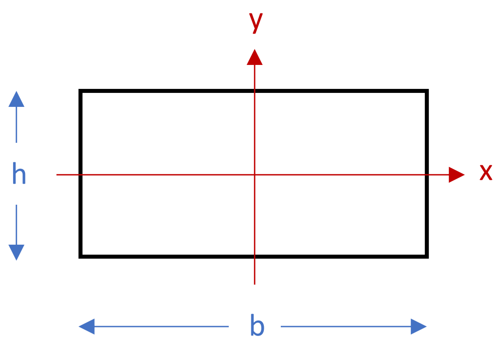
SECTION TOOL DOCUMENTATION

Abstract

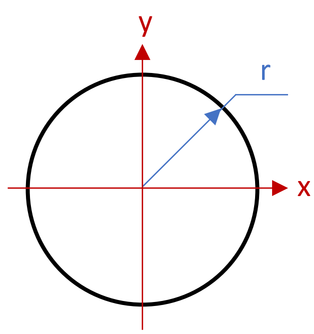
This tool calculates properties of several typical cross sections of a beam. These properties include the area, area moment of inertia relative to major and minor axes, as well as section modulus at extreme fiber relative to the major and minor axes. The current document provides theoretical substantiation and application examples.

Theoretical background

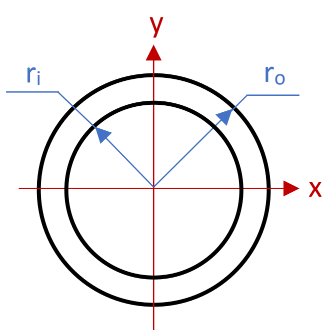
A = area (length)^2; x_c, y_c = distance to extreme fiber (length); I = area moment of inertia (length)^2; Z = section modulus at extreme fiber (length)^3.



$$A = b \cdot h$$
$$x_c = \frac{b}{2};\ y_c = \frac{h}{2}$$
$$I_{xx} = \frac{b \cdot h^3}{12}$$
$$I_{yy} = \frac{h \cdot b^3}{12}$$
$$Z_{xx} = \frac{b \cdot h^2}{6}$$
$$Z_{yy} = \frac{h \cdot b^2}{6}$$



$$A = \pi \cdot r^2$$
$$x_c = y_c = r$$
$$I_{xx} = I_{yy} = \frac{\pi \cdot r^4}{4}$$
$$Z_{xx} = Z_{yy} = \frac{\pi \cdot r^3}{4}$$



$$A = \pi \cdot (r_o{}^2 - r_i{}^2)$$
$$x_c = y_c = r_o$$
$$I_{xx} = I_{yy} = \frac{\pi \cdot (r_o{}^4 - r_i{}^4)}{4}$$
$$Z_{xx} = Z_{yy} = \frac{\pi \cdot (r_o{}^4 - r_i{}^4)}{4 \cdot r_o}$$

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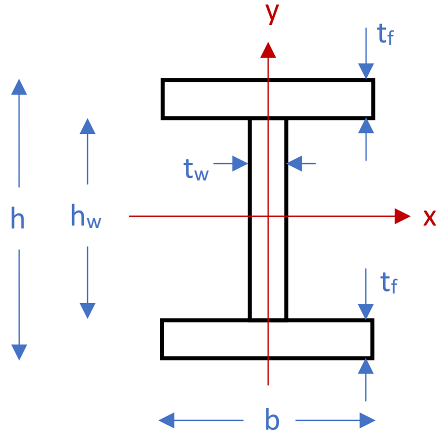
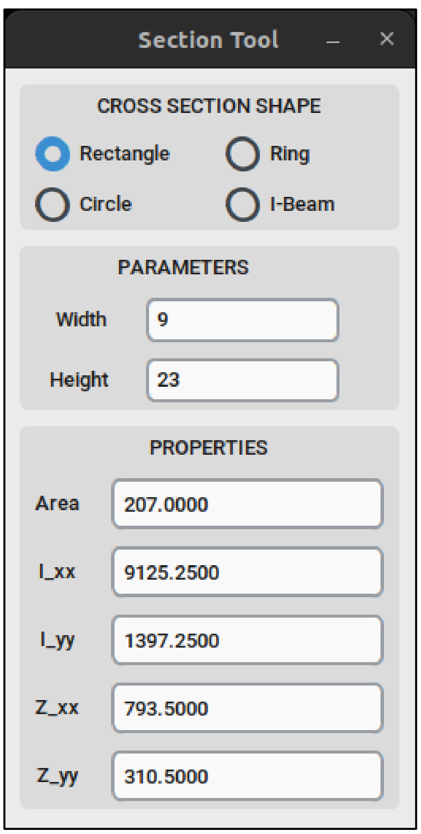


