Blending efficiency Part B:

Core blending and how to improve it

Dr Raymond J. Roberts

RJRoberts Consulting Pty Ltd

Abstract

This report details a microscopic analysis of blended core flake from various particle board plants in Australia. It showed that smaller flake is well resinated and the majority of larger flake was less well resinated, however this was known from current analytical methods. What was also shown was that the variability in resin coverage in core flake from all plants was very significant and averaged between the low teens to the high 70's, with the variability in one, Plant 2d being between 1% to over 90%, If current board is fit for purpose, one could assume that if this variability was reduced, resin loadings and/or density could be reduced without any reduction in board properties.

Flake geometry was shown to have a significant impact on resin distribution particularly the width of the flake across the grain with normal blender settings. It is also demonstrated that the use of the multi-phase wetting system Rezex A™ increased resin spread over larger flake. The use of Rezex A™ reduced variation in resin distribution between flake. Where it was poor, resination of flake in high speed blenders occurs on the *edges rather than faces* of flake putting into question the long held belief about resin being transferred from the face of one flake to another.

Introduction

The ideal particleboard flake has a high aspect ratio i.e. a high surface to volume ratio. This enables more potential contact points to bond with other flake. The corollary to this is a dust particle which has a much lower aspect ratio, analogous to a sphere. Such particles can bond to another at only one point, irrespective of how much resin is applied. As dry flake has a very low surface free energy i.e. is a poorly wetting surface and as the resin mix has a very high surface tension, the interfacial energy between the two is high. This impedes the transfer and spread of resins. If large flake is not effectively resinated, it could produce zones of weakness that will impact on the integrity of the panel.

High speed blenders including PAL type blenders supposedly rely on "wiping" of resin from one flake to another after resin injection. To optimise blending by manipulating dwell times, operators have complex models involving motor current to set paddle and horn angles as well as the resistance of the outfeed flap. However it is still the smallest flake that has the highest resin coverage.

In 2007 the author developed a technique to determine the resin coverage at an individual flake level which demonstrated real blending efficiency of particle board blenders. This was a modification to the technique developed in response to the chipout problem that had been occurring on laminated particle board from a particular plant since the late 1990's which is detailed in Part A.

Materials and Methods

A common measure of blending efficiency is the Kjeldahl test which measures nitrogen content of blended flake usually by size fraction. It gives an average but crucially does not give any measure of variability which as shown below is of fundamental importance to blending. The method detailed in *Appendix 1* overcomes this by actually measuring resin coverage *on a flake by flake basis.*

Analysis of variance (ANOVA) for a randomised block design was used to analyse data. Some data were transformed into natural logarithms to ensure that it complied with the assumptions of ANOVA, i.e. normality with constant variance. Statistical computation was carried out using Genstat (Lawes Agricultural Trust).

Results: existing blending efficiency

Data is presented on the resin coverage of different core flake fractions (over 5000 individual particles were analysed) from various plants in Australia. The resin coverage data is interpreted as a measure of blending efficiency. Obviously the greater the resin coverage, the greater is the blending efficiency. Results are presented in tabular format showing the mean and coefficient of variation COV (The standard deviation divided by the mean) for each core blender. It is important to note that it is not necessarily valid to compare the actual means of resin coverage between different blenders or treatments. It is far more valuable to compare the (COV) between blenders for the larger fractions as this shows true blending efficiency. If a blender was perfectly efficient the COV's for large flake would be similar to that of the smallest flake fractions. This of course will never be achieved with high speed blending, however it was shown that both blending efficiency and flake geometry can be improved.

Flake was supplied to the blenders primarily from ring knife mills. It was expected that the larger fractions would have less resin, however what was significant was the degree of variability of resination of larger core flake. As expected the smaller fractions had the largest amount of resin and the least variation. *Table 1* shows the variability in resin coverage of the two largest fractions. *Table 2* shows the means of blending efficiencies of all fractions for the core blenders. *Table 3* shows COV’s of all fractions for the core blenders. All of the core blenders produced very poor blending of the largest flake fractions. This ranged from below 5% in some cases to above 90%. *Figures 1 & 2* show well and poorly resinated large core flake.

