BAND SAW SAFETY TECHNOLOGIES

Flesh-Sensing Mechanisms & Other Devices

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THE VERTICAL BAND SAW, ubiquitous in the woodworking, metalworking and meat processing industries, has many safety mechanisms available, some of which are not currently required by regulatory or consensus standards organizations.

Despite the prevalence of band saws in many industries including woodworking, the hazards they pose have yet to be fully recognized. According to OSHA data, band saw injuries represent 11.5% of all reported saw injuries from 1984 through 2017 (OSHA, 2019b). Although OSHA, ANSI and International Organization for Standardization (ISO) have established regulations applicable to band saws, these standards do not address all the potential hazards associated with unintentional contact with unguarded moving blades or with a blade inside the guard housing before the blade has coasted to a stop. Further exploration is necessary into safeguards against band saw incidents and the technologies available to preclude blade contact such as flesh-sensing mechanisms, blade-housing interlocks, blade brakes and blade-tracking windows. This article discusses these mechanisms and their availability.

OSHA (1984b) addresses band saws in 29 CFR 1910.213, wherein four succinct statements specific to band saws in the woodworking industry, based on OSHA's adoption of the AMCI O1.1-1954(R1961) standard, now ANSI O1.1, are specified. These regulations require the saw blade to be enclosed or guarded, the outside periphery of the band saw wheel to be encased, the band saw equipped with a tension control device and the in-running feed rolls to be guarded.

Now, nearly 5 decades after OSHA's adoption, which occurred in 1971 with the passage of the OSH Act, the band saw manufacturer and user have numerous other safety procedures and devices available that can be used for incident reduction and amelioration.

KEY TAKEAWAYS

- **Band saw injuries represent 11.5% of all OSHA-reported saw injuries from 1984 through 2017.**
- **Potential hazards associated with band saws include unintentional contact with unguarded moving blades or with a blade inside the guard housing before the blade has coasted to a stop. Kickbacks and kickdowns, particularly from irregularly shaped or rounded stock, are also a potential hazard.**
- **This article explores safeguards to avoid band saw incidents such as flesh-sensing mechanisms, blade-housing interlocks, blade brakes and blade-tracking windows. Many of these state-of-the-art mechanisms are beyond the current regulatory and consensus standard requirements but are available now for use.**

NORDRODEN/ISTOCK/GETTY IMAGES PLUS

Injury Statistics

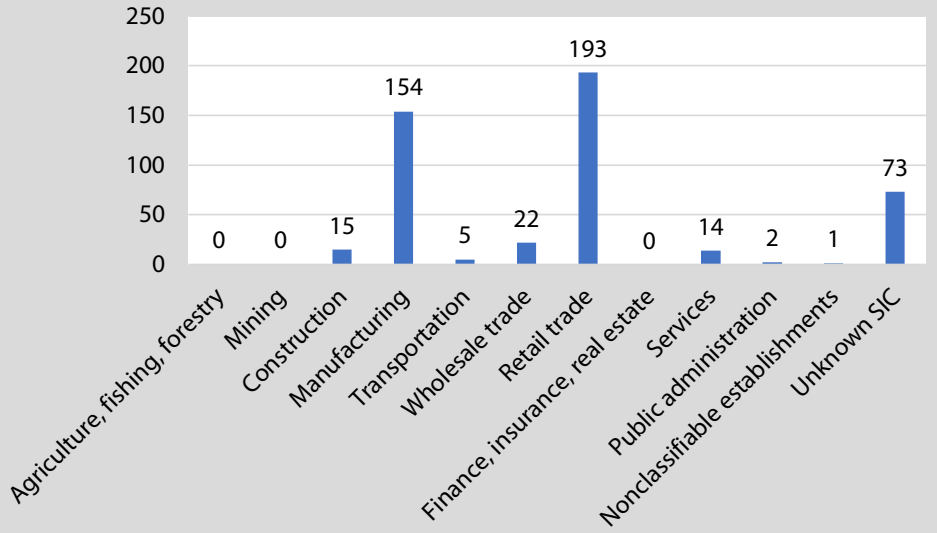
OSHA Fatality & Catastrophe Investigation Data

