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NOISE REDUCTION IN CIRCULAR WOODWORKING MACHINES IN THE PRODUCTION OF WOOD COMPONENTS

Statement of the problem. Woodworking machinery is extensively used in the production of wood components for the construction of objects for various purpose. Operation of woodworking machinery is accompanied by high noise emissions. Circular woodworking machines are the most problematic in terms of their noise characteristics, and also most widespread. The dominating noise source is a saw disk.

Results. Vibration-damping structure is suggested in the form of seals with dry friction placed between clamping flanges and a saw disk. Vibration-damping properties of seals are experimentally examined using H. Oberst's method. The analysis amounted to establishing how the value of the total loss coefficient is affected by the following factors: seal foundation type, frequency of excitation, particles size (dispersion), temperature factor. Based on the obtained results, an experimental study of acoustic efficiency of vibration-damping seals with dry friction was performed, varying being such parameters as the particles size (dispersion) and seal foundation type.

Conclusions. The construction of vibration-damping seals with dry friction with the appropriate particle dispersion and foundation material is based on the results of the experimental study. The suggested construction has considerable advantages over polymeric seals.

Keywords: vibration-damping, noise reduction, circular woodworking machine, seals with dry friction, saw disk, abrasive particles.

Introduction

The construction of objects for various purposes uses woodworking and composite materials based on them (window and door sets, structural panels of paneled houses and other products). Large housing construction firms normally have their own production of these. Prefabricated wood materials are mechanically worked on woodworking benches. Some of the noisiest working environments are found in the woodworking industry, which makes the working conditions of machine operations worse. A level of noise produced by woodworking benches is by 20—30 dB in excess of the regulations.

One of the most radical ways of tackling the reduction of noise caused by circular saw benches (operating noise level is 100—110 dB) is reducing noise radiation in its source of origin. The dominant noise source is a saw disk and less commonly these are other construction parts of the bench (electric handle, vise, etc.) Sound vibration of the saw disk coming in contact with the surface can be largely reduced by as much as 6—8 dB by vibration damping materials. The most efficient technical implementation of this solution is sealing materials (with high vibration damping performances) that are placed between the saw disk and clamping vises. Elastoviscous materials can be used in the construction of vibration damping seals where vibration is dissipated by a viscous friction (in the material proper) [1, 2].

Elastoviscous materials are widely used as vibration damping surfaces but however have a number of disadvantages. First, they are perceived to be efficient if a seal is sufficiently thick which should be 1.5 or 2 times as thick as the saw disk which causes the disk to be loosely fixed and thus longitudinal flapping as the width of a saw cut and worse wood working performance. Secondly, these seals are prone to sudden failures due to emerging shear deformations and spinning caused by high rotational speeds (4000—6000 rpm) of the saw disk and loads during cutting. The latter can contribute to the failure of the saw disk and place the machine operators at a high risk of injury.

1. Construction of vibration damping dry friction seals and their dissipation properties

Paper or cloth coated mineral abrasives are put to use in vibration damping structures which do not possess the above disadvantages that are common to elastoviscous seals. A physical dissipation factor in these seals is dry friction that arises from abrasive particles in contact.

Construction wise

$$E = E'(1 + j\eta), \tag{1}$$

where E is a complex elasticity modulus.

Determining the loss coefficient is better for a comparative analysis of dissipation properties if vibration damping viscous and dry friction seals than the Oberst beam method [4]. Following this method, the total loss coefficient η_Σ of the bearing pile and varying seal glue-applied materials was computed. A steel bearing pile Ст08Ю, 08ПС with the thickness of 2 mm was used in all the series of the experiments. A thermal chamber was used to study the temperature effect on changes in the total loss coefficient η_Σ.

Damping properties of a series production of paper and fabric polishing sheets with mineral abrasive particles of varying dispersity as well as PVC flooring and fabric PVC flooring were experimentally studied. The latter material were researched as most common vibration damping elastoviscous friction coatings.

The scientific justification of vibration acoustic performance of dry friction sealing material structure involved an experimental research of the effect of the following on the total loss coefficient η_Σ:

- backing material (paper and fabric);
- excitation frequency *f*, Hz;
- size of particles (dispersity) of the mineral abrasive material *d*, mkm;
- temperature factor *T*, C^0.

