proposal

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1 Introduction to wood structure and formation

As trees grow they produce wood in order to become taller and wider. Becoming taller and increasing canopy size is an effective way to out compete the other trees and plants for light. With increasing height and width comes increasing weight, wind drag and internal pressures (for water transport), which requires either enough redundant strength in the existing structure (such as young monocotyledons) or for the tree to strengthen its structure as it increases its size. In dicotyledons and gymnosperms this occurs in two ways, apical and cambial growth on branches, roots and the stem(s).

Softwoods have a simpler micro structure than hardwoods, consisting mainly of axially elongated pointed cells named tracheids which serve as both mechanical support structures and water conduits. Although varying with species, softwoods may also contain radially orientated tracheids, radially or axially orientated parenchyma cells and other cell types. Tracheids are the dominant form of cells within the stems and branches.

Hardwoods contain a more complex micro structure with a number of different cell types. Fibres provide structural support as their primary function, while similar to softwood tracheids they differ in some key aspects, being shorter in the longitudinal direction, more rounded in the transverse outline, tend to have smaller lumens and have little role in sap ascent. However the ends do taper to points as in softwood tracheids. Libriform fibres tend to be longer than fibre trachiads, have thicker walls and are solely for support. Fibre trachiads function in both conduction and support, as in softwoods, however their appearance in wood with vessels suggests that they function primarily for support, and perhaps are an intermediate evolutionary feature between the softwood trachiad and the libriform fibre. Septate fibres devide their cell lumens into chambers without crossing the primary cell wall. Septate fibres are produced in the late stages of division just prior to the death of the cytoplasm, and appear to resemble axial parenchyma cells, and have been hypothesised to store starches, oils and resins.

Vessels are the main conduits for sap ascent. Vessels are comprised of multiple vessel elements being joined at the ends to form long conduits, which can

extend short distances (often less than 200mm) or can be as long as the height of the tree. These elements are connected through pores or perforations in perforation plates at the end walls of the cells. The arrangement of vessels into groups is species dependent and usually described as ring porous (the vessels congregate in early wood) or diffuse porous (vessels are distributed throughout both early and late wood).

Rays are formed from radially orientated cells often tracheids or parenchyma. Hardwoods typically contain multisteriate parenchyma rays, but there are a number of species with unisteriate or a combination of ray sizes, comparatively softwoods rearly contain multisteriate rays. Parenchyma ray cells are living within sap wood, however during the transition to heartwood die and are used for storage of extractives. Rays also provide a mechanical advantage by diverting the axial force flow reducing buckling and shear stresses between fibres.

Further cell types also exist, such as vasicentric tracheids which have profuse side wall pitting exhibiting deformation from the expansion of the surrounding vessels. Axial parenchyma cells are generally abundant and tend to exist in vertical files and are expected to play a role in the development of heartwood. More detailed wood anatomy and has little bearing on this project and is discussed in a number of wood anatomy texts.

In order to reorentat stems and branches of (most) trees produce reaction wood which provides a force in order to reorentat the tissue. Typicly this reorentation is toward the light or upwards as is defiend by the negative gravitr-posim hypothesises. Other reasons for reorentation such as reduceing wind drag have also be sugested. In softwoods this reoretion is caused by the production of compression wood. Compression wood forms on the out side of the stem or branch and (expands? so that it is under compression? causeing a restoring force). Hardwoods on the other hand produce tension wood on the inside of the desired curve which (contracts?) resulting in a curve forming. Tradtionly the galaterness layer (G-layer), a layer primerally consisting of low angle cellulose fibrils on the inside of the fibre tracheids, is credited with forming growth stresses within the tension wood. However some hardwoods produce tension wood without producing a G-layer such as E Nitens.

