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Parameters Influencing the Noise Emission of Planing Machines

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Abstract: Regarding woodworking machines, machine acoustics are of particular significance due to the high noise emission of these machines. Among other things, this can be attributed to the adoption of the European Commission Machinery Directive as a national law, which demands protection against noise emission in the design phase of new machines. In order to accomplish this, it is necessary to examine and locate the causes of emissions on existing machines. In this paper, the sound source is located through sound intensity measurements, using planing machines as an example, which are particularly noise-intensive woodworking machines. In addition, different influencing parameters on noise emission are analyzed, such as manual and automatic feed, rotational speed and the influence of the type of wood of the workpiece.

Key words: Production process, noise emission, woodworking machines.

1. Introduction

Planing machines are among the most noise intensive wood cutting machines. From the various planing machines available on the market, specifically a stationary surface planing machine and a thickness planing machine were examined acoustically as described below.

The international standard ISO 7960 Annex B and C [1] forms the basis of the investigations conducted. In this standard, different machine parameters are given and partly established. These parameters would include, for example, manual and automatic feed, depth of cut and excess length of cutting edges. The aim of the investigations conducted is to determine qualitatively and quantitatively of the influence of these parameters on the noise emission.

1.1 General Principle

To completely establish a sound field, it is necessary to measure the sound pressure and particle velocity. Particle velocity can be measured directly with a hot-wire anemometer by Particle Image Velocimetry (PIV) or Laser Doppler Velocimetry (LDV) or indirectly with a microphone pair [2-12]. In this study, the indirect method of sound intensity measurement is applied. This method is the most common method for sound source localization and provides sufficient information about the sound radiation of a source. There are measuring instruments, such as the acoustic camera, which, however, cannot be compared to the classic sound intensity method.

1.2 Procedure

In contrast to the sound pressure method, the sound intensity method determines particle velocity, which is a vector quantity. The calculated sound intensity is also a vector quantity with magnitude and direction. The emission of sound from the machine can be depicted as single frequency band, selected frequency bands or as all frequency bands by using the appropriate software. If dominant frequencies can be found within the machine structure, it may be advantageous to evaluate it by each frequency band. Due to the vectorial nature of the sound intensity method, it is not possible to take

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the room conditions and extraneous noise into account. The extraneous noise can exceed the noise level to be measured up to 15 dB, because higher values will result in faulty readings. As this method allows measuring in the near field of a sound source, the shape of the machine can be modelled arbitrarily with the enveloping surface, forming the basis of the acoustic measurement method. Hence, sound sources can be located by means of measurements near the contours. By evaluating the acoustic sound powers of the partial areas, the sound sources of a machine can be identified [13]. This measurement method is more complex, resulting in an increase of the amount of time needed for measurement in comparison with other methods.

Using the Euler equation, it is assumed for the sound intensity measurement with the two-microphone method that the wavelength is clearly greater than the distance between the microphones. According to Jacobsen, F. [14], the particle velocity in the middle of the microphone axis, called x-axis, from this as in Eq. (1)

$$\rho \frac{\partial v_x}{\partial t} \cong \frac{p(x_1) - p(x_2)}{\Delta x} \quad (1)$$

Where, ρ is the density of the air, p is the acoustic pressure and $\Delta x = x_2 - x_1$ [12].

2. Experimental Tests

2.1 Sound Intensity Measurements

First, sound intensity measurements were carried out on the test machines—a surface planer and a thickness planer. Using these measurements, the sound power was calculated, and a mapping was created to gain an impression of how the sound intensity is distributed over the machine surface.

For the intensity measurement, the machine was divided into areas representative to the actual surface. The machines were operated at no-load, as the intensity was measured by sweeping the probe over every partial area. The surface planer was divided into 139 segments and the thickness planer into 168 segments. Avoiding the influence of the test piece, one single test piece was used for the 139 measurements and a single piece for the 168 measurements. Only 15 segments can be measured with one test piece. Therefore, the intensity measurement could only be completed during idle. Fig. 1 shows the result of the measurements on the surface planing machine.

Measurements in the frequency bands between 250 and 6,300 Hz form the basis of this Fig. 1. Each variation in colour represents a difference of 1 dB between the frequency bands 250 kHz and 6.30 kHz. Areas of high intensity can be seen where the openings are present.

