Fiber Orientation In Short Fiber Reinforced Thermoplastic Composites

By

Ahmad Abdullah Bin Ahmad Johari

0001203

Dissertation submitted in partial fulfillment of

The requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

MAY 2004

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Fiber Orientation in Short Fiber Reinforced Thermoplastic Composites

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AHMAD ABDULLAH BIN AHMAD JOHARI

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

(Dr. Faiz Ahmad)
Main Supervisor

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD ABDULLAH BIN AHMAD JOHARI

ABSTRACT

The objective of this project basically is to study the fiber orientation in short fiber reinforced thermoplastic composites especially at the geometry where the convergence and divergence flow is expected to occur. The material used for the study is chopped glass fiber 3mm in length as the reinforcement and high density polyethylene as the matrix. The study also includes a comparison of fiber orientation and the mechanical properties of the composites with different volume fraction of glass fiber. The volume fraction used is 5%, 10%, 15% and 20% of glass fiber. The mold for the sample is using the standard shape for tensile test or called "dumbbell" shape. The advantage of this mold is able to investigate both the fiber orientation and the mechanical properties using the same mold geometry. The samples are produced using injection molding process with controlled parameters. The samples are characterized using micrographic test for the fiber orientation study and tensile test for the mechanical properties determination. The results show the fiber orientation in the sample confirm with the expected result with slight variation due to processing effects. While for the mechanical test show as the volume fraction increase the Young Modulus also increase. Therefore can be concluded that volume fraction of glass fiber have an effects to the fiber orientation and mechanical properties of the composite.

ACKNOWLEDGEMENT

Praise Allah the almighty and peace upon His messenger, Muhammad S.A.W. I would like to express my deepest gratitude to my supervisor, Dr. Faiz Ahmad for his guidance, assistance, tolerance and support throughout this project. I also would like to thank all the technicians in UTP's Material Laboratory, especially to En. Emtias and En. Mohd Anuar for their help and guidance in conducting the experimental part of the project. Also I would like to thank to my colleagues and friends who given their help and moral support throughout the duration of this project. Lastly I would like to express my gratitude to Universiti Teknologi Petronas for allowing me to complete this project and providing an excellent facilities, equipment and logistic in fulfilling the objectives of this project.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

The quest for improve performance in various area include strength to weight ratio and lower cost at the time when currently used material consider reach the limit of their usefulness has contribute the invention of composite. A composite is designed to display a combination of the best characteristic of each component materials. Basically composite is material having two or more distinct constituents called matrix and reinforcement. The range and types of matrix is very large extending from mineral and inorganic matrix to more industry driven matrix such as glass, carbon and Kevlar. In principle there is no limit of number of permutation of the matrix and reinforcement that can be combined to produce a composite in term of types and composition. The most industry applicable composite is fiber reinforced composite and it developed to exploit the properties of the stiff and strong fibers and plastic because it is a suitable binder and importantly it easy to mold. Fiber reinforced plastic composite acquires strength from the glass and flexibility from the polymer. The requirement of understanding the effect of processing condition on the microstructure and properties of the final component is equally important. The need for improved control of fiber length and orientation during compounding and molding stage is particularly vital when there is different combination matrix and reinforcement.

1.2 PROBLEM STATEMENT

1.1.1 Problem Identification

The properties of composite material are strongly influenced by the proportions and properties of the matrix and the reinforcement. This includes the volume fraction, orientation and distribution of reinforcement in search to produce isotropic composites. The search to find optimum combination of the parameters to produce desired composite properties especially mechanical properties at right cost and production lead time has become industry objective.

1.1.2 Significant of the Study

The significant of this study is to prove by controlling the suitable process parameters able to produce desired fiber orientation. The parameter usually a lie at the production stage, in the case of this study is to control the parameters in injection molding process. The orientation eventually play major roll in determining the composite's mechanical properties.

1.2 OBJECTIVES AND SCOPE OF STUDY

The objectives and scope of the study reflect the time frame and cost limitation to achieve the best possible result. Basically there are four underline objectives in the study:

1. To study the fiber orientation at the geometry where the convergence and divergence flow occurred.
2. Make a comparison on fiber orientation on composite molding with different fiber volume fraction.
3. To understand the injection-molding process for producing composite molding of different matrix / reinforcement volume fraction by controlling process parameters.
4. To carryout microscopic and tensile test to determine the characteristics of fiber orientation and the relation with it's mechanical properties.

The scope of the study is to produce the composite molding, which have convergent and divergent flow characteristic as a result of following parameters:

- Matrix and reinforcement content proportion
- Moulds geometry

Different set of combination of above parameters are experimented to investigate the properties the composites exhibit base on micrographic observation and mechanical test.

CHAPTER 2

LITERATURE REVIEW

The purpose of literature review is to give a brief technical background on the material, process and mathematical expression used in the study. This section is to help reader for better understanding in composite and the underlying technology used.

2.1 COMPOSITE

Composite is a mixture of two or more distinct constituents or phases. Both constituents have to be present in a reasonable proportion and the composite properties should have different properties from its constituents. A man-made composite is usually produced by intimately mixing and combining the constituents by various means.

Composite materials can be classified base as the fiber reinforced composites and particle-reinforced composite. The fiber-reinforced composite can be further classified as continuous (long) and discontinuous (short) fiber. Short fiber is preferable for application because long fiber is more expensive and the manufacturing processes tend to be slow and inflexible.

The stress transfer for short fiber is influence by the aspect ratio, fiber length and orientation, which will determine the mechanical properties of the composites. The concept of critical fiber length gives indication of minimum fiber length in which the maximum allowable fiber stress can be achieved. It is used particularly in the analysis of the strength of aligned short fiber composites. In case of this study 3mm length of fiber is used since it become a standard length for injection molding process.

2.2 MATRIX

The matrix is the phase of the composite that must exist in continuous condition and most of the cases present in larger quantity. Mainly it has three main groups ceramic, metallic and polymeric with distinctive properties. Generally polymer has low strength and young modulus, ceramic are strong, stiff and brittle and metal have intermediate strength and modulus with good ductility.

As for the project polyethylene is used as a matrix and the properties is presented at Appendix A. Basically it is a thermoplastic which is easily flow under stress at elevated temperature so allowing them to be fabricated into required shape component and become solid then retain their shape when cooled to room temperature. The bonding between chains is due to weak Van Der Waals force, which is easily broken by combination of thermal activation and applied stress.

2.3 REINFORCEMET

Generally the reinforcement is harder, stiffer and stronger than the matrix. The function is to reinforce the mechanical properties of the matrix. The geometry and dimension of the reinforcement play a major role of serving it main purpose. Usually the reinforcement presents in form of fibrous or particulate however only the fibrous is extensively used in composite industry. The important characteristic of fibrous is the aspect ration which is the ratio of length to the fiber cross-section and this ratio determined whether the fiber is considered continuous or discontinues.

The reinforcement used in the study is glass fiber. Glass fiber is based on silica (SiO_2). Glass is an amorphous material and there are three type of glass: E-glass, C-glass and S-glass for fiber composite. This study use E-glass type and the properties presented at Appendix A. The strength and modulus are determined primarily by its atomic structure, which consist primarily of covalently bonded tetrahedral.

2.4 FLOW BEHAVIOR

The general idea of fiber orientation distribution study is largely focus on the three characteristic: shear flow, convergence flow and divergence flow. Shear flow occur in the straight tube. Convergence flow occurred as melt passes from wide to narrow cross-section and the divergence flow occurred as the melt passes from narrow to wide cross-section. The fibers tend to align parallel to flow direction in convergent flow. However in divergence flow the orientation tend to orient orthogonally to the flow direction. The reason behind the character is melt is imposed a uniaxial compression and a deceleration of melt movement.

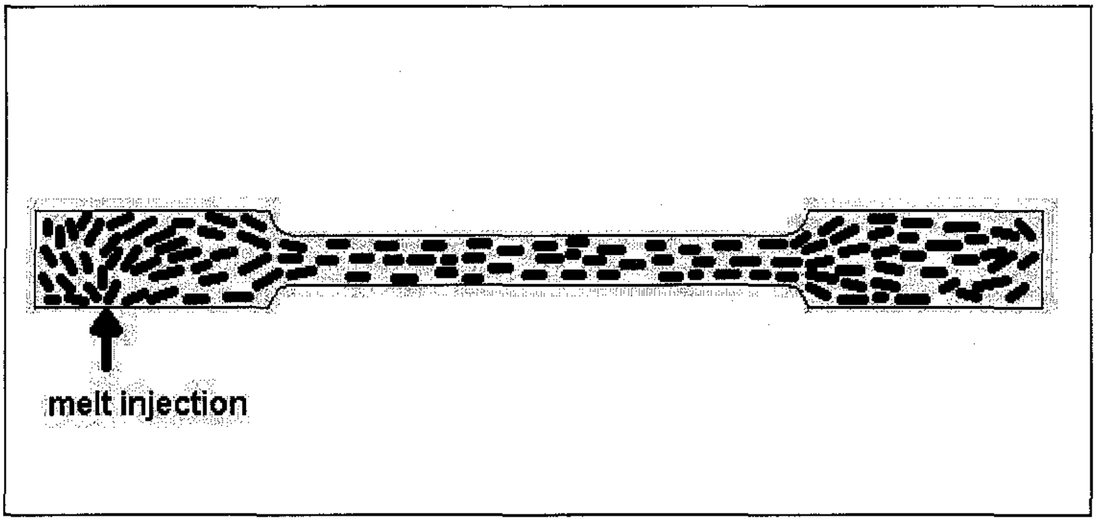


Figure 2.1: The expected fiber orientation inside the sample

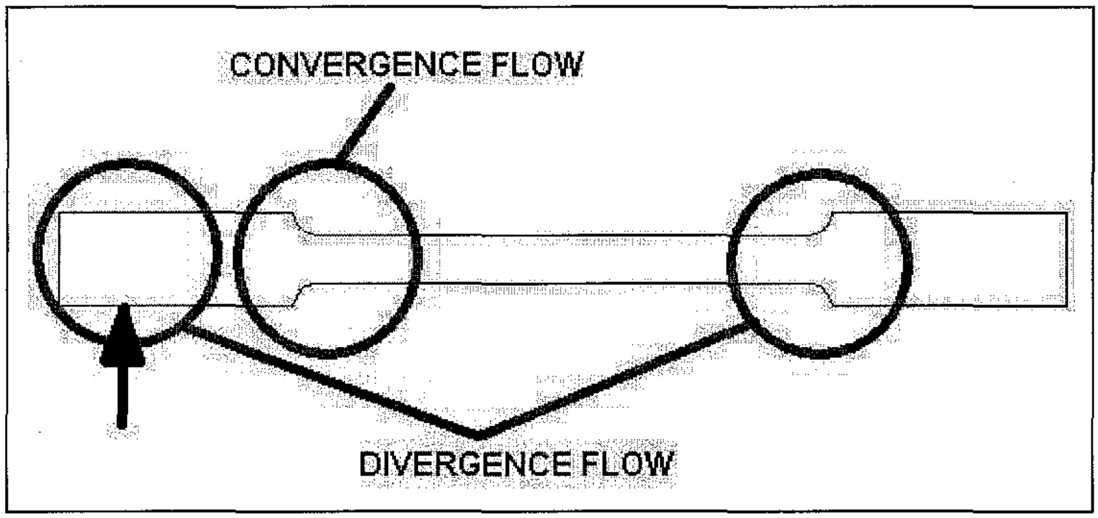


Figure 2.2: The expected location where the convergence and divergence flow may occurred

The technique to access fiber orientation in molded component for the reflection microscopy of the polished surfaces is by observe under microscope as the cylindrical fiber meet the polished surface in ellipse. The ratio of the length of the major axis to the minor axis will determine the orientation any given fiber, with respect to the surface:-

$$\Phi = a/b = \cos^{-1}$$ (**a**, length of the minor axis/ **b**, length of the major axis)

And Φ is the angle between the fiber axis and the normal to the viewing surface. For the short fiber there is three types of fiber orientation may occurred as shown bellow.

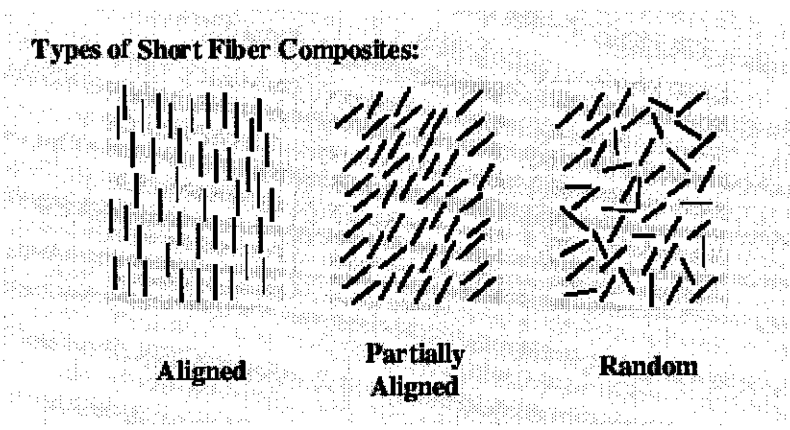


Figure 2.3: Types of orientation alignment in for short fiber

2.5 INJECTION-MOULDINGPROCESS

One of the most common processing methods for plastics is injection molding. The advantages of injection molding are able to produce complex shape and the process lead time is relatively short, which is suitable for mass production. The working principal in simple term is the material is feed into barrel through feeding hopper and heated in a electrical heated barrel so that it becomes soft. It is then forced through nozzle into clamped mould.

The machine will be used for this project is the reciprocating screw type. The two main part of the machine are the barrel and the mould. The barrel consists of screw placed inside the barrel and heater band placed around the barrel to provide the heat. There also a material hopper for batch material consisting polymer granule and short fiber placed together before into the barrel at controlled rate. The screw function is to transport, melt and pressurize the material inside the barrel. The screw is able to move forward like plunger without rotating to inject the melt into the mould. Where it is solidified and component is injected from the mould.

Before the melt enter the mould, its flow through a nozzle. The nozzle is screwed into the end of the barrel and provides the means by which the melt can leave the barrel and enter the mould. The mould consist of two halves and in between its have cavity shaped with desired shape of the final product. The mould cavity is joined to the nozzle by means of the sprue. The sprue anchor pin has the function of pulling the sprue away from the nozzle and ensuring that the molded part remains on the moving half of the mould. After the sprue the melt enter a runner then through a gates. The gates provide convenient weak link by which the molding can be broken off from the runner system.

