New developments in operator protection for forest machines

B. Rummer
Project Leader, US Forest Service, Auburn, AL, USA

S. Taylor
Professor, Biosystems Engineering
Auburn University, AL, USA

M. Veal
Graduate Research Assistant, Biosystems Engineering
Auburn University, AL USA

Summary

Mechanization of forest operations has greatly improved safety of woods work. However, increasing use of machines has also introduced new hazards that must be addressed. Two of these hazards are rollover of swing-type forestry machines (currently excluded from standard protection) and the hazard of thrown objects from cutting devices. Ongoing research projects are developing basic information about the forces that must be resisted to protect operators from these hazards. Analytical modelling of rollover events suggests that current rollover standards for crawler tractors may be appropriate for swing-type designs. Laboratory tests of thrown object impacts on steel cab panels are determining appropriate specifications based on expected object energy levels.

Keywords: *mechanization, protective structures, rollover, safety*

The Problem

Forest operations are well recognized as one of the most hazardous occupations worldwide. Logging tends to have a higher total case incident rate (TCIR) (more injuries per 100 full time workers) and more severe injuries (a higher fatality rate). One of the most successful approaches to improving safety is to mechanize operations, replacing manual chainsaw tasks with machine operators. LaFlamme and Cloutier (1988) noted that conventional logging operations had an incident rate three times greater than similar crews with mechanized delimbing. Bell (2001) conducted a longitudinal study of logging crews in West Virginia and found a significant reduction in claims after the adoption of mechanized felling equipment. Increasing mechanization of forest work in the United States is probably the primary factor responsible for the steady decline in the TCIR. In 1991, the logging TCIR was 1.89 times the

Analytical Modelling of Rollover Behaviour

Rigid body mechanics have been used in the past to study the motion of machines during rollover events. Allison and Mackay (1992) used the rigid body method to calculate the velocity of an armored vehicle's centroid during a rollover accident. In this two-dimensional method, the rollover event can be demonstrated as a series of discrete impacts that occur over successive contact points.

During a rollover event, the velocity of the vehicle centroid is a function of the angular velocity about a fixed point of rotation and the distance from the fixed rotation point to the vehicle's centroid. To analyse a vehicle rollover, a two-dimensional view of the vehicle is used to define the outer points of the vehicle that could possibly contact a ground surface during the rollover. These contact points are assumed to be the points about which the vehicle will rotate during the rollover. Then, equations of motion are used to calculate the velocity of the vehicle's centroid as it rotates around these various contact or impact points. For a given slope, the motion equations can be used to describe the path of the vehicle as it would roll down the slope. When the centroid velocity goes to zero, this indicates that the vehicle has stopped rolling over.

Using pre- and post-impact velocity data, the amount of kinetic energy lost during the impact can be calculated by this method. If needed, the plastic deformation of the cab roof supports can be evaluated by assuming that plastic hinges will develop at the extremities of the cab support pillars. Also, transverse and axial forces experienced by the cab pillars can be calculated. These force data can then be equated to losses in kinetic energy to solve for the displacement of the cab supports.

Using the methods described by Allison and Mackay (1992), researchers at Auburn conducted analyses of hydraulic excavator rollovers on 10-meter-long, 30-degree slopes. The analyses were conducted for 13 different hydraulic excavators as used in construction activities, 11 excavators outfitted for forestry use with 46-cm-tall cab risers, and 11 excavators outfitted for forestry use with 122-cm-tall cab risers. In addition, similar analyses were conducted for 11 crawler tractors. Masses of the machines analysed ranged from 4 tonnes to 30 tonnes.

Manufacturer's specification information combined with limited field measurements was used to determine two-dimensional geometry of the machine as seen from a front view of the machine. The centroids of the machines were determined using estimated densities for the different portions of the machines. Using the geometry information, distances were determined from the centroid to each of the possible contact points.

To simulate machine rollovers down the 30-degree slope, successive contact points were calculated using the machine geometry data. Then, centroid velocity was determined immediately before and immediately after each of the contact points using the analytical procedures described previously. Since kinetic energy is lost at each contact of the machine with the ground surface, the lateral and vertical components of this energy lost were calculated for each contact between the machine and the ground surface. Although the analysis assumes the machine is a rigid body, these levels of kinetic energy would be similar to those to which the ROPS would be exposed.

