HARVESTING TECHNICAL NOTE

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“Walking Machines” in Forest Operations

Summary

This report describes a woodlot logging operation where a Kaiser Spyder S2 (2000) “walking machine” bunched manually felled trees on a slope for extraction by cable skidder. The operation of the machine was recorded by video camera and the video data analysed. The results provided data for productivity estimates for bunching in tree size of approximately 1.5 m^3 by a Kaiser Spyder or similar type machine. The performance and applicability to New Zealand conditions of similar machines is discussed.

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Introduction

A class of small wheeled excavator-type machines called “walking machines” or “spiders”, due to their unique design with stabilisers or “legs” which can be raised, lowered, extended or retracted, have been available for about 40 years. In the early 1980s American foresters saw the potential of “spiders” or “walking” excavators as harvesters working on steep terrain[1].

In recent years the evolution of parallel hydraulics and electronics has allowed building increasingly agile and quick "spiders", and eventually the idea of adapting these machines for use in other forestry operations has been taken up by European manufacturers.

There are a large number of these machines being produced, largely central European in origin. The two main manufacturers are Kaiser in Liechtenstein and Menzi Muck in Switzerland. Machines are also made in Italy by Euromach. Menzi Muck has recently made forestry-specific models, fitting machines with small harvester heads such as the Konrad Woody 50 (65-cm capacity).

They have been evaluated in tasks ranging from civil engineering in steep terrain to stream clearing in areas of environmental sensitivity to site preparation to harvesting operations such as thinning and felling and bunching (Figure 1).

An FFR project – “Mechanisation of harvesting on steep slopes” – includes the investigation of machines with steep slope capability with the potential to improve safety and productivity in steep slope harvesting. This Technical Note details some findings from one such investigation of a Kaiser Spyder S2 bunching trees on slopes of 25 - 30 degrees.

Figure 1. The Kaiser Spyder S2 operated by Karl Schwitzer in Cambridge.

The Machine

The Kaiser Spyder is one of a family of similar “walking excavators”. Table 1 compares some specifications of the Kaiser Spyder S2 and the Menzi Muck A91.

The engine drives three Danfoss pumps, the first dedicated to the arm and the processor, the second one powering the legs and four-wheel drive and the third one activating the rest of the service functions. Management of pumps and

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motors is assigned to an electronic control unit that coordinates the actions of each function.

As these machines have developed over the past 20 years for forestry use, engine capacity has increased from 60kW to 117kW and components been made more robust.

Table 1. Comparison of two walking excavators.

	Kaiser Spyder S2	Menzi Muck A91 Mobile
Weight (approx kg)	9980	10500
Engine Power rating	116.9kW	104kW
Lift capacity	5.5 tonne @ 3m 2.8 tonne @ 5m	6.0 tonne @ 2.8m 2.0 tonne @ 5m
Break out force	92KN	73.6KN
Reach	8.22m	8.27m
Slew Torque	48000Nm	46000Nm

Reviews of literature and manufacturers' specifications have shown that the largest machine from all "walking excavator" manufacturers is approximately 12.5 tonnes in weight and manufacturers offer a diverse range of features (machine sizes, wheel or track configurations, attachments and winch options).

The slewing and lifting capacity of these machines is greater than the overall weight would suggest. One operator compares these aspects of performance to that of a 20 tonne tracked excavator (K. Schwitzer, *pers.com*). This is largely because of the dedicated hydraulic pumps and flow rates.

It was also suggested that one reason for the capping of total machine weight at about 12-13 tonnes is because of the reliance of the machine on its stabiliser feet when working on steeper slopes. In these conditions, the weight of the machine is transferred to the stabilisers.

Compared with tracked excavators, the "spider" has a higher power / weight ratio, so that relatively light models have enough power to operate a processor.

Most of the walking excavator machines are quoted as being capable of operating on slopes of 45 degrees (100%). The extent to which tracked or wheeled forestry machines can operate on steep terrain is determined by a number of factors besides health and safety considerations. Terrain factors include slope, obstacle size and frequency, soil cohesion and soil moisture content[1]. In non-cohesive or pumice soils, a limit of 40 degrees (80%) was suggested, with poor productivity on slopes over 26 degrees (50%).

On steeper slopes productivity of the machine reduces due to increased move time, less shear accumulator use (stability issues) and reduced boom length (R. Spinelli and K. Stampfer, *pers. com*).

Although some have 4WD capability, other models, especially those designed for steeper slopes, are two-wheel-drive and when on slopes, move by extending/crowding the boom including telescopic extension (e.g. Kaiser Spyder S2).

Some are also fitted with winches up to 5 tonne capacity for climbing assistance and as a safety precaution.