These are attributed to the design and are located in the front of the machine at the bottom, as well as below the machine table. In addition, it can be assumed that the cutter head of the surface planer with its eddy trails is an area with high sound radiation.

In regards to the thickness planer, the high noise emissions are caused by the cutter head located in the upper half of the machine, the gearbox located in the lower half of the machine as well as the openings, as shown in Fig. 2.

Due to the improbability of getting reliable data with 10 different test pieces or 12 different test pieces and the considerable amount of time needed for the measurement, the sound intensity was measured on the machines only at no-load. During operation, sound pressure measurements were carried out on the enveloping surface in accordance with or at the therein defined work station [1]. Allowing for correction factors, the sound power level was calculated from the measurements on the enveloping surface using Eqs. (2) and (3):

$$L_{WA} = \overline{L_{pA}} + L_S - K_1 - K_2 \qquad \text{(dB(A))} \quad (2)$$

$$L_S = 10 \cdot \lg\left(\frac{S}{S_0}\right) \qquad \text{(dB(A))} \quad (3)$$

$$K_1 = -10 \cdot \log\left(1 - 10^{-0,1\Delta L}\right) \quad (4)$$

$$\Delta L = \overline{L_p^{'}} - \overline{L_p^{''}} \quad (5)$$

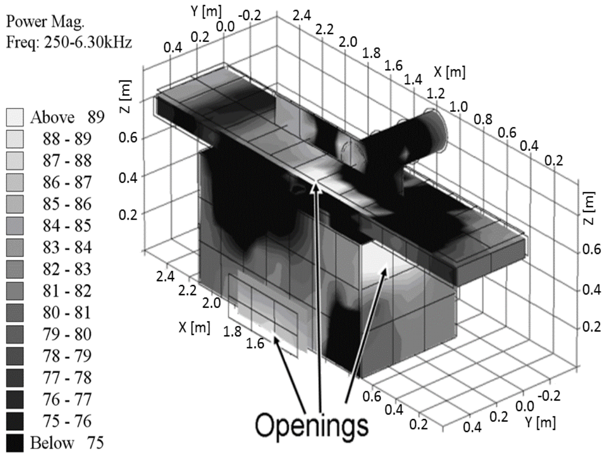

Fig. 1 Distribution of sound power over the surface of a surface planer.

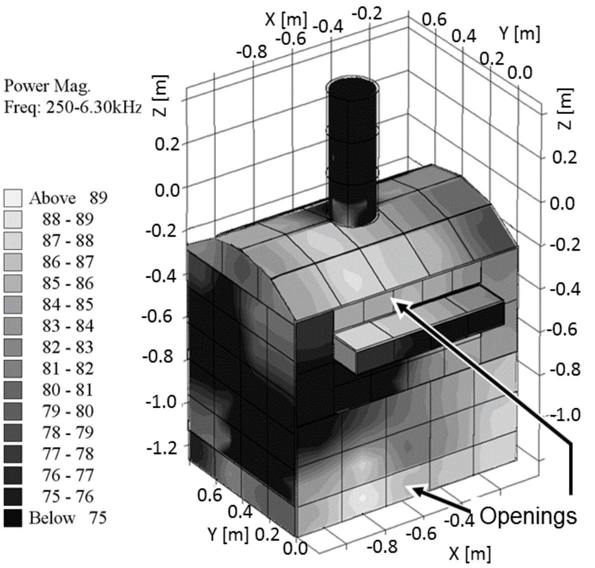

Fig. 2 Distribution of the sound intensity on the surface of a thickness planer.

The Eq. (3) contains: *S*: area of the measured surface in square meters and $S_0 = 1$ m^2.

The extraneous noise corrections are in Eqs. (4) and (5):

Where, ΔL is the difference between the extraneous noise level and the level of the sound source to be examined. The sound pressure level measured at the work station is given as the work station related emission sound pressure level.

2.2 Sound Pressure Measurements

The fundament of the investigations is based on the international standard ISO 7960 Annex B and C [1]. In this standard, different machine parameters are given and partly established. The aim of the tests conducted during this project was to determine qualitatively and quantitatively of the influence of these parameters on noise emission [15]. In addition to the parameters listed in the measurement regulation ISO 7960 [1], the influence of the operator was also evaluated on the surface planer. Specifically on a thickness planer, the number of tool cutting edges was analyzed in regards to the influence on the noise emission. The results of a series of experiments can be found in the diagrams.

