Wood Sci. Technol. 13: 301–309 (1979)

Wood Science and Technology

The Effect of Workpiece Vibration on Planing Noise

C. Tanaka*
University of California, Forest Products Laboratory, Richmond, California

Summary. Effects of the workpiece surface vibration on planing noise were investigated theoretically and experimentally. A method of calculating the sound pressure level generated by the workpiece surface vibration due to the impact of planing knives was developed. Sound pressure levels and sound spectra calculated using this method show good agreement with measured values.

Introduction

Several studies (Brooks, Bailey, 1975; Heydt, Schwarz, 1977; Pahlitzsch, Liegmann, 1956; Stewart, 1972; Tanaka, 1975; Tröger, 1969) have dealt with the sources of noise and how it is generated in planers. According to these papers, planing machines emit different kinds of noise during machine idling and the actual cutting process. The main source during idling is aerodynamic interaction between the rotating cutterhead and stationary table edges. Aerodynamically induced noise is produced by both monopole and dipole mechanisms. During actual cutting, the main source of planing noise is the air-borne and structure-borne noise due to mechanical vibration of the workpiece surface caused by a periodic contact of the cutter knives. The structure-borne noise dominates the level and nature of planing noise at ordinary rotational speeds of the cutterhead.

To accomplish noise reduction by modifiying the machine equipment, it is necessary to investigate the effect of workpiece surface vibration on planing noise. For this purpose, a combined theoretical-experimental program was undertaken to determine the relationship between workpiece surface vibration levels and noise levels radiated from the workpiece as a result of this vibration, and to calculate the corresponding sound pressure levels.

---

* Visiting Scientist at U.C. Forest Products Lab., 1977–78; Faculty of Agriculture, Shimane University, Matsue, Japan

0043-7719/79/0013/0301/$ 1.80

Experimental Program

The experimental parameters independently varied included rotational speed, location of microphone and width of wood planed. The width, length, and height of the hand-feed planer used for this experiment are 360 mm, 1850 mm and 760 mm, respectively. The diameter and length of the six straight cutterhead knives are 125 mm and 306 mm, respectively. The length, width, thickness and clearance angle of the knife made of SKH2 steel are 306 mm, 25 mm, 3 mm and 30 degrees, respectively. Knives were always kept sharp because of the rise in noise level with increasing knife wear (Tanaka, 1975). The feed speed and the depth of cut were kept constant at 11.1 m/min and 0.3 mm. The workpiece material was Ezo-matsu (*Picea jezoensis* Carr).

The planing direction was parallel to the longitudinal axis on the radial and tangential sections of the workpiece. The test workpieces were 1900 mm in length, 40 mm in thickness, and in various widths of 200 mm, 100 mm and 50 mm, and were selected, as carefully as possible, for their structural uniformity and absence of knots. They were conditioned to approximately 13 percent moisture content.

For the sound pressure and the acceleration measurements, a precision sound level meter with condenser microphone, an accelerometer, a charge amplifier, a frequency analyzer and a level recorder were used. An accelerometer was bonded to the end of the workpiece to measure the acceleration level of the workpiece surface generated during planing. The measurement direction for acceleration was perpendicular to the planer table.

Results and Discussion

The planing noise consists of the aerodynamic noise in idling and the noise due to the planing action. Comparison of the sound spectrum in idling with the one in planing shows that the level difference is more than 10 decibels in the frequency range above 800 Hz as shown in Figure 1, when the cutterhead speed is less than 5000 rpm. Therefore, the idling noise has a negligible effect on the overall planing noise in this frequency range.

The noise due to the planing action may be thought to be composed of the vibration noise caused by the impact of knives on the workpiece, friction due to the contact between knives and workpiece, and the like. To facilitate the determination of the dominant factor of noise production during planing, a narrow band frequency analyzer was used, and the relationship between the sound spectrum and the acceleration spectrum of the workpiece surface was investigated. The resulting spectra are shown in Figure 2. The noise and workpiece surface acceleration spectra caused by impact of the knives on the workpiece show a similar pattern with a series of corresponding peaks. This indicates that the noise produced by the workpiece surface vibration significantly affects the planing noise.

