DEVELOPMENT OF A WOOD HARDNESS TESTER FOR DETECTING DECAY IN ASPEN

1995

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ABSTRACT

To assist the Alberta forest industry in making accurate surveys of decay levels in aspen stands, the Forest Engineering Research Institute of Canada (FERIC) developed an advanced prototype of a wood hardness tester. Based on the penetration depth of a spring-loaded needle into fresh or frozen wood, the hardness tester can be used to identify two levels of decayed fibre. FERIC's 1994 prototype of a wood hardness tester builds on a prototype hardness gun, or H-Gun, developed by the Northern Alberta Institute of Technology in 1990. The FERIC wood hardness tester is light-weight, durable, and easily manufactured; in field tests, data acquisition was six to eight times faster than with the H-Gun. This prototype development was funded by the Northern Forestry Centre of Forestry Canada through the Canada-Alberta Partnership Agreement in Forestry (PAIF).

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INTRODUCTION

Over the last five years in Alberta, the harvesting of aspen has increased to meet the fibre demand of recently built pulp and oriented strand board mills. However, the relative frequency of fungal decay occurring in aspen results in quantities of unusable fibre large enough to affect the costs of recovery. The ability to quantify decay in aspen stands prior to harvest could have significant impacts on harvesting and silvicultural planning, and on harvesting economics. Traditionally, decay has been estimated subjectively by inserting a pocket knife or other sharp tool into a sectioned stem to determine relative wood hardness. Foresters have not had an effective tool or technique to accurately survey the extent of decay or fibre degradation in an aspen stand.

In 1990, the Northern Forestry Centre of the Canadian Forest Service undertook a project to design an effective tool for measuring aspen decay. Northern Forestry Centre identified five categories of defect occurring in aspen, and developed a methodology for sampling and measuring these defects (Hiratsuka et al. 1990). The methodology involves using a special prototype tool, called a wood hardness gun or H-Gun (Figure 1), developed by the Northern

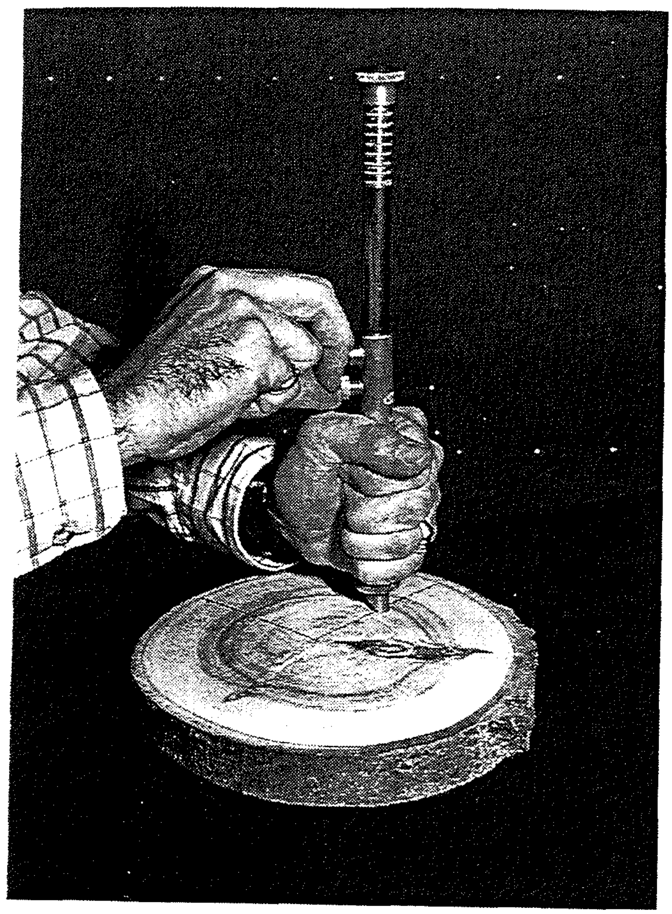

Figure 1. Wood hardness gun, or H-Gun, developed by the orthern Alberta Institute of Technology in 1990.

