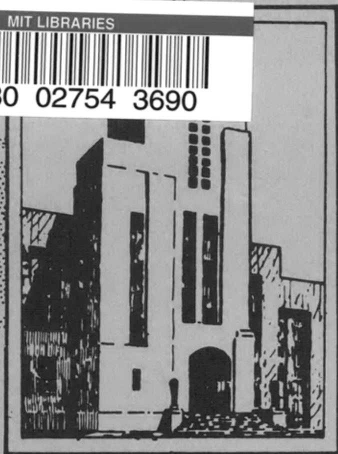

DEPARTMENT OF THE NAVY

DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

o

AERODYNAMICS

o

STRUCTURAL MECHANICS

o

APPLIED MATHEMATICS

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID

by

J.N. Newman

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

December 1961

Report No. 1465

PRNC-TMB-648 (Rev. 3-58)

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID

by

J.N. Newman

Reprinted from
Journal of Ship Research
Vol. 4 Number 1 June 1960

December 1961 Report No. 1465

A Note on the Stripwise Damping of a Submerged Spheroid[1]

By J. N. Newman[2]

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of the preceding paper. Various limiting cases are investigated and the possibility of negative local damping is discussed.

In the Kaplan and Hu paper [1][3] slender body techniques have been employed to determine the local damping force at any transverse section of a submerged oscillating spheroid. The purpose of the present note is to show that these results may be generalized to the case of an arbitrary prolate spheroid without the restriction of slenderness, by utilizing spheroidal co-ordinates in the manner of Havelock [2, 3]. This method of analysis is also advantageous since it facilitates direct integration of pressure on the body to determine the local damping force and moment.

The derivation of the present results is given in the Appendix. For a general prolate spheroid the heave damping force $\partial F/\partial x$ and pitch damping moment $\partial M/\partial x$, per unit length, are given by the following expressions:

$$\frac{\partial F}{\partial x} = -4\pi^2 \rho\sigma k_0{}^3 bl^3 e^3 (1 + k_2) e^{-2k_0 f} w (l^2 - x^2)^{1/2} \cdot \sum_{n=0}^{\infty} (-)^n (4n+3) \frac{P_{2n+1}{}^1(x/l)}{\dot{Q}_{2n+1}{}^1(1/e)} \cdot \int_0^{\pi/2} \frac{J_{2n+3/2}(k_0 el \cos\theta) J_{3/2}(k_0 el \cos\theta)}{(k_0 el \cos\theta)^3}\, d\theta \qquad (1)$$

$$\frac{\partial M}{\partial x} = -4\pi^2 \rho\sigma k_0{}^3 bl^4 [e^4 + (2 - e^2)^2 k'] e^{-2k_0 f} q x (l^2 - x^2)^{1/2} \cdot \sum_{n=0}^{\infty} (-)^n (4n+5) \frac{P_{2n+2}{}^1(x/l)}{\dot{Q}_{2n+2}{}^1(1/e)} \cdot \int_0^{\pi/2} \frac{J_{2n+5/2}(k_0 el \cos\theta) J_{5/2}(k_0 el \cos\theta)}{(k_0 el \cos\theta)^3}\, d\theta \qquad (2)$$

where

l = semi-length of spheroid
b = maximum radius of spheroid
e = $[1 - (b^2/l^2)]^{1/2}$ = eccentricity
ρ = fluid density
σ = circular frequency of oscillations
k_0 = σ^2/g
k_2 = coefficient of lateral virtual mass
k' = coefficient of virtual moment of inertia
f = depth of submergence of the centroid
w = heave velocity
q = pitch angular velocity
x = longitudinal distance from the centroid

J_n is the Bessel function of the first kind, $P_n{}^m$ and $Q_n{}^m$ are the Legendre functions[4] of the first and second kind, respectively, and $\dot{Q}_n{}^m$ is the first derivative of $Q_n{}^m$.

