2.11. $\epsilon_{AB} = \dfrac{0{,}5\,\Delta L}{L}$

2.13. $(\gamma_C)_{xy} = -11{,}6(10^{-3})$ rad, $(\gamma_D)_{xy} = 11{,}6(10^{-3})$ rad

2.14. $\epsilon_{AC} = 1{,}60(10^{-3})$ mm/mm, $\epsilon_{DB} = 12{,}8(10^{-3})$ mm/mm

2.15. $\epsilon_{AB} = 16{,}8(10^{-3})$ m/m

2.16. $(\gamma_{nt})_A = 0{,}05024$ rad, $(\gamma_{nt})_B = 0{,}05024$ rad

2.17. $\epsilon_{AB} = -4{,}686 \times 10^{-3}$ mm/mm, $\epsilon_{AC} = 20{,}000 \times 10^{-3}$ mm/mm, $\epsilon_{DB} = -30{,}000 \times 10^{-3}$ mm/mm,

2.18. $\epsilon_{AB} = 1{,}61(10^{-3})$ mm/mm, $\epsilon_{CD} = 126(10^{-3})$ mm/mm

2.19. $(\gamma_A)_{xy} = -0{,}0262$ rad, $(\gamma_B)_{xy} = -0{,}205$ rad, $(\gamma_C)_{xy} = 0{,}205$ rad, $(\gamma_D)_{xy} = 0{,}0262$ rad

2.21. $\epsilon = 2kx$

2.22. $\gamma_{xy} = -0{,}0200$ rad

2.23. $\gamma_{xy} = 0{,}02$ rad

2.25. $\gamma_{xy} = 0{,}0142$ rad

2.26. $\epsilon_{DB} = -0{,}00680$ mm/mm, $\epsilon_{AD} = 0{,}0281(10^{-3})$ mm/mm

2.27. $\epsilon_x = 0$, $\epsilon_y = 0{,}00319$, $\gamma_{xy} = 0{,}0798$ rad, $\epsilon_{BE} = -0{,}0179$ mm/mm

2.29. $(\gamma_C)_{xy} = -0{,}137$ rad, $(\gamma_D)_{xy} = 0{,}137$ rad

2.30. $\Delta y = 2{,}03$ mm

2.31. $\Delta L = 30{,}00$ mm

2.33. $\Delta L = 42{,}252$ mm

2.34. $\epsilon_{AB} = \dfrac{v_B \operatorname{sen}\theta}{L} - \dfrac{u_A \cos\theta}{L}$

Capítulo 3

3.1. $E_{\text{aprox}} = 26{,}67$ GPa

3.2. $E_{\text{aprox}} = 387{,}3$ GPa, $u_r = 0{,}0697$ MJ/m^3

3.3. $u_t = 0{,}595$ MJ/m^3

3.4. $E_{\text{aprox}} = 260{,}8$ GPa, $\sigma_e = 448$ MPa, $\sigma_{\text{lim}} = 890$ MPa, $\sigma_R = 753{,}8$ MPa

3.5. $E = 290$ GPa, $P_e = 32{,}80$ kN, $P_{\text{máx}} = 62{,}20$ kN

3.6. $E = 290$ GPa, Valor$_{\text{RE}} = 0{,}08621$ mm, Valor$_{\text{ps}} = 3{,}91379$ mm

3.7. $u_r = 0{,}145$ MPa, $u_t = 132$ MPa

3.9. $E = 38{,}5$ GPa, $u_r = 77{,}00$ MPa, $u_t = 134{,}75$ MPa

3.10. $L = 1.250{,}363$ mm

3.11. $L = 254{,}143$ mm

3.13. $\Delta P = 220{,}22$ kN

3.14. $E = 766{,}3$ MPa

3.15. $A_{\text{exig}} = 150$ mm^2, $P = 7{,}5$ kN

3.16. $\delta_{AB} = 10{,}586$ mm

3.17. Satisfaz exigências tanto de tensão quanto de deformação

3.18. $d_{AB} = 3{,}54$ mm, $d_{AC} = 3{,}23$ mm, $L_{AB} = 750{,}49$ mm

3.19. $P = 65{,}63$ kN

3.20. $A_{BC} = 571{,}43$ mm^2, $A_{AB} = 142{,}86$ mm^2

3.21. $\alpha = 0{,}708°$

3.22. $P = 11{,}3$ kN

3.23. $\delta_{AB} = 3{,}970$ mm

3.24. $w = 3{,}40$ kN/m

3.25. $T = 4{,}50$ kN

3.26. $\delta = 0{,}126$ mm, $\Delta d = -0{,}00377$ mm

3.27. $\epsilon_y = -0{,}01500$ mm/mm, $\gamma_{xy} = -0{,}00524$ rad, $\epsilon_x = 0{,}00540$ mm/mm