Typically poorly resinated larger flake was resinated around the edges or raised sections of the flake (*Figure 3*). Larger flake has the potential to give particleboard higher bending strength and glue bond durability. It is therefore axiomatic that if these fractions are not blended efficiently, there could be zones of weakness in the panel necessitating the need for higher densities or resin loadings.

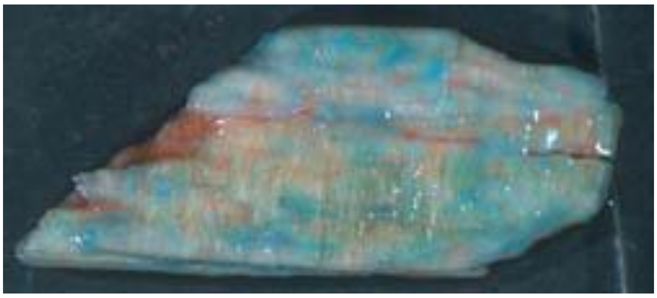

Figure 1: Image of well resinated flake

Figure 2: Image of poorly resinated flake in latter note resin coverage only around the edge

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

Table 1; Table showing the variability of resin coverage with the two largest flake fractions 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	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

Table 2; Table showing 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

Table 3; Table showing coefficients of variation of resin coverage for all core blenders.

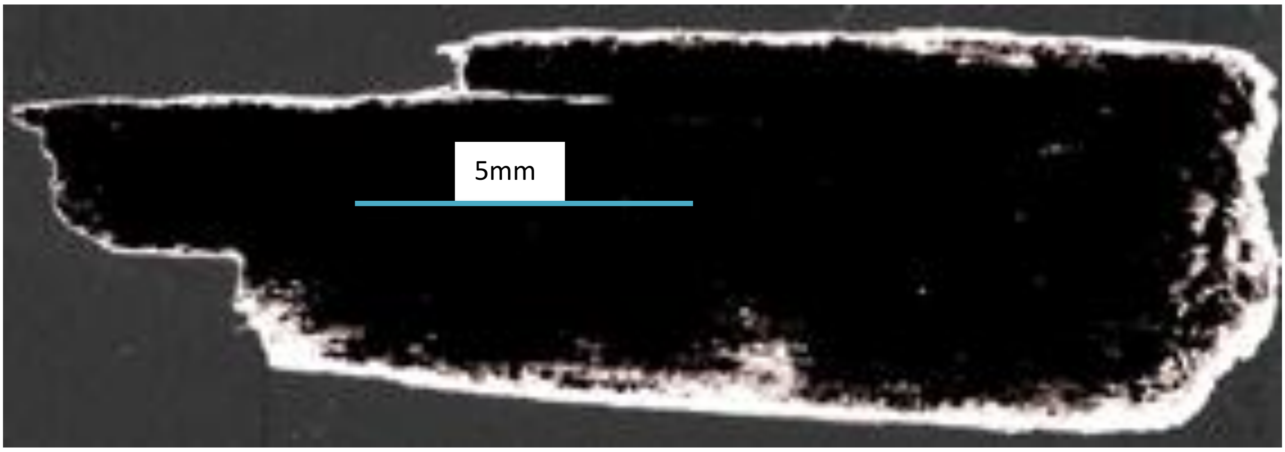

Figure 3; Binarised image showing a large core flake resinated only around the edge.

Results: improving blending efficiency

As shown when solving the chipout problem, if the interfacial energy between flake and resin is reduced, resin coverage immediately improves. This can be achieved either by increasing the surface free energy of the flake by increasing flake moisture content or by reducing the surface tension of the resin mix. The former is impractical in single daylight or continuous presses due to the excessive build-up of steam leading to possible delamination of board or a longer de-gassing stage, leaving the only option to reduce the surface tension of the resin mix using a suitable wetting agent. Such a wetting agent must be compatible with existing resins which are complex fluids susceptible to the solids fraction "dropping out". This was observed in laboratory work while identifying a suitable wetting agent to solve chipout. It also must not affect the rate of cure of the resins. For single daylight and continuous presses fast cycle times are critical for productivity. From laboratory trials using contact angle goniometry over 40 surfactant combinations were examined and a number of combinations were used in various plant trials. The self-assembling nature of many surfactants limited their effective use and as a large number were incompatible with resins, the use of surfactants was found not to be a suitable option. A newly developed wetting system Rezex A™ was found to be by over an order of magnitude the best wetting system to reduce the surface tension of resin mixes, yet having no effect on either resin stability or cure. It also did not have any critical micelle concentration limitations. Two full scale plant trials were conducted on the Plant 2b line which has PAL blenders to test under full production conditions the effectiveness of Rezex A™.

