Optimization of Particle Size Distribution

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CHIMAR HELLAS S.A.

Contents

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2. Engineering services for formaldehyde and resin plants
3. Procurement of resin plants, reactors, tanks, glue kitchens
4. R&D services for third parties
5. Technical support services for **resin**, **WBP** producers & **OEMs**
6. Specialty chemicals production upon request (Hardeners, FR, Wetting / Release agents)
7. Participation in EU research projects
8. Specialty services:
   a) Accredited testing
   b) Resin and board analysis
   c) IPR protection and patent portfolio management
   d) Quality management systems
   e) Sales representation

CHIMAR in figures

- 36 Years
- 37 Countries
- 70+ Industrial sites
- Combined capacity: > 0.9Mtons of liquid resin
- 24 strong team:
  - 8 Chemical & Electrical Engineers
  - 8 Petroleum & Forest Technologists
  - 4 Chemists
  - 4 Finance & Administration

Introduction of the Work

- Efforts to increase profitability in particleboard production have been focused on the optimization of the adhesives and equipment used.
- The present work examines the effect of :
- wood species and
- wood particle size distribution on the properties of lab scale particleboard.
- Wood chips from various particleboard plants were used.
- The influence of the particle size distribution was examined in an experimental design using response surface regression analysis for two levels of density and different wood species.

Scope & Objectives

The scope of this work was to examine the effect of the wood furnish on the properties of lab scale particleboard.

To serve the above mentioned scope the following were examined:

- Effect of wood species
- Particle size and resin factor
- Particle size distribution

Methodology (1/2) board parameters

Lab particleboard production	
Board dimensions, cm x cm x cm	44 x 44 x 1.6
Target Density, kg/m^3	620 & 660
Resin factor, % dry on dry wood	8
Resin type	Urea Formaldehyde
Resin molar ratio, F/U	1.4
Press Cycle, s	128 (8s/mm)
Hardener	40% Ammonium Sulfate
Hardener Level, % dry on dry resin	3.5
Paraffin wax emulsion, % dry on dry wood	0.5
Target Mat moisture, %	9.5

Methodology (2/2) chip parameters

Optimization of particle size distribution	
Design of experiment:	Response surface regression
Center points:	5
Factor 1:	Dust <1 x 1 mm
Factor 1 examined level:	15 – 30%
Factor 2:	2 x 2 mm > Medium > 1 x 1 mm
Factor 2 examined level:	30 – 60%
Complementary factor to 100%	Coarse > 2 x 2 mm
Examined densities	660 & 620 kg/m^3
Responses:	I.B., N/mm^2
	M.O.R., N/mm^2
	24h Thickness Swelling (TS), %

Laboratory equipment


High speed rotary blender


Lab press

Tensile strength measuring device

Wood Species (1/2)

Species	Eucalyptus grandis		Pinus sylvestris	
pH, []	5.0		5.3	
B.C., ml 0.1N HCl	4.5		6.5	
3-layer lab particleboard properties				
Density, kg/m^3	620	660	620	660
I.B., N/mm^2	0.62	0.70	0.49	0.63
M.O.R., N/mm^2	13.4	15.5	14.5	17.5
24h T.S., %	10.0	10.9	21.9	21.6
F.C., mg/100g	18.9	16.1	27.9	26.6

Core layer: 60% Medium (> 1x1mm & <2x2mm) & 40% Coarse (> 2x2mm)
Face layer: 100% Dust (<1x1mm)
Face to Core ratio: 40 : 60

Wood Species (2/2)

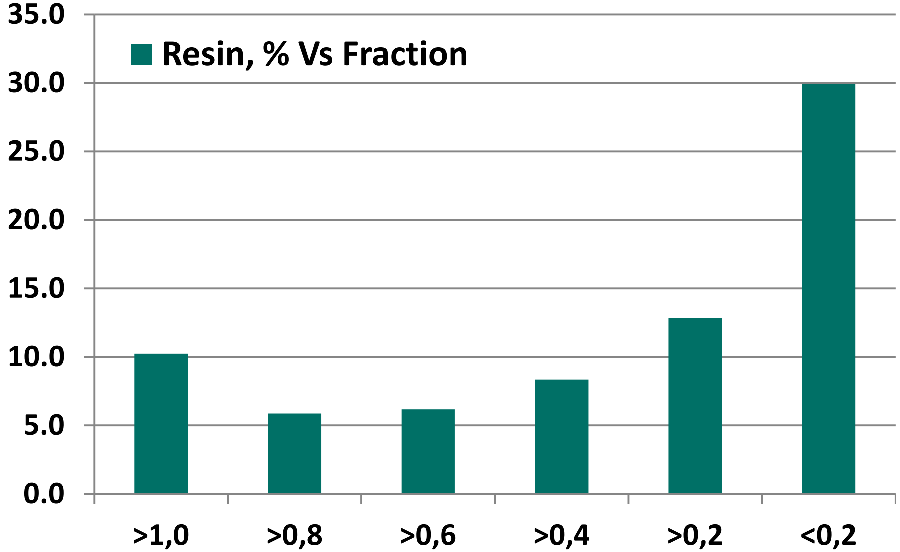
- The properties of the lab scale particleboard made from eucalyptus grandis are superior to those made from pinus sylvestris
- Higher IB, lower TS and lower formaldehyde content
- Only M.O.R. is increased in the case of pinus sylvestris which could be an indication of different chip geometry, enhancing M.O.R. (height, width to length ratio)

