MEMORIAL UNIVERSITY Faculty of Engineering and Applied Science

Engineering 8674 - Design for Ocean and Ice Environments
Engineering 9096 – Sea Ice Engineering

F I N A L E X A M I N A T I O N

Date: Thur., Apr. 17, 2010 **Professor: Dr. C. Daley**
Time: 9:00 - 11:30 pm

Answer all questions. Total 100 marks. Each question is worth marks indicated **[x].**
Watch your time. 150min/100 marks = 90 sec/mark!
Please answer on the question paper. Use the back of the sheets as needed.
Good luck.

NAME: ______________________________

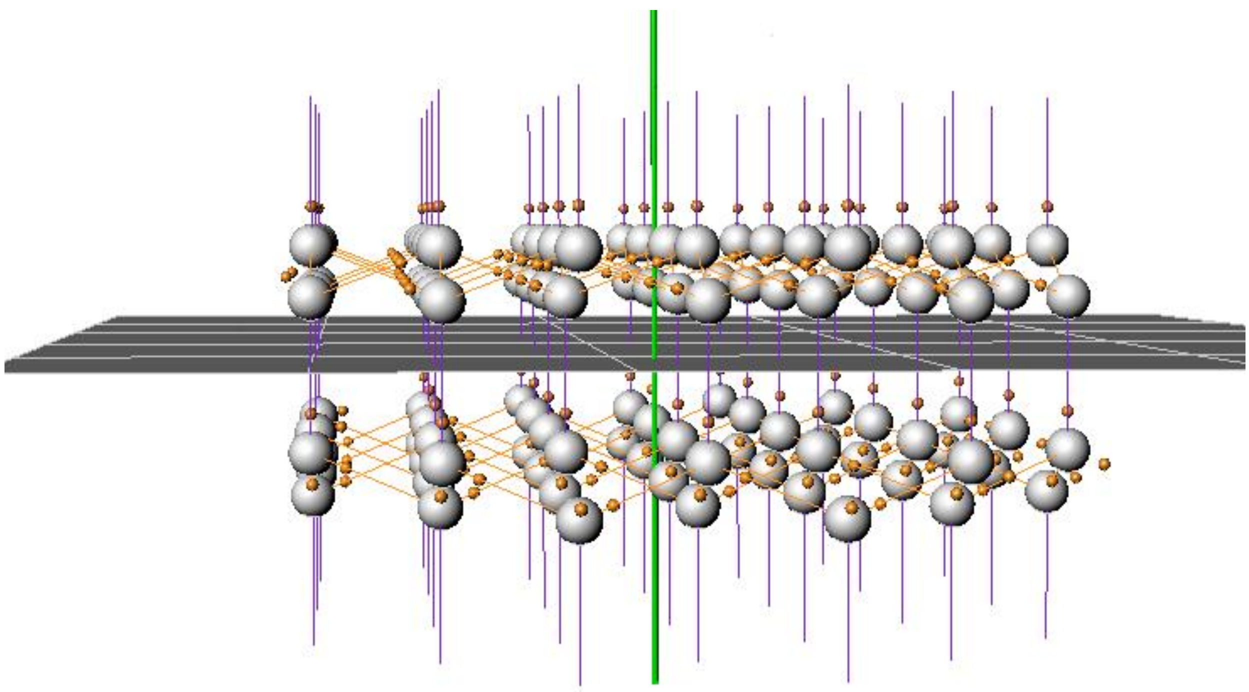
STUDENT NUMBER: ______________________________

1. There are 10 questions worth 1 mark each. Fill in the answers (or complete the phrase) in the spaces provided.

[10]

1. On Hudson's first voyage what did he expect to find at the north pole? ______________________________
2. In ice mechanics, polarized light is used to;______________________________
3. Which of the following is not an area of ice engineering interest- Chukchi Sea, Norwegian Offshore, Fox Basin, Pechora Sea:________________________
4. The word "Albedo " refers to ______________________________
5. There are approximately ______ forms of 'ice' crystals, but there is/are only ___ found naturally.
6. "Nilas" refers to;______________________________
7. The water temperature at the bottom of a pond or small lake in winter is: ______________
8. In ice mechanics, a ring test is used to measure:______________________________
9. The word "comminution " refers to: ______________________________
10. Process pressure area refers to changes in pressure…(fill in)_______________________

2. <u>Describe</u> and <u>label</u> the sketch shown below. **[15]**



3. Ice Growth and Bearing Capacity [15]

Consider the following scenario. Late in the evening on Jan.11th a man on a snow machine was crossing a bay in the ocean covered by fast sea ice (no snow). The total weight of man and machine was 750 lb. He broke through the ice and barely managed to save himself and get home. He returned with friends on January 18th, when the ice thickness in the bay was 25cm. The weather records for mean daily temperature are tabulated below.