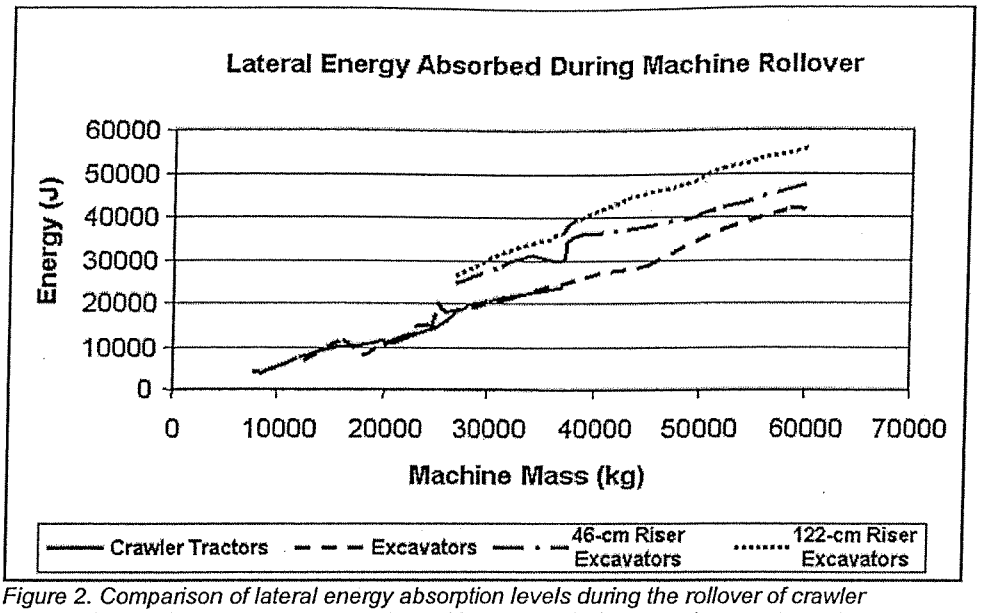

Figure 2. Comparison of lateral energy absorption levels during the rollover of crawler tractors, hydraulic excavators, excavators with 46-cm cab risers, and excavators with 122-cm cab risers. Results are based on rigid body mechanics methods.

Thrown object protection

Modern, high-production forest machines cut and process wood using a variety of cutting mechanisms (Figure 3). Chainsaw cutters, for example, are found in harvesters, processors, slashers and feller-bunchers. Disk saws are commonly used on feller-bunchers. Various grinding or shredding cutters are employed in mulching and mastication machines. Under certain conditions, machine parts may become detached and thrown from these machines. Pieces of cut material, stones, or other debris can also be discharged at high velocity from some types of forest equipment. A number of anecdotal reports illustrate the hazard.

In June of 1992, a 45-year-old fully trained operator was operating a knuckle-boom log loader and sawing trees into log lengths. The chain on the bucking saw broke and sent a small chain fragment flying through the air. The chain fragment penetrated the safety glazing and lodged deep in the operator's stomach (Howe 1992). It should be noted that the safety glazing was shattered prior to this event, indicating the possibility that there was a prior thrown object impact. In 2001, a tooth was ejected from a rotary-disc sawhead and traveled over 76 m [250 ft] through the air. The sawtooth passed through a mobile home, damaging several walls inside the home (Wetzel 2001).
Thrown objects may be caused by reasons other than mechanical failure. The energy transferred into a material from contact with a high-speed rotating disk may cause the material to quickly break apart and small pieces of the material to be thrown at high velocities. In July 1996, a saw hand working near a feller-buncher was struck in the chest by a broken piece of a pine tree. The piece of pine penetrated the saw hand's chest leading to a critical, but non-fatal, injury (Alt 1996). In the summer of 1995, the disc on a feller-buncher scraped the side of a pine tree lying on the ground. The disc shaved off a 15-cm-wide [6 in.] x 2.5-cm-deep [1 in.] x 274-cm-long [108 in.] piece of wood. The piece of wood was launched through the air and struck an observer. The thrown piece

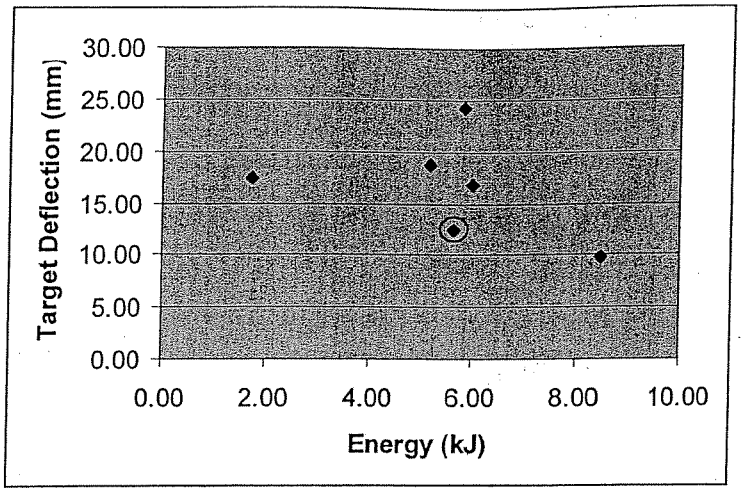

Figure 4. Thrown object test results from shots at 11 ga A606 sheet steel. The circled point did not penetrate the surface.

Thrown object testing continues to examine the effect of object mass, velocity and geometry of impact. High-speed imagery will be added to the test facility to enhance understanding of the dynamics of these events.

Future Work

The findings of these research projects are leading to development of improved international standards for forest machines. The ROPS modelling results will be incorporated into an upcoming revision of ISO 8082 that will address appropriate requirements for machines with a cab and boom on a rotating platform. The thrown object testing will be completed to support a new work item for standard development. Both of these projects will provide a rational basis for assigning performance requirements that can address evolving hazards of mechanized forest operations.

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