It is easily verified that integration of (1) and (2) over the range $-l \leqslant x \leqslant l$ yields the total force and moment

[1] Discussion of paper, "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of this issue.

[2] Seaworthiness Branch, David Taylor Model Basin, Washington, D. C.

[3] Numbers in brackets designate references at the end of the paper.

[4] There are two common definitions of the Legendre functions which differ by $(-1)^m$. The standardization used here is that which is given in [4].

Nomenclature

b = maximum radius of spheroid
e = eccentricity of spheroid
f = depth of submergence
g = gravitational acceleration
h = distance along axis
k_0 = σ^2/g = wave number
k_2 = coefficient of lateral virtual inertia
k' = coefficient of virtual moment of inertia
l = semi-length of spheroid
q = pitch angular velocity
t = time
w = heave velocity
(x, y, z) = Cartesian co-ordinate system
ϵ_s = 1 when $s = 0$, = 2 when $s \geqslant 1$
(ζ, μ, ω) = spheroidal co-ordinate system
ζ_0 = $1/e$
θ = variable of integration
ρ = fluid density
σ = circular frequency of oscillations

as derived by Havelock [2]. Because of the presence of the infinite series the foregoing equations are somewhat more complicated than the slender-body results, equations (45) and (46) of [1]. For this reason no computations have been made from (1) and (2), although there would be no particular difficulty in doing so. Nevertheless a few qualitative conclusions may be drawn.

The case of a slender spheroid corresponds to $e \to 1$. Substituting the asymptotic expansion [4] of $\dot{Q}_n{}^1(1/e)$ as $e \to 1$ and noting that the resulting infinite series is related to the expansion[5] of $e^{ik_0ex\cos\theta}$, equations (1) and (2) reduce to the slender-body results of [1].

The other limiting case is $e \to 0$, or a sphere of radius l It then follows that

$$\frac{\partial F}{\partial x} \to -\frac{\pi^2}{2}\rho\sigma k_0{}^3 l^4 w e^{-2k_0f}(l^2 - x^2)^{1/2} \cdot \sum_{n=0}^{\infty} \frac{(-)^n\,(4n+3)}{(2n+1)[(n+1)!]^2}\left(\frac{k_0 l}{2}\right)^{2n} P_{2n+1}{}^1(x/l) \qquad (3)$$

and $\dfrac{\partial M}{\partial x} \to 0$.

Another limiting case which permits simplification is that of high frequency, or $k_0el \to \infty$. For this we require an asymptotic expansion of the integrals in (1) and (2), or of the integral

$$I_n{}^m(K) = \int_0^{\pi/2} \frac{J_{m+3/2}(K\cos\theta)J_{m+2n+3/2}(K\cos\theta)}{(K\cos\theta)^3}\,d\theta$$

Changing the variable of integration to $z = K\cos\theta$ and neglecting terms of order $1/K^2$ we obtain[6]

$$\begin{aligned} I_n{}^m(K) &= \int_0^K \frac{J_{m+3/2}(z)J_{m+2n+3/2}(z)}{z^3(K^2 - z^2)^{1/2}}\,dz \\ &\cong \frac{1}{K}\int_0^{\infty} \frac{J_{m+3/2}(z)J_{m+2n+3/2}(z)}{z^3}\,dz \\ &= \frac{2}{K(n+1)!(2n+2m+5)(2n+2m+3)(2n+2m+1)} \quad \text{for} \quad n = 0, 1 \\ &= 0 \qquad\qquad \text{for} \quad n \geqslant 2 \end{aligned}$$