3.28. $d' = 38{,}0861$ mm

3.29. $\nu = 0{,}300$

3.30. $L = 50{,}0377$ mm, $d = 12{,}99608$ mm

3.31. $E = 227.500$ MPa, $P = 9{,}896$ kN

3.33. $p = 741$ kPa, $\delta = 7{,}41$ mm

3.34. $\epsilon_x = 0{,}00750$ mm/mm, $\gamma_{xy} = 0{,}01222$ rad, $\epsilon_y = -0{,}00375$ mm/mm

3.35. $G = 31{,}60$ GPa

3.36. $d' = 12{,}4716$ mm

3.37. $\epsilon = 0{,}0010186$ mm/mm, deformação $\epsilon = 0$

3.38. $\delta L_{AB} = 2{,}1171$ mm

3.39. $P = 0{,}885$ kN

3.40. $L = 69{,}806$ mm

3.41. $\epsilon_p = 0{,}00227$ mm/mm, $\epsilon_l = 0{,}000884$ mm/mm

3.42. $E_{\text{aprox}} = 250$ GPa

3.43. $u_t = 118(10^6)\dfrac{\text{N}}{\text{m}^2}$

Capítulo 4

4.1. $\delta_A = -3{,}64(10^{-3})$ mm

4.2. $\delta_{AB} = -1{,}74769$ mm

4.3. $P_1 = 304{,}69$ kN, $P_2 = 609{,}38$ kN

4.4. $(\delta_A)_D = 3{,}8483$ mm

4.5. $\delta_B = 2{,}31$ mm, $\delta_A = 2{,}64$ mm

4.6.
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4.47.
4.49.
4.50.

4.6. $P_1 = 70{,}46$ kN, $P_2 = 152{,}27$ kN

4.7. $p = 21{,}8$ MPa, $\delta_{BC} = 1{,}13$ mm, $\delta_{BA} = 0$

4.8. $\delta_1 = 0{,}736$ mm

4.9. $\alpha_{DC} = 0{,}0039°$, $\beta_{AB} = 0{,}0334°$

4.10. $\delta_A = 2{,}990$ mm

4.11. $\delta_F = 0{,}34$ mm

4.12. $\alpha_{AC} = 0{,}00143°$

4.13. $\delta_{tot} = 33{,}87$ mm

4.14. $W = 9{,}69$ kN

4.15. $\delta_F = 2{,}23$ mm

4.16. $\delta_B = 12{,}37$ mm

4.17. $P = 50{,}47$ kN

4.19. $\delta_D = 17{,}3$ mm

4.20. $d_{CD} = 12.887$ mm, $d_{AB} = 22.321$ mm

4.21. $w = 13{,}41$ kN/m, $x = 1{,}35$ m
Hastes AB e CD falham simultaneamente.

4.22. $F = 12{,}0$ kN, $\delta_{A/B} = -0{,}864$ mm

4.23. $F = 17{,}0$ kN, $\delta_{A/B} = -1{,}03$ mm

4.25. $$\delta = \frac{PL}{\pi E r_2 r_1} + \frac{\gamma L^2(r_2 + r_1)}{6E(r_2 - r_1)} - \frac{\gamma L^2 r_1^2}{3Er_2(r_2 - r_1)}$$

4.26. $$\delta = \frac{0{,}511P}{\pi r_0 E}$$

4.27. $$\delta = \frac{2{,}63P}{\pi r E}$$

4.29. $$\delta = \frac{\gamma L^2}{6E}$$

4.30. $\delta = 0{,}1804$ mm

4.31. $\sigma_{aço} = 24{,}323$ MPa, $\sigma_{conc} = 3{,}527$ MPa

4.32. $d_{aço} = 44{,}95$ mm

4.33. $\sigma_{al} = 27{,}5$ MPa, $\sigma_{aço} = 79{,}9$ MPa

4.34. $\sigma_{aço} = 65{,}9$ MPa, $\sigma_{conc} = 8{,}24$ MPa

4.35. $d = 33{,}9$ mm

4.37. $\sigma_{aço} = 5{,}335$ MPa, $\sigma_{lat} = 2{,}792$ MPa,

4.38. $d_{aço} = 58{,}88$ mm

4.39. $T_{AC} = 1{,}249$ kN, $T_{AB} = 6{,}251$ kN

4.40. $A_{AB} = 3{,}60911$ mm^2

4.41. $P = F_{lat} = 198$ kN

4.42. $T_{AB} = 1{,}469$ kN, $T_{A'B'} = 1{,}781$ kN

4.43. $P_b = 14{,}4$ kN

4.45. $w = 45{,}9$ kN/m

4.46. $\sigma_D = 13{,}4$ MPa, $\sigma_{BC} = 9{,}55$ MPa

4.47. $\theta = 63{,}7(10^{-6})$ rad

4.49. $d_{AC} = 1{,}79$ mm

4.50. $$\sigma_{AB} = \frac{7P}{12A}, \sigma_{CD} = \frac{P}{3A}, \sigma_{EF} = \frac{P}{12A}$$