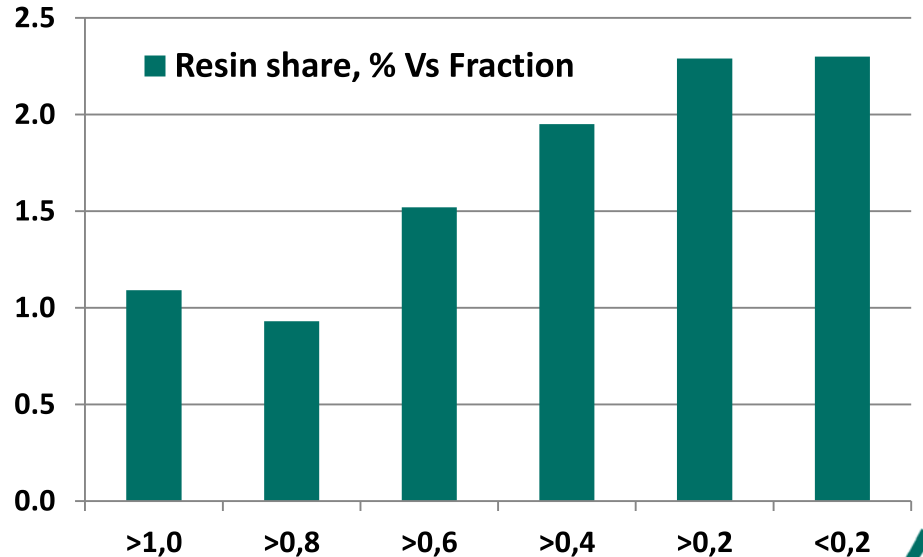
Particle size & resin factor (1/4)

Radiata pine				
Screen	Fraction	N	Resin	Resin share
	%	%	% dry/dry wood	%
>1.0	10.61	3.16	10.24	1.09
>0.8	15.86	1.95	5.87	0.93
>0.6	24.61	2.04	6.18	1.52
>0.4	23.34	2.65	8.35	1.95
>0.2	17.88	3.83	**12.83**	2.29
<0.2	7.70	7.60	**29.93**	2.30
		Total resin factor, %		**10.0**

We see that 25% of the material takes up almost 50% of the binder

Particle size & resin factor (2/4)
Radiata pine



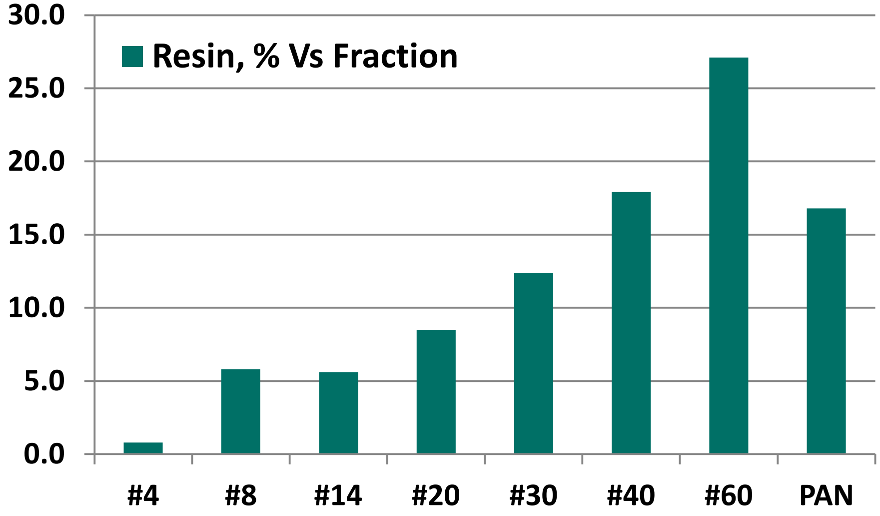


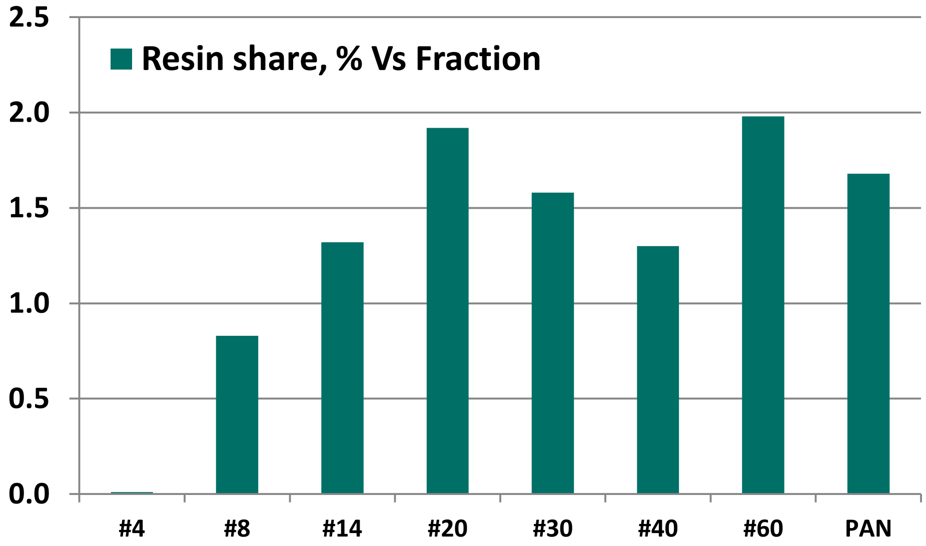
Particle size & resin factor (3/4)