Thus for high frequencies (1) and (2) become

$$\frac{\partial F}{\partial x} \cong \frac{2\pi^2}{5}\rho\sigma k_0{}^2 b l e^2(1 + k_2)e^{-2k_0f}w(l^2 - x^2) \cdot \left[\frac{4}{\dot{Q}_1{}^1(1/e)} - \frac{5(x/l)^2 - 1}{\dot{Q}_3{}^1(1/e)}\right] \qquad (4)$$

$$\frac{\partial M}{\partial x} \cong \frac{2\pi^2}{7}\rho\sigma k_0{}^2 b l e^{-1}[e^4 + (2 - e^2)^2k']e^{-2k_0f}qx^2(l^2 - x^{\cdot} \cdot \left[\frac{4}{\dot{Q}_2{}^1(1/e)} - \frac{7(x/l)^2 - 3}{\dot{Q}_4{}^1(1/e)}\right] \qquad (\cdot$$

In the limit $e \to 1$, equations (4) and (5) are identical the strip-theory results as given by equations (47) ar (48) of [1], demonstrating analytically the validity of tl strip theory at high frequencies.

Perhaps the most interesting characteristic of the thre dimensional solution is the possibility of negative loc damping due to interference. The total damping for and moment must be positive but it is not necessary f the local damping to be positive at every section. It apparently impossible to draw general conclusions regar ing the signs of (1) and (2). However certain facts a evident:

1 For sufficiently low frequencies $\partial F/\partial x$ and $\partial M/\partial$ will be positive for all x, since the terms in (1) and (with $n = 0$ will dominate.

2 For very high frequencies, equations (4) and (show that $\partial F/\partial x$ and $\partial M/\partial x$ are positive at the midd of the spheroid, but $\partial F/\partial x$ will be negative at the en if $e < 0.972$, or the length-beam ratio is less than 4.2 and $\partial M/\partial x$ will be negative at the ends if $e < 0.986$, the length-beam ratio is less than 5.92. (These concl sions are not valid for the sphere since we have assume that $k_0el \to \infty$ in deriving (4) and (5).)

3 It also may be shown that for the slender spheroi the local damping will be negative at some sections f certain frequency ranges, although at very high or lo frequencies the damping is positive everywhere.

In conclusion it would appear that for any sphero there will exist frequency bands over which part of tl body will experience negative damping. More preci knowledge may be gained by carrying out computatio on equations (1) and (2).

References

1 Paul Kaplan and Pung Nien Hu, "Three-Dime sional Stripwise Damping Coefficients for Heave ar Pitch of a Submerged Spheroid," JOURNAL OF SH RESEARCH, vol. 4, June 1960, pp. 1–7.

2 T. H. Havelock, "The Damping of Heave ar Pitch: A Comparison of Two-Dimensional and Thre Dimensional Calculations," *Transactions, Institution Naval Architects*, vol. 98, October 1956, pp. 464–468.

3 T. H. Havelock, "The Forces on a Submerg Body Moving under Waves," *Transactions, Institutio of Naval Architects*, vol. 96, April 1954, pp. 77–88.

4 A. Erdélyi, editor, "Higher Transcendental Fun tions," vol. 1, chapter 3, McGraw-Hill Book Compan Inc., New York, N. Y., 1953.

APPENDIX

The velocity potential of a heaving spheroid may represented [2] by an axial distribution of vertical dipol between the foci, of moment

[5] P. M. Morse and H. Feshbach, "Methods of Theoretical Physics," McGraw-Hill Book Co., Inc., New York, N. Y., 1953, p. 1466.

[6] The last step follows from a known result in the theory of Bessel functions; cf. G. N. Watson, "A Treatise on the Theory of Bessel Functions," Cambridge University Press, second edition, paragraph 13.41.

$$M(h) = \frac{1 - e^2}{4e^3} \cdot (1 + k_2)(l^2e^2 - h^2)w \quad (6)$$

and for a pitching spheroid by a similar distribution of moment

$$M(h) = \frac{1 - e^2}{4e^3} [1 + (2\zeta_0^2 - 1)^2 k'](l^2e^2 - h^2)qh \quad (7)$$

where

l = semi-length of spheroid
b = maximum radius of spheroid
$e = [1 - (b^2/l^2)]^{1/2}$ = eccentricity
$\zeta_0 = 1/e$
h = distance along axis
k_2 = coefficient of lateral virtual inertia
k' = coefficient of virtual moment of inertia
w = heave velocity
q = pitch angular velocity

