Automated Detection of Internal Decay in Wooden Utility Poles

Utility companies need to monitor the condition of wooden poles regularly and predict their future condition accurately to operate their distribution system continuously and safely. This paper covers the current methods and techniques used in wooden pole maintenance across the globe and presents an analysis of the same points, considering the need for automation in wooden pole testing to enable standardized outcomes.

Introduction

The current market for utility poles is driven primarily by wood. Wooden poles are popular and widely used to carry electric power lines and telephone lines all over the world due to their high strength per unit of weight, low installation and maintenance costs, and excellent durability when they are properly treated with wood preservatives. Increased energy demand and the extension of current power networks are the main drivers of this market's growth opportunities. In all, the energy transmission and distribution segment is the largest consumer of utility poles [1].

The tree species most commonly used for poles is the Scots pine (Pinus sylvestris), but other species such as jack pine, western red cedar, and Douglas fir are also used. Wood is a natural biological material and, unfortunately, is susceptible to fungal and insect attacks. Decay in wood usually occurs when its moisture content exceeds its fiber saturation point. The outer surface of a pole, although usually treated with CCA (chromated copper arsenate), creosote, or with other wood preservatives to protect it from fungi and insects, can still be attacked by fungi. The internal parts of the pole can be attacked by basidiomycetes fungi that enter the wood during the drying process through deep checks and splits or through the knots that form due to branches. Ultimately, failure of wooden poles is inevitable once they lose their structural strength due to decay [5].

The inspection and treatment of wooden utility poles is necessary for determining the strength and serviceability of a pole. It's extremely important to determine the deterioration and degradation of utility poles and predict the next failure in order to prevent it or reduce its effect through maintenance or a contingency plan.

Replacing a utility pole can be expensive, which is why it's necessary to determine which power poles are healthy, which have some deterioration but can last for some time (this needs to be predicted), and which ones need to be replaced immediately. In other words, an effective pole inspection program strikes a balance between accurately identifying poles that put both system reliability and human life at risk while minimizing the number of still serviceable poles being replaced. However, due to a complex combination of variables (i.e. wood species, preservation methods and material, soil and climate conditions, insect and mechanical damage, waste management, inspection methodology, and human error) involved, no fail-proof inspection method exists that can guarantee the condition of a standing wood pole with 100 percent accuracy [2].

Current methods and techniques

The three predominant methods used to inspect wooden poles are visual, sound, and bore-based inspections [3].

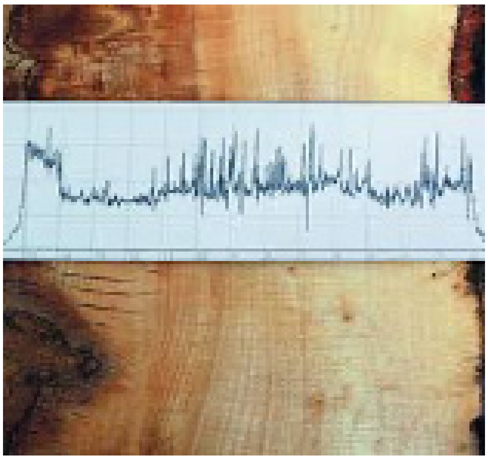
Visual inspection is suitable for identifying gross defects visible above the ground level. Many utility pole inspections for measuring rot or strength are currently being performed with the naked eye, simply by looking closely. Is there visible rot or decay in the wood? Are there cracks, holes, burn marks, or other imperfections in the structure? These factors can significantly impact a utility pole's ability to handle stress.

Inspection based on sound is another method that's been used for generations: skilled pole inspectors tap the wooden utility poles with a hammer at certain intervals all along the pole as well as along the circumference, recording their own perspective on whether the point at which it is tapped is good or decayed, based on their hearing ability and experience. Sturdy and solid wood will produce a clear and resonating sound. At places where there might be rot or decay, the wood will produce a dull thud. However, this method is limited by the rather limited frequency range perceptible by the human ear, the upper limit of which is about 20 kHz.
If any points of probable decay are found, the inspector bores into them with a drill. This allows them to measure the level of decay within the pole. Inspection of the sawdust coming from the bore hole will convey if decay is present or if there is soft, spongy, or punky wood present in the pole. If the bit goes in rapidly without resistance, it means there is a decay pocket in the hole or a void [4].

These and other similar methods of testing poles for decay may not give accurate results. Research showed that a large number of poles are replaced unnecessarily, and a significant number of poles continue to fail unexpectedly while still in service, causing damage to assets as well as human lives. Consequently, several semi- and/or nondestructive methods are also used to determine the internal defects of utility poles. Numerous attempts have been made to detect internal decay within wooden utility poles in a minimally invasive manner. You'll find popular techniques below.

