Solving the problem of chipout in laminated particleboard and improving the performance of high speed blenders

A detailed examination using SEM, light microscopy, and Goniometry

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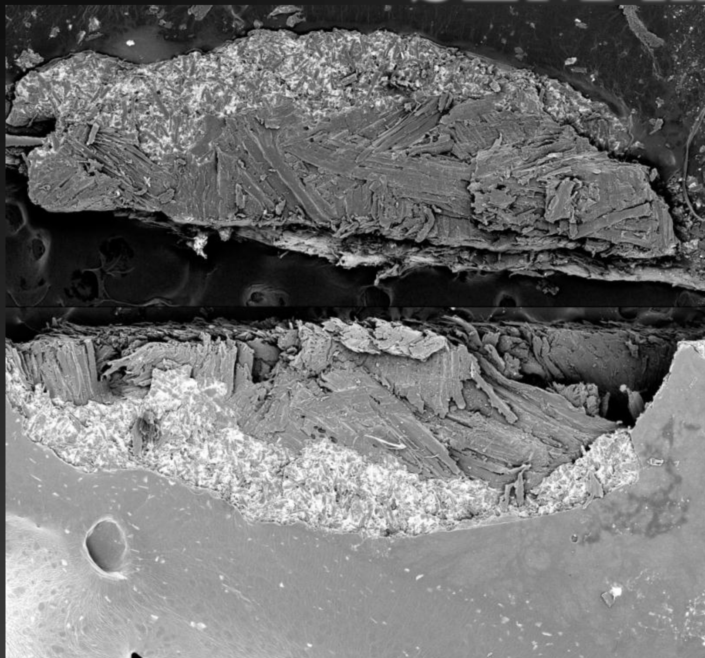
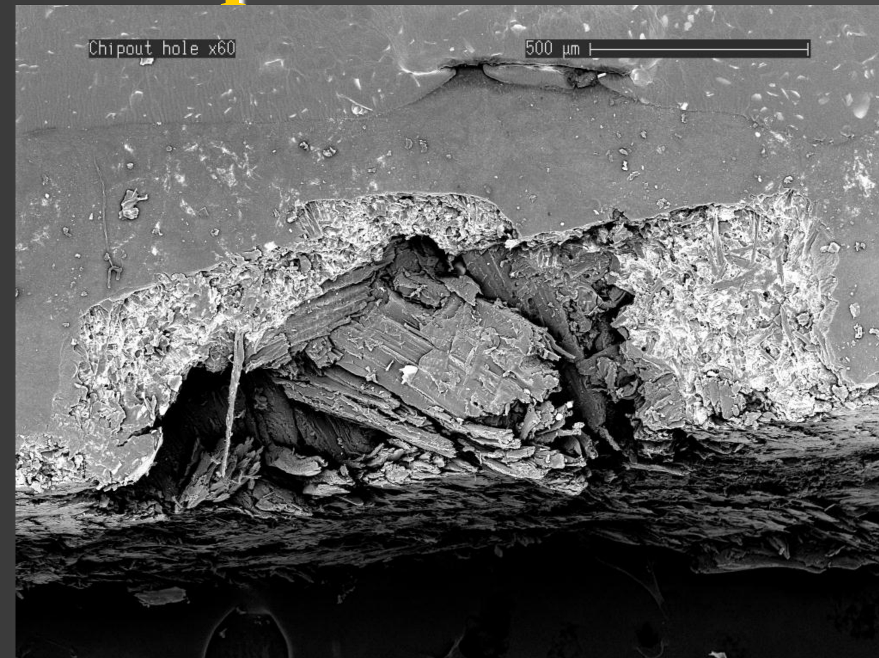
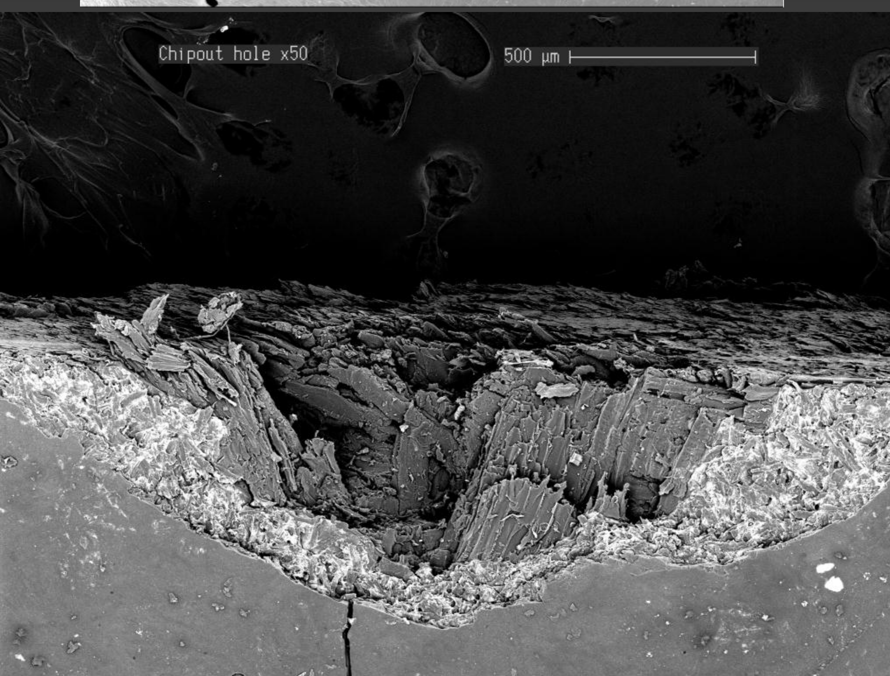
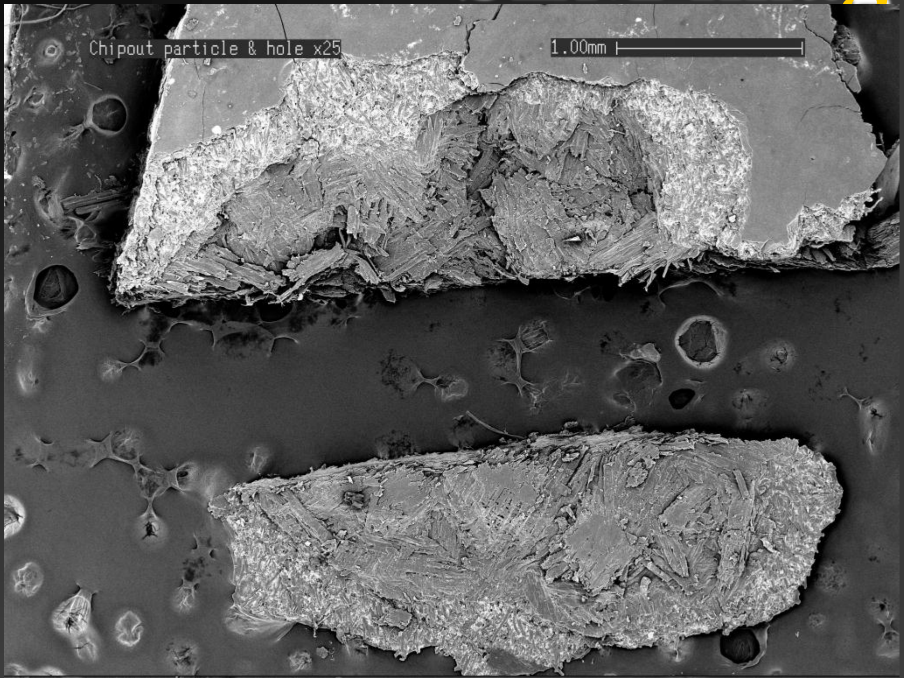
SEM images of chipout