Southern yellow pine					
Sieve	Opening	Fraction	N	Resin	Resin share
	mm	%	%	% dry/dry wood	%
#4	4.750	2.0	0.26	0.8	0.01
#8	2.360	14.4	1.89	5.8	0.83
#14	1.400	23.7	1.83	5.6	1.32
#20	0.850	22.5	2.72	8.5	1.92
#30	0.600	12.7	3.82	12.4	1.58
#40	0.425	7.3	5.25	17.9	1.30
#60	0.250	7.3	7.38	27.1	1.98
PAN		10.0	4.97	16.8	1.68
			Total resin factor, %		**10.6**

We can see the same trend here where 17% of the material takes up more than 35% of the binder

Particle size & resin factor (4/4)
Southern yellow pine





Particle size distribution (1/11)
Experimental design

Run	% Dust	% Medium	% Coarse
1	15	60	25
2	30	30	40
3	23	66	11
4	23	45	33
5	23	45	33
6	12	45	43
7	23	45	33
8	23	45	33
9	23	23	54
10	33	45	22
11	23	45	33
12	15	30	55
13	30	60	10

One layer boards
5 centre points, designed by MINITAB statistical software
Full results are omitted due to size of tables and complexity

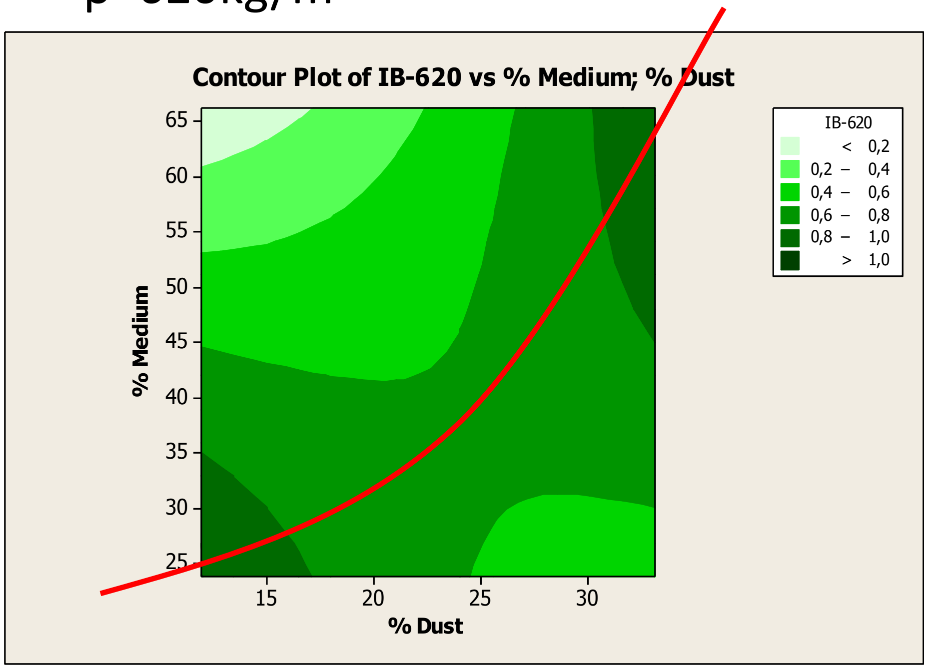
Particle size distribution (2/11)
Pinus elliottii – I.B., N/mm^2

Regression equations:

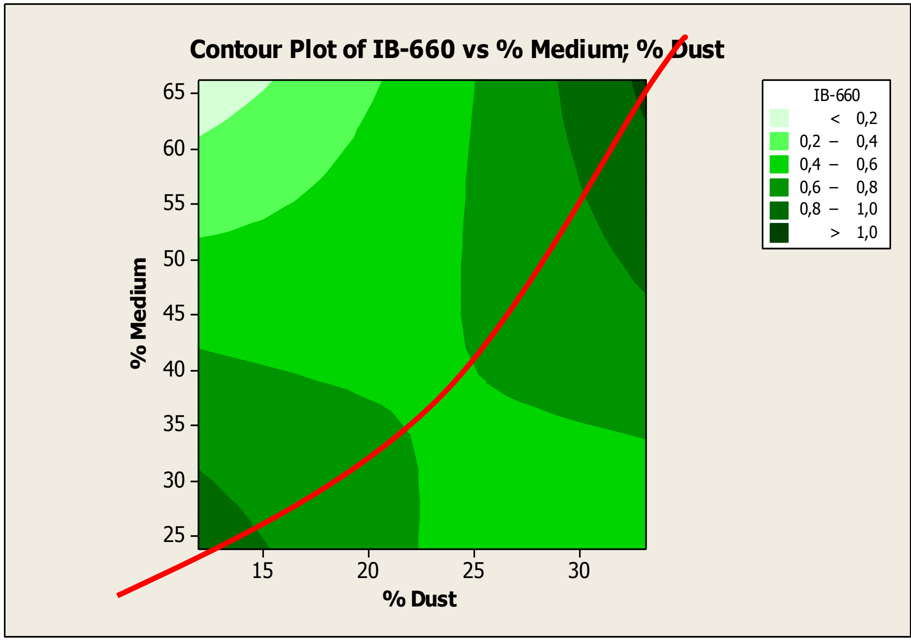
IB-620 = 2,43 - 0,105 % Dust - 0,0288 % Medium + 0,000963 % Dust*%Dust - 0,000139 %Medium*%Medium + 0,00159 %Dust*%Medium