OSHA (2019b) fatality and catastrophe investigation data from 1984 through 2017 indicate that 4,160 incidents occurred related to the search term *saw*, many of these being finger amputation injuries. The data also show that many of these inci-

dents involved maintenance work on band saws that had not yet come to a complete stop before work was started. The data reflect saw incidents from all industries in both the public and private sectors. In addition, the data indicate that 60 incidents were recorded in 2017 (as of Aug. 14, 2017) that included references to band saws, and that 479 band saw incidents have been reported since 1984 from all industries. Many more incidents involving band saws may have occurred, but may not have been recorded in the OSHA database using the term *band saw*. These 479 band saw incidents represent 11.5% of OSHA-reported saw injuries over the past 34 years.

Figure 1 shows search results for the 479 band saw incidents for 1984 to 2017 (OSHA, 2019b). As noted, these band saw incidents are derived from data recorded from all industries reporting band saw incidents including woodworking. Of the reported incidents, 347 (72%) occurred in the manufacturing and retail trade industries.

FIGURE 1
OSHA-REPORTED BAND SAW INCIDENTS BY SIC CODE



Note: Search results for the 479 band saw incidents from April 2, 1984, through Oct. 11, 2017, as recorded on the OSHA website, compiled on Aug. 29, 2018. As the OSHA website is continuously updated with new incident entries, a reader visiting the website may find data that is discordant with data contained in this report.

An additional analysis was made limited to a specific time range of the most recent 60 band-saw-related incidents recorded by OSHA (reported between Jan. 3, 2017, and Aug. 14, 2017) such that each incident was categorized as either a) occurring during regular use or maintenance; or b) whether the operators and guarding were described as being in compliance with safe procedures.

The data show that 1.67% of the incidents occurred during maintenance activity for blade replacement and 20% of the incidents were due to improper operation or removal of guarding. The remaining 78.33% were noted as having occurred due to contact with the blade during normal operation. The safety technologies, procedures and training discussed in this article address the band-saw-related injuries that occurred during regular use or maintenance or were due to improper operation, as well as the other injuries that could have been eliminated or ameliorated by avoiding blade contact.

CPSC: NEISS Hospital & Emergency Department Reports

An additional database from a sample study of woodshop machinery injuries compiled by the National Electronic Injury Surveillance System (NEISS) estimates that band saws are the cause of 3,550 injuries per year (Woodworkers Guild of America, 2019).

Provided through U.S. Consumer Product Safety Commission (CPSC, 2019), data from NEISS are based on hospital and emergency department reports, which includes all injuries as presented, whereas the OSHA data is based on only fatality and catastrophe investigations and is specific to injuries that occurred on a work site where there was an employer-employee relationship. Since the NEISS universe is based on all hospital and emergency department visits regardless of whether an employer-employee relationship existed, it is therefore a much larger database than the OSHA recordable incident database.

From 2001 to 2008, NEISS estimates that hospital emergency departments treated nearly 4,000 injuries associated with band saw and radial arm saws. The NEISS data reports band saws and radial arm saws collectively as one of their data points.

