CE5703 Assignment 2—Jacket Lifting Analysis

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Introduction

Analysis of an offshore jacket lifing process was carried out. The jacket was to be lifted off the transport barge and subsequently upended using sequential manipulation of the crane barge's 2 selected hooks. The design guide used was the McDermott in-house guide.

Crane barge

The crane barge chosen was Asian Hurcules II. The barge stern is assumed to be 20 m from the quayside and a jib offset of 20° is chosen. Thus, horizontal distance between main hook and jib hook $= 48 - 22 = 26\,\text{m}$.

The lift capacity charts show that the crane barge has sufficient capacity and clearance for the lifting operation.

1 Sling tensions and appropriate slings compatible with rigging system

Since the jacket was not weighed, a weight contingency factor (CF) of 1.1 is applied to the calculated weight (W).

$$\begin{aligned}\text{Gross weight} &= \text{W} \times \text{CF}\\ &= 450\,\text{t} \times 1.1\\ &= 495\,\text{t}\end{aligned}$$

Since lift is being conducted offshore by a single vessel, a dynamic amplification factor (DAF) of 1.2 is applied.

$$\begin{aligned}\text{Lift weight} &= \text{gross weight} \times \text{DAF}\\ &= 496\,\text{t} \times 1.2\\ &= 594\,\text{t}\end{aligned}$$

Rigging weight is assumed to be 6 t. Thus,

$$\begin{aligned}\text{Hook load} &= \text{lift weight} + \text{rigging weight}\\ &= 594\,\text{t} + 6\,\text{t}\\ &= 600\,\text{t}\end{aligned}$$

Sling tensions at lift off

Considering equilibrium and taking moments about point A:

$$H_1 \cos\phi_1 = H_2 \cos\phi_2 \tag{1}$$

$$H_1 \sin\phi_1 + H_2 \sin\phi_2 = 600\,\text{t} \tag{2}$$

$$H_2 \sin\phi_2(30) = 600(16) \tag{3}$$

$$H_2 \sin\phi_2 = 320\,\text{t}$$

$$H_1 \sin\phi_1 = 600 - 320 = 280\,\text{t}$$

Consider the case of $\phi_1 = 75°$

From Eqn 1,

$$H_2 \cos\phi_2 = \frac{280}{\sin 75°} \times \cos 75° = 75\,\text{t}$$

Combining with Eqn 3,

$$\tan\phi_2 = \frac{320}{75} = 4.27$$

$$\phi_2 = 76.8°$$

$$H_1 = \frac{280}{\sin 75°} = 290\,\text{t}$$

$$H_2 = \frac{75}{\cos 76.8°} = 328\,\text{t}$$

For preliminary calculations, assume sling angles ϕ_1 and $\phi_2 = 70°$.

Thus, sling tensions

$$T_1 \text{ at A} = \frac{H_1}{2\cos 20°} = 154\,\text{t}$$

$$T_2 \text{ at B} = \frac{H_2}{2\cos 20°} = 175\,\text{t}$$

Sling tensions when jacket is vertical

Distance between diagonally opposite lift points $= \sqrt{14.15^2 + 19.15^2} = 23.81\,\text{m}$. Thus, minimum sling length to achieve $> 60°$ angle to the horizontal is 24 m.

Since lifting arrangement is indeterminate, a skew factor of 1.5 (75-25) is applied.

$$\text{Factored hook load} = 1.5 \times 600 = 750\,\text{t}$$

Consider an angle of 30° between the slings and the vertical:

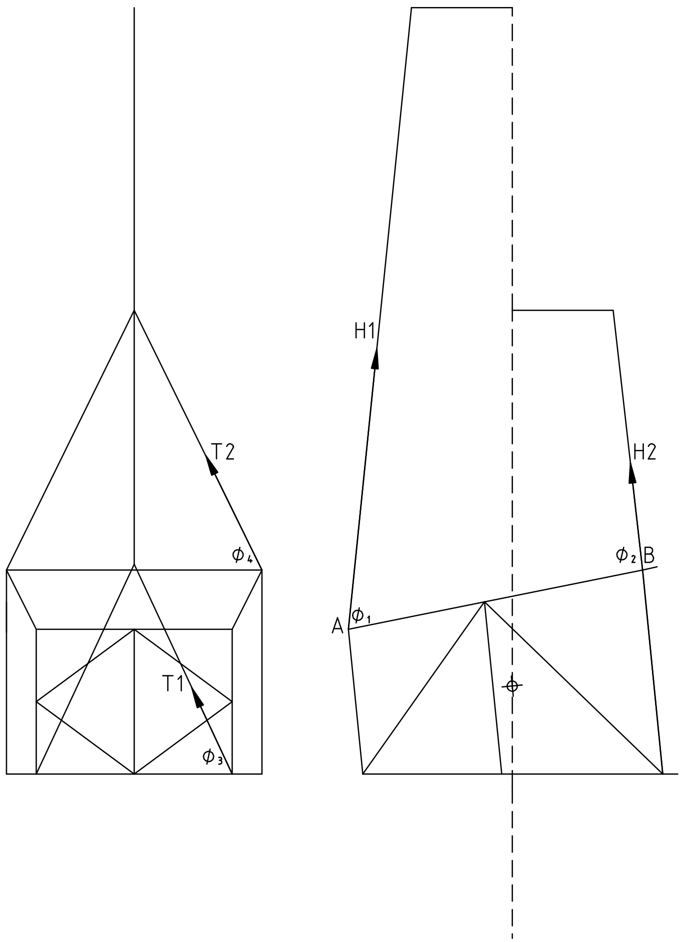
$$T_1 = \frac{750}{4\cos 30°} = 217\,\text{t}$$

Sling selection

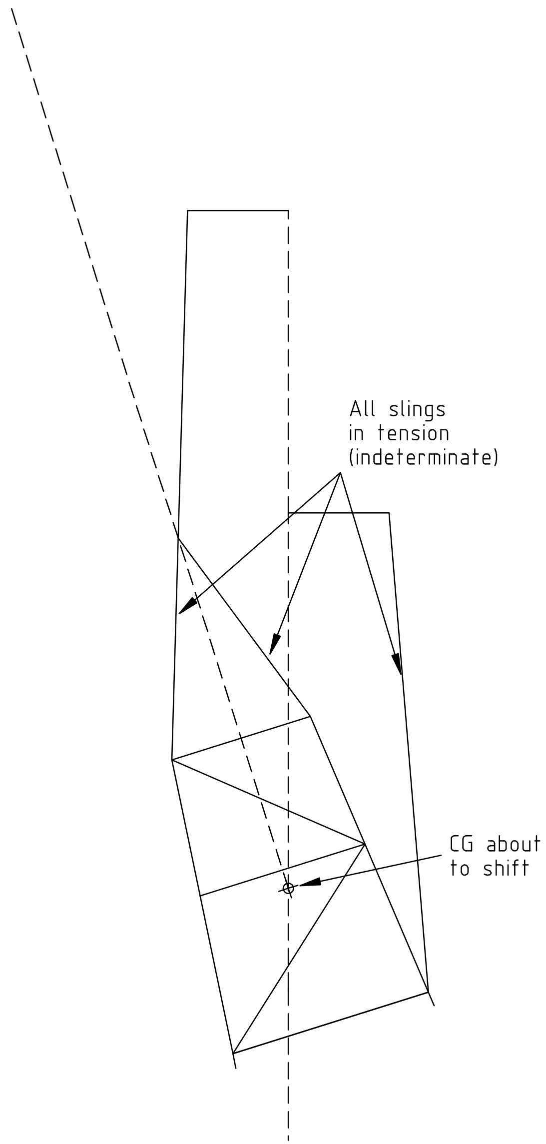
Considering fairly calm conditions during installation, a factor of safety of 3 is taken for sling selection.

