Gympie Chipout; a report on the identification of the root cause and the solution using laboratory and plant trials

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Abstract. This report fully details all work on the problem of chipout at the Gympie factory of Carter Holt Harvey Panels carried out by the author including a full literature review on the blending of particleboard. All of the techniques used were developed while the author was a undergoing doctoral and post doctoral studies at the Australian National University. It includes the identification of the mode of failure of chipout, a full statistical analysis of all trials carried out by CHH in 2002, and full details of all laboratory work carried out at both ANU and the Hexion Technical Centre, Deer Park Vic. It also includes full details of plant scale trials carried out at the Gympie factory. The report is divided in to the following sections;

- Statistical analysis of previous work.
- Comparison of Gympie and Mt Gambier furnish and cycles using a lab press
- Identification of mode of failure
- Blending efficiency of G1 furnish
- Wettability of flake
- Plant trial on G1
- Recommendations

Keywords: Wetability, Microscopy, Surface tension, Surface energy, Surfactants, Blending, Chipout, Machinability, Particleboard, Laminating

1. Introduction

The problem of machinability of LPM manufactured from Gympie particleboard has been significant since 1997. An improvement was made with the reduction of dryer outlet temperatures however since the introduction of flat bed routers at remanufacturing facilities, the problem has become more apparent. On such routers particleboard made from Gympie presses was substantially worse than board made from Mt Gambier PB1 or PB2 product of which is transported to SE Qld in lieu of the unsatisfactory nature of the Gympie product. This was believed to have cost the company $500,000 per month.

2. Statistical analysis of previous work

1. There is a significant side effect. It is always on the top of the board from laminating. Given it is from both rawboard lines and G1 board is turned once and G2 board is turned twice it can only be an artefact from testing or something that is occurring from the laminating press. This can be sorted out with routing at JB's.

2. There appears to be a difference between both rawboard presses with board from G1 having higher levels of chipout than board from G2.

3. It certainly appears as though higher surface resin loadings result in better chipout performance.

4. More MF resin in the paper gave conflicting effects however a detailed trial conducted by me in 2001 eliminated paper as a possible cause and should be discounted. However the difference in laminated finish i.e. velvet or decor could be analysed.

5. The addition of PVA resin to the MUF had no effect however as a single resin system it appeared to have an effect, which was not picked up in the original analysis. This may need to be pursued however at a lower priority.

6. The removal of shavings appeared to decrease chipout whereas the original analysis did not pick this up. This could indicate that with shavings dust levels increase and this was shown in some trials to increase chipout.

7. The addition of surfactants had no effect. This is an interesting finding and needs more work as surfactants improve the wettability and penetrability of liquids on solids by reducing the interfacial energy between them. This is an entirely different effect of reducing viscosity of the (by adding water) as this does not change the wettability of the liquid to any degree and in some cases can make it worse.

8. The addition of dust to the surface flake gave inconclusive and conflicting results, I believe that no inference should be drawn from this until laboratory work is carried out.

9. Reducing surface resin loadings had a major negative effect on chipout on G1 but not on G2. This is a confusing result and may have to be redone in the lab.

10. On G1 it appeared as though when the first surface spreader was set to 70

11. Changes in overall density on G1 did not appear to have any effect on chipout.

12. The use of two spreaders appeared to improve chipout

13. Two pass sanding improved chipout

14. The reduction in surface density caused a significant improvement.

15. The addition of PVA had a negative effect on chipout.

As a result of the conflicting and non-conclusive information from the work carried out in 2002, it was recommended that laboratory work be carried out at Hexion's laboratory press at Deer Park using flake from Mt Gambier and Gympie with press cycles approximating G1 and MGPB2. Classification of the surface flake was also considered as a factor.

This made a 3 factor (Flake, Press cycle and Surface flake classification) 2 level design (Gympie & Mt Gambier, Gympie & MGPB2 and Classified & Not classified) i.e. 8 treatments per replicate. The 2 additional replicates meant a total number of treatment of 24 boards.

3. Comparison of Gympie and Mt Gambier furnish and cycles using a lab press

A lab board study was undertaken at Hexion's Deer Park Technical Centre to study the effect of various parameters on chip-out. The experimental design was fully orthogonal and statistical analysis was carried out using analysis of variance. The following details the factors studied where sieved surface flake .

Treatment	**High**	**Low**
Press cycle	*G*1	*MGPB*2
Flake	*Gympie*	*MGPB*2
Surface	*Sieved*	*Unsieved*

Full details of press cycles and set-ups can be obtained from the author.

There were no significant factors at the 95% confidence level however at the 90% confidence level there was a significant difference *(p = 0.081)* in machinability with different sources of surface flake with board made from Gympie flake having 22.3 chips per hundred metres whereas flake from Mt Gambier having 14.5 chips per hundred metres. However it must be noted that even though the press cycles were accurate representations of the cycles for G1 and MGPB2 the method of blending was very different from high speed blenders. All of the components of the surface resin to be added were mixed prior to blending. Due to the very low water tolerance of the MUF resins used the resin mix had a fairly high viscosity and was very slow to pass through the paint gun nozzle into the blender, hence blending times were of the order of minutes rather than seconds. As will be shown later this in itself was very valuable information.