Trial 1

The first trial involved comparing normal blender setups without Rezex A™ (Treatments 1 & 4) with one treatment with Rezex A™ at 0.2% on wood weight with flap open and normal horn and paddle settings (Treatment 2). The final treatment was Treatment 3 with horn and paddle angles advanced. All settings are detailed in *Table 4*. The study involved analysing resin distribution and flake dimensions on over 1,000 individual flake particles.

Blender zone	Treatment 1,2 & 4 horn position (Normal)	Treatment 3 horn position (Advanced)
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°

Table 4: Blender setups for trial 1 Plant 2b, a negative angle retards flake progress through blender and a positive angle enhances flake progression i.e. reducing dwell time.

For the largest 4 flake fractions there was a significant increase in resin distibution on flake in Treatments 2 & 3 over Treatments 1 & 4 *(Figures 4a – d)* with p values shown on the individual graphs. Interestingly however there was no difference in any fractions between Treatments 2 & 3. In other words the more aggressive changes in blender setup at Treatment 3 did not result in any reduction in the overall distribution of the resin on the largest flake fractions nor was there any increase in variability. *Figures 4a – c* show reductions in variation in Treatments 2 & 3 compared with Treatments 1 & 4. Note also there was a significant difference in resin coverage between Treatments 1 & 4 with flake from both the 2.8-3.35mm and 1.7-2.8mm fractions, yet these were both control Treatments and show there was and still could be significant process variation that needs to be explained. There were no significant effects with the smallest fraction studied.

In the flake blended *without Rezex A™* and with standard blender setups (Treatments 1 & 4) with data pooled over the largest four flake fractions there was a very significant and substantial relationship between the length and width of the flake and resin coverage. The data was modeled as a multiple linear regression with the expression r = ax +by+c; r = resin coverage, x = flake width, y = length, c is the constant.

The equation is $r = (-10.8 * width) – (1.8*length) + 78.2$ ($p < 0.001$) with the percentage of variation accounted for being over 40%. This means that 40% of the variation of resin coverage is explained by this simple linear model. In other words all other effects on resin coverage, i.e. droplet size, surface free energy of flake, surface tension of the resin etc. are explained by the remaining 60%. Therefore flake geometry is one of the most important considerations of resin distribution *in a non-wetting system*. The wider the flake the more poorly it is resinated. To model it in a linear fashion is however simplistic and a lot more work needs to be done on it to get a predictive model but from these results it is absolutely possible. However it is shown that with decreasing flake length and decreasing flake width, resin coverage is greater *in a non-wetting system*. This is due to larger poorly resinated flake being coated with resin around the edges (*Figure 3*), therefore it would appear that large flake in high speed blenders wets from the edge rather than along the face which is a commonly held view. It also shows that high speed blenders cannot effectively blend larger flake. It reinforces the hypothesis that in a non-wetting system flake tends to resinate from the edge.

When using Rezex A™ the following is the relationships between flake geometry and resin coverage; the equation is $r = (-2.7 * width) –(0.9*length) + 71.9$ ($p < 0.001$) where the percentage variation accounted for being 11% i.e. about a quarter of that when not using Rezex A™. Note the coefficients of the independent variables width and length are much lower than for the model without Rezex A™. Therefore with the use of Rezex A™ the relationship of flake geometry to resin coverage is not nearly as important. With Rezex A™ improved flake geometry can be achieved *while maintaining or improving resin coverage and significantly reducing the variation in resin coverage on flake.*