For T_1, required MBL $= 217 \times 3 = 651$ t
For T_2, required MBL $= 175 \times 3 = 525$ t

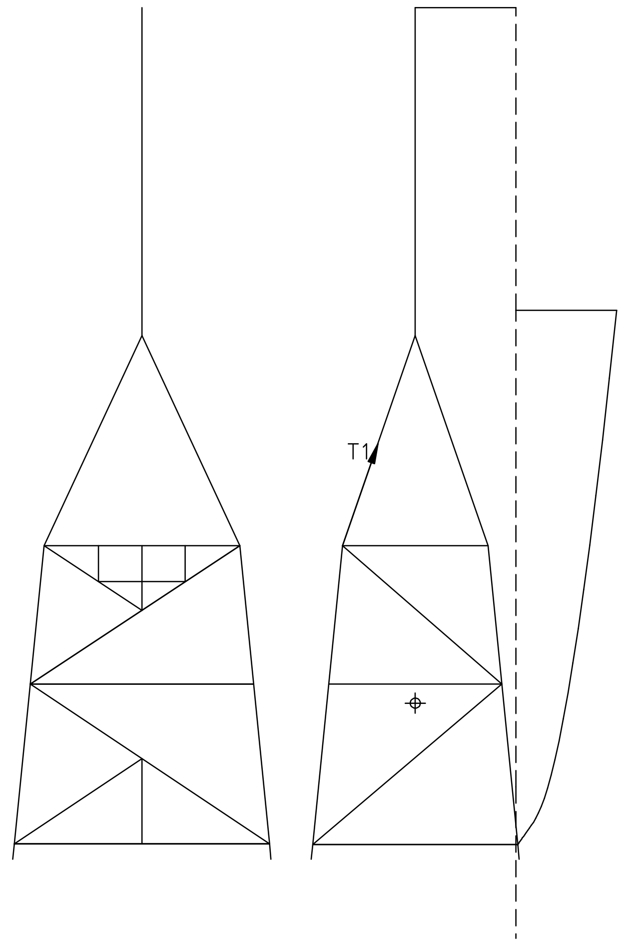
From Asian Lift slings list,
Use slings $\Phi 103$ mm $\times$ 27.5 m length for T_1, MBL $= 800$ t.
Use slings $\Phi 90$ mm $\times$ 13 m length for T_2, MBL $= 556$ t.



Lift off



Critical
Intermediate
Stage



Jacket is
vertical

3 Trunnion and padeye design

Trunnions for bottom framing

To adopt a factor of safety consistent with the other rigging components (slings, etc.), a safety factor of 2 is adopted.

Required trunnion brace strength $> 2 \times 175\,\mathrm{t} = 350\,\mathrm{t}$.

Consider brace/sling diameter ratio of 4 to ensure bending loss in sling is minimised),
brace diameter $> 4 \times 90\,\mathrm{mm} = 360\,\mathrm{mm}$.

End plate diameter > trunnion brace dismeter + 1.2 × sling diameter

Shear strength of brace $= \frac{A_v \sigma_y}{\sqrt{3}} = \frac{2 d t \sigma_y}{\sqrt{3}}$.

Choose brace with $d = 500$ mm and $t = 20$ mm;
Brace strength $= \frac{2\times500\times20\times345}{\sqrt{3}}\,\mathrm{N} = 3980\,\mathrm{kN} = 398\,\mathrm{t}$ (OK)

Choose end plate with $d = 610$ mm and $t = 20$ mm;
End plate diameter $> 500\,\mathrm{mm} + 1.2 \times 90\,\mathrm{mm} = 608\,\mathrm{mm}$ (OK)

Choose bearing plate with $d = 460$ mm and $t = 25$ mm;
Bearing stress is taken as $0.9 f_y$.
Bearing plate thickness $> \frac{350\times10\times1000}{500\times345\times0.9}\,\mathrm{mm} = 22.5\,\mathrm{mm}$ (OK)

Padeyes for top framing

To adopt a factor of safety consistent with the other rigging components (slings, etc.), a safety factor of 2 is adopted.

Required shackle safe working load, $P > 2 \times 217\,\mathrm{t} = 434\,\mathrm{t}$.

From Asian Lift shackles list,
Use SWL 500 t Crosby W/Body Shackle, pin Φ 181 mm, inside width 250 mm, inside length Φ 666 mm.

Taking d as pin diameter, and W as pin inside length,
Diameter of lifting eye hole, $D = d \times 1.04 = 181 \times 1.04 = 188\,\mathrm{mm}$.