Fig. 3 presents the results of the operator's influence on the work station related emission sound pressure level of the surface planer.

The same operation, namely the surfacing of a beam, was carried out by 9 test subjects of both sexes 5 times according to standard [1].

Regarding the noise emission, fluctuations are observed between the test subjects as well as the single measurements of each operation of one person. At first, it was assumed that the differences were caused by the varying manual feed rate and the pressure in which the workpiece was pressed onto the work table. If the contact pressure is too low, the workpiece can vibrate and the noise emission will increase. Therefore, one single person, capable of planing with a constant low noise level was chosen to carry out the planing tests.

The thickness planer examined afterwards has an automatic feed system, which is linked to the drive of the machine. The feed rate can be varied via different gear combinations. The results are illustrated in Fig. 4.

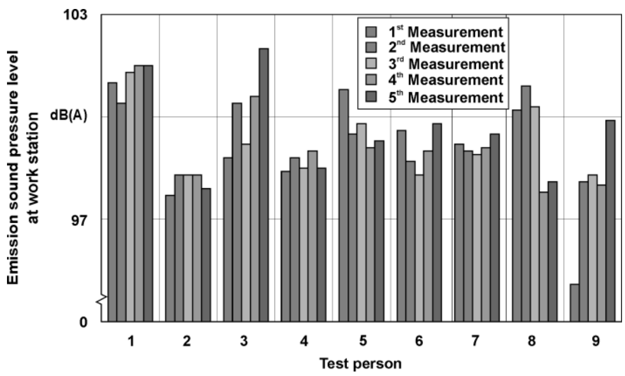

Fig. 3 Operator's influence on the noise emission of a surface planer.

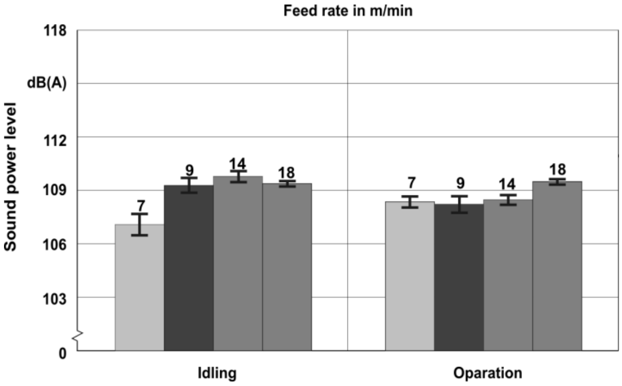

Fig. 4 Influence of the automatic feed system on the noise emission of a thickness planer.

Fig. 4 shows the mean values of the sound power level for the examined thickness planer, depending on the variation of the automatic feed. For the measurements during operation, one piece of wood for every feed rate was used. The test pieces used in the feed rate test had the same number of knots, the same growth ring width and the same structure. It was found that the sound power level increased slightly with an increase in feed rate. However, this rise is relatively small.

From Figs. 3 and 4, it is evident that the operator has a more significant influence on the noise emission of the planing machine than the feed system. It was also observed that the varying feed rate cannot account for the differences in noise emission during manual feed. These differences are instead caused by the varying contact pressure of the workpiece.

Fig. 5 shows how the rotational speed of the examined surface and thickness planer influences the respective work station related emission sound pressure level. The measurements on the thickness planer were carried out at the entry of the wood into the machine. The rotational speed was varied between 500 revolutions per minute and 5,100 revolutions per minute. The noise emission during idling was measured at each rotational speed 5 times. As the rotational speed rose, the noise emission values of both machine types clearly increased. The measurements were carried out during idling to avoid the influence of the operator and the workpiece.

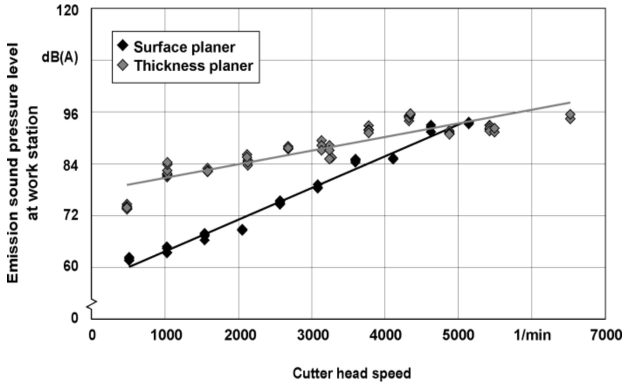

Fig. 5 Influence of rotational speed on the work station related emission sound pressure level of a surface planer and a thickness planer during idling.