Primarily, at different resolutions this work focuses on the fibre tracheids as they are the structual cells expected to be responcable for growth stresses in normal and reaction wood within hardwoods. The fibre tracheids consist of a number of cell wall layers depending on the species, the particualar cell and its primary function. Normal wood fibres within Eucalyptus species (CHECK THIS) consist of a middle lamaner (conecting the fibre to the sourding cells) a primary cell wall and a secondary cell wall consisting of S1, S2 and S3 layers (produced in coronalogical order so the exact composition will change depending on the cells developmental stage). The S2 layer is the largest layer and consists of cellullose macrofibrils wraped helicly around the cells longitudinal axis. This cellulose is contained within a matrix of hemicelluloses (examples) and lignin giving the cell wall properties of a fibre reninforced matrix. –how does this provide structure–

In order for the living cambrial cells to produce wood, each cell must go

through devision from its perant cell, growth and death. Because the cambriam (and apical merastem) are continually deviding it alows for the tree to be a dynamic structure changing its form to become better adapted to its current enviromental setting even though large portions (ie the wood) are dead. The transition form devision through elongation and development to death is expected to play a role in the development of growth stresses within the stem.

1.1 Basic cell division

Dicotyledons and gymnosperms grow in two main ways, upward apical growth and outward cambial growth. Note monocotyledons (for example palms) do not produce secondary growth and instead diameter forms as part of primary growth.

As the cambium is forming, fusiform and ray initials are created. (how are the initials created) Fusiform initials are short radially and tangetialy with tapered ends. From the cambial initials, cells to the inside create the vertical elements of xylem (tracheids, vessels, fibers, parenchyma, etc.), while cells outside become phloem. Ray initials produce horizontal elements (rays).

Cambial cells divide in two ways, periclainal and anticlinal. Periclainal cell division occurs to the inner and outer of the cambial layers. As the cell division to the inside occurs the volume of secondary xylem that is being formed increases the tangential stress on vascular cambium resulting in an extention of the cambial circumference. Although over time many plants show an increase in the longitudinal and tangential dimensions of the cambial initials it is likely that this expansion is mainly facilitated by anticlinal division followed by the expansion of the daughter cells next to the pedant.

1.2 Cell formation, elongation and death

During primary wall formation rapid elongation occurs. When the cells devdie from their perants they remain fixed to their nabiours via the midel lamina. The intenal hydrostatic (turgor) pressure causes cell expantion. The osmotic flow of water from the outside the cell to the inside (due to a lower solute concentration outside the cell than in) which is constrained by the primary cell wall, the primary cell wall becomes under increasing tension as more water flows into the cell. Because the centre of the cell has restricted movment, in order for elongation (to disipate the increaseing tensile forces generated from the inflow of water) to occour the cell turns the biosythesis of cell wall constituants to produce tip growth. Growth at the tips of the cells allows for the cells to remain a cosntnat thickness, so no streching is needed during the elongation phase, as has been sugested previously. The expantion of the cells is suspected to be controld via modulation of the primary cell wall rather than via turgor pressure. – note that primary wall has randomly orentated MFs embeded in hemicellulose and pectic compounds and becomes lignified after S layer added , ML is non lignifed, note often compound middle laminer is used to describe the ML and P at once as are hard to distinguish— Once the cell has reached its full

size biosynthises of the S1 starts. Typicly the S1 layer is thin and comprises of very high angle microfibrials, within the layer many laminates are found. Within each laminate the MFs are closly aligned, however between each laminate they can (but do not nessassery) differ greatly, or even reverse the direction of the helix the MFs form around the cell, although lower right to upper left orentation tends to be favered. Close to the S2 layer the MFA decreases repidly. The S2 layer bound to the inside of S1 is typicly much thicker and has more verticly orentated micorfibrils compeared to the primary, S1 and S3 layers, these MFs circle the cell axis from lower left to upper right. S2 contains the majorty of the lignin within the cell. In some cases, most commonly in late wood a thin S3 layer is also produced with high MFA, reversing the direction of the MF helixs to lower right to upper left.

Finally if tension wood is being produced a Gelatonus layer may be proued on the inside of the inner most wall (S2 or S3). The G-layer has near verticly orentated microfibrils and very little lignification. It is suspected that the G-layer plays an important role in the generation of reorentation stresses.