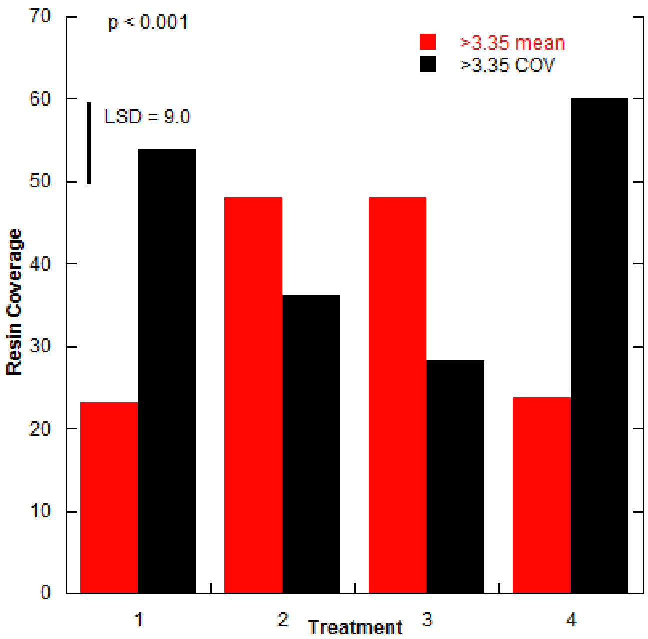

Figure 4a: Flake > 3.35mm

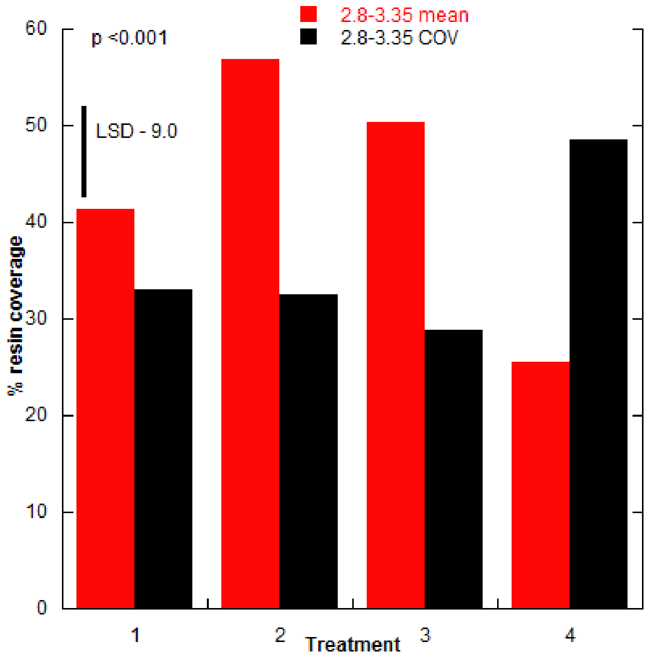

Figure 4b: Flake 2.8 - 3.35mm

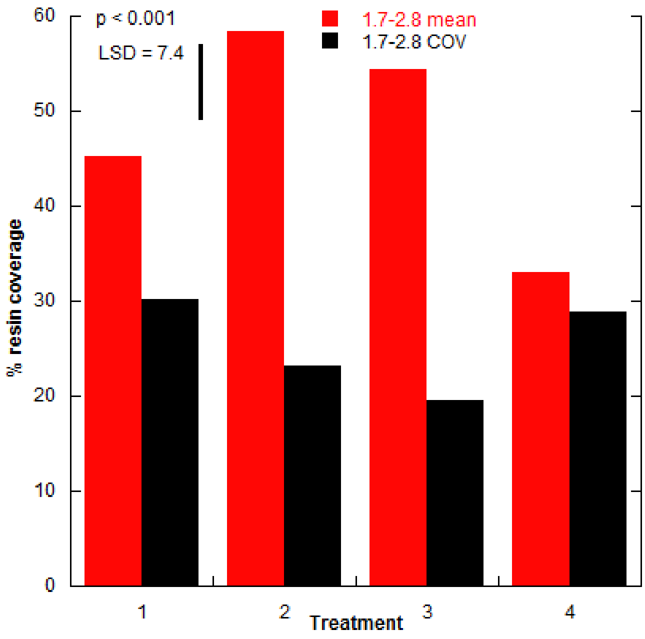

Figure 4c: Flake 1.7 – 2.8mm

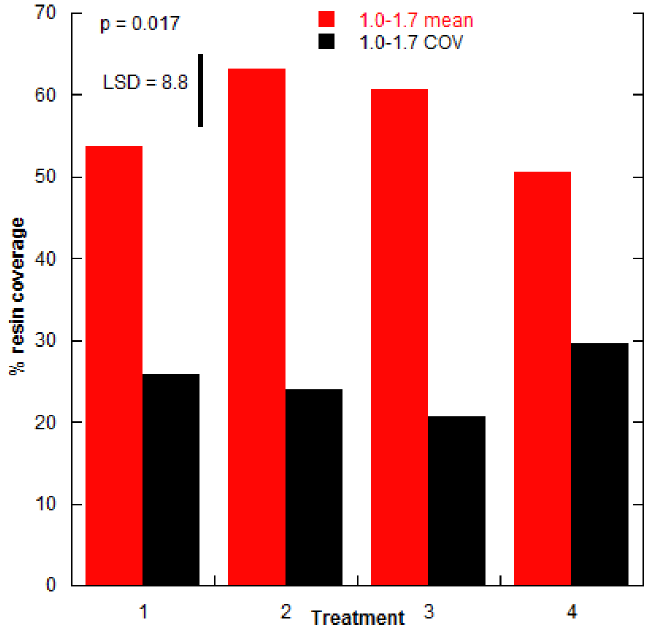

Figure 4d: Flake 1.0 – 1.7mm

Trial 2

This was a trial involving 4 different dose rates of Rezex A™; 0, 0.05, 0.1 & 0.15% on dry wood weight, whether the flap was open or closed and 3 different injection nozzle positions, 20, 40 & 60mm from the cooling jacket. Two flake fractions were examined which comprised over 50% of the total volume of core flake; >3.35mm and 1.7 – 2.8mm fractions.

This equated to 960 separate samples of flake i.e. 20 from each of the fractions over 24 treatments with two flake fractions (>3.35mm & 1.7-2.8mm) ex the core blender at Plant 2b with PAL blenders. *Table 5* shows the very significant effect *($p < 0.001$)* on resin distribution with the use of Rezex A™ when the data is pooled over all treatments.

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

Table 5: Resin coverage as a function of dosage of Rezex A™

Note reduction in variation in resin coverage with the use of Rezex A™ (*Tables 6 & 7*).

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

Table 6: 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

Table 7: Variation in resin coverage flake 1.7 – 2.8mm

Without the use of Rezex A™ the 20 & 40mm injection nozzle positions gave the best resin distribution results for the 1.7 – 2.8mm flake fractions however had no effect on the larger flake fraction. With Rezex A™ nozzle position had little effect on resin