Resistograph

Driven by a drill motor, a long and thin needle is inserted into the wooden pole to determine its density, often with the intent of identifying areas of substandard structural integrity such as decay. Variations in resistance to torque are recorded by a stylus on graph paper. Newer models may record information digitally. Inspection by resistograph for each pole is conducted at breast height and below ground using a 45-degree adapter (e.g., The IML-RESI F-300 instrument). Variations in resistance result in increases and decreases in the amount of torque applied to the drill shaft (Figure (1)). The poles aren't harmed because the drilling hole closes itself due to a special drilling angle that was customized for the drill bit. Additionally, with a 45-degree adapter, it's possible to examine a utility pole below ground level
(Figure (2)).



Figure(1): Graph recorded

Figure(2): 45-degree adapter

The main disadvantage of this instrument is that it is heavy and leaves holes at the point of measurements, which might cause further decay [5].

Micro hammer

Utility poles can also be inspected using an IML Micro Hammer to display their interior condition. The IML Micro Hammer measures the time it takes an impulse to travel through the utility pole. Due to the characteristic sound velocity of each wood species, the measurement values clearly display the interior conditions of a utility pole.

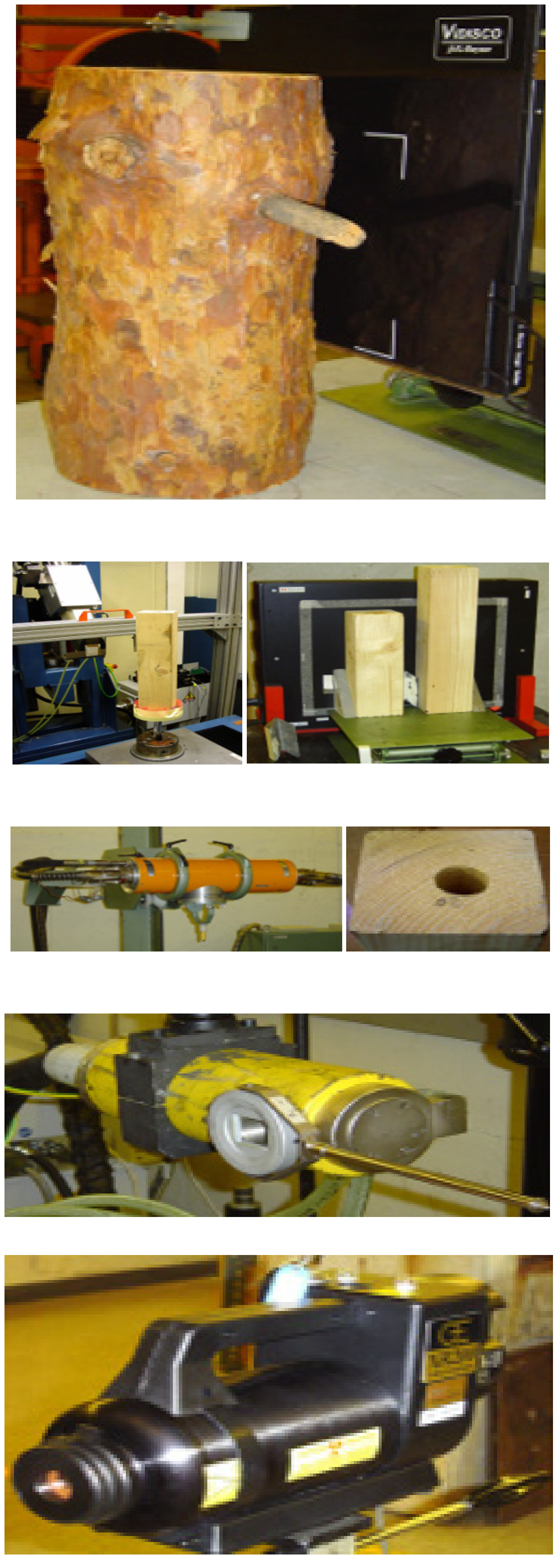
The time for the pulse to travel across the pole is measured. The waves of ultrasound travel at speeds of approximately 2000 m/s in sound wood and slow down to speeds in the range 1200–1500 m/s when passing through/around early-stage decayed sections. The waves slow down to speed of less than 1200 m/s in completely decayed or damaged wood. The time of flight indicates of the presence of decayed material[5].