Blog Forum Reports of Kickback Injuries

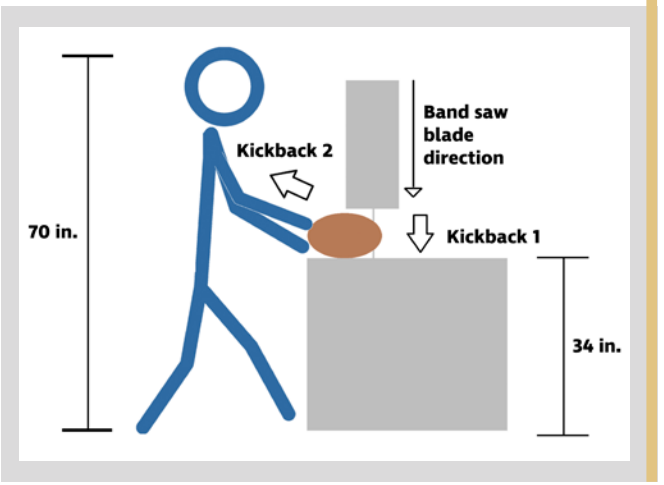
The action of the vertical band saw blade is typically a force pushing down onto the stock that holds it against the table; therefore, kickback is not a hazard usually associated with band saws, as it is with table saws (OSHA, 2019c). However, several blog posts discuss incidents in which rounded or irregularly shaped stock has been kicked down then thrown back at the operator, producing serious facial and head injuries. Several blog forums describe personal accounts of band saw kickbacks (Brown, 2008; Padre, 2008; Whitesell, 2016).

To avoid band saw kickbacks, some manufacturers suggest cutting rounded pieces in a transversal direction. This can also help avoid pieces getting twisted during cutting. Other band saw manufacturers recommend additional protection against kickback by using a work stabilization block.

Figure 2 shows the direction of the band saw kickback when the operator is attempting to cut a rounded object. A kickback can occur while using any type of saw including a band saw. The downward motion of the band saw blade on

FIGURE 2

DIRECTION OF BAND SAW KICKBACK WITH ROUNDED OBJECT



a rounded object, or irregularly or trapezoidal-shaped work piece may cause the end of the object to kick down before the band saw potentially kicks the object back, possibly striking the operator in the face or upper extremities. This can occur because a rounded object does not have as much surface area in contact with the table as dimensional lumber. Posts from blog forum users who have experienced kickdowns and resulting kickbacks have noted that this has occurred after the rounded object has partially passed through the saw blade. Then the rounded object continues to rotate downward, which allowed the uncut portion to rise above the table on the infeed side of the blade and the kickback to result. To avoid kickback, some manufacturers recommend adding a suitable locking device so that the stock cannot be rotated crosswise. Photo 1 shows an example of a locking device used while cutting rounded stock.

Regulatory/Consensus Standard Requirements for Band Saws

This section discusses the ANSI, ISO, and OSHA regulatory and consensus standard requirements related to the use of woodworking machinery and specifically band saws (defined as machines that have a continuous band toothed steel driven by two or more wheels). OSHA does not currently have standards on blade-tracking windows for band saws nor for door interlocks on band saw wheel covers.

ANSI O1.1-1954(R 1961) was the source for the OSHA standards in 29 CFR 1910.213, identified as woodworking machinery requirements. ANSI O1.1-2013 addresses training and maintenance for all woodworking equipment. Employees must be trained in both maintenance and operation to comply with the ANSI standard. However, OSHA uses other safety requirements published by ANSI, ISO and in manufacturers' operating manuals as surrogate OSHA standards through use of the General Duty Clause. Consensus standards and manufacturers' operating manuals have been the basis for establishing that the hazard is a recognized hazard, which is a prerequisite for use of the General Duty Clause. These documents have also been the basis for opinions offered by testifying forensics experts in personal injury lawsuits.

Photo 1: Work piece stabilizer for rounded stock.

Wheel Coasting Hazard

Table 1 (p. 38) presents the ANSI O1.1 standards and ISO standards that address the wheel coasting hazard and the requirement for an emergency stop control. There is no OSHA standard that addresses the wheel coasting hazard.

The original 1971 OSHA standard 29 CFR 1910.213(i) included the sentence, "Effective brakes should be provided to stop the wheel in case of blade breakage," as documented in Table 1 (p. 38). As this sentence is advisory rather than mandatory by inclusion of the word *should*, it was removed in 1984 based on the federal lawsuit addressing the enforcement of mandatory and advisory standards. Specifically, *Federal Register, 49*(29), dated Feb. 10, 1984, detailed the changes made to 29 CFR 1910.213. It states, "This final rule revokes 153 of the 194 provisions of the general industry standards (29 CFR Part 1910), which were proposed for revocation on May 28, 1982 (47 FR 23477). These provisions use the word *should* or other advisory language instead of the mandatory *shall*" (OSHA, 1984a, p. 5318; J. Cramer, personal communication, Aug. 2, 2018).

