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CMEIG Engineering Position Paper

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Chain Shot Phenomenon

Background

The K-Saw is a hydraulically powered chain saw used in conjunction with a log grab to trim felled trees to length (see Figure 1). The K-Saw has been fitted to various manufacturers' hydraulic excavators.

Figure 1 The K-saw commonly attached to a hydraulic excavator.

On the 30th March 2005, an incident occurred in Tasmania whereby an operator of a PC300-7 hydraulic excavator, fitted with a log grab and K-Saw attachment was struck in the neck by a projectile that entered the front window. It is believed that the projectile was a piece of chain link that had broken off the K-Saw chain. This projectile has been referred to as the 'chain shot phenomenon' and is shown in Table 1.

Further to this incident Komatsu Australia Limited (KAL) has carried out extensive research world wide to determine if a suitable protective screen has been tested and proven to prevent chain shot. As no record of conclusive testing or a standard could be found, KAL commissioned SMP Svensk Maskinprovning AB, to conduct testing. SMP is a forestry testing facility in Sweden that has carried out extensive research on chain shot for SKOGFORSK (The Forestry Research Institute of Sweden) and has purpose built equipment that can produce 'chain shot' type failures.

Testing

The objectives of the test program were:

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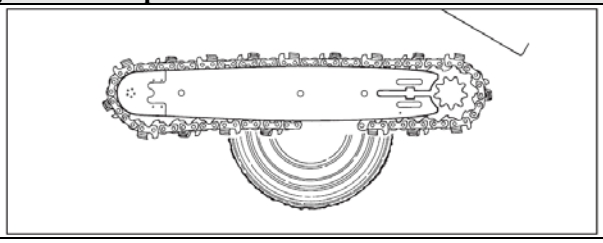
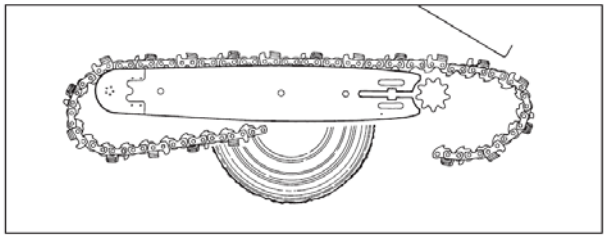
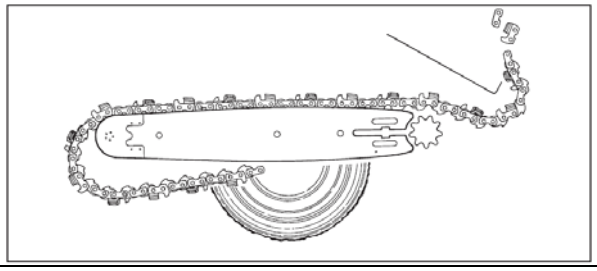
- Provide a recommendation for a protective window to protect operators in the event of chain shot. Accident reports have shown that polycarbonate sheeting as thick as 12mm has been penetrated by chain shot – as such thicker sections and different materials were used for testing.
- Develop a device (ie chain arrestor) that can reduce the risk of chain shot in the direction of the operator.

Table 1 The Mechanical Harvesting Handbook (Oregon, 2004) explains the phenomenon of chain shot.

Sequence of events	**Diagrammatic representation**
After a chain break ……	
The free end of the chain begins to whip away from the break.	
If the chain is not contained by the saw box or an energy-absorbing guard, the broken chain's free end can speed up rapidly and carry immense dynamic energy.	
At the peak of the whip, chain parts may break loose and be ejected at high speed, especially if the free end of the chain strikes the saw box. Chain shot can cause chain parts to be thrown in many directions, especially along the plane of the saw bar.	Fragments have been measured at between 180 and 310 m/s under laboratory simulated conditions.

SMP built a test rig using the base parts from an actual K-Saw to cause a chain to break during operation, hence causing a chain shot to occur (see Figure 2). The test windows selected for the test program were listed in Table 2, and Table 3 summarises the laboratory results.

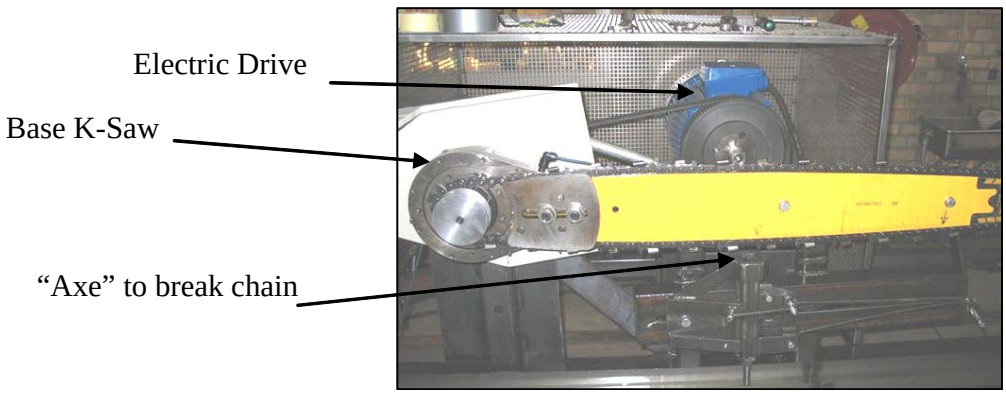


Figure 2 The K-saw test rig design by SMP.

