Session 4
Paper (c)

# INTERNAL DEFECT SCANNING

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## Introduction

I am here today speaking on behalf of the Production Technology Department, Massey University. The department itself has research interests which might be of interest to this conference this week. We do some research in the detection of surface defects of boards using image processing techniques, crack propagation in timber (that's the understanding of crack propagation with a view of learning how to control it), and the expansion of plywood. That's particularly run on behalf of a manufacturer who wishes to turn plywood into large scale pieces of equipment, as he needs to know what the expansion properties are. Other than that, the department has interests in measurement and management of quality, of which I'm not going to speak anything of today, even though this is all about quality, because my colleague, Dr Brian Wenmoth will tell you much more about that on Friday. We will also deal with machine vision, particularly its industrial uses, and process control, that's one of my interests. In particular, we are looking at the application of modern mathematical methods in process control to the improvement of the quality of process control. And finally, others in the department are looking at automation of manufacturing.

My interests, of course, in process control don't really impinge on what the talk is about. However, I do some electronics design contract research work, and this is leading to the development of a piece of specialised computer hardware, which will produce X-ray computed tomography pictures at video rates. We have proved the feasibility of doing that at a very economical cost. Really what we are talking about is technology, not just image processing, and future technology is going to impinge on all of the elements you hear of.

Assessment of the logs on skids or at mills is also going to use devices such as radar length measurement, particularly for characterising the log and maybe determining where it should be bucked. Other uses for scanning technology are log value assessment by vendors and customers, and optimal milling.

The latter two, in fact, can be delt with by internal defects scanning, and that's the title of my talk today. Really we are crystal ball gazing. Nobody is doing it yet for real, not out in industry, not out in the logging scene, and not in the saw-mills. However, recent research has shown that there is a considerable financial gain, particularly in the larger saw mills, from implementing some form of internal scanning. However, those particular studies were concerned with hardwoods, and there is still a question mark as to whether internal research scanning is going to be a real practical value for radiata pine. I think it probably will, but that's only a reaction; what we need is hard facts. Some of those hard facts I do believe have been gained, but they have not been publicly released, so we have a question mark there.

Most of these measurement methods determine indirectly a measure of density. That implies that the defects we are trying to locate must have a difference between the defect density, and the surrounding wood. Now, of course that wood might be mature, it might be pith, which would be the defect itself or it might be sapwood. The difference between the density of the defect and the sapwood will depend on what the type of defect is. If one is mainly looking for knots sapwood then tha is particularly difficult in Pinus radiata, because they happen to be very closely related with each another in terms of density. We may be looking for inclusions as they're easy to find as the density difference is quite great. We might be looking for the core to the sapwood to determine core diameter of the log.

That's really the problem, trying to locate and position the defect core in Pinus radiata. The measuring methods currently being studied are X-ray CT Scanning, Impedance CT Scanning, Ultrasound CT Scanning, and recently Nuclear Magnetic Resonance.

Let's have a look at how each of these work, because in actual fact, there is no winner in this field - not yet. Some are more advanced than others, and some have particular properties which may be useful, but none are proven, so we ought to have a look, and see how they work.

Internal defect scanning using X-rays

This is very much the same as the medical world, however, of course, the equipment itself will be constructed in a much more rugged fashion, and indeed be quite a lot larger than medical scanners that are currently available. The other thing that is of importance is that we want the information to come through at the same rate that the log is moving through the mill or through the yard. That means coming up with essentially real time rates for the pictures coming out. Actually, we need it a little bit faster than that, because those pictures themselves will need further processing down the line to contain the information that we actually require for cutting. That's our opening point there. The X-Ray machine itself.

There is an X-ray machine available as the Americans are studying it. In fact the company that produces it has a team which is developing the machine for log scanning. However, they are only developing it in terms of hard woods for the American market. They are trying to get it into the large scale saw-mills in America. They will be successful, I suspect as there is a financial gain to be made. How much of that research will be relevant to Pinus radiata has some question over it.

In an X-ray Scanner we pass X-rays through the log, we collect them on the detectors, we pass them to that interface equipment which in effect, is a computer, which analyses those X-rays and determines a picture. The analysis equipment afterwards turns those pictures either into a 3D scan, or into information about the position, size and type of defects. The interface equipment and the analysis is currently being developed. The X-ray equipment is currently being developed. None, of course, is out there yet, but it will be.

The X-ray equipment available is fast and rugged. I've seen the Imatron equipment, and they have passed logs through it. I doubt if it will last long in its present state in the field, but it will be developed. It is portable as it will certainly fit on the back of a Mack truck! They call that portable. Picture reconstruction can be done in real time. I have been shown that it is feasible at very low cost. The results analysis is available, and people are studying that at the Waikato University, and producing algorithms for the extraction of information from the X-ray pictures.

Impedance CT Scanning

Here, what we do is we apply voltages between two of the points, and measure the voltages at other points around the log. The equipment has to make contact with the log. Notice that in the X-ray equipment, there was no necessity for contact between the measurement equipment and the log. Indeed, the only moving parts in the Imatron equipment is the conveyor for the log itself; there are no other moving parts in the equipment. In this one, however, we have to make point contact with the log at something like 32 or 64 points around the circumference of the log. That's not impossible, but we must have points going into the log. They don't have to break the surface by very much to be effective. The path of the current between a point is not a straight line and that makes the analysis of the results very much more difficult. X-rays don't get deflected; rather they get absorbed, and therefore the path is a straight line. You know what the path is, and therefore we only have to calculate the density along the path.