Alberta Institute of Technology. Using the H-Gun, which has a spring-loaded needle that penetrates the wood to a depth related to its hardness, measurements are taken along two perpendicular axes of the exposed surface of a sectioned stem sample. The readings are indicators of wood hardness and are used to determine the extent of the decay (defect boundary) and, using a standard formula, the volume of defect. Although the prototype H-Gun provides accurate and useful information, the data-collection process is slow, making the tool rather inefficient.

In 1993, the Northern Forestry Centre provided funding to FERIC through the Canada-Alberta Partnership Agreement in Forestry (PAIF) to develop the H-Gun into an advanced prototype of a wood hardness tester that would facilitate faster data acquisition, and which could be adapted to other species. The new design would be light, compact, rugged, and resistant to moisture and dirt contamination. It should be easily manufactured from specifications FERIC would provide.

METHODOLOGY

Through consultation with the Canadian Forest Service, FERIC defined the desired operating characteristics for an advanced prototype of a wood hardness tester. The penetration performance of the H-Gun was analyzed and the results were used as the baseline specifications for designing the main spring of the new prototype.

Several concepts were developed in an effort to meet all the requirements. To retain maximum control over the prototype development, all fabrication and assembly were undertaken at FERIC's Western Division shop. FERIC built a preliminary prototype to test some of the functions. This led to development of the advanced FERIC prototype which was shop tested, calibrated, and delivered—complete with operating instructions and engineering specifications—to the Northern Forestry Centre for field evaluation.

DEVELOPMENT OF THE ADVANCED FERIC PROTOTYPE

Design Features. FERIC proposed two modifications to the prototype H-Gun to improve its operational effectiveness. The new design should feature electronic sensing and display of the needle penetration, and an automatic reset after each reading. Electronic sensing will eventually allow recording on hand-held data loggers, resulting in much faster data acquisition and analysis than possible with the H-Gun.

Figure 2 illustrates the basic components of the FERIC prototype and describes its operation. The tool consists of a wand, umbilically connected to a box containing most of the electronics and the digital display. A sealed cover on the box provides access to the batteries and the calibration adjustments.

The penetration needle is a 1.6-mm-diameter spring wire attached to a shuttle that slides in acylinder. The needle is driven into the wood by a main spring that delivers 1.75 Nm of kinetic