IB-660 = 2,26 - 0,0932 % Dust - 0,0312 % Medium + 0,000704 % Dust*%Dust - 0,000085 %Medium*%Medium + 0,00161 %Dust*%Medium

$\rho=620 kg/m^3$



$\rho=660 kg/m^3$



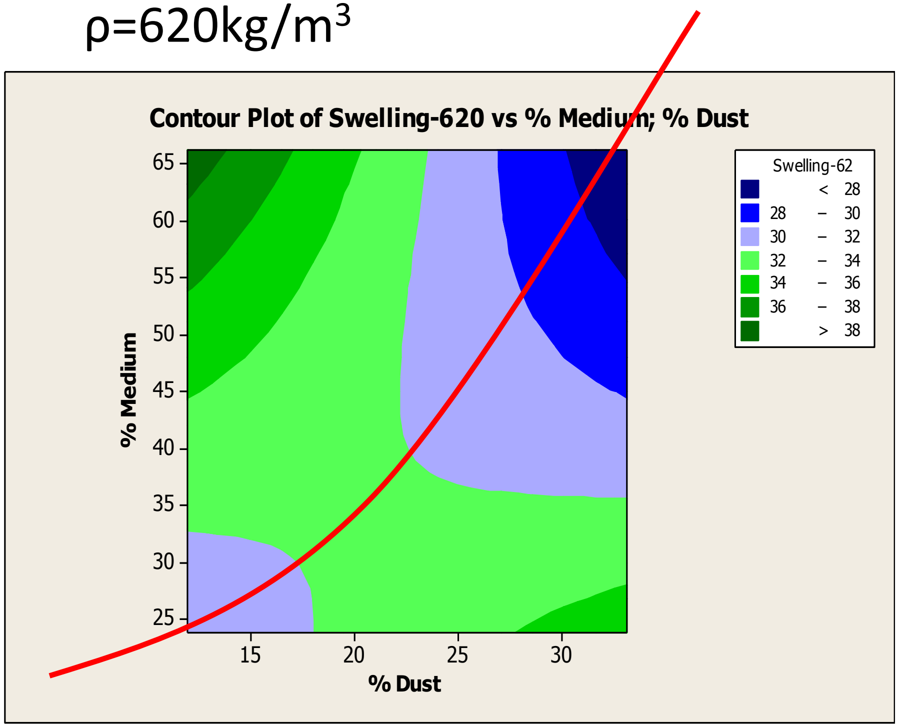
Particle size distribution (3/11)
Pinus elliottii - Swelling, %

Regression equations:

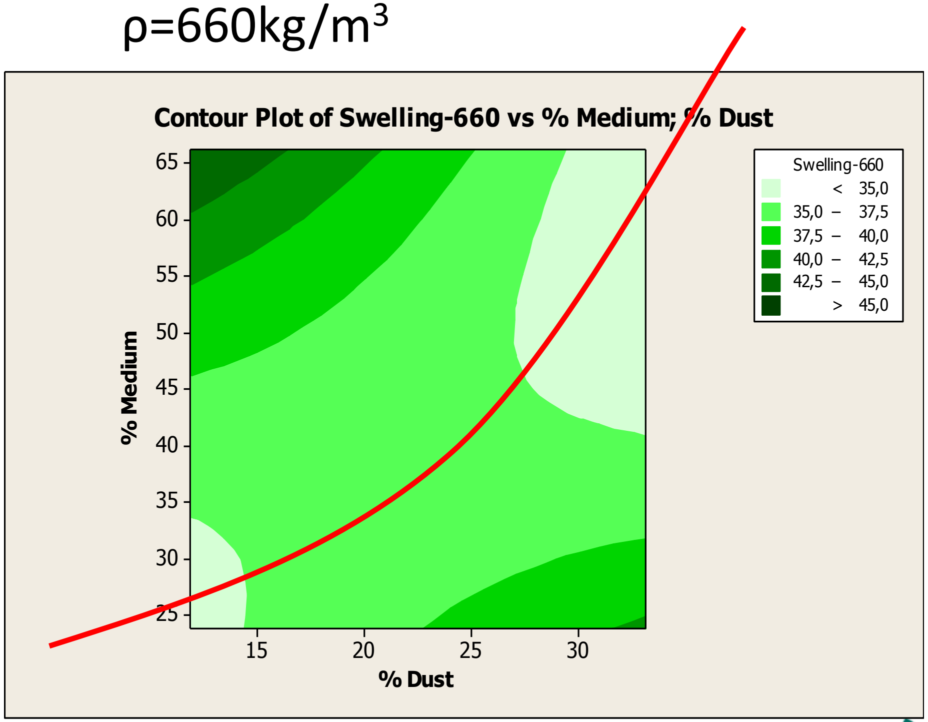
Swelling-620 = 21,4 + 0,635 % Dust + 0,258 % Medium + 0,00065 % Dust*%Dust+ 0,00187 %Medium*%Medium - 0,0192 %Dust*%Medium