At some point during the formation of the seconday cell wall, or soon after the cell shrings verticly and expands tangentially. Because of the connectivness between cells this results in growth stresses forming within the stem, this phenomonan is descussed in greater detail in —-. After the seconday wall formation cell 'death' occours as part of the transition from sap wood into heartwood. While the hollow, dead cells play an importnat role in water transport and mechanical support of the tree, over time any residual nutrant that can be used by living cells— heatwood stuff—-

What is the deal with Rays—-

1.3   Cells and wood in the context of a whole tree

Wood as a materal within the tree has three major functions to achive; water transport, nutrant transport and mechanical struture. Softwoods achive water transport and mechancial struture within trachieds, while parenchima cells are used for nutrant transport. Hardwoods have evolved a more complicated internal structure of vessels and fibre tracheids in order to seperates out the functions of water transport and mechanical support respectivly.

–advantages and disavantages of this–

The growth stresses that form as part of cell formation are throught to provide a superiour mechanical structure. Because of the continual formation of new cells providing growth stresses on the perifery of the stem the older wood which has completed its formation and cell death must be contracted further with each new layer of cells atempting to contract. The result of this is the older wood near the centre of the stem becomes compressed while the newer cells can not contract to the extent that would leave them in their lowest energy state remain in tension, until the bond between the old wood and new is seperated releasing the forces restricting this contraction (and extention in the centre)

Reaction wood as described above provides the ability for the stem to reorentate in order to be best adapted to its enviroment at any given time.

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These properties of wood allow for an adaptive organism to survive..

2   History of work on growth stresses

It is suspected that growth stresses develop within trachieds during the forma-
tion the secondary cell wall, although the exact timeing and mechanism for
developing growth stresses is still of much debate. The most current thoery is
a hybrid of the older cellulose contraction and lignin swelling hypothesis.

A breif discussion of work relating to growth stresses prior to 1965 is given
below, Archer (growth stresses book intro) provides a full review of sugested
theories up until 1965.

Wood workers have unintenionally known of growth stresses within trees for
centries. Usually refered to as 'a pull towards the sap' when cuting boards good
craftsmen would section the log in such a way as to get a stright board once it is
removed from the log (and the growth stresses relesed). Most work early on in
the study of growth stresses sorounded investigating how/why boards changed
shape when cut from an intact stem.

Martley (1928) was posibly the first to study growth stresses in a scientific
manner. Initally he argued that the curvature of planks sawn from logs was due
to the current growth not being able to support the dead weight of the tree until
lignification was complete. As a result the centre is under compression while
the perfifery had zero stress. However calculations showed that the self weight
was not sufficent to cause the observed longitudinal dimention changes of the
timber.

After Martley's work a small number of authors investigated growth stresses
through the 30's and 40's. Jacobs, although testing 34 hardwood species, fo-
cused mainly on Eucalyptus and in 1938 argued that (longtudinal) tension suc-
cessively develops in the outer layers of the stem as it grows, and as a concequnce
of of the tension, compression must form in the centre of the stem. Jacobs later
used E. gigantea to descibre a strain gradient developing during growth. Ex-
perementally Jacobs made use of strip placking, measuring the deflection of the
board after removal from the log, and the length change when the planks were
foced back straight. He showed that wood tends to shrink in the longitudinal
direction at the perifferly while extend near the pith (indicating in the log the
planks are under compression in the centre and tension at the extremities).

Further Jacobs put foward a number of hypothesis to explane how the growth
stresses were forming. First arguing that it is very unlikly that dead cells (wood)
could extend within the core in order to create the observed stress gradiant.
Instead sugesting the causes of; weight of the tree, surface tension and sap
stream forces, cellulose and collodal complexes, lignin intercellular substances
and the primary or secondary cell wall. Although without any evidence did not
claim any of these to be the major cause.