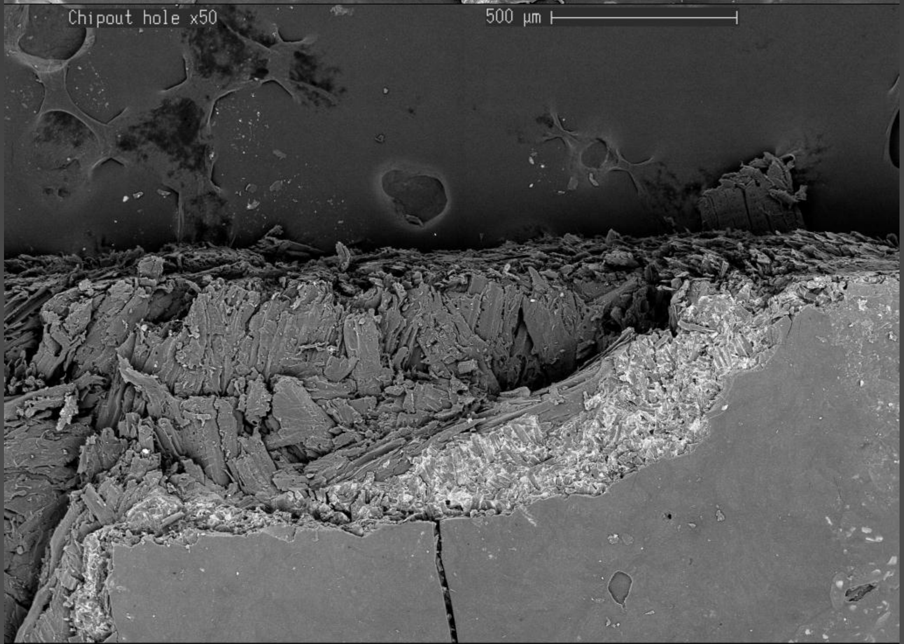


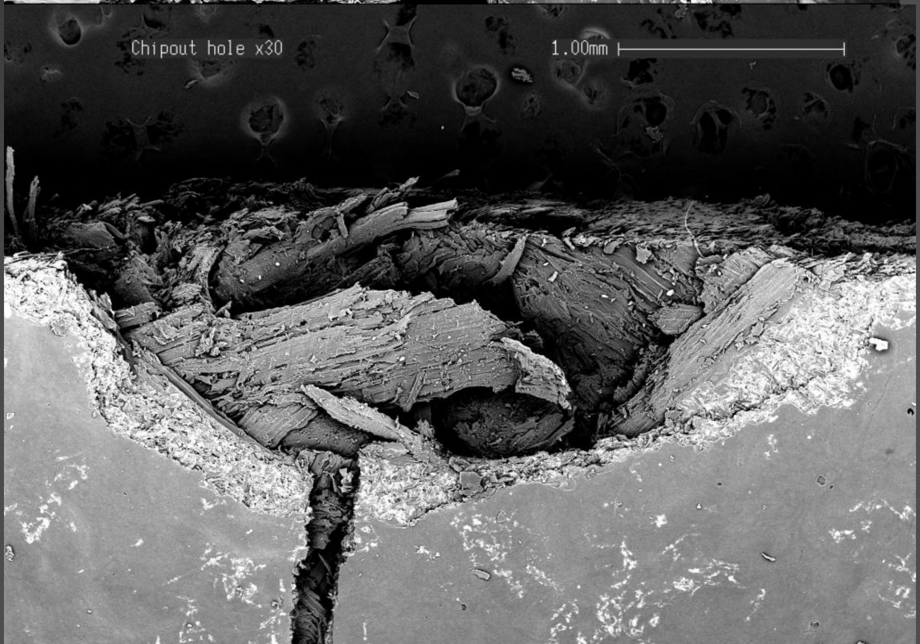




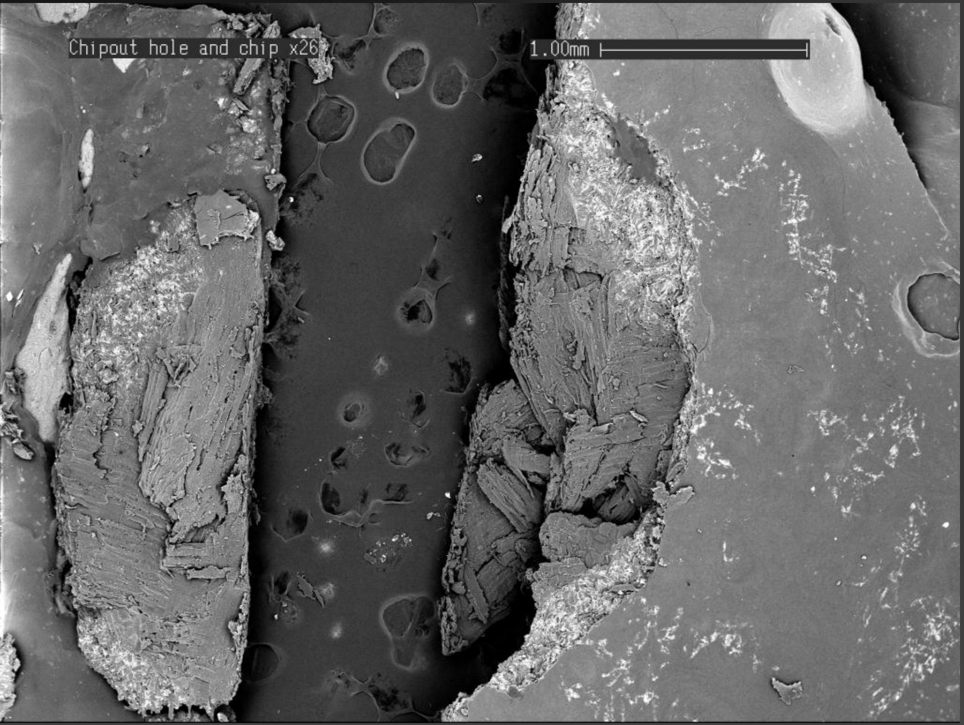
SEM images of chipout

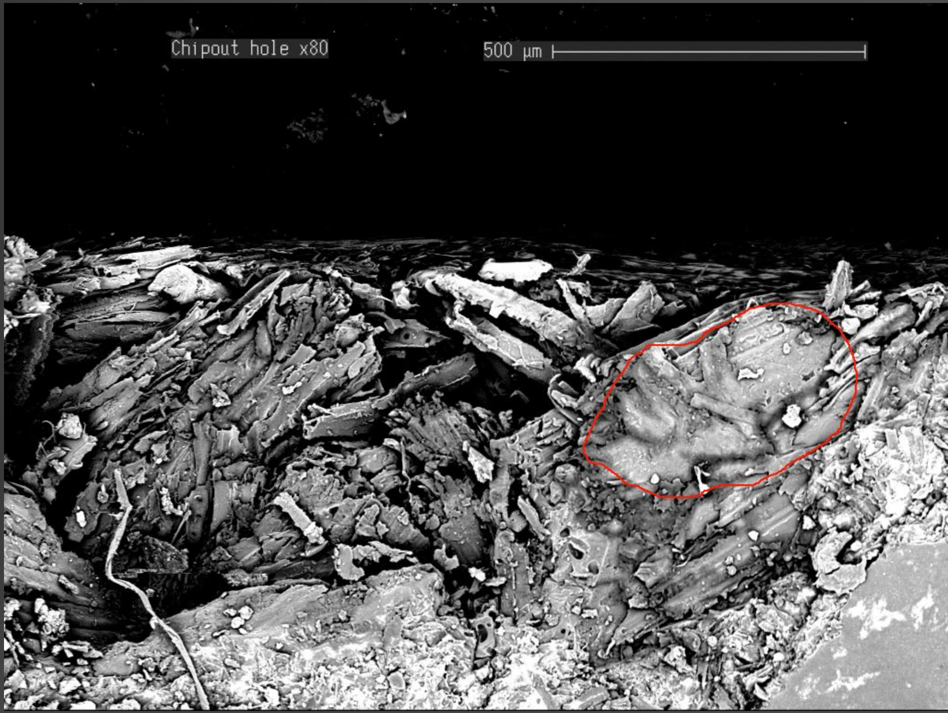






Summary of SEM analysis

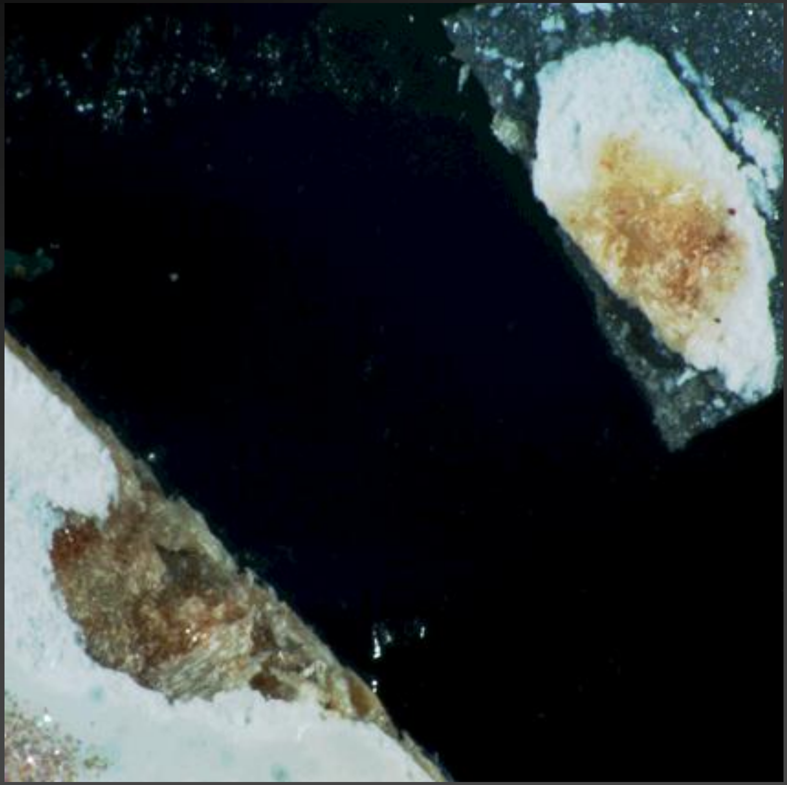


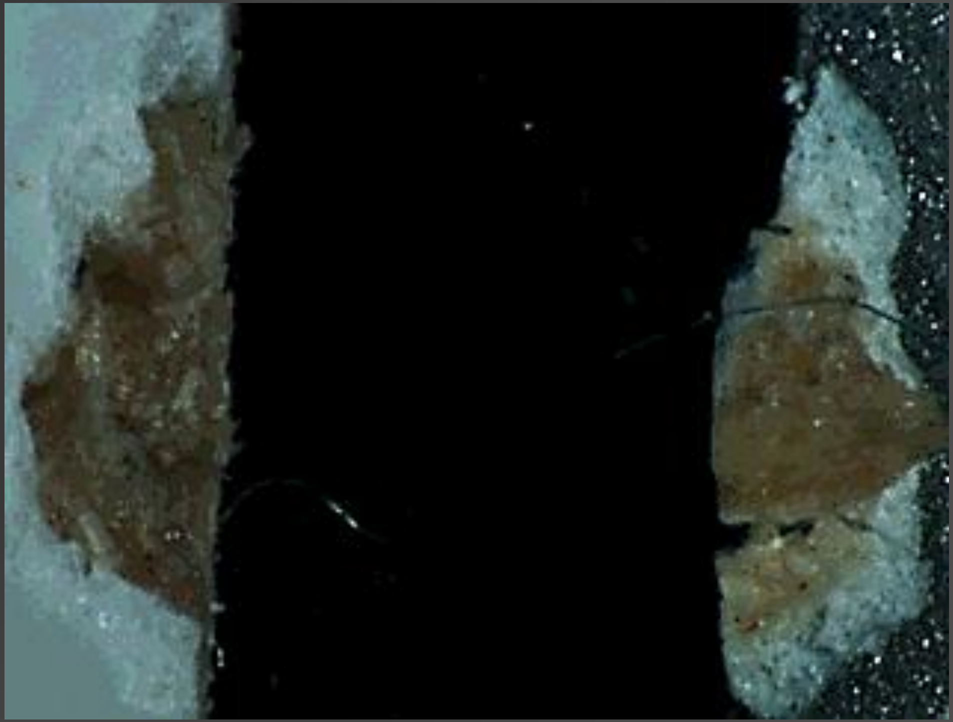


- Chipout and resultant hole, no sign of resin on either
- Hole from chipout with resin highlighted

- ***In 98 samples only one showed any resin***

Mode of failure