Choose Use main plate, $T = 104$ mm, $R = 226$ mm, and cheek plate, $t = 64$ mm, $r = 200$ mm;

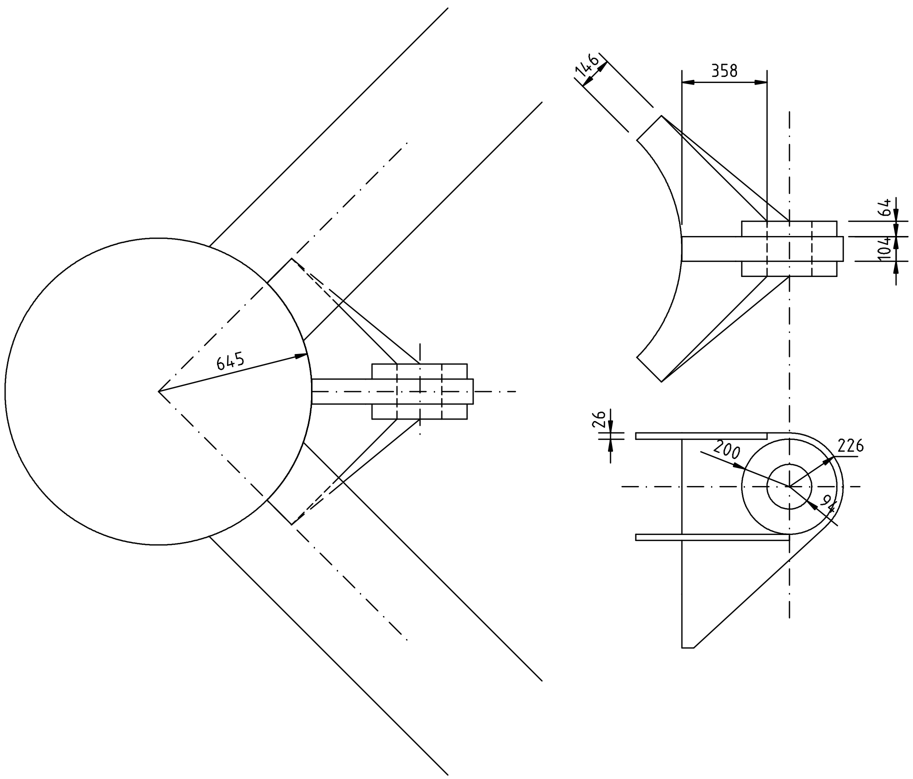
Edge distance, $R \geq 1.25D = 1.25 \times 181 = 226\,\mathrm{mm}$ (OK)

Combined thickness of main plate and cheek plates, $a \approx W - 12\,\mathrm{mm} = 250 - 12 = 238\,\mathrm{mm}$
$a = 104 + 2 \times 64 = 232\,\mathrm{mm}$ (OK)

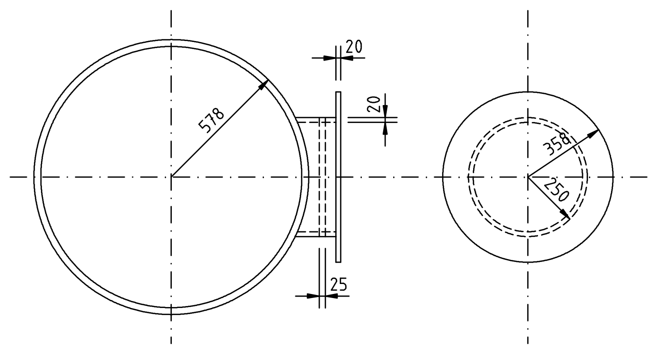
Bearing stress, $f_p = \frac{P}{Da} = \frac{434\times10000}{188\times232}\,\mathrm{MPa} = 99.5\,\mathrm{MPa} < 0.9 f_y = 270\,\mathrm{MPa}$ (OK)

Pull-out shear stress, $f_{ps} = \frac{P/2}{2t(r-0.5D)+T(R-0.5D)} = \frac{434\times10000/2}{2\times64(200-0.5\times188)+104(226-0.5\times188)} = 79.5\,\mathrm{MPa} < 0.4 f_y = 120\,\mathrm{MPa}$ (OK)

Tension failure stress, $f_t = \frac{P}{\text{failure length}\times T} = \frac{434\times10000}{2\times226\times104} = 92\,\mathrm{MPa} < 0.6 f_y = 180\,\mathrm{MPa}$ (OK)



Padeye



Trunnion