Stresses relating to reaction wood recived more attention through the 30s
and 40s for both soft and hardwoods. Jacobs 1945 stated that the reorentation
of stems is caused by a modification to the already existing stress gradient

throughout the stem. One option he presented was simply that the eccentric growth causes larger number of cell sheves to be added to the upper side of the curve each providing the same amount of contraction force, this results in a angle correction even with identical cells. Sap tension is also considered, but more importantly Jacobs notes the posability of tensions being formed within the cell walls of tension wood. Munch 1938 specualted that the addition of matter into the cell wall could cause compression wood. .. Jacobs 1945 also found that it was commanly the case that the amount of compression wood developed and the stem angle recovery had a poor relationship. He sugested maybe it was infact the normal strain pattern in tension which correct the lean, the compression wood mearly acted as a pivot, not contributing a tensile force on the lower side of the stem.

Boyed 1950 Developed a new expemental techneque in order to investigate the stress profile further. By cutting a slit longitudinaly in the centre of the log, attaching strain gauges onto the wood inside the slit and sucseivly shortening the log from both ends he obtained direct extention measurments from inside the stem. –found that the crossover point is is about 1/3 rad of the log from the perifphery–

Most commanly growth stresses were investigated from the longitudinal direction, however cells also change dimention in the transverse direction, this leads to a more complicated three dimetional stress feild developing within even a straight stem. koehler 1933 showed that a saw cut radially through a disk has a tendancy to close near the perifery sugesting that the periferal cells are under tangential compression with the inner cells under radial tension. He sugested this was the cause of shakes in standing timber. jacobs 1945 removed inner circals from disks of a number of speceis and found when an inner portion is removed the disks cercunfrance incresses. Jacobs again argued that strain in the sap stream along with cells being wider tangentally than radially led to the observed lateral stresses. Although he also mentions the posability of secondary thickening from the deposition of lignin as a posabe contributing factor. boyed 1950a developed and experement whereby he removed a wedge from a disk and meaured the radial expantion, showing the disks were infact under radial tension. Further aditinal species were found to be in agreement with the results of jacobs 1945 when the inner circils were removed from disks. Boyd also shows that the longitudinal stresses maifesting as transverse stresses via poisson ratios are only aproximatly one tenth that of the measured stresses.

Boyd 1950c provides an indepth rebutel of the available theries at the time, arriving at the conclusion the the cell wall development must control the shape change which results in growth stresses. Further he postulates that cellulose is primarily responsible with lignin and carbohydrates also playing important rolls when stresses are formed in normal, compression and tesnion wood.

wardrop 1965 commented that a tensile stress generated in the cellulose transitioning into a crystaline state could be the explination for cells contracting during the formation of the secondary wall. Cellulose contraction alighned well with the observation of the G-layer (which has a very low MFA) being comman in a number of tension wood producing species, and also gave the ability for low

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MFA normal wood to contract. Bamber 1978 further argued cellulose contraction claiming turgor pressure in normal wood cells remained high enough that the cells did not contract before the lignin was deposited, once/during lignin deposition the cellulose became crystaline and shrunk, causing the cell to become shorter, the mechanism for tension wood is essentially the same. Compression wood on the other had was explaned by the cellulose being layed down and then the turgor pressure decreasing, causing the cell to contract before lignin was deposited. In turn the cellulose was under compression, resulting in the tendency for the compression wood cells to expand.

Boyd (1972) presented (or rather poplerised) the alternative hypothesis of lignin swelling (first conceved by Munch 1938). Tensile stress is gained in cells of low MFA by lignin deposition into the cell wall, pushing the cellulose fibrils appart, which in tern shrinks the longitudinal length of the cell and incresses the tangential width. When MFA is high, the opersite occours, lengthing the cell and reduing its tangential width. This shape change is not redally apartent in compression wood (characterised as short fat trachaids) untill the release of the stress acting on the CW, where by the cells become longer and skinnier.

Around the same time two other lesser known hypothesis were presented, strains due to changs in water content Hejnowicz 1967, argued that the stresses in compression wood are related to the inhibition of water by the cell walls, which results in swelling, because the expansion of compression wood is equal to the shrinkage due to drying. –paper disproving this–

brodzki 1972 hypothesised strains due to 1,3-linked glucan (laricinan) deposition within the helical checks of the S2 cell wall layer could be the most significant factor in longitudinal growth stress generation. Boyd 1978 refuted this idea arguing (along with other issues) that the laricinan would expand into the cell luman not casuing any stresses in the cell wall, unless a (non-observed) constraining meadian restricted the expantion.

