12. APPENDIX 1

Composition variables

Table A1: Average performance used to determine optimum conditions

Factor	Level	Measured value (MPa)			
		Flexural modulus	Flexural stress at yield	Young's modulus	Tensile strength at break
Polymer type	LLDPE	*5594*	42.21	4735.8	7.07
	Irradiated	3294	27.79	3346	5.2
	Fusabond	5031.7	*45.05*	*4953.4*	6.21
	AA & LLDPE	4258	33.54	4474.8	*7.23*
% Polymer	8%	623.7	12.5	3168	1.07
	14%	5192	35.51	4920.6	7.27
	20%	*6842*	48.97	*5172*	8.92
	24%	5520	*51.61*	4249.4	8.45
Particle size	90	3760	35.67	3101.6	4.86
	125	4098	33.73	3840	6.82
	180	5109	35.71	*6043.2*	*7.32*
	250	*5210*	*43.48*	4525.2	6.71

Table A2: Variance ratios at a 10% level of significance

	Flexural properties				Tensile properties			
	Modulus		Stress at Yield		Modulus		Stress at break	
	Unpooled	Pooled	Unpooled	Values not pooled	Unpooled	Pooled	Unpooled	Pooled
	F= 3.3	F= 2.81	F= 3.3		F= 3.3	F= 2.6	F= 3,3	F= 2.6
Polymer type	4.1	2.9	24		0.5	Pooled	0.9	Pooled
wt% Polymer	30.2	21.8	121.8		0.8	Pooled	13.6	13.3
Particle size	2.2	Pooled	7.1		1.6	0.97	1.2	Pooled

Preparation variables

Table A3: Average performance used to determine optimum conditions.

Variable	Level	Measured value (MPa)			
		Flexural modulus	Flexural stress at yield	Young's modulus	Tensile strength at break
Temperature (°C)	150	7115	60.45	6899	8.7
	200	7773	70.61	6853	11.28
	250	7463	70.04	6924	11.75
	300	8185	84.05	7510	9.85
Time (min)	5	7297	68.9	6744	9.77
	10	6905	69.17	7545	10.53
	15	7485	70.35	6447	9.27
	20	8822	76.73	7450	12
Pressure (MPa)	5	5037	55.7	7262	8.53
	6.5	7786	74.3	6185	9.54
	8	7493	71.05	7992	13.1
	10	10193	84.1	6747	10.4
Mass (g)	150	8002	79.86	6671	14.76
	200	6603	66.04	7257	9.12
	250	7073	66.08	7280	7.6
	300	8831	72.57	6978	10.09

Table A4: Variance ratios at a 10% level of significance

	Flexural properties				Tensile properties			
	Modulus		Stress at Yield		Modulus		Stress at break	
	Unpooled	Pooled	Unpooled	Pooled	Unpooled	Pooled	Unpooled	Pooled
	F= 5.3	F= 5.3	F= 5.3	F= 2.8	F= 5.3	F= 2.6	F= 5,3	F= 2.6
Temperature	5.6	5.6	4.8	3.8	0.1	Pooled	0.4	Pooled
Time	18.4	18.4	0.7	Pooled	0.3	Pooled	0.3	Pooled
Pressure	115.9	115.9	7.3	5.6	0.5	1.5	0.8	Pooled
Mass	25.6	25.5	2.1	Pooled	0.1	Pooled	2	3.2

Densities and voidage

Table A5 : Density and voidage

wt% polymer	theoretical density kg/m^3	Particle size range			
		125 - 180 μm		250 - 300 μm	
		Density kg/m^3	Voidage	Density kg/m^3	Voidage
0	3000	1515	0.49		
8	2528	1527	0.39	1746	0.36
10	2432	1657	0.32	1381	0.32
12	2344	1575	0.33	1705	0.31
14	2261	1581	0.3	1705	0.28
16	2185	1598	0.27	1487	0.29
18	2113	1552	0.27	1550	0.27
20	2046	1586	0.22	1597	0.22
22	1982	1389	0.01	1655	0.17
24	1923	1607	0.16	1388	0.32
26	1867	1604	0.14	903	0.17
28	1815	1679	0.07	1259	0.45
30	1765	1504	0.15	1254	0.09

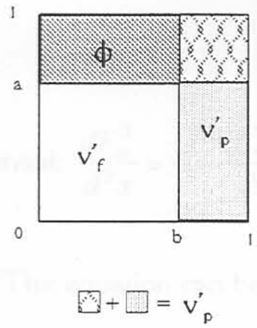
Table A6: Important physical properties of muscovite and phlogopite [18]

