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Thrown object testing of forest machine operator protective structures

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Summary

High-speed chains or rotating disks are commonly used to cut and process trees during forest harvesting operations. Mechanical failure or fatigue of these tools can lead to a potentially hazardous situation where fragments of chain or sawteeth are thrown through the operator enclosures on forest machines. This poster presentation discusses the development and validation of a facility to conduct thrown object tests for windows and doors used in operator protecttive structures on forest machines. The testing facility consists of a high-pressure pneumatic launch system that propels sawteeth and chain fragments at velocities in excess of 150 m/s.

Keywords: *Operator Protective Structure, thrown object, forest machine.*

Introduction

Industry standards outline the performance criteria for structures needed to protect operators of forest machines (ISO, 2003). While protective structure standards have increased the level of safety for forest machine operators, there are additional hazards faced by equipment operators that are not addressed by current safety standards. One such hazard that has not been addressed is thrown objects. Currently, no performance criteria exist for protecting forest machine operators from thrown objects.

Forest harvesting machines employ a variety of methods to fell trees, two of which involve high-speed chainsaw harvesting heads or high-speed rotary heads. The chainsaw harvesting heads have chain speeds up to 45 m/s and the main component of a rotary head is a disk that spins at approximately 1 175 rpm. A typical rotary head is comprised of a disk that has a diameter of 1.22 m and a number of steel-carbide sawteeth that are attached to the disk to allow the sawhead to cut through trees. A sawtooth flying from the disk may have a velocity in excess of 150 m/s. There have been instances where chains have broken apart or sawteeth have separated from the disk. Once a sawtooth or chain fragment is flying through the air, a potentially fatal situation has developed, as the operator's cab may be vulnerable to penetration by one of these projecttiles. Not only are mechanical components potential projectiles, but there is evidence that suggests wood fragments can be thrown at velocities high enough to cause fatalities. To develop proper standards that help machine manufacturers offer the most efficient protection available to machine operators, it is necessary to investigate the phenomena of thrown object impact.

Since the forces experienced by operator protective structures during thrown object impacts are poorly understood, the overall goals of our research are to develop estimates of thrown object loads that might be experienced by the OPS and then to develop recommendations for standardized thrown object testing methods. The specific objective of this poster presentation is to discuss the design and fabrication of a test fixture to allow destructive tests of assemblies used on forest machine OPS.

Development Of The Test Device

A compressed-air cannon was chosen for the test device because it has a renewable fuel source (air), is has only one moving part (a pneumatic cylinder), and it can achieve the necessary launch velocities. The gas cannon created for this investigation is known as the THrown Object Research device or THOR. Veal et al. (2003) provided a detailed description of THOR. The primary criteria used to design THOR were precise control of projectile velocities and the ability to achieve velocities in excess of 150 m/s. To meet these criteria, THOR was designed to hold 75 litres of compressed air at pressures up to 2.413 MPa. THOR is composed of three main parts: a reservoir, a barrel, and a firing piston (Figure 1). The reservoir is a steel tube with an outside diameter of 305 mm and a wall thickness of 19 mm. The reservoir is 1.52 m in length. Steel slip-on flanges 63.5-mm-thick were welded to the ends of the reservoir. Blind flanges were bolted to the slip-on flanges to seal the reservoir. The barrel, which is placed inside the reservoir, is a steel drawn-over-mandrel (DOM) tube that has an outside diameter of 95 mm and a wall thickness of 10 mm. The barrel has a length of 1.83 m.

The firing piston is located inside the reservoir and at the base of the barrel. This firing piston, which is a pneumatic pancake cylinder, was chosen because it is extremely thin when retracted; therefore it will not interfere with the flow of air when a projectile is launched. Also, a pneumatic cylinder provides quick extension/retraction stroke movements, which are essential to proper operation. An air amplification system is used when pressures above 896 kPa are needed. THOR uses a series of solenoid valves to control the intake and removal of compressed air. The valves control the operation of the air pressure amplifier, the extension and retraction of the firing cylinder, the pressurization of the outer reservoir, and an emergency pressure dump to atmosphere feature.

Before firing THOR, a projectile is placed into the barrel. Then, the firing piston is pressurized, which forces the top of the piston against the rear end of the barrel thereby sealing it from air in the reservoir. Next, the reservoir is pressurized. To initiate the launch of the projectile, a valve is opened to release the pressure from the firing cylinder. The reservoir pressure forces the firing cylinder to retract, which in turn allows the high-pressure air in the reservoir to flow into the barrel and force the projectile out.

