Overall Design Approach (top level overview)

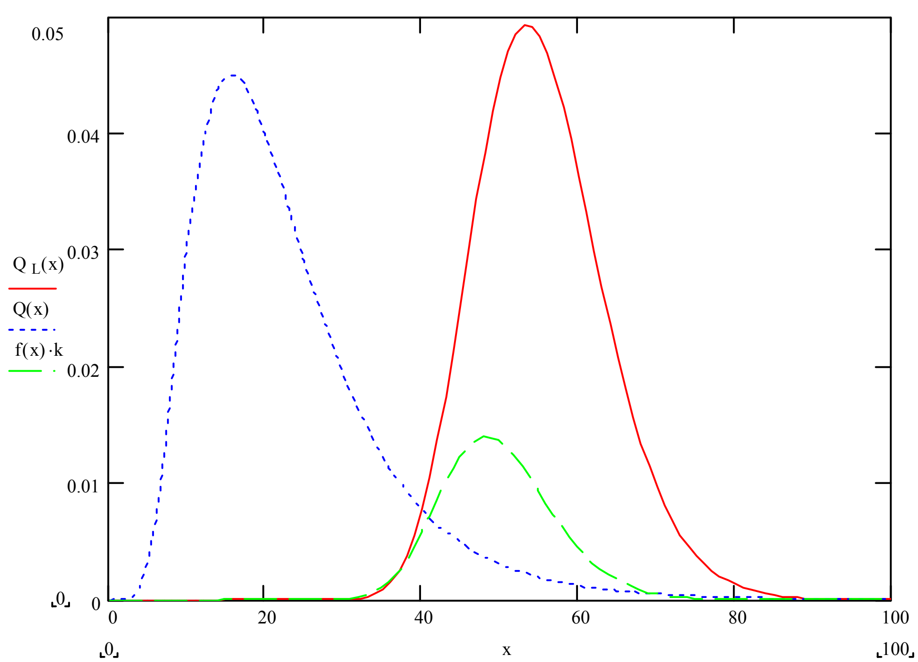
Ship Structure Design is a stochastic and time dependent process.

- What parameters are uncertain?
-
  - Loads
    - waves, sea state, speed, direction, etc…
  - Load effects
    - Assumptions in analysis
    - Variation in application
    - Modeling assumptions, e.g. shear lag
  - Materials
    - Dimensions
    - Properties
    - Fabrication
  - Loads
    - Live load variation (hotel balcony, whale watching)
    - Equipment
    - Sea state and response

Note which affect limit
Limit & load effect

Want load effect < limit

Have distributions for pdf(R), and pdf(Q):



Recognizing stochastic nature of situation

Risk = $prob_{failure} = prob\left(Q \geq Q_L\right)$

Safety = $prob\ \left(Q < Q_L\right) = \left(1 - P_f\right)$

What has been the traditional approach?

1. Philosophy — Safe Life
   Fail Safe

   Safe Life - rule out any damage or failure throughout life of ship

   Fail Safe- accept some risk of damage as long as life or ship survivability not at risk

Tradition => Safe Life with few exceptions involving unlikely catastrophic events, e.g. plating at missile magazine boundary load blast.

2. Establish strength criteria and/or allowable strength limits to prevent

   a. yielding
   b. elastic instability or buckling

   - Example yielding

     apply safety factor to $MS = 1.25$

     allowable (working) stress = $\dfrac{\sigma_Y}{1.25}$

     apply SF to other materials based on MS but dependent on $F_{ultimate}$

     e.g. Max Stress = $\dfrac{1}{2}\left[\dfrac{F_\mu}{factor_\mu} + \dfrac{F_Y}{factor_Y}\right]$

   - Buckling/instability

   buckling – define maximum column strength F_C as function (end restraints, slenderness ratio $\dfrac{L}{\rho_{\text{radius gyration}}}$)

   beams (including plate/stiffener) – combination stresses calculate

   F_C column strength

   apply factor e.g., allowable stress < 60% F_C ... etc.

Apply safety factor when all is said and done

Reference DDS 100-4 Strength of Structural Members
DDS 100-6 Longitudinal Strength Calculation

Adequate but always looking for improvement and more quantitative assessment even if probabilistic. Consistency.

<u>What have Civil Engineers done?</u>

Up to ~10-20 years ago design philosophy

allowable stress design ASD
load; limit; factor of safety
apply factor to resistance
and separately to (all) loads

(LRFD) as improvement to give designer "greater flexibility, more rationality, and possible overall economy". pg. 6-138 AISC LRFD commentary

Developed LRFD

Load and Resistance Factor Design issued spec as an "alternate" in 1986

Took approach of more clearly differentiating between strength and serviceability

Standard (AISC) more specific with respect to strength.
Designer has more flexibility regarding serviceability requirements.

Strength => prevention of damage/failure

Serviceability > swaying, deflections (my house beam)

"The design strength of each structural component or assemblage must equal or exceed the required strength based on the nominal factored loads. The design strength φR_n is calculated for each applicable limit state as the nominal strength R_n multiplied by a resistance factor ϕ"...