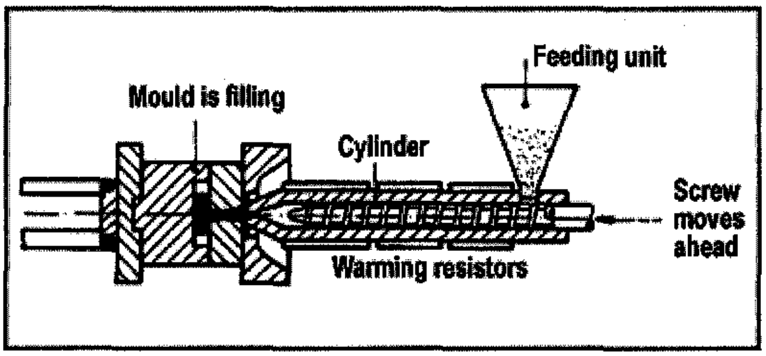


Figure 1 / 3 - Injection phase

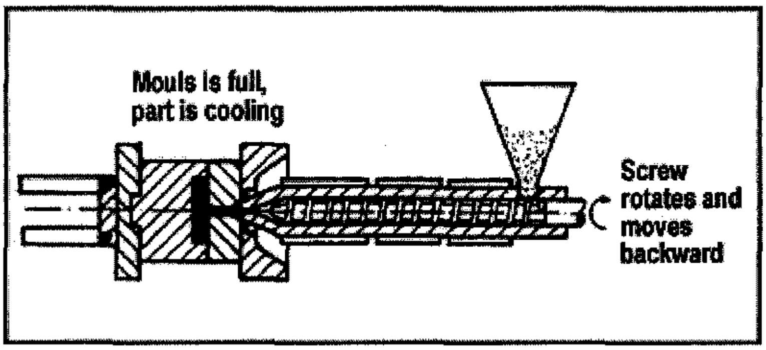


Figure 2 / 3 - Holding pressure phase

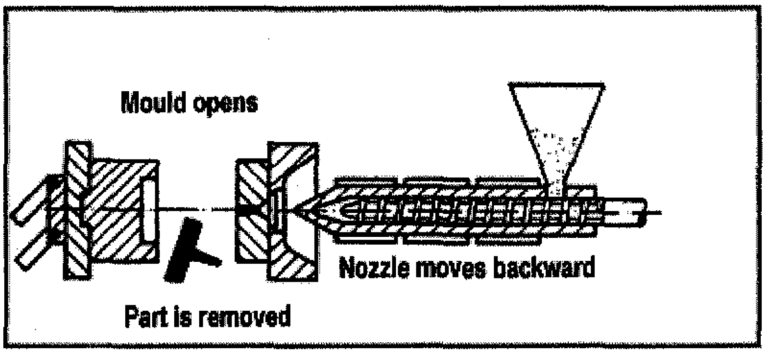


Figure 3 / 3 - Demoulding phase

CHAPTER 3

METHODOLOGY

The methodology of the study is divided into two phases. The first phase is to prepare the samples of composite material using injection molding process. The second phase is to test and analyze the sample in regard of microscopic examination and tensile test for mechanical properties determination.

3.1 PREPARATION OF THE SAMPLES

The material used in the study is high density polyethylene and glass fiber. There are many variations of the materials available in market and for this study the materials selected must be compatible for injection molding machine.

The selected high density polyethylene is LADENE® HDPE resin and the glass fiber used is chopped glass fiber with average the length of 3mm and 20μm diameter. The full properties of the materials provided by supplier can be referred to Appendix A.

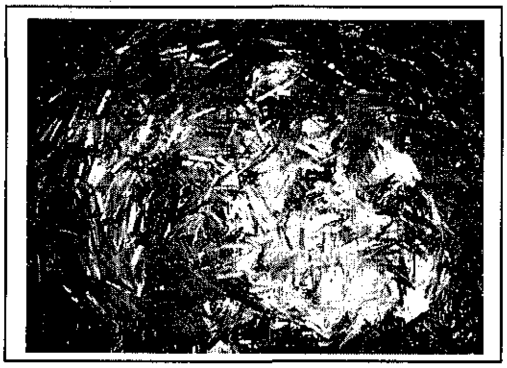
Before the injection molding can be performed. The HD-PE and the glass fiber is weight according the requirement of each samples specification. There are five batch of the sample produced base on the volume fraction of the glass fiber. The weight of one batch is 0.5kg and the individual weight of HD-PE and glass fiber of the batches is presented in table 3.1.

Fiber Vol. Fraction	Pc(kg/m3)	Wf(kg)	Wpe(kg)
05%	1040	0.062	0.438
10%	1120	0.114	0.386
15%	1200	0.160	0.340
20%	1280	0.200	0.300

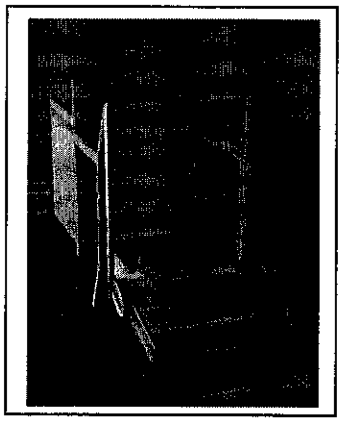
Table 3.1: The weight of glass fiber and HD-PE regard to volume fraction.

The next stage of the sample preparation is injection molding process. The machine parameter is first setup to tally with the materials used. The main parameter to be set is the heater temperature and basically the temperature need be higher than the melting point of high density polyethylene. There are three heater bands and the temperatures used are 130°C, 145°C and 160°C. The mold pressure using the default value and if there is splash on the mold then the pressure can be increase gradually.

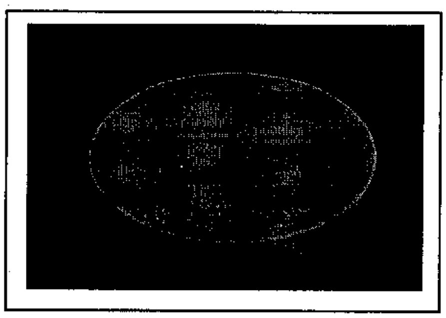
The high density polyethylene and fiber glass is put into a container and the mixture is blend manually to ensure the proportion is even. The mixture is then put into a hopper before gradually enter into the injection molding machine barrel where a screw placed. The function of the screw and the barrel is to melt the matrix and mix the materials homogenously before injected into the mould. One batch of the mixtures roughly can produce around 30 composite samples. The graphically summary of the project work presented bellow:



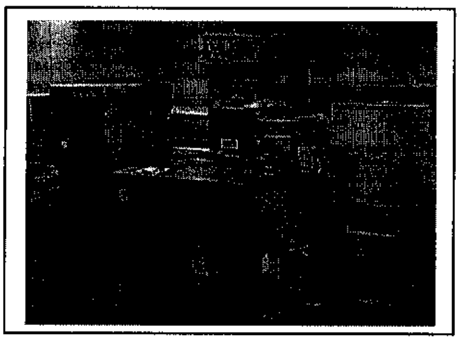
Glass fiber with length of 3mm and 20μm diameter.



Glass fiber and HD-PE is weighted



Glass fiber and HD-PE is manually blend



The mixture is injected into mold

Figure 3.1: Sample preparation work order

3.2 SAMPLE TESTING

In the sample testing phase there are two tests conducted. First is the microscopic test to investigate the fiber orientation within the samples. Originally the tests suppose to use X-Ray however due to technical problem only microscopic test can be conducted. The second test is tensile test and the function is to analyze mechanical properties of the composite and relate the result with microscopic test base on different percentage of fiber glass volume fraction.

3.2.1 Microscopic Test

The microscopic test is conducted at selected section of the samples especially where the convergence and divergence flow expected to occurred. Therefore the samples need to be cut at selected section. The cutting process starts by cutting the main section into pieces using mechanical cutter. The surface of the sample pieces is then cut using precision cutter to get a smooth cutting surface for clear micrographic examination.

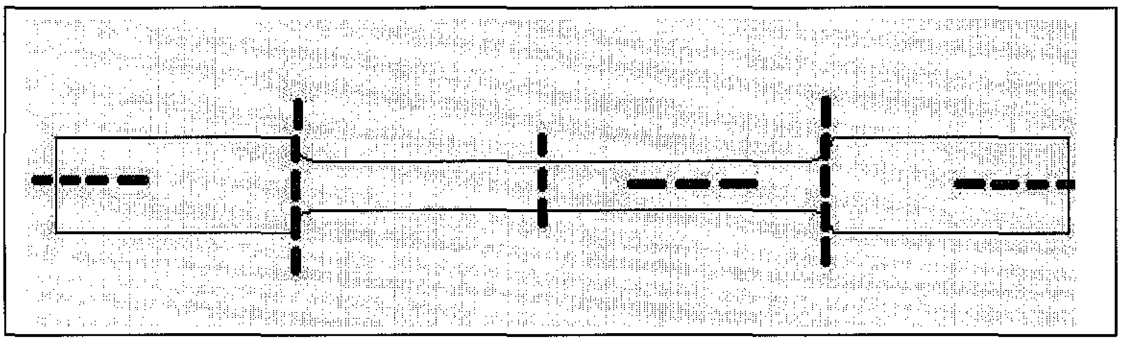
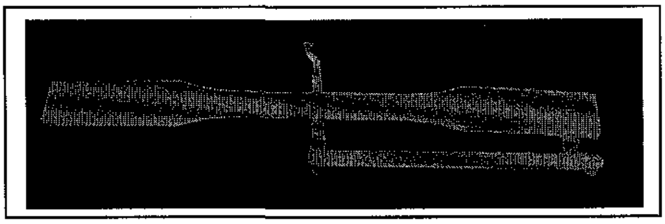
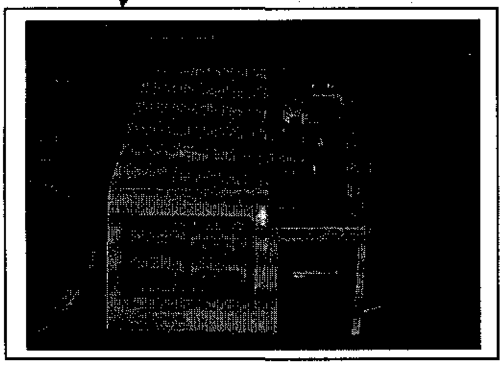


Figure 3.2: The cutting places on the sample.

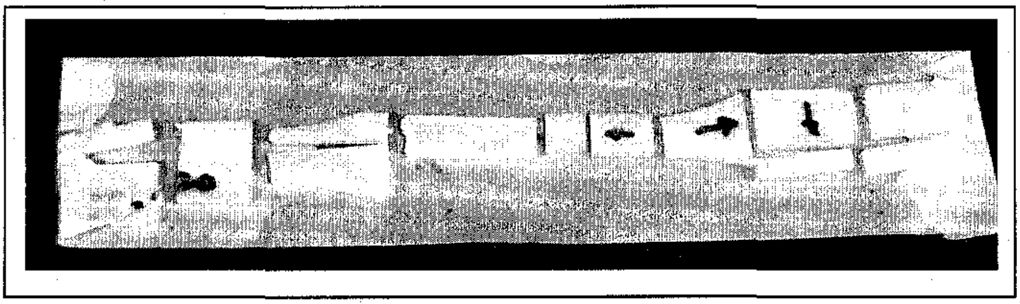
The sample pieces are washed to eliminate the oil on the surface due to oil used in precision cutter then polish using diamond paste of 3 micron. Finally it is dried using hair drier to vaporize the water droplet on sample surface. The sample pieces are then put under high magnification microscope to observe the surface at the selected section using magnification of 50x, 100x and 200x. The microscope is connected to computer to visualize the image and the image can be store into computer format file (JPEG) for further references.



The sample produced



The samples is cut using precision cutter then polished



The look of the sample after cutting process

The pieces of the sample is put under microscope and recorded into a computer

Figure 3.3: The sample micrographic testing process work order

3.2.2 Tensile Test

The tensile test is conducted using LLOYD Instrument® tensile testing machine which connected to computer to record the mechanical properties of the sample. The sample produce by injection molding have standard shape for tensile testing. Therefore the sample can be test directly without any alteration. Before the test is carried out, the test parameter need to be determined and setup on the special built software. The parameters are the dimension of the sample and operational parameter including the pulling speed and pulling force. The software then record the mechanical value of the samples from the information feed from the tensile test machine and also produce the graph of stress-strain.

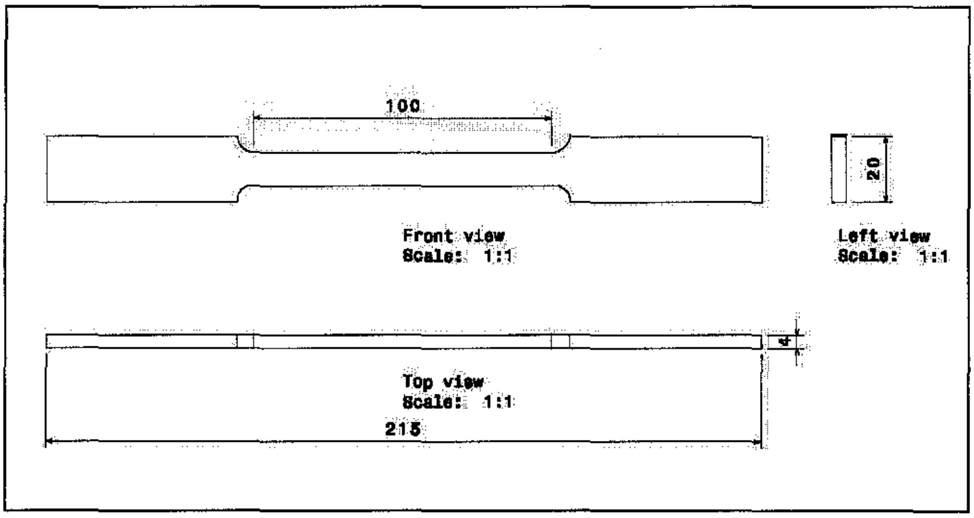


Figure 3.4: The dimension of standard shape for tensile test or "dumbbell"

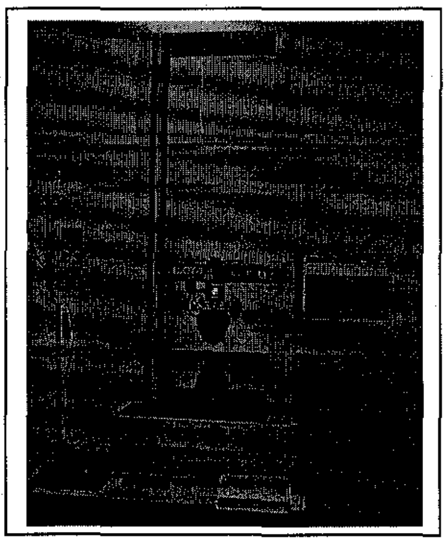


Figure 3.5: The tensile testing machine used to analyze the mechanical properties of the samples.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter show the results and observation on the tests conducted. The tests results are the micrographic test and tensile test. This chapter is divided into two parts to serve each test and the discussion also include at each part of the section. The reason to combine the result and the discussion for each test is for the ease of understanding the discussion by relates the result through graphical presentation.

