Accident Prevention Through Engineering Design-II

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Safety vs. Accident Prevention

- Up to now, we have focused on safety in the wood shop as it relates to optimum operation of tools and in wearing gear.
- Another element to safety is preventing accidents due to wood failure in projects and tools.

Material Failure is Affected by:

- Optimum design of projects (March 2014)
- Optimum design of tools (March 2014)
- Optimum material selection in tools and projects

Which is Stronger? Why?

A

B

C

Examples

- A baseball bat has the “label” in a certain position indicating grain orientation.
- Chair tenons or spacers should be orientated for optimum strength

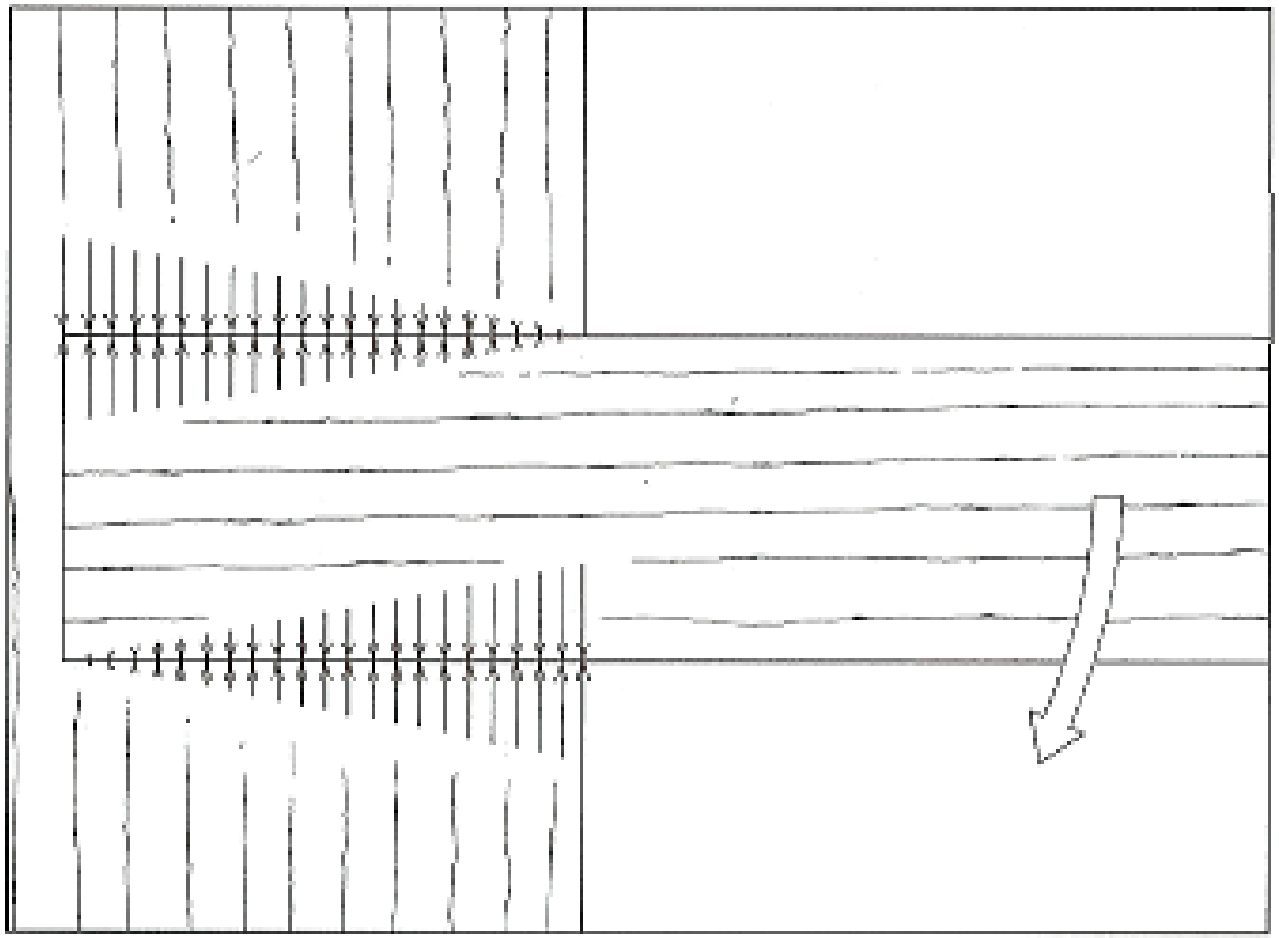

Figure 4.11 • In a mortise and tenon subject to racking, as in a chair, the strength of the tenon in compression perpendicular to the grain is critical.

