Wood Expansion and Contraction

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The summer of 2011 in Gauteng was a remarkably wet one – I measured about 1100mm of rain, nearly double the long term average. Autumn has also been quite cool and wet, with higher humidity levels than normal. You have probably noticed lots of sticking doors and drawers. The end of summer is the best time to trim those sticking doors and drawers – they are probably not going to swell much more. Unfortunately, by the time you read this, the air has already started drying out as we slide into winter on the Highveld.

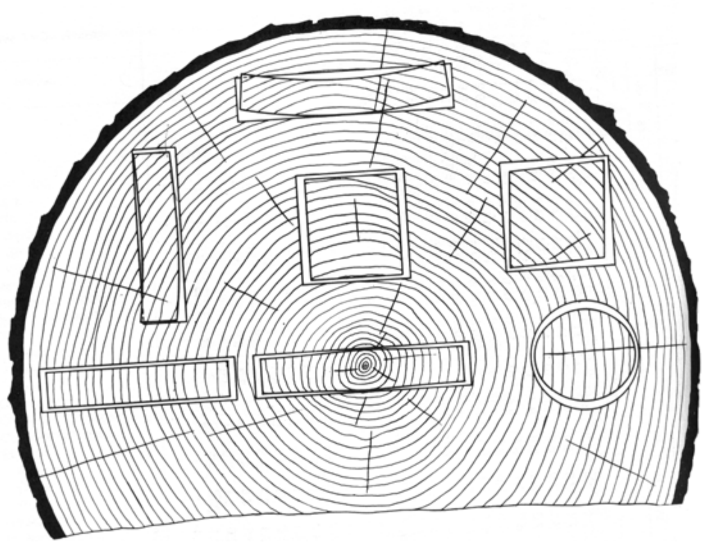
Wooden drawers and door stick because wood swells when it absorbs moisture. In summer, with higher humidity, the higher water content of the air is slowly reflected by the increasing moisture content of wood. We notice this because the wood swells slightly as it absorbs moisture. The process reverses in our dry Highveld winters. The lower humidity levels slowly draw moisture out of the wood, and the wood shrinks slightly.

Fine furniture requires close fitting doors and drawers. However, if you hope to avoid jammed drawers and sticking doors, you need to understand the basics of wood movement.

When wood is performing its primary function of supporting the leaves of a living tree, it is saturated with water. When the tree dies, the wood slowly dries out. If the wood is harvested for timber for furniture and joinery, the wood is seasoned and transforms from a relatively plastic, wet material to a harder, dry material. As the wood dries out it undergoes some changes – it alters chemically and it shrinks. The wood will loose water until it eventually reaches a level that is consistent with the humidity surrounding the wood. This is called the Equilibrium Moisture Content (EMC). A thin sheet of veneer will dry rapidly and then quickly track the environmental humidity. Conversely, a large log will take a very long time to equalize. The rule of thumb for drying or seasoning wood is “a year per inch thickness”. This is obviously not a hard-and-fast rule – variables such as temperature, humidity, coatings, air movement, grain direction and wood species affect drying. It does give you an idea of how slow the process can be.

To complicate matters further, wood is not a homogenous material and the grain direction influences how much it changes size. When it dries, it shrinks much more across the grain than with the grain. It also shrinks more in the direction of the rings (tangentially) than across the rings (radially). You will have seen this in how a slice through a tree trunk dries – cracks appear radiating from the centre pith to the outside of the trunk as the cells shrink when they loose moisture. The drawing below shows how wood shrinks as it dries depending on the location in the log. [Source: US Forest Products Laboratory (FPL) book.]

How much does wood shrink as it dries from wet down to the EMC? If you look at tables of wood properties, such as those published by the US FPL, you will see two figures quoted for each species – radial and tangential shrinkage from wet to EMC. Radial shrinkage is typically 2 to 6%. Tangential shrinkage (along the direction of the rings) is typically twice as much – 5 to 10%, but can be up to five times as much. Longitudinal shrinkage – along the grain is small enough – 0.1 to 0.3% - to be neglected.
Some figures are shown in the able below. You can see that they vary significantly between species. There is also considerable variation within a species and even within the same tree. (Turners will bear this out – they will have seen that a succession of bowls turned from the same tree will crack or not, not always predictably.)



Unfortunately, the movement of wood doesn’t stop once it has dried out and reaches the EMC. As the humidity around the wood changes, moisture diffuses into or out of the wood. This is gradual and can be almost imperceptible.
All wood moves as the moisture content changes with the seasons, so you need to know how to deal with it and make allowances in your designs. Man-made boards such as plywood tend to be more stable as the alternating grain directions cancel out movement, but it is only reduced and not eliminated. Sealing the wood with paint or varnish reduces the rate of moisture migration in or out, but doesn’t stop it completely.

