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Idling noise from circular saws made of metals with different damping capacities

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Abstract Circular saw construction using materials with high internal damping has been found to be an effective way to suppress whistling noise during saw idling. A high-damping alloy called Silentalloy (12Cr-3Al-Fe) was previously shown to be an effective material for this purpose. Tests with Silentalloy suggested that a logarithmic decrement of at least 0.07 is needed. Silentalloy does have some disadvantages, such as modest strength, difficult heat treatability, and "special order" status. The purpose of these experiments was to confirm the general applicability of the minimum effective logarithmic decrement of 0.07 and to find more practical metals for saw-blade construction. Three commercially available metals of different damping capacity were selected. The idling noises of saws made of these metals were compared with those of saws made of typical saw steel and Silentalloy. The minimum logarithmic decrement for whistling-noise suppression was found to be approximately 0.01. On a logarithmic scale, this value is similar to the 0.07 value previously found for a Silentalloy saw. A ferromagnetic steel (20Cr-3Al-Fe) was found to be a useful alternative to Silentalloy from the viewpoint of strength, but the cost of this steel makes it unsuitable for mass production. The success in identifying an effective alternative material to Silentalloy provides encouragement for the identification of other high-damping alloys among the 13Cr-Fe to 18Cr-Fe series without the cost disadvantage of ferromagnetic steel.

Key words Circular saw · Whistling noise · Resonance · Damping alloy · Noise

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Introduction

Whistling noise[1] often occurs with circular saws used in the wood industry. This noise is produced by a circular saw only when idling and disappears just as cutting starts.[2] As the whistling noise is characterized by an intense discrete tone, the mechanism of the whistling noise had been proposed[2] and has been proven experimentally[3] to be a saw-blade resonance excited by aerodynamic forces.

Three approaches can be considered for suppressing the whistling noise: restraining vortex shedding behind a tooth,[4] changing the resonant frequency of a saw blade, and giving damping capacity to the saw body. It is difficult to restrain vortex shedding so long as teeth exist. Placing slots in the periphery of a body is recognized to be effective in change saw resonant frequency,[5–7] but the noise then occurs at different saw speeds.[8] Therefore, using a damped body metal may be the most practical way to suppress the whistling noise completely.

There are three methods[9] of giving damping capacity to a saw blade: system damping, structural damping, and material damping. The first method has been put into practice to make comb-like slots over a wide area of a body using a CO_2 laser.[10] The vibration energy is damped by the friction between the tips of the teeth of one side in a comb and the bottom of the other side, but the comb slots noticeably weaken the saw blade in terms of strength and rigidity, and the friction causes wear of the contacted points. The second method was used in Germany[11] to develop and commercialize a saw blade including viscoelastic layers, but the presence of these viscoelastic layers prevents effective saw-blade tensioning. The construction is also much more complex than that of typical circular saws, and it is difficult to make a thin saw body.

With the third method, a tungsten/carbide-tipped circular saw[8,12,13] was developed whose body is made of a high-damping alloy called Silentalloy (SIA).[14] The strength of SIA is considerably less than that of a typical saw steel, such as SKS5, so a circular saw made of a stronger damping alloy named CSK was developed in cooperation with Toshiba

Corp. and was successful in suppressing the whistling noise.[15] Both SIA and CSK alloys have practical disadvantages in that they are somewhat difficult to heat-treat, they are two to three times more expensive than typical saw steel (SKS5), and they are available only by special order.

The authors also investigated how high the damping capacity must be to suppress the whistling noise. In this investigation, advantage was taken of the fact that the logarithmic decrement of SIA can be adjusted by heat treatment. The tests indicated that a logarithmic decrement greater than 0.07 is needed to suppress the whistling noise completely for a circular saw of 305 mm diameter.[16]

The objective of this study was to confirm the transferability of the value of 0.07 to other metals and thereafter to investigate and identify alternative high-damping metals that have higher strength, can be obtained at lower cost, and are more easily available commercially. Three commercially available metals from different constituent series were selected whose damping capacities were expected to have a logarithmic decrement in the range around 0.07. The idling noises of saws made of these metals were compared with those of saws made of typical saw steel (SKS5) and SIA.