Figure 2. A Menzi Muck A91 Forestry-version with Woody 50 Harvester attachment. (Artcom Tradebridge website)

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Previous Machine Studies

An early study of a Kaiser X5M Spyder[2] equipped with a small shear head found that productivity on steeper slopes was reduced on increased slopes due to increased move time, less shear accumulator use (stability issues) and reduced boom reach. The authors noted that such a bunching system in small wood held the possibility of using large yarders to extract the bunches. The authors also assessed the movement speed of the X5M identifying a maximum movement distance of 1.5m per boom push (a rate of approximately 0.12 km/hr). Move time was also identified as the element having the greatest effect on production.

More recent studies of these types of machines in Canada have focussed on demonstrations for site preparation and debris removal (Figure 3), especially near or in streams[3]. Costs of site preparation (mounding) were considered to be high by Canadian standards[4]. In this study the author also found that move time occupied a high proportion of cycle time (37%). One use of a walking machine involved bunching loads for heavy-lift helicopters on steep terrain. This resulted in significant increases in helicopter payloads and the operation was deemed by Weyerhaeuser to be cost-effective (R. Krag. *pers.com*.).

Another study involving a Menzi Muck, 53kW A71 working in cable logging operations in Norway[5] found the A71 did not reach the targeted productivity of 10 m^3 per scheduled hour because of mechanical downtime. Slopes worked during the study exceeded 22 degrees. The A91 version in current use in harvesting is claimed to be more robust.

A recent evaluation in thinning operations in Iceland[6] demonstrated the effect of operator experience and of small tree size on the productivity of the Menzi Muck A91. Productivity per scheduled hour was 1.1 m^3/hr in 0.1 m^3 tree size and 4.7 m^3/hr in 0.2 m^3 tree size, on easy terrain. The results were largely attributed to the heavy stocking and because the operator had not had sufficient time on the machine and harvester head.

Higher production rates had been reported by Frick *et al.* [7] with a smaller machine, a Menzi Muck A71. In 0.1 m^3 tree size the author reported productivity of 5.5 m^3/hr and 14 m^3/hr in 0.2 m^3 trees.

Figure 3. A Menzi Muck A91 working in the Wellington area – clearing vegetation with a circular saw attachment (Source: Paul McCready).

Estimated cost of a Menzi Muck machine (Figure 3), landed is of the order of NZ$ 500,000. Many similar machines are available second hand and prices are available. A used A91 in the US was quoted at US$156,225.

One possible use for this kind of machine, which has been tested at a number of sites, is bunching for extraction. The concept of bunching for extraction is not new, and has been used successfully in ground-based operations in New Zealand for many years. Recent FFR reports have covered operations in New Zealand where bunching for cable extraction has resulted in increases in cable system productivity[8].

A study of a similar Italian-made machine, Euromach 9000 Forester, had revealed that these machines could be a viable option, able to reach good production levels[9]. It was recommended that the machine should be equipped with shatterproof glass and protective guard-rails and possibly provided with a more powerful engine. This is especially true for cable logging systems, as the harvester works close to the line and may be subject to greater risks from flying objects. A special consideration was given to the idea of using these types of machines to clear the chute under the hauler since they have the advantage over regular excavators of being able to position themselves safely on a wide variety of terrain features.

Study Area and Operation

A Kaiser Spyder S2 (2000) was recently observed while working in a farm woodlot near Cambridge. The machine, owned by a local contractor, Karl Schwitzer, was clearing slash and branches and aligning radiata pine trees on a short steep slope for uphill extraction by a cable skidder (Figure 4).

Figure 4. Kaiser S2 Bunching on a slope terrain on a slope (est. 18 degrees).

The Spyder was equipped with a bunching grapple on a fixed rotator (non-dangling rather than a rotating grapple). This meant that it could use its standard method of pushing itself uphill supported by two wheels and the extending boom.

It was observed clearing slash on an improvised skid and was quick in its movements using its four wheels – two driven. The operator (Karl Schwitzer) commented that the newer machines and the Menzi Muck A91 in particular had about 40% more power available to lift and slew functions.

Study Method

Some video footage was taken of the Kaiser Spyder working and moving. Estimates of cycle times for bunching trees were derived from the observed element times. Movement speed, based on time and distance per push, was also estimated.

The work cycle was broken down into the following time elements (Table 2):

Table 2. Description of time elements.