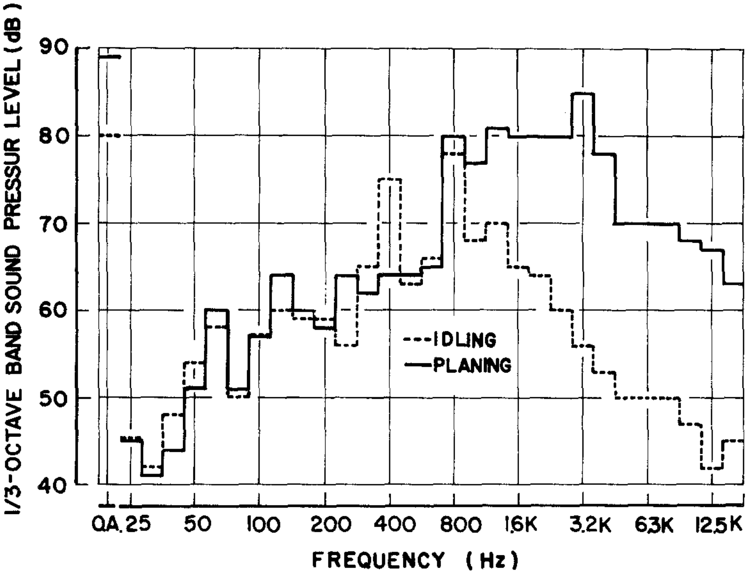

Fig. 1. Comparison of the sound spectra in idling and in cutting. Cutterhead speed is 4000 rpm. Width of wood planed is 10 cm

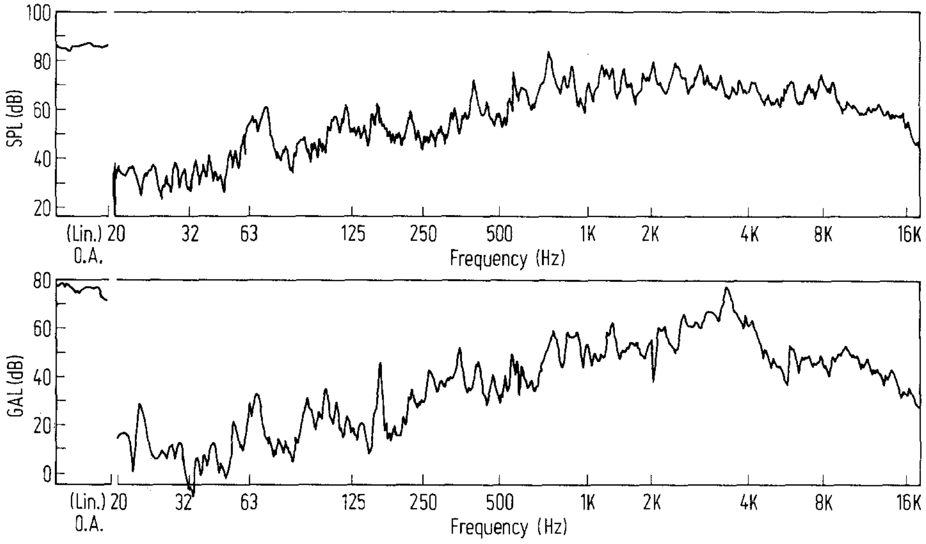

Fig. 2 Relationship between sound and acceleration spectra of workpiece surface in actual planing Cutterhead speed is 4000 rpm. Width of wood planed is 10 cm

Theoretical Development

In calculating the sound pressure level caused by the workpiece surface vibration, it is assumed that the sound pressure level in planing (L_o) consists mainly of the pressure level in idling (L_N) and the one due to the planing action only (L_C). In this case, (Tanaka, 1975) L_C is given by:

$$L_C = L_N + 10\log_{10}(10^{(L_o - L_N)/10} - 1)\ (\mathrm{dB}) \tag{1}$$

It is further assumed that the testing environment is a reverberation room. Then, the acoustic power (W) radiated from the workpiece with surface area (S), when its surface vibrates as a result of planing action, is defined as follows (Gösele, 1953):

$$W = \sigma\rho C U^2 S \tag{2}$$

where σ is the radiation efficiency, ρ the density of air in kg/m^3, C the speed of sound in air in m/sec, U the average root-mean-square velocity of the vibrating workpiece surface and ρC the acoustic impedance of air.