The experimental research results suggest that the dominant influence on the value of η_Σ in the “panel-vibration damping dry friction seals” system is exerted by the oscillation frequency and dispersity of mineral abrasive particles. At the excitation frequency of over 500 Hz the loss coefficient is increasingly greater η_Σ and reaches its maximum (0.03) at the frequency of 1000 Hz. As the size of particles increases, the total loss coefficient η_Σ goes up and reaches its maximum at the particle size of 180 mkm for a fabric backing material and 250 mkm for a paper backing material (0.03). A further increase in the size of particles causes the values of η_Σ to decrease. As the temperature increases, the total loss coefficient η_Σ remains almost unchanged and increases a bit. The above property puts vibration damping dry friction seals at advantage to polymer elastoviscous materials whose damping properties deteriorate as the temperature goes up. This makes them unrivalled in the operation of saw disks that experience significant temperature loads during sawing. The type of the backing material of vibration damping dry friction seals does not have much effect on the value of η_Σ.

The above described method allows for more reliable results as for the high frequency values (1000 Hz). However, it is not only the evaluation of dissipation properties of vibration damping dry friction seals (by the value of η_{Σ}) that is of scientific and practical interest but it is also the experimental research of their acoustic performance (ΔL, dB, dBa) in the regulated range of noise frequency (up to 8000 Hz) on a laboratory setup and in the course of natural experiments. It is noteworthy that the focus of the research is their acoustic performance in a high frequency range (of over 1000 Hz) since saw disk noise spectra are dominated by this frequency range.

2. Experimental research of acoustic performance of vibration damping dry friction seals

The research of acoustic performance in the application of vibration damping dry friction seal was performed experimentally using the following method.

The noise reduction estimate ΔL, dB of damped thin-walled metal structures cannot be currently theoretically computed due to the complexity of sound vibration propagation. The efficiency of the application of dry friction vibration damping coatings with a varying dispersity is found experimentally.

It was suggested that the following physical model is used. Since the acoustic performance estimate is comparative, the physical model of the excited saw disk can be an excited steel panel. The thickness of the panel was chosen to be 2 mm, since the thickness of most common saw disks are equally sized. The dimensional size of the panel is chosen to be 500×500 mm in order for the length of the bending wave starting from 250—500 Hz to fit in this size. The samples of vibration damping dry friction sealing materials in the form of a square was put on the centre of the panel and fixed adhesively. The ratio of the area of vibration damping dry fiction sealing materials and the panel is chosen to be ½, since it is impossible to cover the saw disk of the vibration damping dry friction sealing material considering the operating regulations. The coating area is confined by the sawing depth.

For the comparative measurements the noise levels ΔL there is no need to change the excitement mode of the panel in the estimation of the influence of different parameters of vibration damping dry friction sealing materials and conversely its stability is required to be provided for all the series of measurements.

The following excitement scheme of a steel panel was suggested. The steel panel is fixed at the frame angle by rigid braces. In the lower part of the setup under a steel panel there is an excitement device in the form of electric engines (rotation frequency n = 1300 rtm) with a rigid shaft with a steel drummer at the end of it. During the rotation of an electric engine of a rigid shaft the latter inclining from the axis due to the centripetal force beats the centre of the steel panel with the drummer. In this excitement mode the noise radiated by the panel is perceived to be constant since the time interval between the impulses was $t < 0.05$ sec. In order to rule out the possibility of additional oscillation energy coming in through the braces to the metal sheet due to the vibration of the engine the frame of the setup was made of wood and the engine itself was made on a vibration insulated base from a layer plywood and soft rubber. From the service safety considerations the excitement setup was surrounded by a fine cellular steel grid.

The acoustic performance estimate of vibration damping dry friction sealing material was the reduction of a noise level ΔL:

$$\Delta L = L - L_n, \tag{2}$$

where 0 is the noise level from the panel, dB; L_n is the noise level from the panel with the application of vibration damping dry friction sealing materials, dB.

The acoustic measurements were carried out with ВШВ-003 devices and Octava 101A. The above methods made use of the current guidelines on noise and its measurement. The following varied through the course of the experimental research:

- dispersity of mineral abrasive particles d, mkm;
- type of the backing material (paper or fabric).

The results of the experimental research are in Fig. 1—5.

Fig. 1 and 2 present the diagrams (according to the experiment results) which indicate decreasing nose levels of the sound pressure ΔL, dB and from 125 to 8000 Hzin octave strips in different values of d, mkm.

