Technical Notes

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Dynamic Elastic Analysis of a Seabed Corer

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Introduction

THE general purpose of a typical seabed corer, or penetrator, is to obtain samples of seabed sediment to ascertain its chemical and physical properties. The penetrator is lowered to a predetermined depth above the ocean floor (30-40 m) and allowed to free-fall to achieve the desired velocity to penetrate the sediment. The corer is then retrieved with a cable system to the ship. Complications arise from such effects as cable dynamics; instabilities of the system as it is being lowered, as it free-falls, and as it is retrieved; buckling forces as the corer enters the sediment; and pull-out forces involved in retrieval.

Burchett[1] is investigating bending response of long corers during penetration of ocean sediment. Karnes et al.[2] are currently investigating optimum mechanical designs and performance of various coring systems. Requirements placed on the system from plugging of the core barrel during penetration are also under investigation.[3]

Described briefly in the present Note is a method for determining the elastic response of a long seabed corer during free-fall. The analysis is essential due to the possibility of corer attitudes resulting in structural failure during penetration deceleration.

The geometry of the corer used in the present analysis is presented in Fig. 1. The purpose of the afterbody is to house electronic sensing and measuring devices, to provide additional weight necessary for penetration, and to store cable payed out during free-fall and subsequently used in retrieval.

Equations of Motion

The following equations of motion reflect the fact that worst-case conditions are considered. Forces acting on the afterbody, which tend to stabilize the vehicle, have been neglected. Hydrodynamic effects arising from considerations of virtual mass, which may be significant, have been neglected entirely. The core barrel is assumed to be void of water. Axial elasticity is assumed negligible. Other assumptions include those associated with simple beam theory. These assumptions are believed to put an upper bound on the stability and elasticity of the system. More detailed analyses have been carried out in Ref. 4.

With the coordinate system as defined in Fig. 2, the global equations of motion follow. Products of inertia and their time rates of change are assumed negligible.

$$\dot{u} = -wq + (g - B/m)\cos\delta + F_{x_b}/m$$

$$\dot{w} = uq + (g - B/m)\sin\delta + F_{z_b}/m$$

$$\dot{q} = M_{y_b}/I_{yy}, \quad \dot{\delta} = q, \quad \dot{X}_e = u\sin\delta - w\cos\delta$$

$$\dot{Z}_e = u\cos\delta + w\sin\delta$$

Here, B is the bouyancy force; F_{xb} and F_{zb} are the total forces acting in the x_b and z_b directions, respectively; and M_{yb} represents the total moment about the y_b axis.

The approach used to determine local deflections is influence coefficient theory, which involves modeling the body as beams attached at the center of mass. Deflections give rise to stiffness forces defined as

$$\{F_{\rm stiff}\} = [S]\{Y_{\rm el}\}$$

where $[S]$ is the stiffness matrix of the "beams." Since stiffness forces are determined at specified points along the body, applied forces are summed across the span of an "element" extending half way between adjacent specified points. The resulting force is applied at the midpoint of the element. Assuming small deflections, local equations of motion of the elements, expressed in the local reference frame $X_{\rm el} - Y_{\rm el}$, are

$$\{m\ddot{Y}_{\rm el}\} = \{F_{\rm el}\} - \{F_{\rm stiff}\} + \{m[\ddot{z}_b - (X_{\rm cg} - X_{\rm el})\dot{q} + Y_{\rm el}q^2]\}$$

where $\{F_{\rm el}\}$ denotes hydrodynamic, weight, and bouyancy force components in the $Y_{\rm el}$ direction. Drag and applied normal forces acting on the afterbody, which represent forces, are set equal to zero for all time, again in an attempt to put an upper bound on the problem of stability.

Initial conditions are also intended to represent a worst-case possibility. The corer is initially given a velocity of $w = 0.6$

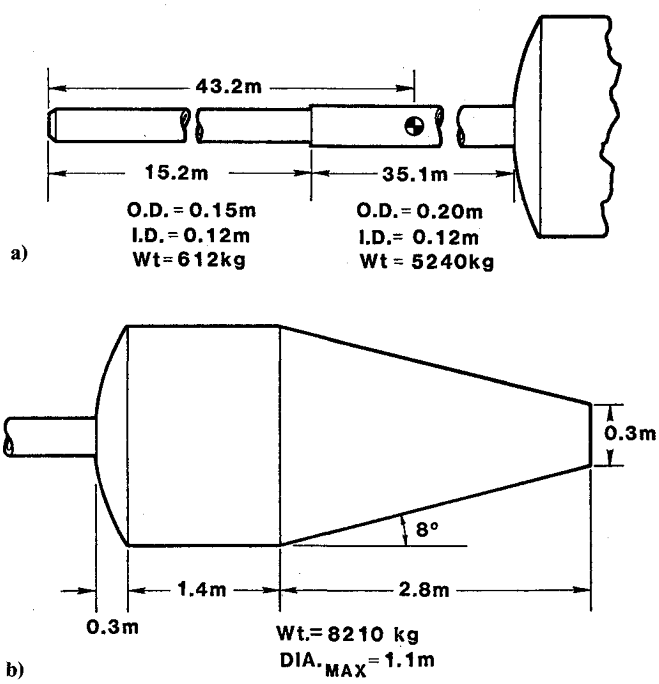

Fig. 1 Geometry of the step-tapered core barrel (a) and afterbody (b).