Instrumentation to measure the mean square velocity, U^2, over the amplitude and desired frequency range was not available. However, the mean square acceleration, a^2, can be determined with a sensitive accelerometer. Then, assuming narrow measurement bandwidths:

$$U^2 = (a/2\pi f)^2 \tag{3}$$

where f is the vibration frequency. Substituting Eq. (3) into Eq. (2) yields:

$$W = \sigma\rho c\,(a/2\pi f)^2 S \tag{4}$$

Rewriting Eq. (4) in logarithmic form results in

$$\mathrm{P.W.L.} = 10\log_{10}\sigma + \mathrm{gal} - 20\log_{10}f + 10\log_{10}S + 90.1\ (\mathrm{dB}) \tag{5}$$

where P.W.L. is the power level, $\mathrm{P.W.L.} = 10\log_{10}P/P_o$. P_o is a reference power of 10^{-12} watts and gal is the acceleration level. $\mathrm{gal} = 20\log_{10} a/a_o$, a_o being a reference acceleration of 1 cm/sec^2.

Equation (5) expresses the relationship between the workpiece surface acceleration levels, gal, and the power level radiated from the workpiece of surface area (S). There is a relationship between the power level of a source and the sound pressure level which is measured at some distance from the source. That is, when a sound source is a non-directional line source, the sound pressure level (S.P.L.) measured at some distance from the source is expressed as (Nippon Onkyo Zairyo Kyokai 1966):

$$\text{S.P.L.} = \text{P.W.L.} + 10\log_{10} l/d\,(\tan^{-1} l/_2 d) - 8\ (\text{dB}) \tag{6}$$

where l = the length of the sound source
d = distance from the sound source to the measuring point

When a sound source is a non-directional point source, the sound pressure level (S.P.L.) at the measuring point is calculated by Eq. (7).

$$\text{S.P.L.} = \text{P.W.L.} - 20\log_{10} d - 11\ (\text{dB}) \tag{7}$$

where d is the distance from a sound source to the measuring point. Substituting Eqs. (6), (7) into (5) yields the following equations:

$$L_c = 10\log_{10}\sigma + \text{gal} - 20\log_{10} f + 10\log_{10} S + 10\log_{10} l/d\,(\tan^{-1} l/_2 d) + 82.1\ (\text{dB}) \tag{8}$$

$$L_c = 10\log_{10}\sigma + \text{gal} - 20\log_{10} f + 10\log_{10} S - 20\log_{10} d + 79.1\ (\text{dB}) \tag{9}$$

These two equations show the relationship between the sound pressure levels due to the planing action only and the workpiece surface acceleration. Equations (8) and (9) show that the sound pressure levels can be calculated once the nature of the noise source, the radiation efficiency and acceleration of the workpiece surface, are specified.

The experimental investigation was, therefore, directed toward the nature of noise source during machine operation, and the radiation efficiency of the workpiece surface.

Experimental Results

Table 1 summarizes the values of sound pressure levels measured at various distances from the source. In this experiment, a condenser microphone was placed at 50, 100, 150 and 200 cm from the end of the cutterhead. These locations were 100 cm above

Table 1. The reduction of sound pressure level with the distance from planer

Distance cm	Cutterhead speed rpm 2000		4000	
	Width of wood planed cm 5	10	10	20
50	89dB	89dB	91dB	98dB
100	85	86	90	98
150	83	84	90	96
200	81	83	86	94

floor level and on a line parallel to the rotational axis of cutterhead. The rotational speeds of cutterhead were 2000 and 4000 rpm.

