RSI Technical Note 036

Estimating the steady-state load on a winch during VMP recovery

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1. Overview

This document describes the methodology used to estimate the load on the winch connected to a tethered VMP when the instrument is being recovered using the winch.

The line tension at the winch is estimated by summing the static and flow-induced (i.e. drag) loads of both the instrument and the tether at a steady-state. Inertial forces (such as forces caused from ship heave) are ignored and are beyond the scope of these calculations.

2. VMP Loading

The static load of a VMP on the winch is equal to its weight in seawater. Table 1 shows various physical properties of a VMP-250 and VMP-500.

Table 1: Various physical properties of a VMP-250 and VMP-500.

Instrument	Mass [kg]	Weight in Water [N]	Fall Rate [m s^{-1}]
VMP-250	11	25	0.6 - 0.8
VMP-500	25	69	0.6 - 0.7

The drag force, F_D on the VMP is calculated using (1).

$$F_D = \frac{1}{2} \cdot C_D \cdot \rho \cdot A \cdot v^2 \tag{1}$$

Where C_D is the dimensionless drag coefficient, ρ is the density of seawater [kg m^{-3}], A is the object area [m^2] and v is the VMP speed [m s^{-1}].

The VMP has a complex geometry making it difficult to calculate the object area used to empirically derive the drag coefficient. However, if the terminal velocity on the VMP as it descends is known, a coefficient of drag (2) can be calculated by equating the VMP weight in water with its drag force as the instrument falls at terminal speed (3).

$$\alpha = \frac{1}{2} \cdot C_D \cdot \rho \cdot A \tag{2}$$

$$F_G = \alpha \cdot {v_T}^2 \tag{3}$$

$$F_D = \alpha \cdot v^2 \tag{4}$$

Where α is the effective drag coefficient for the VMP [kg m^{-1}]. F_G is the weight in water of the VMP [N] and v_T is the VMP terminal speed [m s^{-1}].

It is assumed for the speed range of the winch, the brushes will not deform enough to significantly alter the coefficient of drag. In reality there will be some deflection of the brushes, which will lower the instrument's coefficient of drag as the winch speed increases beyond the instrument's terminal velocity.

3. Tether Loading

If the length of tether in the water is known, then the weight in water, F_g [N] on the tether can then be calculated using (5) .

$$F_g = \gamma \cdot L \tag{5}$$

Where γ is the weight in seawater per unit length of tether [N m^{-1}] and L is the length of tether in the water [m]. Table 2 lists the weights of various tethers.

Table 2: Properties of various tethers.

Tether	Diameter inch (mm)	Tether Weight in Seawater lb kft^{-1} (N km^{-1})	Tether Weight in air lb kft^{-1} (N km^{-1})	Tether Working Load lb (N)	Tether Breaking Load lb (N)	Tangential Drag Coefficient[1]
Cortland Cable, 0.270" Diameter	0.27 (6.86)	10 (145.9)	40 (583.6)	275 (1224)	1900 (8457)	0.005
Cortland Cable, 0.197" Diameter	0.197 (5.00)	5 (72.9)	18 (262.6)	200 (890)	1400 (6231)	0.005
Samson Validator II Rope, 0.250" Diameter	0.25 (6.35)	5.8 (84.6)	22.2 (323.9)	430 (1914)	4300 (19140)	0.010

The tether drag, F_d is calculated using the same formula as (1) with the total surface area of the tether immersed in water acting as the object area, A [m^2] (6).

$$A = \pi \cdot D \cdot L \tag{6}$$

Where D is the tether diameter [m] and L is the length of the tether in water [m].

A drag coefficient for flow tangential to a cylinder is used for calculating the tether drag, and for the cables is assumed to be similar to a polyethylene telephone cable (0.005); the rope is assumed to have a similar drag coefficient to a stranded steel aircraft cable (0.010)[1].

[1] Figure 9-1. Drag coefficient vs Reynolds Number for flows normal and tangential to smooth and rough circular cylinders. Adapted from Berteaux, H.O. *Buoy Engineering*. p.101. (Wiley & Sons) 1976.

The total load on the winch is then calculated using (7).

$$F_W = F_G + F_D + F_g + F_d \tag{7}$$

Table 3 shows the calculated load on a winch pulling a VMP-250 and 1000 meters of 0.27 inch diameter Cortland Cable at a speed of 1.5 [m s^{-1}].

Table 3: Sample Calculations of loading on the winch pulling a VMP-250 and 1000 meters of 0.27 inch diameter Cortland Cable at a speed of 1.5 [m s^{-1}]

		Metric		Imperial	
	Symbol	Value	Units	Value	Units
Winch Speed	v =	1.50	m s^{-1}	4.92	ft s^{-1}
Tether Properties					
Tether Weight per Unit Length (in seawater)	γ =	146	N km^{-1}	10	lb kft^{-1}
Length of Cable in Water	L =	1000	m	3280	ft
Tether Weight in Seawater	F_g =	146	N	32.8	lb
Seawater Density	ρ =	1025	kg m^{-3}	64.0	lb ft^{-3}
Seawater Dynamic Viscosity (20°C)	μ =	1.88E-03	kg s^{-1} m^{-1}		
Reynolds Number around Tether	Re =	5.61E+03			
Tether Tangential Drag Coefficient	C_d =	0.005			
Tether Diameter	D =	6.86	mm	0.270	in
Tether Surface Area in Water	A =	21.551	m^2	231.86	ft^2
Tether Drag Force	F_d =	124	N	27.9	lb
VMP Properties					
VMP-250 Weight in Seawater	F_G =	25	N	5.6	lb
VMP-250 Terminal Velocity (using 2x 20 inch Diameter Brushes)	v_T =	0.80	m s^{-1}	2.62	ft s^{-1}
VMP-250 Coefficient of Drag	α =	39.1	kg m^{-1}		
VMP-250 Drag Force	F_D =	88	N	19.8	lb
Winch Loads					
Load on Winch	F_W =	383	N	86.1	lb

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