Through the late 70's and 80's archer produced a number of studies –refs– mainly concerning the mathamtical treatment of the stress feilds within trees.— Archer —

Gills 1973

More recently theories regarding the nature of hemicelluloses and their bonding have been used in an atempt to remove some of the issues assocated with the cellulose contraction theory. One major issue of callulose contraction is that in its inital form it was argued that the crystilisation process of cellulose shortend its length. –ref– showed that when cellulose crystalised it became longer as the chains increased order. Two theories have been advanced to combat the issue of lengthinging during crystalisation in order to retain an updated version of the cellulose contraction hypothesis.

— argues that at the edge of the cellulose fibrils the cellulose becomes dissordered and is concequently able to bond with hemicelluloses, which have a slightly shorter repeate length than the cellulose crystel. These hemicelluloses bondend to the outside of the fibril cause the fibil to be compressed in the cystaline centre, while under tension on the surface. An intersting concequnce is the contraction of the cellulose due to the hemicellulose bonding should be

dependent on the area/volume to circunfrance/suface area ratio. A potentual way to test this hypothesis is ducussed in section —

The seccond theory put foward in an atempt to correct the issues souronding cellulose lengthinging during crystalisation is from — who argues that hemicelluloses form within the fibrils and push them appart causeing the cellulose fibrils to contract. Interestingly mechanicly this is very similar to the lignin swelling hypothosis. By in causing the MFs to no longer run stright, instead they have to use some of their length to devate passed a culster of hemicelluloses concequently shortening the over all distance the fibril can cover. One side effect of having these devations is fibrils should not have a consistant cross sectional area over their whole length, where the hemicelluloses have been deposited should result in an increased cross section. potential way to test this?–

The most resent attempts made to describe the formation of growth stresses have been made by yamamoto and his team. They argue a combination of both lignin swelling and cellulose contraction is needed, called the unified hypothesis. It should be noted that — and others sugested that both theories were likely to contribute to growth stress generation. By unifing the hypothesises they follow the current thinking of a number of authors in other areas of wood science that both tension and compression wood are not distictly different types of wood and are instead extreme versions of normal wood.

issues with current understanding: When and how do the stresses get generated is still of much debate, over the last couple of decades it has become fairly widly accsepted that the generation of the stresses occours during or imediatly after the deposition of the seconday cell wall. Most commanly either the G-Layer or the S2 layer are considered responcable. why do they varry so much between indervidualls and species? One of the more debated topics around growth stress generation is whether the generation mechanisums for stress in reactionwood are extreme versions of the same mechanisums in normal wood. The G-layer is not found in normal wood, however on rear ocastions .. .. lignin swelling could potentially fit this criteria for normal and compression wood, hopwever modification of boyds theory would be needed due to the depence of a MFA as some wood with lower than about 40 degree MFA still produces compressive forces. Boyds theory combinded with excessive mild compression wood formation in corewood still alows for the same tensile generation mechanisums to be used by older cambriams, as long as the MFA is suited to the task. how can we quantify the mechanical advantage with so much varablity what about the other unusuall forms of reaction wood, hebe etc

Note Muller et al 2006 found low hemicellulose content in G-layer timell 1969 higher conc of lignin in s2 layer when G-fibres present

2.1 Why growth stresses exist

Hardwoods typicly have much larger growth stress magnitudes than softwoods. –why– is this true 'xylem cell development'?— some have claimed conifers have compression throughout the stem when young, not until old that they follow the same trend as hardwoods

Prehapse the leading argument for the reason of growth stresses existance is the mechanical hypothesis. The mechanical hypthesis argues that a number of wood properties, inclusing the development of growth stresses evolved in order to provide increase mechancial stability to trees in order to increase their servival. The mechanical hypotheisis as applied to growth stresses argues that because wood is stronger in tension than compression by preloading the outer edge of the stem in tension it increaseing the non-destructive bending radius on the inside of the curve when a force is applied causing the stem to bend. –dosnt explain why hardwoods have larger GS than softwoods, or why young softwoods exibit compression.– This hypothesis struggles to explane the differences between hard and softwoods, particularly at young ages. If mechancial stability is infact the driver for growth stress generation at young ages, why do young angiosperms and genosperms produce esentually opersite solutions?.

