CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Determination of the Optimum Condition for Glass Fiber Reinforced
Polypropylene

Processing variables such as pressure at melting period,
pressure at cooling stage, holding time, melting temperature and glass
fiber content are the important parameters affecting its composite
properties. Influences of the processing variables were considered in
the aspect of flexural properties.

4.1.1 Determination of Optimum Pressure at Melting Period

Table 4.1   Effect of Pressure at Melting Period on Flexural Strength and
Flexural Modulus

Pressure at Melting Period (psi)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Glass Content (% by weight)	Void Content (% by volume)
0	94.12(8.97)*	2286.00(342.67)	27.87(3.14)	3.82(0.97)
200	91.33(5.22)	2081.40(228.75)	29.65(0.86)	3.72(0.92)
500	93.66(3.62)	2625.80(378.12)	29.68(3.19)	1.02(0.46)
1000	88.75(6.17)	1847.46(232.78)	35.26(4.20)	4.09(0.51)

* The numbers in parenthesis are standard deviation.

Temperature: 200   °C
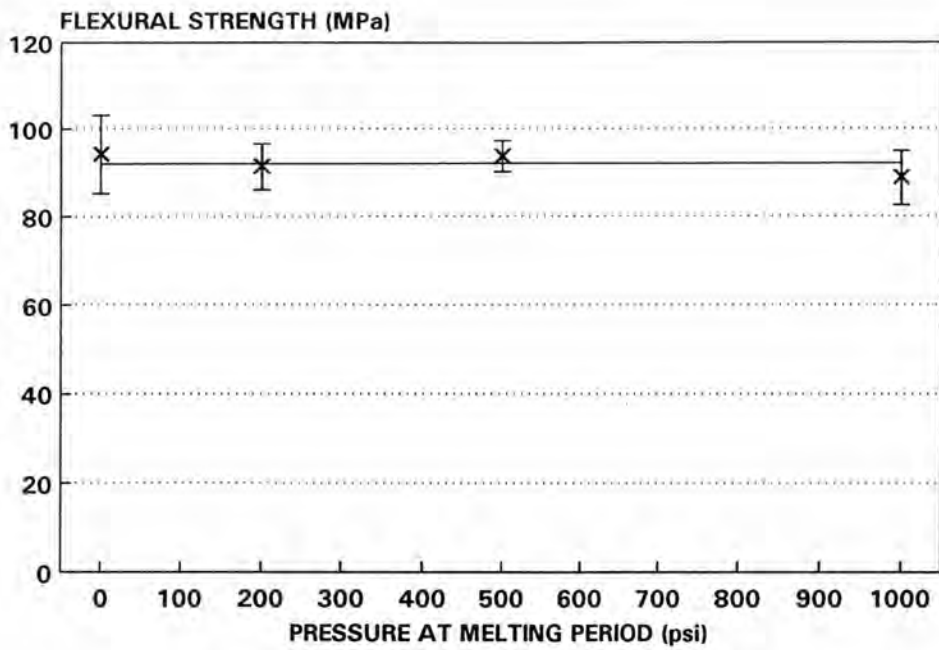Holding time: 5   mins
Pressure at cool: 1000   psi

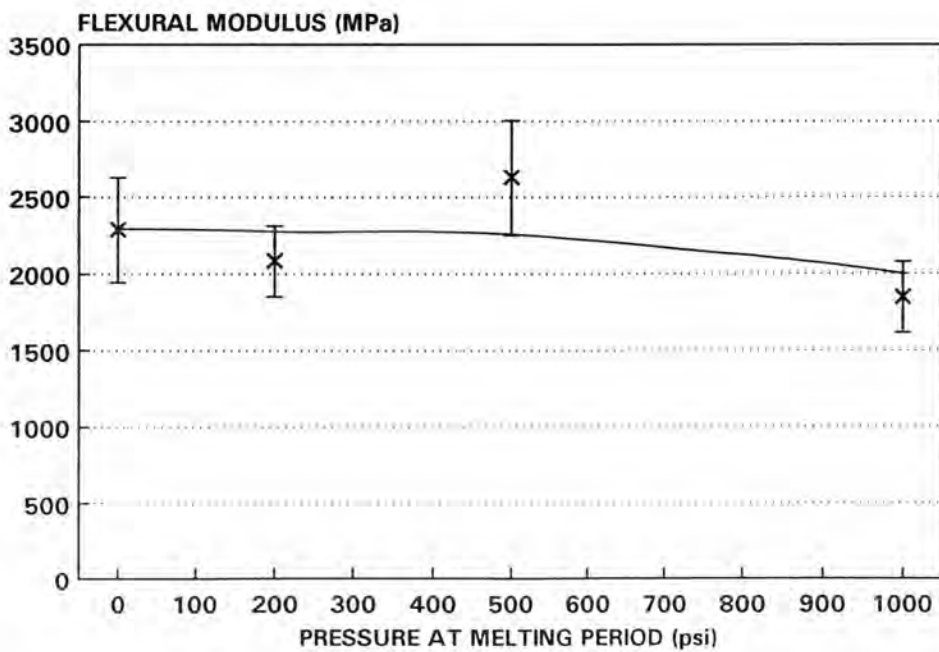Figure 4.1a   Effect of pressure at melting period on flexural strength

Figure 4.1b   Effect of pressure at melting period on flexural modulus

Flexural strength and flexural modulus of GRP, fabricated with various pressure at melting period but constant pressure at cooling stage (1000 psi), melting temperature (200°C), holding time (5 min) and glass content (35% by weight) were determined and shown in Table 4.1 and Figure 4.1. No significant difference in the flexural properties of the composites was observed. The results indicate that pressure at melting stage has no influence on flexural properties of the composites. It can be postulated that the chang of pressure at melting stage does not affect its internal stress which reduce to its mechanical properties.(50) Indeed the residual stress, internal stress, in composite was obtained by appling stress during cooling stage.

4.1.2 Determination of Optimum Pressure at Cooling Stage

Various pressure at cooling stage were applied during processing of glass fiber reinforced polypropylene. Whereas pressure at melting period, melting temperature, holding time and glass content were keep constant at 0 psi, 200°C, 5 min and 35% by weight, respectively. The results as shown in Table 4.2 and Figure 4.2 indicates that using pressure at cooling stage between 200-500 psi results to maximum flexural strength and flexural modulus. It was also observed that void content was the lowest when using the pressure between 200-500 psi. However, it is difficult for hydraulic press used in this study to adjust the pressure below 500 psi, therefore 500 psi was used for the whole study. Applying appropriate pressure at cooling stage would increase attachment ability between glass fiber and the matrix

resulting to an increase in flexural properties. However, applying too

Table 4.2   Effect of Pressure at Cooling Stage on Flexural Strength and
Flexural Modulus

Pressure at Cooling Stage (psi)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Glass Content (% by weight)	Void Content (% by volume)
0	22.95(4.56)*	229.70(120.22)	29.26(5.06)	10.30(2.60)
200	103.88(10.97)	2512.90(223.65)	31.04(4.16)	1.65(1.08)
500	102.21(2.03)	2420.80(286.38)	31.32(4.73)	1.02(0.39)
1000	94.12(8.97)	2286.00(342.67)	27.87(3.14)	3.82(0.97)
1500	96.93(6.14)	2301.5(323.59)	27.46(3.45)	0.70(0.34)

* The numbers in parenthesis are standard deviation.

Temperature: 200   °C
Holding time: 5   mins
Pressure at melt: 0   psi

much pressure at cooling stage would give a residual stress in the composite product resulting to a decrease in flexural properties.