Hoadley's "Understanding Wood"

Materials

- Don’t forget the quality of material (wood with knots, grain run-out).
- Strength can be assesses based on engineering handbook data.
- Wood, unlike metals and plastics, has grain which affects its strength in different directions.

Engineering Data

Strengths of wood (parallel and perpendicular to grain) under:

- Tension
- Compression
- Bending
- Shear
- Strength per unit weight

TABLE 4.1—Strength properties* at 12% MC of some commercially important woods grown in the United States.

FSPL, fiber stress at proportional limit; MCS, maximum crushing strength; MTS, maximum tensile strength; MSS, maximum shear strength; MR, modulus of rupture; E, modulus of elasticity	Compression: ‖ to grain FSPL (σ') PSI	Compression: ‖ to grain MCS (σ_{max}) PSI	Compression: ⊥ to grain FSPL (σ') PSI	Tension: ⊥ to grain MTS (σ_{max}) PSI	Shear: ‖ to grain MSS (τ_{max}) PSI	Static bending: FSPL (σ') PSI	Static bending: MR (σ_{max}) PSI	Static bending: E (lb/in²) 10^6 PSI
Hardwoods								
Alder, red (*Alnus rubra*)	4,530	5,820	540	420	1,080	6,900	9,800	1.38
Ash, white (*Fraxinus americana*)	5,790	7,410	1,410	940	1,950	9,900	15,400	1.77
Basswood, American (*Tilia americana*)	3,800	4,730	450	350	990	5,900	8,700	1.46
Beechwood, American (*Fagus grandifolia*)	4,680	7,300	1,250	1,010	2,010	8,700	14,900	1.72
Birch, paper (*Betula papyrifera*)	3,610	5,690	740	—	1,210	6,900	12,300	1.59
Birch, yellow (*B. alleghaniensis*)	6,130	8,170	1,190	920	1,880	10,100	16,600	2.01
Butternut (*Juglans cinerea*)	4,200	5,110	570	440	1,170	5,700	8,100	1.18
Cherry, black (*Prunus serotina*)	5,960	7,110	850	560	1,700	9,000	12,300	1.49
Chestnut, American (*Castanea dentata*)	3,780	5,320	760	460	1,080	6,100	8,600	1.23
Cottonwood, eastern (*Populus deltoides*)	3,490	4,910	470	580	930	5,700	8,500	1.37
Elm, American (*Ulmus americana*)	4,800	5,520	850	660	1,510	7,600	11,800	1.34
Elm, rock (*U. thomasii*)	4,700	7,050	1,520	—	1,920	8,000	14,800	1.54
Hackberry (*Celtis occidentalis*)	3,710	5,440	1,100	580	1,590	5,900	11,800	1.19
Hickory, pecan (*Carya illinoensis*)	5,180	7,850	2,130	—	2,080	9,100	13,700	1.73
Hickory, shagbark (*C. ovata*)	6,805	9,210	2,170	—	2,430	10,700	20,200	2.16
Honeylocust (*Gleditsia triacanthos*)	5,250	7,500	2,280	900	2,250	8,800	14,700	1.63
Locust, black (*Robinia pseudoacacia*)	6,800	10,180	2,260	640	2,480	12,800	19,400	2.05
Magnolia, southern (*Magnolia grandiflora*)	5,420	5,460	1,060	740	1,530	6,900	11,200	1.40
Maple, red (*Acer rubrum*)	4,650	6,540	1,240	—	1,850	8,700	13,400	1.64
Maple, sugar (*A. saccharum*)	5,390	7,830	1,810	—	2,330	9,500	15,800	1.83
Oak, black (*Quercus velutina*)	4,750	6,520	1,150	—	1,910	7,900	13,800	1.64
Oak, northern red (*Q. rubra*)	4,580	6,760	1,250	800	1,780	8,500	14,300	1.82
Oak, pin (*Q. palustris*)	3,700	6,680	1,760	700	1,840	7,600	13,300	1.51
Oak, southern red (*Q. falcata*)	2,910	6,090	1,080	510	1,390	6,000	10,900	1.49
Oak, white (*Q. alba*)	4,760	7,440	1,070	800	2,000	8,200	15,200	1.78