The reduction of sound pressure level is given as a function of distance from a source. When the source approximates a point source, the reduction of sound pressure level (ΔI) is given by $\Delta I = 20 \log_{10} l_2/l_1$. When the sound source is a line source, the reduction of sound pressure level (ΔI) is given by $\Delta I = 10 \log_{10} l_2/l_1$, where l_1

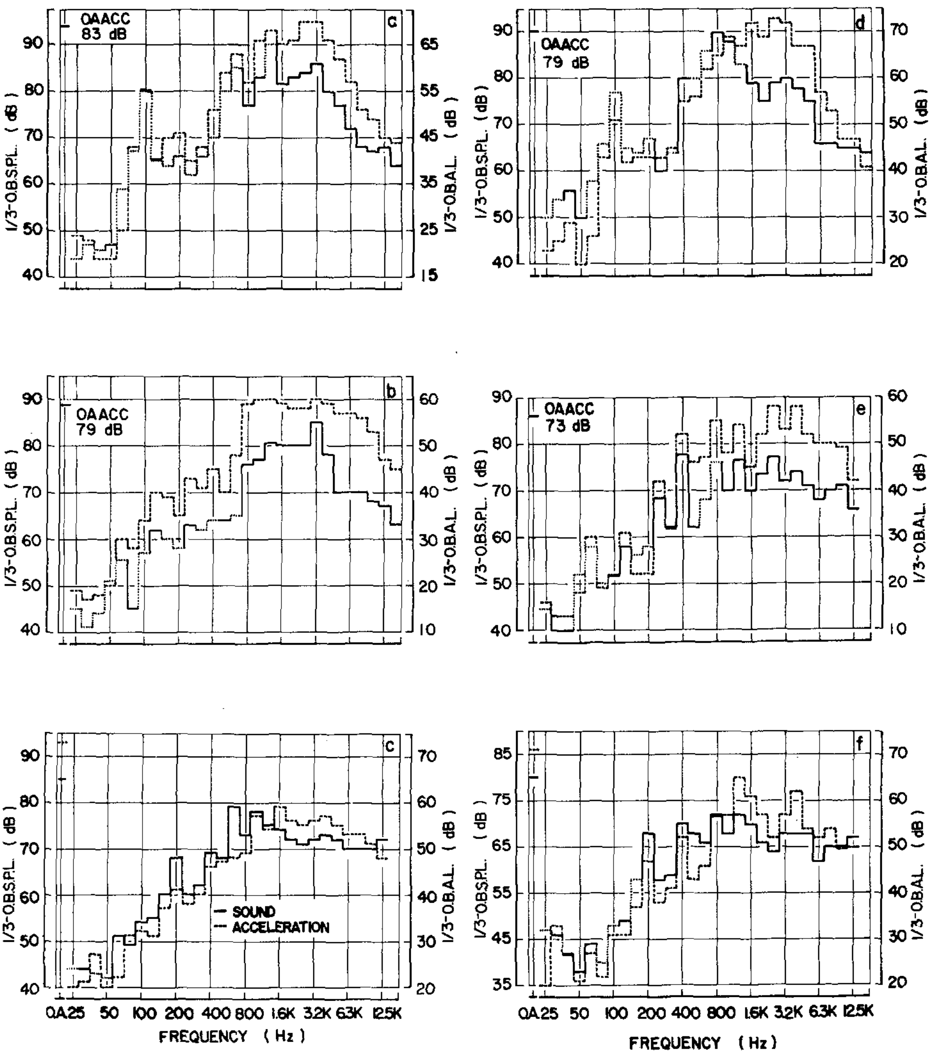

Fig. 3. Relationship between sound spectra due to the planing action only and acceleration spectra of the workpiece surface vibration. OAACC means overall level of acceleration. 1/3-O.B.S.P.L. means 1/3-octave band sound pressure level, 1/3-O.B.A.L. 1/3-octave band acceleration level. Width of wood planed is 10 cm in tests a, b and c, and it is 5 cm in d, e and f. Cutterhead speed is 6000 rpm in a and d, 4000 rpm in b and e, and 2000 rpm in c and f

is the distance of the measuring point from the sound source, and l_2 is the distance of a second measuring point from the source. The sound source in planing may be considered to be a line source by comparing Table 1 with the two equations of pressure levels. Hence, the relationship between the workpiece surface vibration and the sound pressure levels due to the planing action is given by Eq. (8).

