HIGH-SPEED GRINDING MACHINES WITH TURBINE DRIVES AND GAS-LUBRICATED SPINDLE UNITS

Kosmynin A.V., Kabaldin Yu.G., Vinogradov V.S., Chernobai S.P.

Komsomolsk-on-Amur State Technical University

The article presents designs of air grinding tools with gas-lubricated bearings and turbine drives as well as their technical characteristics.

In industry a great amount of works is carried out with the use of air grinding tools.

The air grinding tools offered on the market by Russian and foreign companies are, for the most part, low-speed ones with a volumetric rotor motor which have a great specific weight per unit of power. As a result of the rotor unbalance and using rolling bearings in this kind of air tools, substantial noise and vibration levels occur. The operating life of the bearings themselves is not long.

Nowadays, abrasive disks with a peripheral velocity of up to 120 m/sec are commercially produced. To use them more effectively, a high-speed air tool capable to provide increased productivity became a necessity. This requirement is met by air turbine grinding tools with gas-lubricated bearings.

The use of gas bearings allows to reduce abrasive and milling tool wear, to extend considerably air tool service life and to increase productivity at low cutting forces, to solve the problem of an operator protection from vibration and acoustic actions, to improve work-piece surface finish, to ensure reliable work in dusty places as well as at high and low temperatures and humidity.

There is a number of designs of air grinding tools with gas-lubricated bearings presented in technical literature [1-3]. But for various reasons, this kind of tools is not so far commercially produced in Russia. They are entirely absent in the ranges of products of leading foreign companies in the field of air grinding tools (Atlas Copco, Dezoutter, Bosch, etc.).

It is apparent that the widespread introduction of air grinding tools with gas-lubricated bearings into the industry should be quickened by the works on the improvement of tool designs which provide low-cost production practice in enterprises with up-to-date machinery. Special attention should be paid to the commercial design of tools, their unit and component materials.

The solution to the problem has been embodied to an extent in three designs of the high-speed air grinding tool Models ВПМШ 150.01, ВПМШ 035.01 and ВПМШ 015.01 developed at the Komsomolsk-on-Amur State Technical University (KnASTU).

The general view of the high-speed air grinding tool Model ВПМШ 150.01 is shown in Figure 1.

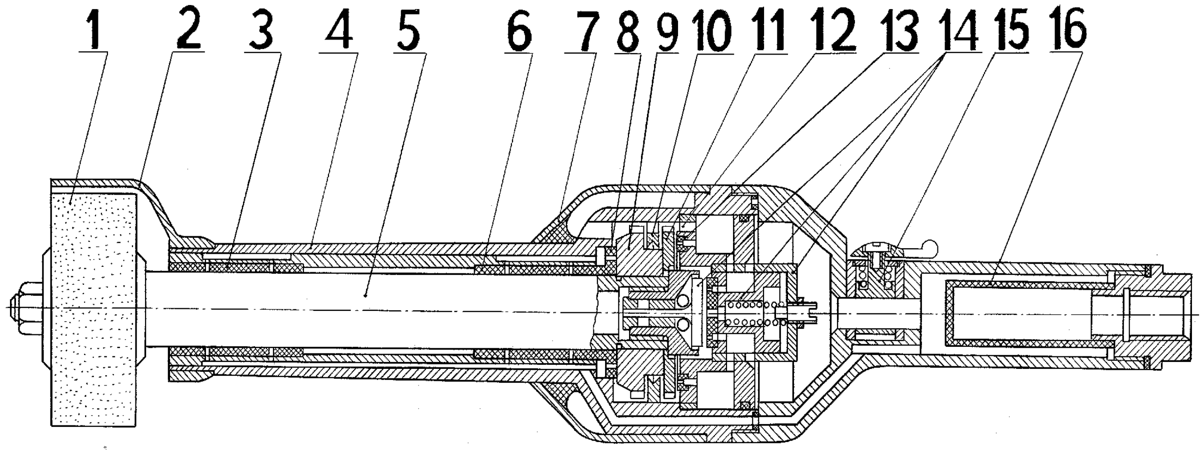

Figure 1. Design of the air grinding tool Mod. ВПМШ 150.01

The tool is dedicated for edge preparation, weld finish, foundation surface finish, etc. The main structural members of the Mod. ВПМШ 150. 01 are a body, a spindle, a turbine drive, gas static bearings, a rotational speed governor, a noise silencer, an air filter and a starting valve.