Fig. 1 presents the dependency of the noise level reduction of the sound pressure ΔL, dB, a vibration excited panel + vibration damping dry friction paper sealing material in different values of the dispersity of particles *d*. The graphic dependencies suggest that the character of the curves both of paper and fabric backing materials is identical and increases as so does the values of the frequency *f*, with the highest performance observed at a high frequency range. The diagrams also show the dependence of the acoustic performance of vibration damping dry friction sealing materials on the dispersity of mineral abrasive particles *d*, mkm, which reaches its maximum at the dispersity of 255 mkm on the paper and 180 mkm on the fabric backing material.

The comparison of the frequency characteristics suggested that as the dispersity of particles is over 355 mkm and less than 150 mkm there is a drop in the acoustic performance both of the paper and fabric backing material and the optimal value of dispersity of particles ranges between 255 mkm and 180 mkm.

Fig. 2 identifies the dependence of the noise level reduction of the sound pressure Δ*L*, dB, vibration excited panel + vibration damping dry friction sealing material of the fabric backing material in different values of dispersity of particles *d*.

The diagram plainly suggests that all the coatings are most efficient in a high range. The maximum acoustic performance (8—9 dB) is observed in the octave strips of 4000 and 8000 Hz at the value of *d* = 255 mkm of the paper and *d* = 180 mkm on fabric backing materials.

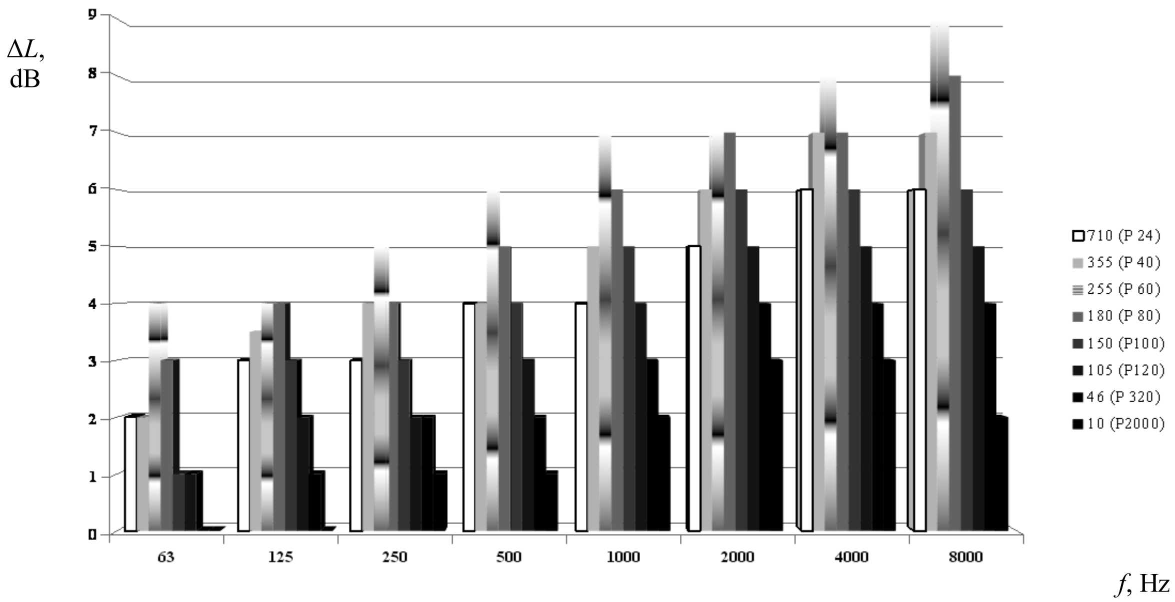

Fig. 1. Reduction of a noise level of the sound pressure Δ*L*, dB, vibration excited panel + vibration damping dry friction sealing material in different values of dispersity of particles on the paper backing material *d*