distribution. Without Rezex A™ the flap in the closed position gave the best resin coverage. With the use of Rezex A™ at any dosage the flap being open or closed had little effect on the resin distribution. This means that with Rezex A™ one can operate with blender flaps open and nozzles in any position with resulting improved flake geometry and still have very good resin distribution. See *Figures 6a & b* for all the data on resin coverage.

In regard to flake geometry, when using Rezex A™ and with the flap open, there was a very significant increase in the proportion of the largest flake fraction (>3.35mm) from 15.6% to 25.1% ($p < 0.001$) and an increase in average width from 8.7 to 9.3mm ($p = 0.025$) i.e. greatly improving flake geometry and the potential of improving the bending strength of the particleboard along with the potential to create less fines. It would appear that opening the flap had a greater impact on flake geometry than did advancing the paddle and horn angles. *Figure 7* shows the effect of modified blender settings in conjunction with the use of Rezex A™ on flake geometry *with flake from the same source.*

Board samples were taken only for compliance testing for physical properties however there was no significant effect on MOR, MOE, IB and MOR-A. Further studies will be carried out to look at the effect on property data.

Figure 5 showing the effect of flake blended without Rezex A™ and with standard recommended blender settings, raw flake on the left of the image.

Figure 6 showing the effect of flake blended with Rezex A™ with modified blender settings, raw flake on the left of the image.