THOR Performance

Using equations for adiabatic expansion, theoretical performance curves of velocity versus reservoir pressure were developed for a given projectile mass. An example curve for a 480 g projectile is shown in Figure 1.

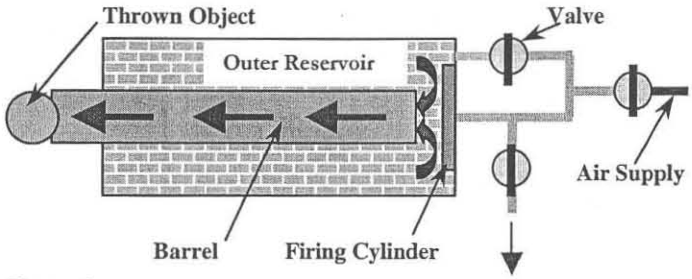

Figure 1.
Conceptual sketch of THOR, the compressed-air launch device.

Once the theory behind the device was established, a number of projectiles were launched to determine the actual performance characteristics of THOR. The projectiles launched during these initial tests were sawteeth placed in sabots discussed by Veal et al. (2003). Together, a sawtooth and sabot weighed 480 g. A range of pressures between 310 kPa and 861 kPa were investigated. The projectile velocities produced by the pressures investigated can be seen in Figure 2.

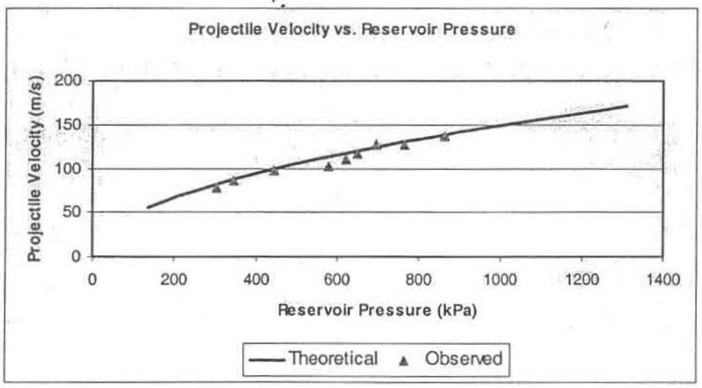

Figure 2.
Plot of theoretical and observed projectile velocities vs. reservoir pressure for THOR.

From this figure, it appears THOR launches projectiles in a manner consistent with the projectile velocities that can be calculated using the formulas of adiabatic expansion. The greatest difference between a theoretical and an observed velocities for a given reservoir pressure was 6%. Multiple launches were conducted at a given reservoir pressure to determine the repeatability of THOR. Projectile velocities were repeatable within a range of $\pm$ 5%.

Summary

Some of today's forest machines have the ability to launch sawteeth and other woody debris at high speeds through the air. These projectiles may have the capability of piercing the operator's cab and threatening the safety of forest machine operators. The ability of current OPS to protect forest machine operators is not well established, as current design standards do not properly address the thrown object hazard. The development of the THrown Object Research device, THOR, allows research to be conducted that will improve the OPS in forest machines. THOR is a compressed air cannon capable of launching projectiles up to velocities of 150 m/s.

References

ISO. 2003. ISO 11850: Machinery for forestry—self-propelled machinery—safety requirements. International Organization for Standardization, Geneva. 12 p.

Veal, M.W., S.E. Taylor, and R.B. Rummer. 2003. Development of a Test Device for Evaluation of Thrown Object Hazards. In Press, Journal of Agricultural Safety and Health.

Profile

This paper will be co-presented by Bob Rummer, US Forest Service and Dr. Steve Taylor, Auburn University. Dr. Rummer is the Project Leader for the Forest Operations Research Unit in Auburn, Alabama. He has degrees in Forest Management, Forest Products, and Industrial Engineering. He has been with the Forest Service in Alabama since 1983. Dr. Taylor is a Professor of Forest Engineering at Auburn University. He received his B.S. and M.S. in Agricultural Engineering at the University of Florida and his Ph.D. from Texas A&M University. He has been on the faculty at Auburn since 1989 where he teaches and conducts research in Forest Engineering and Structural Wood Engineering.

Their presentation today will focus on current projects examining operator protection on forest machines.

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