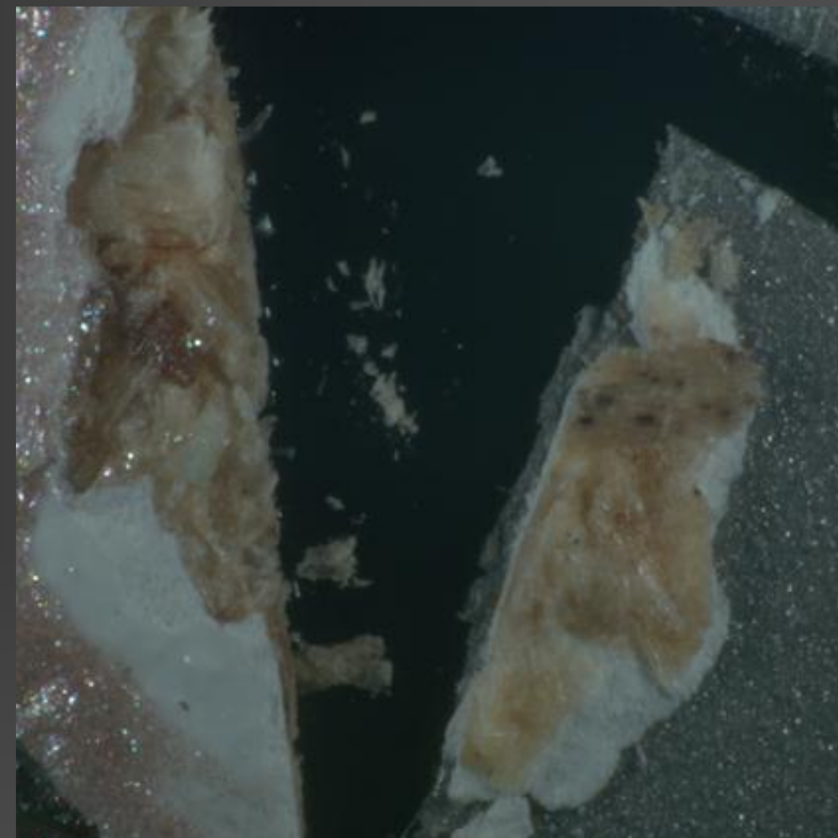




Paper and flake particles were being chipped out

Mode of failure



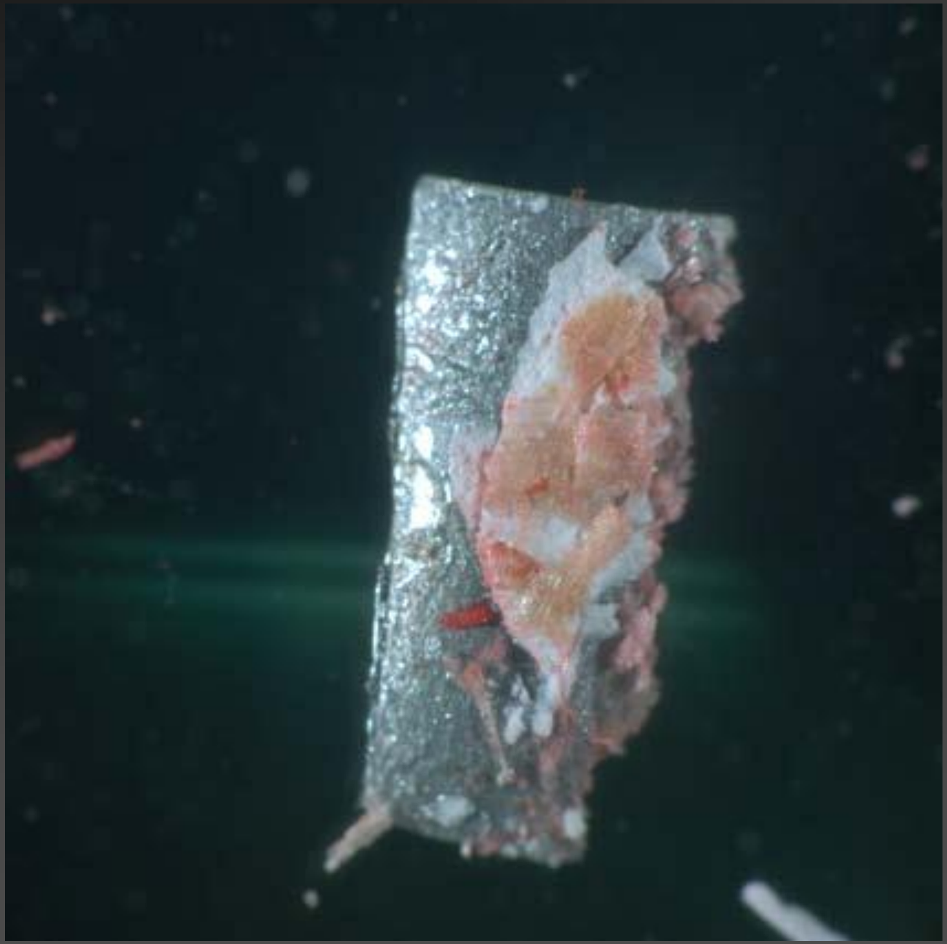


- Whole particles are being dislodged.
- Particles are not fracturing.
- Brittleness of particles not cause of chipout

Examination of particle geometry

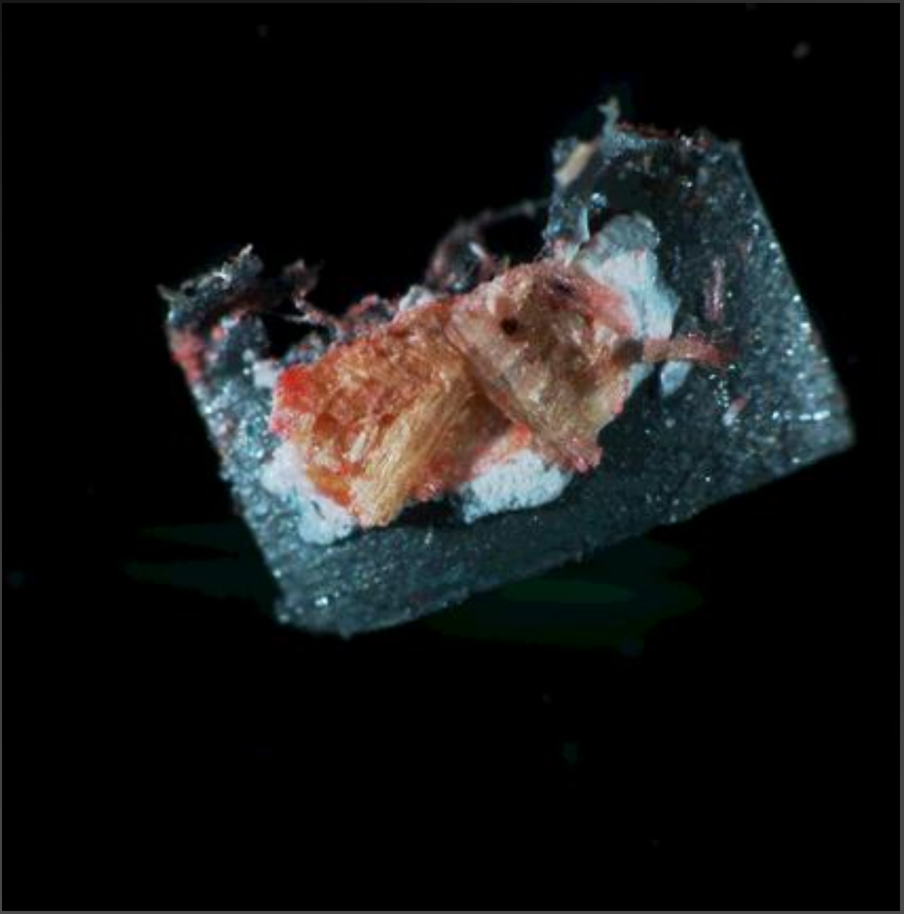
Particle geometry was good i.e. no “cubic” flake observed, therefore not considered significant part of the problem.