Element	Description	Start	Finish
Slew empty	Boom movement horizontally – grapple empty	As the grapple opens to drop a tree - and the grapple is empty	When the grapple is closed on a tree
Push away/crowd	Use of the boom to push or crowd	At the end of slew empty	When the grapple leaves the branch or tree
Grapple	Acquisition by the grapple of a branch or tree	As the grapple contacts a branch or tree	When the grappled branch or tree is lifted/slewed
Slew loaded	Boom movement horizontally – grapple closed	As the grapple closes on a branch or tree	When the grapple opens to drop a branch or tree
Move (uphill)	Machine movement – boom pushing	When grapple is closed and boom extends – or wheels start to turn	When the wheels stop turning and the boom lifts and slews.

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Results

Fifty-six minutes of video was analysed and average times for work cycle elements were calculated (Table 3). There was a total of 35 cycles identified: 22 cycles where only branches and slash were moved, and eight cycles where trees or logs were pushed or crowded. Two logs and three whole trees were slewed.

The interactions with whole trees involved lifting and slewing three separate trees of approximately 1.0 tonnes each, and pushing/moving a tree of an estimated 2.0 tonnes.

Table 3. Average times for work cycle elements.

Element	Average time per cycle (sec)	Percentage of cycle (%)
Slew empty	7.8	41
Push/crowd	3.3	17
Grapple	2.3	12
Slew loaded - slash	4.5	24
Slew loaded - tree	1.0	5
	18.9	100%

Moving speed up a 25 - 30 degree slope, on an even surface was estimated at approx. 0.7km/hr.

As there is interest in the application of a “spider-type” machine for felling and/or bunching trees, the average tree slewing cycle and movement times were used to produce estimates of the machine’s felling and/or bunching performance in a large-scale forest environment.

The average cycle time to slew the three observed trees, with an estimated volume of 1.0 m^3 per tree (one swing – from one side of the machine to the other) was 19.5 seconds.

A spreadsheet productivity model was constructed using a number of assumptions, including area worked and tree size (Table 4).

Estimates of productivity for felling and bunching, and bunching alone for different tree stockings, machine swing radii and push distances were calculated for a Kaiser Spyder or similar type machine equipped with a feller-director-type head. The working pattern involved a working cycle in a downhill direction and a return uphill to a start point.

Table 4. Assumptions used in the felling and bunching productivity model.

Assumed Variables	**Value**
Fell time/tree (sec)	50 sec
Bunch time/tree (sec)	60 sec
Tree size (m^3)	1 m^3
Area (ha)	1 ha (50*200m)
Swings per tree	3
Move speed (m/sec)	0.23 m/sec
% of swing area felled/bunched	50%
Swing radius (m)	3,5,7 m
Push distance (m)	2,3,5 m
Stocking (stems/ha)	200,400,600 stems/ha
Calculated variables	
Trees per swing radius	
Swath width	
Moves/swath	
Trees/swath	

Variables such as stocking, swing radius and push distance had previously been identified as important, mainly because of their effect on moving time[2].

The effect of stocking on fell and bunch productivity is shown in Figure 5.

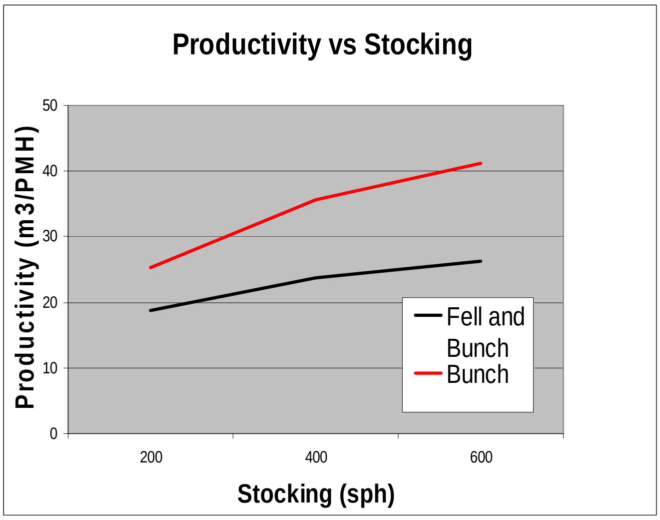

Figure 5. Productivity vs. Stocking (Push distance 3 m, Swing radius 5 m).

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In terms of scale, this variable out of the three tested had the largest effect on productivity, through its direct effect on moving time.

The effect of swing radius and stocking on fell and bunch productivity is shown in Figure 6.