4.51. $P = 1{,}16$ kN

4.53. $\sigma_{aço} = 102$ MPa, $\sigma_{lat} = 50{,}9$ MPa

4.54. $P = 126$ kN

4.55. $T_{AB} = T_{CD} = 16{,}7$ kN, $T_{EF} = 33{,}3$ kN

4.56. $\delta_B = 0{,}073522$ mm

4.57. $F_{EF} = 6{,}316$ kN, $F_{CD} = 1.053$ kN

4.58. $$F_1 = \left(\frac{A_1E_1}{2A_1E_1 + A_2E_2}\right)P,$$

$$F_2 = \left(\frac{A_2E_2}{2A_1E_1 + A_2E_2}\right)P$$

4.59. $$A_1' = \left(\frac{E_1}{E_2}\right)A_1$$

4.61. $F_B = 0{,}2712$ kN, $F_C = 0{,}8136$ kN, $F_D = 1{,}8983$ kN

4.62. $\delta_D = 0{,}003867$ mm

4.63. $F_A = F_B = 25{,}6$ kN

4.65. $F_{AB} = 12{,}0$ kN (T), $F_{AC} = F_{AD} = 6{,}00$ kN (C)

4.66. $F_B = 16{,}9$ kN, $F_A = 16{,}9$ kN

4.67. $\delta_{esp} = 0{,}0390$ mm

4.68. $T_{BC} = 45{,}2804$ kN, $T_{DC} = 135{,}8411$ kN

4.69. $\Delta\theta = 0{,}180°$

4.70. $s = 0{,}7425$ mm

4.71. $L' = 139{,}056$ m

4.72. $\sigma_{al} = 15{,}05$ MPa, $\sigma_{lat} = 33{,}85$ MPa, $\sigma_{aço} = 135{,}41$ MPa

4.73. $T_1 = 55{,}45°$C, $\sigma = 1{,}45$ MPa

4.74. $F = 489{,}03$ kN

4.75. $F = 477{,}29$ kN

4.76. $\Delta_{folga} = 8{,}640$ mm, $F = 76{,}80$ kN

4.77. $T' = 45{,}77°$C, $F = 61{,}958$ kN, $\sigma = 87{,}65$ MPa

4.78. $\sigma = 185{,}58$ MPa, $L_{al}' = 200{,}117793$ mm

4.79. $F = 6{,}99$ kN

4.81. $F_{AB} = F_{EF} = 1{,}85$ kN

4.82. $\sigma = 134{,}40$ MPa

4.83. $F = 18{,}566$ kN

4.84. $\sigma_{aço} = 24{,}68$ MPa, $\sigma_{lat} = 30{,}64$ MPa

4.85. $$F = \frac{\alpha AE}{2}(T_B - T_A)$$

4.86. $F = 2{,}442$ kN

4.87. $\sigma_{máx} = 190$ MPa

4.89. $P = 44{,}1$ kN

4.90. $P = 5{,}4$ kN

4.91. $\sigma_{máx} = 217{,}78$ MPa
4.93. $P = 19$ kN, $K = 1{,}26$
4.94. $P = 72{,}00$ kN, $\sigma_{méd} = 45{,}00$ MPa, $K = 1{,}60$
4.95. $P = 77{,}1$ kN, $\delta = 0{,}429$ mm
4.96. $\sigma_{aço} = 250$ MPa, $\sigma_{al} = 171{,}31$ MPa
4.97. $P = 126$ kN
4.98. **a)** $F_{aço} = 444$ N, $F_{al} = 156$ N;
b) $F_{aço} = 480$ N, $F_{al} = 240$ N
4.99. $\Delta\sigma_{AB} = 60$ MPa (T), $\Delta\sigma_{BC} = 60$ MPa (T)
4.100. $\delta_{Total} = 18{,}286$ mm
4.101. $w = 21{,}9$ kN/m, $\delta_G = 4{,}24$ mm
4.102. **a)** $w = 18{,}7$ kN/m, **b)** $w = 21{,}9$ kN/m
4.103. **a)** $P = 92{,}8$ kN, **b)** $P = 181$ kN
4.105. $w = 2{,}00$ kN/m, $\delta = 1{,}500$ mm
4.106. $\delta = \dfrac{\gamma^2 L^3}{3c^2}$
4.107. $\delta = \dfrac{3}{5}\left(\dfrac{\gamma}{c}\right)^{\frac{2}{3}} L^{\frac{5}{3}}$
4.108. $P = 549{,}78$ kN, $\Delta\delta = 0{,}180$ mm ←
4.109. $P = 549{,}78$ kN, $\delta''_C = 0{,}300$ mm
4.110. $F = 64{,}189$ kN. Sim, porque conforme o rebite esfria, as chapas e as cabeças do rebite também se deformarão. A força F_T no rebite não será tão grande.
4.111. $P = 22{,}5$ kN
4.112. $F_C = 0{,}974$ kN, $F_B = 0{,}433$ kN
4.114. $F_B = 8{,}526$ kN, $F_A = 8{,}606$ kN
4.115. $P = 19{,}776$ kN
4.116. $\sigma_{aço} = 13{,}23$ MPa, $\sigma_c = 1{,}92$ MPa, $\delta = 0{,}15881$ mm
4.117. $A_{aço} = 11{,}397{,}38$ mm^2, $\delta = 0{,}15793$ mm
4.118. $\delta_D = 1{,}17$ mm
4.119. $\delta_{A/B} = 0{,}491$ mm

