TREE BIOMECHANICS SERIES

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Off-Centered Cavity Impact On Stem Strength

One aspect of hollow stem assessments for strength loss involves various forms of stem cross-sectional area damage. One of the scenarios often cited but seldom determined is a stem which has a cavity of a given diameter, but the cavity is not centered in the middle of the stem. This publication will look at one means of estimating relative strength of a stem with a closed, off-centered cavity. This publication is a simple theoretical review of complex and dynamic mechanisms associated with the tree, soil, and environment. This publication is intended to assist tree specialists better appreciate tree biomechanics.

Off-centered cavity stem strength values are dependant upon the thinnest portion (smallest radial thickness) of the ring of wood surrounding the cavity, and the size of the cavity. A stem with a large cavity with thick walls is only slightly weaker than a solid stem. A relatively small cavity with thin enclosing wood walls can make the tree weaker than a solid stem. Compressive faulting in the thinnest wall area is a common form of catastrophic failure in stems with large diameter cavities. Figure 1 provides a graphical definition of these calculations.

Table 1 provides the relative strength in percent of a stem with an off-center, closed cavity and compares it with a solid stem of the same diameter. The diameter of the cavity compared with the diameter of the stem, and the thickness of the thinnest woody wall surrounding the cavity (also listed as a percent of stem diameter) must be specified. For example, a 25 inch diameter stem with a 10 inch diameter cavity having a 2.5 inch thick wall as the thinnest portion of the surrounding stem material has a relative strength of 87% that of a solid stem. In this case, both the cavity size and the thickness of the wall have a relatively small impact on stem strength. See Table 1.

Conclusions

Off-centered cavities impact stem strength only when they are relatively large in diameter and when bounding stem material is relatively thin in the cross-sectional view. Impacts on strength remain proportional to cross-sectional area remaining.

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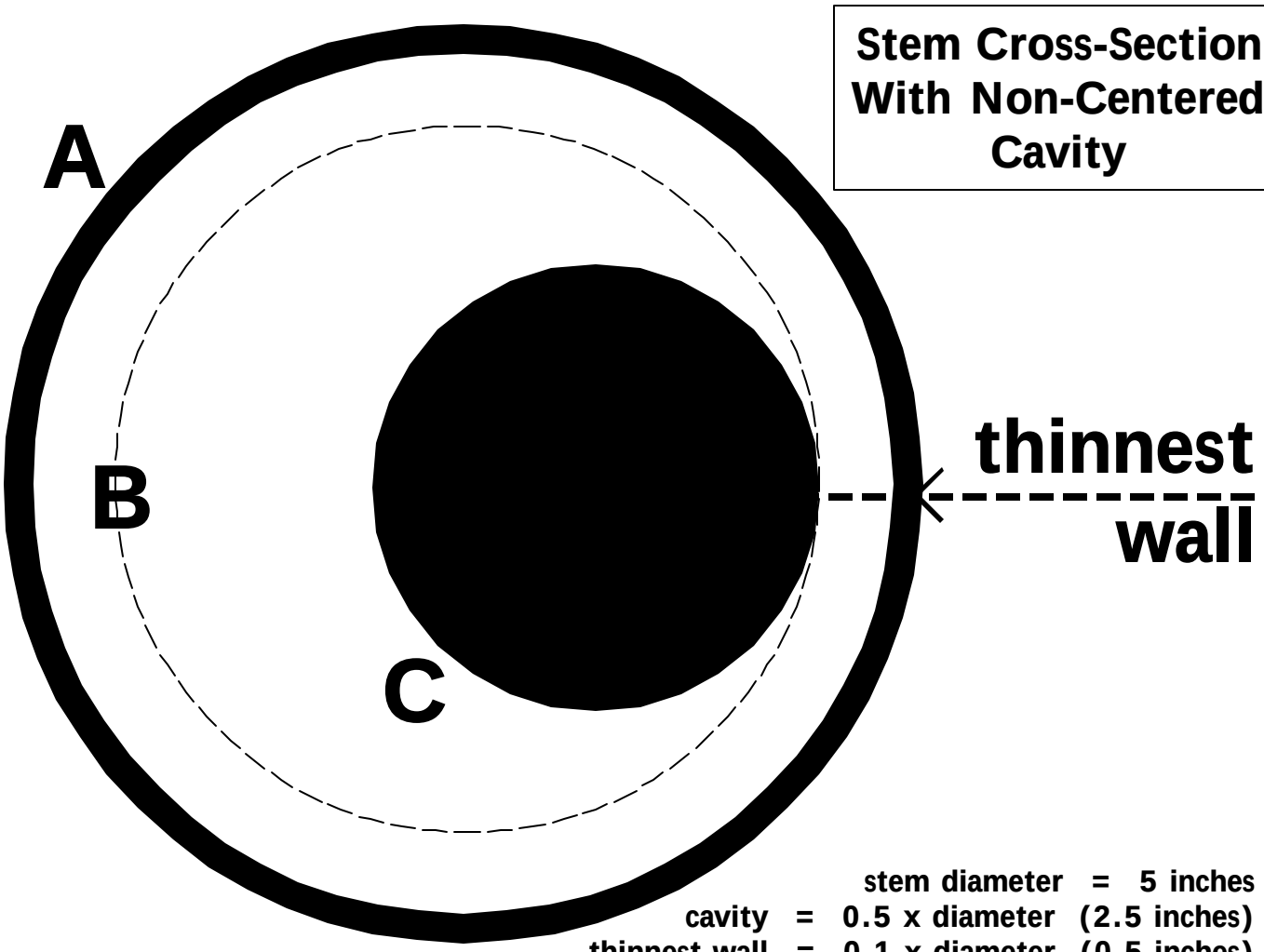