4.1.3   Determination of Optimum Holding Time

In the processing of glass fiber reinforced polypropylene, when the temperature reached 200°C, the mixture was held for 0, 5, 10, 20 and 30 minutes, respectively. Then it was cooled under applied pressure of 500 psi. Table 4.3 and Figure 4.3 show that an increase in holding time results to a decrease in flexural strength and modulus. It is considered to be due to degradation of polypropylene as described in 2.1.4.1. Degradation of polypropylene results to a decrease of molecular weight which was confirmed by melt flow rate of polypropylene as shown in Table 4.4 and Figure 4.4. The longer holding
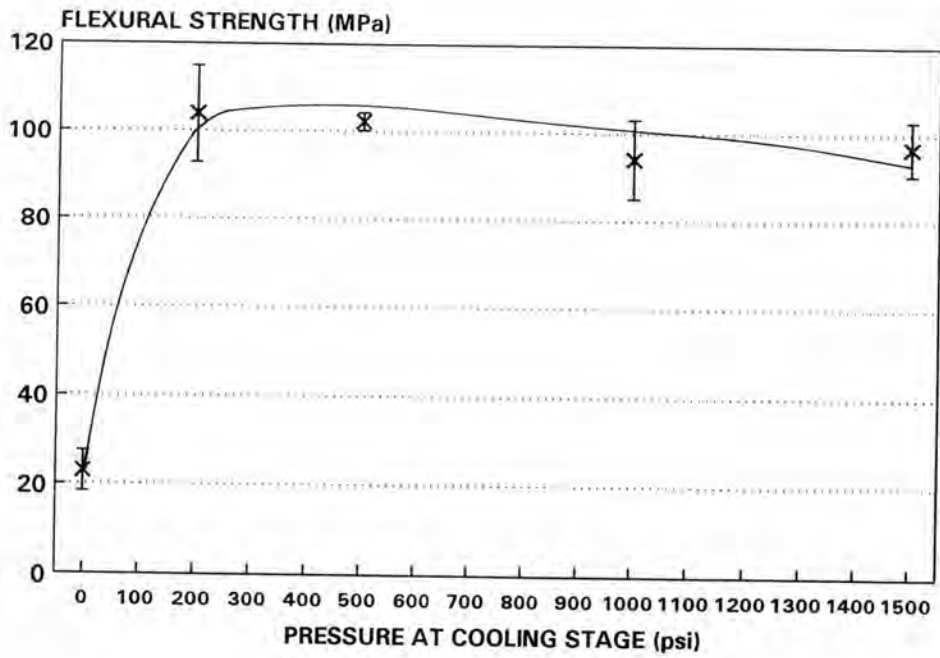
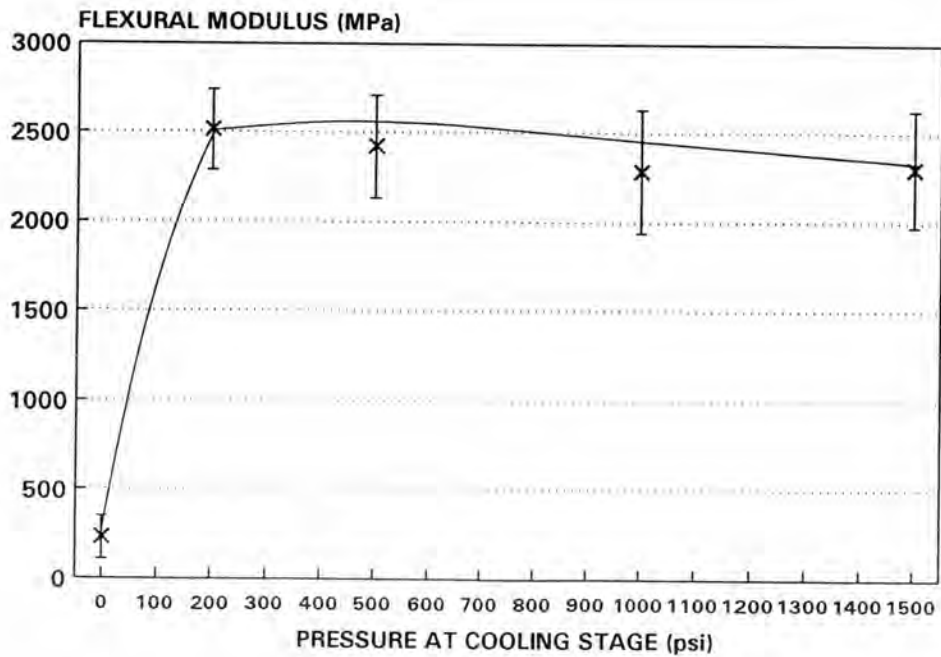Figure 4.2a   Effect of pressure at cooling stage on flexural strength

Figure 4.2b   Effect of pressure at cooling stage on flexural modulus

Table 4.3 Effect of Holding Time on Flexural Strength and Flexural Modulus

Holding Time (min)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Glass Content (% by weight)	Void Content (% by volume)
0	100.52(7.33)*	2288.71(344.22)	25.98(1.70)	0.37(0.22)
5	102.21(2.03)	2420.80(286.38)	31.32(4.73)	1.02(0.39)
10	97.64(6.63)	2228.63(338.75)	26.04(2.32)	0.84(0.29)
20	86.31(7.13)	1883.67(312.50)	26.13(3.21)	1.62(0.96)
30	80.05(6.15)	1886.63(149.61)	27.32(2.56)	1.77(0.92)

* The numbers in parenthesis are standard deviation.

Temperature: 200   °C
Pressure at melt: 0   psi
Pressure at cool: 500   psi

time the higher melt flow rate was observed. The results also indicate that why flexural properties of the GRP decreases as holding time.

Melt flow rate method were useful for indicating deterioration resulting from degradation of polymer in processing. Increasing viscosity numbers leads to a reduction of polymer flow at processing temperatures. Viscosity number is proportional to the chain length of polymer. They can, on certain assumptions, be used to calculate average molecular weight. The melt flow rate or melt flow index, determined according to ASTM D 1238 is a technological comparative value. The measured value, which is the amount extruded from the standard plastometer in g/10 min, depends on the given material and the chosen combination of total load and temperature operating on the melt. It should be quoted and often given as "condition". They can indicate a high molecular weight polymer.(51)
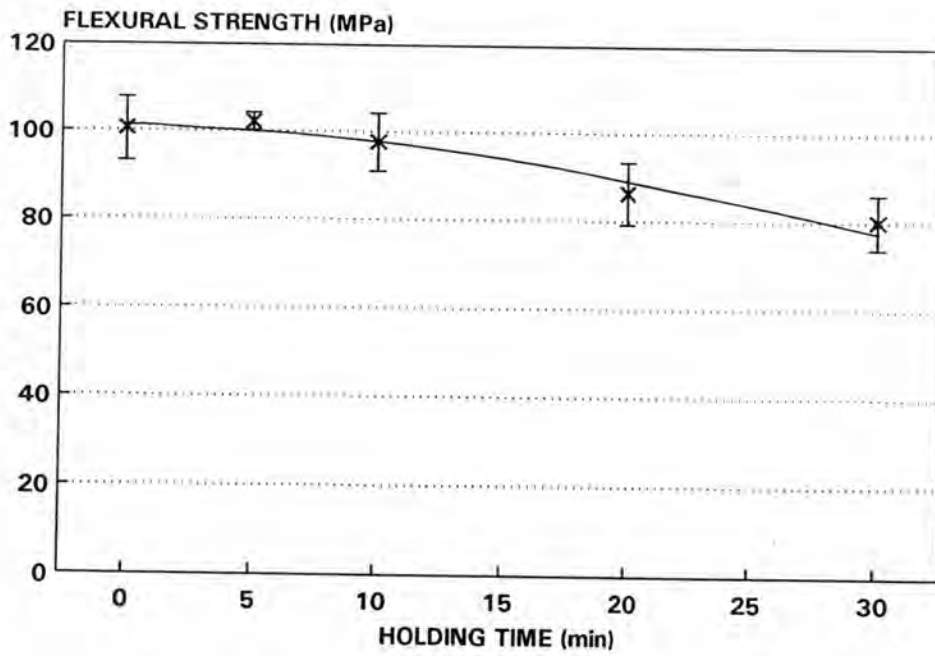
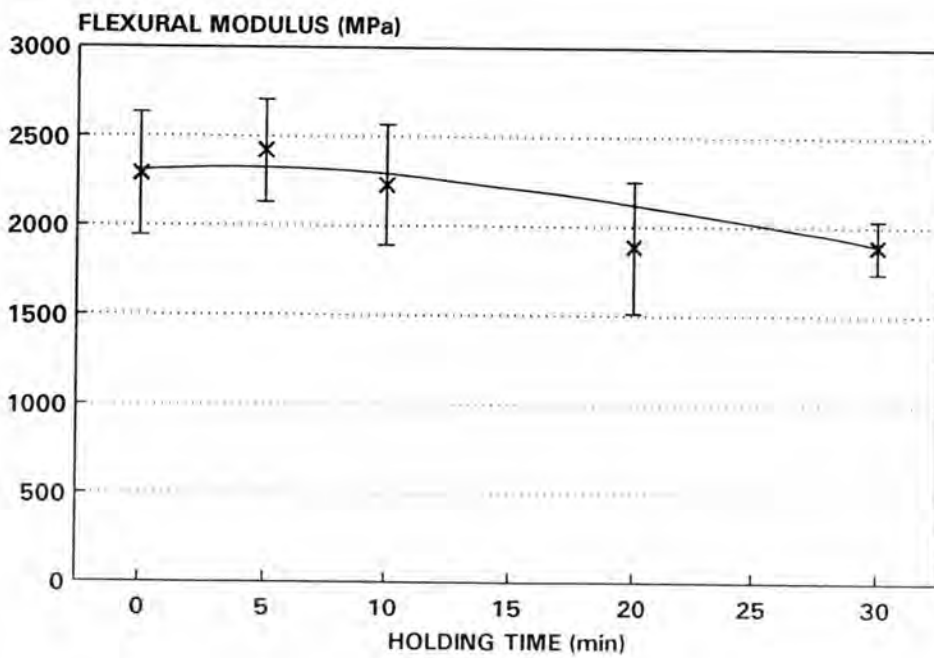Figure 4.3a   Effect of holding time on flexural strength

Figure 4.3b   Effect of holding time on flexural modulus

Table 4.4 Effect of the Holding Time on Melt Flow Rate

Holding Time (min)	Melt Flow Rate (g/10 min)
Original	4.98(1.01)*
0	15.60(2.97)
5	15.57(3.07)
10	16.00(4.11)
20	19.38(5.66)
30	25.66(4.53)