4. Identification of mode of failure

The aim of the study was to determine the mode of failure of chipout that is affecting market acceptance of laminated HMR particleboard from Gympie. Chipout (Figures 1 & 2) occurs when during machining of the edge of laminated particleboard, chips of the laminated surface break of the machined edge. Up to date, the exact mode of failure has not been determined, i.e. was just impregnated paper alone or whole or part particles being removed from the freshly machined edge.

4.1. Sample preparation

Sections of Gympie laminated 16mm HMR particleboard from the G1 line were taped using gaffer tape on the edges and routed using the Holzher spindle moulder that is the standard tool used by CHH to measure chipout. This enabled the piece chipped out to be retained and matched with the hole it left. The hole was then gently removed from the remainder of the board using a scalpel.

Samples for examination using light microscopy needed no further preparation. Samples for SEM imaging were attached to 12mm aluminium SEM stubs using double-sided carbon tape.

The samples were subjected to sputter coating at $1x10^{-4}$ Torr and SEM analysis $1x10^{-5}$ Torr.

As wood is a poor conductor of electricity, the specimens were rendered fully conductive by coating them with a 250 angstrom film of gold and palladium (60:40) in order to prevent "charging" distortions of SEM images. Gold coating was carried out in an argon gas sputter

coating unit (Emitech K550X) using 20 mA ion current for approximately 240 s. All of the techniques used are fully detailed in All of the techniques used are fully detailed in [2].

4.2. Imaging using SEM

The samples were examined using a Cambridge Instruments S360 Stereoscan scanning electron microscope fitted with a high brightness lanthanum hexaboride (LaB_6) electron source. Secondary electron and backscattered electron images were obtained. The latter had the most contrast between the resin coated and uncoated particles. A filament current of 1.9 A, a probe current of 1.21 nA and an electron accelerating voltage (EHT) of 20kV was used during imaging. Sample magnifications varied according to the particular feature being imaged with the magnifications being noted on the image along with a scale bar. All of the techniques used are fully detailed in [2].

4.3. Imaging using light microscopy

A Wild Photomakroskop M400 with a high-resolution digital camera was used to obtain images. Varying magnifications were used which are noted in each image caption.

4.4. Microscopy results

4.4.1. *Results of SEM analysis*

Of the 92 samples examined using SEM, only one sample showed any evidence of resination either on the chipout piece of chipout hole (Figure 4). Note in the image that where there is resin present, the detail on the surface of the flake appears somewhat blurred and where there is no resin on the flake the surface detail can be seen with high clarity. Figure 3 shows both the hole and particle caused by chipout. This image shows that the only resin evident is the saturating resin within the LPM paper. There is no resin on any of the flake either in the remaining hole or the chipout particle itself. What SEM analysis does not make clear however is whether the particles of flake are actually breaking as opposed to being chipped out whole, which would obviously result in little resin being apparent or whether there is very poor resin distribution. Figures 1 & 2 show details of the hole left by chipout and the particle that caused it.

Chipout/SEM/Image60.eps

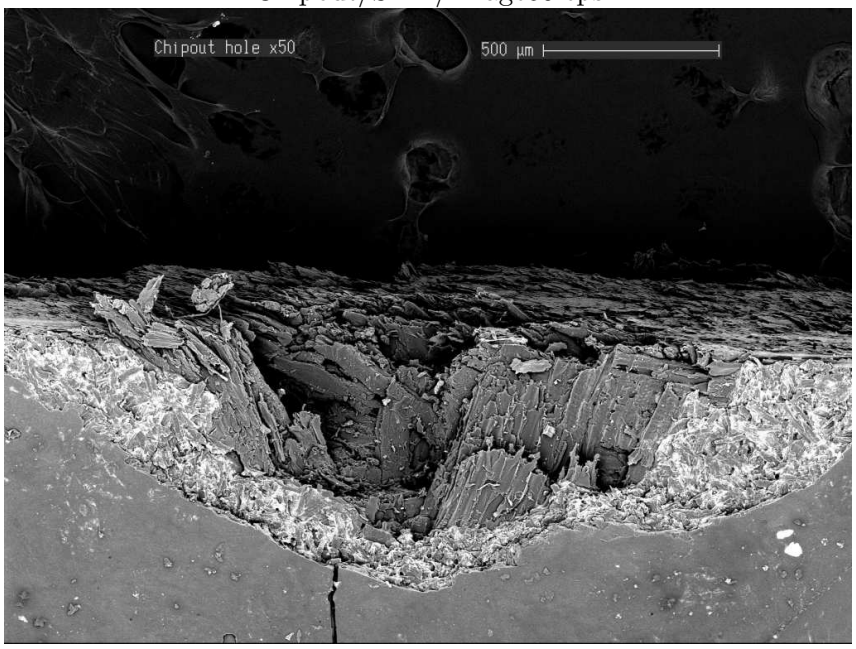


Figure 1. Scanning electron microscopy image x50 of the void caused by chipout.