4.1 MICROSCOPHIC TEST

The first objective of the test is to study the fiber orientation especially at the convergence and divergence flow occurred and the effect of geometry on the fiber orientation. The second objective is to make comparison of fiber orientation behavior between two different samples with different glass fiber volume fraction. Overall there are six different sections had been analyze where different behavior of fiber orientation can be observed. Figure 4.1
shows where the specimen is cut and the discontinue line show where the surface of specimen put under microscope and the arrow show position melt enter the mold.

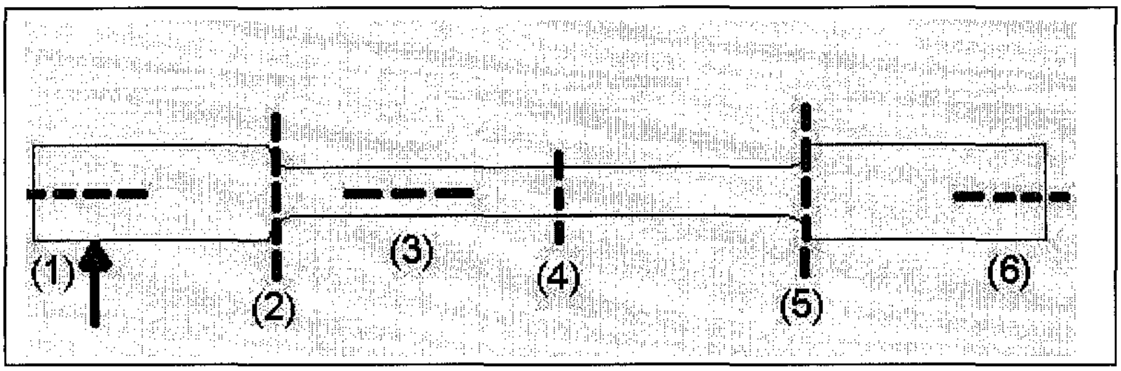
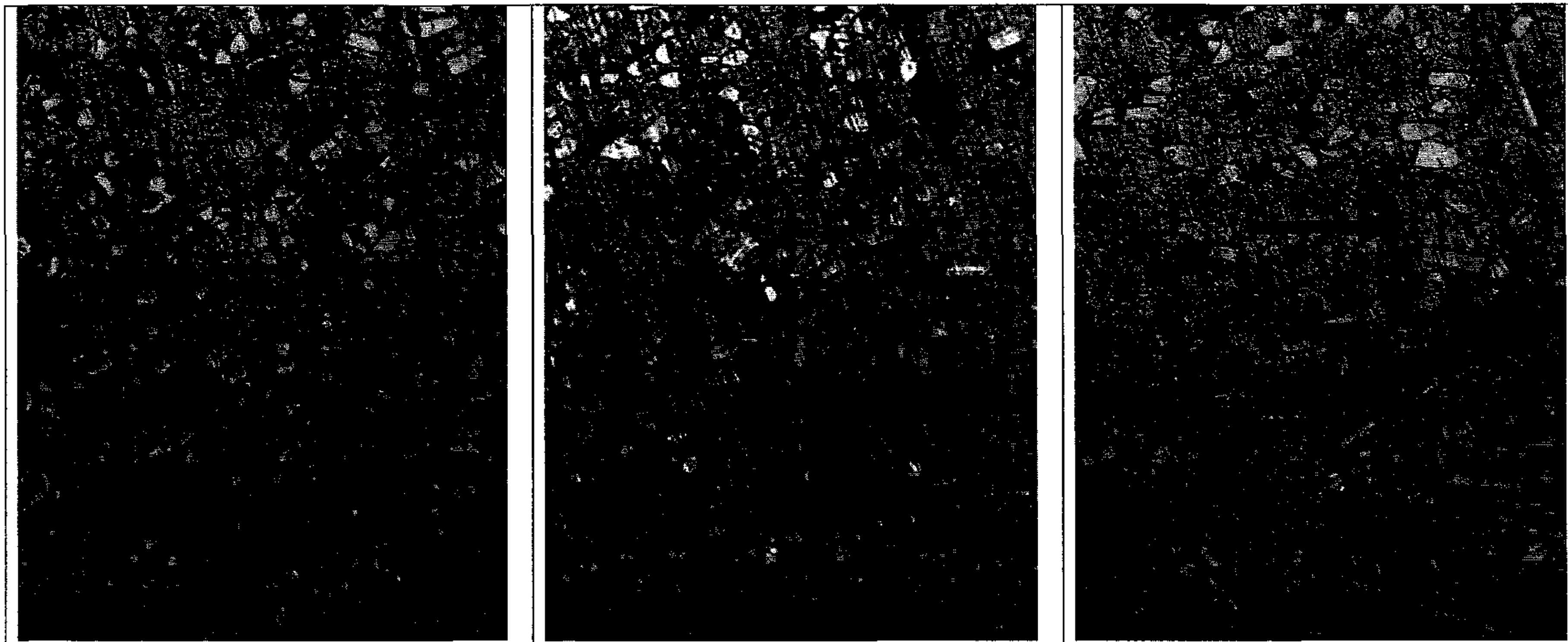


Figure 4.1: The position of where the specimen is cut

4.1.1 Fiber Orientation at Specific Geometries

The result is taken from single sample for flow continuity and each section is presented in three graphical sequences of order to show the change of fiber orientation. The magnification used in this test is 50x or 100x depend on the area need to be show. The sample used is 20% glass fiber in volume fraction. The reason to use this specimen is because 20% sample has the highest fiber volume fraction among the sample batches produced therefore provide the highest fiber orientation visibility due to high fiber density against the matrix. The graphical results are assisted with an arrow to show the direction of fiber orientation. The results are shown starting at the next page.

FIGURE 4.2: SECTION (1)

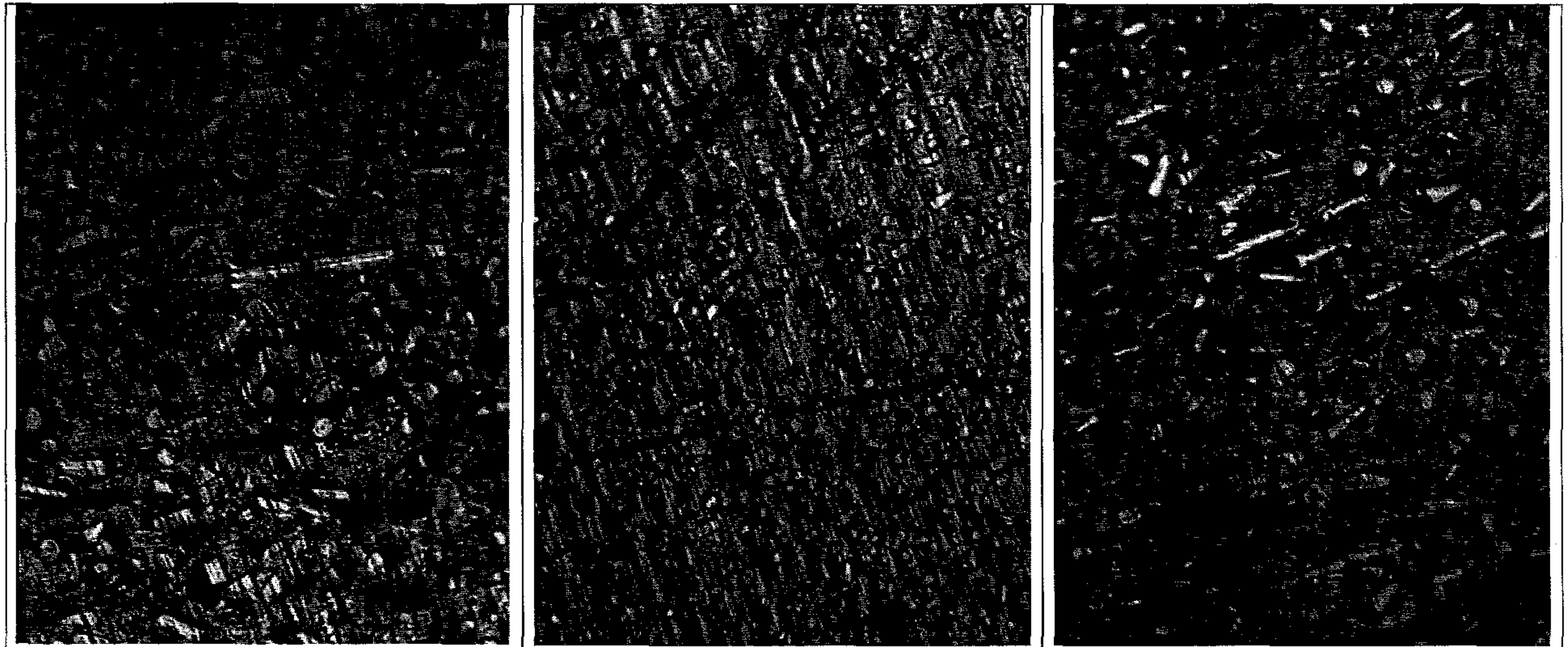


Part A (100x)	Part B (100x)	Part C (100x)

Observation:

Sections (1) represent the location where melt start to enter into mold. At Part B the fiber oriented parallel with the incoming flow with small angle of distortion toward right side. Part A show a complex orientation without preferred direction however for Part C the diverge angles is big, almost normal to initial flow. The reason for this behavior is the flow is move toward mold cavity which is normal to gate entrance. The fiber density is higher at Part A and C compare to Part B due to compaction due restricted flow area.

FIGURE 4.3: SECTION (2)

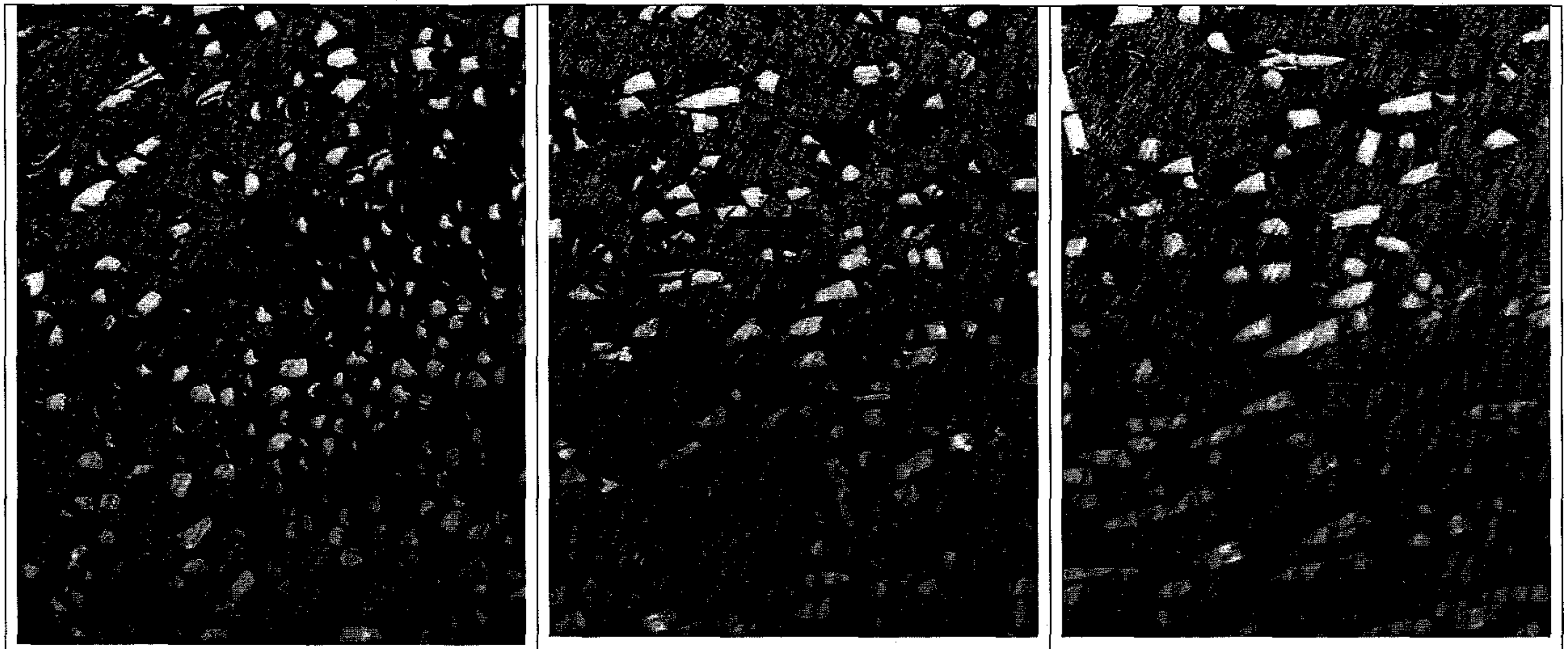


Part A (100x)	Part B (50x)	Part C (100x)

Observation:

Sections (2) represent the cross-section where convergence flow is expected due to reduction of area of cross-section. The middle section (Part B), the fiber orientation is parallel to flow direction. However fiber orientation near to wall of the mold (Part A and Part C) tends to converge directed to mid-section of the flow.

FIGURE 4.4: SECTION (3)

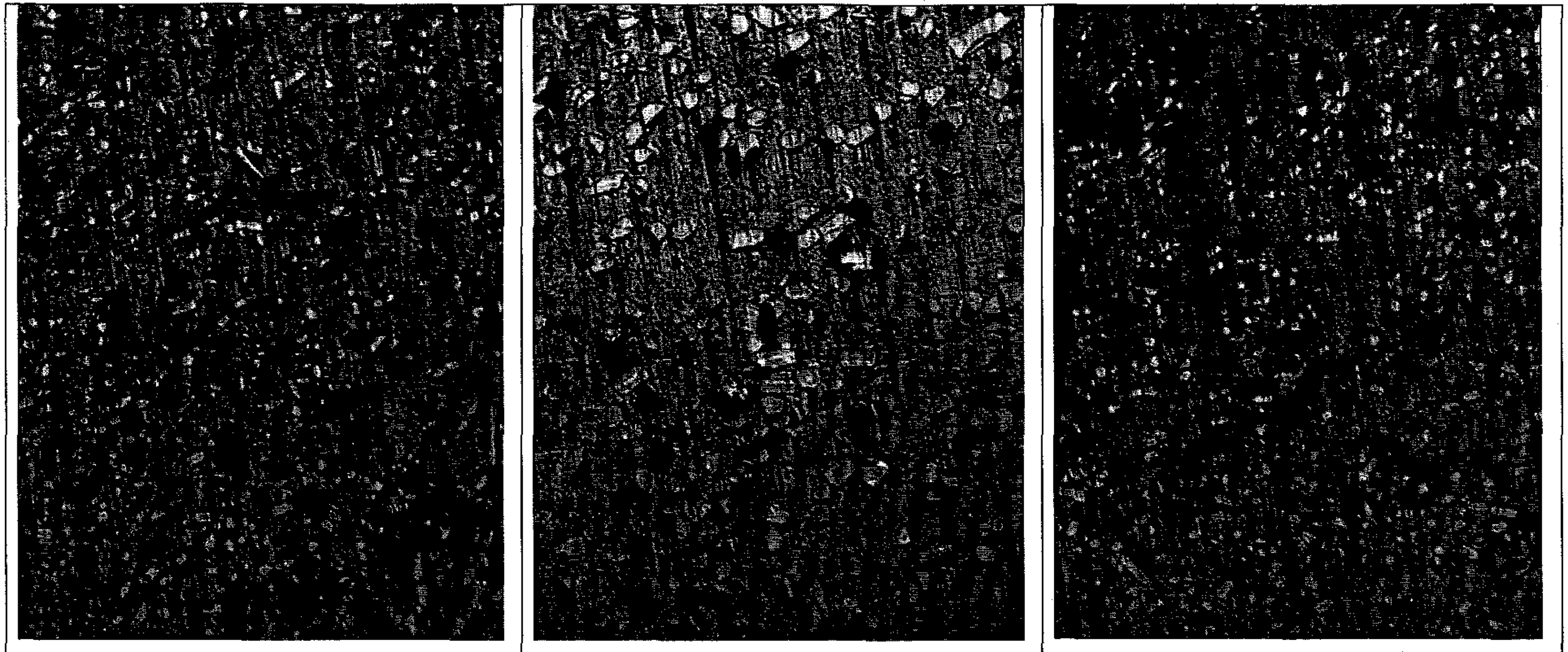


Part A (100x)	Part B (100x)	Part C (100x)

Observation:

Sections (3) show the parallel cut of the sample start at reducing cross-section area until the cross-section area become constant. In Part A shows the fiber orientations is in random direction and try to rearrange itself due to confine space. As flow continue at Part B, the fiber start to oriented parallel to the flow with small angle of distortion due to shear flow. When cross-section becomes constant the fiber oriented parallel to the melt flow.

