

# Emergency Rudder Design Guidelines

by Paul Kamen

## DESIGN REQUIREMENTS:

- Cheap and easy to build
- Light weight

## SOLUTION:

Build blade like surfboard. Thick blade for strength and light weight. Moderately rough surface okay.

Keep gudgeons well separated to keep upper gudgeon lightly loaded.

For swim step transom, use stern pulpit to support top gudgeon.

## MATERIALS AND SUPPLIERS:

Foam blank - "Lastafoam" medium density urethane foam boards available from Svendsen's in 1.5" x 4' x 8' sizes or cut fractions at \$8.59 per square ft.

Epoxy: TAP Plastics 314 marine epoxy resin (\$50.25/gallon) and 143 slow hardener (\$33.35/half gallon). Or West System epoxy (West Marine or Svendsen's).

Glass: "Knytex" from Tap Plastics, or similar. This is a mat-cloth combination totaling 25.3 oz. per sq. yard. \$12 per 36" of 50" wide material. Selvege tape lapped around leading and trailing edges. (Tech. contact at TAP: Russ Miller, manager at San Leandro, 510-357-3755.)

Rules for fiberglass/resin/foam work:

- 1) Always make a test patch
- 2) Cut glass carefully to size before mixing resin
- 3) Use a very good particle mask

## DEPLOYMENT:

Allow full rotational degrees of freedom at lower gudgeon during deployment. Only one bolt in rudder and one bolt in transom, fitted loosely. Additional bolts added after top gudgeon is in place to establish alignment.

## DESIGN METHODOLOGY:

### 1) ESTIMATE DESIGN SPEED

- This determines the maximum force on the rudder blade. Suggest 10 knots for 45

ft. boat, 6 knots for 30 ft. boat.

## 2) DETERMINE LENGTH OF THE BLADE

- Try to go to at least half the depth of the original rudder, and up to the middle or upper stern rail. (Measure depth from the transom bottom, not from the static waterline.)

## 3) CALCULATE FORCE ON THE BLADE:

- Use the formula:

$$F = A * C_l * 1/2 * \rho * V^2$$

F = force (lb)

A = area below transom (ft<sup>2</sup>)

C<sub>l</sub> = Coeff. of lift (use 3.0 to allow for pumping transients)

ρ = density of water (1.9905 slugs/ft<sup>3</sup>)

V = design speed (ft/sec)

(1 knot = 1.6878 ft/sec)

$$F = 8.5 * A * V^2$$

F = force (lb)

A = area below transom (ft<sup>2</sup>)

V = design speed (knots)

[example: 1 ft. x 4 ft. blade, 7 knots: F = 1,666 lb.]

## 4) DETERMINE BENDING MOMENT AT THE LOWER GUDGEON:

- Assume the force is centered between the lower gudgeon and the blade tip. if this distance is L, then:

$$M = 1/2 * L * F$$

M = bending moment (ft-lb)

L = distance from lower gudgeon to tip (ft)

F = maximum blade force at design speed

[example: L = 4 ft, so M = 3,332 ft-lb]

## 5) DETERMINE THE REQUIRED SECTION MODULUS:

- Use 10,000 psi as design stress in low-tech laminate.

Required "section modulus" =  $M * 12 / 10,000$  (the 12 is to change moment from ft-lb to in.-lb)

[example: SM required = 4.0 in<sup>3</sup>

## 6) DETERMINE THE REQUIRED THICKNESS OF FIBERGLASS LAMINATE:

- $SM = W * (T^3 - t^3) / (6 * T)$   
(section inertia divided by half of max thickness)

SM = section modulus (in.<sup>3</sup>)

W = width of blade (in.)

T = overall thickness of blade (in.)

t = thickness of core material (in.)

[example: blade is 12" wide (but use 10" to account for shaping), core is 1.5" thick: By trial and error, use T = 2.02". SM = 4.02 in<sup>3</sup>. So required thickness of fiberglass = 1/2 (2.02 - 1.50) = 0.26 in.]

## 7) CALCULATE LOAD ON UPPER GUDGEON:

- Upper gudgeon force:  $F_U = M/D$

$F_U$  = force on upper gudgeon (lb)

M = Bending moment at lower gudgeon (ft-lb)

D = distance between gudgeons (ft)

[example: For D = 6.0,  $F_U = 3,332/6 = 555$  lb]

## 8) CALCULATE LOAD ON LOWER GUDGEON:

- Lower gudgeon force:  $F_L = F_U + F$

F = force on blade (lb)

$F_U$  = force on upper gudgeon (lb)

[example:  $F_L = 555 + 1666 = 2221$  lb.]

## 9) SIZE PINTLES:

For pins in double shear (as in turnbuckle clevis pins) use safety factor of 5 and look in rigging catalog for appropriate turnbuckle size. Or use allowable shear stress of 6,000 psi for same result.

$A = 1/2 * FP/\sigma$  (for double shear)

$\sigma$  = allowable shear stress (use 6,000 psi for 316 stainless)

FP = force on pintle (upper or lower, lb)

A = required area of pintle pin (in.<sup>2</sup>)

Solve for required pin diameter =  $\sqrt{4 * A / \pi}$

[example:  $A = 1/2 * 2,221/6,000 = 0.1851 \text{ in.}^2$ ; pin diameter = 0.486 in., use 1/2 in. diameter pin for bottom pintle. For top, 1/4 in. diameter is sufficient, but use 3/8 in. for easier alignment.]