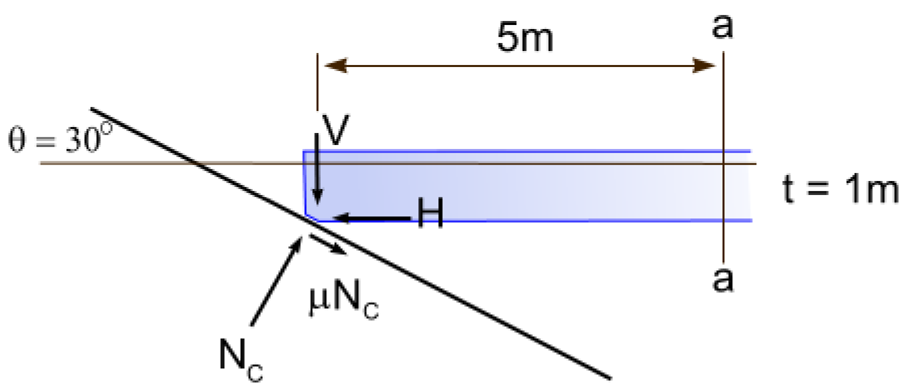
a) From this data, estimate the ice thickness when the man fell through the ice.

b) Estimate which day could he have safely crossed the ice? (assume the flexural strength was 0.5MPa)

Date	Mean Daily Temperature C
Jan 12	-8
Jan 13	-10
Jan 14	-12
Jan 15	-9
Jan 16	-18
Jan 17	-22
Jan 18	-12

4. Consider a case of sea ice striking a sloping structure. The ice is 1m thick. The slope of the structure is 30 degrees. The ice-structure friction factor is 0.1. The ice will crack at the section 'a-a' when the tensile stress reaches 1 MPa. The goal is to find the normal force Nc just when the ice breaks. You can ignore shear stresses, and assume that the horizontal force H acts along the bottom edge of the ice. Determine V and H for a 1m wide strip of ice (ie 1m into the page).

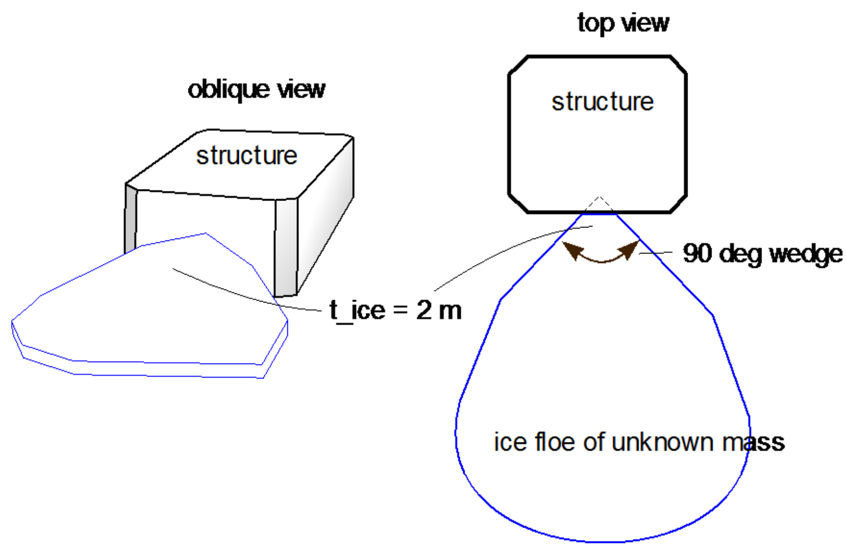
a) What is the ratio V:H ?
b) Draw the pattern of axial stress in the ice at a-a.
c) Find V, H and Nc when the max axial stress at a-a is 1MPa **[20 total,** 5,5,10 each**]**



5. Consider the case of ice-structure impact where an ice floe strikes a fixed (and essentially rigid offshore structure). The people on the structure observe the ice coming straight towards them. From a film record looking straight down at the ice contact event, they estimate the impact velocity at 1 m/s, the ice edge angle of 90 degrees, and the ice thickness (at the edge) to be 2m thick. They also estimated that the ice crushed (ie penetrated) 2m into the structure prior to stopping. They want to estimate the mass of the ice.