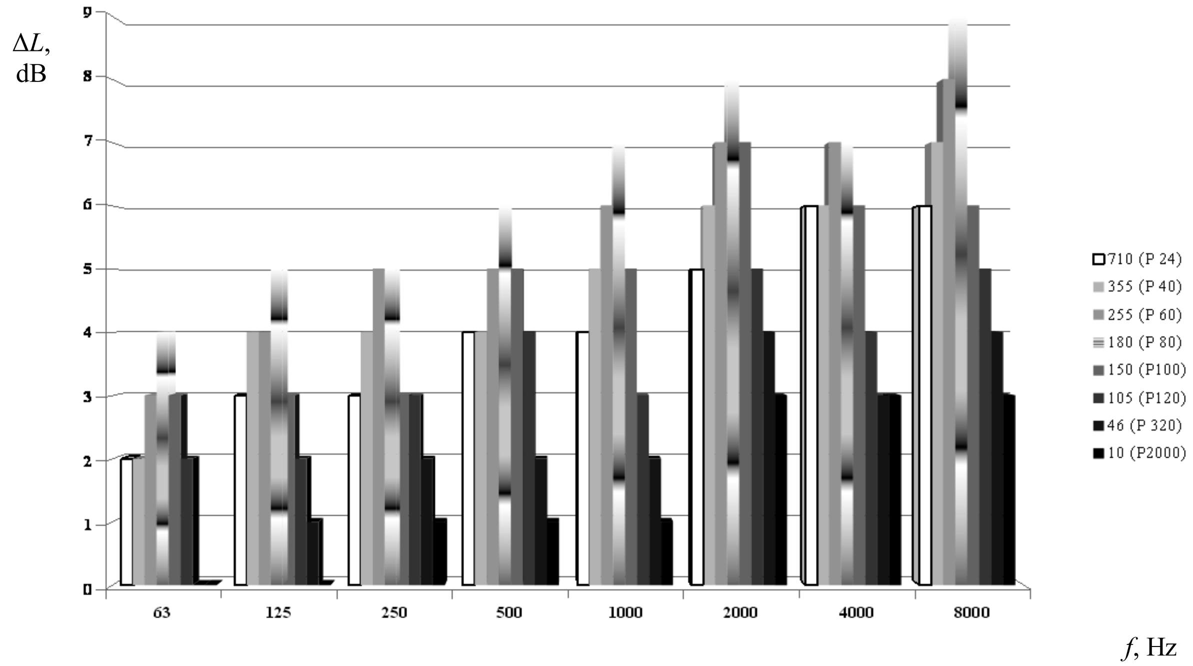

Fig. 2. Reduction of a noise level of the sound pressure ΔL, dB, vibration excited panel + vibration damping dry friction sealing material in different values of dispersity of particles on the fabric backing material d

Fig. 3 presents a diagram that identifies changes in the levels of noise radiated by the system “panel—vibration damping dry friction sealing material” in different values of dispersity of particles d which is 100 mkm and 710 mkm the highest acoustic performance is observed (ΔL =5 dB) (it is to be noted that the coating area of the panel is 50 %).

The experimental research was carried out for the comparative estimation of acoustic performance of vibration damping dry friction seals and vibration damping coatings.

Fig. 4 presents the spectra of acoustic performance ΔL, dB, PVC flooring, vibration damping dry friction seals on the fabric backing material and the paper backing material. The comparison of acoustic performances of these coatings suggests that they are equally efficient through the entire high frequency range and PVC flooring is surpassed by vibration damping dry friction seals in the medium and low frequency range.

Therefore it can be inferred that vibration damping dry friction seals compared to polyvinylchloride flooring has a better acoustic performance in a wider frequency range.