Tool body ***4*** is made of aluminum alloy and anodized (the coating thickness is 10…20 μm). There are some drill holes in the body for supplying compressed air to and removing from the gas bearings. Ahead, on the thickened part of the body there is an outlet for the turbine-used air.

For the accurate conjunction of components, the internal surfaces of the body have been finished to R_a = 0.32 μm at a radial run-out of no more than 10 μm.

Spindle ***5*** is made of steel 30ХГСА (grade in accordance with GOST), heat-treated to *HRC* 45…50 and chromium-plated. The high surface hardness and finish achieved by grinding lessen the probability of spindle damage in case of accidental contacts or abrasive particles fallen into the clearance. To reduce unbalance, axial spindle run-out of no more than 5 μm is permissible.

Grinding wheel ***1*** or a milling cutter is attached to the output end of the spindle by a collet chuck. At the opposite end of the spindle there is a groove for attaching first-stage turbine wheel ***11*** and second-stage turbine wheel ***9***. Between the turbine wheels there are guide vanes ***10*** and ahead of the first-stage wheel is nozzle diaphragm ***12*** with converging nozzles. The small-sized turbine is a double-row one with velocity stages. The outer diameter of the turbine drive wheels is about 75 mm. As the turbine disks material, we use duralumin Д16Т. Using a light alloy for this purpose reduces the unbalance and stress levels in the disks and blade root section which occur by the action of centrifugal forces.

The turbine wheels have shrouds which reduce channel-to-channel air leak along the blade end surfaces and through the radial clearance.

The high-speed air grinding tool Mod. ВПМШ 150.01 is fitted with two gas journal bearings and two gas thrust bearings. Journal bearings ***3*** and ***6*** with drain grooves are double-row ones with 12 holes 0.4 μm in diameter in each row. The relative length of the bearings is 1.2. For the maximum load-bearing capacity the clearance between spindle and bearing shells is 50…70 μm. One journal bearing can endure a load of about 60 N at the relative eccentricity *e* = 0.5.

The axial force is taken by bearing ***8,*** with the second-wheel disk as its thrust collar, and by end thrust bearing ***13*** of rotational speed governor ***14***. The thrust bearing faces are provided with labyrinth seals. The bearings have 12 supply holes each, these holes being placed in two annular rows. The diameter of each hole is 0.4 mm. One thrust bearing can endure a load of about 50 N.

The shells of both journal and thrust bearings are secured in mounting seats by pasting-in. For this purpose epoxy-resin adhesive is used. As the practice has shown, this kind of joint is reliable in operation and easy to perform.

The bearing-shell material is black-lead АГ1500 Б83. It has low friction coefficient and does not “catch hold” with the metal in case of accidental contacts at high speeds. Black-lead also behaves well in humid gases.

To reduce high-frequency noise generated by the turbine, the tool is provided with silencer ***7***. The principle of its operation is in reducing the flow energy owing to its repeated turns and expansion. The noise silencer presents a cap screwed on to the turbine casing.

For removing solid particles and oil from the air, the tool is fitted with filter ***16*** made of porous material. The choice of material was defined by its low resistance to air flow and capability to pass particles which are smaller in size than the average radial bearing clearance, which makes it possible to remove particles from the clearance with the air flow.

Casing ***2*** protects an operator from chips, abrasive particles or a sudden break of an abrasive disk.

The air grinding tool Mod. ВПМШ 150.01 works as follows. When joining the tool in air mains and with starting valve ***15*** close, the compressed air is delivered to the journal bearings only, allowing the spindle “to float up”. With the starting valve open, the air goes simultaneously to the thrust bearings and, through the nozzle diaphragm, to the turbine wheels, making the spindle to rotate. The turbine-used air emerges through the opening, expands in the space between the silencer cap and the body and leaves the tool through the drilled holes in the cap.