10, 10 each part, **[20 total]**

a) assuming ice crushing pressure of 1 MPa estimate the mass of the ice.
b) Assuming ice crushing pressure of P= Co A^ex, where Co=1 MPa and ex = -0.5, estimate the mass of the ice



6. Design Codes. 5 marks per part **[20 total]**

Consider a design problem involving the development of an oil production structure for the arctic. The intended location is in northern Baffin Bay, in 150meters of water. There is sea ice and icebergs to be contended with.

a) What sort of structures and design options would you consider for this case?
b) What are the jurisdictional and regulatory issues that you would consider to be important?
c) Discuss the factors that you would think are most important to a risk assessment of the possibility of ice damage?
d) What codes and standards would you use to help with the design?

Formulae

Table 1: Physical Properties of Fresh Water Ice 1h at 0°C

Density	917 kg /m^3
Melting point	0°C
Specific heat (heat capacity)	2.01 kJ / kg /°C
Latent heat of fusion (or melt)	334 kJ / kg
Thermal conductivity	2.2 W / m / °C
Linear expansion coefficient	55·1O^{-6} / °C
Vapor pressure	610.7 Pa
Refractive index	1.31
Acoustic velocity	
longitudinal wave	1928 m/s
transverse wave	1951 m/s

$$Q = \frac{k_i \cdot \Delta T}{h_i} \qquad (1)$$

Where Q is heat flux in W/m^2, k_i is thermal conductivity in W / m / °C, h_i is the ice thickness in m and ΔT is the temperature difference across the ice sheet.

$$\frac{\Delta h_i}{\Delta t} = \frac{Q}{L \cdot \rho_i} = \frac{k_i \cdot \Delta T}{h_i \cdot L \cdot \rho_i} \qquad (2)$$

Where t is time, and ρ_i is density of the ice.

the standard growth equation:

$$h_i = \sqrt{\frac{2 \cdot k_i}{L \cdot \rho_i} FDS}$$

Converted to freezing degree days:

$$h_i = .037\sqrt{FDD} \quad \text{[m]}$$

A more practical estimate would be found with the following equation (Cammaert and Muggeridge, 1988);

$$h_i = .025\sqrt{FDD} \quad \text{[m]}$$

$$\nu_b = .001 \cdot S\left(.53 - \frac{49.2}{T}\right)$$

where T is temperature (°C), S is salinity (ppt) and ν_b is the brine volume ratio.

Strength has been empirically related to brine volume as follows: Peyton (1966) proposed Cook Inlet (south of Alaska):

$$\sigma = 1.65\left(1 - \sqrt{\frac{\nu_b}{275}}\right)$$

Frederking and Timco (1980) report Southern Beaufort Sea:

$$\sigma = 24\left(1 - \sqrt{\frac{\nu_b}{33}}\right)$$

Peyton (1966) suggested the following mean (regression) values for tensile strength:

$$\sigma_t = 0.82\left(1 - \sqrt{\frac{\nu_b}{142}}\right) \quad \text{case a) across grain}$$

$$\sigma_t = 1.54\left(1 - \sqrt{\frac{\nu_b}{311}}\right) \quad \text{case b) along grain (18)}$$

The four point bending test is a lab test conducted with a machined (or at least cut) sample of ice. The strength value from such a test is;

$$\sigma_f = \frac{3 \cdot P \cdot a}{w \cdot h^2} \qquad (21)$$

The cantilever beam test. In the simplest case the flexural strength is found from the formula;

$$\sigma_f = \frac{3 \cdot P \cdot L}{w \cdot h^2} \qquad (22)$$

1.1 Beam on Elastic Foundation

$$EI\frac{d^4 v}{dx^4} + kv = 0 \qquad (23)$$

Where v is deflection, EI is the beam stiffness and k is the foundation modulus. For water density ρ and beam of width w, $k = \rho g w$. For later convenience we define a term called the characteristic length λ;

$$\lambda = \left(\frac{4EI}{k}\right)^{1/4} \qquad (24)$$

To find the influence of the water foundation, the solution of the differential equation (eqn 23) is needed. For the case of a semi-infinite beam, with an end load P, the solution of the system is;

