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Clamping Carriages and Skyline Tensions

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Figure 1 - A cable operation using a clamping carriage

Introduction

Carriage clamps offer additional control over carriage position on the skyline (Figure 1). This can be an advantage during slackpulling, hooking on and breaking out (powered clamps may also be activated for unhooking). Clamping carriages are becoming more common in New Zealand, and there is a need to understand the way clamping carriages can influence tension loadings, particularly on skylines and tailhold anchors.

Skyline tension monitoring systems are often used in conjunction with clamping carriages to improve productivity and safety. The information provided by a tension monitor is useful, but must be interpreted correctly by the hauler operator to avoid potential hazards.

This report explains:

- how the carriage clamp may alter skyline tension between the hauler winch unit and the tailhold
- how this tension is affected by the relative positions of the carriage and the drag at breakout
- operating techniques to help minimise any adverse effects of clamping carriages on skylines and anchor
- how current tension monitoring equipment interprets and presents skyline tensions.

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Clamping carriage system mechanics

Clamping carriages generally use either a powered clamp (Figure 2a), or a mechanical stop (Figure 2b), to 'attach' themselves to the skyline.

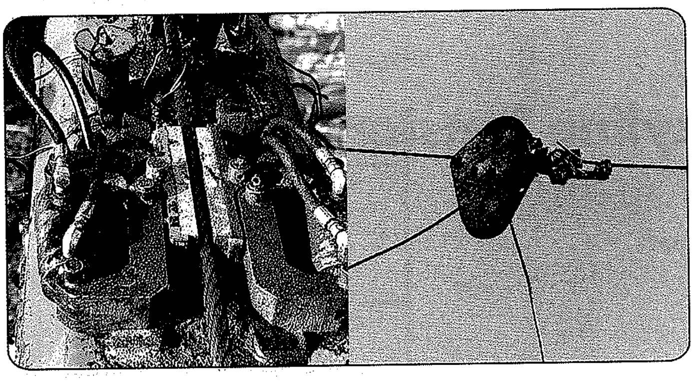

Figure 2 - Examples of a (a) powered clamp and (b) mechanical stop

When the carriage is not clamped to the skyline, it will act and react like any non-clamping carriage (that is, roll freely). In this case, the skyline tension on either side of the carriage will remain the same (Figure 3).

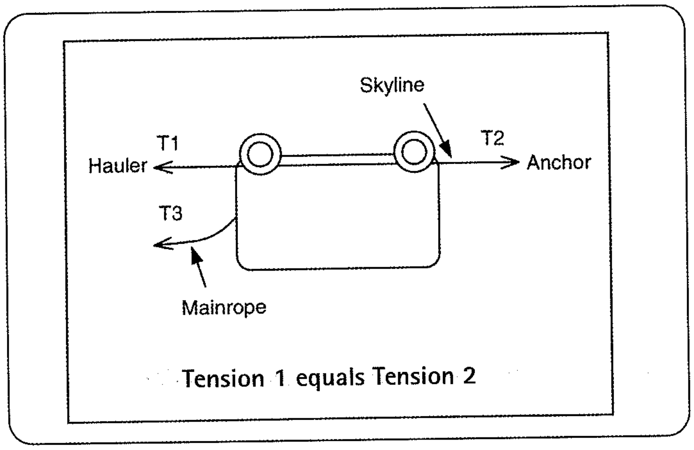

Figure 3 - Forces for a non-clamped carriage

Once the carriage is clamped to the skyline, any force applied to the carriage (for example, from winding in the mainrope) will cause a difference in skyline tensions across the carriage clamp (Figure 4).

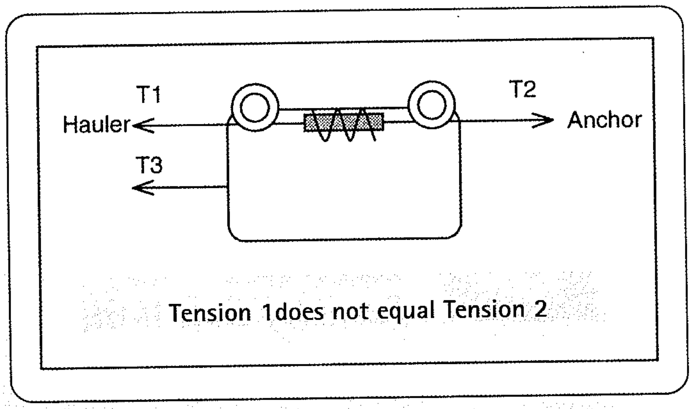

Figure 4 - Forces for a clamped carriage

If the hauler operator applied enough tension to the mainrope with the carriage still clamped, the tension in the front part of the skyline (T1) would decrease. In contrast, the tension in the back part of the skyline (T2) will increase, up to the point where the back part of the skyline and/or the skyline tailhold anchor would fail.