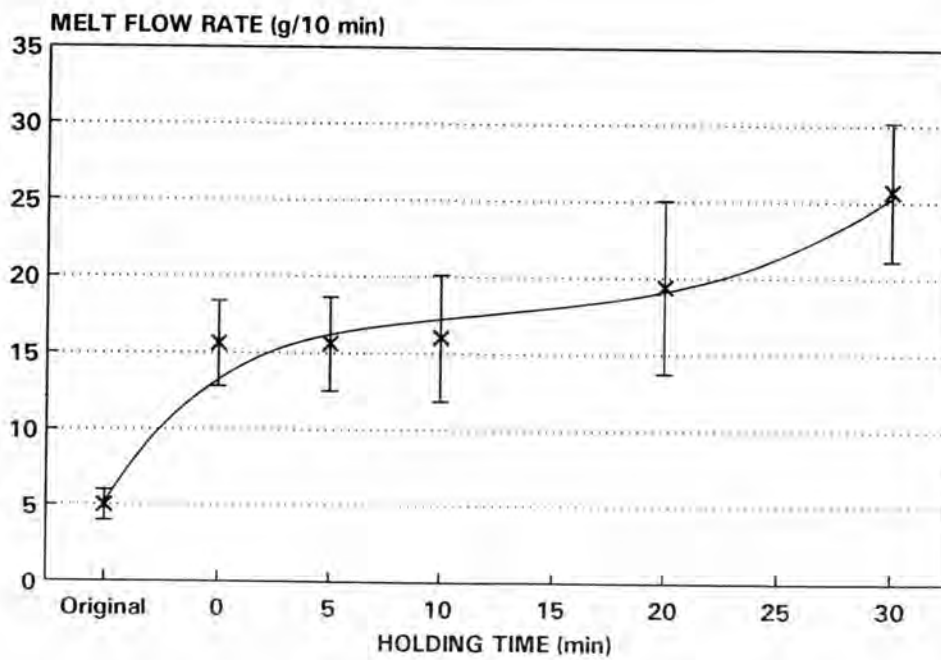* The numbers in parenthesis are standard deviation.

Figure 4.4 Effect of holding time on melt flow rate

4.1.4 Determination of Optimum Melting Temperature

In the process of glass fiber reinforced polypropylene, heat was applied to obtain expansion of molten polymer. In this study, melting temperature was varied from 180, 200, 220, and 240°C as shown in Table 4.5 and Figure 4.5. It was found that melting temperature at 180°C gave a low flexural strength and modulus because polypropylene

Table 4.5 Effect of Melting Temperature on Flexural Strength and Flexural Modulus

Melting Temperature (°C)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Glass Content (% by weight)	Void Content (% by volume)
180	76.91(11.17)*	1899.14(358.75)	27.98(1.68)	2.78(0.69)
200	100.52(7.33)	2288.71(344.22)	25.98(1.70)	0.37(0.22)
220	90.06(4.51)	2124.17(162.71)	28.33(0.74)	0.31(0.21)
240	92.20(5.22)	2090.40(414.53)	29.06(2.11)	0.64(0.46)

* The numbers in parenthesis are standard deviation.

Holding time: 0   min
Pressure at melt: 0   psi
Pressure at cool: 500   psi

powder did not completely melt in the process (T_m of polypropylene about 176°C) and the viscosity is still high. The flexural strength and modulus increased with melting temperature upto 200°C, and decreased again with higher temperature, which is considered as polypropylene degradation. Therefore, 200°C should be an optimum melting temperature for the GRP process.
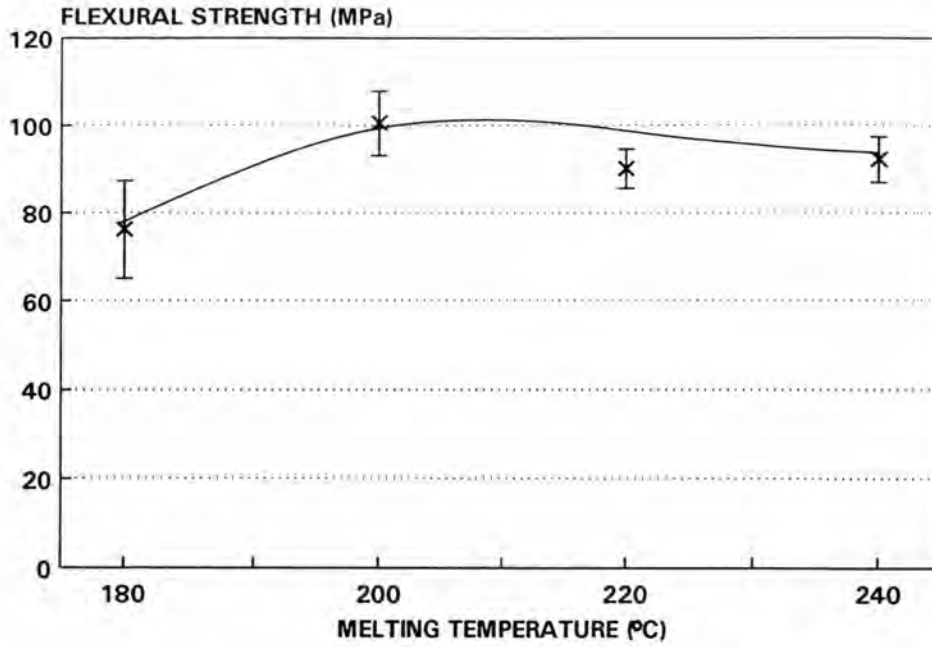
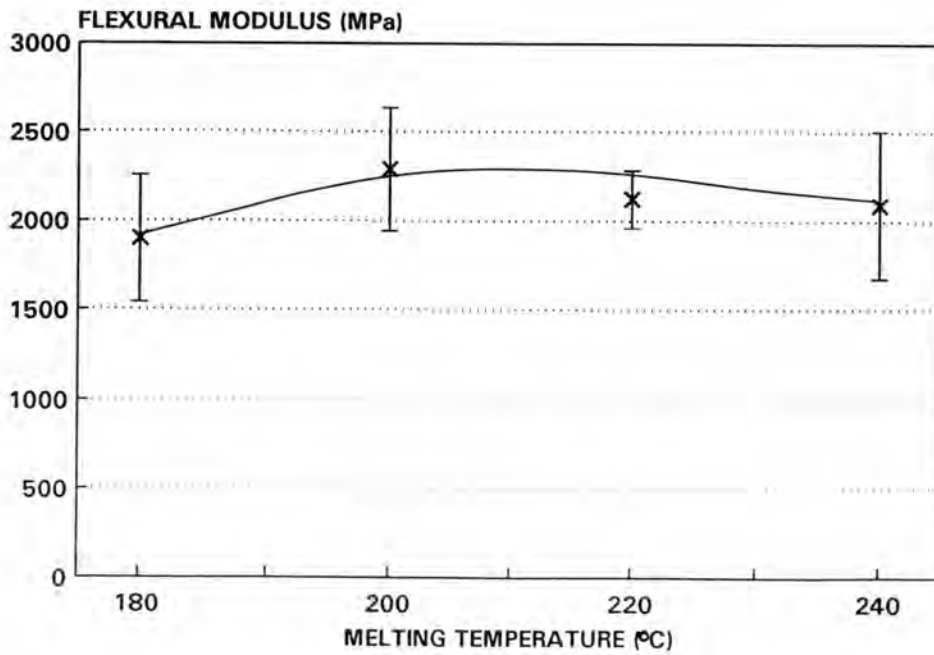Figure 4.5a Effect of melting temperature on flexural strength

Figure 4.5b Effect of melting temperature on flexural modulus

4.1.5 Determination of Optimum Glass Fiber Content

Glass fiber content in the composites greatly affected flexural strength and modulus as shown in Table 4.6 and Figure 4.6. Maximum flexural strength and modulus were observed when using glass content about 30-40% by weight.

It is considered that, below the optimum fiber content, an increase in fiber content gives the increase in capability of load -bearing of the composites because the fiber remained to serve the ability to bear the load tranferred from the matrix. Above the optimum fiber content, increase in fiber content gives the decrease in capability of load-bearing of the composites because the fiber could not serve the ability to bear the load tranferred from the matrix. The

Table 4.6 Effect of Glass Fiber Content on Flexural Strength and Flexural Modulus

Percent of Glass Fiber (%)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Glass Content (% by weight)	Void Content (% by volume)
20	77.11(4.60)*	1101(177.04)	18.37(2.10)	4.23(0.44)
25	85.67(7.91)	1386.75(129.11)	21.95(1.24)	0.75(0.57)
30	100.52(7.33)	2288.71(344.22)	25.98(1.70)	0.37(0.22)
35	105.79(9.12)	2776.56(845.46)	31.32(2.02)	0.75(0.51)
40	90.86(8.13)	2542.57(134.25)	35.61(1.27)	1.08(0.55)
50	73.84(11.79)	2034.57(404.07)	44.65(2.83)	3.37(2.07)

* The numbers in parenthesis are standard deviation.