Figure 3 shows workpiece surface acceleration spectra and sound spectra due to the planing action only. In this experiment, the microphone was located at a point 100 cm from the end of the cutterhead and 100 cm above the floor level. The $^1/_3$-octave band sound pressure levels due to the planing action only were calculated by Eq. (1). In the measurement of $^1/_3$-octave band sound pressure levels, the $^1/_3$-octave band pressure levels due to idling showed higher levels in some frequencies than similar bands in planing. In this case, $^1/_3$-octave band sound pressure levels obtained during the planing operation were regarded as being due to the planing action only neglecting the portion due to machine idling. These levels are shown by dotted lines in Figure 3.

The radiation efficiency of the workpiece surface (σ) was determined by substituting the levels drawn in Figure 3 into Eq. (8). The results are shown in Table 2. Since it has been reported (Tanaka, 1975) that the workpiece thickness does not affect the planing noise level, the thickness of the workpiece was ignored in the calculation of the total surface area of workpiece.

Figure 4 shows the comparison of the sound spectra due to the planing action only with the one which was calculated by substituting the results of Table 2 and the $^1/_3$-octave band acceleration levels in Figure 3 into Eq. (8).

Table 2. Average radiation efficiency divided by a square of frequency (σ/f^2), of the workpiece

The width of wood planed: 5 cm

Cutterhead speed rpm	Frequency	
	25 ~ 800 Hz	1,000 ~ 16,000 Hz
2000	1.01×10^{-5}	1.15×10^{-6}
4000	2.67×10^{-5}	3.63×10^{-6}
6000	3.69×10^{-5}	2.01×10^{-6}

The width of wood planed: 10 cm

Cutterhead speed rpm	Frequency	
	25 ~ 800 Hz	1,000 ~ 16,000 Hz
2000	1.24×10^{-5}	3.28×10^{-6}
4000	1.08×10^{-5}	4.12×10^{-6}
6000	1.61×10^{-5}	2.86×10^{-6}