Deflection: $v = \frac{2P}{\lambda k} \cdot e^{-x/\lambda} \cdot \cos x/\lambda$

(6)

Slope: $\theta = -\frac{2P}{\lambda^2 k} \cdot e^{-x/\lambda} \cdot (\cos(x/\lambda) + \sin(x/\lambda))$

Moment: $M = \lambda P \cdot e^{-x/\lambda} \cdot \sin(x/\lambda)$

Shear: $Q = -P \cdot e^{-\beta x} \cdot (\cos(x/\lambda) - \sin(x/\lambda))$

(7)

The maximum bending moment occurs at a distance x_c from the free end:

$$x_c = \frac{\pi}{4}\lambda \qquad (8)$$

$$\lambda = \left(\frac{E}{3\rho g}\right)^{1/4} h^{3/4} \qquad (29) \qquad (13)$$

Which for typical ice properties is;

$$\lambda = C \cdot h^{3/4} \qquad (30)$$

$$\ell = \sqrt[4]{D/k} \qquad (55)$$

$$\omega = w/\ell \qquad (56)$$

$$x = r/\ell \qquad (57)$$

$$p' = p/k \qquad (58)$$

(15)

For a concentrated load the solution is;

$$w = \frac{p\ell^2}{2\pi D} kei(r/\ell) \qquad (16)$$

$$w_{\max} = \frac{p\ell^2}{8D} \qquad (61)$$

$$\ell = \sqrt{\frac{p}{8 \cdot k \cdot w_{\max}}} \qquad (62) \qquad (17)$$

This can be re-expressed as a bearing capacity that as;

$$P = \frac{4}{\log\left[\frac{E \cdot h^3}{k \cdot c^4}\right]} \sigma_{flex} \cdot h^2 \qquad (67)$$

$$\cong 0.5 \cdot \sigma_{flex} \cdot h^2$$

Korzhavin

$$p_{ice} = I \cdot m \cdot k \cdot \sigma_c \qquad (70)$$

Where

I - indentation (confinement) factor, say 2.5 – 3.0 for narrow indentors

m - shape factor (above)

k - contact factor (starts at 1 for full contact and drops to .6 with loss of contact for spalling)

σ_c – uniaxial crushing strength

Seaki's force equation can be converted to show that effective pressure decreases with contact width;

$$\bar{p} = \frac{F}{b \cdot h} = 3.9 \cdot \sigma_c \cdot b^{-.39} \qquad (71)$$

<u>kinetic energy</u> (KE):

$$KE = \tfrac{1}{2} m \cdot v^2 \text{ (for head-on collisions)(72)}$$

$$KE = \tfrac{1}{2} m_e \cdot {v_n}^2 \text{ (for oblique collisions)(73)}$$

m_e is the 'effective' mass

v_n is the 'normal' velocity

<u>crushing energy</u> (IE):

$$IE = \int_0^x F(x)dx \qquad (74)$$

$$F(x) = p(A(x)) \cdot A(x) \qquad (75)$$

$$V = N_c(\cos\theta - \mu \sin\theta) \qquad (76)$$

$$H = N_c(\sin\theta + \mu \cos\theta) \qquad (77)$$

$$\sigma_{flex} = \frac{V \cdot L}{\frac{1}{6}t^2} \qquad (79)$$

The tensile stress in the ice is;

$$\sigma_t = \sigma_{flex} - \frac{H}{t} \qquad (80)$$

Combining the above and letting $L = 10t$ gives;

$$\sigma_t = \frac{V}{t}(60 - \frac{\sin\theta + \mu\cos\theta}{\cos\theta - \mu\sin\theta}) \qquad (81)$$

Therefore, the vertical, horizontal and normal forces (per unit width), become;

$$V = \frac{\sigma_t \cdot t}{(60 - \frac{\sin\theta + \mu\cos\theta}{\cos\theta - \mu\sin\theta})} \qquad (82)$$

$$H = \frac{\sigma_t \cdot t}{(60\frac{\cos\theta - \mu\sin\theta}{\sin\theta + \mu\cos\theta} - 1)} \qquad (83)$$

$$N_c = \frac{\sigma_t \cdot t}{(60 \cdot (\cos\theta - \mu\sin\theta) - (\sin\theta + \mu\cos\theta))}$$