Materials and methods

The main properties of the chosen saw body metals are listed in the order of their damping capacity in Table 1,[17,18] along with those of SKS5 and SIA[14] for reference. The five metals studied were stainless steel (SUS304), alloy tool steel (SKS5), ferromagnetic steel (HCF), pure iron for a magnetic material (SUYP1), and Silentalloy (SIA). The logarithmic decrements were measured using cantilever specimens of 10 × 140 (beam length) cut at 0 and 45 degrees to the rolling direction and determined under an amplitude of 0.8 mm. All abbreviations of metals except SIA and HCF in this table are defined by Japanese Industrial Standards.

Two circular saws were made from each body metal, and one of the two was used to measure noise. All circular saws used in this experiment had a diameter of 305 mm, a body thickness of 2 mm, a kerf width of 3 mm, and 80 tungsten/carbide-tipped teeth. The saws did not have any slots.

Each circular saw was rotated in an apparatus driven by a variable-speed motor covered by a shield box. The apparatus was placed in the middle of a workshop of width 7.2 m, length 15 m, and height 3.9 m. The inner wall and the ceiling of the room were finished with concrete and lined with excelsior board, respectively. The recommended space for noise measurement around the apparatus (i.e., the free field) was judged to be a space of 1.2 m from the center of a noise source.

The background noise was measured within the range of rotational speed 1000–6000 rpm. As the differences in noise levels between the source and the background in the range of 1000–1300 rpm were less than 10 dB, the noise levels corresponding to it were corrected to the true levels.

Noise from each circular saw was measured using a precision sound-level meter (Brüel and Kjær, 2209) with a 1-inch condenser microphone (Brüel and Kjær, 4145), a fast Fourier transform (FFT) analyzer (NEC Sanei, 7T23S), and a digital plotter. The microphone was placed at a distance of 1 m from the center of a saw on the axis of the arbor of the apparatus. The noise and power spectrum from a saw were measured at intervals of 100 rpm within the range 1000–6000 rpm.

Results and discussion

Figure 1 shows the measured noise levels versus the rotational speed for the five saws. Many peaks of various sizes

Table 1. Main properties of metals used in the saw body

Properties	SUS304 (stainless steel)	SKS5 (alloy tool steel)	HCF (ferromagnetic steel)	SUYP1 (pure iron)	SIA (silentalloy)
Composition	18Cr-8Ni-Fe	0.8C-1Ni-Fe	20Cr-3Al-Fe	Fe	12Cr-3Al-Fe
Density (kg/m^3)	8000	7700	7300	7870	7460
Logarithmic decrement[a] ($\times 10^{-2}$)	0.25	0.60	1.33	1.56	10.4
Thermal expansion ($\times 10^{-6}$/°C, 30°–100°C)	17.3	11.3	13.2	12.9	9.6
Modulus of elasticity (GPa)	193	213	176	196	162
Tensile strength (MPa)	>520	1350	559	–	370–470
Fatigue limit (MPa)	245	1200	392	–	176
Elongation (%)	55–60	10	25	25–45	>15
Vickers hardness (H_V)	153	410	192	132	150
Relative cost[b]	1.3	1	16	1.7	3.3

Data are from Amano et al.,[14] Nishizawa and Sudo,[17] and Kondo and Fujita[18]
[a] Measured mean value at 0 and 45 degrees to the rolling direction
[b] Trial calculation for 2.0 mm thickness

can be seen at different speeds for SUS304 and SKS5 saws. Whistling noise could always be heard clearly at these major peaks. No peaks exist for the other three saws, and no whistling noise could be heard. The noises for the other saw of the same body metal were similar to those in Fig. 1 except for the saws that emitted the whistling noise, as already mentioned.[19]