$$A = 2 \cdot b \cdot t_f + h_w \cdot t_w$$
$$x_c = \frac{b}{2};\, y_c = \frac{h}{2}$$
$$I_{xx} = \frac{1}{12}(b \cdot h^3 - b \cdot {h_w}^3 + t_w \cdot {h_w}^3)$$
$$I_{yy} = \frac{1}{12}(h \cdot b^3 - h_w \cdot b^3 + h_w \cdot {t_w}^3)$$
$$Z_{xx} = \frac{1}{6}(b \cdot h^2 - \frac{{h_w}^3}{h} \cdot (b - t_w))$$
$$Z_{yy} = \frac{1}{6}(h \cdot b^2 - h_w \cdot (b^2 - \frac{{t_w}^3}{b}))$$

Application examples

The following section presents program output and a comparison with the methods described in Reference 1. Although the referenced document does not specifically mention the section modulus, it can be easily estimated as proposed in the examples below. Please note that the program uses a dimensionless approach, which means that the user is responsible for inputting the correct values.

Example 1. Rectangle

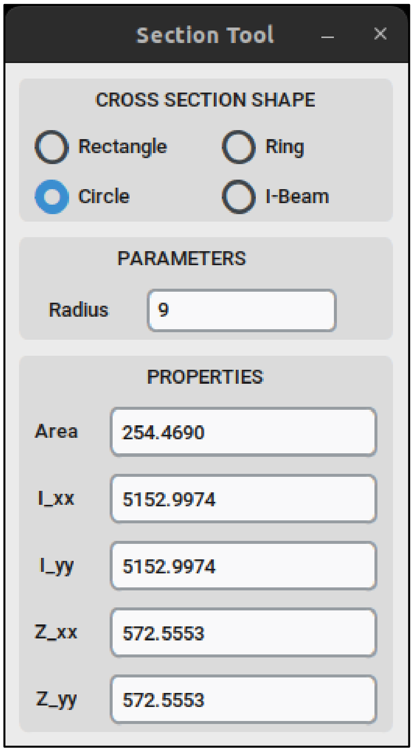


Value check according to Table A.1, Section 2 formulae per Reference 1:

b = 9, d = 23

$$A = b \cdot d = 9 \cdot 23 = 207.00\ (length^2)$$
$$x_c = \frac{b}{2} = \frac{9}{2} = 4.50\ (length)$$
$$y_c = \frac{h}{2} = \frac{23}{2} = 11.50\ (legth)$$
$$I_{xx} = \frac{1}{12} \cdot b \cdot d^3 = \frac{1}{12} \cdot 9 \cdot 23^3 = 9125.25\ (length^4)$$
$$I_{yy} = \frac{1}{12} \cdot d \cdot b^3 = \frac{1}{12} \cdot 23 \cdot 9^3 = 1397.25\ (length^4)$$
$$Z_{xx} = \frac{I_{xx}}{y_c} = \frac{9125.25}{11.50} = 793.50\ (length^3)$$
$$Z_{yy} = \frac{I_{yy}}{x_c} = \frac{1397.25}{4.50} = 310.50\ (length^3)$$

Example 2. Circle



Value check according to Table A.1, Section 15 formulae per Reference 1:

R = 9

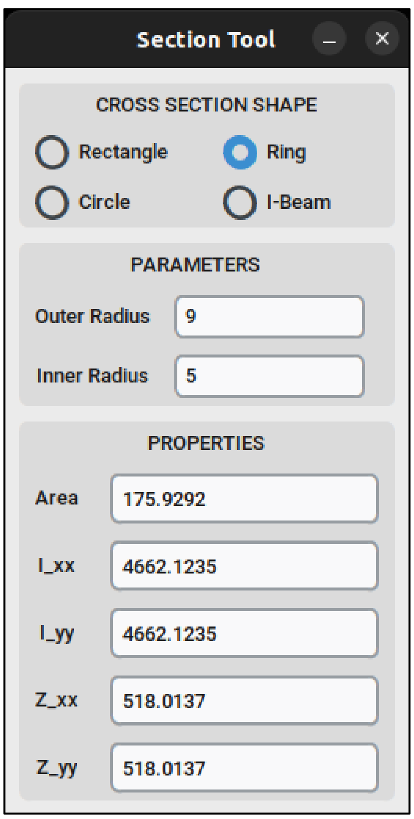
$$A = \pi \cdot R^2 = \pi \cdot 9^2 = 254.47\ (length^2)$$