FIGURE 4.5: SECTION (4)

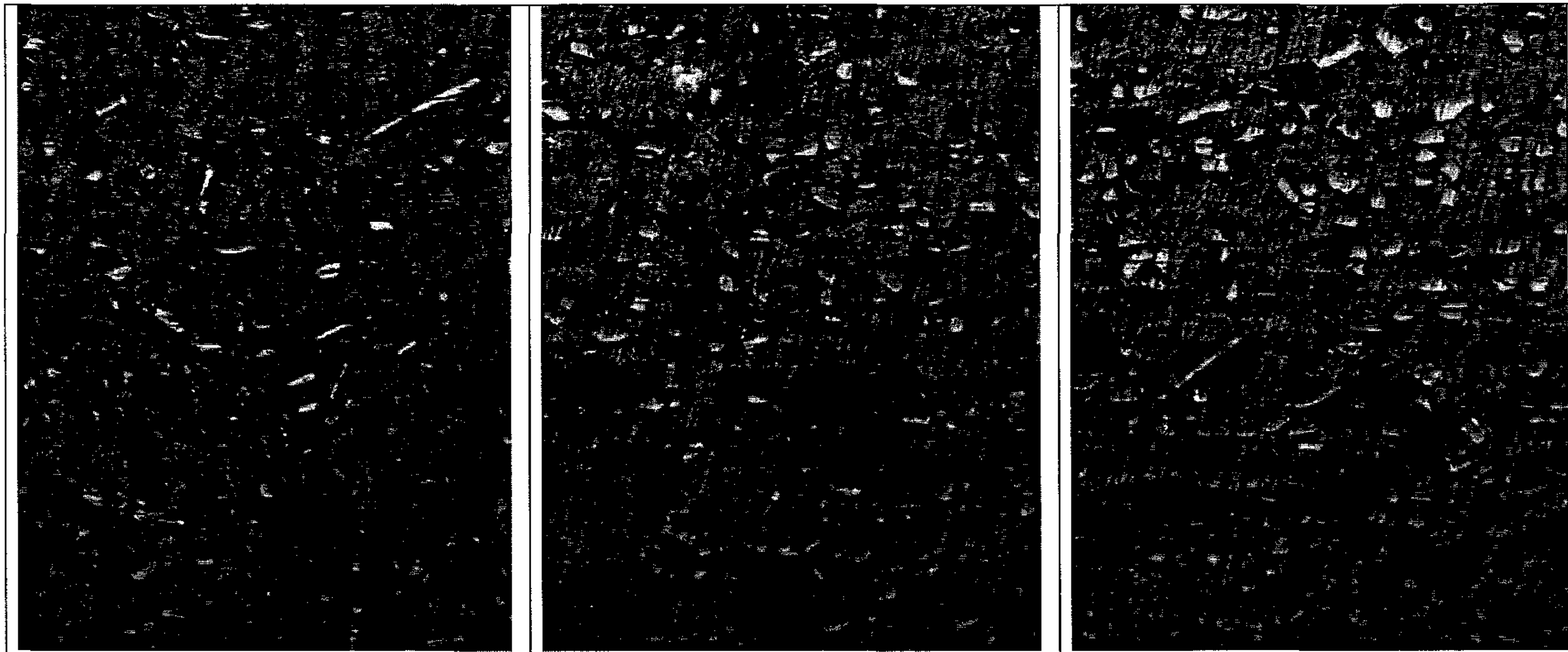


Part A (50x)	Part B (100x)	Part C (50x)

Observation:

A section (4) is the cross-section cut at the center of path of the smallest flow area. The fiber orientation behavior is expected to be parallel to the flow and this is shown in Part A, B and C.

FIGURE 4.6: SECTION (5)

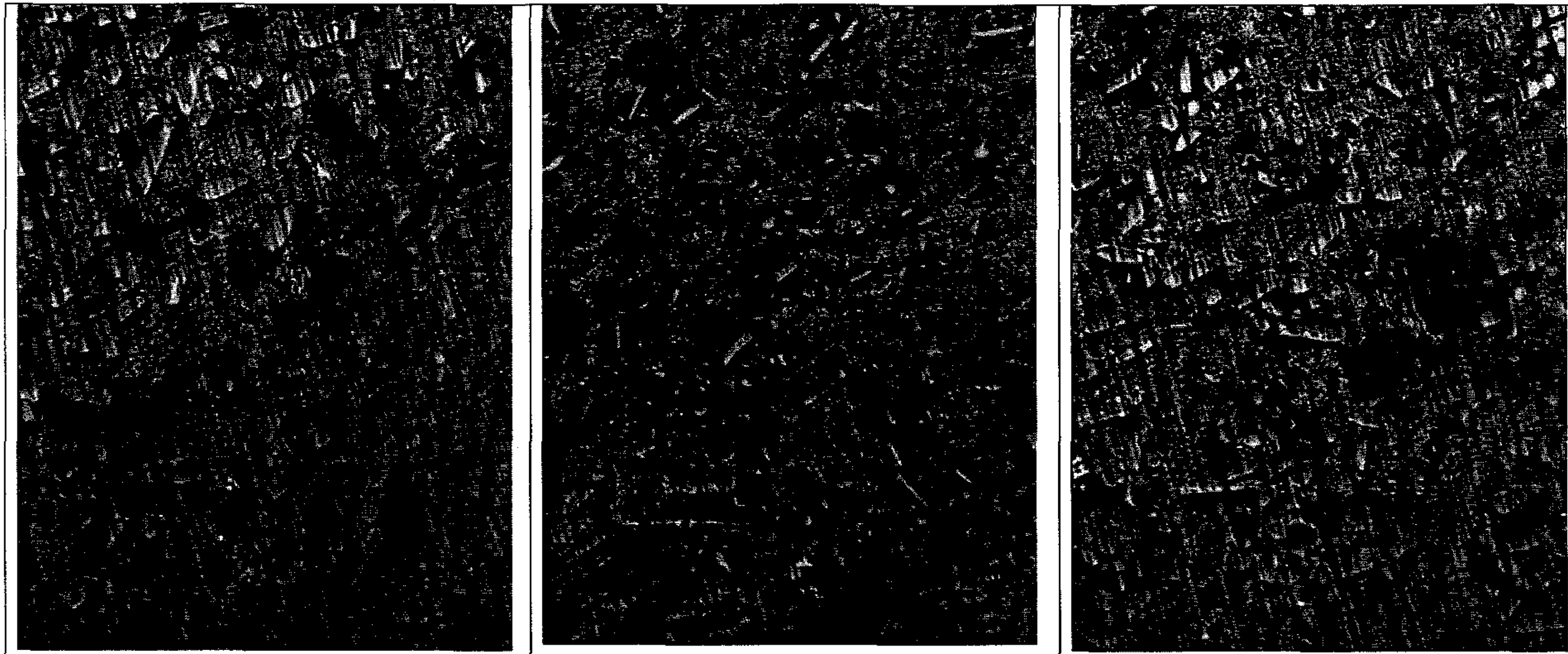


Part A (100x)	Part B (100x)	Part C (100x)

Observation:

Sections (5) represent the increasing of flow area which causes the flow to diverge due to increase in cavity. The mid section show the fiber orientation almost parallel to the flow (Part A) and as expected the side close to the wall become diverge. This shown by the large deflected angle however at Part C it is not so apparent. Compare to section (2) where convergence occurred, the fiber density is relatively small.

FIGURE 4.7: SECTION (6)



Part A (100x)	Part B (50x)	Part C (100x)

Observation:

Sections (6) show the orientation at the end of the sample. The fiber orientation is become complex and random especially at the Part A and C. There is no apparent flow behavior to show whether it convergence or divergence flow. The mid section indicates some of the fiber orientation almost normal to melt flow.

The short fiber orientation behavior of the sample is in complex manner which shows the flow geometry is the major parameter affecting fiber orientation. The processing parameters also play role in fiber orientation and the major variable are the injection speed, melt and mold temperature. As expected the fiber orientation show a diversion flow at the gate (section (1)) of Figure 4.2 and at the section (5) of Figure 4.6.At the gate and section (5) a sudden relaxation upon entry into the mold larger cavity create a radial diverging flow configuration and it develop outward filling the mold. This melt component oriented orthogonally to the mold axis.

While for the convergence flow, the fiber orientation is shown at the section (2) of Figure 4.3. In converging region responsible for the fiber to oriented at preferred direction along the flow direction as is identified at the section (4) of Figure 4.5. Theoretically the shear flow behavior will visible at the section (4) however the tests do not show any indication, probably because of the cross sectional area is small.

The tip of both end of the sample shows a random and complex fiber orientation because the sudden deceleration of the flow velocity due to compressive force applied to the flow on the mold wall. The compressive force changes the orientations of the fiber near the mold wall and gradual change of orientation for the neighboring fibers to rearrange at preferable direction. This happen because the movement any given fiber will interact and influenced by the neighboring fiber.

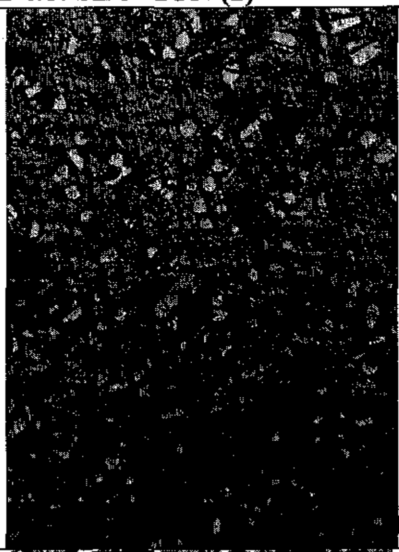
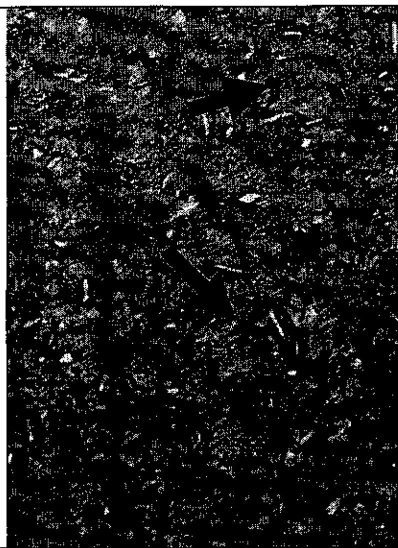
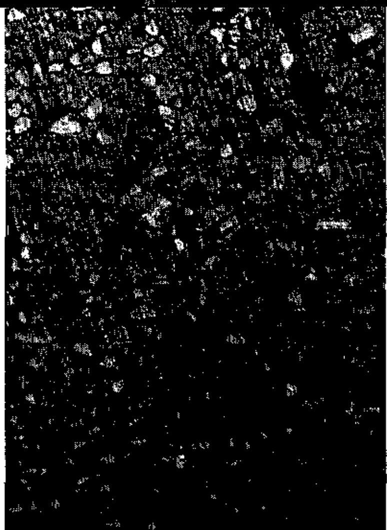
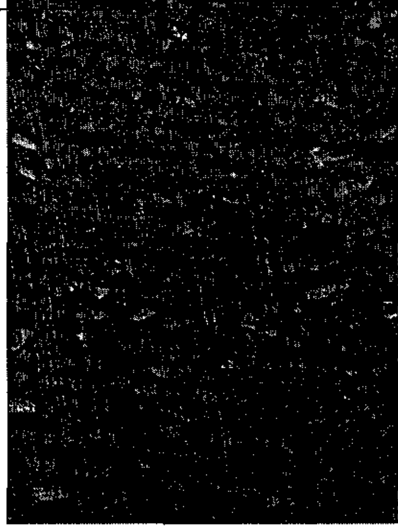
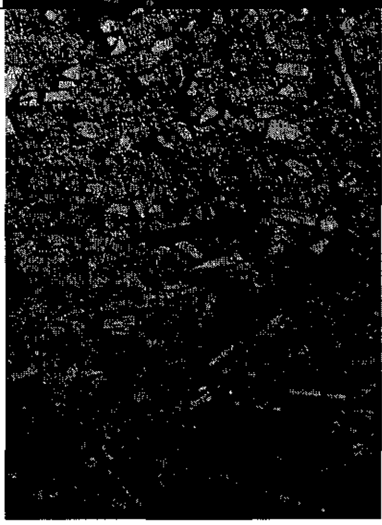
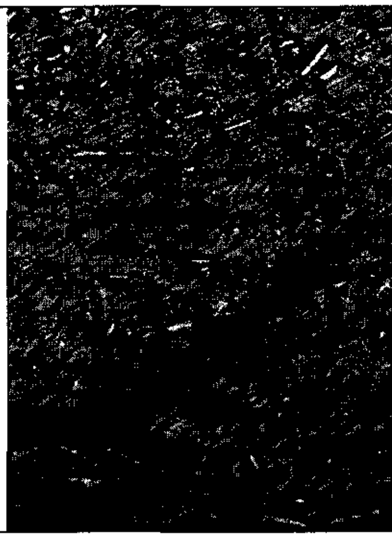
One of the observation is there is less concentration of fiber near the wall. The theory behind the behavior is as the melt enter the mold area, it will solidify faster than normal because of lost heat to relatively low temperature of mold. The thickness of the layer is depending on the processing parameter stated at the beginning. Other observation is high orientation of the fiber parallel to the flow at the area close to the wall at the section (4) of Figure 4.5.