Swelling-660 = 27,1 + 0,822 % Dust + 0,010 % Medium - 0,00097 % Dust*%Dust+ 0,00541 %Medium*%Medium - 0,0205 %Dust*%Medium

ρ=620kg/m^3



ρ=660kg/m^3



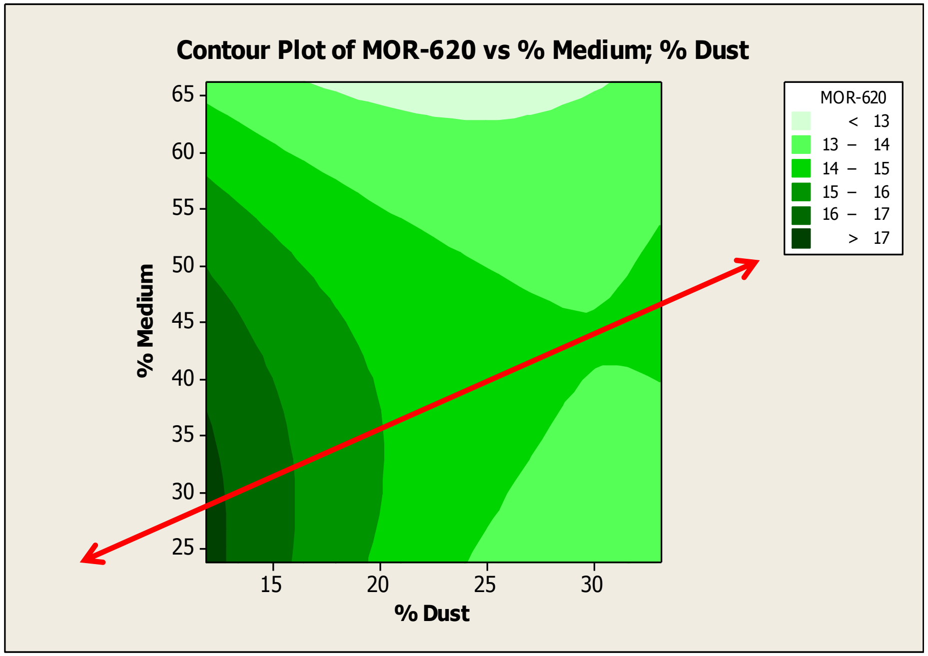
Particle size distribution (4/11)
Pinus elliottii - M.O.R., N/mm^2

Regression equations:

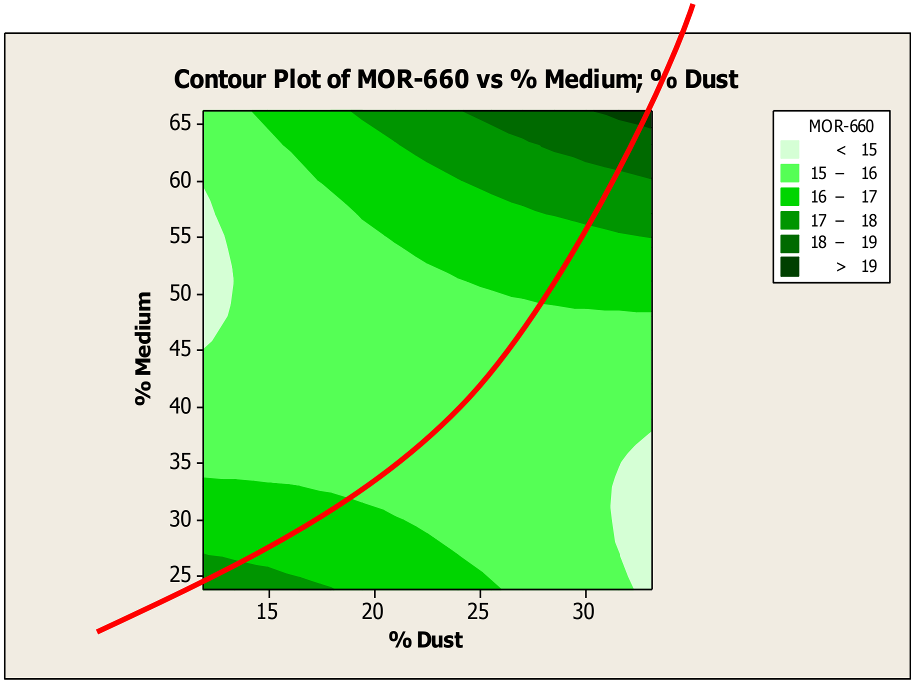
MOR-620 = 18,3 - 0,456 % Dust + 0,151 % Medium + 0,0077 % Dust*%Dust - 0,00212 %Medium*%Medium

MOR-660 = 26,7 - 0,192 % Dust - 0,440 % Medium - 0,0025 % Dust*%Dust+ 0,00337 %Medium*%Medium + 0,00734 %Dust*%Medium

ρ=620kg/m^3



ρ=660kg/m^3



Particle size distribution (5/11)
Pinus elliottii – at a glance

Density, kg/m³			620			660		
Value	Size	%	IB	TS	MOR	IB	TS	MOR
Best	Dust	Low			√			
		High	√	√		√	√	√
	Medium	Low			√			
		High	√	√		√	√	√
Improved	Dust	Low	√	√	√	√	√	√
		High		☺				
	Medium	Low	√	√	√	√	√	√
		High						
Worst	Dust	Low	√	√		√	√	
		High			√			√
	Medium	Low						√
		High	√	√	√	√	√	

Particle size distribution (6/11)

Pinus elliottii - Conclusions

- The best properties of boards are obtained at high density with high percentages of dust and medium size chips
- Improved properties of boards are obtained at low density with low percentages of dust and medium size chips
- It is interesting to note that some boards produced at a lower density have all properties improved compared to some higher density boards

IMPORTANT:

The last observation shows that optimisation of the particle size distribution of the used material can have huge economical impact on the profitability of a particleboard production line.