Chipout/SEM/IMAGE62.eps

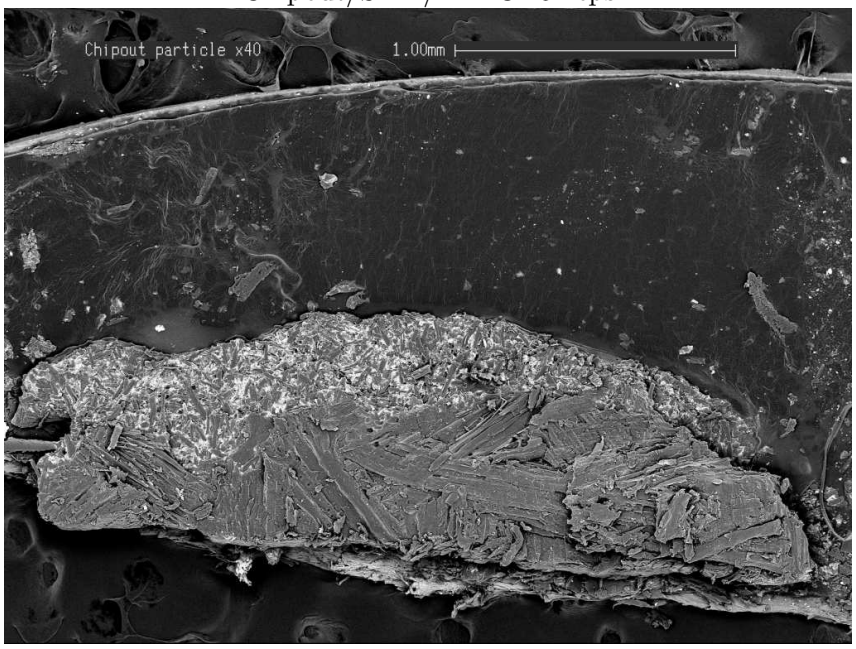


Figure 2. Scanning electron microscopy image x40 showing the particle that came out of the chipout hole in Figure 1.

Chipout/SEM/Image33.eps

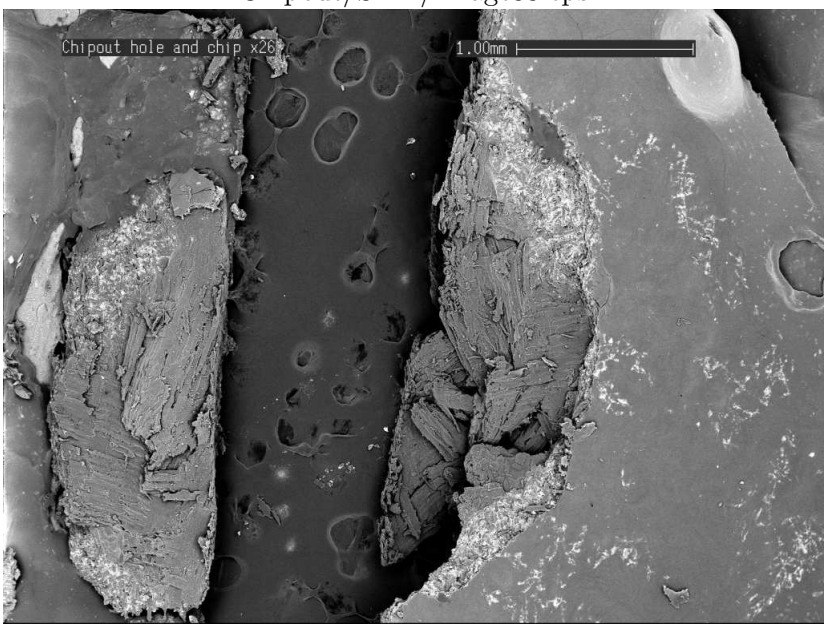


Figure 3. Scanning electron microscopy image x26 of the void (RHS) and particle (LHS) caused by chipout.

Chipout/SEM/IMAGE50mod.eps

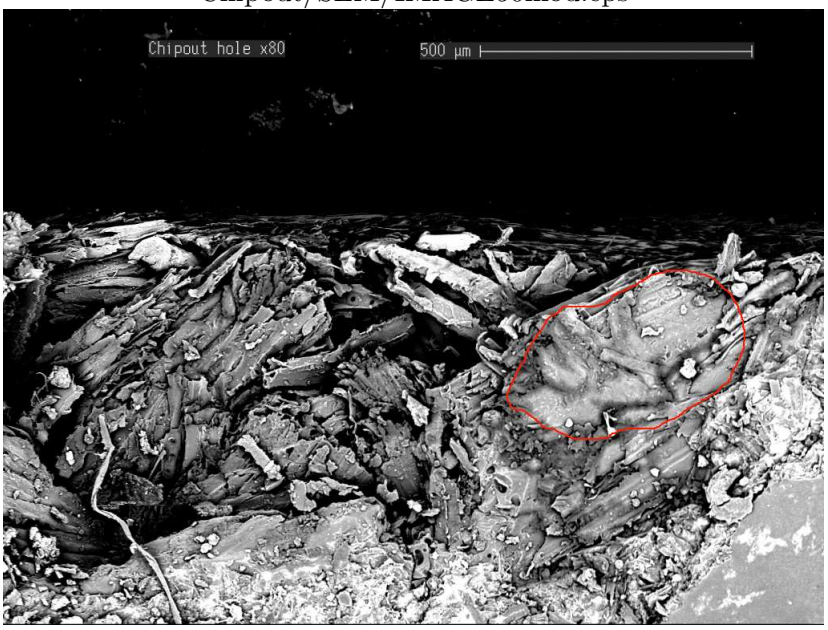


Figure 4. Scanning electron microscopy image x80 showing some resination of particles in the chipout hole.

4.4.2. *Results of Light microscopy*
28 samples were examined with light microscopy.