Particles removed by chipout



Particles show red dye indicating little resin

Particles removed by chipout



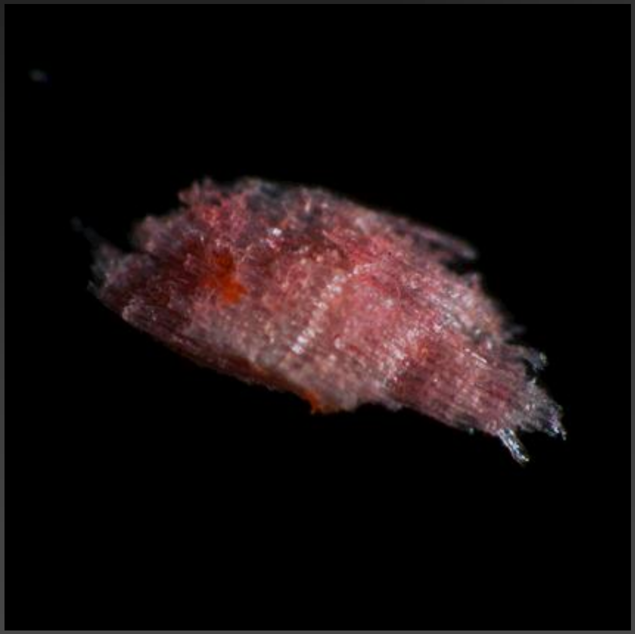
Particles show red dye indicating poor resin distribution

Microscopic examination

- Whole particles were being dislodged
- Particles were not cubic
- SEM examination implied a lack of resin in chipout samples
- Further work was required to verify this
- A technique was developed using Safronin O which stains for presence of lignin.

Potential Root Cause

- **Microscopy examination showed a lack of coverage of resin in chipout samples**

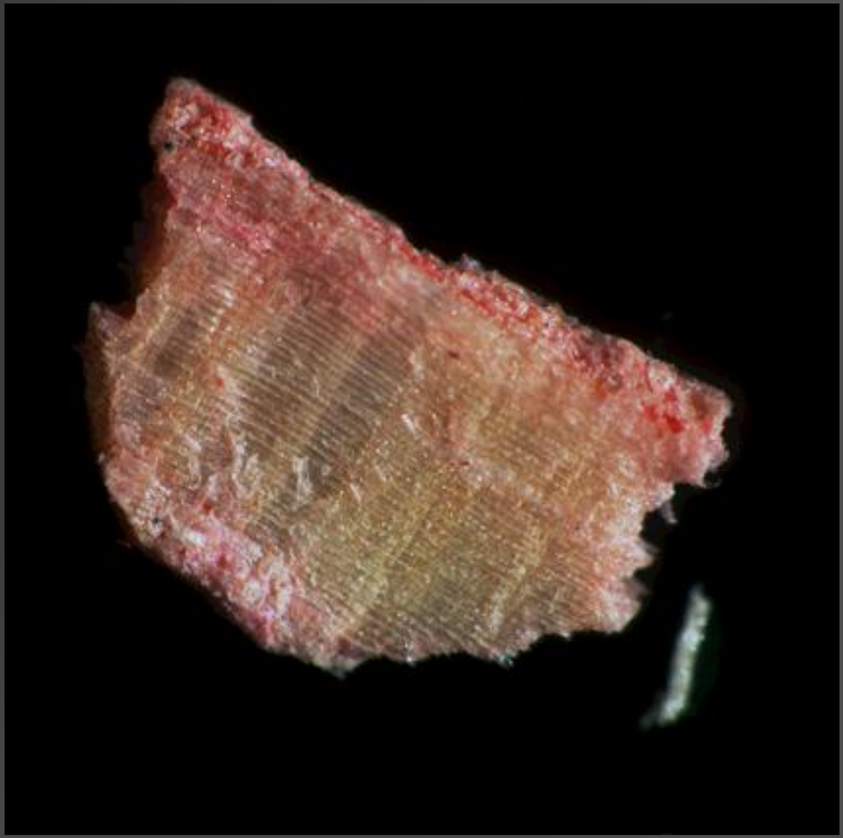


Poorly resinated surface flake ex blender

Poorly resinated surface flake ex blender

Potential root causes

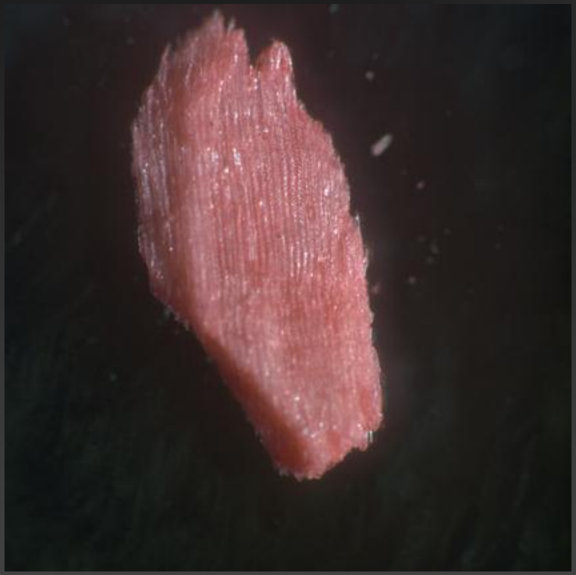
Poorly resinated surface flake ex blender



Well resinated surface flake ex blender this was uncommon

Surface flake ex G1

2mm



Ex weighbelt

Ex blender

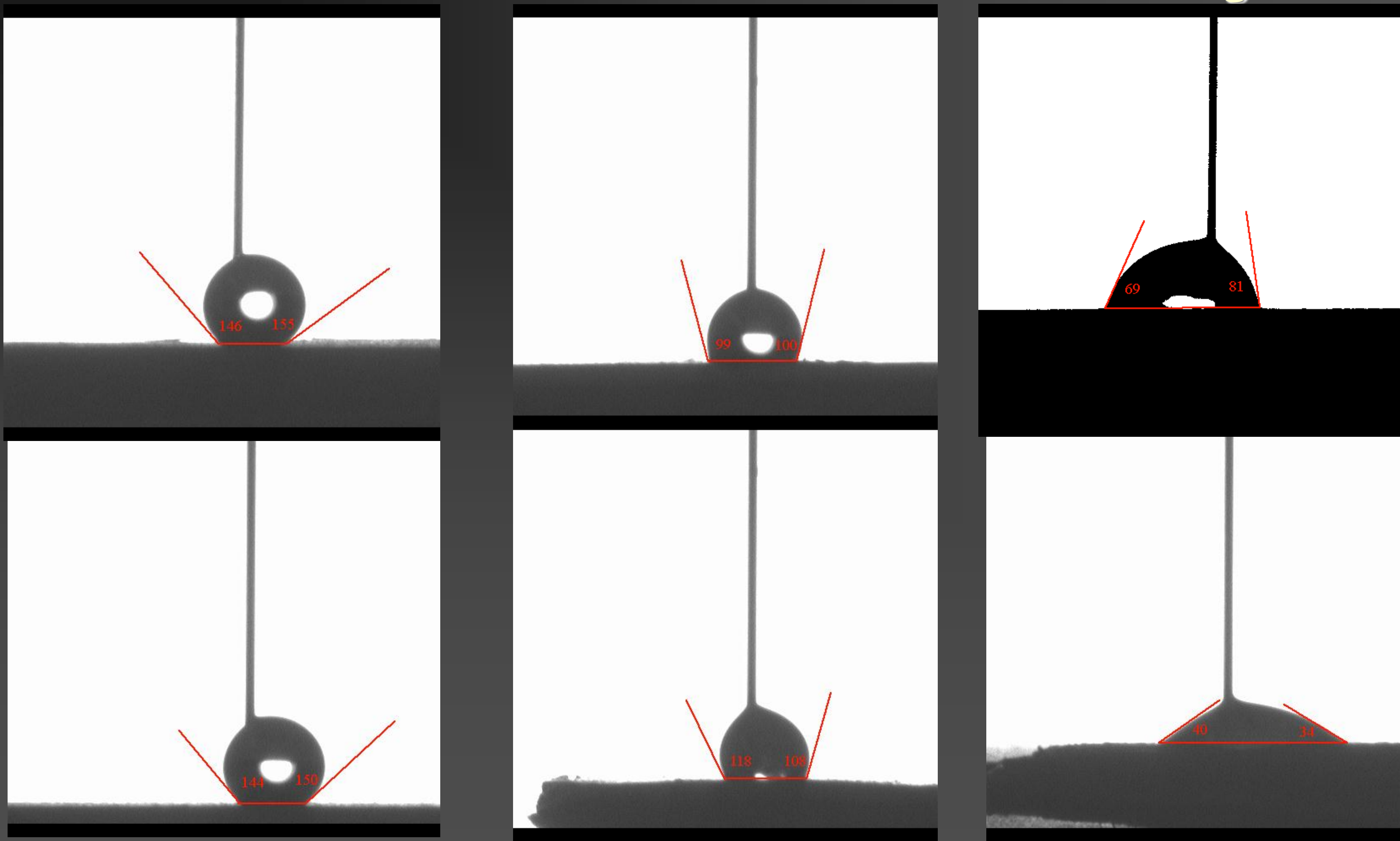
Very poor distribution of resin on surface flake ex spreader