The potential of a vertical dipole at $(h, 0, -f)$ is, as in [1],

$$\phi = M \cos \sigma t \left[-\frac{z+f}{r_1^3} + \frac{z-f}{r_2^3} + 2k_0 \int_0^\infty \frac{J_0(k\omega')}{k - k_0} e^{k(z-f)} k dk \right] - 2\pi k_0^2 M \sin \sigma t\, J_0(k_0\omega') e^{k_0(z-f)} \quad (8)$$

where

$$\omega'^2 = (x-h)^2 + y^2$$
$$r_1^2 = \omega'^2 + (z+f)^2$$
$$r_2^2 = \omega'^2 + (z-f)^2$$
$$k_0 = \sigma^2/g$$

and the (x, y, z) co-ordinate system is Cartesian, with the z-axis vertical upwards and $z = 0$ the plane of the undisturbed free surface.

The potential of the spheroid is obtained by substituting (6) or (7) for the moment M in (8) and integrating over the axis of the spheroid. Only the term involving $\sin \sigma t$ in (8) will contribute to the damping and we shall therefore delete the terms in square brackets in (8). For heave the potential is then given by

$$\phi = -\frac{\pi}{2e^3} (1 - e^2)(1 + k_2) k_0^2 w_0 \sin \sigma t\, e^{k_0(z-f)} \int_{-el}^{el} (l^2e^2 - h^2) J_0(k_0\omega')\, dh \quad (9)$$

where w_0 is the amplitude of the heave velocity, $w = w_0 \cos \sigma t$.

Using the integral expression for the Bessel function and carrying out the integration over h, we find that

$$\phi = -\frac{(1 - e^2)}{4e^3} (1 + k_2) k_0^2 w_0 \sin \sigma t\, e^{k_0(z-f)} \int_0^{2\pi} e^{ik_0(x \cos\theta + y \sin\theta)} \cdot \int_{-el}^{el} e^{-ik_0h \cos\theta} (l^2e^2 - h^2) dh d\theta$$

$$= -\sqrt{\frac{\pi}{2}} (1 - e^2)(1 + k_2) k_0^2 l^3 w_0 \sin \sigma t\, e^{k_0(z-f)} \cdot \int_0^{2\pi} e^{ik_0(x\cos\theta + y \sin\theta)} \frac{J_{3/2}(k_0 el \cos\theta)}{(k_0 el \cos\theta)^{3/2}} d\theta \quad (10)$$

For pitch we obtain in the same manner

$$\phi = -i \sqrt{\frac{\pi}{2}} (1 - e^2)[1 + (2\zeta_0^2 - 1)^2 k'] q_0 \sin \sigma t\, k_0^2 e l^4 e^{k_0(z-f)} \cdot \int_0^{2\pi} e^{ik_0(x \cos\theta + y \sin\theta)} \frac{J_{5/2}(k_0 el \cos\theta)}{(k_0 el \cos\theta)^{3/2}} d\theta \quad (11)$$

We now introduce spheroidal co-ordinates [2] given by

$$x = el\mu\zeta$$
$$y = el[(\zeta^2 - 1)(1 - \mu^2)]^{1/2} \sin \omega$$
$$z = el[(\zeta^2 - 1)(1 - \mu^2)]^{1/2} \cos \omega - f$$

with the spheroid defined by the surface $\zeta = \zeta_0$, and we employ an expansion derived by Havelock [3]:

$$e^{k_0(z + ix\cos\theta + iy \sin\theta)} = \tfrac{1}{2} e^{-k_0 f} \left(\frac{\pi}{2k_0 el \cos\theta}\right)^{1/2} \sum_{n=0}^{\infty} \sum_{s=0}^{n} \epsilon_s i^{n-s} (2n+1) \cdot \frac{(n-s)!}{(n+s)!} J_{n+1/2}(k_0 el \cos\theta) P_n^s(\mu) P_n^s(\zeta) \cdot \left\{ \left[\left(\frac{1 + \sin\theta}{\cos\theta}\right)^s + \left(\frac{1 - \sin\theta}{\cos\theta}\right)^s \right] \cos s\omega - i \left[\left(\frac{1 + \sin\theta}{\cos\theta}\right)^s - \left(\frac{1 - \sin\theta}{\cos\theta}\right)^s \right] \sin s\omega \right\} \quad (12)$$

where

$$\epsilon_0 = 1$$
$$\epsilon_1 = 2 \quad \text{for} \quad s \gtrless 1$$

An expansion of the velocity potential in spherical harmonics may now be obtained by substituting (12) in (10) and (11). Before doing so, however, we shall ensure that the boundary condition on the spheroid is satisfied exactly by adding a corrective dipole distribution, in the same manner as in [1] when the force was determined from the extended Lagally theorem. Following Havelock [3] this is accomplished simply by replacing the function $P_n^s(\zeta)$ in (12) by the function

$$P_n^s(\zeta) - Q_n^s(\zeta) \frac{\dot{P}_n^s(\zeta_0)}{\dot{Q}_n^s(\zeta_0)}$$

where a dot denotes the first derivative. On the spheroid $\zeta = \zeta_0$ this is simplified by use of the Wronskian

$$P_n^s(\zeta_0)\dot{Q}_n^s(\zeta_0) - Q_n^s(\zeta_0)\dot{P}_n^s(\zeta_0) = (-)^{s+1} \frac{(n+s)!}{(n-s)!} (\zeta_0^2 - 1)^{-1}$$

Collecting these results the heave velocity potential on

$\zeta = \zeta_0$ is given by the expansion

$$\phi = \pi e^2(1 + k_2)k_0^2 l^3 w_0 \sin \sigma t \; e^{-2k_0 f}$$
$$\cdot \sum_{n=0}^{\infty} \sum_{s=0}^{n} \epsilon_s i^{n+s}(2n + 1) \frac{P_n^s(\mu)}{\dot{Q}_n^s(\zeta_0)} \cos s\omega$$
$$\int_0^{\pi} \left(\frac{1 + \sin \theta}{\cos \theta}\right)^s \frac{J_{n+1/2}(k_0 el \cos \theta) J_{3/2}(k_0 el \cos \theta)}{(k_0 el \cos \theta)^3} \, d\theta \quad (13)$$

while for pitch

$$\phi = \pi e^3[1 + (2\zeta_0^2 - 1)^2 k']q_0 \sin \sigma t \; k_0^2 l^4 e^{-2k_0 f}$$
$$\cdot \sum_{n=0}^{\infty} \sum_{s=0}^{n} \epsilon_s i^{n+s+1}(2n + 1) \frac{P_n^s(\mu)}{\dot{Q}_n^s(\zeta_0)} \cos s\omega$$
$$\int_0^{\pi} \left(\frac{1 + \sin \theta}{\cos \theta}\right)^s \frac{J_{n+1/2}(k_0 el \cos \theta) J_{5/2}(k_0 el \cos \theta)}{(k_0 el \cos \theta)^3} \, d\theta \quad (14)$$

The damping force and moment at a given section may now be obtained by substituting the potential in Bernoulli's equation and then integrating around the section. The damping force per unit length is given by the expression.