Figure 5 shows a chipout particle showing that the area of paper is larger than the actual amount of wood particles removed. This was the case in every instance showing that even if a small particle is dislodged a resultant much larger section of laminated paper is removed leaving a bigger void caused by chipout. The paper actually delaminates i.e. the melamine coated layer splits from the UF impregnated core. This is more clearly shown by SEM. especially in backscattered mode. Figure 6 shows the corresponding void from the chipout particle in Figure 5. Figure 7 shows a chipout particle and corresponding void. It also shows that the chipout particle has evidence of sap-stain fungus and there is no corresponding sap-stain fungus on the chipout void. This suggests that the particles are chipping out whole i.e. they are not actually splitting up.

The other aspect that was examined was the particle geometry of Gympie surface flake. It can be seen from Figures 8 & 9 that the aspect ratio of the flake is excellent and only very few "cubic" flakes were observed. The flake geometry shown in the images is very good and would only enhance the ability of the flake to be maintained in the surface matrix and thus was not considered as part of the problem.

Chipout/Lightmicroscopy/Image5compressed.eps

Figure 5. Light microscopy image x32 showing the particle removed during chipout.

Chipout/Lightmicroscopy/Image4hole.eps

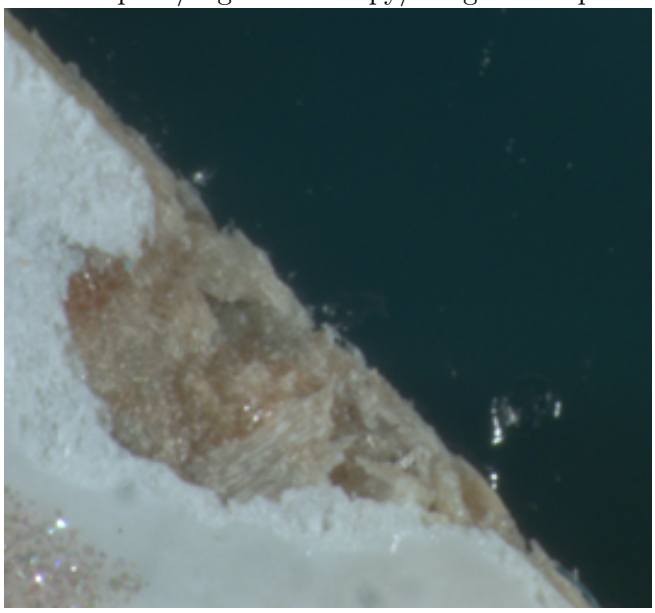


Figure 6. Light microscopy image x16 showing the void caused by the removal of the particle in Figure 5.

Chipout/Lightmicroscopy/Image17.eps

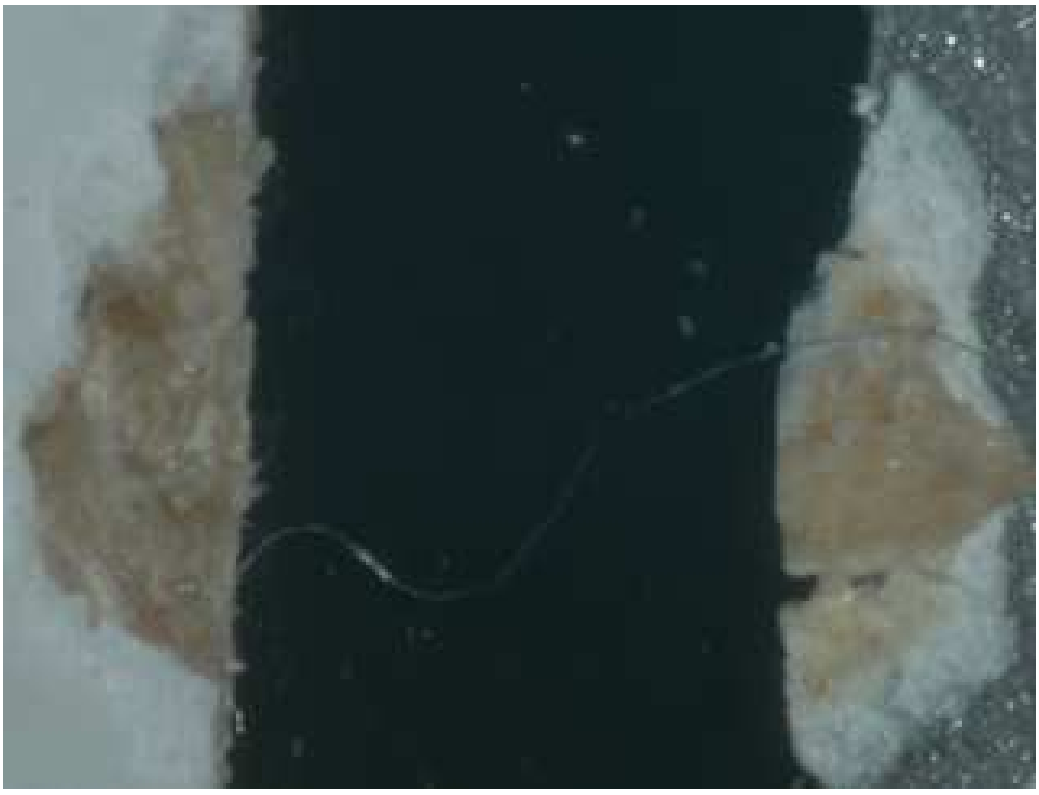


Figure 7. Light microscopy image x16 showing both the void and particle caused by chipout. Note that the evidence of sapstain in the hole is not evident in the removed particle, i.e. the particles which were removed were whole and not fractured.