Figure(3): Micro hammer

Shigometer

The Shigometer, a device that has been compared to the moisture meter, uses a pulsed current to measure changes in electrical conductivity associated with decay. A small hole is drilled into the wood, and a twisted wire probe connected to a meter is inserted into the hole. As the probe encounters zones of decreased resistance, the meter reading drops. Zones of large meter declines (50-75% of that indicated for sound wood) are then bored or drilled to determine the nature of the defect. The Shigometer has performed very well in detecting decay in living trees, but wood in service is normally too dry to permit the use of this instrument. Nevertheless, several studies show that the Shigometer is a reasonable method for detecting decay if it is used under proper conditions by trained operators who understand its operation and interpretation [7].

The main disadvantage is that a hole needs to be drilled to carry out the experiment, which can expose the pole to further decay.



Figure(4): Experimental setup and Instruments

X-Rays and Tomography Scanner

X-rays were once commonly used for detecting internal voids in wood. As the X-rays pass through the wood, the presence of knots or other defects alters the density of the resulting radiograph. X-ray technology has advanced considerably since the first field units were developed; however, the high cost of equipment, safety factors associated with the use of ionizing radiation, and the need for expert interpretation of results have largely eliminated its use in wood. Despite these problems, X-rays are particularly useful for detecting insect and marine borer infestations in wood[6].

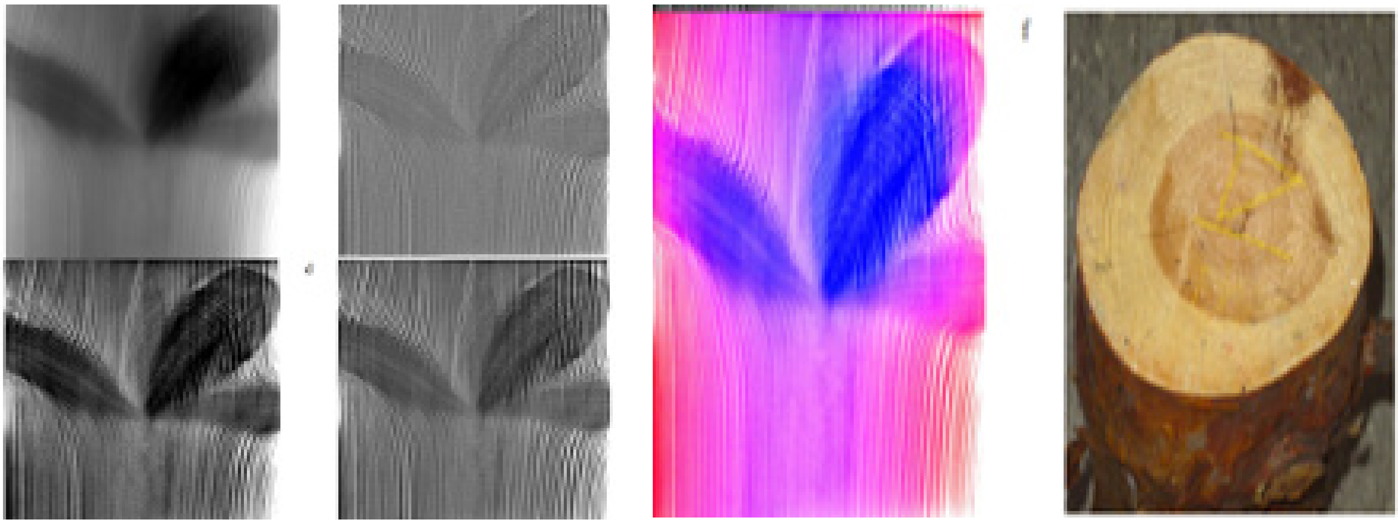


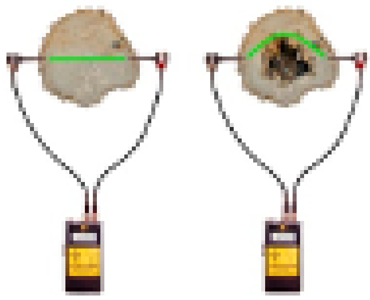
Figure (5): Result of digital radiography of a pine tree trunk showing knots and indications of degradation

The main disadvantage of this method is that it requires significant lab setup and is very costly. More importantly, exposure to X-rays is hazardous, so it cannot be carried out where people reside.

Ultrasonic Decay Detection

Ultrasonic waves have been used for assessing the condition of wood poles that are in service. This technique involves the transmission of high-frequency waves into the wood. The velocity is then computed as the distance between the transducers divided by the first arrival time. The condition assessment is performed by comparing the measured velocity with a referential value that depends on the wood species. Ultrasonic tests have been able to identify the presence of moderate to advanced decay [8].

The main drawback of ultrasonic testing is the high attenuation of the wave propagation, particularly when the wood is decayed. Therefore, the right selection of ultrasonic transducers, waveform acquisition system, and signal processing methods are fundamental for using ultrasonic testing in wood poles.