The fiber density and distribution is varies from one section to another which indicate volume fraction of glass fiber at specific place not always the same as original composition. If one position have higher volume fraction therefore it compensate other to have less. Plus with the complex orientation of the fiber, these increase the anisotropy of the mechanical properties of the composite.

4.1.2 Fiber Orientation Comparison in Different Volume Fraction

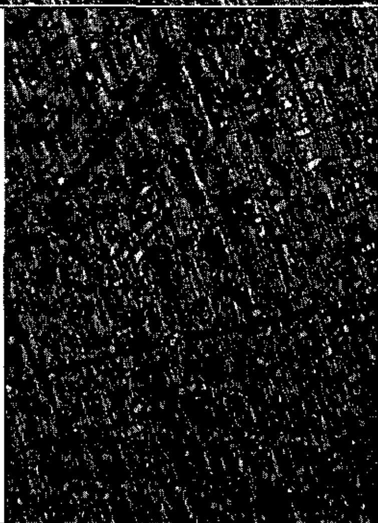
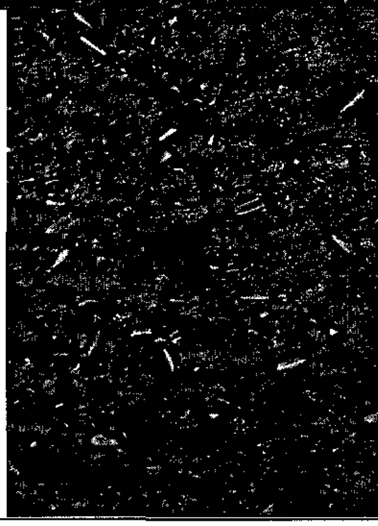
The comparison is between samples of 20% and 15% glass fiber volume fraction because both represent the highest contain of glass fiber. This provides the high visibility of fiber orientation when observe under microscope. The sample still uses the same six different sections for the test. The graphical results are assisted with an arrow to show the direction of fiber orientation. The results are shown starting at the next page.

FIGURE 4.8: SECTION (1)

Part A		
Part B		
Part C		
	20%	**15%**

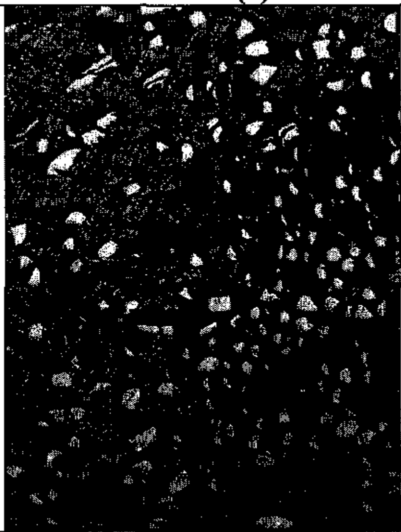
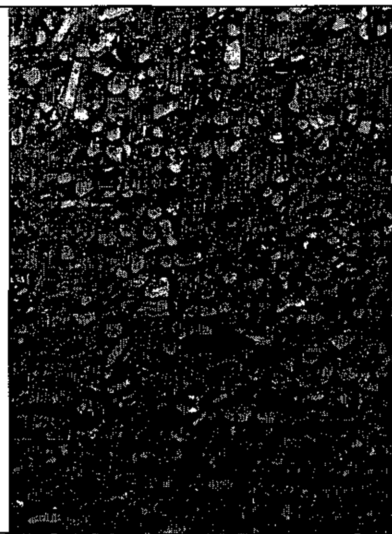
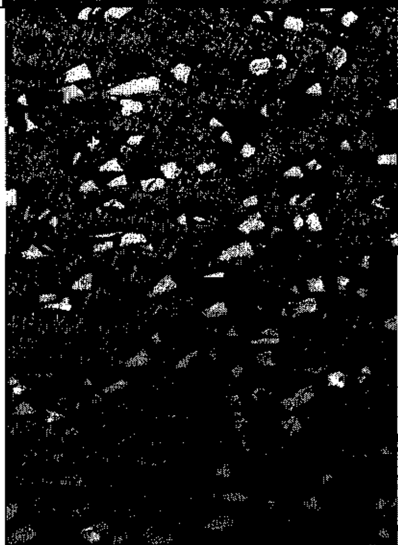
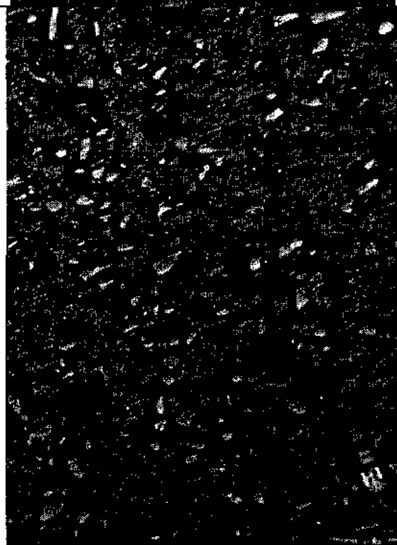
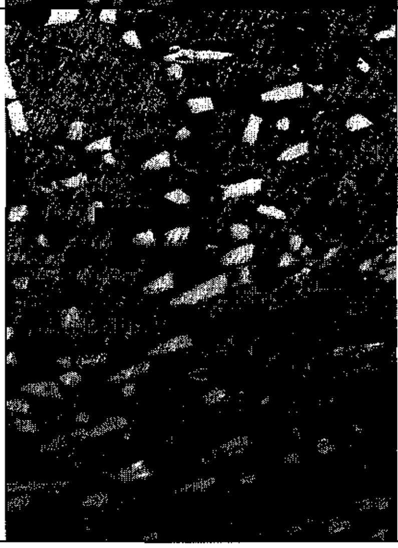
Section (1) represents location of the gate and clearly visible the fiber oriented to the right side due to melt filling the mold cavity. At Part A, there is no preferable direction.

FIGURE 4.9: SECTION (2)

Part A		
Part B		
Part C		
	20%	**15%**

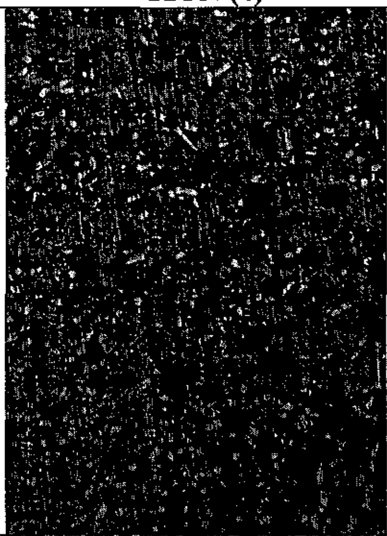
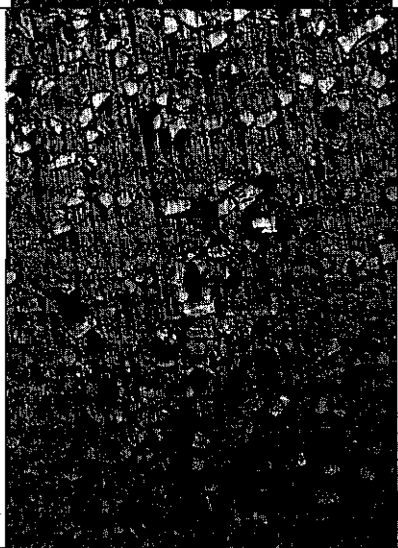
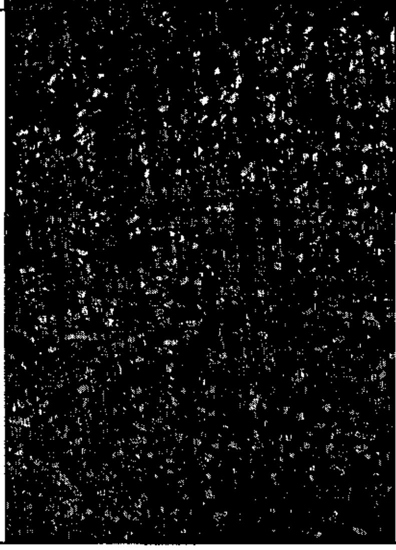
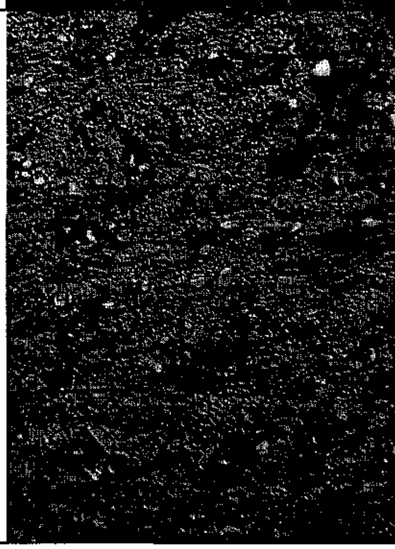
Section (2) represents convergence flow to occur. In 15% sample the fiber alignment not so apparent because the effect of shear flow is less in sample with low percentage of glass fiber.

FIGURE 4.10: SECTION (3)

	20%	15%
Part A		
Part B		
Part C		

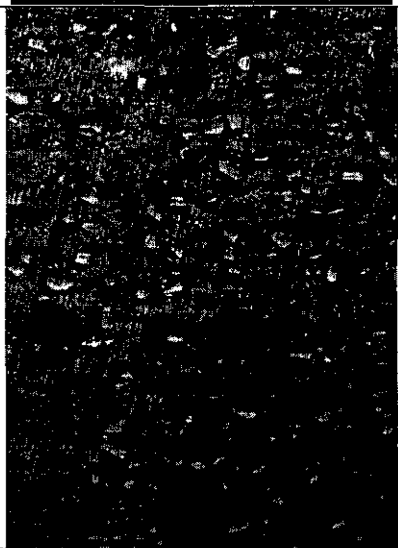
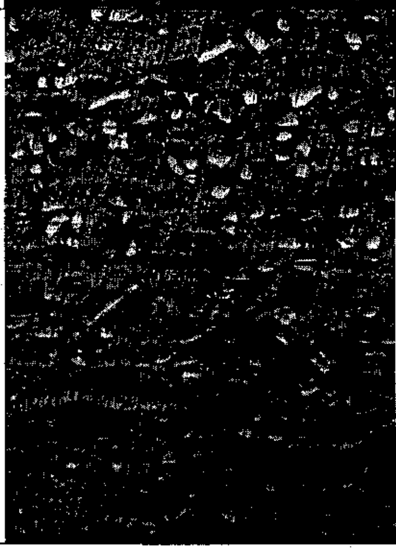
Sections (3) show both sample gradually oriented the fiber parallel to the melt flow due effect of shear stress.

FIGURE 4.11: SECTION (4)

Part A		
Part B		
Part C		
	20%	**15%**

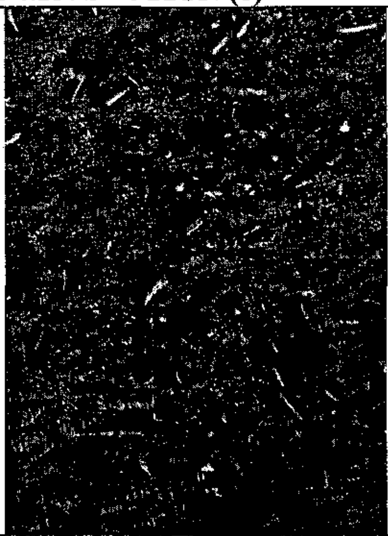
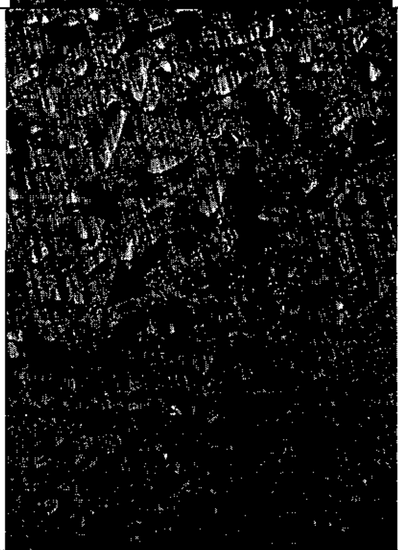
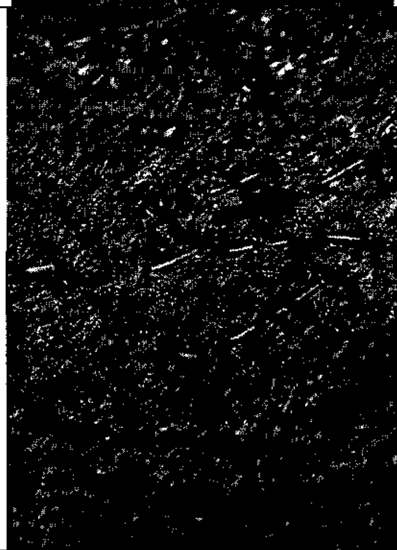
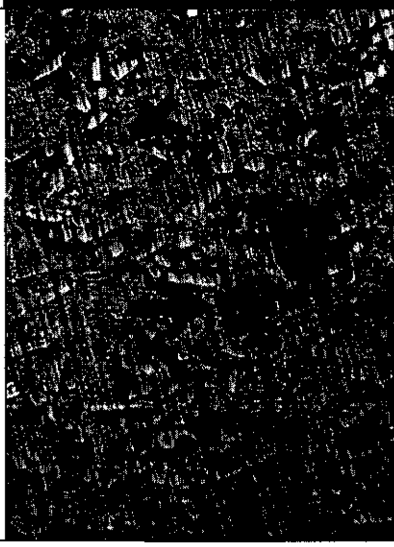
Sections (4) both sample show the fiber orientation is parallel with the melt flow.

FIGURE 4.12: SECTION (5)

Part A		
Part B		
Part C		
	20%	**15%**

Sections (5) represent increase in cross-section and divergence flow is expected. The fiber orientation on both sample align orthogonally at Part A and B while Part A maintain it original orientation.

FIGURE 4.13: SECTION (6)

Part A		
Part B		
Part C		
	20%	**15%**

Sections (6) show the orientation at the end of the geometry and both sample show a complex and random orientation.

The result of the comparison show at the specific place in the sample geometry, the fiber orientation in 15% and 20% volume fraction follow almost the same pattern. The directions of the fiber follow the expected pattern in convergence and divergence flow. The results also show the different in fiber density at each section therefore confirm the characteristic of different volume fraction as the 20% volume fraction of glass fiber sample have higher fiber density compare to 15% volume fraction of glass fiber sample.

4.2 TENSILE TEST

The objectives of the tensile test is make comparison of mechanical properties of different samples with 0%, 5%, 10%, 15% and 20% glass fiber by volume fraction. Bellow show the combine graph of 0%, 5%, 10%, 15% and 20% glass fiber by volume fraction into single graph to give direct comparison. The individual graph of the test is presented at Appendix B and raw data at Appendix C.