<u>factored</u> nominal loads, e.g.

A 4-1 1.4 D dead
A 4-2 1.2 D + 1.6 L + 0.5 (L_r or S or R)
.
. etc. D $\equiv$ dead, L $\equiv$ live, L_r $\equiv$ live roof, S $\equiv$ snow, R $\equiv$ initial rainwater or ice -. exclusive of ponding

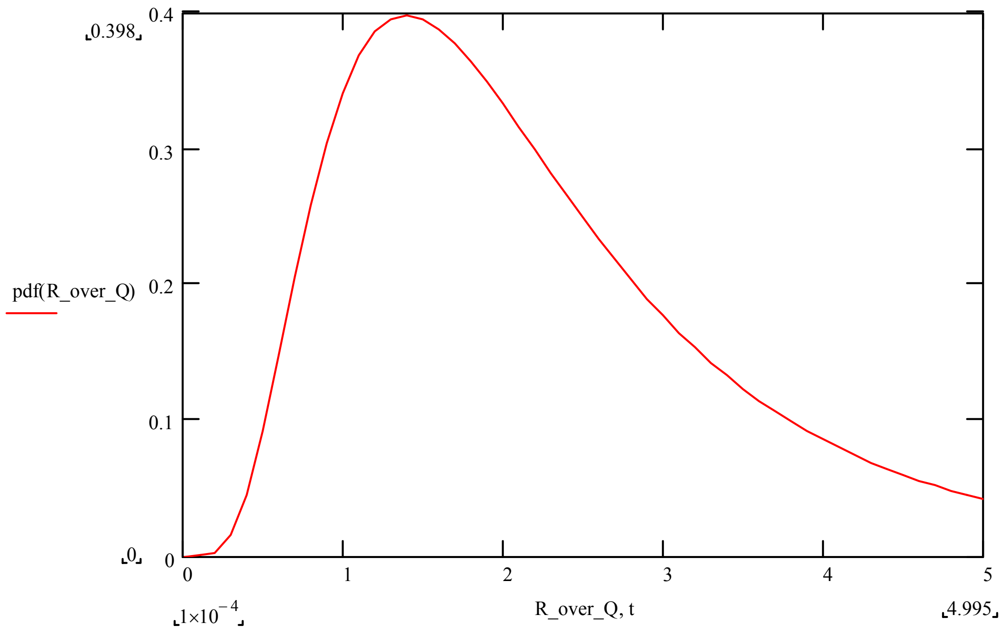
A 4-6 etc.

General Format

$$\sum \gamma_i Q_i \le \varphi R_n$$

apply to selected members

based on probabilistic model with R and Q assumed statistically independent determine/specify:



with respect to serviceability

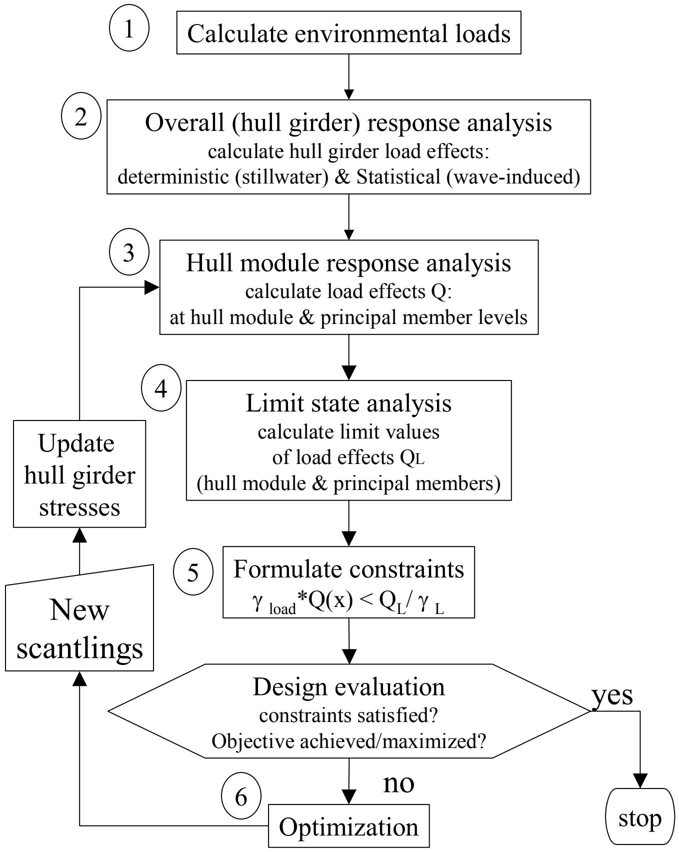
"The overall structure and the individual members, connections, and connectors should be checked for serviceability."

What's going on for Ships?

Similar: work in progress.

Review overall approach

Hughes fig. 1.1



As with civil engineering (and other disciplines) define two limit states as structure or member becomes unfit for intended use.