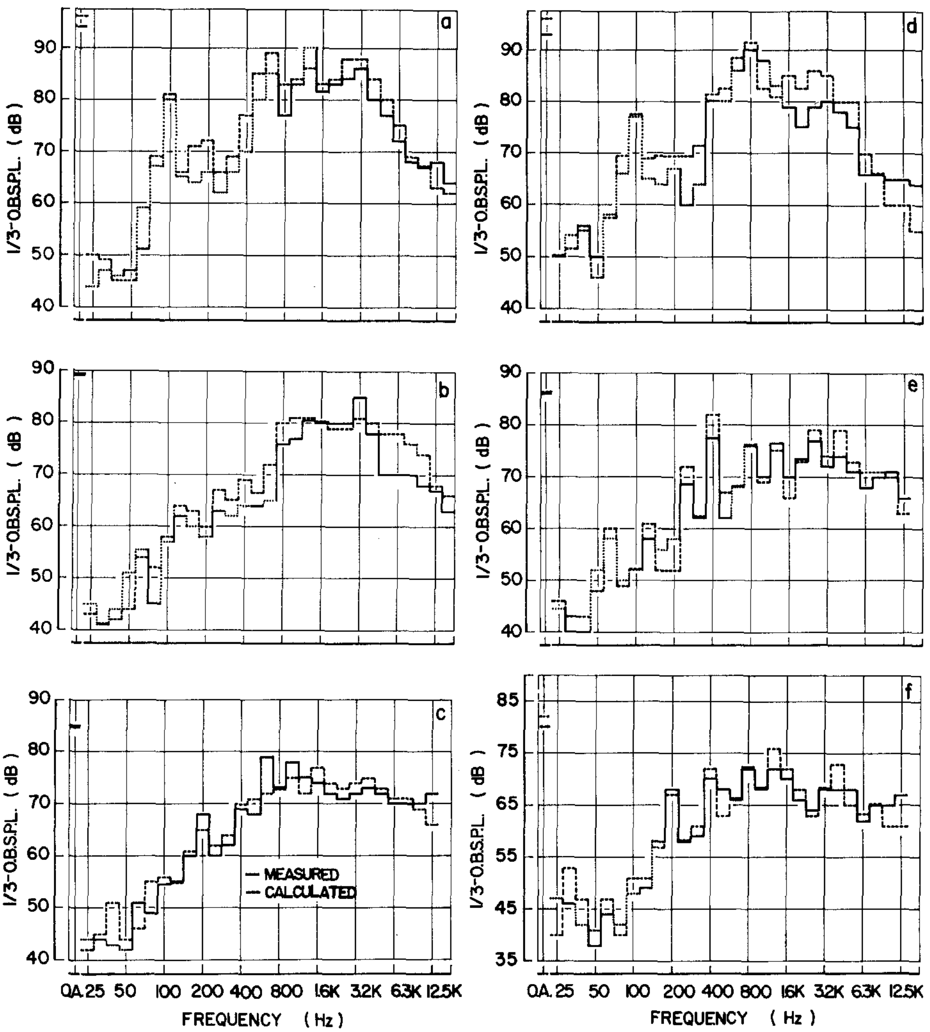

Fig. 4. Comparison of sound spectra due to the planing action only with the one that was calculated. $^1/_3$-O.B.S.P.L. means $^1/_3$-octave band sound pressure level. Width of wood planed is 10cm in a, b and c, and 5cm in d, e and f. Cutterhead speed is 6000rpm in a and d, 4000rpm in b and e, and 2000rpm in c and f

A good agreement is observed. This indicates that the source of noise generation in planing is mainly controlled by the workpiece surface vibration. Hence, it is considered that a planing method which reduces the workpiece surface vibration levels should be developed to achieve a significant noise reduction during machine operation. The results also show that it is possible to calculate the sound pressure level in planing by finding the radiation efficiency of the wood being planed and the workpiece surface vibration levels caused by the planing action.

Conclusion

The sound pressure level and the sound spectrum in planing were investigated theoretically and experimentally. Sound pressure levels and sound spectra calculated show good agreement with those measured.

Acknowledgments

The author wishes to express his appreciation to Professor Fred E. Dickinson, Director of the Forest Products Laboratory, University of California, for his help in publishing this paper during his stay at the Laboratory. The author is also indebted to Dr. Barney E. Klamecki and Mr. George Tsai, University of California Forest Products Laboratory, for their helpful advice and critical reading of the manuscript.

References

Brooks, T. F., Bailey, J. R. 1975: Mechanisms of aerodynamic noise generation in idling woodworking machines. ASME Paper 75-DET-47

Gösele, K. 1953: Schallabstrahlung von Platten, die zu Biegeschwingungen angeregt sind. Acustica 3; 243–248

Heydt, F., Schwarz, H.-J. 1977: Geräuschuntersuchungen und Maßnahmen zur Geräuschminderung an mehrseitigen Hobel- und Fräsmaschinen für die Holzbearbeitung. Holz Roh- Werkstoff 35: 323–326

Nippon Onkyo Zairyo Kyokai 1966: Soon Taisaku Handbook. Gihodo, Tokyo, 253 (In Japanese)

Pahlitzsch, G., Liegmann, E. 1956: Geräuschuntersuchungen an einer Abricht-Hobelmaschine. Holz Roh- Werkstoff 14: 121–136

Stewart, J. S. 1972: A therotical and experimental study of wood planer noise and its control. Dept. Mech. Aerosp. Eng., N. C. State Univ., Raleigh, N. C.

Tanaka, C. 1975: Studies on the hand feed planer noise. Bull. Shimane Univ. Forests 3

Tröger, J. 1969: Über den Mechanismus der Schallentstehung beim Spanen. 2. Mit.: Untersuchungen über den Leerlauflärm. Holztechnologie 10: 265–269

(Received July 21, 1978)

C. Tanaka
Faculty of Agriculture
Shimane University
1060 Nishi Kawatsu cho
Matsue 690, Japan