If the reason conifers have compressive forces when young is excessive compression wood to enable reorentation, maybe this idicates that normal wood is more colosly realated to tension wood than compression wood. What forms of mild tension wood are known of?

speculation from various authors Typicly when atempting to determain the reasons for why wood properties exist one of four hypothesis are used; mechanical, hydrolic, time dependent and a combonation of the previous three. Inital speculation as the the reason for growth stresses existance came from Martley (1928) who breifly entertained the mechancial hypothesis based on self weight. Jacobs (1945) sugested they were a biproduct of sap tension, which he later retracted Jacobs (196?) when sap pressures were recalculated at a much lower value than the genrally beleived values at the time. .. Growth stresses undobutable have an effect on the mechanical stability of trees, although it is consevable that the effect may be biproduct of another driver.

2.2   Intro to the issues growth stresses cause

for harvesting dangerous for feller splitting of log at felling internal checking boyd 1950

within mills bending/bowing/warping during cutting jaming up saws, large proportion of waste, multiple cuts required to get boards to desired dims

lost revenue, final yield less than 30

3   Theoretical and experimental understanding of growth stresses

3.1   Background of breading

Because growth stresses cause a number of issues for harvesting and milling timber tree breading programs can be used in order to select for genetics which reduce these effects. –previous breading for GS– There is no reason to expect breading for growth stresses differes significanly from (convetanally) breading

trees for any other trait, which is process which has been developed over centries. Over the last few decades many advances have been made in experemental and statistical techneques which rapidly improve the time and acuracy of conventinal breading.

field techniques Typically breading trials, like any sciantific exprements are designed in order to minamise noise from uncontroled varables,

laboratory techniques

stat techniques

mention tradeoff with durability etc

3.1.1 Beading work in this thesis

What we actually have:

Harewood trial: dec 2014 has bosistoana and argophloia copiced from old planting that mon has GS data from. –from data can show (kind of as could argue same enviromental effects caused it) genetic relationship. New Harewood trial, 2016 harvest, will have a number of species potential to copice bos again if needed.

Woodvile, 2016/2017 harvest will have Bosistoana, argophloia and possibly globoidea. May or may not be the same families as the various drylands trials.

NOTE family means same mother, not same father. If collected at different times even from the same tree variability exists due to possibly of different set of fathers. Also some self propagate, but we don't know which ones or what proportion, so ignore this.

Progeny trials are alpha latauses, harewood is a standard randomised individual trial.

Contact Ruth McConnachie: rgcmcconnochie@xtra.co.nz for DFI details.

slit tests Pairing Test and Longitudinal Growth Strain: Establishing the Association 2008 is the earlyest paper I can find on the split/paring test. note kens papers from mon

surface tests

Potentually use NIR http://www.afs-journal.org/articles/forest/pdf/2002/05/05.pdf Has some useful info on wave lengths associated with bonds ic cellulose

Non-destructive evaluation of surface longitudinal growth strain on Sugi (Cryptomeria japonica) green logs using near-infraredspectroscopy

statistics

Progeny trials are alpha latauses, harewood is a standard randomised indervidual trial.

PLSR etc for NIR work

normal breading stats?

3.2 Background of chemistry work

lignin swelling

cellulose contraction

what has been done in the past? that xray syncotron experement etc

3.2.1 Chemistry work in this thesis

Do all of the DFI species have a G-layer? Maybe include some Nitens tests if they don't. check MFA and SD for S_2 in tension, normal and compression/opposite wood Get cellulose lignin and hemicellulose(s) contests for tension normal and compression/opposite wood Split hemicelluloses where possible, eg xyloglucan etc. Torsion tests on individual cells, again for tension, normal and compression/opersite. Maybe remove G-Layer in tension wood and compare to normal and compression wood of similar MFA and compounds etc.

