation of the HPA.

When designing, determine the mass and construction of the foundations, to ensure maximum absorption of vibration. The units are mounted on a special suspension for absorbing vibrations.

Aviation installations are placed in noise isolation, additional housing made of porous materials.

In ground installations, primary noise cancellation and vibration are achieved by increasing the metal intensity of the unit design. At the design stages of the shop building determine the types and sizes of noise-proof surfaces on the walls of the shop buildings, use small windows made of thick glass. At the stage of operation, the vibration parameter is one of the main controlled parameters of the plants, and the adjacent workshop area is planted with parks, which are natural noise absorbers.

Possible leakages of fuel and lubricants (PMM) and chemicals necessary for the normal operation of the systems for providing technological cycles of the COP are also negative factors of influence.

The reduction of such leakages is to reduce the level of PTE violations and to reduce the risk of an accident at the GTS facilities of Ukraine.

The developed automatic reliability control system includes modules for evaluating the efficiency and error-free performance of PTE, controls changes in reliability levels and prevents accidents occurring when operating the COP equipment.

It is more difficult to ensure the reliability of operation of equipment outside the territorial boundaries of GTS enterprises. We are talking about MG, electrochemical protection stations, latches and pass belts, GDS and hydraulic fracturing. To protect these objects from human exposure, it is necessary to provide risk areas with additional warning signs indicating the dangerous factors that carry these objects.

Conclusions by section

A sophisticated natural gas transportation system requires the use of the latest advances in reliability, efficiency of production processes management and greening of production facilities.

Therefore, the operation of any sophisticated technical system requires the introduction of a number of measures for safe and reliable operation. When considering the gas transportation system, it should be remembered that its operation is not only connected with the transport of dangerous substance, but also with the operation of powerful, complex and dangerous installations.

Therefore, in terms of safety, reliability and environmental friendliness it is impossible to limit the reduction of the pipeline accident, it is worth paying attention to the emissions and energy consumption of the drives of gas-pumping units.

To improve environmental safety at the COP and GDS, a set of measures should be implemented, namely:

- the use of more environmentally friendly ODS odorants;
- installation of long length pipes at sufficient height to dissipate methane combustion products;
- location of the CU and GDS with observance of the conditions of the sanitary protection zone;
- the use of forest stands to compensate for the spread of noise around the perimeter of the COP;
- Provision of effective silencers that reduce the noise level of the GDN reduction node;
- use of panels filled with sound-absorbing material, walls on CS and GDS;

- the use of shut-off valves, equipped with measuring instruments and automatic devices for automatic shut-off of cranes in the technological process of gas transportation to prevent natural gas from entering the atmosphere.

CHAPTER 5
LABOR PRECAUTION

5.1. Dangerous and harmful production factors that occur in the work areas of the compressor station

The main physical hazardous and harmful production factors affecting the operator during operation of the gas pumping unit in accordance with GOST 12.0.003-74 are:

- increased concentration of harmful substances in the air of the working area;
- increased noise in the workplace;
- increased vibration level;
- insufficient illumination of the working area;
- elevated and lowered surface temperatures; high surface temperature of workpieces and tools;
- moving parts of production equipment;
- increased voltage in the electrical circuit and increased level of static electricity;

The increased concentration of harmful substances results from the malfunctioning of ventilation on the CS. This can lead to poisoning of personnel and an accident as a whole, which can result in deaths and huge financial losses as a result of stopping the COP. Therefore, in order not to have an increased concentration of harmful substances, the work area of the COP around the perimeter is equipped with special sensors that respond to the concentration of harmful substances and transmit information to the operator.

The production equipment on the CS in the course of operation generates mechanical vibrations of different time, which have an adverse effect on the body of the workers in the form of noise and vibration.