The designs of air grinding tool Mod. ВПМШ 035.01 and ВПМШ 015.01 presented in Figure 2 differ from the Mod. ВПМШ 150.01 in that they have no speed governor and turbine wheel shroud. The nozzle diaphragm is combined with the thrust bearing. Besides, the drive of the Model ВПМШ 015.01 is a simple-impulse turbine.

As a material for the gas-bearing shells in the Models ВПМШ 035.01 and ВПМШ 015.01 we use bronze black-lead. The shells are made by the powder metallurgy method. This material is more workable than black-lead. Bronze black-lead has low friction coefficient and, along with black-lead, behaves well in humid air. The steel-bronze combination does not produce strong adhesive bonds between each other which can cause spindle failures such as deep tears and stretches.

Owing to “self-balancing” of the grinding wheels during the operation, all the tools run steadily at a rated rotational speed till the full wear of grinding wheels. In the design of a turbine drive for the presented here air grinding tool models, we used the latest scientific achievements in the field of experimental study of small-sized turbines, with updating the mathematical model as applied to the object to be developed. The journal and thrust gas static bearings were designed in accordance with the KnASTU developed method of performance calculations [4]. As a whole, the design calculations of a turbine drive and gas bearings are oriented to the modern engineering capacities of Russian enterprises.

The technical characteristics of the developed air tools at a compressed air pressure of 0.5 MPa are presented in Table 1