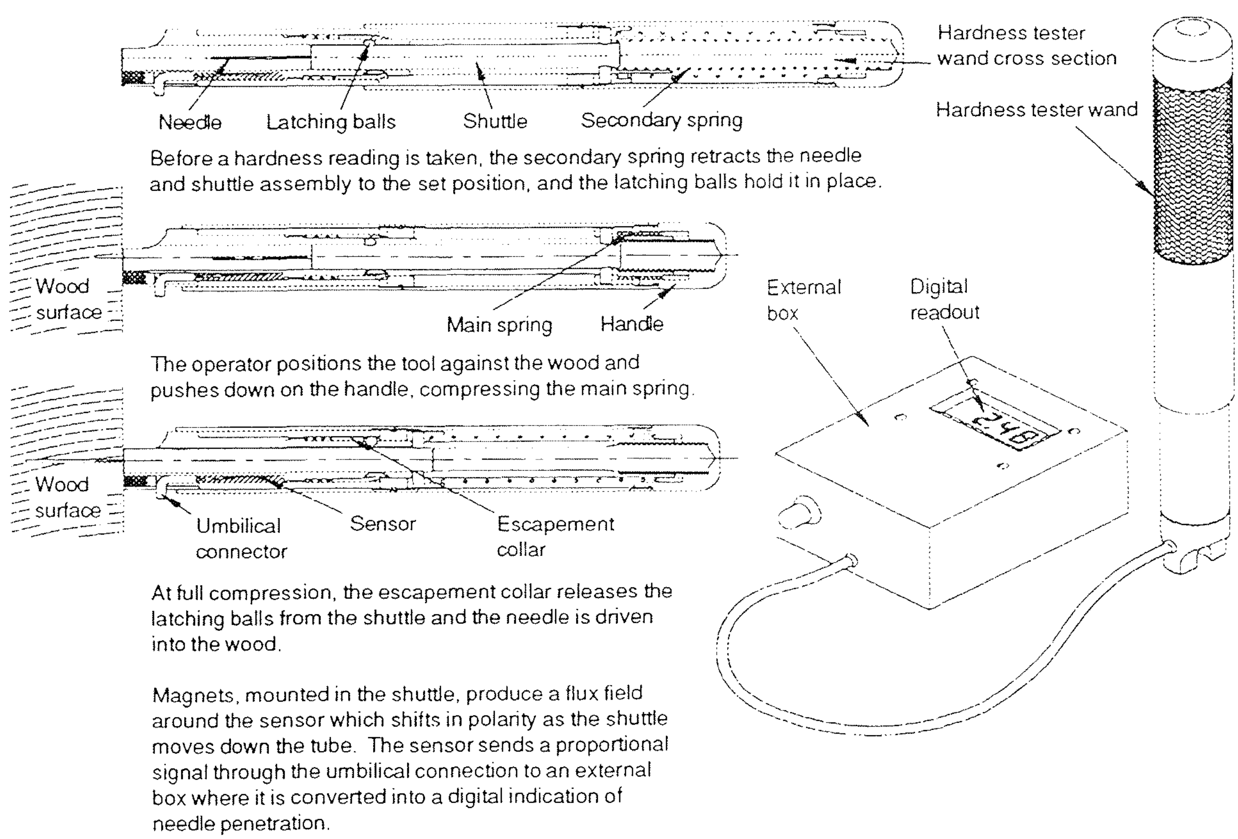

Figure 2. Wood hardness tester: Basic components of the advanced FERIC prototype.

energy at the point of initial contact, and 2.48 Nm at the full penetration of 40 mm. This matches the operating characteristics of the H-Gun.

To initiate a reading, the operator positions the tool against the wood and pushes down on the wand, compressing the main spring (Figure 3). The movement of an escapement collar allows the retraction of two latching balls from pockets machined in the shuttle, and the needle is propelled into the wood. When the operator pulls the needle out of the wood, a secondary spring automatically returns the shuttle to the set position where the latching balls re-engage the shuttle.

The resulting reading is an electronic display of the depth of needle penetration. Using a standard formula, the needle-depth reading is extrapolated to determine wood hardness, which is an indicator of the type and extent of decay.

Electronics. Four technologies were considered for the electronic readout, including an optical encoder, a capacitance encoder, a linear displacement transducer, and a Hall analog displacement sensor.[1] The Hall system was selected ont he basis of its availability and reliability, and its adaptabily to the design.

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[1] The output voltage of a Hall analog sensor is determined by the polar proximity of an adjacent magnetic field. This relationship provides a means of monitoring movement and position.