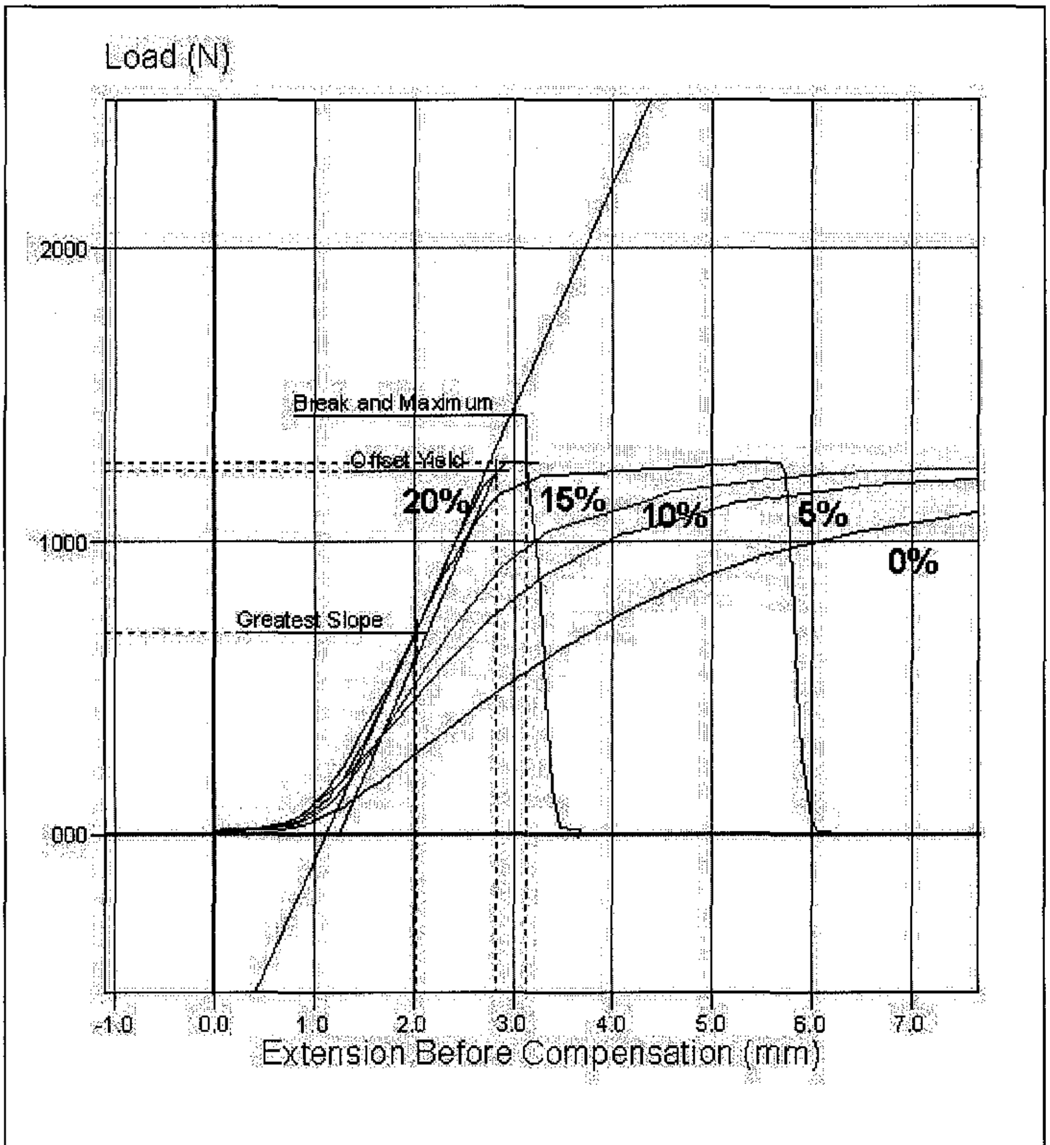


Figure 4.14: Strain-stress graph of composites with volume fraction of glass fiber.

The data collected from the test is represented in individual graph represent particular properties:

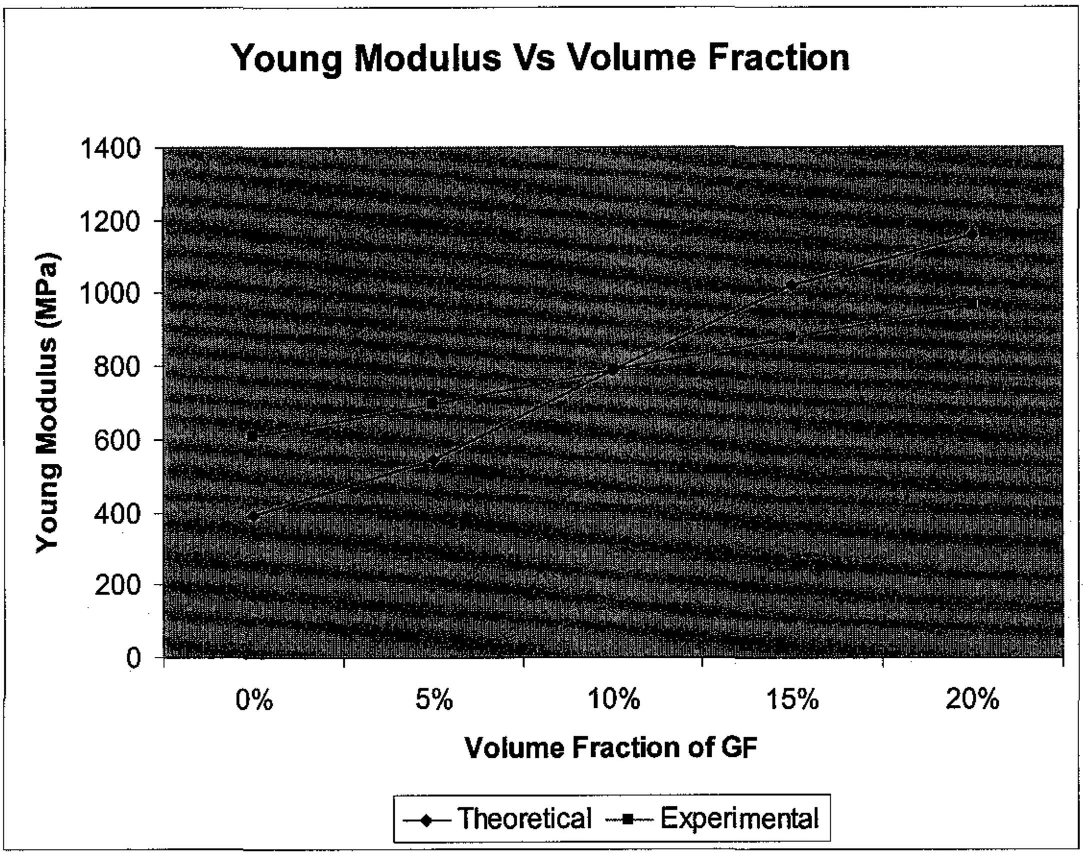


Figure 4.15: Young modulus again percentage of volume fraction of glass fiber

Percentage	0%	5%	10%	15%	20%
Young Modulus (MPa)	610	700	789	879	968

Table 4.1: The theoretical young modulus base percentage of volume fraction.

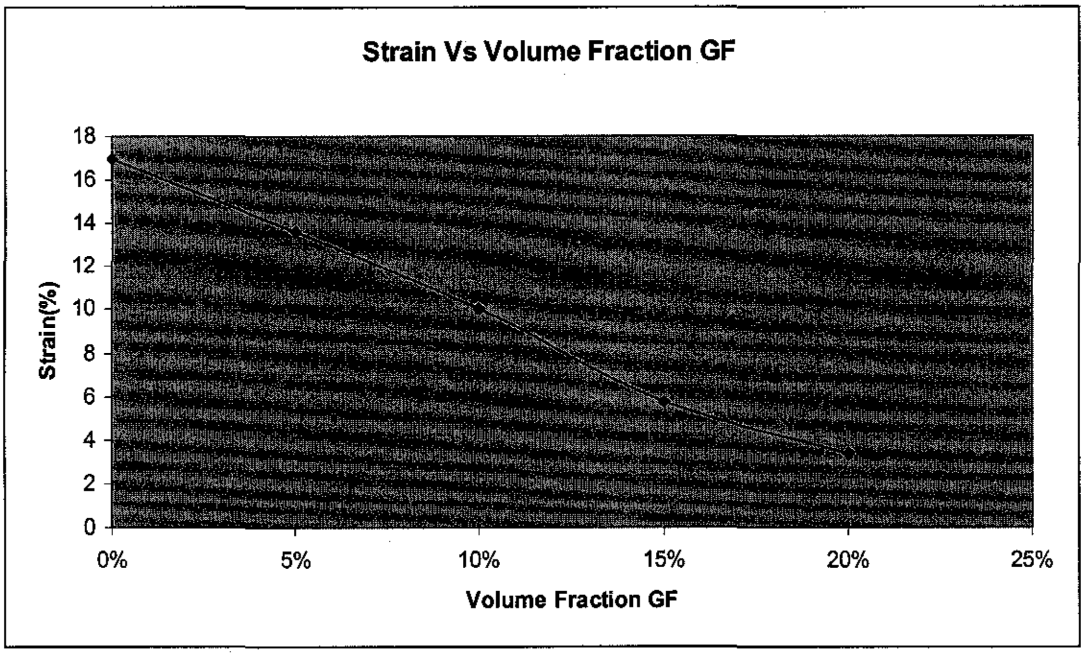


Figure 4.16: strain rate again volume fraction of glass fiber

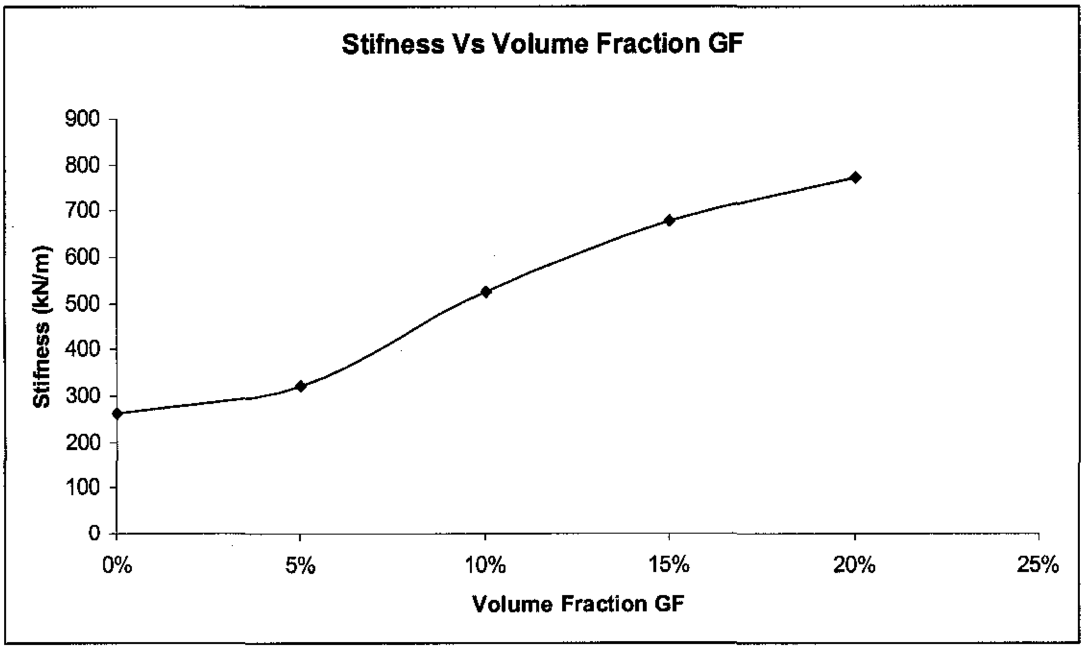


Figure 4.17: stiffness again volume fraction of glass fiber

The Figure 4.15 shows the graph of young modulus against percentage of volume fraction of glass fiber both for experimental result and theoretical result. Generally as the percentage of volume fraction increase the young modulus increase which indicate increase of tensile also strength increase. However comparison between theoretical and experimental value show a slight deviation. Interestingly the value for the pure HD-PE is different from the value given by the vendor and the only indication of the result is the influence of injection molding process. This may cause by the internal void. As for fiber filled samples the deviation primarily because by the fact the fiber is not fully align and fiber density may varies at different geometry as shown in microscopic examination. Other suspected reason is the bonding between the fiber and matrix is not so effective however this statement only can be confirm with observation using scanning electron microscopic (SEM).

The Figure 4.17 shows graph of stiffness against volume fraction of glass fiber. As fraction of glass fiber increase the strain rate is increase. Basically this show the mechanical properties increase with the volume fraction of reinforcement. This supported by the Figure 4.16 of graph strain rate against volume fraction of glass fiber. As fraction of glass fiber increase the strain rate is decrease. The strain rate indicate the ductility of the material which mean as the volume fraction of glass fiber increase the composite material become less ductile or in other meaning is become more brittle. This indicate there are limitation percentage of volume fraction to produce composite with desired result of having the best combine characteristic of the matrix and the reinforcement. If the composite become too brittle due to excessive reinforce volume fraction, the composite will fail catastrophically which very undesirable for any mechanical design.

Mechanical properties of a composite depend strongly on short fiber orientation, fiber concentration, and fiber length distribution. Fiber length distribution is considered consistent since the fiber has average length 3mm but for fiber orientation and fiber concentration largely depend on the injection molding process. The result from the micrographic test clearly show the fiber orientation and fiber concentration is not consistence therefore it varies at different geometries even different sample have it own fiber orientation characteristic. Therefore the result from tensile test already expected to be deviate from theoretical results.

As been stated above one of the main reasons of deviation in mechanical properties is the effectiveness of interface between the matrix and the reinforcement. These interfaces play a critical role and, in many cases, become a limiting factor in improving mechanical properties for a short fiber composite, a strong interface is desirable to transfer load from the matrix to the fibers because stronger interface can increase the effective length of the fiber that carries load. Compromising interfacial bond strength in short-fiber composites may result in complete fiber interfacial debonding and pullout. This may produce a significant loss of the composite strength with only a minimal improvement in the composite toughness.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Conclusively, this study able to show the characteristics of fiber orientation is influenced by the mold geometric profile especially at convergence and divergence flow. The composite with different fiber volume fraction have a similar fiber orientation characteristic at certain geometry profile. The study also show the fiber volume fraction have a direct effect on the mechanical properties of the composite. Noticeably the young modulus increase with the increase of fiber volume fraction however the experimental values have slight deviation with theoretical value .The deviation already predicted because the fiber is not fully aligned base on micrographic test result and the bonding between the fiber and matrix is not so effective however this statement only can be confirm with observation using scanning electron microscopic (SEM).. The test result shows the impotency of controlling the injection molding parameters equally vital with material selection which both influence the overall properties of the composite.