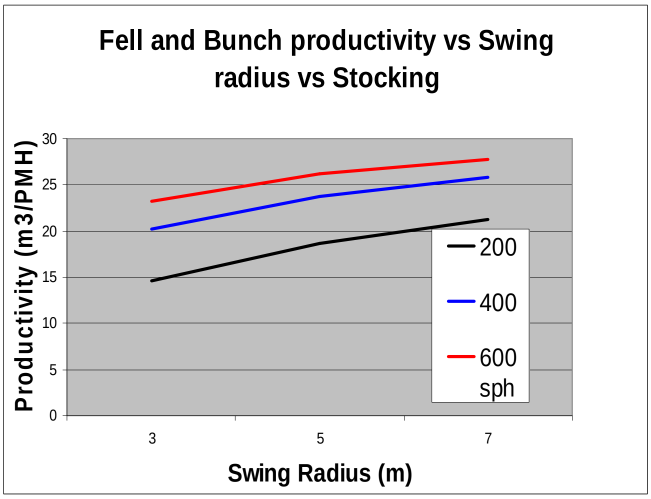

Figure 6. Fell and Bunch Productivity vs. Swing radius and Stocking (Push distance 3m).

Swing radius also had an effect on productivity, through its direct effect on moving time. Schiess and Schuh (1985) found that swing radius reduced with increasing slope. It is unclear if this effect also occurred with the more modern machines[2].

The operator in this study estimated that movement distance per boom push was about 5 m (K. Schwitzer, pers.com).This method of movement also meant that either a fixed (non-dangle) attachment or a live heel must be used.

The effect of push distance and stocking on fell and bunch productivity is shown in Figure 7.

Push distance also had an effect on productivity, through its direct effect on moving time. Schiess and Schuh (1985) found that push distance reduced with increasing slope. Karl Schwitzer found with the S2 model, that on the slopes he has worked push distance is 5-6 m both uphill and downhill.

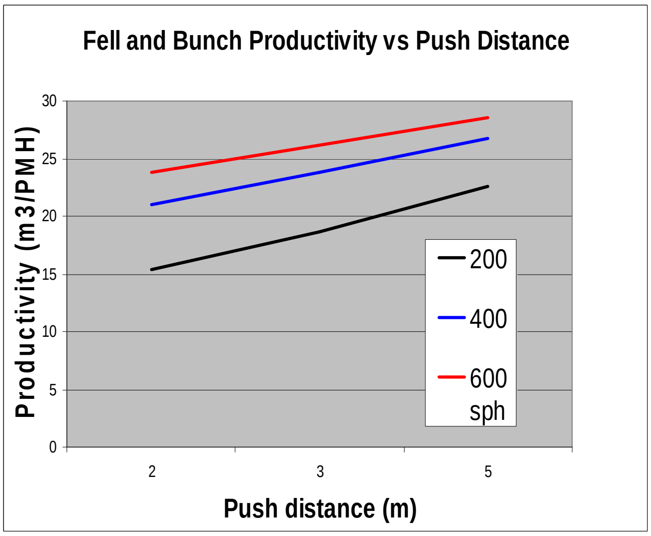

Figure 7. Fell and Bunch Productivity vs. Push distance and Stocking (Swing radius 5 m).

The following recommendations were made from this study:

- A suitable machine for forestry applications i.e. Felling and bunching, would be a non-4WD, “Powerline” equipped Menzi Muck A111 or A91. The power line option is an independent hydraulic pump with a prioritised supply. Non-4WD, because four wheels (rather than two driven wheels with two stabilisers) are a disadvantage in terms of stability on slopes.

- A suitable head attachment would be a 500 mm fixed, shear-type (favoured for low maintenance). Also a fixed, rather than a “dangle” type head would mean dispensing with the weight of a heel boom (meaning larger trees could be handled).

- The Spyder S2 has a slewing and lifting performance similar to a 20 tonne excavator.

- Time for a new operator to learn to use the machine would be 30 to 40 hours. In addition, care is needed to read the terrain so that downhill movement in particular and movement in general can be carried out safely and efficiently.

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Conclusions

Performance was consistent with the performance quoted in the specifications of the current S2 model i.e. a lift capacity of 5.5 tonnes at 3.0m, and 1.6 tonnes at 7.0m.

It was confirmed that move time, or travel time is a key issue with the operational use of walking-type machines and significantly affects productivity. Move time is also necessarily affected by stocking and, in thinnings, the number of trees removed.

Although slopes at the site where the Kaiser Spyder S2 was observed were not overly steep, there is reason to believe this kind of machine could be used on some of the steepest terrain currently being cable logged[2]. This would depend on favourable tree size and soil conditions.

As a result of this investigation and after discussion with the operator, it is suggested that consideration be given to a trial using the most powerful variant of the current “walking excavator” designs. The machine may be capable of working in up to 1.5 m3 tree size. The machine would have to be fitted with a suitable attachment if any slewing of trees is required. A foot or heel boom would also be necessary to enable movement. Possible applications include Douglas Fir thinning/bunching in steep terrain and bunching/presenting of small trees for grapple or choker extraction.

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