The testing indicated that relying on a safety screen would not provide sufficient operator safety and therefore, solutions incorporating a chain arrestor were sought.

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The chain arrestor was designed by KAL in conjunction with SMP and Komatsu Forest R & D team. Figure 6 shows the prototype device fitted to the test rig. The chain arrestor works by collecting the chain in the event of breakage and preventing the whip lash effect that can cause chain shot.

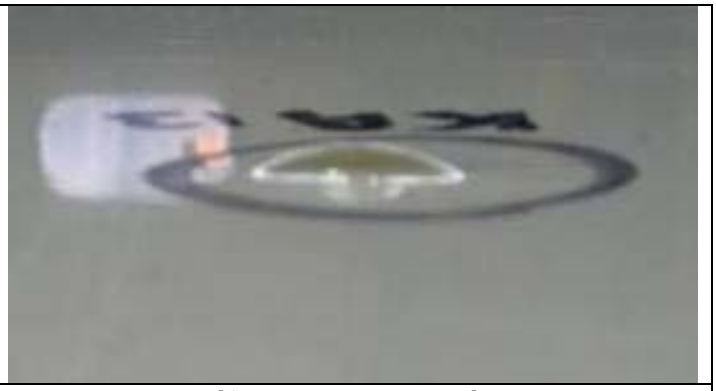
Table 2 Three window configurations were tested.

Type	Total thickness (mm)	Description
1	19	Polycarbonate - LEXGARD® RC-750 laminate - three-ply LEXAN® polycarbonate
2	19	Polycarbonate / Acrylic - LEXGARD MP750 laminate is a three-ply LEXAN® polycarbonate and acrylic laminate
3	32	Polycarbonate - LEXGARD® SP-1250 laminate - four-ply LEXAN® polycarbonate laminate

Table 3 Window test results.

Type	No. of tests	Observations
1	10	Projectiles were able to penetrate the material and cause a 5mm deformation on the rear surface on the window. Refer to Figure 3.
2	7	Projectiles where able to penetrate the outer polycarbonate layer, but were contained by the acrylic layer. The rear layer of polycarbonate was not penetrated, however it was partially delaminated. Refer to Figure 4.
3	9	Projectiles were able to penetrate the material to a maximum depth of 18 mm. Refer to Figure 5.

(a) Link lodged into the window.



(b) Protrusion on rear side.

Figure 3 Photos from type 1 test (refer to Tables 2 and 3 for more details).

(a) Damage from projectile.

(b) Links that hit the window.

Figure 4 Photos from type 2 test (refer to Tables 2 and 3 for more details).

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(a) Damage from projectile. (b) Links that hit the window.

Figure 5 Photos from type 3 test (refer to Tables 2 and 3 for more details).

Figure 6 The proposed K-saw chain arrestor.

In the 22 tests that were carried out with the chain arrestor fitted there were no instances in which chain shot occurred.

Recommendations for K-Saw machines

The Association would like to recommend the following approaches to the safe use of K-Saw machines:

- Fit the Lexgard MP750 19 mm Polycarbonate Acrylic Laminate or the Lexgard SP-1250 32 mm polycarbonate laminate to the front windows of all machines (in the case of machines requiring impact resistance and where steel bars are not fitted, then SP-1250 should be fitted)
- Fit the chain arrestor
- Review the speed and maximum pressure of the saw to enure they are within specification.
- Fit tamper indicators to the adjustments for the pressure and flow control valves.
- Extend the exclusion zone extension at least 50 m line of site through the front window.
- Update operator and other technical documentation to reflect best practice changes.

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Recommendations for use of third party hydraulic powered harvesting saws

The Association would like to recommend the following approaches to the safe use of third party hydraulic powered harvesting saws:

- Follow all manufacturers' guidelines in relation to safety requirements
- In the absence of test results on a protective front window, a Lexgard SP-1250 32 mm polycarbonate laminate should be fitted to the front window of all machines.
- Extend the exclusion zone extension at least 50 m line of site through the front window.

Conclusions

The chain shot incident in Tasmania identified that users must take all due precautions appropriate to the operating circumstances to protect operators and any others in the vicinity of the sawing operation.

All three window options (ie Lexgard RC-750, MP750, and SP-1250) provided penetration resistance to chain shot in the laboratory conditions with the chain arrestor. The MP-750 (Polycarbonate / Acrylic) and the SP-1250 (32 mm Polycarbonate) provided a significantly higher level of penetration resistance of chain shot.

The chain arrestor prevented chain shot from occurring in 100% of the tests and is a better design solution than a screen alone.

Bibliography

Oregon Cutting Systems Group Blount Inc (2004) *Mechanical Harvesting Handbook* Portland, Oregon, USA (Click here to download a soft copy of the handbook)

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