ISO Safety Feature Performance Level

The performance level requirement (PLr), a key parameter in the ISO standard, is the required performance of the safety feature necessary to adequately keep the operation safe (Keyence Corp., 2019). The performance level (PL) is typically measured in the probability of dangerous failures per hour. The five performance levels addressed by this standard vary from level "a" to level "e" with corresponding failures per hour escalating from 0.001% to 0.01% for level a and 0.000001% to 0.00001% for level e. ISO 13849-1 sets an acceptable probability of dangerous failure per hour for each PLr.

TABLE 1

REGULATORY & CONSENSUS STANDARD REQUIREMENTS FOR BRAKES & WHEEL COASTING

Brakes	
Standard	**Requirement**
ANSI O1.1-1971 [Revision of O1.1-1954(R1961)], 1975, 1992, 2004, 2009, 2013	•Section 6.2.1, 1971, Enclosing Band Saw Blades: "Effective brakes should be provided to stop the wheel in case of blade breakage."[a] •Section 5.1.1.5, 2013, specifies that "an effective means of stopping the blade motion shall be provided to minimize the coasting hazard."
Federal Register, 36(105), May 29, 1971	•1910.213(i) *Bandsaws and band resaws.* "Effective brakes should be provided to stop the wheel in case of blade breakage." (This provision was withdrawn on Feb. 10, 1984.)
Emergency Stop Controls	
Standard	**Requirement**
ANSI O1.1-1992, 2004, 2009, 2013	•4.4.2.1, Application: "All machines shall incorporate one or more emergency stopping means, which upon momentary operation, shall safely stop all machine motions. These emergency stopping means shall be located at all operator control stations and, if inherent hazards are present at other operating positions, an emergency stopping means shall be provided at each position. Exception: On a manual machine with a single motor and motor controller, the motor stopping means is considered the emergency stop." •ANSI O1.1-2004, 2009, E4.4.2.1, Application: "Emergency stopping means include pull cables, mushroom buttons, pressure mats, presence-sensing devices and similar devices. Set up positions are not considered operator control positions."
ISO 19085-1:2017[b]	•"Machines with more than one machine actuator or where provision is made for use with more than one machine actuator (e.g., with a socket for demountable power feed) shall be fitted with an emergency stop control. Electrical emergency stop control systems shall comply with the requirements of IEC 60204-1:2005, 9.2.5.4.2 and 10.7. Mode selection shall be in accordance with the following requirements (see also ISO 1200:2010, 6.2.11.10): a) The mode selected shall override all other control or operating modes, except emergency stop. b) The mode selector shall be lockable in any position, e.g., by a key-operated switch. c) Changing the mode shall not initiate any movement of the machine. d) When changing modes, the machine shall be brought to a normal or operational stop except when changing from a mode with lower safety measures (e.g., setting) into a mode with higher safety measures. The SRP/CS for mode selection shall achieve PL_r = c. See also 8.3 and IEC 60204-1:2005."
29 CFR 1910.213(b)(1)	•"A mechanical or electrical power control shall be provided on each machine to make it possible for the operator to cut off the power from each machine without leaving his position at the point of operation."

Note. [a]ANSI O1.1 1924, 1930 and 1944 editions did not include a provision requiring brakes to be provided on band saws. [b]ISO 19085-1:2017, Woodworking Machines—Safety, Part 1: Common Requirements, provides options of interlocking movable guards in accordance with section 6.5.2. These include movable guards with interlocking without guard locking, movable guards with interlocking with guard locking, hold-to-run control, two-hand control, electro-sensitive protective equipment (ESPE) and pressure-sensitive protective equipment (PSPE). Examples of PSPE include pressure-sensitive mats and floors; trip bars and pressure-sensitive edges; and pressure-sensitive bumpers, plates, wires and similar devices.