Wettability of different species

- Before 1997 board made with Hoop pine (Araucaria cunninghamii) surface was OK
- Most Australian board is made with Radiata and is OK
- Current board made with predominantly Slash pine (P. elliotii)
- There appeared to be a species effect
- This was 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 (interfacial energy)
- The surface free energy of each species was measured using contact angle goniometry

Wettability of different species

P. elliottii | P. radiata | A. cunninghamii



The problem

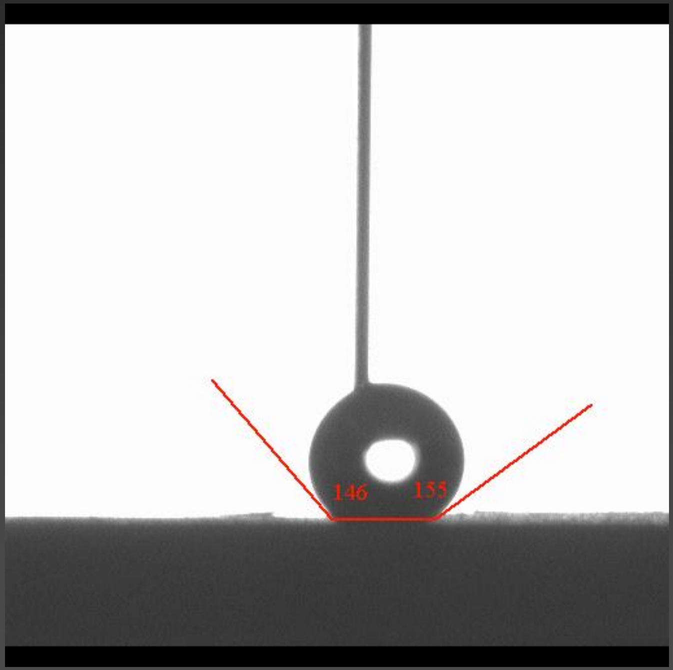
- Chipout problem caused by poor resination of surface flake.
- This is due to low surface free energy of slash pine and high surface tension of resin mix (high interfacial energy) akin to a droplet of water on Teflon. It is specific to slash pine due to the conversion of the high levels of wood resins to fatty acids (which are very hydrophobic) on the surface of the flake during drying.
- Solutions;
  - Increase surface free energy of flake by higher moisture contents or
  - Decrease the surface tension of the resin mix by adding compatible chemicals such as surfactants

Interim solution

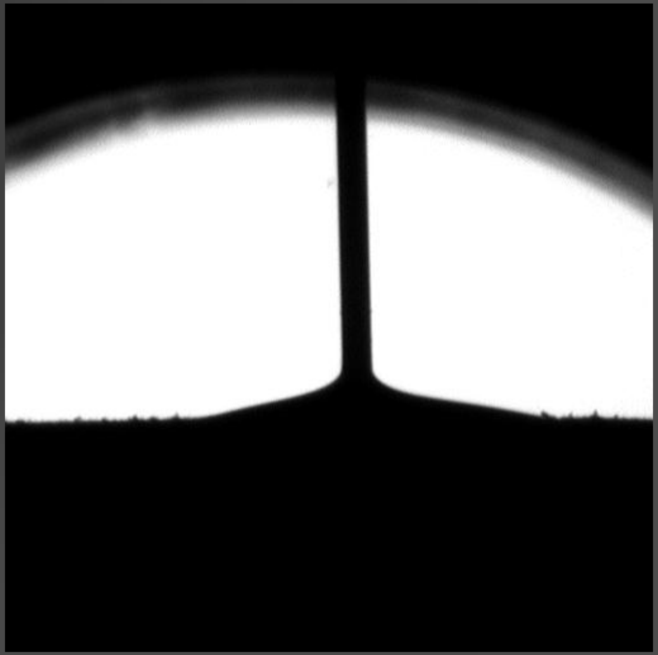
- Dozens of existing surfactants were tested under laboratory conditions using goniometry and were found to be much less effective.
- Initially a non-ionic surfactant Teric N9 was added to the flake by way of pre-blending water addition. This was subsequently found to be unnecessary due to the highly effective nature of the newly developed multi-phase wetting system.
- N9 was also added to the resin mix as well
- However this did not work at very high drier temperatures during times of high flake demand during the wet season.

Implemented solution

- A multi-phase wetting system Rezex A™ was developed to reduce the surface tension of the MUF resin while being compatible with resin/wax/hardener mix



Resin without Rezex A™ wetting slash pine



0.2% Rezex A™ in MUF resin wetting slash pine

Chipout - conclusion

- The study identified the cause of chipout as being poorly blended flake
- A solution using a multi-phase wetting system Rezex A™ was implemented
- The board is now the preferred board in the northern Australian market
- Cost savings of A$100K's per month were achieved, many millions of dollars
- The factory has had major capital expense totally unrelated to chipout to extend it's productive life
- Particleboard a mature product with a new lease of life

Core blending efficiency (or lack of)

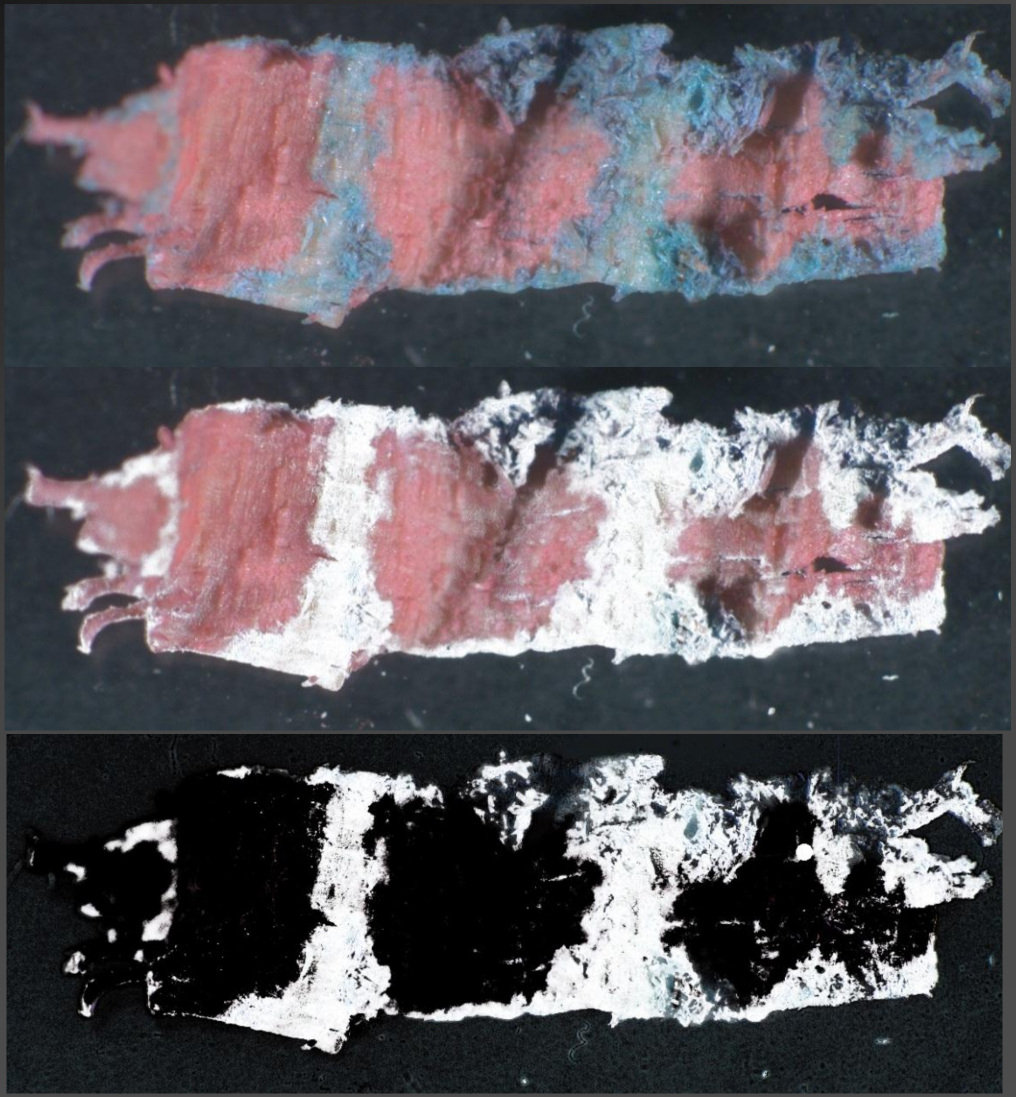
- The next section details microscopic examination of blending efficiency of core blenders from 7 particleboard plants in Australia
- Dry flake has very low surface free energy and resins have high surface tension therefore the interfacial energy between the two is large impeding transfer or resins in high speed blenders
- The best flake is that with a high surface to volume (aspect) ratio, usually larger flake which have many potential bonding points
- Smaller spherical like flake irrespective of how much resin is added can only have very few bonding points
- A new technique was developed which unlike the widely used Kjeldahl method measured resin coverage and variation on a flake by flake basis
- It is well known that the larger flake which is most important for board properties is the least well resinated, what is not known is the degree that this is the case