A purely vertical load causes failure at a load of;

$$V_{vert} = \frac{\sigma_t \cdot t}{60} \qquad (85)$$

The ratio of the N_c force to V_{vert} is;

$$\frac{N_c}{V_{vert}} = \frac{1}{((\cos\theta - \mu\sin\theta) - (\sin\theta + \mu\cos\theta)/60)}$$

The net forces applied to the ice are;

$$V = N_c(\cos\theta - \mu\sin\theta) - W\sin\theta \cdot (\sin\theta + \mu\cos\theta) \qquad (87)$$

$$H = N_c(\sin\theta + \mu\cos\theta) + W\cos\theta \cdot (\sin\theta + \mu\cos\theta)$$

Again using equations (79) and (80);

$$\sigma_t = \frac{V}{t}(60 - \frac{\sin\theta + \mu\cos\theta}{\cos\theta - \mu\sin\theta}) \qquad (89)$$

This can be rearranged to give the required vertical force to cause flexural (tensile) failure in the ice:

$$V = \frac{\sigma_t t}{(60 - \frac{\sin\theta + \mu\cos\theta}{\cos\theta - \mu\sin\theta})} \qquad (90)$$

With (87), the required normal force Nc is;

$$N_c = \frac{V + W\sin\theta \cdot (\sin\theta + \mu\cos\theta)}{(\cos\theta - \mu\sin\theta)} \qquad (91)$$

$$P = C \cdot A^{-0.5}$$

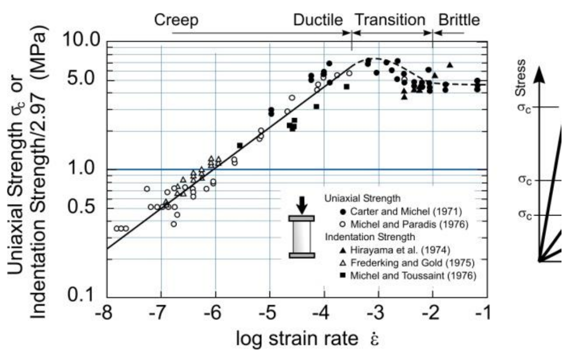


Figure 1. Influence of strain rate on uniaxial strength.

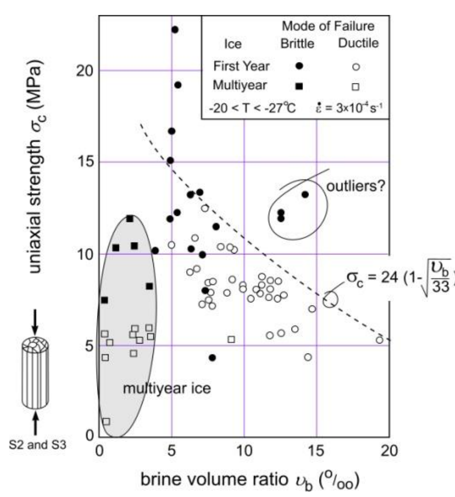


Figure 2. Compressive strength of Beaufort Sea ice.

The projected normal area is for spherical indentation;

$$A_n = 2 \cdot \pi \cdot R \cdot \zeta_n \qquad (93)$$

The force is;:

$$F_n = p_o A_n^{ex} \cdot A_n$$
$$= p_o (2 \cdot \pi \cdot R)^{1+ex} \cdot \zeta_n^{1+ex} \qquad (84)\ (94)$$

The indentation energy is:

$$IE = \frac{p_o}{(2+ex)}(2 \cdot \pi \cdot R)^{1+ex} \cdot \zeta_n^{2+ex} \qquad (95)$$

Which can be expressed in a more general form as :

$$IE_e = \frac{p_o}{fx} fa \cdot \zeta_n^{fx} \qquad (86)\ (96)$$

$$fx = 2 + ex \qquad (97)$$

$$fa = (2\pi \cdot R)^{fx-1} \qquad (98)$$

$$KE_e = \frac{p_o}{fx} fa \cdot \zeta_n^{fx} \qquad (101)$$

Solving for the normal indentation:

$$\zeta_n = \left(\frac{KE_e \cdot fx}{p_o \cdot fa}\right)^{\frac{1}{fx}} \qquad (102)$$