Temperature: 200 °C
Pressure at cool: 500 psi
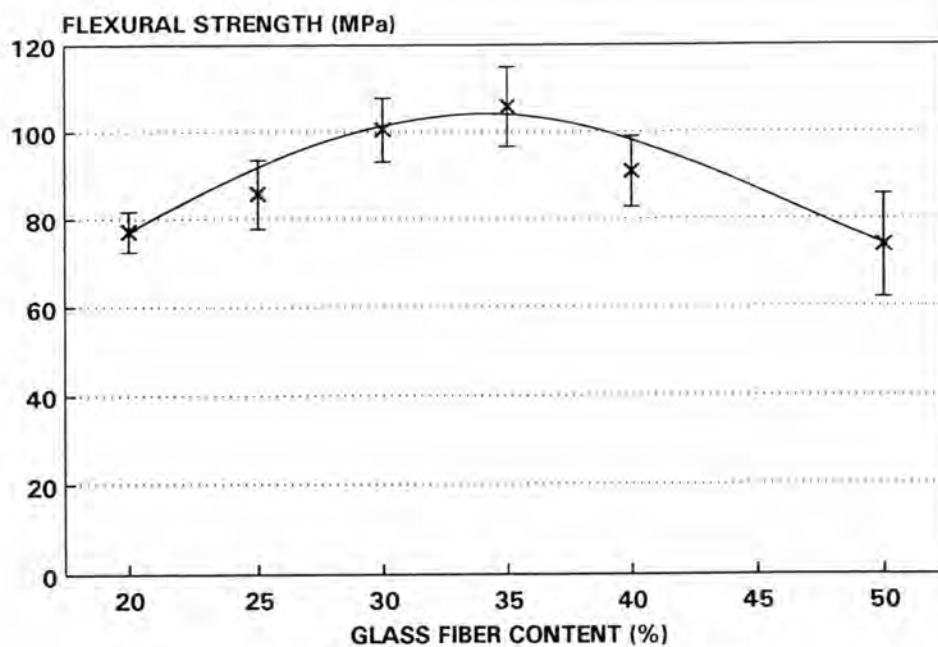Pressure at melt: 0 psi
Holding time: 0 min

Figure 4.6a Effect of glass fiber content on flexural strength
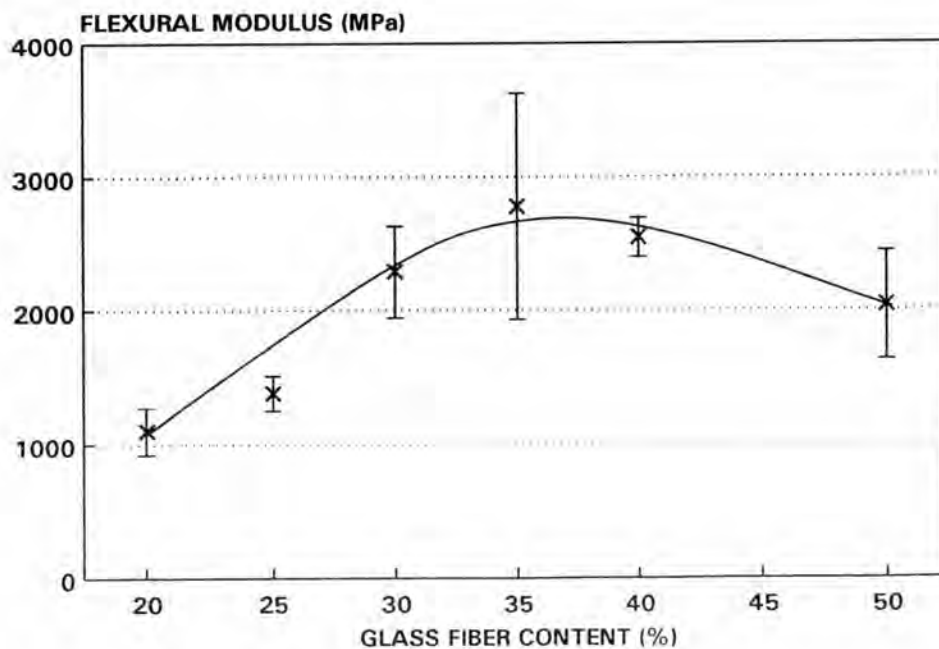

Figure 4.6b Effect of glass fiber content on flexural modulus

loss of ability to bear load of the fiber may be due to interfacial voids generated from the difficulty of the matrix to penetrate throughly the holes among the fiber. The number of voids among the fiber and matrix would increase with the amount of fiber loading. In this experiment, the amount of the glass fiber in composites over 35% would decrease the flexural strength and modulus.
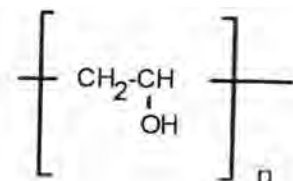
4.2 Investigation of the Effect of Surface Treating Agent on Flexural Properties of the GRP

4.2.1 Effect of Surface Treating Agent Coated on Coupling Agent Free Glass Fiber

Compatibility between hydrophilic glass fiber and hydrophobic polypropylene is expected to be enhanced by using appropriate surface treating agents or coupling agents. The following surface treating agent was separately treated on coupling agent-free or heat-cleaned glass fiber. Then the treated fiber was used to fabricate GRP with the optimum condition obtained from 4.1 which is $200^{\circ}C$ melting temperature, 0 psi melting pressure, 0 min holding time, 500 psi cooling pressure and 35% by weight glass content.
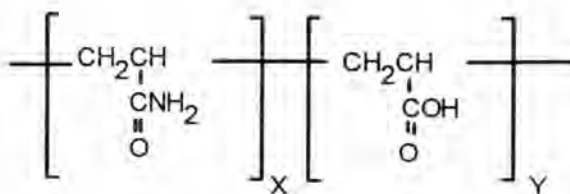
Anionic Polyacrylamide (Fogger)

Polyvinylalcohol (PVA)

R-O-CH$_2$-COONa

CH$_2$OH

OH

OH

R =   CH$_2$OH

OH

OH
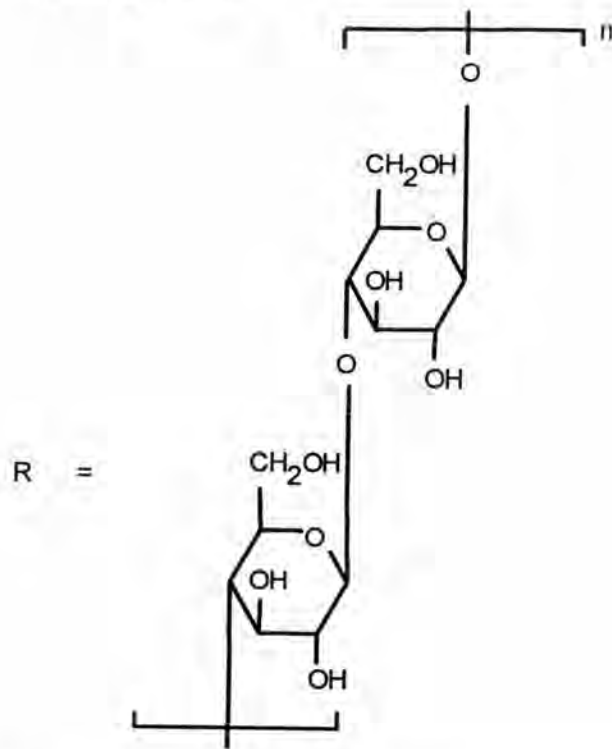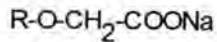
Sodium carboxymethylcellulose (CMC)

Polypropylene - Maleic
Anhydride (E43P)

$$CH_3$$
$$CH_2=C-CO-O-CH_2CH_2CH_2Si(OCH_3)_3$$
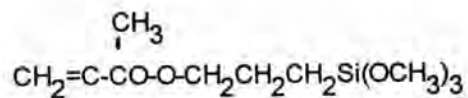
3 - Methacryloxypropyltrimethoxysilane (A-174)

Figure 4.7a and 4.7b show the effect of surface treating agent coated on coupling agent-free glass fiber on flexural strength and modulus, both from experiment and from calculation. The results from calculation should be more reliable than those from experiment because the effect of voids in the composite is eliminated. By using polynomial regression equation method in computer software of S.P.S. (52), the flexural strength and modulus were determined with enclosure of the effect of glass fiber content and void content. The

Table 4.7 Effect of Surface Treating Agent Coated on Coupling Agent Free Glass Fiber on Flexural Strength and Flexural Modulus
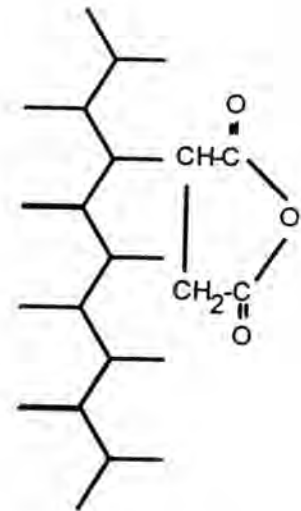
Surface Treating Agents (0.10%)	Flexural Strength (MPa)		Flexural Modulus (MPa)		Glass Content (% by weight)	Void Content (% by volume)
	From experiment	From calculation**	From experiment	From calculation**		
None	45.73(3.22)*	48.58	1526.20(214.6)	1759.71	38.06(1.87)	2.55(1.40)
A-174	66.37(10.17)	57.89	2834.88(661.7)	2228.53	32.73(3.85)	1.32(0.91)
PVA	60.76(8.44)	58.25	2785.15(470.9)	2764.60	37.64(4.11)	1.21(0.28)
CMC	57.66(5.32)	51.90	2056.78(494.2)	1889.83	36.80(3.32)	1.03(0.22)
Fogger	53.17(2.91)	50.80	1288.60(251.2)	1642.56	32.98(3.76)	1.20(0.63)
E43P	42.48(2.35)	48.54	1126.00(224.3)	2132.09	34.01(3.96)	1.32(0.59)

* The numbers in parenthesis are standard deviation.
** From Table 4.11

results show that the coupling agent-free glass fiber (heat-cleaned glass fiber) treated with each surface treating agent gave higher flexural properties than the untreated glass fiber. These indicate that there is an interfacial adhesion induced by any surface treating agent between the fiber and the matrix. Indeed, in the absence of such adhesion, the fiber would act as a void and therefore stress concentration exists, thereby it reduce the flexural strength and modulus of the composites.(53) In the present of surface treating agent, the appearance of interfacial adhesion may be due to a role of fiber wetting via physical absorption or secondary chemical bond, i.e., van der waals force.