Capítulo 5

5.1. **a)** $T = 0{,}87$ kN·m **b)** $T' = 0{,}87$ kN·m
5.2. $r' = 0{,}841r$
5.3. $r' = 0{,}707r$
5.5. $\tau_{\substack{máx \\ abs}} = 75{,}5$ MPa
5.6. $\tau_C = 28{,}75$ MPa, $\tau_D = -11{,}66$ MPa
5.7. $\tau_{máx} = 45{,}82$ MPa
5.8. $\tau_{máx} = 45{,}82$ MPa, $\tau_p = 35{,}80$ MPa
5.9. $\tau_{AB} = 62{,}55$ MPa, $\tau_{BC} = 18{,}89$ MPa
5.10. $\tau_{máx} = 14{,}5$ MPa
5.11. $\tau_{máx} = 11{,}9$ MPa
5.13. $d_i = 60$ mm
5.14. $T_1 = 215$ N · m, $(\tau_{máx})_{CD} = 4{,}00$ MPa, $(\tau_{máx})_{DE} = 2{,}58$ MPa
5.15. $\tau_{\substack{máx \\ abs}} = 5{,}38$ MPa
5.17. $(\tau_{EA})_{máx} = 5{,}66$ MPa, $(\tau_{CD})_{máx} = 8{,}91$ MPa
5.18. $\tau_A = 13{,}79$ MPa, $\tau_B = 24{,}14$ MPa
5.19. $\tau_C = 28{,}73$ MPa
5.21. $\tau_{\substack{mín \\ abs}} = 0$ ocorre em $x = 0{,}700$ m.
$\tau_{\substack{máx \\ abs}} = 33{,}0$ MPa ocorre em $x = 0$. Entretanto, por conta do princípio de Saint-Venant, a $\tau_{\substack{máx \\ abs}}$ obtida ***não é válida***.
5.22. $d = 34{,}4$ mm. Entretanto, a análise ***não é válida*** por conta do pincípio de Saint Venant.
5.23. $\tau_{méd} = 1{,}17$ MPa
5.24. $\tau_A = 159{,}15$ MPa
5.25. $\tau_B = 159{,}15$ MPa
5.27. $t_0 = 133$ N · m/m, $\tau_A = 0{,}255$ MPa, $\tau_B = 0{,}141$ MPa
5.29. $T_0 = 670$ N · m, $\tau_{\substack{máx \\ abs}} = 6{,}66$ MPa
5.30. $\tau_{máx} = \dfrac{2TL^3}{\pi[r_A(L - x) + r_B x]^3}$
5.31. $T_B = \dfrac{2T_A + t_A L}{2}$; $\tau_{máx} = \dfrac{(2T_A + t_A L)r_o}{\pi\left(r_o^4 - r_i^4\right)}$
5.32. $t = 5{,}17$ mm
5.33. $t = 2{,}998$ mm
5.34. $\tau_{máx} = 9{,}382$ MPa
5.35. $d = 15$ mm
5.36. $t = 3{,}427$ mm
5.37. $\tau_{máx} = 46{,}055$ MPa
5.38. $d = 20$ mm
5.39. $(\tau_{AB})_{máx} = 1{,}04$ MPa, $(\tau_{BC})_{máx} = 3{,}11$ MPa
5.40. $\tau_{máx} = 48{,}634$ MPa
5.41. $d_A = 12{,}4$ mm, $d_B = 16{,}8$ mm
5.42. $\omega = 3.135{,}714$ rpm
5.43. $d = 35$ mm
5.45. Aumento percentual na tensão de torção = % aumento em $\phi = 6{,}67\%$
5.46. $d_i = 201$ mm, $\phi = 3{,}30°$
5.47. $\phi_{A/D} = 0{,}879°$
5.49. $\tau_{máx} = 20{,}797$ MPa, $\phi = 4{,}766°$
5.50. $\phi_{C/D} = 0{,}243°$
5.51. $\phi_B = 5{,}74°$