Origin of idling noise in circular saws
and its suppression

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Summary. This paper concerns the mechanism of noise generation and methods of noise reduction for idling circular saws. Experiments were conducted to examine the sources of saw noise. Saw resonant vibration is proven to be excited aerodynamically rather than by mechanical imbalance. The source of noise generated from a resonating saw and that generated from a nonresonating saw are shown to be identical. A mathematical model is proposed to formulate the dependence of the noise source upon saw kinematic and geometric parameters. Based upon this model and the associated experiments, several potential techniques for noise reduction through design of saw tooth geometry are recommended and discussed.

Introduction

Cutting with a circular saw is probably the most common manufacturing process in the wood industry. One of the major problems facing the industry is the excessive noise generated during sawing. Virtually all sawing operations exceed the 90 dB (A) noise level, usually considered the maximum allowable for 8 hours of continuous noise exposure. Excessive noise can cause both permanent hearing loss and reduced production efficiency for industrial workers. Also, saw vibration associated with noisy saws decreases cutting accuracy, increases product waste, and reduces tool life. Steps to reduce noise exposure have been taken by the industry through use of barriers, ear plugs and the like. However, these are short term remedies to a major technical problem-design of saw blades that are high productivity tools while producing noise within acceptable limits. Field observations have shown that a saw may be idling as much as 80% of the operation time (Bies 1980). If idling noise is lowered, the total daily exposure of high level noise can be substantially reduced. The permissible level of non-idling noise can then be increased according to the OSHA (Occupation Safety and Health Administration, U.S. Department of Labor) noise regulation.

Cudworth (1960) first classified high intensity noise in circular saws as siren noise (aerodynamic) plus resonant blade vibration noise. This classification has been accepted by virtually all researchers. Aerodynamic noise, by definition, is caused by the interaction of moving, rigid saw teeth with the surrounding air, and
vibration noise is caused by the transverse motion of the blade propagating noise into the surroundings like a loud speaker or drum. Resonance is a particularly large amplitude vibration at a single characteristic frequency of the saw blade. When a saw is resonating, the generated noise consists of discrete tones of high intensity and is usually referred to as screaming noise or whistling noise.

The theoretical solution for the air flow induced by a rotating disk in the laminar regime was solved by Von Karman (Schlichting 1968). In the normal range of saw operating speeds, however, the flow within the disk boundary layer near the blade periphery is fully turbulent. Little detailed information on the turbulent flow beyond the disk edge is known. The saw teeth complicate the flow field because the turbulent flow separates into vortices from the sharp edges of the teeth. The flow field is further complicated by the fact that each tooth rotates through the turbulent wake of preceding teeth. Experimental research is necessary for classification of the air flow-cutting tooth interaction and the noise source.

Two different mechanisms had been proposed to explain the cause of the resonant vibration. In one, the vibration originated from mechanical excitations, such as motor imbalance or shaft eccentricity (Wakefield, Wray 1976). In the other, the vibration resulted from aerodynamic origins (Dugdale 1968; Mote, Leu 1980; Pahlitzsch, Friebe 1971; Stewart 1978). Moreover, the sources of aerodynamic noise and resonant vibration noise were often thought to be fundamentally different because the characteristics of these noises appear to be different: resonant vibration noise consists of high intensity discrete tones, while aerodynamic noise is relatively broad-band in its frequency distribution. Because of the complexity of the noise source mechanism, noise suppression techniques were usually investigated in a cut-and-try manner. As a result of experimental testing without emphasis upon basic physical understanding, suggestions for blade and tooth design from different researchers were often contradictory (Mote, Leu 1980).

The present studies were undertaken to clarify the fundamental sources of saw noise. First, a series of saw vibration experiments was conducted in an evacuated chamber (vacuum chamber), and it confirmed that the saw resonant vibration is aerodynamically excited. Second, vibration and noise experiments were undertaken in a semi-anechoic chamber, and they showed that the sources of resonant vibration noise and aerodynamic noise in sawblades are identical. An analytical model was then proposed to relate the noise source strength to the tooth design parameters. Methods of noise reduction through attenuation of noise source strength are recommended based upon this model and the associated experimental findings.

Aerodynamic origin of saw resonant vibration

Saw vibration experiments were conducted in an evacuated chamber (Fig. 1) to permit separation of the mechanical and aerodynamic excitations. The pressure level inside the chamber was continuously adjustable between 7.6 and 760 mmHg. Specially designed aluminum sawblades, 4.8 mm thick and 257 mm in diameter, were driven by a motor outside the chamber in the speed range 600 to 3600 RPM. Blade vibration was detected with a non-contacting displacement transducer fixed