To identify the whistling noise, power spectra of noise levels at 3100 rpm were recorded (Fig. 2) for SUS304, SKS5, HCF, and SUYP1 saws. Large, pointed peaks on the gentle mountain in the frequency range 2–5 kHz in the power spectra for SUS304 and SKS5 saws show the existence of the whistling noises caused by a blade resonance. On the other hand, no large, pointed peaks were observed in the power spectra for HCF and SUYP1 saws. Small peaks of roughly 60 dB in the range 600–800 Hz were almost the same as peaks observed in the power spectrum of the idling noise of the apparatus without a saw. Whenever a large, pointed peak was observed on the gentle mountain of a power spectrum, the whistling noise could be heard from the saw.

The judgment as to whether a saw emits a whistling noise was accomplished by referring to the power spectrum of each noise over the rotational speed range used in this experiment. The judgment about the whistling noise is shown in Fig. 3, representing the logarithmic decrement of the body metal in the ordinate. The bar graphs for the saws that emit a whistling noise are shaded.

It is clear that the SUS304 and SKS5 saws emitted whistling noise at many rotational speeds. On the other hand, in common with the SIA saw, the HCF and SUYP1 saws were silent at all rotational speeds. A boundary value of the logarithmic decrement above which a saw does not emit a whistling noise exists somewhere between 0.0060 and 0.0133 for circular saws of this size. Though circular saws vary in size, this boundary value may still be effective for saws 255–405 mm in diameter.[15] The mean value of this range is approximately 0.01, which is lower than the value of 0.07 obtained previously for SIA,[16] but on a logarithmic scale, a value of 0.01 can be considered similar in size to 0.07.

Ferromagnetic steel (HCF) was found to be a more suitable body metal than SIA for circular saws used for secondary processing because this metal has twice the yield strength of SIA and is somewhat more readily available commercially. HCF does have some disadvantages, as its mass production is difficult and it is costly. The identification of HCF suggested that the metals whose main components are 13Cr-Fe to 18Cr-Fe are suitable for a quiet circular saw body because the saws made from 12Cr-3Al-Fe and 20Cr-3Al-Fe metals did not emit whistling noise. Therefore, it is still necessary to find a more suitable body metal from the viewpoint of cost, based on the minimum value of 0.01 in logarithmic decrement.

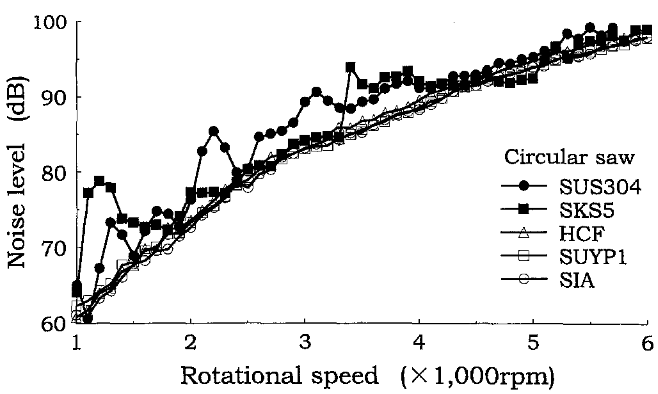

Fig. 1. Noise levels of circular saws whose bodies were made of various metals with different damping capacities at intervals of 100 rpm from 1000 to 6000 rpm