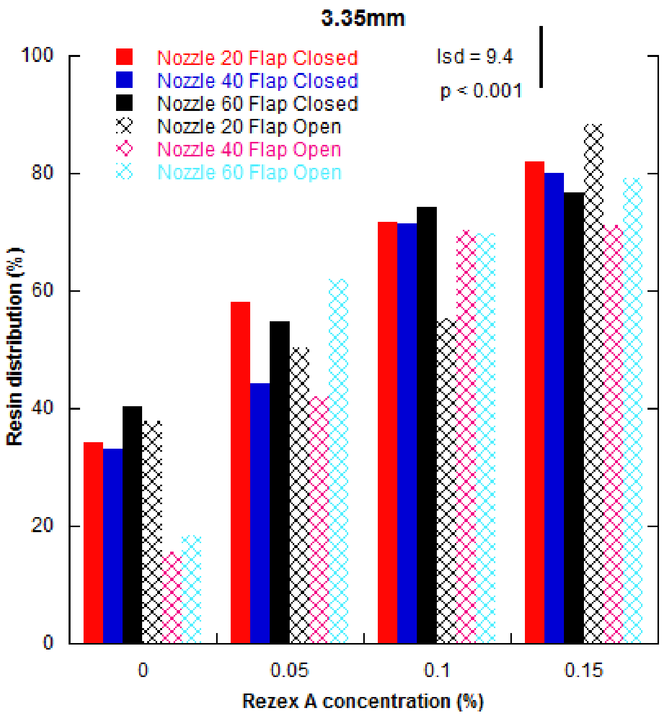

Figure 7a: Effect of Rezex A™ loading interacted with nozzle and flap position on resin distribution on flake > 3.35mm

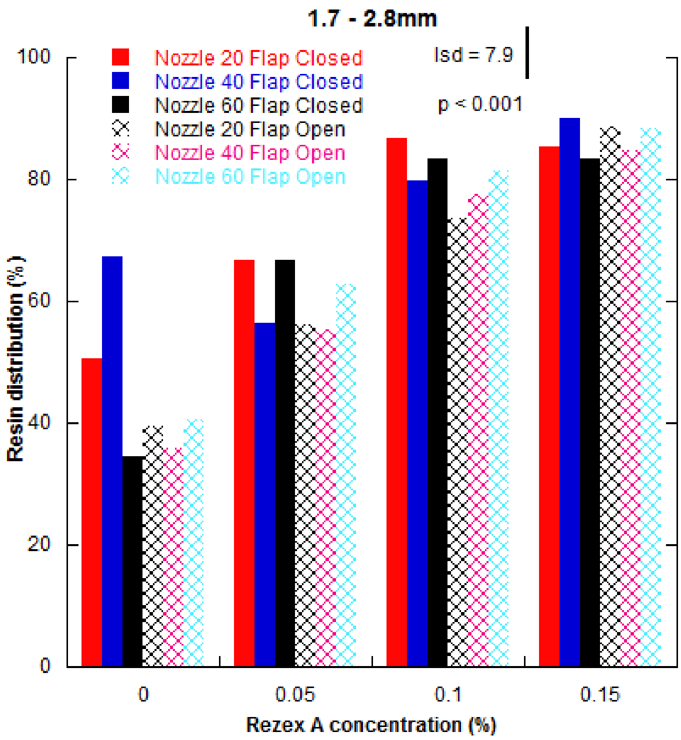

Figure 7b: Effect of Rezex A™ loading interacted with nozzle and flap position on resin distribution on flake 1.7 – 2.8mm

Conclusion

This study concentrated on mean resin distribution and variation in resin distribution at an individual flake level. It was shown that with the use of the multi-phase wetting system Rezex A™, resin is more effectively and evenly distributed over larger flake. With the modification to blending conditions associated with the use of Rezex A™, there was a substantial improvement in flake geometry while still maintaining and improving resin distribution on the larger flake.

The use of Rezex A™ allows far more flexibility in the setups of blenders including reducing motor current and saving power and above all allows for modifications to blender setups to improve flake geometry.

It has been shown that variability in resin distribution is reduced with the use of Rezex A™. this gives potential for reductions in resin usage and/or reductions in density and hence amount of wood used. These could lead to significant cost savings.