Chipout/Lightmicroscopy/Image8.eps

Figure 8. Light microscopy image x32 showing particle geometry of Gympie surface flake.

Chipout/Lightmicroscopy/Image11.eps

Figure 9. Light microscopy image x32 showing both particle geometry of Gympie surface flake. Note the high surface area to volume (aspect) ratio.

5. Blending efficiency

As demonstrated above SEM and light microscopy examination showed that firstly there was insufficient resin on both the chip-out particles as well the remaining void. It was also shown that the particles were not fracturing and that particle geometry was not a factor. A technique was developed to determine the distribution of resin on individual flake. The presence of red dye on the flake indicates a lack of resin. Figures 10 & 11 & 12 & 13 show a heavy presence of red dye on all of the particles that had chipped out. This shows that there was very little if any resin on these particles fully explaining why they chipped out, i.e. if particles are not strongly bound to each other in the surface then machining will easily dislodge them, hence chip-out.

Chipout/Lightmicroscopy13April/Image4.eps

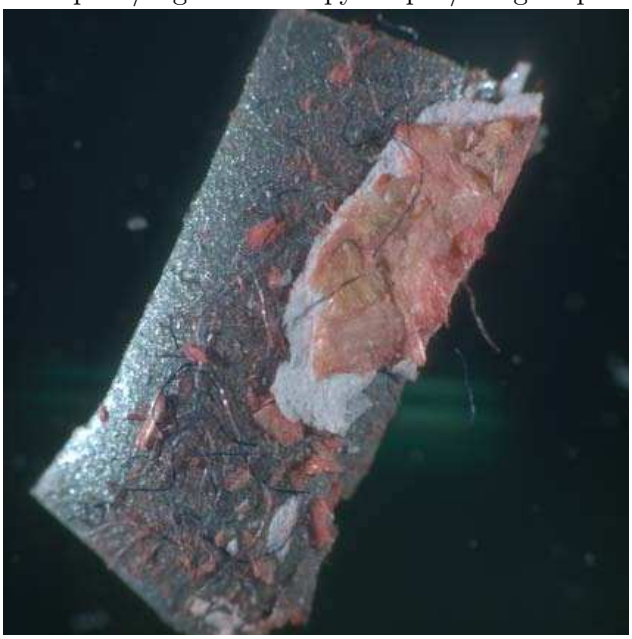


Figure 10. Light microscopy image x10 showing both particle removed as a result of chip-out, note presence of red dye indicating little resin.

Chipout/Lightmicroscopy13April/Image7.eps

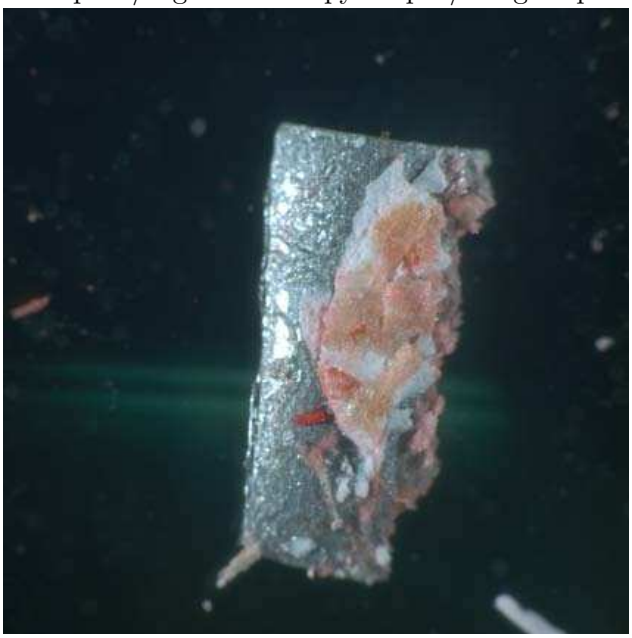


Figure 11. Light microscopy image x10 showing both particle removed as a result of chip-out, note presence of red dye indicating little resin.

Chipout/Lightmicroscopy13April/Image10.eps

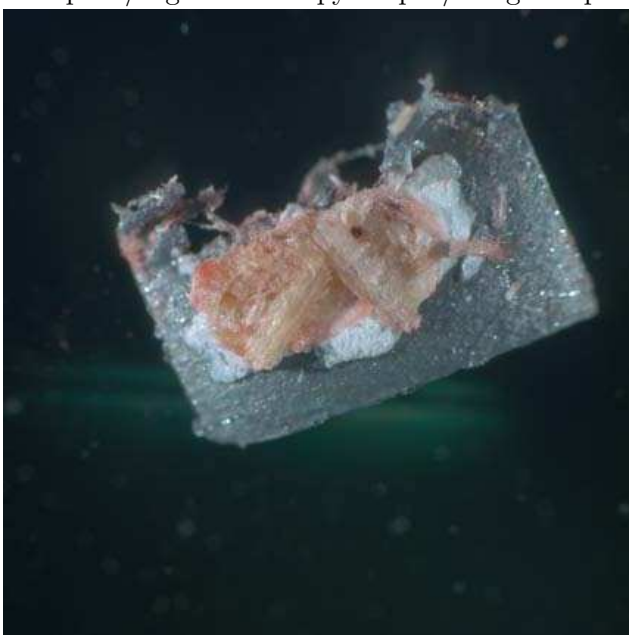


Figure 12. Light microscopy image x10 showing both particle removed as a result of chip-out, note presence of red dye indicating little resin.