The normal force can be found by substituting eqn. (102) into (96), with (97) and (98) to give

$$F_n = p_o \cdot fa \cdot \left(\frac{KE_e \cdot fx}{p_o \cdot fa}\right)^{\frac{fx-1}{fx}} \qquad (103)$$

Which in our spherical case becomes:

$$F_n = \left[p_o \cdot (2 \cdot \pi \cdot R)^{(1+ex)}\right]^{\frac{1}{2+ex}} \cdot \left(\frac{1}{2} M_e \cdot V_n^2 (2+ex)\right)^{\frac{1+ex}{2+exx}}$$

Lindqvist's resistance equation

$$R_{ice} = (R_C + R_B)(1 + 1.4 \cdot v / \sqrt{g \cdot H_{ice}}) + R_S \cdot (1 + 9.4 \cdot v / \sqrt{g \cdot L}) \qquad (105)$$

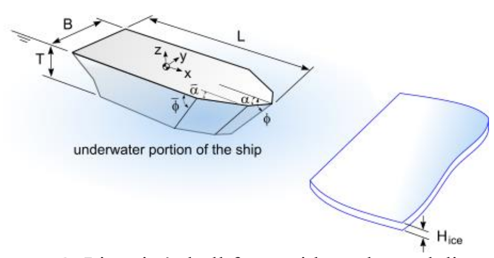


Figure 3. Linqvist's hull form with angles and dimensions.

1.1.1 Ice Crushing Term R_C

Linqvist starts by estimating the vertical force needed to fail an ice edge in flexure:

$$F_v = 0.5 \cdot \sigma_b \cdot H_{ice}^2 \qquad (106)$$

Where σ_b is the flexural strength of ice. He then assumes that this force is generated (continuously) on each side of the stem and resolves the x (along ship) component, which is the resistance that the ship will feel;

$$R_C = F_v \frac{\tan\phi + \mu \cdot \cos\phi / \cos\psi}{1 - \mu \cdot \sin\phi / \cos\psi} \qquad (107)$$

Where μ is the friction factor, ϕ is the stem angle, α is the waterline angle and;

$$\psi = \arctan(\tan\phi / \sin\alpha) \qquad (108)$$

These equations are dimensionally consistent, so any units will work.

1.1.2 Ice Breaking Term R_B

The breaking resistance term (see appendix in Linqvist 1989 for derivation) is as follows;

$$R_B = k \cdot B \cdot \left(\frac{H_{ice}^3}{l_c^2}\right)(\tan\psi + \mu\cos\phi / (\sin\alpha \cdot \cos\psi))(1 + 1/\cos\psi) \qquad (109)$$

Where k is a constant, B is the beam of the ship, the angles are as shown previously and l_c is the characteristic length of the ice sheet;

$$l_c = \sqrt[4]{\frac{E \cdot H_{ice}^3}{12\rho_w g(1-\upsilon^2)}} \qquad (110)$$

Lindqvist makes the following assumptions to simplify the equation. Poisons ratio is 0.3. The elastic modulus is 2 GPa. He assumes the cusp length is 1/3 of the characteristic length and the shear strength is equal to the flexural strength.

$$R_B = .003 \cdot \sigma_b \cdot B \cdot \left(\frac{H_{ice}^{1.5}}{\sqrt{m}}\right)(\tan\psi + \mu\cos\phi / (\sin\alpha \cdot \cos\psi))(1 + 1/\cos\psi) \qquad (111)$$

1.1.3 Ice Submergence Term R_S

The submergence resistance term (see appendix in Linqvist 1989 for derivation) is derived from energy consideration and is as follows;

$$R_S = \delta\rho \cdot g \cdot H_{ice} \cdot \left(B \cdot T \cdot (B+T)/(B+2T) + \mu(A_u + \cos\phi \cdot \cos\psi \cdot A_f)\right)$$

Where $\delta\rho$ is the density difference between ice and water (the cause of buoyancy) A_u is the area of the flat of bottom and A_f is the area of the bow. With approximations for the areas involved, Linqvist proposed the alternate formula;

$$R_S = \delta\rho \cdot g \cdot H_{ice} \cdot B \cdot \left(T\frac{B+T}{B+2T} + \mu\left(.7 \cdot L - \frac{T}{\tan\phi} - \frac{0.25 \cdot B}{\tan\alpha} + T \cdot \cos\phi \cdot \cos\psi \cdot \sqrt{\frac{1}{\sin^2\phi} + \frac{1}{\tan^2\alpha}}\right)\right) \qquad (114)$$

POPOV

$$M_e = \frac{F_n}{a_n} \qquad (115)$$

The effective mass is; (104)

$$M_e = \frac{M_{ship}}{C_O} \qquad (116)$$

where Co is the mass reduction coefficient.