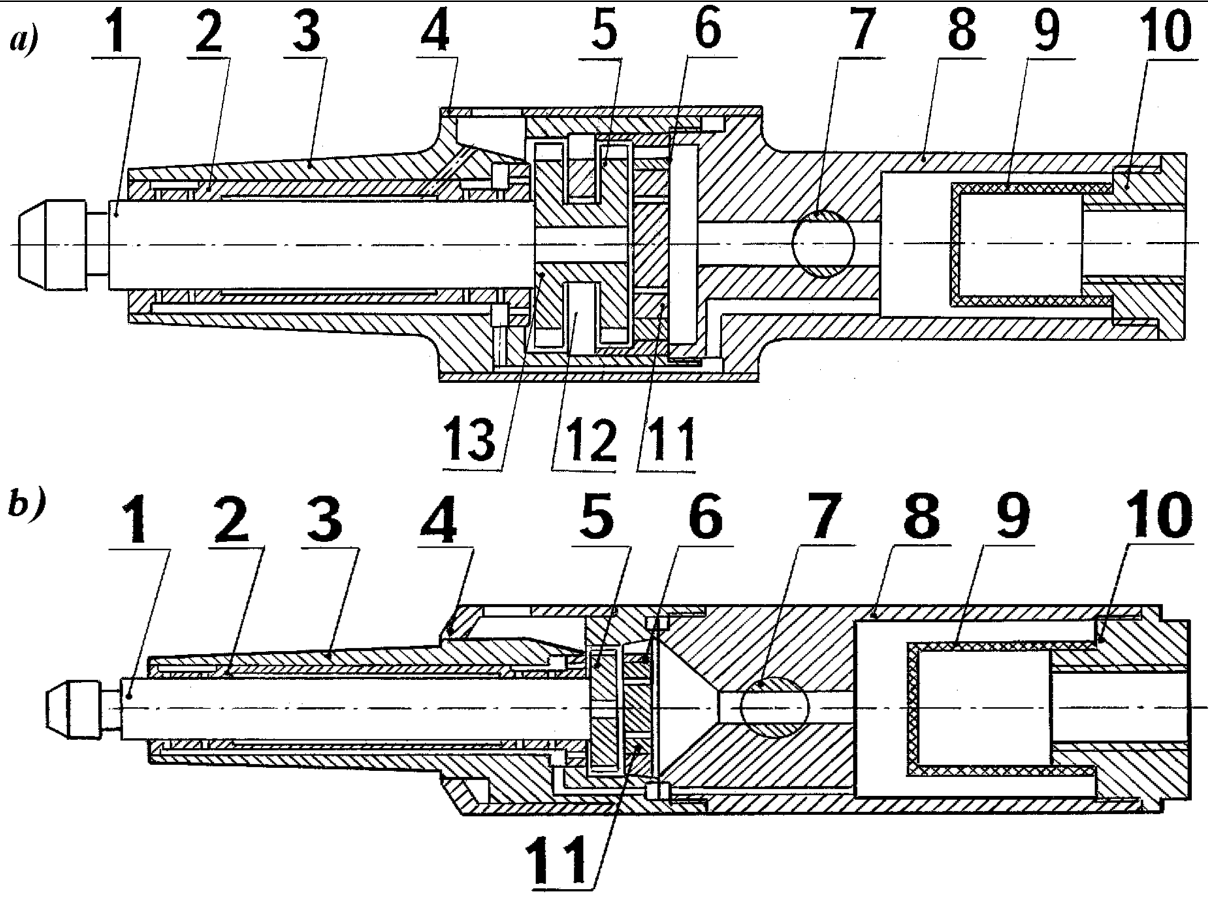

Figure 2. Designs of the high-speed air grinding tool Mod. ВПМШ 035.01 ***(a)*** and ВПМШ 015.01 ***(b)***:
1 – spindle, 2 – gas static journal bearing, 3 – spindle body, 4 – silencer, 5 – first-stage turbine wheel, 6 – nozzle diaphragm, 7 – starting valve, 8 – turbine casing, 9 – filter, 10 – nipple, 11 – thrust bearing, 12 – guide vanes, 13 – second-stage turbine wheel

Table 1. The technical characteristics of the developed air tools at a compressed air pressure of 0.5 MPa

Characteristic	Model		
	ВПМШ 150.01	ВПМШ 035.01	ВПМШ 015.01
Drive power, kWt	1.5	0.25	0.085
No-load spindle speed, rpm	29000	105000	237000
Air consumption, m^3/min	1.90	0.68	0.29
Overall dimensions, (L x W), mm	380 ´ 83	260 ´ 48	175 ´ 33
Weight, kg	3.60	0.65	0.25
Collet chuck diameter, mm	10	6	6
Specific speed (spindle diameter ´ rotational speed), mm/min	$5.5 \cdot 10^5$	$1.47 \cdot 10^6$	$2.13 \cdot 10^6$

With 120 m/sec abrasive machining speed, it is acceptable to fit the air grinding tool Models ВПМШ 150.01, ВПМШ 035.01 and ВПМШ 015.01 with grinding wheels accordingly 80, 20 and 10 mm in diameter. Such relatively small diameter values are not limiting ones, because even at present a number of enterprises are ready to produce abrasive wheels running at rim speeds up to 300 m/sec.

The air tools beta tests were carried out by PC ”KamAZ-Instrument”, the Irkutsk Research Institute of Aircraft Technology and Industrial Engineering, JSC “Amur Ship-building Plant” and the Komsomolsk-on-Amur Aircraft Production Association named after Yu.A. Gagarin. Their expert commissions have pointed out a steady work of the tools over the whole load range, a higher productivity (3-5 times higher) in comparison with the industry-used tools, high surface finish (R_a = 0.63…1.25 μm when milling copper or aluminum alloys, and R_a = 0.16…0.32 μm when machining steels with the use of spray coolants), smooth startup and no vibration notable for an operator.

The measurement of noise and vibration levels of the air grinding tool Models ВПМШ 035.01 and ВПМШ 015.01 was performed by the State Hand-Held Machine Testing Center and those of the Model ВПМШ 150.01 was performed by Dalzavod (Vladivostok). The actual sound power levels of the air tools are shown in Figure 3.