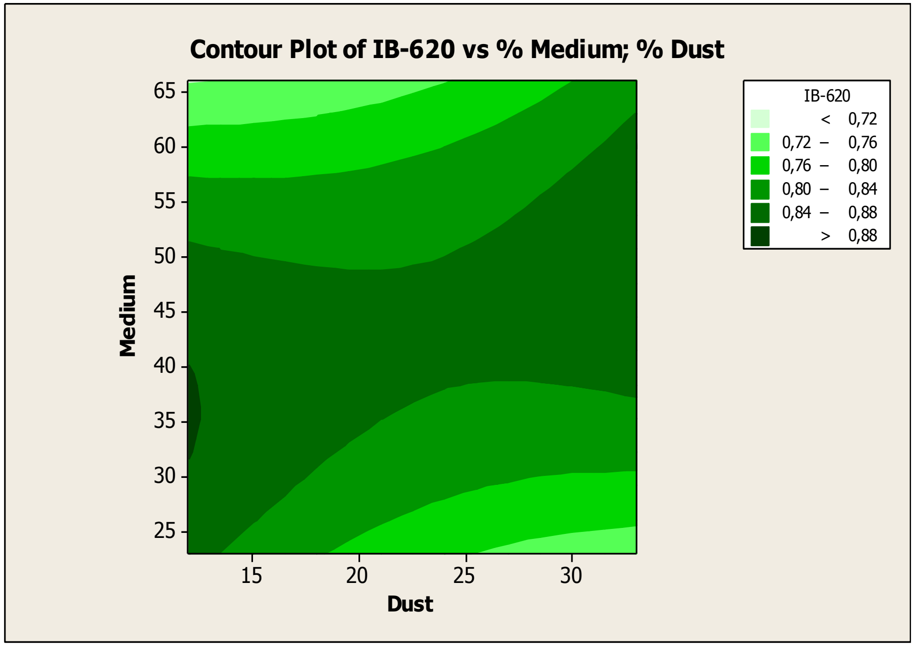
Particle size distribution (7/11)
Pinus sylvestris - I.B., N/mm^2

Regression equations:

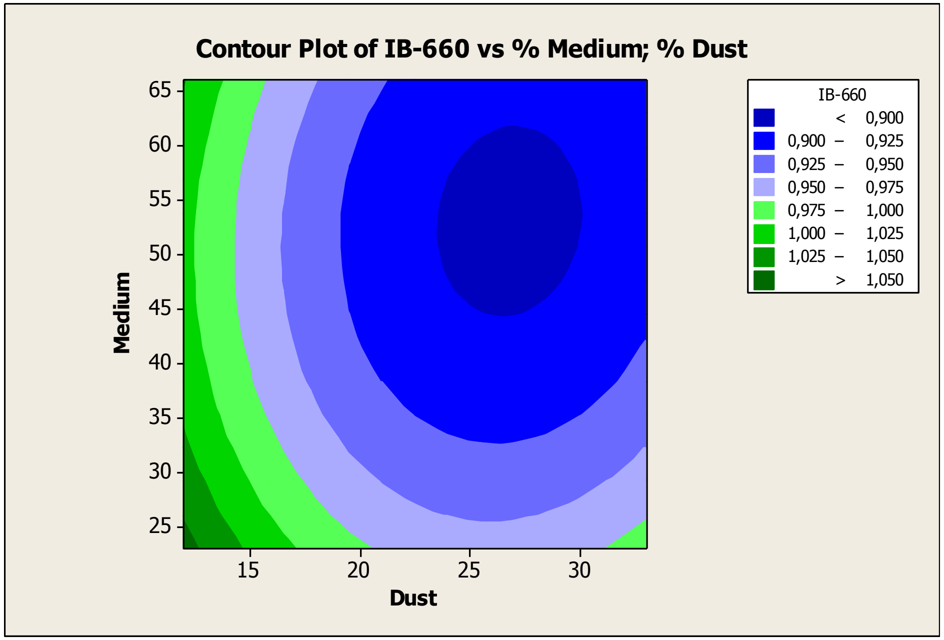
IB-620 = 0,858 - 0,0197 % Dust + 0,0102 % Medium + 0,000188 % Dust *% Dust- 0,000183 % Medium*% Medium + 0,000248 % Dust* % Medium

IB-660 = 1,46 - 0,0274 % Dust - 0,0077 % Medium + 0,000517 % Dust * % Dust+ 0,000074 % Medium* % Medium