The inertial properties of the vessel are as follows,

Hull angles at point:
α = waterline angle
β = frame angle
β' = normal frame angle
γ = sheer angle

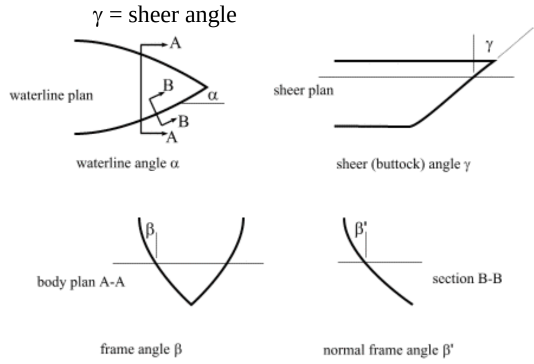


Figure 4. Hull angle definitions.

The various angles are related as follows,

$$\tan\beta = \tan\alpha \cdot \tan\gamma \qquad (117)$$

$$\tan\beta' = \tan\beta \cdot \cos\alpha \qquad (118)$$

Based on these angles, the direction cosines, l,m,n are

$$l = \sin\alpha \cdot \cos\beta' \qquad (119)$$

$$m = \cos\alpha \cdot \cos\beta' \qquad (120)$$

$$n = \sin\beta' \qquad (121)$$

and the moment arms are

$$\lambda 1 = n \cdot y_p - m \cdot z_p \text{ (roll moment arm)} \qquad (122)$$

$$\mu 1 = l \cdot z_p - n \cdot x_p \text{ (pitch moment arm)} \qquad (123)$$

$$\eta 1 = m \cdot x_p - l \cdot y_p \text{ (yaw moment arm)} \qquad (124)$$

The added mass terms are as follows;

AMx = added mass factor in surge = 0 (125)
AMy = added mass factor in sway = 2 T/B (126)
AMz = added mass factor in heave = 2/3 (B Cwp^2)/(T(Cb(1+Cwp))
AMrol = added mass factor in roll = 0.25 (128)
AMpit = added mass factor in pitch
= B/((T(3-2Cwp)(3-Cwp)) (129)
AMyaw
= added mass factor in yaw = 0.3 + 0.05 L/B (130)

The mass radii of gyration (squared) are;

rx^2 = Cwp B^2/(11.4 Cm) + H^2/12 (roll) (131)
ry^2 = 0.07 Cwp L^2 (pitch) (132)
rz^2 = L^2/16 (yaw) (133)

With the above quantities defined, the mass reduction coefficient is

Co = l^2/(1+AMx) + m^2/(1+AMy) + n^2/(1+AMz) + $\lambda 1^2$/(rx^2(1+AMrol) + $\mu 1^2$/(ry^2 (1+AMpit)) + $\eta 1^2$/(rz^2 (1+AMyaw)) (134)

1.1.4 Contact with General Wedge (Normal to hull)

a general wedge-shaped edge indentation (normal to hull). The projected areas, vertical, horizontal and normal are;

$$A_v = \frac{\zeta_n^2 \cdot \tan(\phi/2)}{\cos^2(\beta`)} \quad (135)$$

$$A_h = \frac{\zeta_n^2 \cdot \tan(\phi/2)}{\sin(\beta`)\cos(\beta`)} \quad (136)$$

$$A_n = \frac{\zeta_n^2 \cdot \tan(\phi/2)}{\sin(\beta`)\cos^2(\beta`)} \quad (137)$$

The pressure-area approach is used again. Substituting (137) into (75) we arrive at:

$$F_n = p_o A_n^{ex} \cdot A_n$$

$$= p_o \left(\frac{\tan(\phi/2)}{\sin(\beta`)\cos^2(\beta`)} \right)^{1+ex} \cdot \zeta_n^{2+2ex} \quad (138)$$