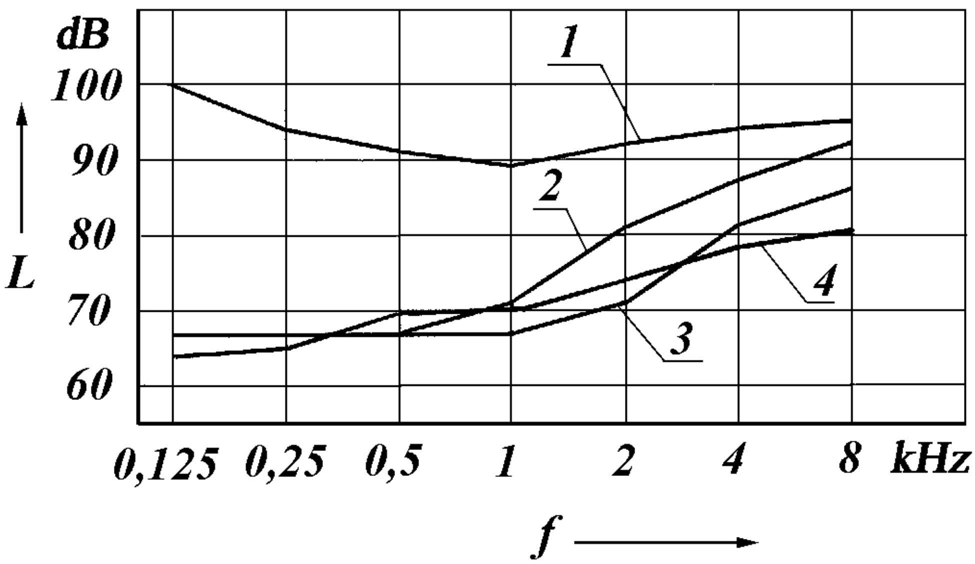

Figure 3. Actual sound power levels ***L*** of the air grinding tools in center frequencies octaves-bands ***f***:
1 – GOST 12.2.030-83, 2 – ВПМШ 035.01, 3 – ВПМШ 015.01, 4 – ВПМШ 150.01

The results of the air tool vibration level tests are presented in Table 2 where first is the parameter of the Mod. ВПМШ 150.01, next is that of the Mod. ВПМШ 035.01 and last is that of the ВПМШ 015.01.

According to GOST 17770-86 “Hand-held machines. Vibration characteristics requirements”, the permissible vibration level on all center frequencies is 109 dB.

Table 2. The results of the air tool vibration level tests. First the parameter of the Mod. ВПМШ 150.01, next is that of the Mod. ВПМШ 035.01 and last is that of the ВПМШ 015.01.

Direction	Vibration level (dB) at center frequency (Hz)							
	8	16	31.5	63	125	250	500	1000
X	60/94/92	60/108/97	60/107/81	61/101/79	72/100/83	75/104/87	65/102/86	64/101/85
Y	58/93/99	61/109/104	62/108/88	59/107/80	60/105/80	78/99/80	66/100/81	61/104/82
Z	62/106/96	61/108/102	60/105/85	62/101/79	64/99/79	76/97/79	64/98/80	62/97/81

The air grinding tool Models ВПМШ 035.01 and ВПМШ 015.01were put into full-scale production in the amount of 1200 pcs/month by LC "Contact" (Komsomolsk-on-Amur). As a result of this tool testing, a hygiene certificate has been issued by the Russian Federation State Committee of Sanitary and Epidemiological Inspection.

The tools designs, their main structural members and units are covered by the Russian Federation patents. The developed air grinding tools are in demand in Russia, CIS countries, South Korea, China. The tools were also demonstrated at a number of Boing Corporation enterprises (USA).

Literature

Kotlyar I.V. Turbine-driven hand grinders with gas lubrication supports [Text] / Kotlyar I.V., Kuznetsov Yu.P., Semashko L.V. // Machine building reporter. - 1983. - №3. – pp. 38–40.

1. Chegodayev D.Ye. Gas lubricated power hand tool vibration reducing [Text] / Chegodayev D.Ye. // Machine building reporter. - 1992. -№9. - pp.22–23.
2. High-speed air-controlled hand machine. Information paper. [Text] // Nikolayev: NKI – 1985, p. 1.
3. Kosmynin A.V. Gas bearing parts of high speed turbine-drives of metal-working machinery [Text] / Kosmynin A.V., Vinogradov V.S. – Vladivostok: Dalnauka, 2002. – p. 327.