Vibrations are mechanical oscillatory motions, the sources of which are gas pipelines, equipment and some types of hand tools on the CS. If the oscillating parts of the equipment touch the body of the working person, the vibration acts as a professional hazard. The points of its application are most often hands and feet. Most of the work on the COP is performed under visual control (monitoring the work of mechanisms, apparatus, readings of measuring instruments and in the performance of production operations). In this case, the human body carries a degree of load and undergoes tension, which under certain conditions leads to fatigue of the organ of vision and general fatigue of the body. Inadequate illumination affects the degree of fatigue of the eyes, which depends on the degree of intensity of the processes that accompany the visual perception of objects of the outside world.

It should also be noted that insufficient illumination of the work area can lead to increased eye strain and weakening of attention during the working day, which is unacceptable in the work area of the COP. Over time, this factor leads to the professional unfitness of the specialist.

An increased or lowered surface temperature is dangerous because the COP operator may receive light and moderate burns.

Moving parts of process equipment at the CS are very dangerous, as they can cause injuries of varying severity. An automatic security and alarm system is used to ensure the safety of the COP operator. The moving parts of the process equipment are closed with shields.

For protection against high voltage in the electric field and against static electricity, a special protective suit, rubber shoes and gloves are used. And also uses an automatic warning and alarm system.

5.2.1 Technical and Organizational Measures to Reduce the Impact of Hazardous Production Factors on the Compressor Station

The project envisages all necessary technical solutions and measures that ensure the safety of operation of the CU in compliance with the operating regulations and all safety requirements:

- use of equipment in explosion-proof execution in premises and outdoor installations where there are explosive environments;
- to ensure normal operating conditions all necessary automatic control and protection systems, which operate when deviation from the set parameters, are provided;
- control and regulation of all basic technological parameters is carried out from the operator;
- the most used automated equipment, which does not require constant presence of service personnel;
- Installation and repair of station equipment mechanized, performed with the help of special lifting equipment;
- lightning protection and protection of equipment and pipelines against repeated manifestations of lightning and static electricity;
- fixed stationary gas analyzers in rooms and outdoor installations;
- safety valves installed;
- if necessary, service areas, installation and operating aisles are provided;
- accessibility to the components of the equipment during their maintenance;
- hot surfaces of the equipment in the service areas are covered with thermal insulation;
- a system for the collection and organized discharge of gas into the atmosphere;
- capacity of emergency drain of coolant - DEG from heaters is provided.

The layout of the equipment and local KVP equipment is made taking into account safe maintenance, convenience of repairs, installation and audits.

Pipelines to provide passage below them are laid at a height of 2.2 m from the ground. The number of service personnel and their time at the equipment, as a source of noise, vibration and possible gas emission, are minimized.

The operation of the main technological equipment of the COP is carried out in an automated mode and does not require constant presence of service personnel.

The necessary safety precautions must be observed when checking, adjusting and dismantling the relief valves, as these operations are performed without interruption of gas supply by disconnecting one of them with a three-way valve or switchgear installed before the relief valves.

For creation of normal conditions of operation all necessary systems of automatic control and protection which work at deviation from the set parameters are provided. In areas where natural gas leakage is possible, signaling of explosive gas concentration in the air is provided. A siren is provided for sound signaling.

The elimination of the causes of emergencies and the elimination of accidents should be carried out in accordance with the instructions for operation and safety, developed at the enterprise, taking into account the current regulatory documents, as well as the instructions of the manufacturers of equipment.

DNA OP 0.00-1.070-94 Rules of construction and safe operation, vessels operating under pressure.

DNA OP 0.00-1.20-98 Rules of safety of gas supply systems of Ukraine.

GOST 51.81-82 Occupational safety in the gas industry. Basic terms and definitions.

GOST 51.55-79 Safety signs for gas industry enterprises.

GOST 12.2.063-81 PRSP. Industrial pipeline fittings. General safety rules.

GOST 12.2.085-82 UPS. Vessels working under pressure. Safety valves.

GOST 12.1.030-81. Electrical safety. Protective grounding, grounding.

5.2.2 Calculation of the grounding of the gas turbine drive

remote shut-off of the COP from the main gas pipelines and simultaneous bleeding of gas from the process equipment and pipelines of the COP onto the candles.