The material of the test sample is described with "softwood of medium quality, rough-planed" [1]. Measurements of the work station related emission sound pressure level at the wood entrance of the machine were conducted with 13 test samples of this kind of wood and were machined with a thickness planer under standard conditions. The results are presented in Fig. 6.

First, each test sample, found in an unplaned condition, was placed into the machine. Then the noise emission was measured 3 times during the machining of the samples, which was found in a planed state. The difference of the noise emission during the machining of the unplaned and the rough-planed samples are minor. The differences in the noise emission of the individual test samples can be seen more clearly below.

The series of experiments was repeated, measuring the work station related emission sound pressure level

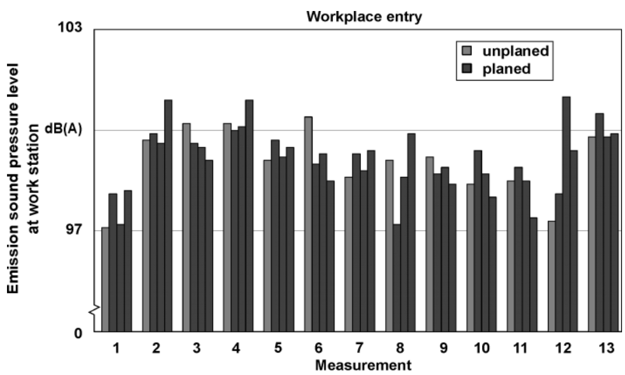

Fig. 6 Influence of the wood on the work station related emission sound pressure level of a thickness planer at the wood entrance.

at the wood exit. This produced a comparable diagram, however, the variation in noise emission is larger than at the wood entrance of the machine. This difference is caused by the heterogeneity of the wood material. The number of branches and the distance between annual rings play an important role. In the summertime, the tree grows faster and develops a light, soft cell structure. In the wintertime, it forms harder, darker cells. If the tree does not grow that much due to environmental and site influences, the hard and soft structures came be found closer to each other. The noise emission of a workpiece produced from a trunk with a short distance between annual rings is higher than the noise emission of a workpiece with a larger annual ring distance.

Due to the findings from the series of experiments presented in Fig. 6, an attempt was made in ruling out the influence of the material on noise emission for all subsequent parameter variations. Consequently, workpieces that were as similar as possible to each other were used for the variation of a single parameter. The result from this is that the individual parameters are comparable in their relative effect on noise emission, but not in their absolute level values. In addition, further experiments were carried out, and other parameters were varied. Further details can be found [13].

3. Conclusions

The aim of the investigations described afore was to determine those parameters that influence the noise emission of the machines considerably and those whose influence is marginal. Fig. 7 shows all the parameters examined on both test machines—a surface planer and a thickness planer, and their influences on the noise emission of the respective planing machine. Cutting parameters such as feed rate, depth of cut, the number of blades and the cutter head speed as well as boundary parameters such as the excess length of blades, the distance to parallel stop, the type wood and operator were investigated.

The results of this research project correlate with the measurements carried out on the other machine types

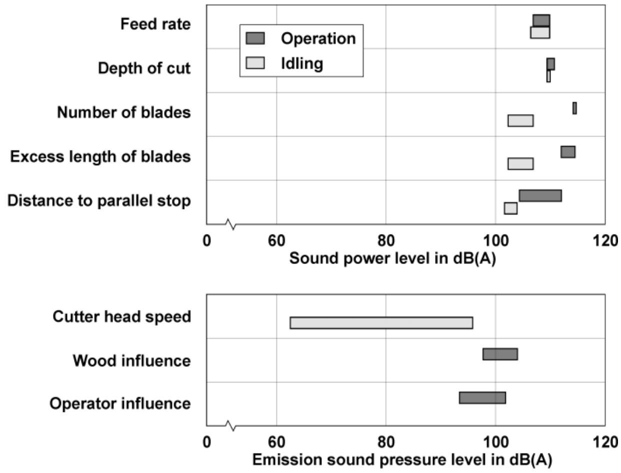

Fig. 7 Fluctuation range of the examined parameters regarding the noise emission of surface and thickness planers.

were described [16-18].