Based on these factors, the methods for determining the strength characteristics of wood can be divided into two categories: destructive testing (DT), like resistograph, microhammer, and non-destructive (NDT) testing, like X-Ray and ultrasonic-based solutions. NDT-based solutions are capable of predicting pole strength without disturbing its service. With these techniques, it's possible to locate problem areas and fix them before they become hazardous, making it the preferred option. In contrast, techniques that require invasion, however small, can potentially compromise the long-term health of a wooden pole.

Further, the global utility poles market size is projected to reach $58.8 billion by 2026 [9]. There are several major market players within the global utility poles market: Valmont Industries Inc., Skipper Ltd., Nippon Concrete Industries Co. Ltd., El Sewedy Electric Company, Hill & Smith Holdings PLC, Stella-Jones, FUCHS Europoles GmbH, Omega Factory, Pelco products Inc., RS Technologies Inc., and Osmose, to name a few. Automated wooden pole inspection and maintenance is of current interest to wooden utility pole companies like these, as well as researchers/academic institutions working in related areas [10, 11, 12, 13, 14].

Incidentally, a non-destructive automated wooden pole inspection and evaluation solution could lead to several business opportunities in the global market. Additionally, if such a solution is integrated with relevant robotics and AI technologies, the result would provide a more optimized, reliable, and standardized process. Because robotics and AI are current focus areas and capabilities of Wipro, the automation of wooden pole testing is a current business interest for Wipro. It's necessary to examine this opportunity innovatively.

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Dr. Sujatha J is academically qualified with a doctorate from IISc, Bangalore, and has over 30 years of teaching, research, and training experience across various renowned organizations. Currently, she is a senior consultant with the CTO office at Wipro. Her work is centered on the areas of AI, cognitive systems, and Custom Robotics. Her contributions are through the research and development of POCs for solving problems that are of customer interest, team development, and patent/white paper generation. To her credit, she has 17 international publications, and 11 patents filed, out of which five have been granted and the remaining pending. In addition, she constantly interacts with academia for mutual benefits. Dr. Sujatha also serves as a member of the industry advisory board for academia and is a member of IEEE, IETE, and ISTE, India.

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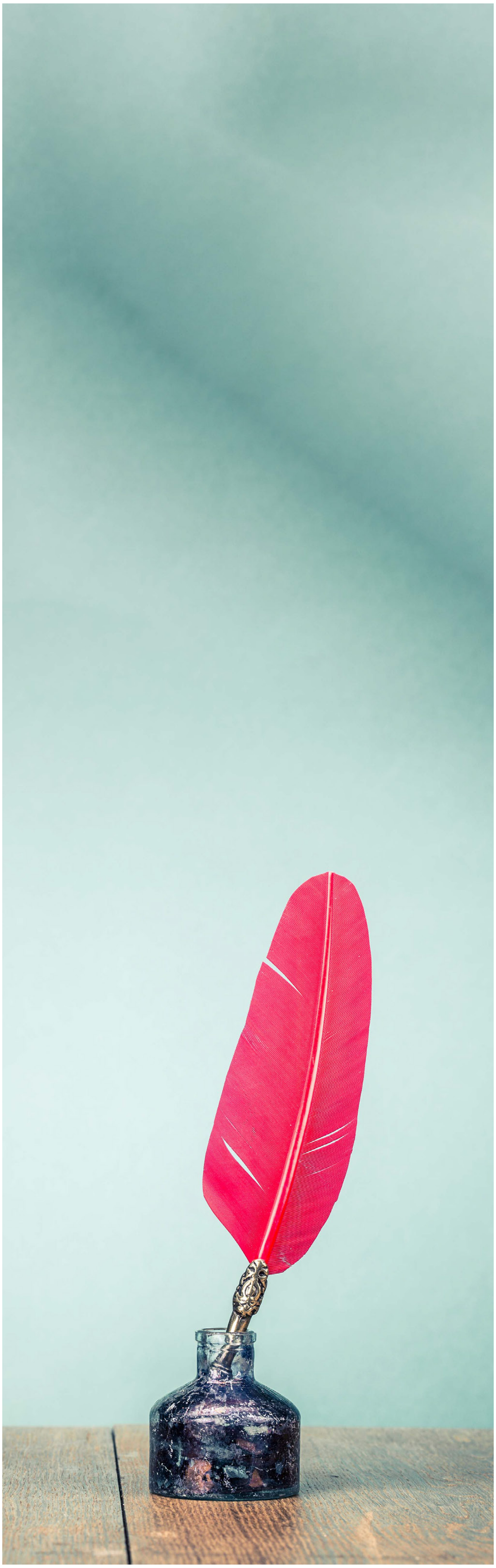

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