$$\frac{\partial F}{\partial x} = -2\pi^2 \rho e^3(1 - e^2)^{1/2}(1 + k_2)\sigma k_0^3 l^5 \dot{w} e^{-2k_0 f} P_1^1(\mu)$$
$$\cdot \sum_{n=1}^{\infty} i^{n+1}(2n + 1) \frac{P_n^1(\mu)}{\dot{Q}_n^1(\zeta_0)} \int_0^{\pi}$$
$$\frac{J_{n+1/2}(k_0 el \cos \theta) J_{3/2}(k_0 el \cos \theta)}{(k_0 el \cos \theta)^3} \, d\theta \quad (1$$

and the moment per unit length is given by

$$\frac{\partial M}{\partial x} = \frac{2\pi^2}{3} \rho \sigma k_0^3 l^7 e^4(1 - e^2)^{1/2}[1 + (2\zeta_0^2 - 1)^2 k]$$
$$q e^{-2k_0 f} P_2^1(\mu) \sum_{n=1}^{\infty} i^{n+2}(2n + 1) \frac{P_n^1(\mu)}{\dot{Q}_n^1(\zeta_0)} \int_0^{\pi}$$
$$\frac{J_{n+1/2}(k_0 el \cos \theta) J_{5/2}(k_0 el \cos \theta)}{(k_0 el \cos \theta)^3} \, d\theta \quad (1$$

Since only the odd terms in (15) and the even terı in (16) survive the integration, these results are equiv lent to (1) and (2).

INITIAL DISTRIBUTION

Copies	
7	CHBUSHIPS 3 Tech Info Br (Code 335) 1 Appl Res (Code 340) 1 Prelim Des (Code 420) 1 Sub (Code 525) 1 Lab Mgt (Code 320)
3	CHBUWEPS 1 Aero & Hydro Br (Code RAAD-3) 1 Ship Instal & Des (Code SP-26) 1 Dyn Sub Unit (Code RAAD-222)
4	CHONR 1 Nav Appl (Code 406) 1 Math Br (Code 432) 2 Fluid Dyn (Code 438)
1	ONR, New York
1	ONR, Pasadena
1	ONR, Chicago
1	ONR, Boston
1	ONR, London
1	CDR, USNOL, White Oak
2	DIR, USNRL (Code 5520) 1 Mr. Faires
1	CDR, USNOTS, China Lake
1	CDR, USNOTS, Pasadena
1	CDR, USNAVMISCEN, Point Mugu
1	DIR, Natl BuStand Attn: Dr. Schubauer
10	CDR, ASTIA, Attn: TIPDR
1	DIR, APL, Johns Hopkins Univ, Silver Spring
1	DIR, Fluid Mech Lab, Columbia Univ
1	DIR, Fluid Mech Lab, Univ of California, Berkeley
5	DIR, Davidson Lab, SIT
1	DIR, Exptl Nav Tank, Univ of Mich
1	DIR, Inst for Fluid Dyn & Appl Math, Univ of Maryland
1	DIR, Hydrau Lab, Univ of Colorado
1	DIR, Scripps Inst of Oceanography, Univ of California
1	DIR, Penn St. Univ, University Park
1	DIR, Woods Hole Oceanographic Inst
1	Admin, Webb Inst of Nav Arch, Glen Cove
1	Dir, Iowa Inst of Hydrau Research
1	DIR, St Anthony Falls Hydrau Lab
3	Head, NAME, MIT, Cambridge 1 Prof. Abkowitz 1 Prof. Kerwin
1	Inst of Mathematical Sciences, NYU, New York
2	Hydranautics, Inc., 200 Monroe St., Rockville, Md
2	Dept. of Engin, Naval Architecture, Univ of California, 1 Dr. J. Wehausen