Sweetgum (*Liquidambar styraciflua*)	3,670	6,320	660	780	1,600	6,600	12,500	1.64
Sycamore, American (*Platanus occidentalis*)	3,710	5,380	880	720	1,470	6,400	10,000	1.42
Tupelo, black (*Nyssa sylvatica*)	3,470	5,520	1,150	500	1,340	7,300	9,600	1.20
Walnut, black (*Juglans nigra*)	5,780	7,580	1,250	690	1,370	10,500	14,600	1.68
Yellow poplar (*Liriodendron tulipifera*)	3,750	5,540	560	540	1,190	6,200	10,100	1.58
Softwoods								
Baldcypress (*Taxodium distichum*)	4,740	6,360	900	270	1,000	7,200	10,600	1.44
Cedar, Alaska (*Chamaecyparis nootkatensis*)	5,210	6,310	770	360	1,130	7,100	11,100	1.42
Cedar, incense (*Libocedrus decurrens*)	4,760	5,200	730	270	880	5,900	8,000	1.04
Cedar, western red (*Thuja plicata*)	4,360	5,020	610	220	860	5,300	7,700	1.12
Douglas-fir (*Pseudotsuga menziesii*)	5,850	7,430	870	340	1,160	7,000	12,200	1.95
Fir, balsam (*Abies balsamea*)	3,570	4,530	380	180	710	5,200	7,600	1.23
Fir, white (*A. concolor*)	3,590	5,350	800	260	930	6,500	9,300	1.38
Hemlock, eastern (*Tsuga canadensis*)	4,020	5,410	800	—	1,060	6,100	8,900	1.20
Hemlock, western (*T. heterophylla*)	5,340	6,210	680	510	1,170	6,800	10,100	1.49
Larch, western (*Larix occidentalis*)	5,820	8,110	980	430	1,410	8,900	13,900	1.86
Pine, eastern white (*Pinus strobus*)	3,670	4,800	440	310	900	5,700	8,600	1.24
Pine, jack (*P. banksiana*)	3,550	5,660	600	420	1,170	5,800	9,900	1.35
Pine, lodgepole (*P. contorta*)	4,310	5,370	750	290	880	6,700	9,400	1.34
Pine, ponderosa (*P. ponderosa*)	4,060	5,270	740	430	1,150	6,300	9,200	1.26
Pine, red (*P. resinosa*)	4,160	6,070	650	460	1,210	7,000	11,000	1.63
Pine, longleaf (*P. palustris*)	6,150	8,220	990	470	1,500	9,300	14,300	1.93
Pine, shortleaf (*P. echinata*)	5,090	7,270	750	470	1,390	7,700	13,100	1.75
Pine, sugar (*P. lambertiana*)	4,140	4,770	590	350	1,050	5,700	8,000	1.20
Pine, western white (*P. monticola*)	4,480	5,620	540	—	850	6,200	9,500	1.51
Redwood (old-growth) (*Sequoia sempervirens*)	4,560	6,150	860	240	940	6,900	10,000	1.34
Spruce, engelmann (*Picea engelmannii*)	3,580	4,770	540	350	1,030	5,500	8,700	1.28
Spruce, Sitka (*P. sitchensis*)	4,780	5,610	710	370	1,150	6,700	10,200	1.57
Spruce, white (*P. glauca*)	3,700	5,470	540	360	1,080	6,500	9,800	1.34
Tamarack (*Larix laricina*)	4,780	7,160	990	400	1,280	6,800	11,600	1.64

Engineering data for wood, from Hoadley

Best Woods?

- Tend to be hard woods (dry redwood limbs break like chalk).
- Hickory stands out.
- Sitka spruce (not listed) is strong per unit weight (remember the Spruce Goose?)

General Observations

- Dry wood is stronger than wet wood (eucalyptus splits easier when wet).
- Wood is stronger in tension than under compression.
- Wood weakens with temperature , 2-5%/10F (perhaps why warm wood is more easily bent).
- Knots and grain run-out weaken wood.

Recommendations

- Watch your design and orient your wood to optimize the grain (chair legs, tenons, etc.)
- Tool handles are important: assess (hammers and mallets).
- Avoid poor material integrity (knots and grain run-out) which compromises strength.