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Table 1 Local element deflection, slope, and bending moments

X_{el}, m	Y_{el}, m	θ_{el}, deg	M, N-m
15.2	0.15	0.1	-10^3 to -10^4
50.3	0.15	1.0	10^4 to 10^5

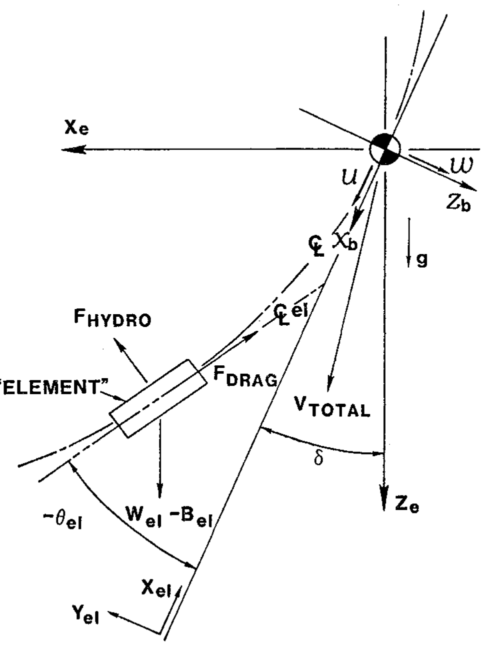

Fig. 2 Illustration of global and local coordinate systems.

m/s and an initial rotation angle of $\delta = 3.0$ deg. All other dependent global variables are initially zero, as are the deflections and velocities for the local equations of motion.

Discussion of Results

The equations of motion were numerically integrated utilizing a total of 36 elements to define the geometry of the corer. The corer was allowed to free-fall for 3 s, at which time the global variables had the following values: $u = 23.6$ m/s, $w = 2.3$ m/s, $q = 0.05$ rad/s, $\delta = 6.4$ deg, $X_e = -0.8$ m, $Z_e = 37.0$ m. The corer assumed an elongated inverted-S shape.

At $t = 3$ s, maximum bending moments occurred at the location of the step taper and at the junction between the afterbody and the upper portion of the barrel. The local element deflection, slope, and bending moment at these locations are given in Table 1 and are approximate due to the local variables being measured at discrete locations along the length of the corer. It is unlikely that the corer will actually experience such large bending moments during free-fall. However, it is intuitive that large bending moments will occur at the barrel/afterbody junction and may even become larger during penetration.

Conclusions

Since most of the mass is concentrated at the upper end of the body, the system is inherently unstable. However, the system inertia is apparently so high that the transient response is somewhat sluggish for the drop times of interest. Non-negligible deflections and bending moments are encountered prior to penetration.

It is not yet known how instabilities and local deflections affect bending response during penetration. The dynamic behavior of the corer as it enters the sediment will be analyzed using output from the present analysis and Ref. 4 to determine if it can withstand penetration loads and if the coring angle is acceptable. Results of these analyses will be discussed in detail in Ref. 1.

References

[1] Burchett, S., "Bending Response of a Long Coring Device Penetrating into Seabed Sediment," in preparation, Sandia National Laboratories, Albuquerque, N. Mex.

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Optimal Correction of Mass and Stiffness Matrices Using Measured Modes

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Nomenclature

A	= analytical mass matrix
K	= given stiffness matrix
M	= optimal mass matrix
N	$= A^{1/2}$ or $M^{1/2}$, respectively
p	$= Y^{1/2} q$
q	= general coordinates vector
R	= rigid body modal matrix
T	= measured and normalized modal matrix
$\tilde{T}_i$	= ith measured mode shape
T_i	= normalized T_i
X	= normalized modal matrix
$\tilde{X}$	= modified modal matrix
$\tilde{X}_i$	= ith modified mode shape
Y	= corrected stiffness matrix
γ, ϵ	= matrix of Lagrange multipliers
Ω^2	= measured frequency matrix
ω_i	= measured frequency

Introduction

IN the usual approach to the identification of dynamic structures, vibration tests are used as the only available information. A different approach was proposed in Refs. 1-4 where it was assumed that in addition to vibration tests mass and stiffness matrices obtained by using analytical calculations are also available. A partial performance of this method can be found in Ref. 5. From the vibration tests one usually obtains an incomplete set of natural frequencies and the mode shapes connected with them. Hence, the available data include the analytically obtained mass and stiffness matrices, as well as the measured modes and frequencies. To

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