A fire safety instruction and emergency response plan should be developed in the premises of the COP, and systematic training and practical training with the firefighting officers should be conducted.

During operation of the CS, it is necessary to systematically monitor:

- by the density of gas pipeline connections, oil seals of equipment and fittings;

- for the correctness of the ventilation systems and the automatic inclusion of emergency exhaust ventilation in the presence of contamination of industrial premises;

- the correctness of the automatic means of switching on the emergency electric lighting system.

Fire hydrants, ponds and overlays should be fitted with sleeves with tips. In the darkened locations of fire hydrants should be marked with light indicators.

Maintenance of equipment must be carried out in accordance with technological and job descriptions.

Hot piping and parts of process and auxiliary equipment must be isolated or enclosed.

Lubricants, flammable substances and detergents should be stored in designated areas (fuel and lubricants (PMM), lubricant recovery point, oil block) in well-ventilated areas. The dishes must be securely closed.

Avoid spreading and accumulating oil and cloth rags in the premises of the CU. They should be collected in special metal boxes with a tight lid, which are installed in the utility rooms. Regularly (after every change) the oiled cloth and cloth should be taken to a safe place provided for removal (removal) of garbage.

Primary fire extinguishers must be available in all CU premises in accordance with established standards.

In case of fire it is necessary to immediately:

- to stop access to gas, lubricants to the place of fire;

- call the fire brigade and the DPD;

- to start extinguishing the fire by the primary means of extinguishing available;

- Report the occurrence of fire management change.

The operator is obliged to notify the official about accidents or sudden illnesses, facts of technological process disturbances, found faults of equipment, installations, devices, tools, protection means and about other dangerous and harmful production factors that threaten the life and health of employees, to which he is directly subordinate.

DBN B.2.5-13-98. Fire automatics of buildings and structures.

CD 51-03-92. List of industrial buildings, premises and structures of the gas industry to be equipped with automatic fire-fighting installations.

NAPS B.06.004-97. List of objects of the same type to be equipped with automatic fire extinguishing and fire alarm systems.

GOST 12.1.010-76 UPS. Explosion hazard. Security requirements.

GOST 12.1.004-91 OSBT Fire safety. General requirements.

SNIP 2.01.02-85. Fire regulations.

5.4. Basic requirements for observing labor safety regulations when operating a projected engine. DNAOP 0.00 - 4.15 - 98

An Occupational Safety Instruction is a normative act that contains mandatory safety requirements for employees when performing work of a particular type or profession in workplaces, workplaces, company premises and construction sites or other places where on the instructions of the owner or his body (hereinafter referred to as the employer), these works, duties or duties are performed.

The main points for the elaboration and implementation of new instructions, revision and cancellation of the current instructions are regulated by DNAOP 0.00 - 4.15 - 98 "Regulations on the development of instructions for occupational safety", approved by the order of the State Inspectorate of Health from 29.01.1998. № 9.

Safety instructions are divided into:

- instructions related to state interbranch regulations on labor protection;
- indicative instructions;
- instructions that apply to the enterprise.

Occupational safety instructions can be developed for both occupations and types of work. Instructions pertaining to state interbranch safety regulations are developed for personnel carrying out blasting operations, servicing electrical installations and equipment, hoisting machines and elevators, boiler installations, pressure vessels, and other personnel safety rules. the works of which are established by cross-sectoral normative acts on labor protection, approved by the bodies of state supervision of labor protection.

These instructions are approved by the appropriate state safety oversight bodies in agreement with the ministries or other bodies to which the instruction or its specific requirements fall, and their observance is mandatory for employees of the relevant professions or when performing the relevant types of work at all enterprises, regardless from their subordination, form of ownership and type of activity.

Exemplary instructions shall be approved by the ministries or other executive bodies, production, scientific-production and other associations of enterprises having the relevant competence, in coordination with the state supervisory bodies of labor protection, to whose competence the instruction or its separate requirements belong, and the National Institute of Labor Protection. These instructions can be used as a basis for the development of operating instructions in an enterprise.