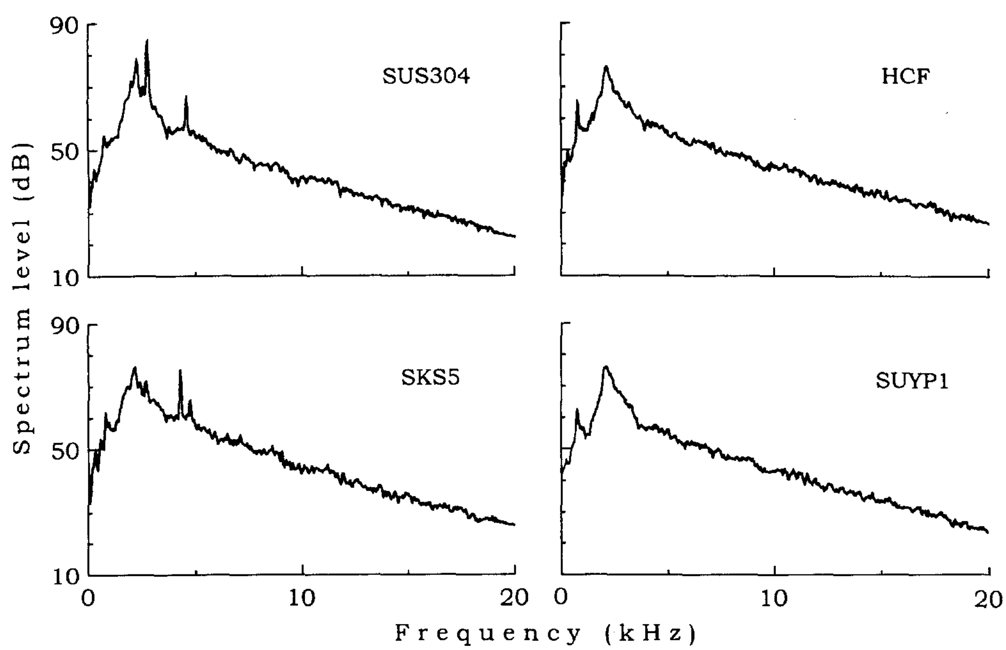

Fig. 2. Typical power spectra of four representative saws in Fig. 1 at 3100 rpm

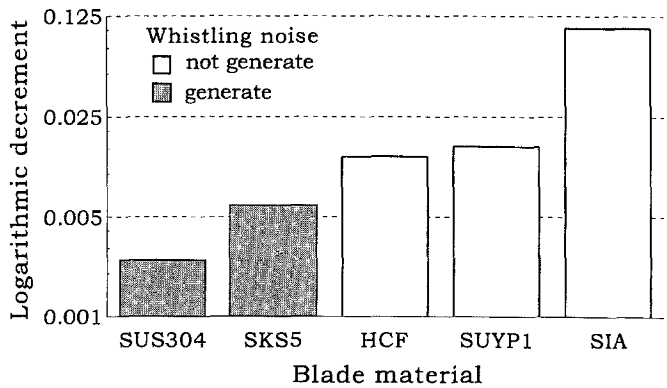

Fig. 3. Relation between logarithmic decrement of body metals and emission of whistling noise

Conclusion

Use of a material with high internal damping capacity to construct circular saws has been confirmed as an effective way to suppress whistling noise. A high-damping alloy called Silentalloy (SIA) had previously been demonstrated for this purpose, but because of the relatively low strength of SIA it was decided to find a stronger metal with sufficient damping capacity to be effective.

Therefore, three commercially available metals were selected whose damping capacities were expected to be in a range around 0.07 in logarithmic decrement and were used to make tungsten/carbide-tipped circular saw blades. The idling noises of the saws made of these metals were compared with those of saws made of typical saw steel and SIA.

The boundary damping capacity beyond which a circular saw does not emit a whistling noise was found to be approximately 0.01 in logarithmic decrement for circular saws 305 mm in diameter. On a logarithmic basis, this value was also judged to be close to the boundary damping capacity of 0.07 previously found for an SIA saw.

A ferromagnetic steel, HCF, was found to be a useful alternative to SIA for a secondary-processing circular saw. This steel is stronger than SIA, but it is more costly and is not suited to mass production. The success in identifying an effective alternative metal to SIA provides encouragement for the identification of other alloys among the 13Cr-Fe to 18Cr-Fe series without the cost disadvantage of HCF.

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