Here, we have two problems - we have to calculate not only the density along the path, or at least the impedance of the path, which is they say, related to density, but also the path itself. So, we have a dual problem here, which makes the reconstruction not impossible, but very much slower. We don't have at the present time have real time for reconstruction. The equipment itself is inexpensive. It is, in fact, the cheapest method so far. However, the computation for the reconstruction of the information, is not in real time, and I hazard to suggest that that is not a practical proposition if you want to put one of these things in a saw-mill. You really have got to have the infomation coming out as fast as the logs go in.

Resolution is only low to marginal. Once again the real problem here is that we've got to determine two things, rather than one. So we need twice as much information to obtain the same resolution. The number of points that make contact give us the resolution, and unfortunately we would be limited to 32 to 64. So the low resolution makes it a marginal method. The most important point, of course, is that it is cheap.

Ultrasound

Ultra-sound penetrates wood in the 100 khz range. At that frequency sound is attenuated in air by the odd millimetre or two. What that means is that we must have no air between the source of the sound and the log that we are trying to measure. The methods that have been used up to present for most of ultrasound scanning for those frequencies is to put it into a liquid bath - usually water. However, there is a particular problem in terms of logs in this situation. If the log is not debarked, or even if it is, there will be large inclusions of air on the surface of the log, and there will be many bubbles in the water. Present ultrasound scanners would see all of those bubbles much better than it would see any defects in the log. So, ultrasound is probable one of the early losers in this situation. However, it is relatively inexpensive, and it is easy to do. We have severe difficulties in putting the sound into the log.

The reconstruction again is difficult because of the path curvature. It is not as bad as the previous method, but the path does curve due to the density, so we would have to concentrate the path as well. It is relatively inexpensive, probably in terms of the X-ray and the NMR It does give us some poor resolution.

Nuclear Magnetic Resonance

The last method is relatively new, even in the medical world. We do have whole body scanners, so we are now approaching scanner sizes which would be appropriate but which are not yet large enough. Outer electromagnetic rings produce a field along the log but only over a short strip. It produces a magnetic field along whatever it is in effect analysing. That magnetic field has to be exceptionally dense, and to do that, the electrical coils that produce the magnetic field have to be run in superconducting mode. To get that at the present time we need liquid nitrogen. In the medical scanners it boils off at a litre an hour. You could buy a few dinners with a litre of that stuff , so the cost of running it, and the problems of safety in terms of the of the fluids, would be a matter to overcome.

Though there are no X-rays of course, (X-rays themselves need good safety measures to ensure that the operator doesn't get dosage of it) the dosage of the excessively large magnetic fields will lead to troubles as it's an invisible thing. Operator safety has not yet been tackled in this.

The method relies upon the ability of the protons within the molecules to be able to preaccess. We generate a very dense magnetic field, a radio field, which has the same frequency as the precession rate of the molecule. It might seem very technical, but there is an important point about this, and that is each molecule has its own precessional rate. This means that this method inherently has the ability to discriminate between the types of molecules that it is actually determining the density of. The best one is hydrogen, and hence water, but we can also discriminate on carbon, potassium and oxygen. That gives us the possibility of not just looking for the water in Pinus radiata, and there is a lot of it inPinus radiata. Indeed that forms the biggest question over the X-ray scanning techniques, as to whether some of the defects have any real significant density difference between them and the surrounding sapwood, because of the saturation of the log and the defect by water.

This method may well have a means of discriminating those defects. We could look for different types of defects, just by simply changing the frequency of the inner magnetic field with the RF detector. At the present time, it's expensive. However, with high temperature, superconductors becoming available, that may well drop. The high maintenance costs associated with liquid nitrogen, even the high temperature methods or materials, will require syrogenics. That will be much closer to the temperature of solid carbon dioxide, dry ice, rather than the more expensive materials currently used.

Its will be bulky as one might expect. To be able to generate a magnetic field of high intensity requires a very large magnet. When you talk about bulky, it will still fit on the back of a Mack truck, so it's still doing as well as the X-ray equipment.

The reconstruction methods are at present slow, but that is really a matter of insufficient knowledge of how to speed that process up. It's an emerging technology, and one that I feel will probably come to fruition.

## Conclusion

In the race I think X-ray computer tomography will in fact, get there first. The Americans are developing it and I feel that they are confident that they will succeed and will get it out there. I suspect that it's going to be there in the next few years. Nuclear magnetic resonance is unproven at present, but it has properties which make it very attractive, particularly when trying to find defects which the X-ray will have significant trouble in doing. And so, that may well prove, in the end to be a better method. It really sums up the crystal ball, if you like, on internal defect scanning. Nobody has done it yet in the field. We have passed logs through the medical scanners, and we have actually interpreted the results to find the defects. But it is not equipment that is currently available. But I feel that it will be.