The required performance level is determined by the frequency, severity and probability of injury associated with a dangerous failure. The more frequent and severe the result of a failure, the more stringent the required performance level (ISO, 2015).

Selected Band Saw Manufacturers & Key Parameters

ANSI O1.1 addresses band saws used in industrial and commercial applications having a total connected power of 5 horsepower (hp) (3.7 kW) or greater, or having three-phase wiring, either of which is the basis for inclusion in the ANSI O1.1 standard. Data on band saws from various manufacturers that have either 5 hp or three-phase wiring and are therefore under the scope of ANSI O1.1 were collected to determine the prevalence of specific safety features. These features included blade coasting/stop indicator/windows, door interlocks, blade brakes and flesh-sensing technologies. This survey was restricted to band saws that had one or more of the mechanical or electrical safety features, including flesh-sensing technologies, safety door interlocks, blade brakes or blade tracking windows. Band saws found during the search that did not list any of the four noted features fell outside the scope of the survey.

Method

Band saws with 5 hp or three-phase wiring were included in the study if they had one or more of the four safety features (i.e., flesh-sensing technologies, safety door interlocks, blade

brakes, blade tracking windows). This resulted in 16 band saws being surveyed that meet the ANSI standard for coverage (i.e., 5 hp or three-phase wiring) and have one or more of the safety features. None (0%) of the saws in the subset is equipped with a safety door interlock; one (6%) is equipped with flesh-sensing technologies; 10 (66%) are equipped with some form of a blade brake; and 86 (53%) are equipped with blade-tracking windows. One respondent did not provide data on all parameters; for those parameters for which data was not provided, the band saw manufacturer was excluded from the statistical profile compiled for that parameter.

Patents and patent applications were reviewed for safety mechanisms as a primary measure used in this article to date the age of the technology. The date for the earliest patent for each safety feature is included as a measure of establishing its earliest usage. The patents for each of the technologies discussed date from 1874, the earliest patent noted for band saw brakes (U.S. Patent No. 151,106, 1874). Patents for flesh-sensing mechanisms are dated from 1974 (U.S. Patent No. 3,785,230, 1974), blade housing interlocks from 1958 (U.S. Patent No. 2,955,693, 1960) and blade-tracking windows from 1960 (U.S. Patent No. 2,963,054, 1960). Patents have varying life spans, typically up to 20 years in length (U.S. Department of Commerce, 2016).

Band Saw Flesh-Sensing Safety Technologies

Technology Availability History

Some flesh-sensing technologies mechanically halt the blade upon sensing that it has come in contact with human flesh. The blade can sense contact with flesh because of the electrical impulses that the human body emits. Flesh-sensing technologies are widely used in the meat processing industry but can also be used in other industries such as woodworking.

Based on patent searches, patented technologies designed to detect the presence of human tissue and react in sufficient time to preclude injury to the operator have been available since 1974. One patent application noted that the safety device for which the patent was being applied provided:

> An automatic safety brake for rotary blade equipment in which a capacitance proximity sensor utilizes the spinning blade as an antenna so that when any portion of the body of the user approaches the blade too closely a cam brake will be instantaneously actuated to stop the rotation of the blade before the body of the user comes in contact with the cutting edge of the blade. (U.S. Patent No. 3,785,230, 1974)

Another patent for similar technology is based:

> Upon a metal conductive glove worn by the operator [and after] contacting the blade or toothed shaft . . . positively stops and then reverses the direction of movement of the rotating member. The operator's glove is electrically connected to a safety mechanism and upon the glove completing a circuit upon contact with the rotating member or equipment immediately disconnects the power drive from the rotating member by actuating a clutch or tensioning cylinder. (U.S. Patent No. 5,272,946, 1993)

For more information on the technologies available from various manufacturers, see the "Flesh-Sensing Technology Manufacturers" sidebar.