It was observed that, the highest flexural properties were obtained when glass fiber was treated with A-174, considering as ability of adhesion enhancement between the glass fiber and the matrix by means of compatibility. A-174 is an organofunctional silane generally recommended for "coupling" organic polymers to mineral
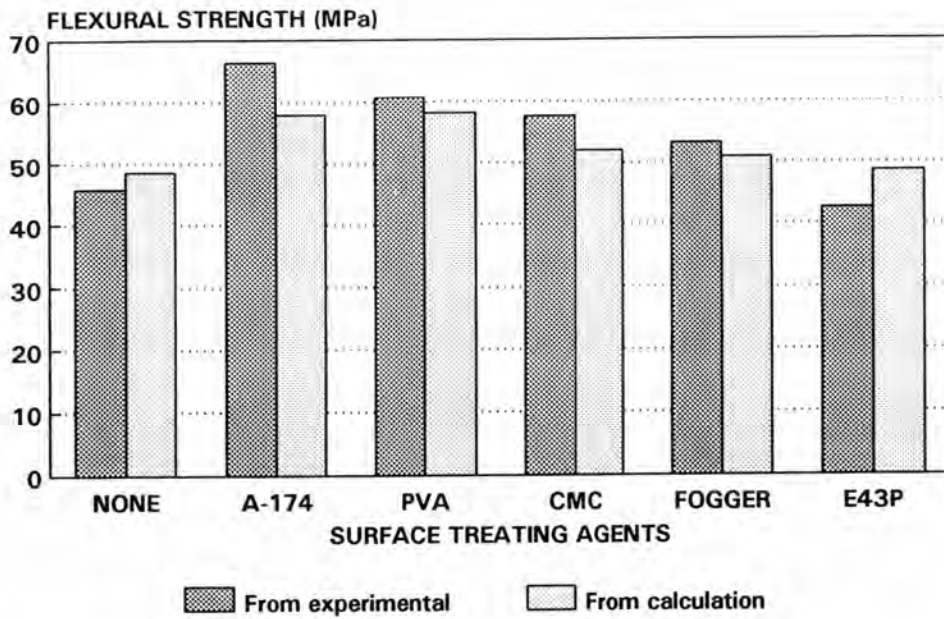
Figure 4.7a Effect of surface treating agent coated on coupling agent-
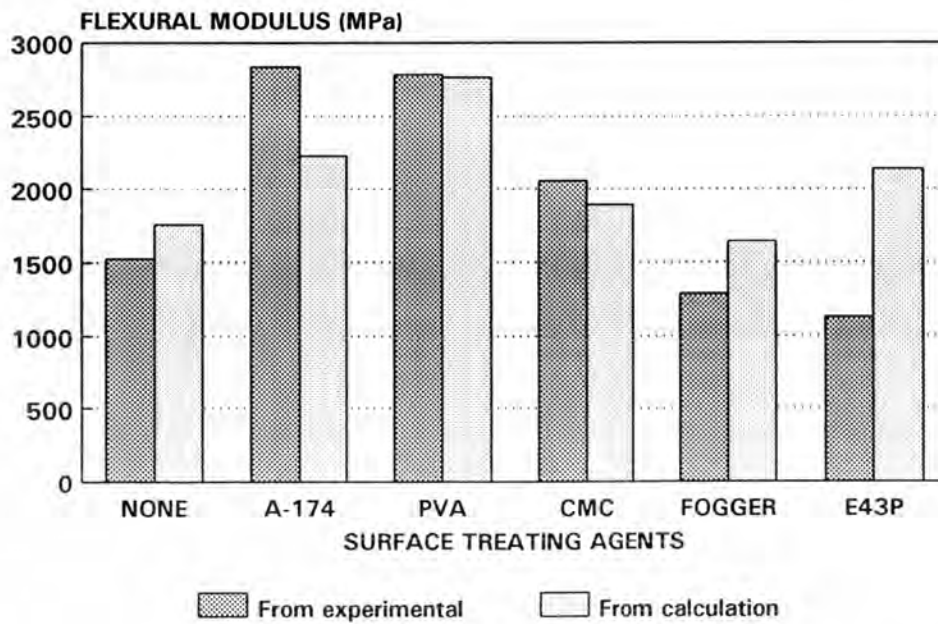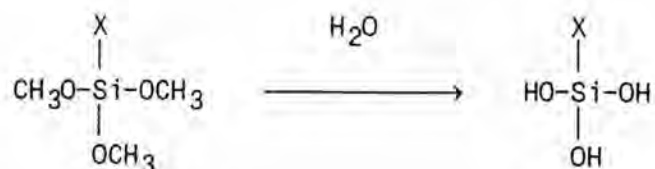free glass fiber on flexural strength

Figure 4.7b Effect of surface treating agent coated on coupling agent-
free glass fiber on flexural modulus

substrates (such as glass).(54) A-174 surface treating agent was prehydrolyzed and applied to glass through a dilute aqueous solution. Upon drying, silanols of the coupling agent condense with silanols of the glass to form covalent siloxane bond with the surface as shown below. The silanes readily form three-dimensional polysiloxane networks through hydrolysis and condensation of the alkoxy groups.

General Structure

$$CH_3O-\underset{\underset{OCH_3}{|}}{\overset{\overset{X}{|}}{Si}}-OCH_3 \quad \xrightarrow{H_2O} \quad HO-\underset{\underset{OH}{|}}{\overset{\overset{X}{|}}{Si}}-OH$$

Trialkoxy silane

$$X: \quad CH_2=\overset{\overset{CH_3}{|}}{C}-CO-O-CH_2CH_2CH_2-$$

Physical Adsorption
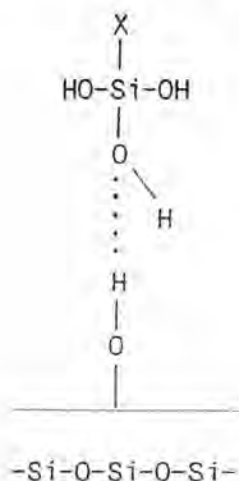
Solvent Evaporation and Hydrogen Bonding

-Si-O-Si-O-Si-   -Si-O-Si-O-Si-
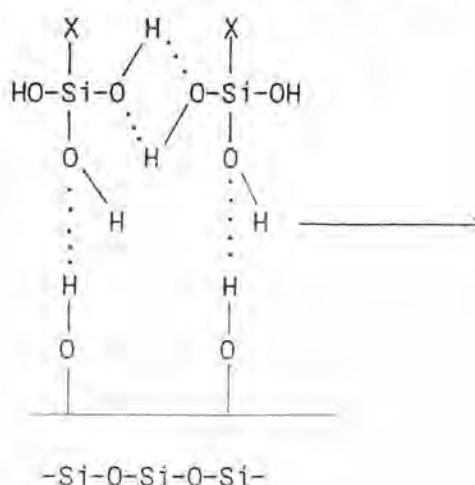
Surface Polymerization

```
       X     X     X
       |     |     |
     -Si-0-Si-0-Si-0-
       |     |     |
       0     0     0
       |     |     |
  _____|_____|_____|_____

     -Si-0-Si-0-Si-0-
```
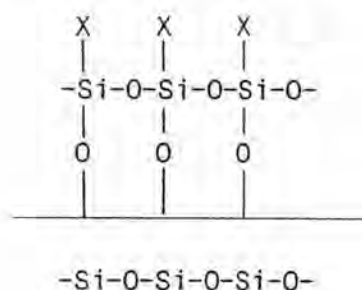
Then, the polymeric siloxane segments may interdiffuse among polypropylene chains without any crosslinking in either phase. In case of other surface treating agents (Fogger, PVA, CMC, and E43P), they also act as the substance improving compatibility of the glass fiber and the matrix, resulting to better flexural properties. This can be postulated that the surface treating agents have a potential to form H-bonding with glass fiber by use of hydrophilic parts and form van der waals force by hydrophobic parts. The hydroxyl groups of PVA and CMC, amide groups of Fogger and maleic anhydride groups of E43P are hydrophilic parts being able to form good H-bond with glass fiber. The hydrophobic parts of hydrocarbon backbone of PVA, Fogger, E43P, and six-member ring of CMC can form good adhesion with the polypropylene matrix. Therefore, the surface treating agents should primarily defined as materials that improve adhesion of dissimilar surface between organic and inorganic boundary layers. This must involve not only an increase in true adhesion, but also better wetting, rheology, and other handling properties. In the polymer composite industries, one should use appropriate surface treating agents for both the resins and the reinforcements.