Note: this can be expressed in a general form as:

$$F_n = p_o \cdot fa \cdot \zeta_n^{fx-1} \quad (139)$$

Where $fx = 3 + 2ex$ (140)

$$fa = \left(\frac{\tan(\phi/2)}{\sin(\beta`)\cos^2(\beta`)} \right)^{1+ex} \quad (141)$$

The indentation energy is found by substituting (140) and (141) into (96), to give:

$$IE = \frac{p_o}{(3+2ex)} \left(\frac{\tan(\phi/2)}{\sin(\beta`)\cos^2(\beta`)} \right)^{1+ex} \cdot \zeta_n^{3+2ex} \quad (142)$$

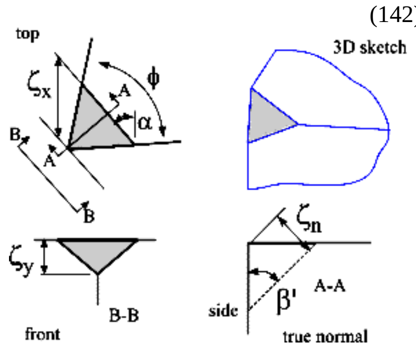


Figure 5. General Wedge-shaped Edge (normal to hull).

1.1.5 Popov Force Calculation

The Popov collision scenarios can be analyzed by equating the normal kinetic energy with the ice crushing energy.

$$KE_e = IE \quad (143)$$

where

$$KE_e = \frac{Me}{2} \cdot Vn^2 \quad (144)$$

which ,using equation (96) can be stated as;

$$KE_e = \frac{p_o}{fx} fa \cdot \zeta_n^{fx} \quad (145)$$

Solving for the normal indentation:

$$\zeta_n = \left(\frac{KE_e \cdot fx}{p_o \cdot fa} \right)^{\frac{1}{fx}} \quad (146)$$

The normal force can be found by substituting eqn. (146) into (139) to give

$$F_n = p_o \cdot fa \cdot \left(\frac{KE_e \cdot fx}{p_o \cdot fa} \right)^{\frac{fx-1}{fx}} \quad (147)$$

$$V_n = V_{ship} \cdot lx \quad (149)$$

where V_n is the normal velocity at the point of impact
V_{ship} is the x-direction velocity (all others are zero)
lx is the x-direction cosine

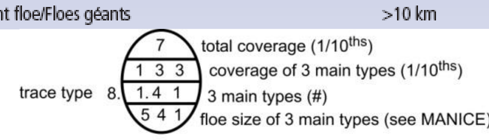
By combining the above equations, a single closed-form expression for the collision force is found;

$$F_n := \left[p_o \cdot \left[\frac{\tan\left(\frac{1}{2}\cdot\phi\right)}{\left(\sin(\beta')\cdot\cos(\beta')^2\right)} \right]^{(1+ex)} \right]^{\frac{1}{3+2\cdot ex}} \cdot \left[\frac{1}{2}\cdot Me\cdot Vn^2\cdot(3+2\cdot ex) \right]^{\left[\frac{(2+2\cdot ex)}{(3+2\cdot ex)}\right]} \quad (151)$$

Color		Ice Type		Thickness		Egg Code #		
		Ice Free						
		< 1/10 unspecified ice						
		New Ice		< 10 cm		1,2		
		Grey Ice		10 - 15 cm		4		3
		Grey-White Ice		15 - 30 cm		5		
		Thin FY	First-year Ice (FY)	30 - 70 cm	>30 cm	7	8 / 9	6
		Medium FY		70 - 120 cm		1.		
		Thick FY		> 120 cm		4.		
		Second-year Ice	Old Ice			8.		7.
		Multi-year Ice				9.		

Floe Size/Grandeur des floes ($F_aF_bF_c$)

Description/Élément	Width/Extension	Code
Pancake ice/Glace en crêpes		0
Small ice cake, brash ice/Petit glaçons, sarrasins	<2 m	1
Ice cake/Glaçons	2-20 m	2
Small floe/Petits floes	20-100 m	3
Medium floe/Floes moyens	100-500 m	4
Big floe/Grands floes	500-2000 m	5
Vast floe/Floes immenses	2-10 km	6
Giant floe/Floes géants	>10 km	7



In this example, there is 7/10ths ice, made up of 1/10th medium FY, 3/10ths grey ice and 3/10ths new ice. There is also a trace of second year ice.