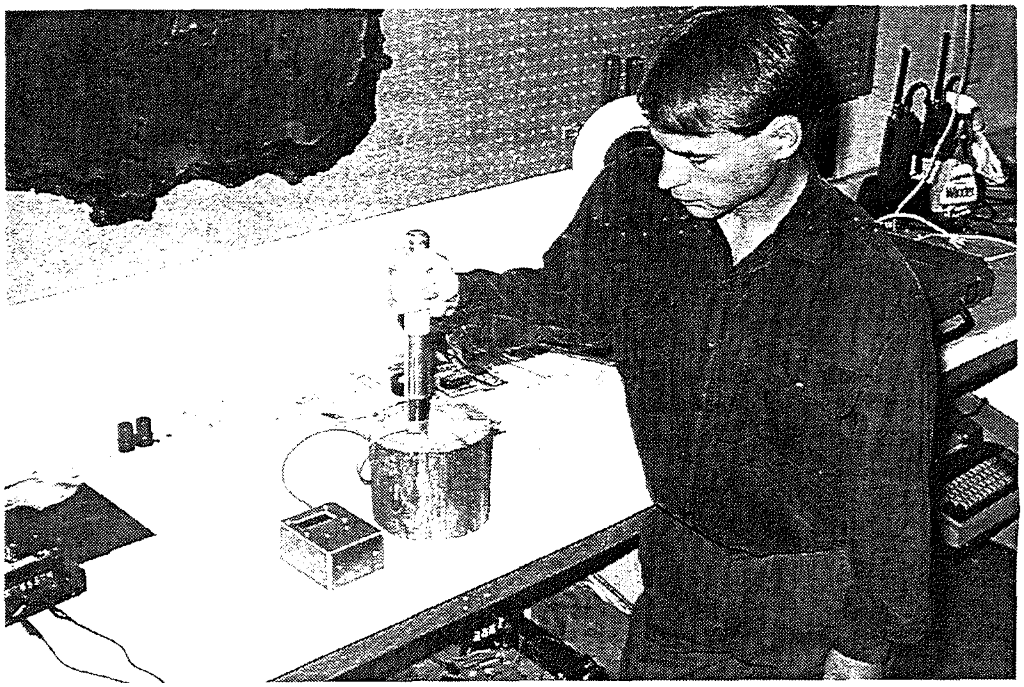

Figure 3. Advanced prototype of the FERIC wood hardness tester.

Magnets, mouns located in the cylinder wall. The sensor generates a voltage in proportion to the polar shift in the flux as the shuttle slides by. The displayed value is proportional to the voltage output from the sensor.

Because the accuracy of the sensor output depends on a linear variation of flux, several magnet arrangements were tried in an effort to produce an acceptable accuracy over the maximum range of shuttle displacement. The best result was ± 0.6 mm over a shuttle displacement of 20 mm. The Canadian Forest Service had determined that the transition from acceptable wood to that which would cause a manufacturing volume loss was identified by a needle penetration exceeding 34 mm. Therefore, the sensor in the advanced prototype was positioned to provide the most accurate readings within the range of 20-40 mm of needle penetration.

Tool Maintenance. The design of FERIC's advanced prototype focused on ensuring the tool would be highly reliable and have minimal maintenance requirements. It was anticipated that needle damage would be the most common cause of tool failure. To allow quick and easy replacement of broken needles, a simple grub-screw needle lock was developed that requires the use of only a small allen wrench. Bent needles need not be replaced as they can usually be straightened by hand.

Brass, austenitic stainless steel, and aluminium were the preferred construction materials because they offer corrosion resistance, minimum disruption of the magnetic field, and, in the case of aluminium, weight reduction. Dissimilar materials were used for the critical rubbing surfaces to eliminate the need for lubricants. Large clearances were specified between moving parts to minimize fouling by contaminant intrusion. Also, large clearances allow the relaxation of dimensional tolerances, which will ultimately contribute to reducing manufacturing costs. No tools are required to unscrew the handle assembly for cleaning. Water, or a solvent other than acetone, may be used for cleaning. The parts should be thoroughly dried prior to reassembly to avoid recontamination.

Prototype Testing. A comparative shop trial of the FERIC prototype and the H-Gun demonstrated a close correlation of readings. However, data acquisition was six to eight times faster with the FERIC prototype.

The FERIC prototype of the wood hardness tester was delivered to the Northern Forestry Centre in August 1994 for field evaluation. The prototype was tested for its ability to take readings of wood hardness that could be extrapolated to accurately identify aspen decay as caused by the fungus *Phellinus tremulae*: TypSe A_1 Decay is advanced decay and its presence would mean the fibre is nonpulpable, while Type A_2 Decay is less advanced indicating the fibre is still pulpable.