The feed rate of the thickness planer was varied. The investigation showed that the sound power evaluated during idling rose only slightly with an increasing feed rate. During operation, no increase or decrease in sound power was apparent with an increase in feed rate. The results show that the feed rate has no significant influence on the noise emission of the machine neither during idle nor during operation mode.

The tests showed that there is no obvious direct correlation between the depth of cut and the noise emission. Using the thickness planer, the depth of cut was varied between 0.5 mm and 2 mm. The noise emission was measured during idling and during operation, and the sound power level was calculated. The noise emission remained nearly constant in both operating conditions.

The established sound power level decreases during idling with an increase of the number of cutting edges. A dependency cannot be determined during operation. The tests were conducted on the thickness planer using 2 cutting edges and 4 cutting edges.

The excess length of the cutting edges was varied between 1 mm and 1.5 mm on the thickness planer. For safety reasons, it was not possible to conduct more extensive tests. The series of measurements revealed that the sound power level increased by more than 3 dB(A) during idling and decreased by about 1 dB(A) during operation as the excess length of cutting edges rose. On the whole, the influence of the excess length of cutting edges can be considered insignificant.

The distance between the parallel stop and the table edge was varied between 105 mm and 205 mm by increments of 15 mm for the series of measurements on the surface planer. As the distance between parallel stop and table edge increased, the sound power level clearly rose by 7 dB(A) during operation. During idling, there was no dependency evident. The cutter head is responsible for the obvious increase in noise emission. If the parallel stop is close to the table edge, the cutter head is for the most part covered. However, if the parallel stop is adjusted towards the middle of the table, a large part of the cutter head remains uncovered. The conversion of the vibrations into airborne sound occurs almost without hindrance and was recorded by the microphone.

Diverse machines have different yet constant cutter head rotational speeds. According to the tests carried out, the rotational speed has a significant influence on the noise emission. The rotational speed of the cutter head plays only a secondary role in the machining of a workpiece. The surface quality is generally determined by the cutting speed. As every machine is operated with exactly 1 specific cutter head diameter and 1 circular path of cutting edges, the cutting speed is indirectly dependent on the cutter head speed. The machines are operated at optimum cutting speed, as the surface quality of the workpiece suffers at lower speeds and the workpiece surface chars at higher speeds. The cutting speed was varied within a large range and proved to be the main influencing parameter on the noise emission of the examined machines.

The material of the test sample is described as “softwood of medium quality, rough-planed” [1]. The experiments showed that the condition of the wood, i.e. rough-planed or planed, had only a slight influence on the noise emission of a machine in comparison to the structure of the wood. However, softwood of medium quality is generally found with a multitude of branches, and therefore, attention should be paid to establishing a fixed number of branches and a fixed annual ring distance when conducting tests in regards to noise emission. Another option would be to give machine a more homogeneous material. Meranti wood, with a particular thickness, would be ideal in this case. This kind of wood is very homogeneous and can reduce the considerable influence of the test samples.

Regarding surface planers, the influence of the operator also proved to be a factor that clearly disrupted the measured noise emission. Fluctuations arose due to manual feed and the various pressures used in pressing the workpiece onto the work table of the machine. If there is not enough contact pressure, the workpiece can vibrate. In the series of experiments conducted, the influence of the operator was minimised by using 1 and the same operator. In general, the influence of the operator could be minimised by using a feeding device. The cutter head would be then covered by the feeding device. Hence, the emission sound pressure level measured at the work station would be lower. This was proved by during the investigation of the varying distance between parallel stop and table edge. If a feeding device is used consistently, the noise emissions of a machine can be made to be more comparable.

The analysis identified the parameters with a major influence during idling and those with a marginal influence. Most parameters that showed a marginal influence during idling demonstrated as well little influence on the noise emission during operation. The noise emission during idling and operation, in regards to the parameters: number of blades and distance to parallel stop, did not show the same degree of influence. The blades cause turbulence and, during operation, the test piece absorbed the turbulences. The reason for the different degrees of influence on the noise emission during idling and operation was described above.

The investigations showed that the testing of some parameters could only be conducted during idling for technical reasons or only during operation, because it is not possible for them to be tested during idling. These procedures are legitimate [16-18].

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