Carriage position and skyline tension

The highest tensions during the extraction phase generally occur during breakout (that is, when the drag is initially pulled in toward the carriage). Breakout is also the phase that will generate the largest tension differences across the carriage clamp. The magnitude of this tension difference at breakout, for any given drag size, is most influenced by the angle created by the mainrope as it passes through the carriage to the drag (Appendix). This angle will depend on:

- the position of the carriage relative to the drag at breakout
- the relative heights of the hauler tower and skyline anchor.

The effects of the angle created by the mainrope as it passes through the carriage to the drag are illustrated for a given set of conditions as follows:

Condition One - Carriage at right angles to the drag

If the carriage is positioned so the drag is pulled in at right-angles to it, the difference between T1 and T2 will be approximately equal to the drag weight plus any extra breakout forces (Figure 5). This situation occurs most often when the relative hauler tower and tailhold heights are the same.

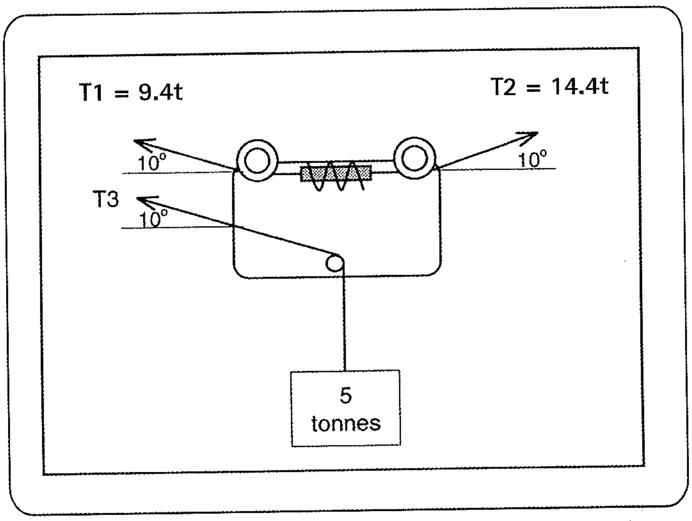

Figure 5 - Carriage at right angles to the drag at breakout. Tension difference = 5 tonnes.

Condition Two - Carriage in front of the drag

If the carriage is positioned so the drag is pulled in from behind it, then the difference between T1 and T2 will be less than in the previous example (Figure 6). This situation is the most desirable breakout position for a clamping carriage. It may occur when logging the front face of a setting (for example, the hauler side of a gully) and/or when the top of the tower is higher than the tailhold anchor (such as uphill extraction). In these situations, the breakerouts will clamp the carriage uphill in front of the drag, so the slack can be pulled downhill.

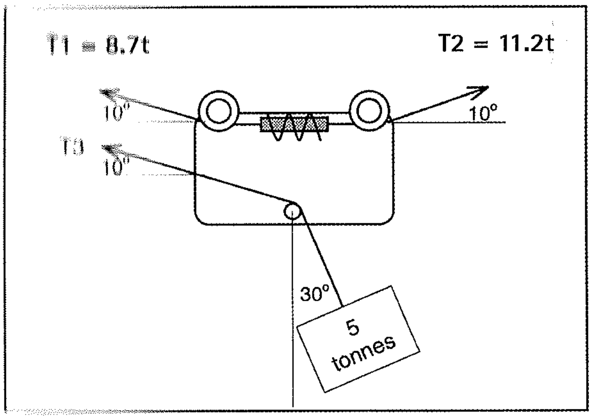

Figure 6 - Carriage in front of the drag at breakout. Tension difference = 2.5 tonnes.

Condition Three - Carriage behind the drag

If the carriage is positioned so the drag is pulled from in front of it, a block-purchase effect is created on the carriage clamp (Figure 7). This situation is the least desirable breakout position for a clamping carriage. It can occur when logging the back face of a setting (for example, the far side of a gully) and/or when the tailhold is higher than the top of the tower (such as downhill extraction). The breakerouts will clamp the carriage uphill, past the drag, so the slack can be pulled downhill.