Characteristic	Unit	Muscovite	Phlogopite
Specific gravity		2.6 - 3.2	2.6 - 3.2
Hardness	Moh	2.8 - 3.2	2.3 - 3.0
Tensile strength	MPa	17.5	10
Shear strength	MPa	22 - 27	10 - 13
Modulus of elasticity	GPa	14 - 21	14 - 21
Maximum operating temperature	°C	500 - 600	800 - 900

13. APPENDIX 2

Voidage

The composite can be represented by the unit volume shown in the diagram below:



The voidage associated with the remaining volume fraction reinforcement, v'_f, is:

$$\frac{v_f'}{(1-\phi_m)}\phi_m = 1 - b \qquad 2.1$$

The volume fraction polymer is:

$$v_p' = 1 - a \qquad 2.2$$

and the volume fraction reinforcement is:

$$v_f' = ab \qquad 2.3$$

The sum of volume fractions should be equal to one, hence:

$$\phi + v_p' + v_f' = 1 \qquad 2.4$$

Substituting equations 2.1 and 2.2 into equation 2.3 expresses v'_f in terms of v'_p:

$$v_f' = \frac{1 - v_p'}{1 + \left(\frac{\phi_m}{1-\phi_m}\right)\left(1 - v_p'\right)} \qquad 2.5$$

Substituting Equation 2.5 into Equation 2.4 result in the expression for voidage (Equation 12):

$$\phi = \frac{\phi_m (1 - v_p^{'})^2}{1 - \phi_m v_p^{'}} \qquad 2.6$$

Young's modulus

Starting with the second order differential: $\frac{dF_m^2}{d^2x} = \frac{(1-\chi)^3 4G_p}{S} \times \left(\frac{F_m}{E_m tW} - \varepsilon \right)$, which can be solved using Laplace transforms. The equation can be written i.t.o. a few constants: $\frac{dF_m^2}{d^2x} - k_1 F_m + k_2 = 0$, where $k_1 = \frac{(1-\chi)^3 4G_p}{SE_m t}$ and $K_2 = \frac{(1-\chi)^3 4G_p W\varepsilon}{S}$. After taking the Laplace transform, the equation becomes: $S^2 f_m - k_3 - k_1 f_m + \frac{k_2}{S}$, where f_m is now a function of S, in the Laplace domain and $k_3 = F_m^{'}(0)$. The previous equation can then be written as:

$$f_m(S) = \frac{Sk_3 - k_2}{S(S - \sqrt{k_1})(S + \sqrt{k_1})} \qquad 2.7$$

Writing Equation 2.7 in terms of partial fractions yields:

$$f_m = \frac{A}{S} + \frac{B}{\left(S - \sqrt{k_1}\right)} + \frac{C}{\left(S + \sqrt{k_1}\right)} \qquad 2.8$$

with the constants: $A = \frac{k_2}{k_1}$, $B = \frac{\sqrt{k_1}k_3 - k_2}{2k_1}$ and $C = \frac{-\sqrt{k_1}k_3 - k_2}{2k_1}$. The constant k_3 can be determined knowing the end conditions, $F_m(x) = 0$ at $x = 0$ and $x = D$.

Transforming Equation 2.8 back to the x-domain, yields:

$$F_m(x) = A + Be^{\sqrt{k_1}x} + Ce^{-\sqrt{k_1}x} \tag{2.9}$$

The constant k_3 can now be determined as: $k_3 = \dfrac{k_2}{\sqrt{k_1}} \dfrac{\left(\cosh\left(\sqrt{k_1}D\right) - 1\right)}{\sinh\left(\sqrt{k_1}D\right)}$. IF the constants A, B, C and k_3 are substituted into Equation 2.9, the result is:

$$F_m(x) = \frac{k_2}{k_1}\left(1 + \frac{\sinh\left(\sqrt{k_1}x\right)\left(\cosh\left(\sqrt{k_1}D\right) - 1\right) - \cosh\left(\sqrt{k_1}x\right)\sinh\left(\sqrt{k_1}D\right)}{\sinh\left(\sqrt{k_1}D\right)}\right) \tag{2.10}$$

By noting that $\sinh\left(\sqrt{k_1}D\right) = 2\sinh\left(\sqrt{k_1}\frac{D}{2}\right)\cosh\left(\sqrt{k_1}\frac{D}{2}\right)$ and that

$2\sinh^2\left(\sqrt{k_1}\frac{D}{2}\right) = \cosh\left(\sqrt{k_1}D\right) - 1$, Equation 2.10 reduces to:

$$F_m(x) = \frac{k_2}{k_1}\left(1 - \frac{\cosh\left(\sqrt{k_1}\frac{D}{2} - \sqrt{k_1}x\right)}{\cosh\left(\sqrt{k_1}\frac{D}{2}\right)}\right) \tag{2.11}$$

To find the average force acting on the particle Equation A5 can be integrated from x = 0 to X = D. This integral is then divided by the length D: $F_{m,avg} = \dfrac{\int_0^D F_m(x)dx}{D}$.