General Calculation Form:

Diameter of Circle B = Diameter of Circle A - Thinnest Wall

Cavity Diameter = Diameter of Circle C

Area of Circle = $(0.7854) \times (\text{Diameter})^2$

Relative Strength of Solid Stem = $((B \times (\text{Diameter})^4) / 64$

Relative Strength of Hollow Stem = $((B \times ((\text{Diameter of Stem})^4 - (\text{Diameter of Cavity})^4)) / 64$

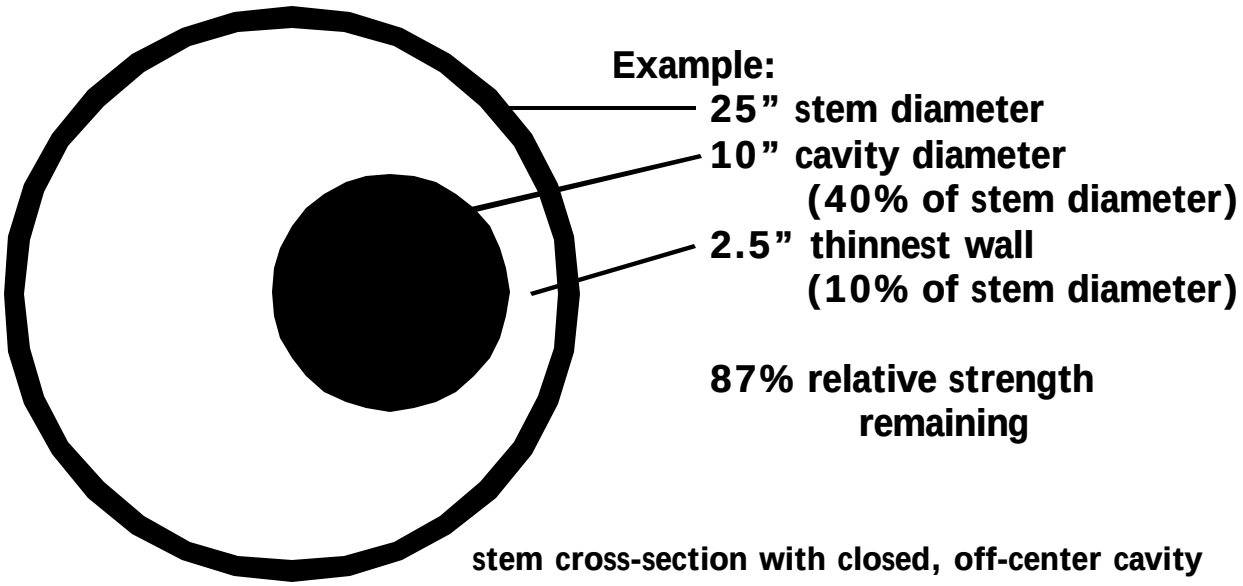
Relative Strength of Stem With Off-Centered Cavity =

$((B \times (((\text{Diameter of Circle A})^4 - (\text{Diameter of Circle B})^4) + (((\text{Area of Circle B} - \text{Area of Circle C}) / \text{Area of Circle B}) \times (\text{Diameter of Circle B})^4)))) / 64$

Figure 1: Graphical definition of off-centered stem cavity calculations. (Note: circular cavity shape factor used)

Table 1: Relative strength (percent) of a stem with an off-center, closed cavity as compared with a solid stem of the same diameter. Figure 1 provides a graphical definition of the calculations used. This table provides values beyond expected measures in order to demonstrate trends in relative strength values. Dotted lines show the example given in the text and below.

Cavity Size (% of stem diameter)	Thinnest Cavity Wall (% of stem diameter)												
	1%	2.5	5	7.5	10	12.5	15	20	25	30	35	40	45%
10%	99%	99	99	99	99	99	99	99	99	100	100	100	100%
20	96	96	96	97	97	97	97	97	98	98	98	99	99
30	91	91	92	92	93	93	93	94	95	96	96	97	97
40	84	85	86	86	**87**	88	88	90	91	92	93	94	95
50	75	76	77	79	80	81	82	84	86	88	89	91	92
60	65	66	68	69	71	72	74	77	80	82	85	87	89
70	52	53	56	58	60	62	65	69	72	76	79	82	85
80	37	39	42	45	48	51	54	59	64	69	73	77	81
90%	21	23	27	31	34	38	41	48	54	60	66	71	75



stem cross-section with closed, off-center cavity