Blender used in following study

Problems associated with high speed blenders

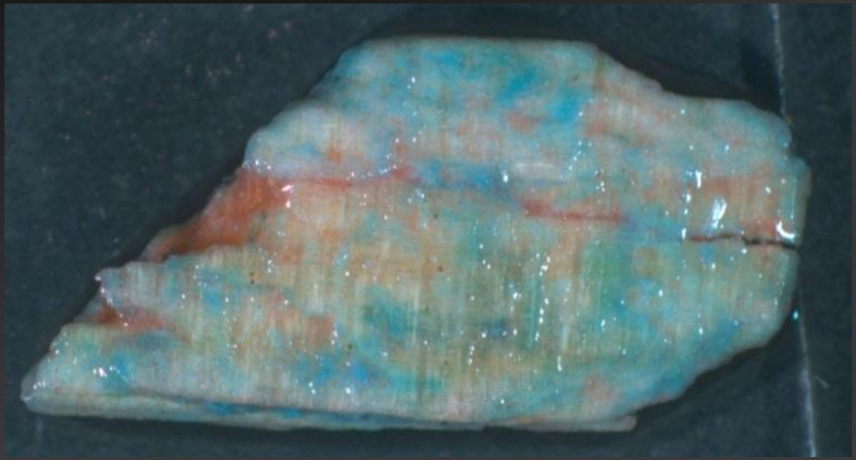
- A lot of money and effort is used to generate particleboard flake
- High speed blenders very efficiently convert good quality large flake into smaller flake potentially reducing strength
- Even newer generation blenders destroy flake geometry
- These blenders rely on relatively long dwell times to achieve resin spreading
- The issue is how to maintain flake geometry and achieve adequate blending

Binarisation sequence of flake To determine resin distribution

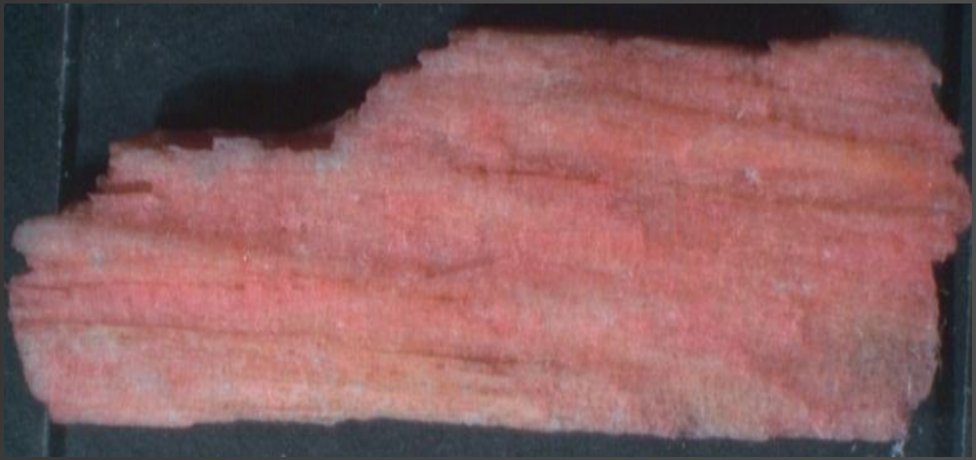


Flake fractions >5.56mm, 2.35-5.56mm, 1.7-2.35mm, 1.0-1.7mm, 0.6-1.0mm, 0.355-0.6mm, 0.212-0.355, 0.125-0.212 and <0.125mm

Resin distribution on core flake



Well resinated core flake

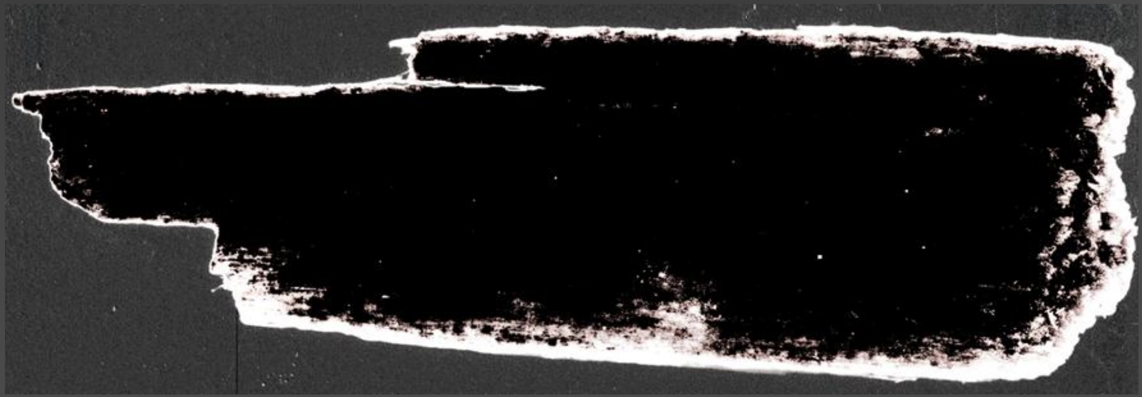


Poorly resinated core flake

- Over 5,000 individual flake particles were analysed
- All core blenders performed poorly blending the larger flake fractions
- Variation from below 5% to above 90% in one case and averaged from low teens to above 70%
- Smaller flake had largest amount of resin and the least variation

Characteristics of high speed blenders

- Blending is a trade off between the spreading of resin on flake and it's destruction
  - Longer dwell times result in more flake destruction
  - Longer dwell times do not necessarily result in more effective resin spreading
- Poorly resinated flake tends to be preferentially resinated on edges rather than on the faces



Resin distribution on core flake

Poorly resinated larger flake was resinated around the edges or raised sections

Press	>5.6mm min	>5.6mm max	2.35-5.6mm min	2.35-5.6mm max
Plant 1a	7.4	68.7	12.7	76.4
Plant 1b	6.4	85.6	11.9	87.1
Plant 2a	10.2	62.4	18.9	77.4
Plant 2b	5.8	64.7	7.6	70.5
Plant 2c	8.5	82.3	6.6	80.9
Plant 2d	1.6	95.1	1.4	89.2
Plant 3	6	46.5	4.3	79.9

Variability of resin coverage with the two largest flake fractions for all core blenders