14. APPENDIX 3

The following table describes the equipment used in this study:

Table A7: Equipment specifications

Equipment	Purpose	Specifications
High speed mixer	Homogenisation of powder mix	*Jones Model HS25 High speed Disperser* **Motor**: 7.5 kW, 380 V **Impeller**: 2x2 blade, the lower following the vessel contour, the upper being flat at right angles. **Vessel**: 25l, without cooling jacket
Heated press	Compression moulding of composite sheets	*20 MPa hydraulic press.* **Bed dimension**: 400x500mm **Temperature range**: Room temperature to 300°C.
Instron	Mechanical testing Tensile (ASTM D638) and flexural (ASTM D790)	Instron Series IX Automated Materials Testing System 1.38 **Capacity**: 5 kN **Cross-head speed**: 5 mm / min, without extensometer 60 mm support span for three point bending tests Samples were obtained by cutting 5 test pieces from each sheet using a standard jig saw

15. Appendix 4

Table A8 lists the results obtained (Young's modulus) from the experiments performed to verify the new model. The columns lists the individual repetitions and the average value at the selected weight percentage polymer used.

Table A8: Results for Young's modulus

Young's modulus (Mpa)

wt % polymer	125-180μm				
	1	2	3	4	Avg
80	138	281	332		250
70	562	437	403		467
60	252	375	371		333
30		1447	1303	1349	1366
28		1426	1559	1446	1476
26	862	851	843		852
24		1119		1095	1107
22	1469	1487	1435		1464
20	1880	1868	1929		1892
18	1349	1614	1063	1486	1378
16	876	1384	899	1138	1074
14	1156	1115	583		951
12	487	398	768	649	576
10	1126	743	755		875
8	1140	478	1283		967

	250-300μm				
	1	2	3	4	Avg
80	131	126	140		133
70	343	489	501		444
60	371	407	376		385
30	744	1052	798	972	892
28	1110	771	1360		1080
26		1403	1195		1299
24	1137	924	943		1001
22	1252	1551	1760		1521
20	1373	1488	1200	1654	1429
18	1762	1952	1605	1518	1709
16	511	1617	1304	1568	1250
14	1179	1337			1258
12	1500	1698	137		1112
10	1181	1170	603		985
8	1004	545	122	729	600

Table A9 lists the results (strength at break) obtained from the experiments performed to verify the new model. The columns lists the individual repetitions and the average value at the selected weight percentage polymer used.

Table A9: Results for tensile strength at break

Tensile strength (MPa)

wt% polymer	125-180µm				
	1	2	3	4	Avg
80	12.0	12.8	12.3		12.4
70	12.6	12.7	11.4		12.2
60	12.4	13.2	12.7		12.8
30	5.7	6.6	6.9	6.7	6.5
28	6.9	7.7	10.7	8.9	8.5
26	3.9	4.5	4.4	4.6	4.4
24	3.9	4.5	2.5	5.0	4.0
22	7.9	8.7	9.1	6.9	8.1
20	8.6	10.1	11.4	6.0	9.0
18	7.3	9.2	6.6	4.6	6.9
16	2.8	6.4	4.4	5.6	4.8
14	3.4	3.4	4.7		5.4
12	1.9	1.8	1.9	1.2	3.4
10	3.3	1.7	2.4		2.5
8	1.9	1.4	1.9		1.5

	250-300µm				
	1	2	3	4	Avg
80	13.6	13.2	13.4		13.4
70	12.4	13.9	12.3		12.9
60	14.1	14.1	14.3		14.2
30	4.1	4.4	6.0	4.6	4.8
28	5.4	3.9	8.8	10.1	7.1
26	7.3	6.0	7.1		6.8
24	5.7	5.4	4.9	7.2	5.8
22	8.1	6.5	9.6		8.1
20	8.2	7.2	8.2	9.5	8.3
18	5.7	10.7	8.7	7.3	8.1
16	2.3	3.2	7.6	8.1	5.3
14	5.8	5.0			5.4
12	4.2	4.9	1.3		3.4
10	3.0	3.1	1.5		2.5
8	2.0	1.9	0.7	1.0	1.4