5.2 RECOMMENDATION

This study is far from perfect to be concluded with result produced due to some limitation encounter throughout the study and the recommendation is to overcome those limitations. The most significant limitation is equipment limitation to fulfill the requirement needed. The result of the study can be more emphasize with the help of X-Ray machine and Scanning Electron Micrographic (SEM). Its help to visualize the overall fiber orientation at specific geometry while the reflection microscopy of polished surfaces only able to visualize a confine area. The SEM would help to identify the fiber bond with the matrix which heavily influences the effectiveness of the composite properties.

APPENDICES

APPENDIX A

E, R and D glass properties

Technical data sheet

Glass composition (weight %)

Composition	E (glass)	R (glass)	D (glass)
Silica SiO_2	53 to 57	58 to 60	72 - 75
Aluminia AL_2O_3	12 to 15	23.5 to 25.5	-
Calcium Oxide CaO + Magnesium Oxide MgO	22 to 26	14 to 17	-
Boron Oxide B_2O_3	5 to 8	-	up to 23
F_2	0 to 0.6	-	-
$Na_2O + K_2O$	< 1	-	< 4
Fe_2O_3	= 0.5	-	-
Miscellaneous	-	<2	< 1

Physical properties

Properties	Unit	E glass	R glass	D glass
Density	g/cm_3	2.60	2.53	2.14
Hardness *(Vickers 50 g - 15 s)*	-	5.6	6.2	-
Sound velocity	m/s	5680	5940	-

Mechanical properties

Properties	Unit	E glass	R glass	D glass
Virgin filament tensile test	MPa	3400	4400	2500
	ksi	493	638	363
Impregnated strand tensile test	MPa	2400	3400	1700
(calculated on fiber cross section)	ksi	348	493	246
Tensile modulus	GPa	73	86	55
	msi	10.5	12.5	8
Tenacity *(sized yarns)*	cN/Tex	Min. 50		
Elongation at break for sized yarns according to binder system	%	2.2 - 2.5		
Elastic recovery	%	100	100	100

Resistance to water according DGC method – DIN 1211

Fiber type	E glass	R glass	D glass
DGG result	7 mg	5 mg	40 mg

Electrical properties

Properties	Unit	E glass	R glass	D glass
Dielectric constant at 1MHz	-	6.4	6	3.8
Dielectric constant at 1 GHz		6.13		4
Loss angle at 1 MHz	-	0.0018 to 0.0039	0.0019	0.0005
Loss angle at 1 GHz		0.0039		0.0026
Volume resistivity	Ohm.cm	10^{14} to 10^{15}		
Surface resistivity	Ohm.cm	10^{13} to 10^{14}		
Electrical rigidity	kV/mm	8-12		

Thermal properties

Properties	Unit	E glass	R glass	D glass
Softening point (Littleton)	°C	840	986	769
Strain point	°C	617	736	
Linear coefficient of thermal expansion	m/m/°C	5.3 10^{-6}	4.0 10^{-6}	3.0 10^{-6}
Specific heat	J/g. °K	0.764 @ 20°C 0.958 @ 200°C	0.732 @ 20°C 0.983 @ 200°C	
Coefficient of thermal conductivity	W/m.°K	1.0	1.0	0.8

Thermal resistance of R and E glass virgin filament (after ageing during 24 hours)

Temperature °C	Residual strength (%) E glass	Residual strength (%) R glass
- 200	100	100
200	98	100
300	82	91
400	65	77
500	46	61
600	14	45
700	-	27

High Density Polyethylene (Hexene Copolymer) Grades

LADENE	Melt Index g/10 min	Density g/cm³	Applications	Key Characteristics
F00952	0.05	0.952	Grocery sacks, shopping bags, strong thin films.	Drawdown ability, extrudability, strength, stiffness.
F01552	0.15	0.952	Notion bags and thin films as quality replacement for paper products.	Excellent drawdown ability, stiffness.

Typical[1] Properties of LADENE® HDPE Resins and Films

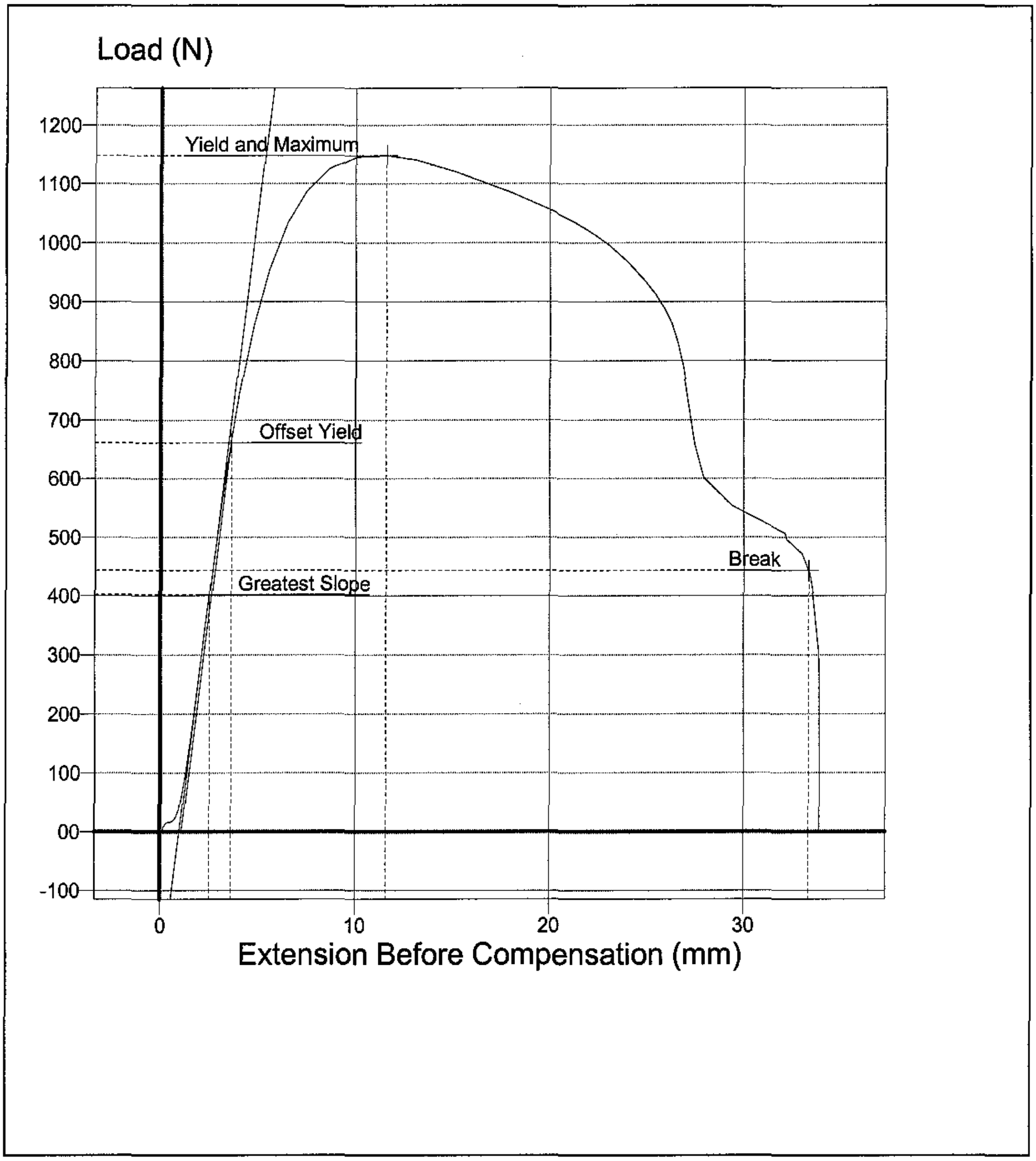
Property	Melt Index		Density	Tensile Strength @Yield MD/TD	Tensile Strength @Break MD/TD	Tensile Elongation @Break MD/TD	Tensile Modulus @ 1% Elongation MD/TD	Dart Drop Impact F₅₀	Elmendorf Tear
Unit	g/10min	g/cm³	MPa	MPa		MPa	g	g	
Test Method	ASTM D-1238 Cond.E	Cond.F	ASTM D-1505	ASTM D-882	ASTM D-882	ASTM D-882	ASTM D-882	ASTM D-1709A	ASTM D-1992
LADENE F00952	0.05	9	0.952	33/31	60/61	300/500	1250/1500	180	11/60
LADENE F01552	0.15	16	0.952	31/30	55/49	400/610	1400/1700	180	4/40

1) Typical values, not to be construed as product specifications.
2) Film property values are typical of 15 micron film extruded at 4:1 blow-up ratio.

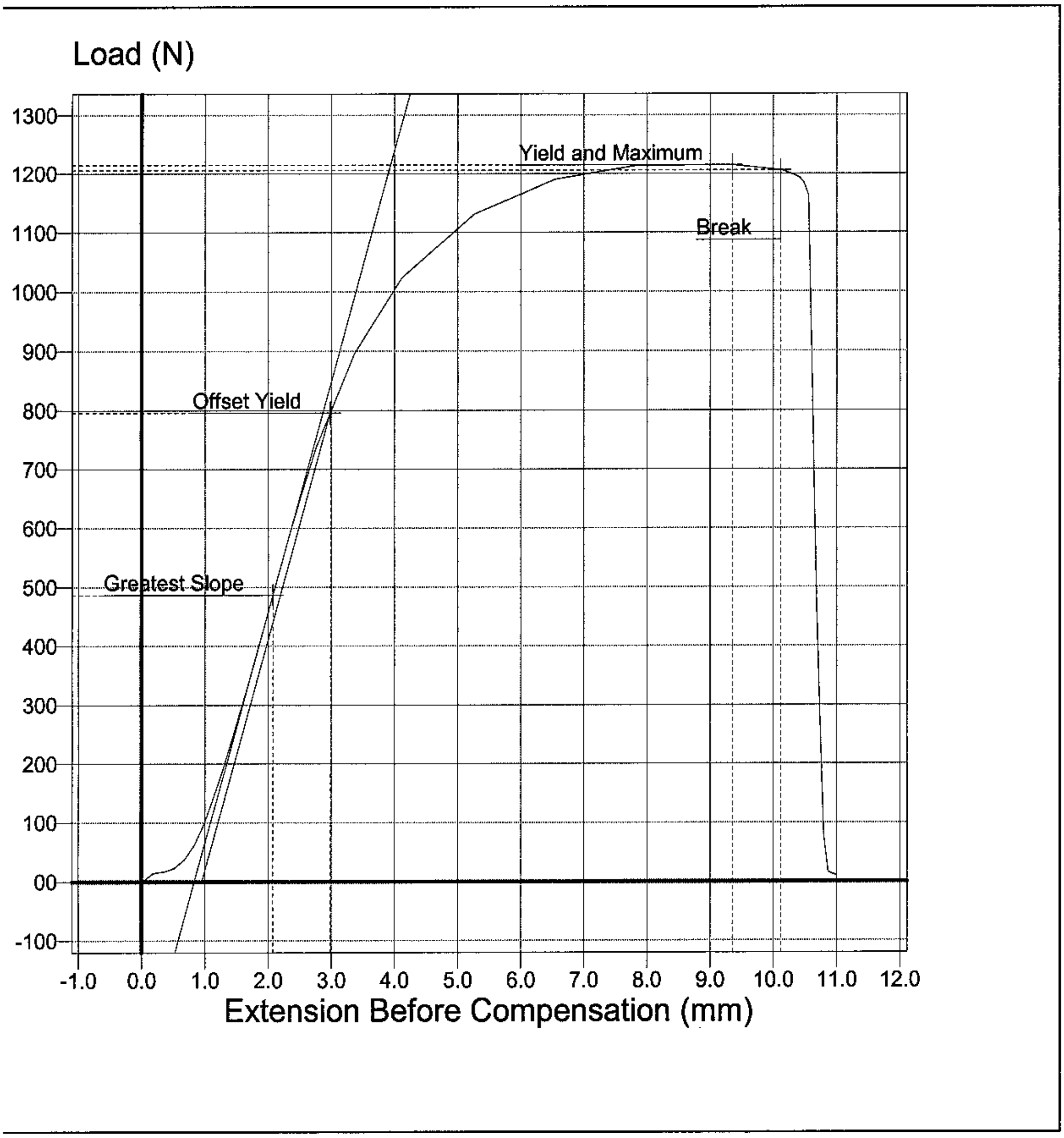
MBT South Africa
Tel: 27-11 622-0942
Fax: 27-11 622-1422
http: //www.mbtsa.co.za
e-mail: info@mbtsa.co.za