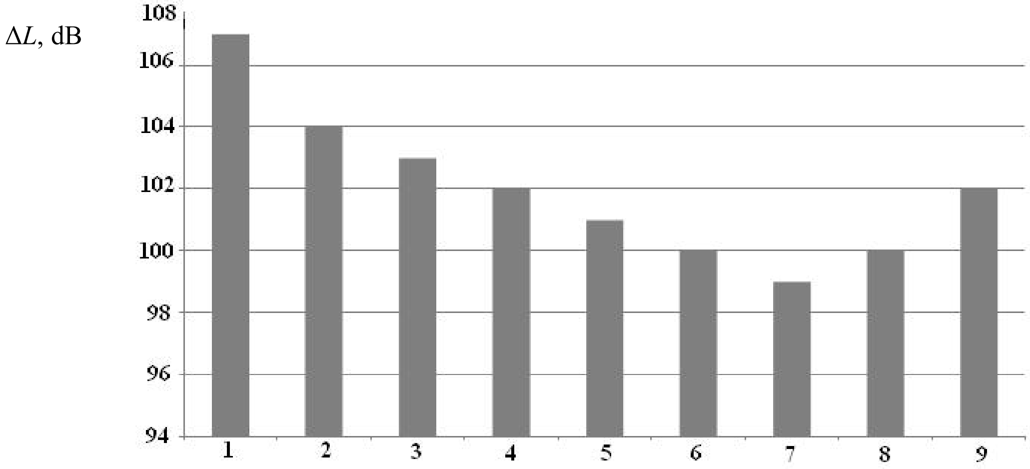

Fig. 3. Change of sound levels *L*, dBA, vibration excited panel + vibration damping dry friction sealing materials on the fabric backing material on dispersity of particles *d*:
1 is an uncovered panel; 2 is the panel + vibration damping dry friction sealing materials (*d* =10.3 mkm);
3 is the panel + vibration damping dry friction sealing materials (*d* =46.2 mkm);
4 is the panel + vibration damping dry friction sealing materials (*d* =100 mkm);
5 is the panel + vibration damping dry friction sealing materials (*d* =150 mkm);
6 is the panel + vibration damping dry friction sealing materials (*d* =180 mkm);
7 is the panel + vibration damping dry friction sealing materials (*d* =255 mkm);
8 is the panel + vibration damping dry friction sealing materials (*d* =355 mkm);
9 is the panel + vibration damping dry friction sealing materials (*d* =710 mkm)

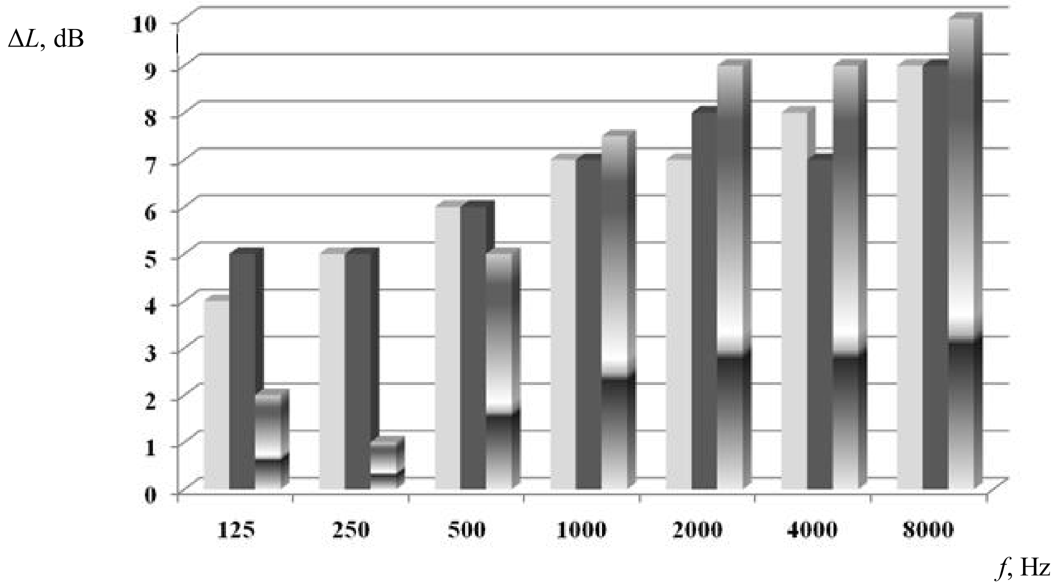

Fig. 4. Comparison of acoustic performances of vibration damping dry friction seals on the paper backing material (⬜), vibration damping dry friction seal on the fabric backing material (■), PVC flooring (▤)

It is noteworthy that the comparison of acoustic performances of these coatings neglects their masses. This is crucial since the comparison of acoustic performances of these coatings does not fully reflect all the advantages and disadvantages of the coatings. Thus the presentation of the performance of the coating where its mass would be considered seems to be more visual and informative.

It is known that the concept of the mass return is used to evaluate the performance of thin-walled metal structures dB/(kg/m^2) which means the value of sound isolation caused by a unit of the structure mass. Considering that we will compare the performance of vibration damping dry friction seals with polyvinylchloride flooring taking into account the surface strength of the materials:

- surface strength of vibration damping dry friction seals on the paper backing material is 1.26 kg/m^2,
- vibration damping dry friction seals on the paper backing material is 0.94 kg/m^2,
- of PVC flooring is 2.7 kg/m^2.

Fig. 5 identifies the ratio of acoustic performance to the surface density Δ*L*/ρ of vibration damping dry friction seals on the fabric backing material, vibration damping dry friction seals on the paper backing material, PVC flooring in the form of graphical dependencies.