ρ=620kg/m^3



ρ=660kg/m^3



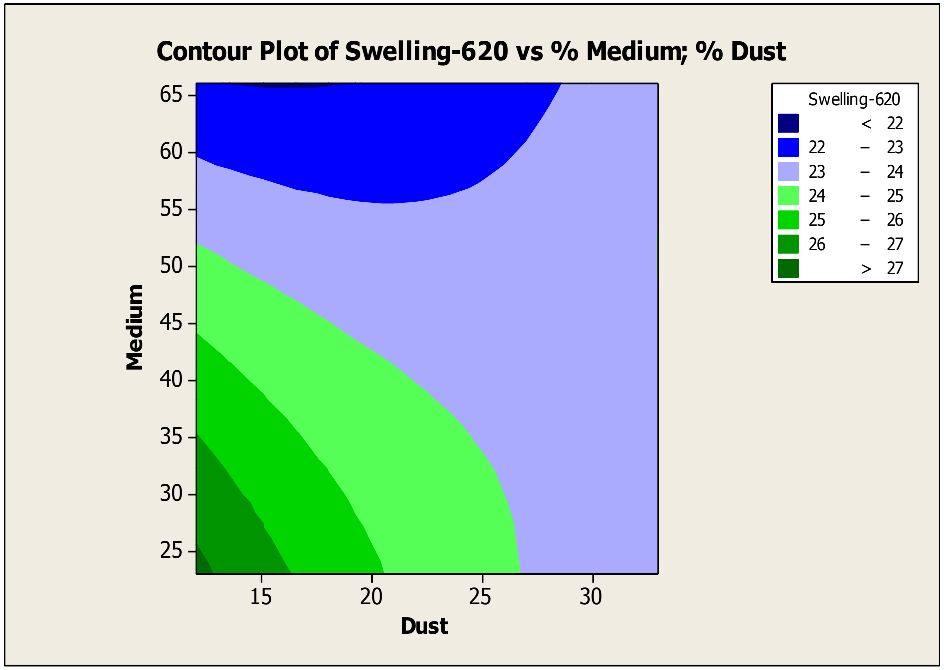
Particle size distribution (8/11)
Pinus sylvestris - Swelling, %

Regression equations:

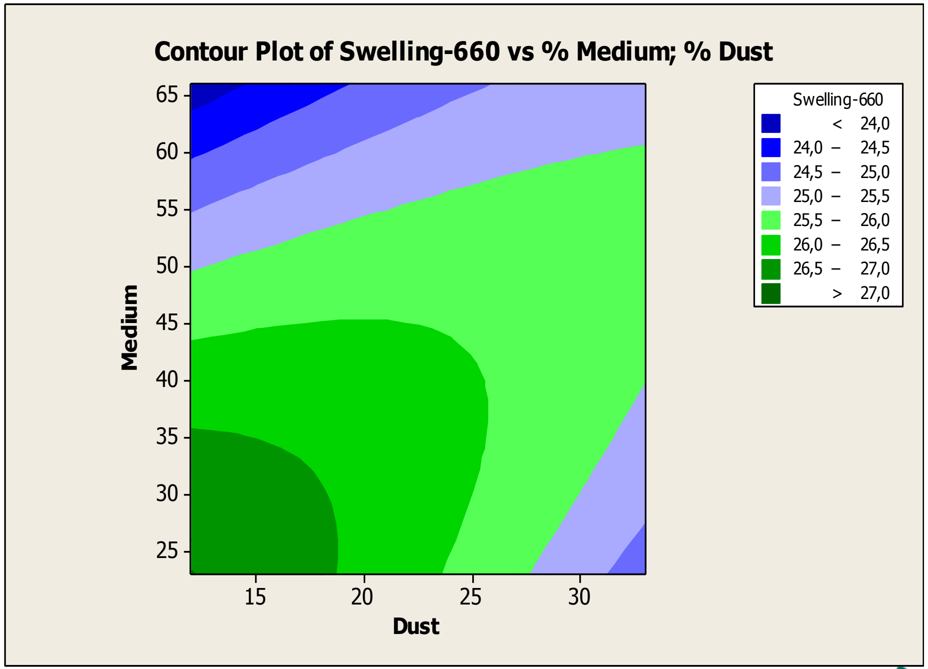
Swelling-620 = 35,6 - 0,626 % Dust - 0,139 % Medium + 0,00683 % Dust *% Dust - 0,000621 % Medium*% Medium + 0,00613 % Dust* % Medium

Swelling-660 = 28,5 - 0,105 % Dust - 0,019 % Medium - 0,00232 % Dust *Dust - 0,00124 % Medium* % Medium + 0,00436 % Dust* % Medium