In case of polypropylene and fiber glass, A-174 seems to be

the most appropriate surface treating agent; however, PVA should be also an appropriate one.

4.2.2 Effect of Surface Treating Agent coated together with the Coupling Agents Available on Commercial General Purpose Glass Fiber

Glass fibers used in this experiment was obtain from Asia Glass Fiber Industry Co., Ltd. (AGI). It was a general purpose grade which was proceeded a film-forming polymer process to produce a uniform protective coating and treated with organofunctional silane to promote adhesion. However, the chemical structures of film-forming polymer and organofunctional silane were concealed. Treatment of any surface treating agent (A-174, PVA, CMC, Fogger, and E43P) gave lower flexural strength than untreatment as shown in Table 4.8 and Figure 4.8. It can be postulated that overcoating of surface treating agent onto AGI glass fiber cannot enhance adhesion between the coupling

Table 4.8 Effect of Surface Treating Agent Coated together with the Coupling Agent Available on Commercial Genera Purpose Glass fiber (AGI) on Flexural Strength and Flexural Modulus

Surface Treating Agents (0.10%)	Flexural Strength (MPa)		Flexural Modulus (MPa)		Glass Content (% by weight)	Void Content (% by volume)
	From experiment	From calculation**	From experiment	From calculation**		
None	105.79(9.12)*	102.09	2776.56(845.5)	2375.93	31.32(2.02)	0.75(0.51)
A-174	65.71(5.78)	39.09	2351.88(798.7)	2978.80	33.21(1.64)	2.46(1.58)
PVA	71.58(9.11)	77.47	2199.90(509.1)	2872.55	32.68(1.75)	1.18(0.44)
CMC	71.64(5.00)	74.36	1764.00(165.9)	2100.78	31.34(3.13)	2.58(0.91)
Fogger	79.09(2.92)	86.72	1661.80(124.3)	3468.68	25.64(4.45)	0.94(0.16)
E43P	70.08(5.47)	68.14	2602.00(441.3)	2616.47	34.04(1.94)	1 35(0.65)

* The numbers in parenthesis are standard deviation.
** From Table 4.11

Figure 4.8a   Effect of surface treating agent coated together with the
coupling agent available commercial general purpose glass
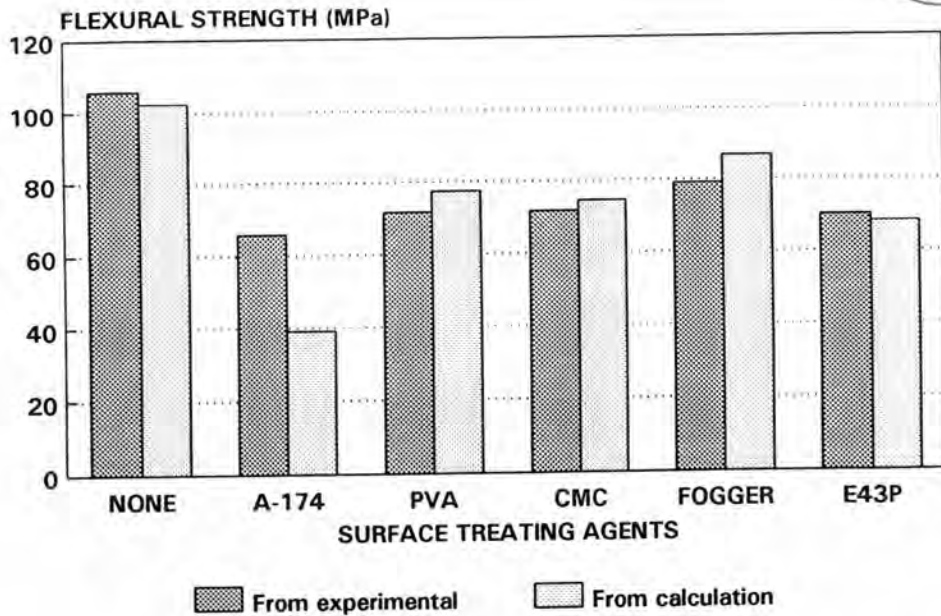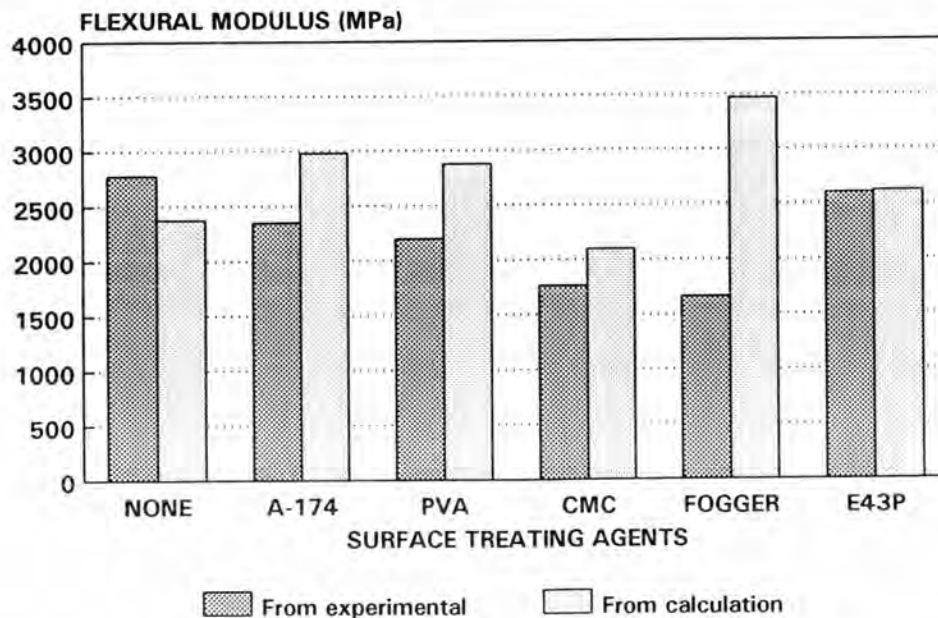fiber (AGI) on flexural strength

Figure 4.8b   Effect of surface treating agent coated together with the
coupling agent available commercial general purpose glass
fiber (AGI) on flexural modulus

agents available on AGI glass and the polypropylene matrix due to the lack of coupling agent reactivity and multilayer forming of sizing agent. It is generally accepted that multilayer forming of sizing agent onto the glass fiber would give worse mechanical properties of the composites. The fact that using original AGI glass fiber to fabricate the GRP obtained the highest flexural strength may be due to suitability of the coupling agent of the AGI glass for the polypropylene matrix.

4.2.3 Effect of Surface Treating Agent Coated together with the Coupling Agent Available on Commercial Glass Fiber Special for Thermosets

Glass fiber obtained from Nippon Electrical Glass Co., Ltd. (NEG) was also used for the present study. It was passed the process of film forming and treated with organofunctional silane suitable for thermosetting plastics especially unsaturated polyester.

Table 4.9 Effect of Surface Treating Agent Coated together with the Coupling Agent Available on Commercial Glass Fiber Special for Thermosets (NEG) on Flexural Strength and Flexural Modulus

Surface Treating Agents (0.10%)	Flexural Strength (MPa)		Flexural Modulus (MPa)		Glass Content (% by weight)	Void Content (% by volume)
	From experiment	From calculation**	From experiment	From calculation**		
None	64.84(6.20)*	54.25	2439.29(369.6)	1749.97	34.86(1.61)	0.70(0.50)
A-174	63.72(9.02)	65.81	2666.00(586.8)	2453.98	33.72(1.51)	2.02(1.03)
PVA	55.75(8.20)	50.63	2114.00(288.6)	2197.37	32.48(2.23)	0.35(0.24)
CMC	68.63(8.67)	75.40	2514.40(479.8)	2046.07	33.00(0.81)	1.29(0.37)
Fogger	64.44(13.07)	66.53	2314.40(232.6)	2362.96	37.80(5.06)	1.07(0.27)
E43P	83.71(8.89)	91.85	2878.30(375.9)	3587.28	33.65(1.46)	1.62(0.73)

* The numbers in parenthesis are standard deviation.
** From Table 4.11

FLEXURAL STRENGTH (MPa)