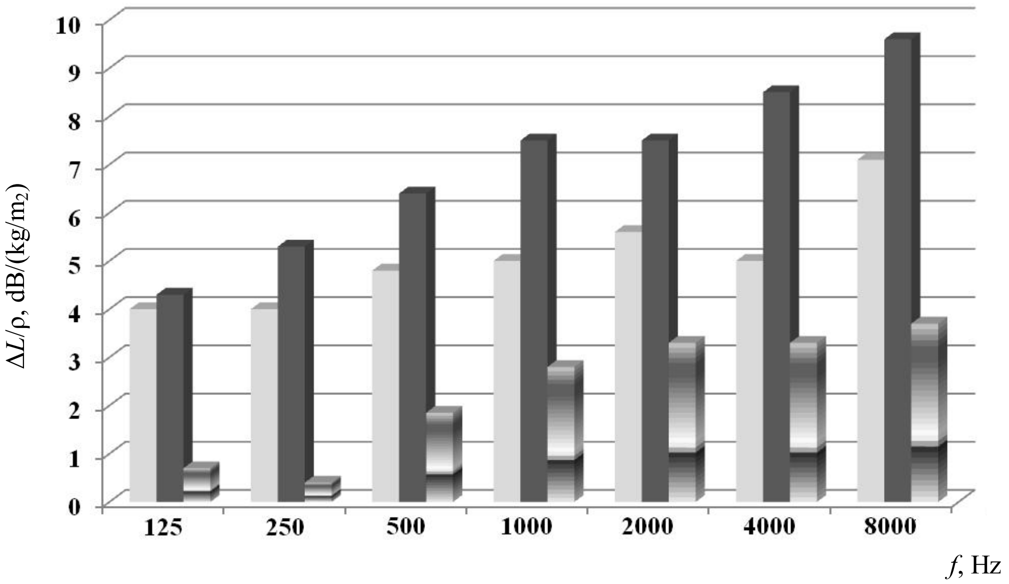

Fig. 5. Acoustic performance of the materials in relation to their surface density:
□ — vibration damping dry friction seal on the fabric backing material,
■ — vibration damping dry friction seals on the paper backing material, ▤ — PVC flooring

Following the graphical dependencies, it can be noted that vibration damping dry friction seals have the mass return 2 or 3 times (!) as high as flooring does and is on average 7 dB/(kg/m^2), which shows the expected acoustic performance of 1 kg of the coating on the damped surface of the panel. This averaged value is 2.3 dB/(kg/m^2) for PVC flooring. It is also obvious that the mass return of vibration damping dry friction seal on the paper backing material is somewhat higher than that of vibration damping dry friction seal on the fabric backing material.

This is to be considered in addressing the problems where the load of vibration damping seals is to be minimized.

Therefore the use of vibration damping dry friction seals to reduce the sound vibration caused by the saw disk rivals the vibration damping coatings from polymer materials in the following ways:

- acoustic performance in the wide frequency range;
- smaller surface density;
- stable damping properties with an increasing temperature;
- sustainability to shear deformation and failure.

Conclusions

The acoustic performance of the structure of vibration damping dry friction seals in order to reduce noise levels of saw disks of circular wood working benches was experimentally proved. Seals use mineral abrasive materials on the paper and fabric backing materials.

The size of mineral abrasive particles was determined that ensures the maximum value of noise level reduction of saw disks which is d = 180 mkm for the fabric backing material and d = 255 mkm for the paper backing material.

The developed structure of dry friction seals with the use of mineral abrasive materials is much more effective compared to identical polymer elastoviscous materials:

- stability of damping properties with an increasing temperature (since saw disks are subjected to significant temperature loads during sawing);
- smaller surface density and thereby mass.

The suggested seal structure is unified and used in a variety of existing circular wood working benches. Besides the seal structure is simple and enables its use in plants where these machines are operated.

References

1. **N. I. Ivanov,** A. S. Nikiforov, *Basis of Vibroacoustics* (Saint Petersburg, 2000) [in Russian].
2. **G. A. Sokolov,** *Noise Reduction in Wood-Working Industries* (Moscow, 1974) [in Russian].
3. **D. S. Osmolovsky,** V. F. Asminin, “Dissipative Properties of Vibration Damping Seals with Dry Friction Using Abrasive Sheet with Abrasive Mineral Particles of Various Dispersion”, in *Russian Forests in the XXI Century* (Saint Petersburg, 2010), pp. 217—222.
4. **H. Oberst,** “Uber die Dampfung der Biegeschurgungen dunner Bleche durch Festhaftende Belage”, Acoustiche Beihefte, 1952, pp. 181—195.
5. **E. Yu. Yudin,** L. A. Borisov, I. V. Gorenshtein, *Noise Reduction in Manufacturing* (Moscow, 1985) [in Russian].