ÇUKUROVA UNIVERSITY
INSTITUE OF NATURAL AND APPLIED SCIENCE

MSc THESIS

Tolga ARUSOĞLU

PROPERTIES OF NATURAL FIBER REINFORCED THERMOSET POLYMER HYBRID COMPOSITE

DEPARTMENT OF AUTOMOTIVE ENGINEERING

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We certify that the thesis titled above was reviewd and approved for the award of degree of the Master of Science by the board of jury on 01/07/2019

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ABSTRACT

MSc THESIS

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Supervisor : Assoc. Prof. Dr. Hasan SERİN
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: Assoc. Prof. Dr. Mustafa ÖZCANLI
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By the emerging eco-friendly economy, automotive sector, and the other industries consider to manufacture renewable materials to reduce carbon emissions, energy consumption and the costs, also improve material properties. The hybridization of natural fiber with glass fiber provides to enhance the mechanical properties of composite material.

On this study, natural fiber reinforced epoxy matrix composite material was manufactured by using a vacuum assisted resin transfer method (VARTM). The tensile, Charpy impact, hardness, and water absorption tests were carried out by using composite specimens. It was observed that the addition of glass fiber to natural fiber, prominently increases the properties of composites at the end of the researches.

Keywords: Natural fiber, glass fiber, composite material, hybrid, VARTM

ÖZ

YÜKSEK LİSANS TEZİ

DOĞAL ELYAF TAKVİYELİ TERMOSET POLİMER HİBRİT KOMPOZİTLERİN ÖZELLİKLERİ

Tolga ARUSOĞLU

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Gelişen çevreci ekonomiyle bereaber otomotiv sektörü ve diğer endüstriler; karbon emisyonunu, enerji tüketimini ve maliyeti azaltıp, malzeme özelliklerini yükselterek geri dönüştürülebilir bir malzeme üretmeyi planlamıştır. Doğal elyafların, cam elyaflarla beraber hibridizasyonu kompozit malzemenin mekanik özelliklerinin gelişmesini sağlamıştır.

Bu çalışmada, vakum infüzyon yöntemiyle doğal elyaf takviyeli epoksi matrisli kompozit malzeme üretilmiştir. Kompozit numuneleri kullanılarak; çekme, Charpy çentik darbe, sertlik ve su emilim testleri yapılmıştır. Araştırmalar sonucunda gözlemlenmiştir ki, doğal elyaflara cam elyafın eklenmesi kompozit malzemenin özelliklerini gözle görülür bir biçimde artırmıştır.

Anahtar kelimeler: Doğal elyaf, cam elyaf, kompozit malzeme, hibrit, vakum infüzyon.

GENİŞLETİLMİŞ ÖZET

Son birkaç yüzyılda buluşların artması, sanayinin gelişmesi ve seri üretime geçilmesiyle birlikte metalik malzemelere olan ihtiyaç artmıştır. Otomotiv sektöründen inşaat sektörüne kadar çok geniş bir yelpazede, metallerin farklı mekanik özelliklerinden yaralanılmaya başlanmıştır. Ancak son yıllarda kompozit malzemelerin kullanımının artması, metalik malzemelere karşı iyi bir alternatif olabileceği görülmüştür.

Kompozit malzemeler en az iki farklı malzemenin makroskobik veya mikroskobik düzeyde, çeşitli üretim teknikleriyle oluşturulan yeni malzemelerdir. Kompozit malzemelere kullanılacak alana göre dayanım, kırılma tokluğu, esneklik, hafiflik, yüksek kimyasal direnç, korozyon direnci, akustik iletkenlik veya yalıtım gibi özellikler kazandırılabilir. Ayrıca kompozit malzemeler havacılık ve uzay, denizcilik, kimya, otomotiv, savunma sanayi, elektronik, inşaat gibi çok farklı uygulama alanlarına sahiptir.

Bu tezin araştırma konularından biri olan hibrit kompozit malzemeler ise, iki ya da daha fazla farklı tipteki fiberlerin oluşturduğu malzemelerdir. Hibrit kompozitlerde amaç, mekanik özellikleri zayıf olan fiber tiplerini tek bir matris içerisinde biraraya getirerek malzemenin özelliklerini geliştirmektir.