For additional protection, other safety measures that would preclude contact with the moving blade should be employed

FLESH-SENSING TECHNOLOGY MANUFACTURERS

The manufacturers listed here are those for which patent applications had been made or have listed their technology in manufacturers catalogs.

- **SawStop (www.sawstop.com/why-sawstop/the-technology)**
- **Bosch REAXX Flesh Detecting Saw (www.boschtools.com/ca/en/more/news-and-extras/press-room/gts-1041a-reaxx.html)**
- **Whirlwind Black Box "Plug & Play" Flesh-Sensing Saw Safety Stop (www.whirlwindtool.com)**
- **Scott Automation Blade Stop (www.scottautomation.com/bladestop; www.scottautomation.com/news/case-studies/bladestop-enhances-safe-operation-at-carbon-processing-facility)**

INTERLOCKS IN THE LAUNDRY & TEXTILE INDUSTRY

ANSI Z8.1-1961, Safety Code for Laundry Machinery and Operations, section 2.19 defines the term *safety interlock* as "a device that will 1) prevent the operation of a machine while the cover or door is opened or unlocked; 2) hold the cover or door closed and locked while the basket or cylinder is in motion" (ANSI, 1961a).

A patent for a safety interlock for laundry extractors dated 1958 explains the purpose of the invention:

> To . . . prevent the motor of the basket from being started while the cover is raised, or even when the cover is closed but is not locked, and which will prevent the cover from being unlocked and raised as long as the basket is rotating. (U.S. Patent No. 2,955,693, 1960)

A standard requiring door interlocks for extractors has been in use in the laundry industry and required in regulatory standards since at least 1961. Specifically, ANSI Z8.1-1961 section 3.1.3.1 on extractors requires that:

> Each extractor shall be equipped with an interlocking device that will prevent the cover from being opened while the basket is in motion, and will also prevent the power operation of the basket while the cover is not fully closed and secured. (ANSI, 1961a)

ANSI Z8.1-1961 section 3.2.1.1 on washing machines states that:

> [A] washing machine shall be equipped with an interlocking device that will prevent the inside cylinder from moving when the outer door on the case or shell is open, and will also prevent the door from being opened while the inside cylinder is in motion. (ANSI, 1961a)

Laundry and textile industry OSHA standards have required interlocks for more than 45 years. OSHA standard 29 CFR 1910.262(y)(1)(ii) for the textile industry, which was adopted in 1971, provides that "each extractor shall be equipped with an interlocking device that will prevent the cover from being opened while the basket is in motion, and also prevent the power operation of the basket while the cover is open." This standard requiring interlocks on extractors and washing machines appears in ANSI L1.1-1956.

in addition to the protection offered by flesh-sensing mechanisms. These include engineering controls for point-of-operation guarding, administrative controls for employee education and training, and procedures that would be specified in a job safety analysis.

Safety Door Interlocks

Interlocks are a critical safety feature that, if employed, should reduce the 1.67% of band-saw-related incidents reported by OSHA between Jan. 3, 2017, and Aug. 14, 2017, that occurred during maintenance activity for blade replacement; interlocks should also similarly reduce the 20% of the incidents that were due to improper operation or removal of guarding.

Based on the 16 band saws surveyed, none of these band saws are equipped with a safety door interlock. However, 13% (2) of the band saws surveyed advertised an interlock feature that instead functioned as a limit switch. Opening the blade housing door of a band saw exposes the operator and others in the vicinity to the unguarded blade and blade transmission mechanisms.

An interlock will preclude the blade housing door from opening if the blade is moving and will prevent the blade from turning until the door is closed. A limit switch placed on the housing door will prevent the motor from starting or continuing to receive power while the door is open. If the door is open, then the switch is open, which prevents the motor from starting; if the door is closed, then the switch is closed, which allows the motor to start. However, if the door is opened while the motor is running, then the motor may take several seconds to coast to a stop, during which time an injury could occur. An interlock for the blade housing door will prevent the blade from moving until the door is closed and prevent the door from being opened until all motion has stopped.