Resin distribution on core flake

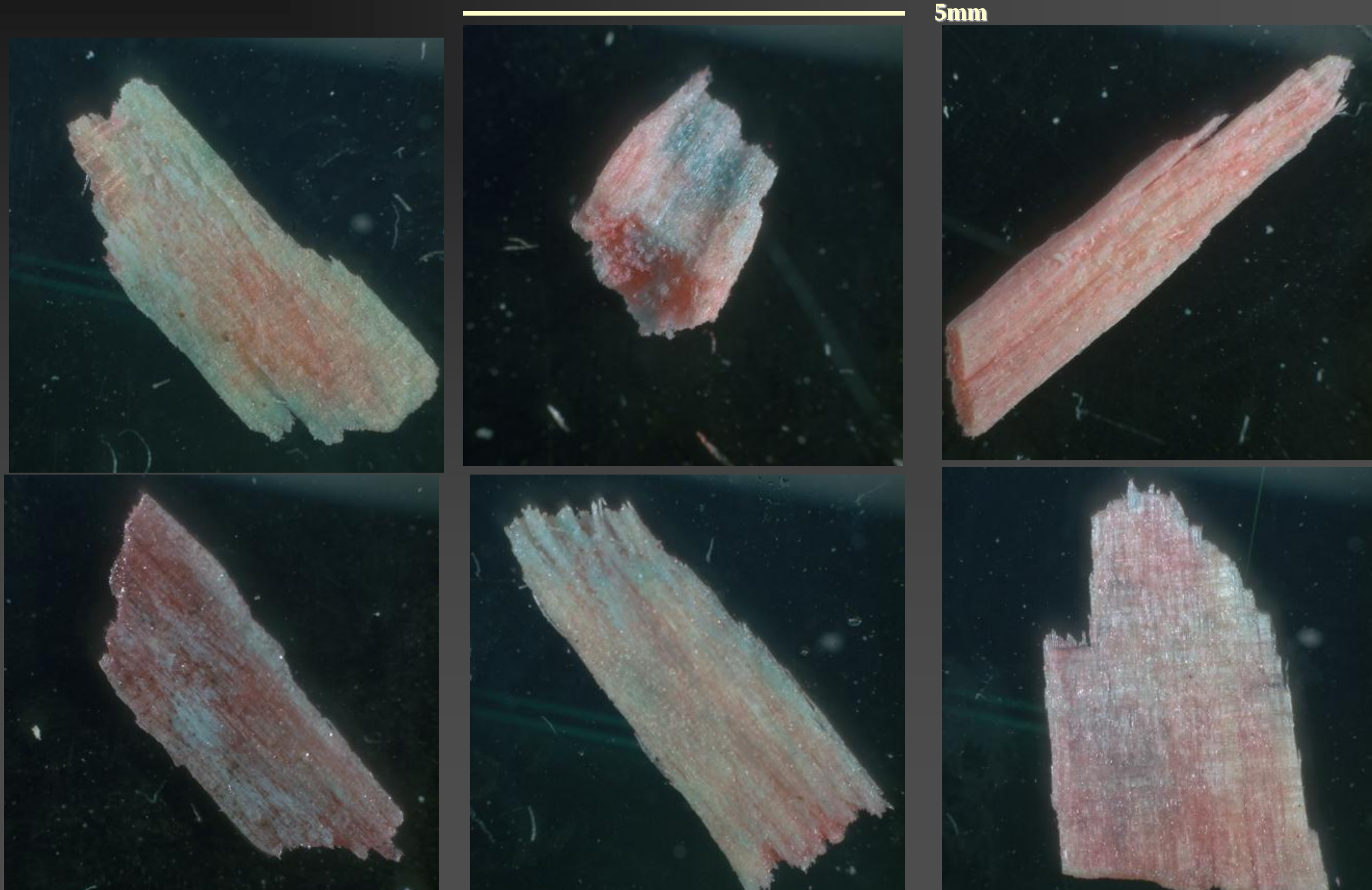
Press	>5.6 mm	2.35-5.6mm	1.7-2.35mm	1.0-1.7mm	0.6-1.0mm	0.355-0.6mm	0.212-0.355mm	0.125-0.212mm	<0.125mm
Plant 1a	26.7	41.7	46.6	62.0	65.7	77.6	74.2	87.8	96.9
Plant 1b	32.9	37.4	43.4	54.6	55.3	58.8	67.4	65.1	89.9
Plant 2a	37.7	44.9	41.6	45.4	47.0	59.7	73.4	85.9	91.2
Plant 2b	24.0	24.6	36.9	43.3	68.2	84.2	94.7	97.6	97.5
Plant 2c	34.1	33.3	34.9	39.9	48.9	74.8	91.6	97.1	97.1
Plant 2d	32.4	33.8	42.5	54.0	78.0	92.0	98.7	98.7	100
Plant 3	20.9	30.0	37.5	48.5	62.4	72.1	77.8	99.0	99.4

Means of percentage of resin coverage for all core blenders

Press	>5.6 mm	2.35-5.6mm	1.7-2.35mm	1.0-1.7mm	0.6-1.0mm	0.355-0.6mm	0.212-0.355mm	0.125-0.212mm	<0.125mm
Plant 1a	62.6	53.0	31.7	18.2	22.9	32.2	17.0	7.5	2.5
Plant 1b	70.7	51.1	46.7	38.3	21.0	12.2	19.3	10.7	10.3
Plant 2a	52.9	35.3	43.5	44.7	33.9	10.1	7.9	6.0	2.9
Plant 2b	60.2	76.6	66.9	48.3	8.9	6.0	3.1	2.8	2.4
Plant 2c	56.8	54.5	38.6	62.7	28.6	14.2	6.0	2.5	2.4
Plant 2d	69.2	75.6	56.9	40.5	9.9	2.6	1.8	1.9	1.1
Plant 3	60.6	77.8	56.7	43.2	23.5	15.6	10.5	1.6	1.1

Coefficients of variation of resin coverage for all core blenders

Variable resin distribution on core flake



Opportunities improving blending efficiency

- Earlier slides have demonstrated a lack of core blending efficiency through variability of resin coverage of larger flake fractions
- If core blending efficiency is improved, this could lead to cost savings resulting from:
  - Improved flake geometry
  - More consistent resin distribution especially over larger flake fractions
  - Resin loading reduction
  - Lower densities
  - Lower blending power demands
- It is far better to achieve resin spreading through chemical rather than physical energy

Myths associated with blending

- That resin is continuously “wiped” from one flake particle to another
- Flake must be held back with the use of negative horn and paddle angles and with positive outlet flap pressure
- Flake is preferentially wet on the face
- Planer shavings have to be hammer milled so the inside of the curled flake may be resinated
- Blending efficiency is improved by complex relationships relating motor current with horn, paddle and flap settings.
- Greater dwell times result in more effective resin spreading.

Improving blending efficiency

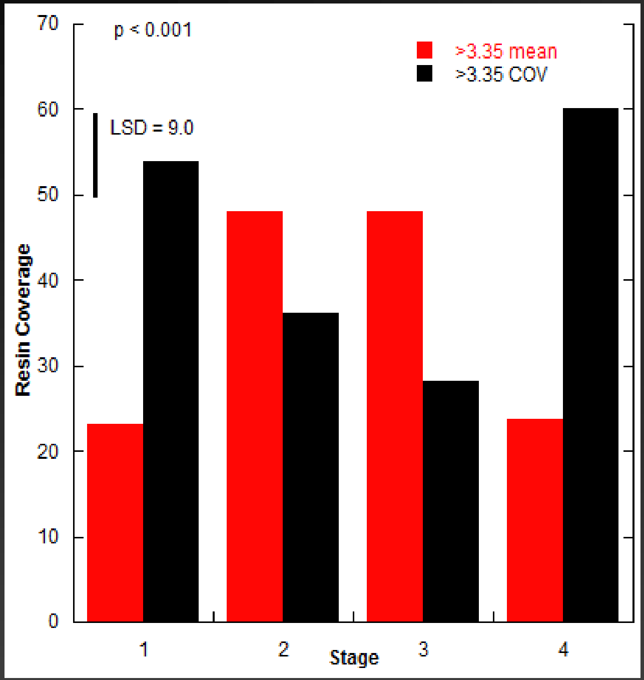
- Two full scale plant trials run on a plant with new PAL blenders
- Trial 1 treatments were paddle angle, Flap position and use of Rezex A™; 1,000 individual flake samples were analysed

Blender zone	Horn position normal Treatments 1 & 4 no Rezex A™, Treatment 3 with Rezex A™ @ 0.2% Flap open	Horn position (Advanced) Treatment 3 with Rezex A™ @ 0.2% flap open
Inlet paddle	10°	10°
Injection zone horns 1-8	0°	0°
Mixing zone horns 9 – 14	-10 to -15°	+15°
Mixing zone horns 15 – 21	-20°	+20
Mixing zone horns 22 – 28	-10 to -20°	+25°
Outlet zone horns 29 – 30	-10 to -20°	0°
Outlet zone horns 31 – 32	-10°	-10°

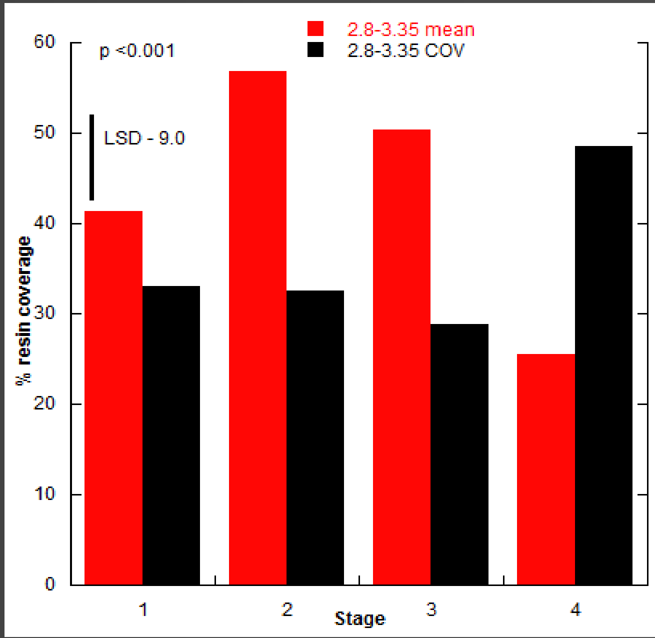
Blender setups for trial 1 Plant 2b, a negative angle retards flake progress through blender and a positive angle enhances flake progression