Physical properties were either as good as or better than normal property data. However no statistical inference can be drawn from this as the only property tests that were done during these initial trials were compliance testing. It is intended to statistically compare the effects of physical properties with much longer term trials.

Patents have been applied for Rezex A™ and the applications.

References

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Khan, J.A., Unpublished report on Pyrolysis at Plants 1a & 1b (2000).

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APPENDIX 1

Samples of blended core and surface flake were sieved into the following fractions: >5.6mm, 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. For fractions larger > 0.6mm samples were treated, imaged analysed individually whereas samples <0.6mm were investigated as groups of flake. All samples were stained in a 0.01% solution of Saffronin O stain in ethynol. The stain highlights lignin, the principle being that if lignin is highlighted red, then that part of the flake is not covered with resin. Samples were placed in the stain solution for one minute, then washed in distilled water until there was no evidence of stain in the wash water. The stained samples were then placed on microscope slides and were imaged using a Wild Photomakroskop M400 with a high-resolution digital camera. Depending on the size of the flake, varying magnifications were used from 3x to 64x. Examples of stained flake are shown in *Figures 1, 2 & 7*.

Images were then digitally modified by binarising them in order to determine how effectively the flake has been resinated. This was achieved using Adobe Photoshop through a number of iterative stages. This is demonstrated in *Figures 7 - 9*. The binarised image was then analysed using Scion Image from the

National Institute of Health. USA, resulting in a percentage of effective resin coverage for each sample of flake. The data was then statistically analysed and is presented in graphical and tabular form. Two key measures are used, firstly the mean of the resin distribution on flake and secondly the coefficient of variation, COV (Standard deviation divided by the mean) both calculated for each fraction of sieved flake. The COV is probably the key measure as it can be used to compare blending efficiencies between different blenders/sites and is a measure of the variation in resin coverage. Analysis of variance (ANOVA) for a randomised block design was used to analyse data. Some data were transformed into natural logarithms to ensure that it complied with the assumptions of ANOVA, i.e. normality with constant variance. Statistical computation was carried out using Genstat (Lawes Agricultural Trust).

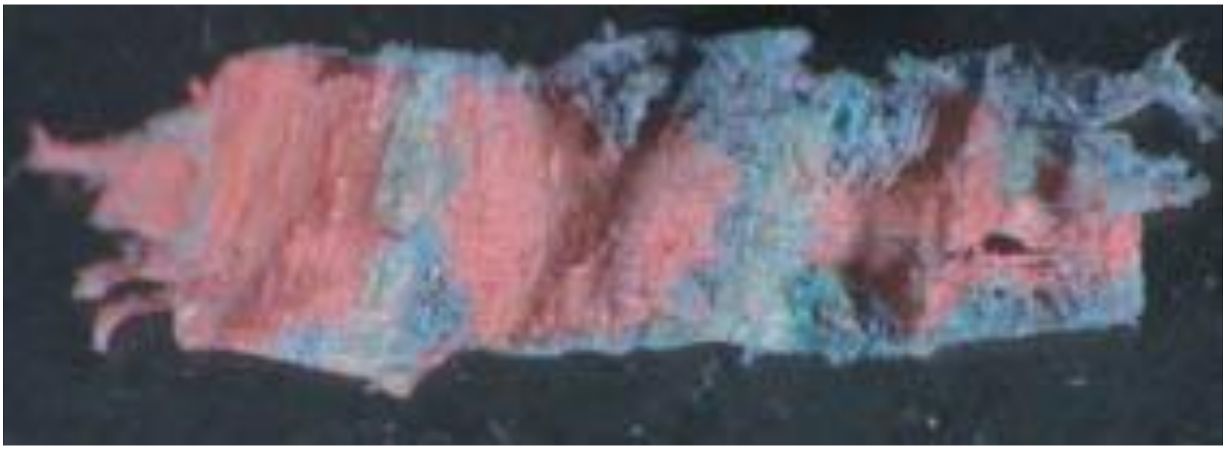

Figure 8, Image of stained core flake showing non-resinated areas in red and resin in blue

Figure 9 Image of stained core flake from Figure 8 through the first Stage of the binarisation process

Figure 10 Image of stained core flake from Figure 8 through the second Stage of the binarisation process