Interlocking guard patents are dated to 1900 (Roberts, 1980). The "Interlocks in the Laundry and Textile Industry" sidebar (p. 39) details the mandated use of interlocks in the laundry and textile industry. A search of the present bandsaw market revealed no currently available bandsaws that incorporate interlocks. However, some bandsaws were advertised by manufacturers as having interlocks when they instead have limit switches.

ANSI & ISO Standards

ANSI, Deutsches Institut für Normung (DIN) and ISO standards describe interlocking devices. ANSI and DIN require that an interlock prevent operation of the machine when guards are not in place and prevent removal of guards under conditions where danger may be present such as the blade passively spinning. ISO allows for manual unlocking or removal of the guard in cases where unlocking the guard takes adequate time for dangerous conditions during run down to cease, and specifies a PLr of "c" for guard interlocking (ANSI O1.1-2013; DIN EN 1088:2008-10; ISO 19085-1:2017).

ISO 19085-1, Woodworking Machines—Safety, identifies the safety requirements and measures for protection against mechanical hazards. These include provisions for hold-to-run, two-hand control, interlocking with electro-sensitive protective equipment, interlocking with pressure-sensitive protective equipment, interlocking of movable guards and interlocking with guard locking of movable guards.

Blade Brakes

Based on the 16 band saw manufacturers or distributors that met the criteria to be included in the survey, 66% (10) of the band saws come equipped with some kind of blade brake. These brakes may be manually activated when desired or some may be automatically triggered under certain conditions.

For example, Hydmech (2019) manufactures band saws that have a blade breakage switch. When the blade breaks, the switch automatically stops power to the band saw motor. According to the manufacturer, the switch operates such that when a blade breaks, "the tensioner will continue to drill the idler wheel up (as it maintains hydraulic pressure for the blade tension) until it contacts the switch," thereby shutting down the saw hydraulic and blade motor (Hydmech representative, personal communication, July 17, 2018).

A patent on improvement in band sawing machines demonstrates a combined belt shifter and brake (U.S. Patent No. 151,106, 1874).

Regulatory and consensus standards applicable to band saws should address currently available technologies to preclude blade contact including flesh-sensing mechanisms, blade-housing interlocks, blade brakes and blade-tracking windows.

Blade-Tracking Windows

Based on the survey of band saw manufacturers and distributors, 53% (8) of the band saws have blade-tracking windows. These windows are positioned on the housing of the band saw to allow operators to visually determine whether the blade is in motion. A patent for a tension-adjusting mechanism for band saws included a blade-tracking window as a necessary element of the mechanism (U.S. Patent No. 2,963,054, 1960). The patent has since expired.

Findings & Recommendations

The prevalence of band saw injuries as shown in OSHA and NEISS data necessitates further exploration into the hazards associated with unintentional contact with the blade and kickbacks as discussed for round or irregularly shaped stock. Regulatory and consensus standards applicable to band saws should address currently available technologies to preclude blade contact including flesh-sensing mechanisms, blade-housing interlocks, blade brakes and blade-tracking windows. To accomplish this, following are five safety systems, devices and employee orientation and training recommended to complement the existing regulatory and consensus standard requirements regarding band saw usage.

1) A blade-braking mechanism provided to automatically stop power to the band saw motor upon blade breakage.

2) A blade-tracking window provided and placed so that the operator has visual contact without opening the blade housing to determine blade motion and blade tracking.

3) A blade-housing interlock provided so that the blade will not turn except for adjustment until the housing is closed and will not open until all blade motion has stopped.

4) Flesh-sensing mechanisms considered as a protective measure as these technologies become available.

5) Operator education and training for saw usage including kickback avoidance. In addition to being trained in the requirements of the OSHA standards, operators should also be trained in the requirements set forth in the operating manual of the band saw being used.

The required implementation of these systems in band saw regulatory and consensus standards should help reduce the number of band saw injuries occurring each year. **PSJ**

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