If possible, design so that the movement doesn't matter or is concealed. Allow a table-top to move slightly on top of the base using clever fixings. Allow for gaps around the edges of panels in frame-and-panel doors. Orientate the grain so that movement occurs in the same direction, and not at right-angles. There are many examples to be seen in old furniture where cracks have developed in tops and panels where movement was not allowed for. If you know what to look for, you will often see cracks in old antiques.

The design may require you to allow for some movement, so how much? This depends on the species, the orientation of the grain in the wood and the moisture content variations.

You can see from the table that softer woods tend to shrink less. Also, softer woods tend to behave better, with less cracking as they dry, presumably because there is more elasticity to give as the wood shrinks. Some woods such as Jacaranda are remarkably well behaved, whereas others such as some oaks are very difficult.

How much to allow for? There is no precise answer, because there are too many variables. Here is an excerpt of a table from the US FPL:

Table 14 – 3—*Coefficients for dimensional change due to shrinkage or swelling*

Species	Dimensional change coefficient [1]	
	Radial C_R	Tangential C_T
		HARDWOOD
Alder, red	0.00151	0.00256
Apple	.00205	.00376
Ash:		
Black	.00172	.00274
Oregon	.00141	.00285
Pumpkin	.00126	.00219
White, green	.00169	.00274
Aspen, quaking	.00119	.00234
Basswood, American	.00230	.00330
Beech, American	.00190	.00431
Birch:		
Paper	.00219	.00304
River	.00162	.00327
Yellow, sweet	.00256	.00338
Buckeye, yellow	.00123	.00285
Butternut	.00116	.00223
Catalpa, northern	.00085	.00169
Cherry, black	.00126	.00248
Chestnut, American	.00116	.00234
Cottonwood:		
Black	.00123	.00304
Eastern	.00133	.00327
Elm:		
American	.00144	.00338

For each species, two Dimensional Change Coefficients are given:

- Radial (C_R) – across the rings and
- Tangential (C_T) – along the lines of the annual rings.

These coefficients are the change in size for a **one percent change** in moisture content (MC). The change is not linear, so these figures are based on a MC of 10% ±4%, giving a range of 6% to 14%. In Gauteng, at the end of winter, you can expect a MC of 6%, whereas at the coast, at the end of the summer rainfall season, you can expect around 11%. So one should allow for up to 5% variation.

The US FPL suggests the following calculation:

$\Delta D = D_I [C_T (M_F – M_I)]$

Where ΔD = Change in dimension
D_I = Initial dimension
C_T = Dimension change coefficient in tangential direction per 1% change in MC
(C_T is > C_R so use C_T for the worst case).
M_F = Moisture content (%) at the end of the change
M_I = Moisture content (%) at the start of the change

For example, using the figures in the table for **Cottonwood, Black** which is probably quite close to our local Poplars:

$\Delta D = D_I [C_T (M_F – M_I)]$
Using a value of C_T = 0.00304 and a range of moisture content from 6% to 11% = 5% :
$\Delta D = D_I [0.00304 \times 5]$
$\Delta D = D_I [0.0152]$ => 1.52% change in size tangentially

Across a table top of 1 meter width (D_I = 1000mm):
ΔD = 1000mm x 0.0152 => 15.2mm variation from dry, desert to moist, coastal conditions

This is probably the worst you could expect from Poplar. However, it is possible if a piece of furniture is moved from one extreme to the other, so it makes sense to allow for it. The value used for Poplar is pretty typical, but there are some higher ones. Scanning through the table gives several species with C_T above 0.004, and only one above 0.005, so 0.005 is the absolute worst case.

You have probably heard stories of some antique found in the Karoo taken down to the holiday home on the coast, or from the coast to Gauteng: It then cracks or splits. The change in humidity probably caused it. The antique was probably badly designed anyway – not allowing for wood movement, but that is no consolation to the owner.

Interestingly, the movement isn't always fully reversible – sometimes through the winter, the wood doesn't seem to shrink back quite as much as it grew in the summer. I suspect that some internal stresses are relaxing as it expands, and this why it doesn't seem to go quite as far back to where it started.

At the end of April 2011, I took the opportunity to tackle those sticking drawers and doors before they shrank down again for another year. Just a few shavings was all it took to free up two drawers made from beech. On the other hand, two cupboard doors made from Wit Peer (Apodites dimidiata – an indigenous hardwood from the Southern Cape) have grown by a couple of millimetres each, seemingly irreversibly over the last 8 years or so.

Sources:

www.wikipedia.org

Wood Handbook: Wood as an Engineering Material. 1987 US Forest Products Laboratory, reprinted by Sterling in 1989.