Chipout/Lightmicroscopy13April/Image13.eps

Figure 13. Light microscopy image x10 showing both particle removed as a result of chip-out, note presence of red dye indicating little resin.

A detailed examination of resin distribution was conducted on blended surface flake ex the G1 spreaders and the situation was exactly the same as with the chip-out particles themselves. There was very little flake that exhibited effective resin distribution. The following images (Figures 14 & 15 & 16) are taken from surface flake from the G1 spreaders, i.e. after blending. Most showed little or no resination. Figure 17 shows some degree of resination, however this degree of resination was rarely seen. Less than 5% of the flake was effectively resinated and >70% of the flake had no resin whatsoever.

It thus became apparent that there was a serious blending efficiency issue with surface flake at Gympie.

Chipout/Lightmicroscopy12April/Image44.eps

Figure 14. Light microscopy image x20 of blended surface flake ex the G1 spreaders showing little resination as seen by presence of red dye indicating little resin.

Chipout/Lightmicroscopy12April/Image50.eps

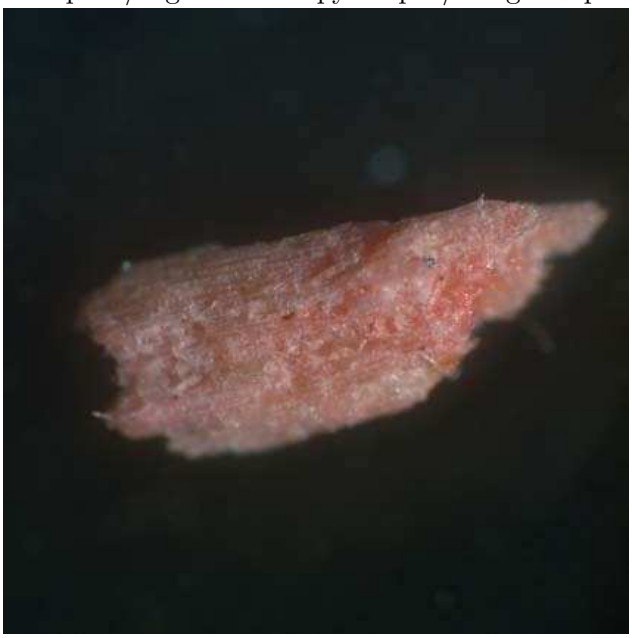


Figure 15. Light microscopy image x20 of blended surface flake ex the G1 spreaders showing little resination as seen by presence of red dye indicating little resin.

Chipout/Lightmicroscopy12April/Image45.eps

Figure 16. Light microscopy image x20 of blended surface flake ex the G1 spreaders showing little resination as seen by presence of red dye indicating little resin.

Chipout/Lightmicroscopy12April/Image46.eps

Figure 17. Light microscopy image x20 of blended surface flake ex the G1 spreaders some resination as seen by a lower concentration of red dye on the flake.

6. Wettability of flake

Before 1997 Gympie board made with Hoop surface was OK and it is known that Mt Gambier board made with Radiata has no machinability problems. However the current Gympie board made with predominantly slash surface and performs very badly when machined on flat bed routers thus t here appears to be a species effect which is thought to relate to how effectively the species blend. Blending is a function of the surface free energy of the flake and the surface tension of the liquid, the interfacial energy between the two. Thus the surface free energy of each species was measured using contact angle determination using a KSV Contact Angle Goniometer.

The following images show how droplets of water wets the different species used by CHH:

It is easy to see from Figures 18 to 20 that Slash pine is a non-wetting species whereas Hoop wets very well, explaining the reason why Hoop surface board machined well. The reason is that there is a very high resin content in Slash pine which under high temperature drying convert to fatty acids on the surface of the flake which are very hydrophobic. This would explain the finding by Ross Cunningham that with reduced drier temperatures resulted in better machinability properties because there is a lower level of conversion of wood resins in the Slash pine to fatty acids. Therefore the chipout problem is therefore caused by poor resination of surface flake, which is predominantly Slash pine. This is due to low surface energy of slash pine and high surface tension of resin mix (high interfacial energy)

Chipout/Dropletimages/Slash.eps

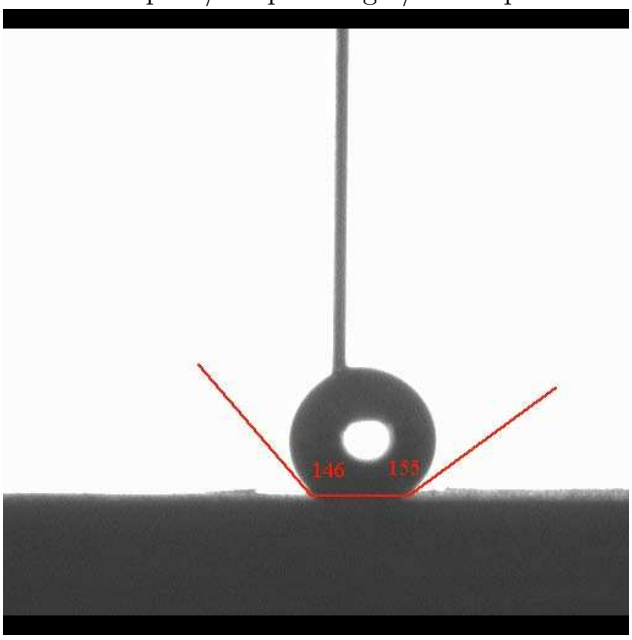


Figure 18. Light microscopy image x20 of blended surface flake ex the G1 spreaders some resination as seen by a lower concentration of red dye on the flake.