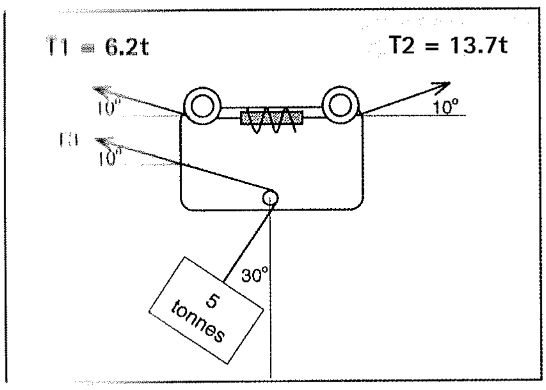

Figure 7 - Carriage behind the drag at breakout. Tension difference = 7.5 tonnes.

In this case, the tension difference between T1 and T2 can be much greater than in the two previous examples. This is because the block-purchase effect magnifies the breakout forces on the clamp, the back section of the skyline and the skyline anchor.

Operational techniques to minimise the tension difference between T1 and T2:

1 Clamp the carriage in desired position.

2 Hook on the drag.

3 Release the skyline clamp and allow the carriage to move forward on skyline, for breakout.

3.1 If this is not practicable, tension the tailrope to help the clamp counteract the pull of the mainrope. (This requires the tailrope to be attached directly to the carriage).

4 Ensure the skyline clamp is 'on'.

5 Breakout the drag.

The tailrope will only affect skyline tensions if it is attached to the carriage itself and is specifically tensioned to assist the carriage clamp to hold the carriage in place.

If the tailrope is instead attached to the end of the mainrope and/or butt rigging (for example, when bridling through the carriage), it will not affect the skyline tensions.

Risk of skyline breakage when clamp is released

Although the highest skyline tensions are generated at breakout, the skyline can be significantly shock-loaded when the clamp is released for inhaul (clamp on to clamp off). This is largely because there is a major re-distribution of tensions when the clamp is released:

Clamp on (after breakout and before inhaul)

- the mainrope tension (T3) is approximately equal to the weight of the drag, and
- T1 does not equal T2.

Clamp off (after the clamp is released for inhaul)

- the mainrope tension drops to a level required to hold the carriage in position on the skyline
- T1 and T2 will equalise.

For example, the situation shown in Figure 7 shows a tension difference between T1 and T2 of 7500 kg. When the carriage clamp is released for inhaul, T1 will increase from 6200 kg to 14409 kg, and the mainrope tension will decrease from 5000 kg.

Both these tension changes will occur in the length of time it takes for the skyline clamp to release (0.5 to 1.0 second). This is equivalent to dropping an eight tonne weight in the middle of the skyline. In any case, the shock load can be extreme and may cause the skyline or anchor to fail.

In addition, releasing the clamp with such a large tension difference across it will also cause the clamp to slip along the skyline as it is releasing. This may lead to unnecessary wear on both the clamp and the skyline.

Operational techniques to avoid shock loading of the skyline:

1. Breakout the drags from behind the carriage, to minimise the tension difference between T1 and T2 (see previous operational suggestions).
2. Once the drag is broken out as far as desired, apply the mainrope clamp (inside the carriage).
3. Release the mainrope tension before releasing the skyline clamp; the mainrope clutch does not have to be disengaged, as backing off on the throttle will allow the mainrope drum to roll back far enough.
4. Release the skyline clamp for inhaul.

Releasing the mainrope tension, before releasing the skyline clamp for inhaul, relieves the tension difference between T1 and T2 as well as reducing the mainrope tension.

Location of a tension monitor

Skyline tension monitoring equipment provides information on skyline tensions during the whole extraction cycle. However, the tension monitor location may lead to incorrect readings when used with clamping carriages.

Tension monitor at the tower end

Most current tension monitor systems are best suited for mounting at the tower end of the skyline. However, when a carriage is clamped to the skyline, the tension monitor will only be recording T1. As has been shown (Figures 5, 6 and 7), T1 tensions can be significantly less than T2.