Readings were taken in samples of both fresh and frozen wood. The averages were consistent with values recorded earlier, using the original H-Gun. If the penetration of the needle in the decayed area is greater than twice the reading of the sound wood, then the decay should be classified as Type A_1; if the reading is less than twice the reading of the sound wood, then the decay should be classified as Type A_2.[2] Relative rather than definite readings are recommended because values from the same sample may vary depending on moisture content and temperature conditions.

The advanced prototype of the wood hardness tester operated without incident during the test, except for a dead battery which occurred because water had leaked into the box containing the electronics. This problem will be solved with a more effective seal design.

Prototype Modification. As the wood hardness tester approaches the production stage, consideration will be given to integrated circuits and connectivity to a hand-held data recorder. Design of the next prototype could incorporate a microprocessor to correlate the display with flux shift. This will eliminate the importance of flux linearity and produce greater accuracy over a longer range of shuttle displacement. In addition, the use of a microprocessor will reduce the power requirement of the unit from three 9-volt batteries to a single battery. As these changes should significantly reduce the size of the electronic package, it may be possible to make it an integral part of the wand, thus eliminating the umbilical connection.

Other Applications. At this time, there is no indication what changes are required for adapting this tool for use with other tree species. However, it is probable that changes to the needle diameter or to the characteristics of the main spring may be needed.

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[2] Source: Teresa Stokes, Alberta Environmental Protection / Land and Forest Services; personal communication, fax, March 1995.

CONCLUSION

In 1993, the Northern Forestry Centre of the Canadian Forest Service provided funding to FERIC through PAIF to develop an advanced prototype of a wood hardness tester. By determining wood hardness, the extent of fibre degradation due to fungal decay in aspen can be extrapolated. If the decay levels of aspen stands can be identified by accurate surveys, planners could prescribe harvesting and silvicultural activities more effectively.

FERIC first developed a preliminary operational prototype to test and refine functional mechanisms, and then an advanced prototype to integrate electronic sensor/display components. Shop testing of the first prototype demonstrated a close correlation of hardness data with that generated by the prototype H-Gun that had earlier been developed by the Northern Forestry Centre (Hiratsuka et al. 1990). During shop testing of the advanced FERIC prototype, the combination of the automatic reset mechanism and the electronic display allowed for the collection of wood hardness data at six to eight times the rate of collection with the H-Gun.

The selection of construction materials and the specification of generous clearances and tolerances make the FERIC prototype light, compact, rugged, resistant to moisture and dirt contamination, and easily manufactured. No lubrication is needed. Replacing a broken needle is the most probable maintenance consideration and this can be done quickly with an allen wrench. The unit is easily disassembled by hand for cleaning.

Field test results were consistent with those from earlier tests of the H-Gun. Based on needle-depth readings taken with the FERIC prototype, it was possible to clearly distinguish nonpulpable decayed fibre (Type A_1) from pulpable decayed fibre (Type A_2). Water leakage into the electronics box demonstrated the need for more effective sealing.

As FERIC's version of the wood hardness tester approaches the production stage, integrated circuits and the installation of a microprocessor are being considered to reduce the size of the electronics package and improve the tool's accuracy.

FERIC's design of a wood hardness tester for aspen offers an effective means of detecting and avoiding defective fibre before it imposes unnecessary cost on harvesting and manufacturing. The resulting economic benefit to the Alberta forest industry could be significant. With further development, this tool and technology could be adapted to tree species other than aspen.

LITERATURE CITED

Hiratsuka Y.; Gibbard D.A.; Bakowsky O.; and Maier G.B. 1990. *Classification and Measurement of Aspen Decay and Stain in Alberta.* Forestry Canada, Northwest Region, Northern Forestry Centre, Edmonton. Information Report NOR-X-314. 29pp.