Chipout/Dropletimages/Radiata.eps

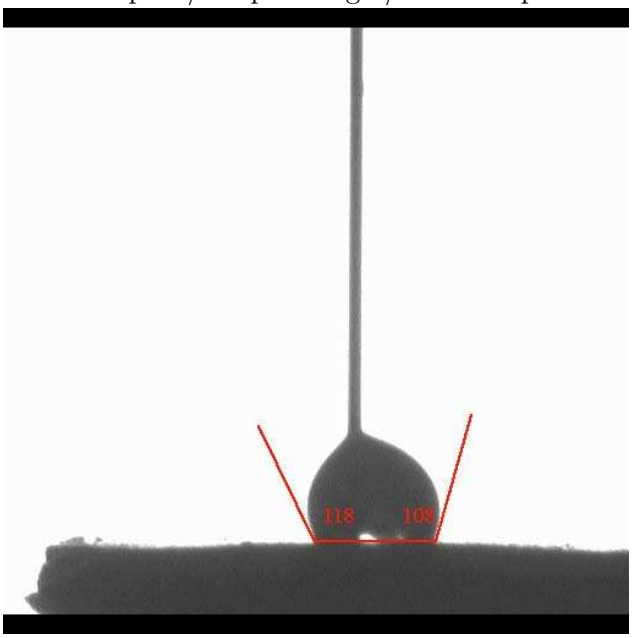


Figure 19. Light microscopy image x20 of blended surface flake ex the G1 spreaders some resination as seen by a lower concentration of red dye on the flake.

Chipout/Dropletimages/Hoop.eps

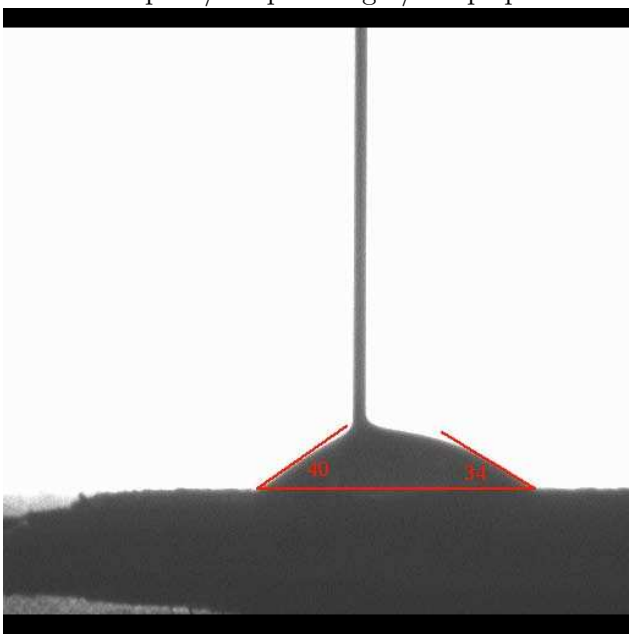
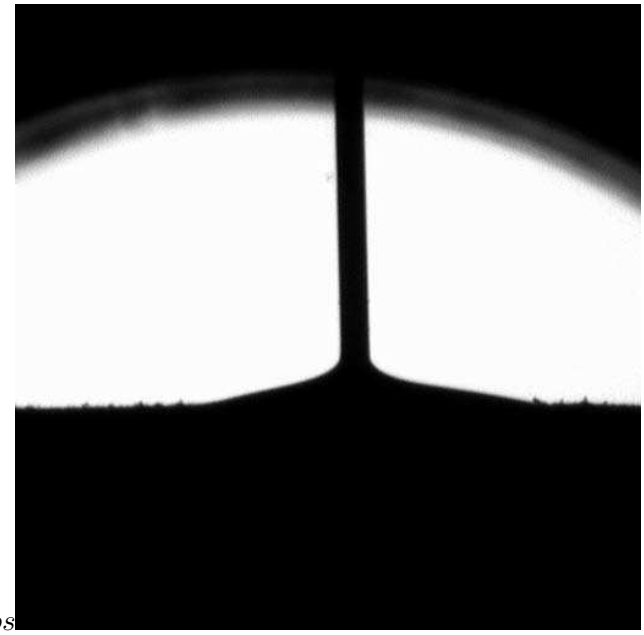


Figure 20. Light microscopy image x20 of blended surface flake ex the G1 spreaders some resination as seen by a lower concentration of red dye on the flake.