The instructions that apply at the enterprise are related to the labor protection regulations in force within the enterprise. Such instructions are developed on the basis of applicable state interbranch and sectoral regulations on occupational safety, exemplary instructions and technological documentation of the enterprise, taking into account the specific conditions of production and safety requirements, set out in the operational and repair documentation of the enterprises-manufacturers of equipment used at the enterprise. They are approved by the employer and are compulsory for the employees of the relevant professions or in the performance of the relevant

works at this enterprise. The safety instructions should be given a name and abbreviation (code, order number).

The title of the instruction briefly indicates for which profession or type of work it is intended, for example: "Occupational safety instruction for the GPA mechanic", "Approximate occupational safety instruction when working with a hand-held power tool". The safety instructions should include the following sections:

- Terms;
- safety requirements before starting work;
- safety requirements at work;
- post-employment security requirements;
- safety requirements in emergency situations.

Optional sections can be included as needed.

Maintenance of the equipment, including its start-up, shut-down and maintenance, must be carried out in accordance with the requirements of the manufacturer's technical instructions. Operation of the GTU with parameters deviating from the values specified in the operating instructions is not allowed.

After the installation of basic and auxiliary equipment during commissioning, when construction, installation, operation and commissioning work is an important organization and a unified guide for the implementation of safety rules. Before supplying gas to the CS, all personnel of construction, installation, commissioning and other organizations involved in the site must undergo a safety briefing, which must be documented.

When mounting the GTU, note the following:

• lifting of the turbo unit should be performed with the help of a special crossbar;

• lifting of other units (suction chamber, block of oil coolers, exhaust device, silencer, etc.) must be carried out in accordance with the insurance schemes and recommendations stated in the technical documentation at GTU.

All leaks and cracks must be removed in the joints of the GTU units, and the oil tank covers must be sealed. On the inoperative unit of the air cleaner unit (VFD) blinds, the engine air intakes must be closed, the oil cooler unit fan inlets are closed.

Works on commissioning, repair and operation of the GTU shall be carried out in accordance with the requirements of the "Rules of safety when installing the equipment of the compressor stations of the main gas pipelines".

The operation and repair of gas turbine installations are allowed for maintenance personnel who have undergone special training, have passed the exams and are admitted in due course to their maintenance and operation.

Before starting the GTU it is necessary to make sure that the sound signal is triggered when the Start button is pressed. It is not allowed to start the unit without enclosures and enclosures on rotating parts and assemblies at a height not exceeding 2 m from the floor level (fans of the oil cooling unit, starting pump coupling) or during their operation.

When operating the GTU it is prohibited:

• enter the engine compartment when starting and operating the engine;

• perform engine work when the GTU system is under current;

• carry out work on the suction chamber and the exhaust shaft of the unit at start-up or when the engine is running;

• Work with the engine, supercharger, POP and suction chamber doors open.

The air in the oil tank must be checked daily for the contents of the combustible gases contained in the log. When the content of combustible gases in the oil tank of the unit more than 1%, the work of the HPA is not allowed.

It is forbidden to find service personnel near the operating unit without PPE for more than 1 hour during one working shift.

The permissible vibration level of the GTU, measured by standard equipment, shall not exceed 30 mm / s.

The sealed partition between the engine and supercharger compartments must be maintained in such a way that no air from the supercharger compartment is allowed to enter the engine compartment. When supplying hot air from the engine to heat the compartments of the unit, the personnel working in the compartments must be informed. Wear safety gloves when handling hot air fittings.

When switching off the power, it is necessary to use stationary portable lanterns, 12V voltage in explosive design.

In winter, the GTU service areas should be periodically cleared of snow.

The emergency shutdown of the unit must be carried out in the following cases:

• if the safety of the operating personnel is threatened;

• when the unit is broken;

• when metal knocks and shocks occur;

• heavy losses of oil or gas;

• oil or gas ignition;

• surging phenomena in the unit.