Figure 4.9a   Effect of surface treating agent coated together with the
coupling agent available on commercial glass fiber (NEG)
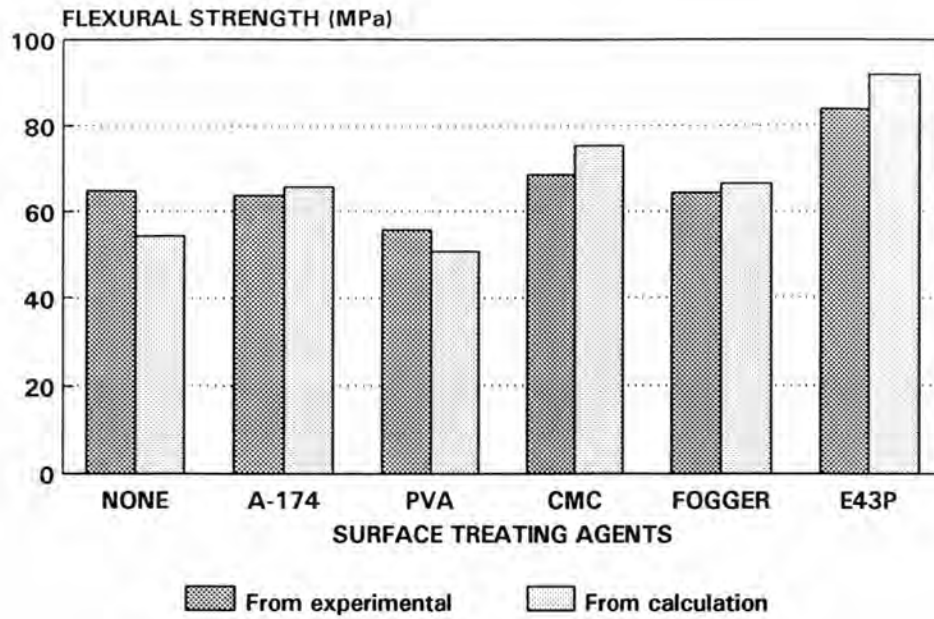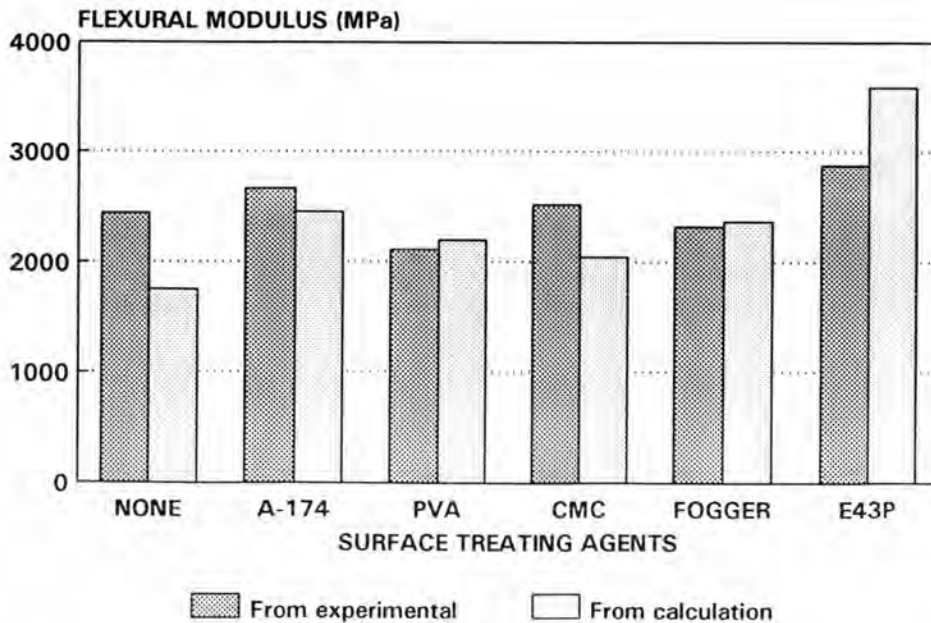on flexural strength

FLEXURAL MODULUS (MPa)

Figure 4.9b   Effect of surface treating agent coated together with the
coupling agent available on commercial glass fiber (NEG)
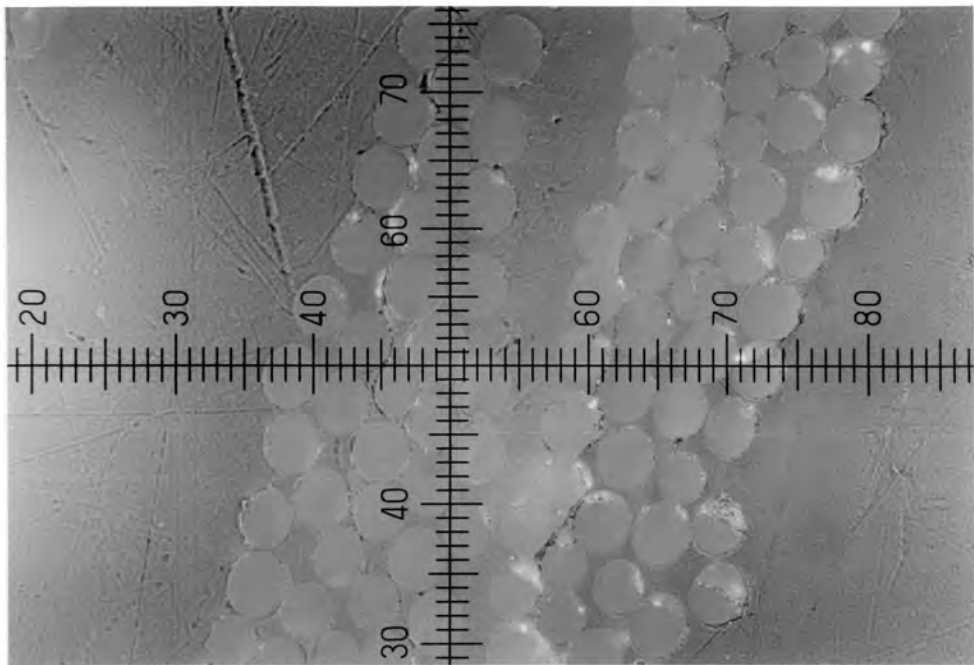on flexural modulus

Figure 4.10a   Microstructure of commercial glass fiber (AGI) reinforced
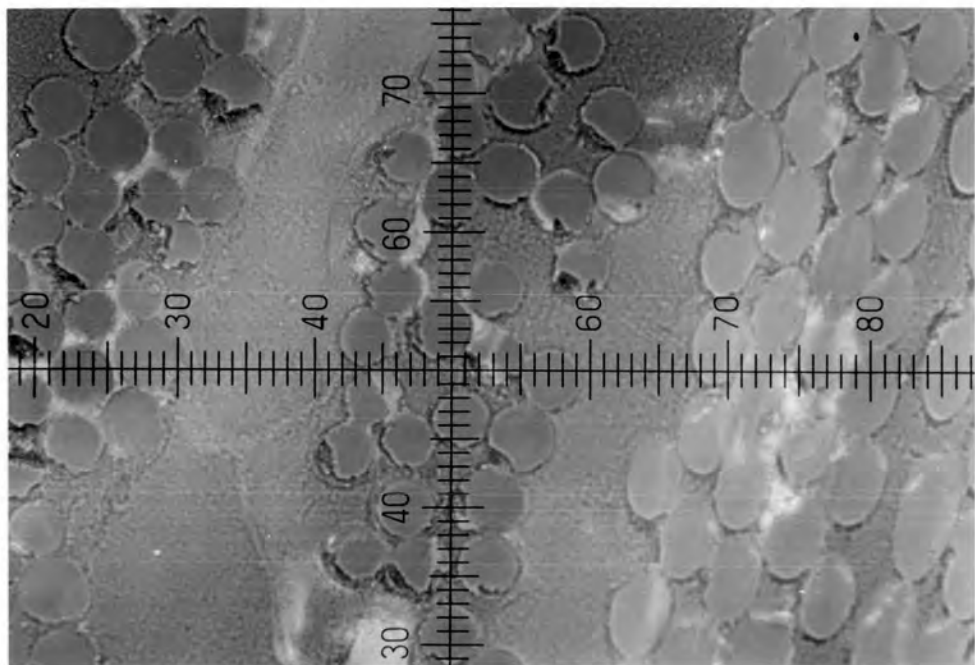polypropylene

Figure 4.10b   Microstructure of commercial glass fiber (NEG) reinforced
polypropylene

Table 4.10   Effect of E43P Concentration Coated together with the Coupling Agents
ıral Modulus

Concentration of E43P (%wt/vol)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Glass Content (% by weight)	Void Content (% by volume)
0.10	83.71(8.89)*	2878.30(375.91)	33.65(1.46)	1.62(0.73)
0.30	70.80(6.97)	2647.29(699.84)	34.70(1.57)	1.72(0.66)
0.50	61.24(6.05)	1780.57(235.93)	34.91(2.07)	1.73(0.51)

* The numbers in parenthesis are standard deviation.

Similar with the AGI glass fiber, NEG glass fiber was also used for GRP fabrication at the same conditions. Inversely, treatment of any surface treating agent onto NEG glass fiber gave better flexural strength than the original one as shown in Table 4.9 and Figure 4.9. The results imply that there is any co-adhesion between the coupling agent of the NEG glass and the surface treating agent with the matrix well.

In order to demonstrate compatibility enhancement of suitable coupling agent, microstructure of the composites was also studied and shown in the figure 4.10a and 4.10b. It was shown in the figure that compatibility between glass fiber and PP matrix of AGI fiber which has coupling agent suitable for either thermoplastic or thermosetting plastics was better than that of NEG fiber which has coupling agent suitable for only thermosetting plastics not thermoplastic.