Copies	
1	Dr. Willard J. Pierson, Jr., Col of Engin, N.Y.U., New York
1	Dr. Finn Michelsen, Dept of Nav Arch, Univ of Michigan, Ann Arbor
1	Prof. Richard MacCamy, Carnegie Tech, Pittsburgh 13
1	Dr. T.Y. Wu, Hydro Lab, CIT, Pasadena
1	Dr. Hartley Pond, 4 Constitution Rd., Lexington 73, Mass
1	Dr. J. Kotik, TRG, 2 Aerial Way, Syosset, N.Y.
1	Prof. Byrne Perry, Dept of Civil Eng., Stanford Univ, Palo Alto, Calif
1	Prof. B.V. Korvin-Kroukovsky, East Randolph, Vt
1	Prof. L.N. Howard, Dept of Math, MIT, Cambridge 39, Mass
1	Prof. M. Landahl, Dept of Aero & Astro MIT, Cambridge 39, Mass
1	Pres Oceanics, Inc., 114 E 40 St, N.Y. 16
1	Mr. Richard Barakat, Itek, 700 Commonwealth Ave, Boston 15, Mass
1	Editor Appl Mech Rev, Southwest Res Inst, San Antonio, Texas
1	Versuchsanstalt Fur Wasserbau und Schiffbau, Berlin
1	Prof. C.W. Prohaska, Hydro-Og Aerodynamisk Laboratorium Hjortekaersvej 99, Lyngby, Denmark
2	Dir, Ship Div, NPL, Feltham, Middlesex, England
1	Prof. F. Ursell, Dept of Math, The Univ Manchester, England
8	ALUSNA, London
1	Dr. G.K. Batchelor, Trinity College, Cambridge Univ Cambridge, England
1	Mr. C. Wigley, G-9 Charterhouse Square, London ECL, England
1	Prof. Sir Thomas Havelock, 8 Westfield Drive, Gosport, Newcastle-on - Tyne, England
1	Dir, BSRA, 5, Chesterfield Gardens, Curzon St., London W. 1, England
1	AEW, Haslar, Hants, Great Britain
1	Dir, Hamburgische Schiffbau-Versuchsanstalt, Bramfelderstrasse 164, Hamburg 33, Germany
1	Dr. Ernst Becker, Ettenheimerstrasse 2, Frieburg-im-Bressau, Germany
3	Dir, Freie und Hansestadt Hamburg Institut fur Schiffbau der Universitat Hamburg Lammersieth 90 Hamburg 33, Germany 1 Prof. Dr.-Ing. Geo P. Weinblum 1 Dr. Grim 1 Dr. Eggers
1	Prof. H. Maruo, Dept of Nav Arch, Yokohama Nat Univ, Yokohama, Japan
1	Prof. R. Timman, Julianalaan 132, Delft, Netherlands
1	IR., J. Gerritsma, Prof. Mekelweg 2, Delft, The Netherlands
3	Nederlandsch Scheepbouwkundig Proefstation, Haagsteeg 2, Wageningen, Netherlands 1 Dr. J.D. van Manen 1 Dr. G. Vössers
1	Chairman, Natl Cnsl for Indus Res, TNO The Hague, Netherlands
1	Prof. J.K. Lunde, Skipsmodelltanken, Trondheim, Norway
1	Dir, Statens Skeppsprovingsanstalt, Goteborgc, Sweden

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.

David Taylor Model Basin. Report 1465.

A NOTE ON THE STRIPWISE DAMPING OF A SUBMERGED SPHEROID, by J.N. Newman. Dec 1961. (Reprint of technical note appearing in Journal of Ship Research, Vol. 4, No. 1, Jun 1960; discussion of paper "Three-Dimensional Damping Stripwise Coefficients for Heave and Pitch of a Submerged Slender Spheroid," by Paul Kaplan and Pung Nien Hu, appearing on page 1 of same issue). UNCLASSIFIED

The stripwise damping of a submerged prolate spheroid is derived utilizing spheroidal co-ordinates. For a slender spheroid the results agree with those of Kaplan and Hu. Various limiting cases are investigated and the possibility of negative local damping is discussed.

1. Submerged bodies--Oscillations--Damping
2. Spheroids--Oscillations--Damping

I. Newman, Nicholas J.