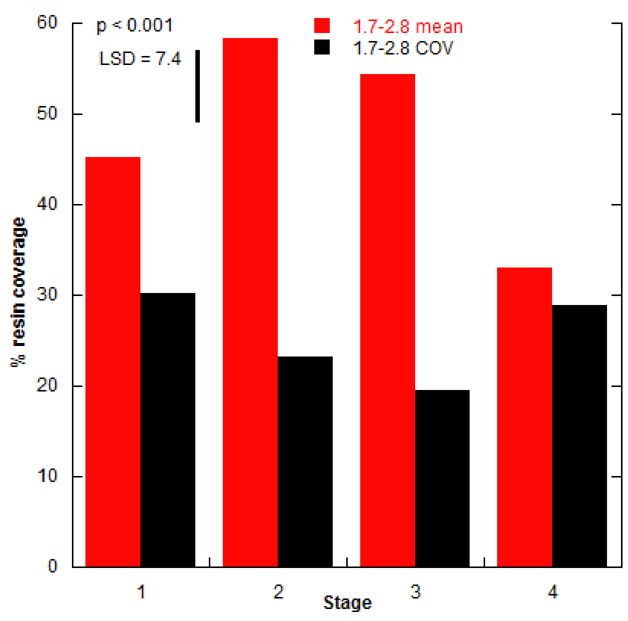
- Treatments 2 & 3 with Rezex A™ gave better mean resin distribution and less variation than Treatments 1 & 4
- No difference between Treatments 2 & 3 showing that with use of Rezex A™ can get better flake geometry and better resin distribution

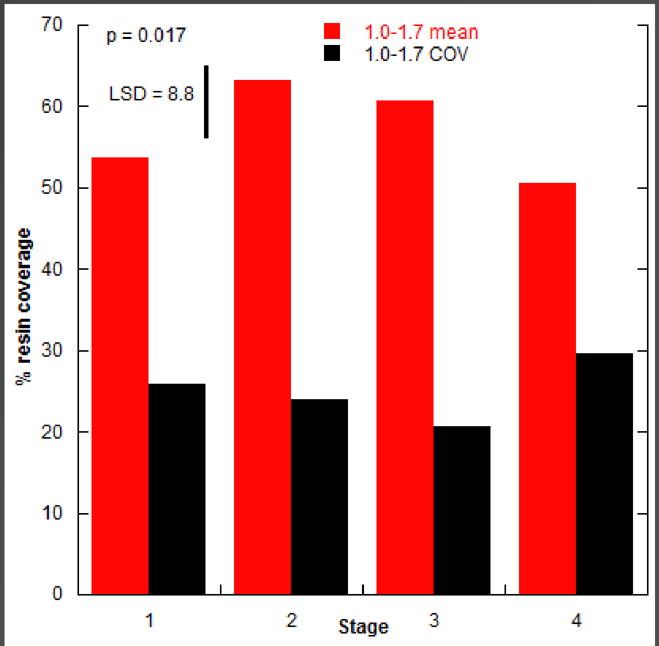
Improving blending efficiency



- Treatments 2 & 3 with Rezex A™
- Note improved overall resin distribution and lower variation







Improving blending efficiency

- Without Rezex A™ i.e. Treatments 1 & 4 there is a statistical relationship between flake geometry and resin coverage:
  - *Resin coverage = (-10.8 * width) – (1.8*length) + 78.2 ($p < 0.001$)*
  - *Explains 40% of variation*
- This is a non-wetting system
- For a wetting system using Rezex A™ The following is the relationship:
  - *Resin coverage = (-2.7 * width) –(0.9*length) + 71.9 ($p < 0.001$)*
  - *Explains 11% of variation*
- Note in a wetting system the amount of variation explained is one quarter that of the non-wetting system and the coefficients of the independent variables are much lower than for the non-wetting system
- Thus with the use of Rezex A™ one can improve flake geometry while improving resin distribution

Improving blending efficiency

- Trial 2 where 960 individual flake samples analysed
- Involved 4 different doses of Rezex A™; 0, 0.05, 0.1 & 0.15%, Flap open or closed
- Three different injection nozzle positions 20, 40, & 60mm from cooling jacket

Rezex_A dosage (%)	0.00	0.05	0.10	0.15
% coverage >3.35mm	29.9	51.9	68.8	79.5
% coverage 1.7 – 2.8mm	44.7	60.7	80.4	86.7

Resin coverage as a function of dosage of Rezex A™

Rezex A™ dosage	COV
0.0	62.9
0.05	32.6
0.10	21.7
0.15	16.7

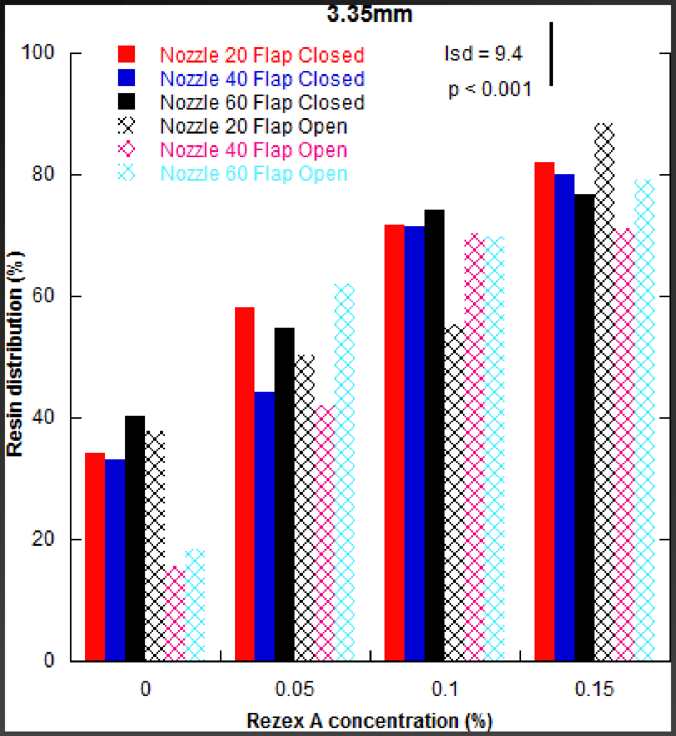
Variation in resin coverage flake >3.35mm

Rezex A™ dosage	COV
0.0	41.4
0.05	26.2
0.10	12.8
0.15	9.9

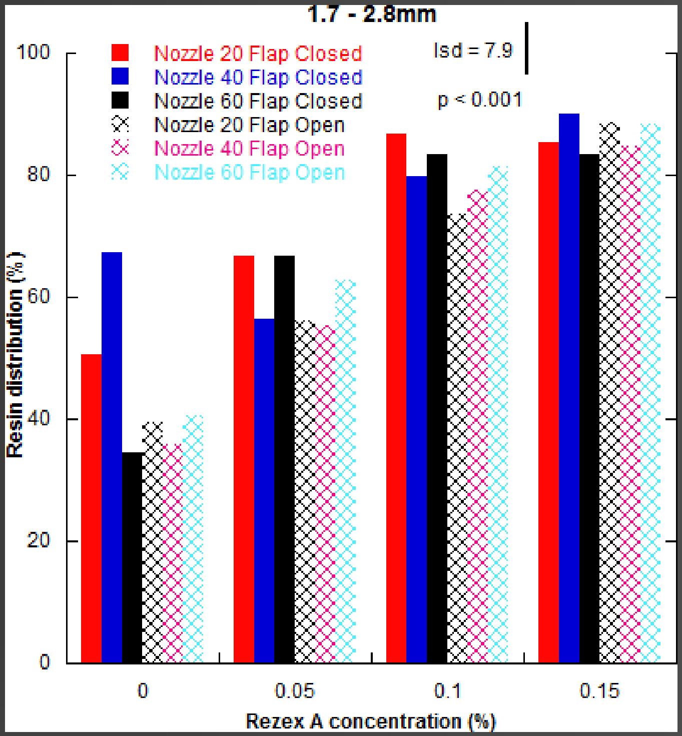
Variation in resin coverage flake 1.7 – 2.8mm

- Resin coverage increased with dosage on fractions making up over 50% of core flake volume
- Variation in resin coverage decreased with dosage
- With the use of Rezex A™ neither flap or nozzle position had any effect

Improving blending efficiency



Effect of Rezex A™ loading interacted with nozzle and flap position on resin distribution on flake > 3.35mm



Effect of Rezex A™ loading interacted with nozzle and flap position on resin distribution on flake 1.7 – 2.8mm

- With flap open the proportion of the largest flake (>3.35mm) increased from 15.6 – 25.1% ($p < 0.001$)
- With the flap open the same flake fraction increased in average width from 8.7 – 9.3mm ($p = 0.025$)
- Compliance testing board equal or better than current board

Improving flake geometry

Effect of blending on flake quality with recommended blender setups without Rezex A™

Improving flake geometry

Effect of modifying blender settings in conjunction with the use of Rezex A™

Conclusions blending efficiency

- Use of Rezex A™ solved chipout problem in plant using Slash pine, would be suitable for other Southern pine species
- Improvements in core flake geometry, improved resin distribution and reduced variation in resin distribution can only be achieved with the use of Rezex A™
- Use of Rezex A™ allows far more flexibility in blender operation with power saving opportunities
- Reduced variation in resin spread may lead to opportunities to reduce resin loadings or density resulting in considerable cost savings and increased plant throughput
- Compliance testing showed as good or superior physical properties, however no statistical inference can be taken from this and more trials are proposed