It was observed that composites consisting of NEG glass fiber treated with E43P gave the highest flexural strength and modulus. It may be considered that maleic anhydride groups of E43P have the best
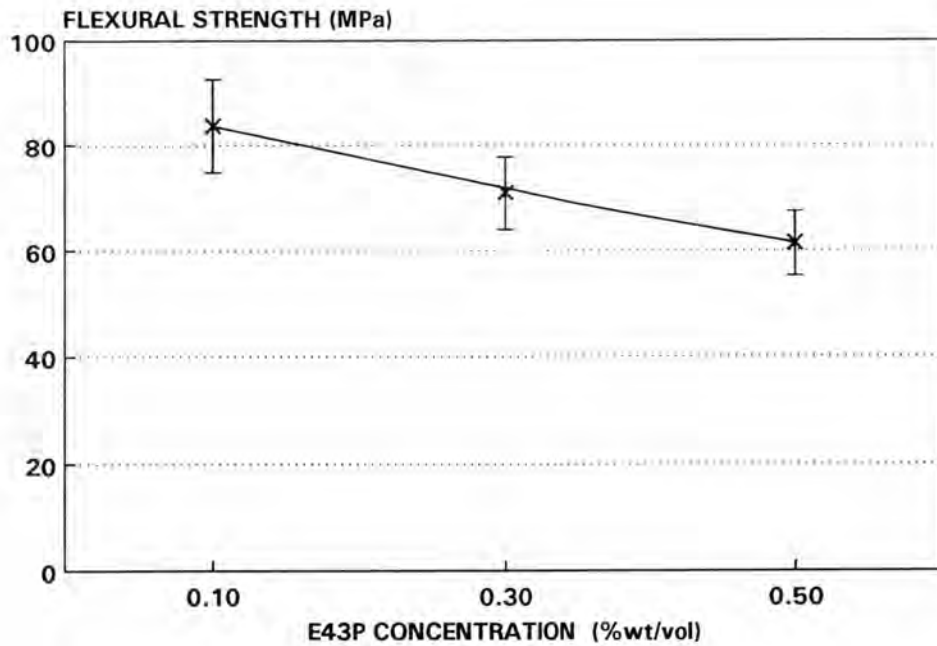
Figure 4.11a Effect of E43P (surface treating agent) together with
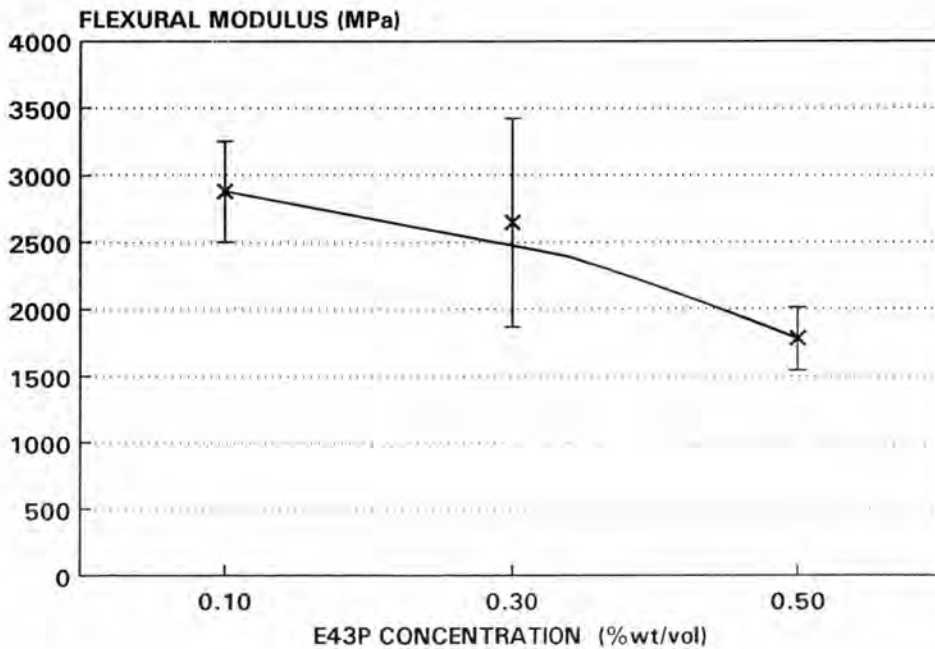the coupling agent on commercial glass fiber (NEG) on
flexural strength

Figure 4.11b Effect of E43P (surface treating agent) together with
the coupling agent on commercial glass fiber (NEG) on
flexural modulus

adhesion with the organofunctional silane of the NEG glass and poly-propylene backbone of the E43P can form good penetration with the polypropylene matrix. This research work have also investigated the effect of E43P concentration on flexural properties. Table 4.10 and Figure 4.11 show the effect of E43P concentration treated onto the NEG glass fiber on flexural strength and modulus of the GRP. The results show that both flexural strength and modulus decrease with the E43P concentration. In the glass fiber manufacturing, less concentration but various kinds of coupling agent are generally used in order to obtain a monolayer of the coupling agents.

4.3 Polynomial Regression Equation for Estimation of Flexural Properties

Flexural strength and modulus of the GRP's were calculated based on 35% by weight glass fiber content and 1% by volume void content Table 4.11 shows coefficient values of some variable terms as shown in the example below.

Example:

$$Fs \ (Fm) = B_0 + B_1G + B_2V + B_3GV + B_4G^2 + B_5V^2$$

where

Fs = flexural strength (MPa),

Fm = flexural modulus (MPa),

G = percent of glass fiber content,

V = percent of void content.

for Optimum Condition,

$$Fs = 1.67 + 5.15G + 32.62V - 1.07GV - 0.06G^2 + 1.43V^2$$

$$Fm = -4902.59 + 477.14G + 844.9V - 6.94GV - 7.9G^2 - 125V^2$$

Table 4.11 Estimation of Flexural Strength and Modulus by Using Polynomial Regression Equation

Condition		Coefficient Value					
		B0	B1	B2	B3	B4	B5
Optimum Condition	Fs	1.67	5.15	32.62	-1.07	-0.06	1.43
(Effect of Glass Fiber Content)	Fm	-4902.59	477.14	844.9	-6.94	-7.9	-125.2

Effect of the surface treating agent coated on coupling agent free glass fiber on flexural strength and modulus

NONE	Fs	-347.46	25.89	-82.41	2.83	-0.43	-5.18
	Fm	15792.51	-546.93	-2415.39	85.70	3.85	-156.06
A-174	Fs	3108.64	-168.42	-335.48	12.24	2.26	-36.13
	Fm	113321.53	-6006.03	-14098.56	514.21	78.79	-1304.24
PVA	Fs	123.69	-1.80	-70.29	3.95	-0.03	-28.32
	Fm	4797.50	514.42	-22045.91	523.48	-13.67	427.73
CMC	Fs	928.65	-31.14	-636.89	10.28	0.29	135.98
	Fm	-8181.47	51.03	13427.07	-237.92	4.26	-2027.27
FOGGER	Fs	42.10	2.40	-17.12	0.52	-0.06	0.72
	Fm	42449.82	-2630.10	865.41	17.84	41.28	-814.68
E43P	Fs	951.63	-60.29	101.21	-3.42	1.00	4.12
	Fm	125608.51	-8186.21	13301.15	-572.75	137.09	1846.40

Effect of the surface treating agent together with the coupling agent on commercial glass fiber(AGI) on flexural strength and flexural modulus

NONE	Fs	1.67	5.15	32.62	-1.07	-0.06	1.43
	Fm	-4902.59	47.14	844.90	-6.94	-7.90	-125.20
A-174	Fs	-2683.31	174.39	-82.11	3.13	-2.78	-3.34
	Fm	40569.86	-2604.48	-116.48	-4.74	43.93	37.09
PVA	Fs	-1693.51	99.76	115.33	-3.46	-1.40	0.77
	Fm	27127.42	-1888.93	3307.34	-97.03	34.23	12.68
CMC	Fs	-147.65	12.15	14.80	-0.83	-0.16	3.29
	Fm	11485.57	-675.48	354.29	-13.87	11.74	10.94
FOGGER	Fs	-140.85	-0.71	457.11	-7.01	0.13	-123.53
	Fm	-7644.57	-832.41	39909.85	-694.90	28.12	-9787.18
E43P	Fs	1010.38	54.50	-92.64	3.36	0.77	-4.35
	Fm	45788.56	-2490.33	-6225.38	194.49	35.51	-90.72

Effect of the surface treating agent together with the coupling agent on commercial glass fiber(NEG) on flexural strength and flexural modulus

NONE	Fs	4319.58	-238.76	-239.24	6.10	3.36	7.17
	Fm	117351.17	-7259.88	35727.49	-957.23	113.38	-2619.39
A-174	Fs	-1686.62	106.72	-38.12	0.22	-1.60	7.13
	Fm	-173431.03	9734.75	6631.24	-125.73	-136.00	-457.47
PVA	Fs	-425.48	24.06	491.60	-16.68	-0.27	57.96
	Fm	-7325.49	472.47	-2705.51	84.73	-5.69	-308.79
CMC	Fs	-1551.57	73.19	762.25	-22.45	-0.74	-8.40
	Fm	-126412.73	7740.40	-2666.44	167.82	-118.10	-990.29
FOGGER	Fs	236.92	-10.88	34.97	1.33	0.13	-31.65
	Fm	-1049.10	192.11	1323.49	-76.92	-1.71	152.66
E43P	Fs	3523.15	-198.46	-218.10	8.01	2.83	-16.60
	Fm	96732.30	-5549.88	-5522.62	250.90	80.67	-976.01