All engine adjustment work can only be performed at

stopped unit. Regular and repair work on the engine should only be carried out after cooling its outer surfaces to a temperature of 450C. During the assembly and dismantling of the unit, it is necessary to use serviceable special tools and devices that guarantee safe work.

It is forbidden:

• use defective hoists and lifting devices for the engine, supercharger cover, rotor and other assembly units;

• Leave the suspended parts on load-lifting mechanisms;

• operate hoisting gears at temperatures below -20 ° C.

Lifting mechanisms that work in pairs should be loaded evenly in order to eliminate their breakage and injury to personnel.

When cleaning and washing parts, use fire-fighting technical detergents.

It is forbidden to store kerosene, gasoline and other flammable materials in the shelters of the GTU or near them.

Operation of the fire extinguishing installation is unacceptable if the service life of the cylinders has expired, as well as defects have been found that preclude the safe operation of the installation. It is prohibited to transport the unit in the presence of extinguishing cylinders. It is only allowed to enter the engine and supercharger compartments after the fire extinguishing system has been operated after careful ventilation and sampling of contamination indoors.

In order to determine the content of harmful substances in the air in the working area, control measurements must be carried out by sampling at least once a year.

The doors of the engine compartment, the suction chamber and the air-cleaning device must be affixed to prohibiting safety signs labeled "Do not enter the GPU".

Conclusions of chapter 5

This section deals with the issues of hazardous and harmful production factors that arise in the work areas of a compressor station; questions of technical and organizational measures to reduce the level of influence of dangerous harmful production factors on the compressor station; issues of fire and explosion safety and more.

GENERAL CONCLUSIONS

One of the problems of gas turbine plants is the problem of noise reduction. Sources of noise are engine elements are compressor, combustion chamber, turbine, power turbine and output device.

Literature analysis showed that the important issue is the use of effective sound-absorbing materials not only in the cold part of the engine (at the engine inlet, in the compressor), but also in the hot part of the engine - the combustion chamber, turbines and the output device.

Therefore, the study of the characteristics of sound-absorbing materials for the hot part of the engine is an urgent issue.

In order to reduce the noise of the hot part of the engine, it is proposed to install porous fiber metal material in the engine under design as sound-absorbing structures. The results show the promise of using this material to effectively reduce noise in the combustion chamber, turbine, free turbine and exhaust device.

Porous fiber metal material grades ShV-1, ShV-2 and ShV -3 and acoustic liners based on these porous fiber metal materials have high acoustic efficiency in a wide frequency range and outperform traditional structures based on honeycomb core and active-resonance structures combining layers of porous material with metal honeycombs;

- structures based on homogeneous single-layer porous fiber metal materials with a porosity of 95% and a density of 0.4 g / cm^3 possess the optimum combination of properties;

- according to the level of corrosion resistance and heat resistance, porous fiber metal material can be used in air conditioning complexes of aviation gas turbine engines with operating temperatures up to 700–750 ° C;

- the use of the extraction of a hanging drop of melt method for the production of metal fibers makes it possible to fabricate porous fiber metal material with an ultra-low density - from 0.3 g / cm3 and lower, which have the necessary set of properties to create effective sound-absorbing constructions.

Compared to other porous materials (from metal powders, ceramics, mineral wool, polymer and metal foams, etc.), porous fibrous metal materials have the optimal combination of properties required for a homogeneous silencer of the airborne aircraft engine. In addition to high acoustic efficiency, they are characterized by high strength combined with ductility, high porosity (up to 98%), and low density. Due to the use of fibers made of heat-resistant and corrosion-resistant alloys, porous fiber metal materials can be used for a long time at temperatures up to 700 ° C and above.

It is almost impossible to manufacture cellular sound absorber materials from a combination of materials, for example, aluminum - steel, titanium - steel, aluminum - composite material. Exist problems associated with the removal of condensate from honeycomb structures.

LIST OF ABBREVIATIONS

GTU	-	Gas turbine unit
HPC	-	High pressure compessor
HPT	-	High pressure turbine
LPC	-	Low pressure compressor
LPT	-	Low pressure turbine
SAM	-	Sound absorbing materials

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