International Journal of Offshore and Polar Engineering
Vol. 3, No. 3, September 1993 (ISSN 1053-5381)

An Experimental Investigation of the Mean and Dynamic Tensions in Towed Strumming Cables

Samuel M. Welch and Marshall P. Tulin*
Ocean Engineering Laboratory, University of California, Santa Barbara, California, USA

ABSTRACT

The mean hydrodynamic drag is shown analytically to play a critical role in the deployment of small-diameter lightweight cables. To examine this parameter, cable tensions accompanied by strumming were measured in a towing tank. Mean hydrodynamic tensions were found in excellent agreement with predictions based on Taylor's analogy. Augmentation of tangential drag coefficients due to strumming of up to 50% were measured, in excellent agreement with similar heat transfer measurements under lateral excitation. Large fluctuations in tension were measured and found to be due to strumming. Excellent theoretical and experimental agreement is reported. These fluctuations increase with cable length and may be important for the integrity and stability of long cables. Strumming was observed over the entire speed range. In the speed range of transition between the lower and next higher natural frequency, simultaneous excitation of significant amplitudes was observed for both modes in their spectral and times series records.

INTRODUCTION

Towed cables stream behind the ship as a result of positive cable tension (positive directed aft). In the case where the cable is uniform and has no attached loads, the steady configuration is straight with an inclination angle α to the flow direction, which depends mainly on a cable Froude number, $F_c=\rho U^2/\hat{\rho} gD$, where $\rho,\hat{\rho}$ are the density of water and the cable in water, respectively, U is the horizontal velocity of the cable, D is the cable diameter, and g is the acceleration of gravity. See Fig. 1 based on:

$$\frac{\rho}{\tilde{\rho}}\frac{U^2}{gD}=\frac{.5\pi}{C_N}\frac{\cos\alpha}{\sin^2\alpha} \tag{1}$$

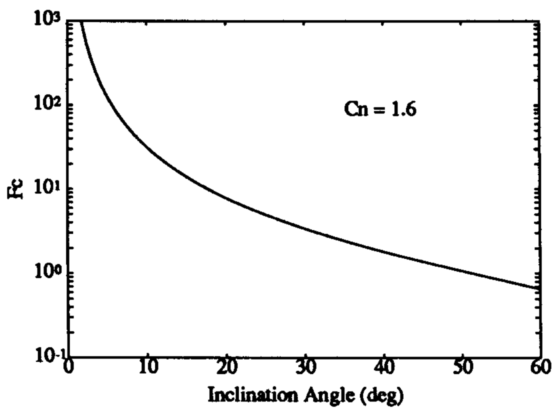

Fig. 1 Cable Froude number, $F_c=\rho U^2/\hat{\rho} gD$, versus inclination angle, α, for a constant normal drag coefficient, C_N (Eq. 1)

*ISOPE Member.

Received December 2, 1992: revised manuscript received by the editors February 22, 1993. The original version (prior to the final revised manuscript) was presented at the Second International Offshore and Polar Engineering Conference (ISOPE-92), San Francisco, USA, June 14-19, 1992.
KEY WORDS: Cables, towing, deployment, strumming, tangential drag, tensions.

where C_N is the coefficient of drag normal to a cable element, D_N:

$$C_N \equiv D_N/.5D\rho U^2\sin^2\alpha \tag{2}$$

The total cable tension, T, is the sum of the tangential component of cable wet weight, T_{wt}, and hydrodynamic drag along the cable, T_H, arising from the cable-wise component of the flow relative to the cable surface, the latter defining a nondimensional tangential drag coefficient, C_T:

$$C_T \equiv T_H/.5\rho\pi D\left|U\cos\alpha-U_P\right|\left(U\cos\alpha-U_P\right) \tag{3}$$

Increasing ship speed thus increases T_H, while increasing payout rate, U_p, decreases it. For $U\cos\alpha > U_p$ (relative flow down the cable) both components of tension increase with distance from the free end, reaching maximum values at the tow point, but their ratio remains independent of position. The total cable tension is of great importance during towing and deployment as sufficiently large tensions will cause failure or damage to the cable, and vanishing tensions will cause cable buckling and associated problems.

The total nondimensionalized tension, T/T_{wt}, is a function of only three parameters, C_T/C_N, α, and the payout ratio, $\beta=U_p/U$:

$$T/T_{WT}=1+\pi\left(C_T/C_N\right)*\frac{\cos\alpha}{\sin^3\alpha}\left|\cos\alpha-\beta\right|\left(\cos\alpha-\beta\right) \tag{4}$$

For sufficiently large payout ratios, $\beta>\cos\alpha$, the possibility of negative tensions arises, and will occur for sufficiently small inclination angles (high F_c) (Fig. 2). The value of this critical payout rate, β^*, is according to Eq. 4:

$$\beta^*=\cos\alpha+\left(\frac{C_N}{C_T}\frac{\sin^3\alpha}{\pi\cos\alpha}\right)^{1/2} \tag{5}$$

shown as Fig. 3.

During deployment on the ocean bottom, payout ratios (β) larger than unity must be employed to prevent bottom dragging of the