SABIC

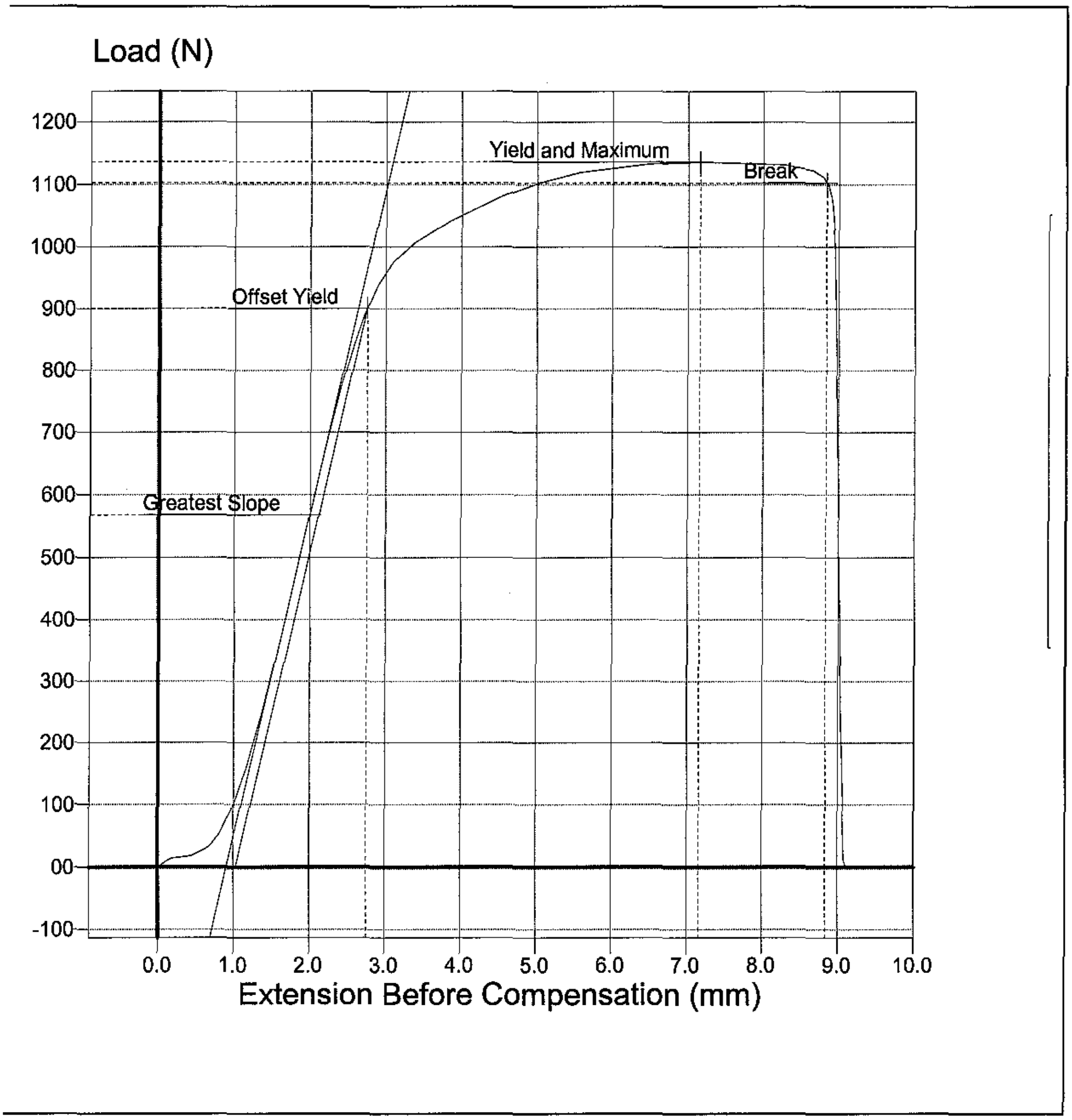
APPENDIX B



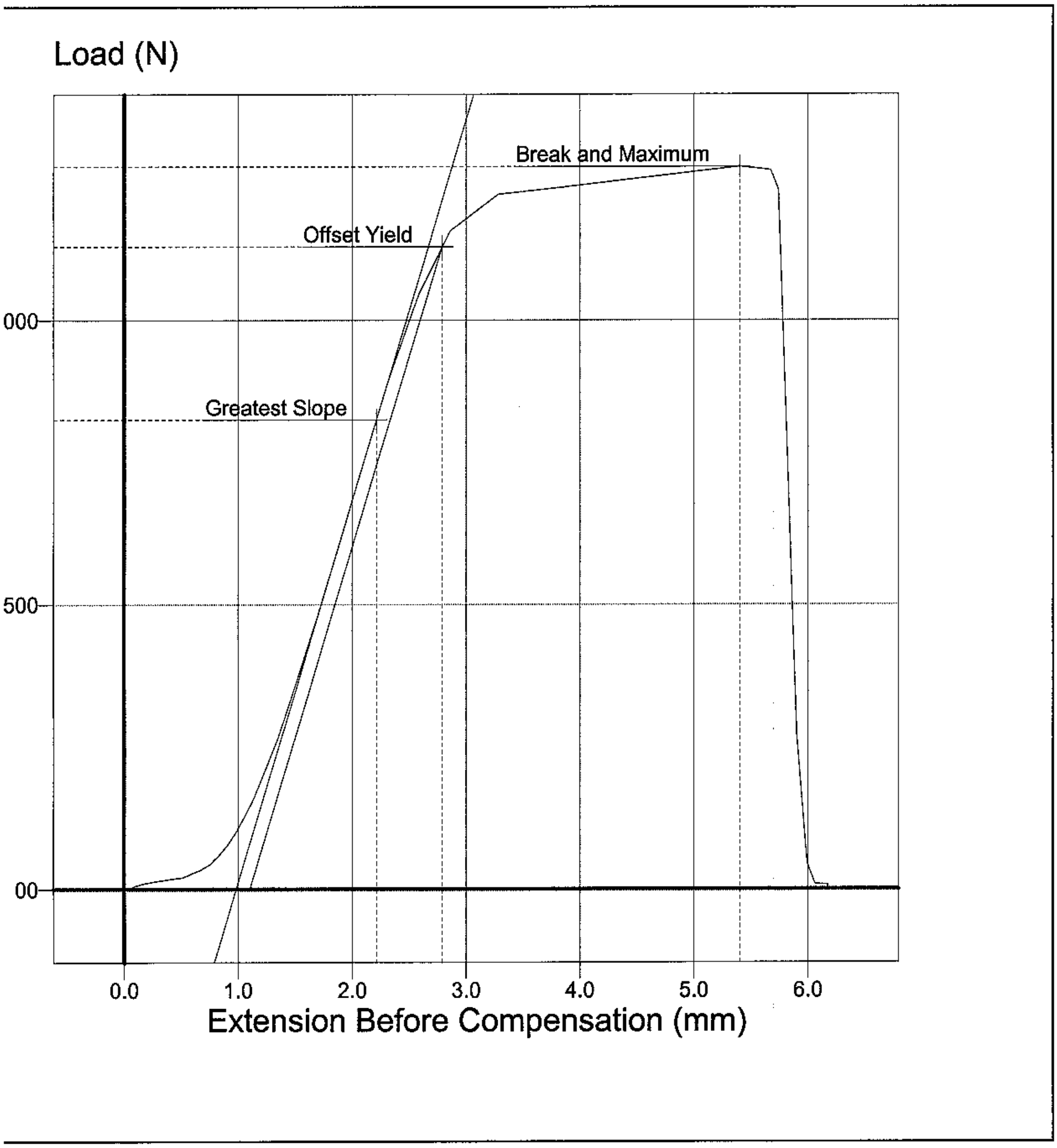
0% Volume Fraction GF



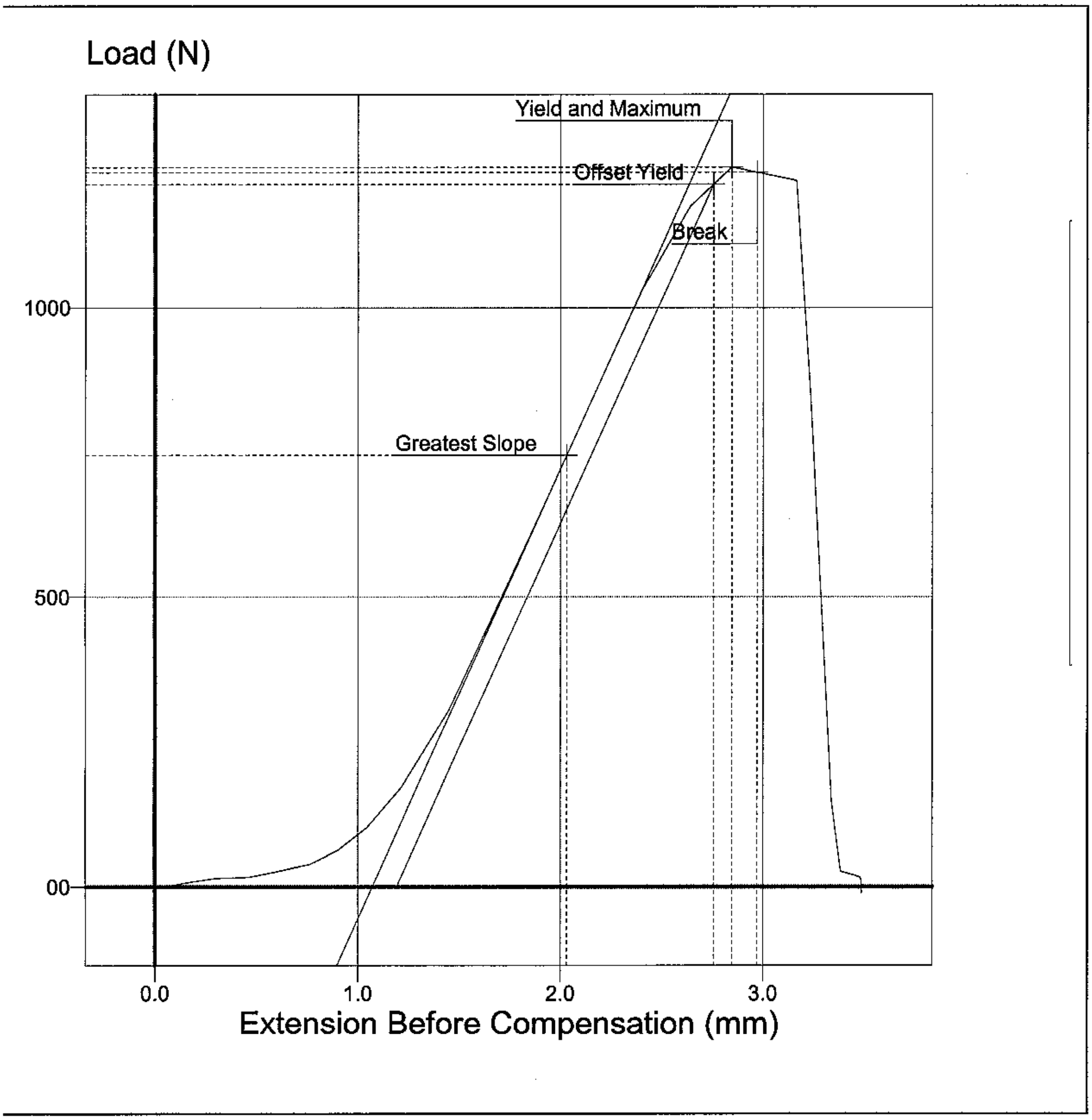
5% Volume Fraction GF



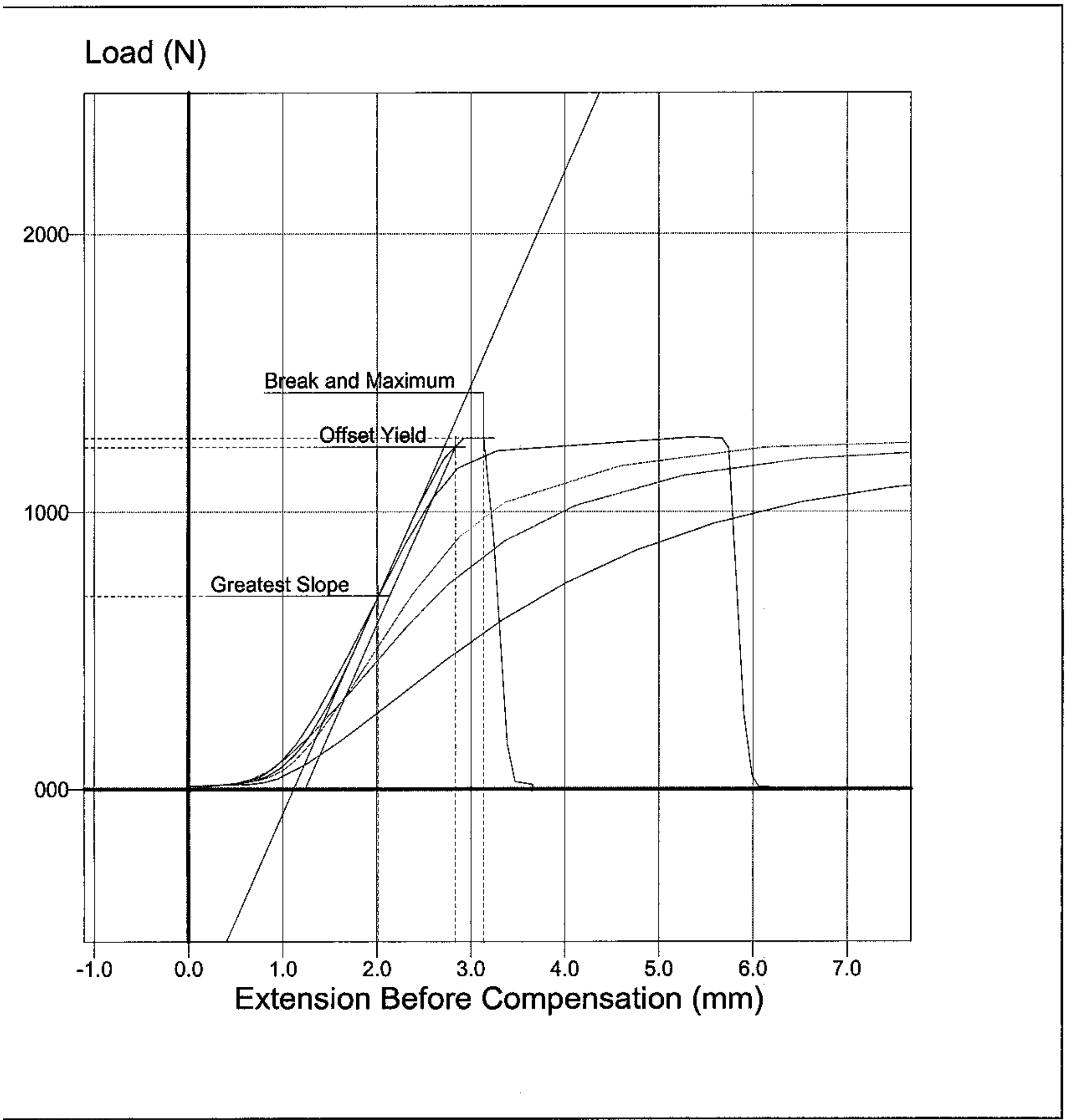
10% Volume Fraction GF



15% Volume Fraction GF



20% Volume Fraction GF


Load (N)
2000
1000
000
Break and Maximum
Offset Yield
Greatest Slope
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Extension Before Compensation (mm)

Combine

APPENDIX C

SAMPLES	YOUNG MODULUS (MPa)	TENSILE STRENGTH (MPa)	EXTENSION AT MAX (mm)	STRAIN (%)	LOAD AT BREAK (N)	STIFFNESS (N/m)
HD-PE 0%GF-1	386.14	28.296	9.719	17.199	444.34	257420
HD-PE 0%GF-2	394.17	28.708	10.610	17.683	443.50	262780
HD-PE 0%GF-3	395.04	28.629	9.543	15.904	450.07	263360
	391.78	28.544	9.957	16.929	445.97	261187
HD-PE 5%GF-1	588.71	30.573	7.689	12.815	1217.60	392480
HD-PE 5%GF-2	587.52	30.372	8.518	14.197	1205.80	391680
HD-PE 5%GF-3	452.69	29.187	8.323	13.872	1166.20	301790
	542.97	30.044	8.177	13.628	1196.53	322099
HD-PE 10%GF-1	890.54	30.983	5.112	8.521	1239.30	593690
HD-PE 10%GF-2	688.92	30.437	6.333	10.550	1214.90	459280
HD-PE 10%GF-3	799.13	31.180	6.647	11.079	1237.60	519420
	792.86	30.867	6.031	10.050	1230.60	524130
HD-PE 15%GF-1	998.71	30.983	3.612	6.020	1239.30	665800
HD-PE 15%GF-2	1057.60	30.264	2.229	3.716	1210.60	705060
HD-PE 15%GF-3	1004.20	31.722	4.421	7.368	1268.90	669440
	1020.17	30.990	3.421	5.701	1239.60	680100
HD-PE 20%GF-1	1157.30	31.651	2.020	3.366	1266.00	771540
HD-PE 20%GF-2	1204.00	32.654	1.891	3.151	1306.20	802260
HD-PE 20%GF-3	1118.20	31.008	2.010	3.505	1235.50	745460
	1159.83	31.771	1.974	3.341	1269.23	773087