6.1. Improving the wettability of Slash pine, lab studies

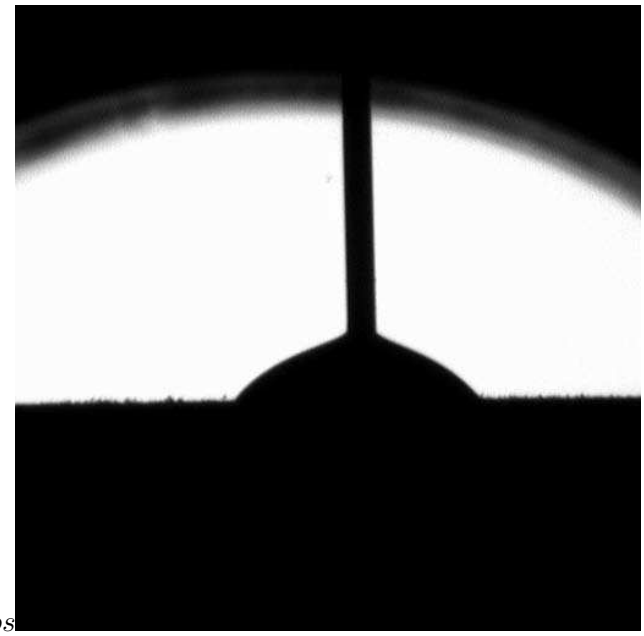
There are two ways to improve the wettability of Slash pine and in doing so affect how well they blend. Increase surface energy of flake by increasing the flake moisture contents or decrease the surface tension of the resin mix by adding compatible chemicals either charged surfactants or longer chain alcohols. A number of surfactants were firstly tested for compatibility with the MUF resins used at Gympie. This ruled out some options.

In the end a number of combinations of concentrations of Teric N9 an alkyl nonylphenol ethoxylate non-ionic surfactant sourced from Hunstman Chemicals were added to water to pre-wet the flake and in so doing increase the surface energy of the wood and to the resin to reduce the surface tension of the resin. In the end a combination of 0.1% N9 added to the water with 0.5% N9 added to the resin proved to be the best combination as determined by measuring contact angle. Figures 21 & 22 show the effect i.e. reducing the contact angle from above 140° to less than 20°.



Chipout/STimages17May/C1$_1$.*eps*

Figure 21. Light microscopy image x20 of blended surface flake ex the G1 spreaders some resination as seen by a lower concentration of red dye on the flake.



Chipout/STimages17May/C1$_3$.*eps*

Figure 22. Light microscopy image x20 of blended surface flake ex the G1 spreaders some resination as seen by a lower concentration of red dye on the flake.

7. Plant trial

A 16 treatment plant trial was carried out on G1 with the following factors:

Treatment	**High**	**Low**
Cycle time	360*s*	234*s*
Water addition	50%	10%
*N*9 *in Resin*	1.0%	0.5%
*N*9 *in water*	0.5%	0.1%

All additions of chemicals were done in the batching tank manually and hence were very accurate.

The boards were laminated and tested on a Morbidelli Author 600X flat bed router at Just Benches on the Sunshine Coast, a major purchaser of Gympie LPM. New cutters were used for each trial and the spindle speed was 18,000 rpm with a feed speed of 30 m/min. Each board was machined for 100 lineal metres, with the chipout being measured every 4th, 8th, 12th, 15th, 20th 25th 30th up to 60th boards i.e. potentially up to 6000 lineal m.

The optimal treatment was a board made at the shortened cycle of 234s with 1% N9 in the resin and 0.5% N9 in water with 10% water (as a ratio of resin) addition. Full results of these trials can be obtained from the Gympie site but in summary, this board produced one large chip per 100 lineal metres, compared with Mt Gambier board which achieved 1.9 chips per lineal metre. An interesting side light that came out of the trial was that the boards with extended cycles had much better physical properties. This led to a short trial with extended cycle times and showed that at 234s, boards were not being fully cured. This would have a major impact on formaldehyde emissions which will be the subject of future work. The reduction in the surface water has had a concomitant effect of reducing the rate of heat transfer to the core of the board. This has resulted in a reduced and slower level of cure for the core resin which was why the boards produced with extended cycles had better physical properties. The undercure of course will also lead to higher levels of free formaldehyde. This was the subject of a separate report ([1]).

Subsequent to the board trials it was recommended to Gympie that the amount of N9 in the resin be increased to 1.5% and in water to 0.75% to allow for variations in addition during production. It was found that there was a regular $3 - 5\%$ shortfall in dosing the N9 into

the resin which had a major negative effect on machinability. The afore mentioned dosages should compensate variations in addition rate and still result in the production of good quality board.

It would appear that reducing the water addition to the surface has reduced the surface density from on average over $1050kg/m^3$ to around $900kg/m^3$. This has had the effect of reducing smaller chips. The increased blending efficiency has had the effect of reducing the generation of large chips.

8. Recommendations

- The amount of Teric N9 in surface resin is 1.5%
- The amount of Teric N9 in water be 0.75%
- The amount of surface water added is 10% of the amount of resin added.
- Surface density be kept at around $900kg/m^3$
- Work be carried out to improve the cure of the core resins given the drier surface moisture.

As stated above given the sensitivity of the dosage volume, it is essential not to under or overdose. Therefore it is very important to ensure that volumetric checks are carried out on a regular basis to ensure that the dosing systems are in fact giving the correct volumes.

A wide ranging literature review was conducted which showed little understanding about the factors discussed above. It is therefore strongly recommended that this information be kept in-house and not given to resin companies as it gives Carter Holt Harvey a significant advantage over other particleboard manufacturers as machinability issues are systemic with the product, and this has been a major breakthrough.

9. Caution

This is a solution for the surface resins only i.e. uncatalysed resins. There appears to be an interaction between the surfactant and speed of the resin and thus possibly formaldehyde emissions. The performance of this surfactant will have to be tested against different resins especially catalysed resins and the use of it in this situation before full analysis will be at the user's peril.

References

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2. Roberts, R., "Liquid penetration into paper". *PhD Thesis, The Australian National University, Canberra, ACT, Australia* (2004).