For example, Figure 7 shows that T1 (what will be indicated on the tension monitoring system) is 6.2 tonnes. At the same time, T2 is 13.7 tonnes. If the skyline's safe working load (SWL) is 10 tonnes, then it would be significantly overloaded at the time when the tension monitor was showing the skyline tension was below the SWL. Tower-end tension monitor accuracy is improved however, when the difference between T1 and T2 is minimised.

Tension monitor at the tailhold anchor

A tension monitor located at the anchor end of the skyline will record the critical maximum tension during breakout (T2). However, at present there are several disadvantages with arrangement:

- there are very few suitable systems for tailhold-mounted tension monitors
- telemetry may interfere with radio communication
- there is some difficulty with maintaining calibration due to regular attachment to and removal from, the skyline during rope shifts
- systems lack ruggedness for contact with the ground during operation and if left in place during rope-shifts.

Appendix

This Appendix presents a general, "weightless-line" solution to the force-balance on a skyline carriage when clamped during breakout, and when unclamped, supporting the drag.

A. Clamp On

General conditions as per Figure 8 below.

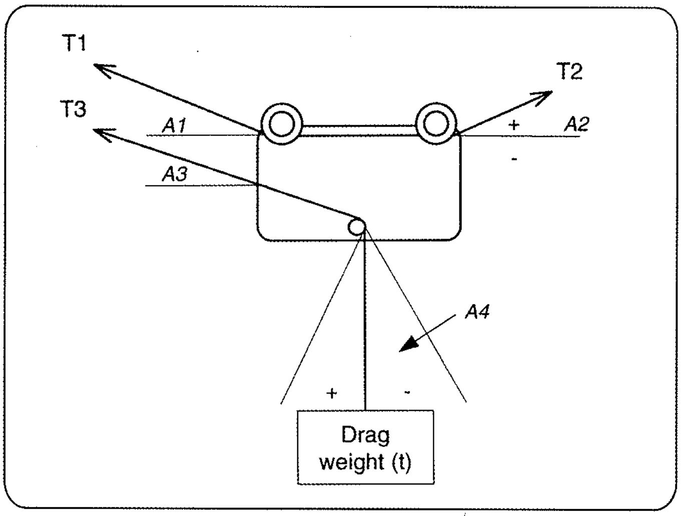

Figure 8 - Force Balance Solution diagram

Where:

T1 = Tension in the Skyline between hauler and carriage

T2 = Tension in the skyline between carriage and tailhold anchor

T3 = Mainrope tension

M = Tension in the mainrope between carriage and drag (assumed to be equal to T3).

A1 = Vertical angle of skyline tension T1

A2 = Vertical angle of skyline tension T2

A3 = Vertical angle of skyline tension T3

A4 = Angle of the mainrope between carriage and drag, from vertical

Assumptions:

1. Angles A1, A2, A3, A4 are known or assumed
2. Drag weight or breakout forces are known (hence, mainrope tension is also known; T3 = M)
3. Skyline clamp is 'on' (i.e., the carriage is clamped to the skyline)
4. Mainrope clamp is 'off'
5. Angle A2 ≠ 0.

Solution

$$T1 = \frac{T3 \times \left(\left(\frac{(\cos A4 - \sin A3)}{\tan A2} \right) - (\cos A3 + \sin A4) \right)}{\cos A1 + \left(\frac{\sin A1}{\tan A2} \right)}$$

(Equation 1)

$$T2 = \left(\frac{(T3 \times (\cos A4 - \sin A3)) - (T1 \times \sin A1)}{\sin A2} \right)$$

(Equation 2)

When T1 is known, it can be substituted into Equation 2, to solve for T2.

The difference between T1 and T2 from these equations, represents the tension difference across the carriage skyline clamp, and is the amount by which a tower-mounted tension monitor will underestimate maximum skyline tension. This difference can be calculated for different values of A4, to illustrate the effect of carriage position (relative to the drag) at breakout.

B. Clamp Off

This appendix presents a general, weightless line solution to the force balance on clamping skyline carriage after breakout, with the drag suspended and the skyline clamp "off".

General conditions as per Figure 8 above.

$$T1 = T2$$

$$T1 = \frac{M}{(\sin A1 + \sin A2 + ((\cos A2 - \cos A1) \times \tan A3))}$$

(Equation 3)

$$T3 = \frac{(-T1\cos A1) + (T1\cos A2)}{\cos A3}$$

(Equation 4)

T1 can be substituted into Equation 4 to solve for mainrope tension, T3.