ρ=620kg/m^3



ρ=660kg/m^3



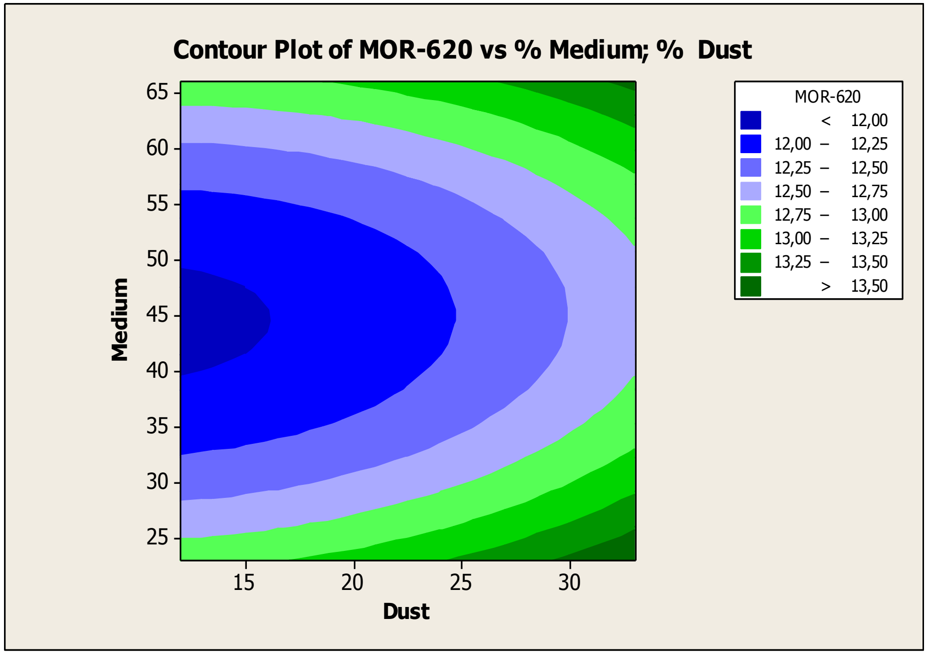
Particle size distribution (9/11)
Pinus sylvestris - M.O.R., N/mm^2

Regression equations:

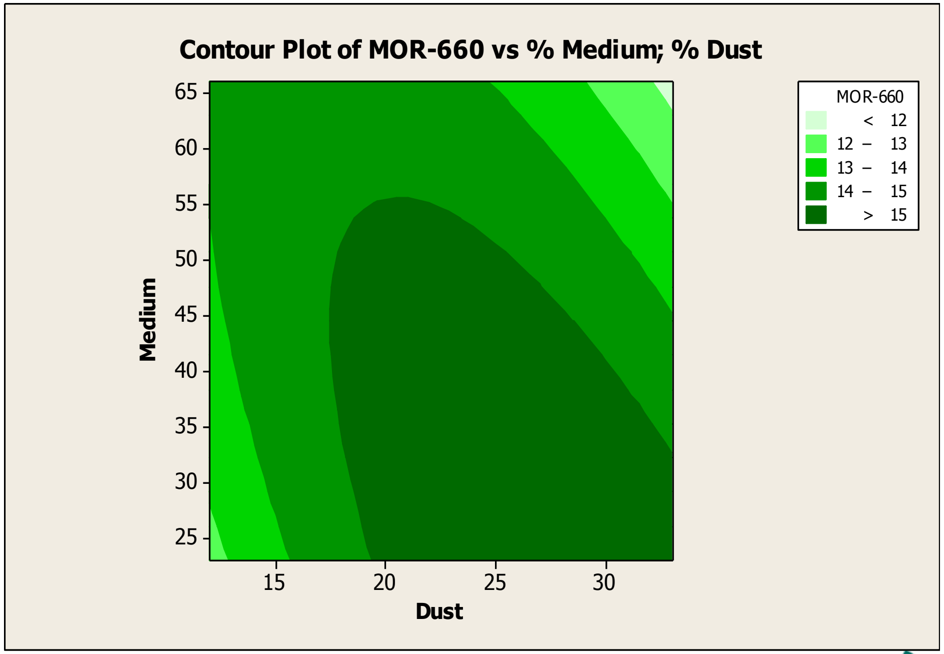
MOR-620 = 16,3 - 0,027 % Dust - 0,189 % Medium + 0,00136 % Dust *% Dust + 0,00210 % Medium* % Medium

MOR-660 = 1,83 + 0,872 % Dust + 0,192 % Medium - 0,0133 % Dust * % Dust - 0,00101 % Medium * % Medium
- 0,00581 % Dust* % Medium

ρ=620kg/m^3



ρ=660kg/m^3



Particle size distribution (10/11)
Pinus sylvestris– at a glance

Density, kg/m³			620			660		
Value	Size	%	IB	TS	MOR	IB	TS	MOR
Best	Dust	Low	√	√		√	√	
		High			√			√
	Medium	Low	√		√	√		√
		High		√			√	
Improved	Dust	Low				√		√
		High	√	√	√		√	
	Medium	Low		☺			√	
		High	√	√	√	√		√
Worst	Dust	Low	√	√	√		√	
		High				√		√
	Medium	Low		√	√		√	
		High	√			√		√

Particle size distribution (11/11)
Pinus sylvestris- Conclusions

- There is no combination of dust and medium size chips that favours all properties of boards
- Improved properties of boards at low density were obtained with high percentages of dust and medium size chips
- It is interesting to note that some boards produced at a lower density have all properties improved compared to some higher density boards.

IMPORTANT:

As in the case of pinus elliottii, the last observation shows that optimisation of the particle size distribution of the used material can have huge economical impact on the profitability of a particleboard production line.

Discussion and conclusions (1/2)

Although both experiments:

- had exactly the same experimental design
- were executed according to the same protocol
- used chips from the pine family,

the optimization did not yield identical results and did not lead to the same conclusions. This is an indication of different chip geometry!

Therefore:

Preparation of chips (milling, sieving etc.) is of cornerstone importance along with the optimized size distribution.

Discussion and conclusions (2/2)

- Wood species greatly affect the properties of the particleboards produced at lab scale
- Wood chips of different sieve fractions have different resin factor
- Smaller chips have higher resin factor
- Altering the particle size distribution by mixing different percentages of wood chip fractions, resulted in variation of the properties of boards produced
- Optimization through surface response regression analysis was possible

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