Get G layer MFA, remove and get S2 MFA, how does this compare to normal wood MFA, or similar GS wood which does not produce a G layer?

Could we somehow measure growth stress release on a single cell? Ideally, grow disordered cells invitro, and separate them from the parent cell as soon as possible, then record when in their formation they undergo what dimension changes. Is there some non-destructive test to check what is going on in the cell? or if we have multiple cells in the same conditions maybe we can destructivly test some during the growth phase, under the assumption they are all growing at the same time. OR remove the cambial layer leaving top and bottom of cell attached to the stem on a large sample, then somehow remove the connection to the cells behind it, then release the top and measure the contraction.

Take pure cellulose measure the repeate length of the cellulose units, then add hemicellulose to it and measure the repeate length, does it contract. Idea being that hemicellulose bind to the dissorded cellulose on the outside of the fibril which have a smaller chain length, resulting in the fibril being under tension on the outside and compression on the inside. outside hemi under tension, inside crystiline cellulose under compression. Could also calculate this by working out the force required to shorten a hypothetical fibril of crystyline cellulose, then trying to find a hemicellulose bonding scheme which would provide it. This could be checked by taking different diameter fibrils, resulting in different surface to volume/area ratios should result in different contractions.

looks like H c c c c H H c c c c H H c c c c H where the H-H bonds are shorter than the c-c bonds (H and c stand for hemi and crystyel)

other comman theory is that hemicelluloses form inside the cyrstel and push the chains apart shortening the length

c c c c c c c c c c c c c becomes c c c c c c H c c c c H c c

to experimentally test lignin swelling is there a way to remove only the lignin from the cell wall? then see how much the wood/cell extended, then cut it again and see if it extends more.

take sample with a G-layer and apply a vacumme pump to it to suck in enzimes whcih degrade only the G-layer (they do exist) and measure the strain releif, then run a split or sectioning test to relice the rest. This will give the proprtion of the reaction GS due to G-layer and due to S2. Would have to some how get the enzyme into the fibres not just the vessels.

Or if we release the stress with a split test/planking etc, then remove the G layer we should see a relaxation back towards the the initally observed state.

3.3   Background of modeling

yammamotos most resent attempt

possible different methods ¿ FEM, DEM, molecular dynamics, gemomentry of stem and cells

3.3.1   Modeling in this thesis

cells as partials in relaxed state

apply body force, ie the growth stress field

get original/non cut stick back

take take groups of repressive cells and use composite theory and position dependent body force (growth strain field) from the sub domain above

introduce time dependence to see how the stress field develops during maturation, composite scale still – each cell can have its own clock so that it has a maturation rate to change its field variables.

take individual cells at macromolecular level and try to produce stress field above during a time dependent maturation function

Molecular dynamics simulations to work out the molecular mechanisms developing the growth stresses

Using the MD sims paramertorize a cell model

Using the cell model develop a time dependent field function

from the field function create representative cell blocks

put the cell blocks together into a stick

cut the stick ¿ do we get out what we put it?

Or just model a single cell and try to show what would be needed under different conditions to make lignin theories work. For example under what conditions can we move away from boyds 40 degrees. Could include a provisor for cellulose contraction in here. Make sure to have a theory which also produces aproprate tangentail stresses

Try to make a model of a single cell using lignin swelling only. G layer can be bowed by S2 layer (S2 under lignin swelling) to cause contraction more efficantly than the S2 layer due to the very low MFA in G. Could then use this model to peramaterise slit experment simulation.

4   Intentions

to improve breeding stock for NZ dryland forestry with respect to eucs being used for structural timber

to increase understanding of growth stress formation particularly in eucalyptus by chemical analysis and computer modeling

5 Objectives

to create a mathematical model and computer simulation of a piece of cambium forming growth

stresses at the macromolecular level

to investigate the chemical causes of GSs by chemical analysis ¿¿ how?

to improve breeding stock for eucs wrt growth stresses from field and lab testing to select appropriate families.

6 Costs

7 Timeline