- Ultimate or collapse – failed to carry load
- Serviceability – loss of vital function

Three types in general

- plastic deformation
- instability
- fracture

Limit value

Q_L function of design parameters *(x)* and in certain cases other stresses, e.g. σ_y in σ_x limit

Load effects

- statistical – waves, material
- non statistical – ship handling

If statistical can base on characteristic value specify $\gamma_0 \ni \gamma_0 \hat{Q}_c(x) \le Q_{L,c}(X)$

where γ_0 is total safety factor

Other constraints fabrication, clearance for stiffness w/o undue impact to frame

Structural Safety Probability approach

risk = $P_{failure}$ = $\text{prob}(Q \ge Q_L)$

safety = $prob(Q < Q_L) = 1 - P_f$

if Q and Q_L independent

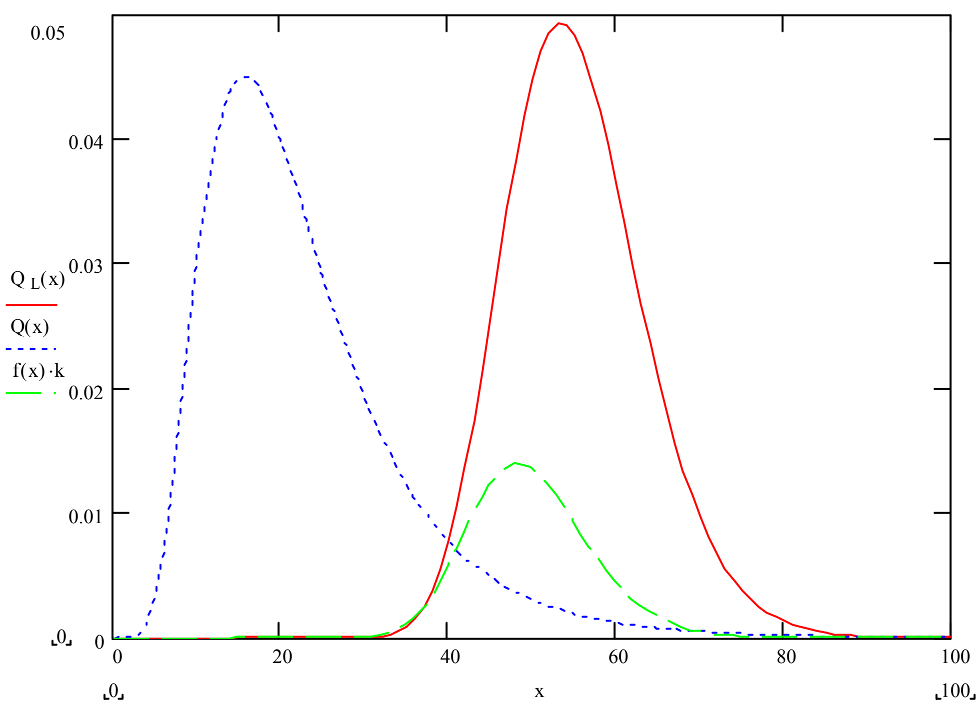
can write down

(don't need to)

but dependent on tails

Approximate probabilistic methods
"second moment method"

1st moment > mean



2[nd] moment > variance = σ^2

Safety Index Method: see text

Define Margin and shows quantitatively connection with probabilistic approach and PSF γ_0

Partial Safety Factor Method

Statistical can be accounted for using characteristic values

could specify $Q_C \ni \text{(prob area)}\left(Q > Q_C\right) = 0.05$

$$Q_{L,C} \text{ prob } \left(Q_L < Q_{L,C}\right) = 0.05$$

if only statistical could specify

$$Q_C \le Q_{L,C}$$

to account for approximational uncertainty

can separate curves

one way apply safety factor γ_0

$$\gamma_0 Q_C \le Q_{L,C}$$

if characteristic value used can be small

<u>Partial Safety Factors</u>

as with civil and traditional design philosophy

should account for differences

safety > usually defined as loss of life

serviceability

as well as probability distribution, assumptions and approximations in analysis, e.g. workmanship

Hughes proposes 4 first three applied to load

γ_{S1} seriousness re : safety

γ_{S2} serviceability

γ_Q uncertainties in loads and load effects

γ_L uncertainties in limit value

Result: $\gamma_{S1}\ \gamma_{S2}\ \gamma_Q\ Q \le \frac{Q_L}{\gamma_L}$

may be defined by regulatory authority

owner specified, *f(function)*

OR: as in Maestro

$$\left(\gamma_{S1}\gamma_{S2}\gamma_L\right)\gamma_Q Q \le Q_L$$

γ_C when collapse involved

γ_S serviceability when yield or deflection?

Handout Figure 1 and 6

Reliability – Based Design of Ship Structures

Classifications for Nonlinear Structural Response

We are going to now shift to doing

Development of Response (Load) and Strength Factors

Structural Analysis

Stress or Forces for Panels, Grillages, and Hull Girder

MAESTRO

assesses 23 such limit states

associated with stiffened panels

girders

transverse frame

will first address loads then take each failure mechanism in first order calculation/look up manner