$$x_c = y_c = R = 9.00\ (length)$$

$$I_{xx} = I_{yy} = \frac{\pi}{4} \cdot R^4 = \frac{\pi}{4} \cdot 9^4 = 5153.00\ (length^4)$$

$$Z_{xx} = Z_{yy} = \frac{I_{xx}}{y_c} = \frac{5153.00}{9.00} = 572.56\ (length^3)$$

Example 3. Ring



Value check according to Table A.1, Section 16 formulae per Reference 1:

R = 9, R_i = 5

$$A = \pi \cdot (R^2 - {R_i}^2) = \pi \cdot (9^2 - 5^2) = 175.93\ (length^2)$$

$$x_c = y_c = R = 9.00\ (length)$$

$$I_{xx} = I_{yy} = \frac{\pi}{4} \cdot \left(R^4 - {R_i}^4\right) = \frac{\pi}{4} \cdot (9^4 - 5^4) = 4662.12\ (length^4)$$

$$Z_{xx} = Z_{yy} = \frac{I_{xx}}{y_c} = \frac{4662.12}{9.00} = 518.01\ (length^3)$$

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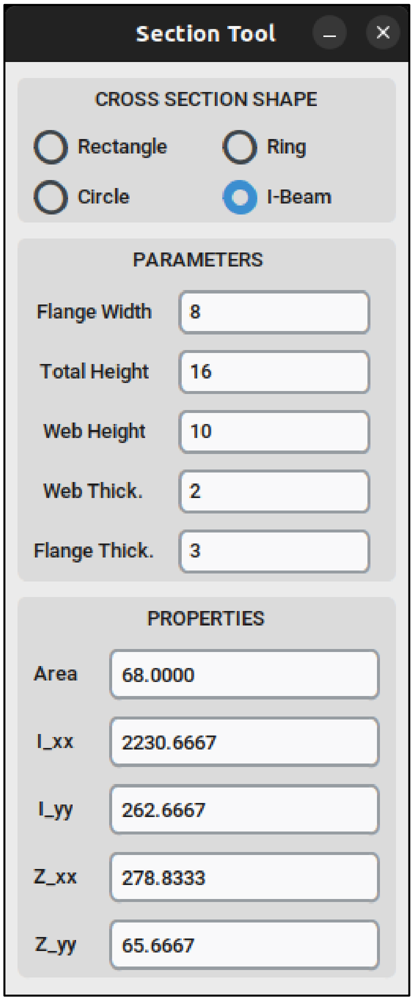
Example 4. I-beam



Value check according to Table A.1, Section 6 formulae per Reference 1:

$b = 8$, $d = 10$, $t = 3$, $t_w = 2$

$$A = 2 \cdot b \cdot t + t_w \cdot d = 2 \cdot 8 \cdot 3 + 2 \cdot 10 = 68.00\ (length^2)$$

$$x_c = \frac{b}{2} = \frac{8}{2} = 4\ (length)$$

$$y_c = \frac{d}{2} + t = \frac{10}{2} + 3 = 8\ (length)$$

$$I_{xx} = \frac{b \cdot (d + 2 \cdot t)^3}{12} - \frac{(b - t_w) \cdot d^3}{12} =$$

$$= \frac{8 \cdot (10 + 2 \cdot 3)^3}{12} - \frac{(8 - 2) \cdot 10^3}{12} = 2230.67\ (length^4)$$

$$I_{yy} = \frac{b^3 \cdot t}{6} + \frac{{t_w}^3 \cdot d}{12} = \frac{8^3 \cdot 3}{6} + \frac{2^3 \cdot 10}{12} = 262.67\ (length^4)$$

$$Z_{xx} = \frac{I_{xx}}{y_c} = \frac{2230.67}{8} = 278.83\ (length^3)$$

$$Z_{yy} = \frac{I_{yy}}{x_c} = \frac{262.67}{4} = 65.67 (length^3)$$

References

1. Young, W.C. and Budynas R.G. (2002) *Roark's Formulas for Stress and Strain. Seventh Edition.* New York: McGraw-Hill

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