Tezin giriş kısmında hibrit kompozit malzemelerin tanımı, kullanım amaçları ve bu amaçlar doğrultusunda uygulama alanlarından bahsedilmiştir. Gelişen sanayi ve araştırmalarla beraber malzemelerin ekonomik olarak ve geri dönüşüm açısından geliştirilmesi amaçlanmıştır. Bu nedenlerden dolayı doğal elyaf takviyeli hibrit kompozit malzemelerin; dayanıklı, hafif, tokluğa sahip olması öte yandan ekonomik, geri dönüşümü mümkün olan ve cam elyaf - jüt liflerinden oluşan ve nispeten doğaya zarar vermeyen altenatif bir malzeme olabilmesi hedeflenmiştir.

Bu çalışmada her biri ortalama 300 gr/m^2 ağırlığında olan %100 saflıkta jüt kumaş, iki farklı dokuma tipine sahip cam fiber kumaşı ve matris elemanı olarak

epoksi reçine kullanılanılarak vakum infüzyon tekniğiyle beş farklı kompozit üretilmiştir.

Deneysel çalışmada, çekme testi yapılarak malzemelerin gerilme mukavemeti, yüzde uzama miktarları, elastisite modülü, akma dayanımı tespit edilmiştir. Yapılan charpy çentik darbe testinde ise; kompozitlerin kopmaya karşı göstermiş olduğu direnç ve absorbe edilen darbe enerjisi ölçülmüştür. Vickers mikrosertlik deneyinde, bir piramit elmas ucun numune üzerinde belirli bir süre kalarak, yükle kalıcı kare tabanlı iz bırakmasından oluşan simetrik izin köşegen ortalaması belirlenerek numunelerin sertlik değerleri bulunmuştur. Su emilimi testinde, su dolu kaplarda belirli aralıklarla oda sıcaklığında bekletilen numunelerin su emme kapasiteleri ölçülmüştür.

Deneyler sonucunda, cam elyaf takviyeli kompozitlerin, doğal elyaf takviyeli kompozitlere göre daha iyi çekme özelliklerine sahip olduğu ve hibrit kompozitlerin jüt esaslı kompozitlere göre daha yüksek çekme değerlerine ulaştığı görülmüştür. Charpy çentik darbe deneyinde cam elyaf esaslı kompozitlerin en yüksek tokluğa ulaşan malzemeler olduğu saptanmıştır. Darbe enerjileri incelendiğinde, hibrit kompozitlerin değerleri birbirine çok yakın çıkmıştır ve aralarındaki fark sadece %7 olarak hesaplanmıştır. Twill dokumalı cam elyaf kompozitin 11, 1 HV ile en yüksek sertliğe sahip olduğu görülmüştür. Yapılan su emilimi deneyinin sonucunda cam elyafların aralarındaki bağlanmadan dolayı hibrit kompozitlerin su emme kabiliyetini yükseltmiştir. Sonuç olarak, cam elyafların bir kompozit malzemenin mekanik özelliklerini jüte göre daha fazla artırdığı gözlemlenmiştir.

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LIST OF ABBREVIATIONS AND NOMENCLATURE

GFRP	: Glass Fiber Reinforced Polymer
GFRC	: Glass Fiber Reinforced Composite
ASTM	: American Society for Testing and Materials
UD	: Unidirectional
GMT	: Glass Mat
EFB	: Empty Fruit Bunches
GF	: Glass Fiber
GJ	: Glass- Jute
SEM	: Scanning Electron Microscopy
BHN	: Brinell Hardness Number
ABS	: Acrylonitrile Butadiene Styrene
PP	: Polypropylene
HDPE	: High Density Polyethylene
LDPE	: Low Density Polyethylene
PVC	: Polyvinylchloride
MW	: Molecular Weight
DP	: Degree of Polymerization
EU	: European Union
GM	: General Motors
UV	: Ultraviolet
RTM	: Resin Transfer Molding
Tg	: Glass Transition Temperature
Tm	: Melting Temperature
C	: Celcius
F	: Fahrenheit
Mpa	: Megapascal

Gpa	: Gigapascal
g/cm^3	: Density
mm	: Milimeter
kg	: Kilogram
$	: Dollar
SMC	: Sheet Molding Composite
BMC	: Bulk Molding Composite
VARTM	: Vacuum Assisted Resin Transfer Molding
&	: Ampersand
PA	: Polyamide
BA	: Biaxial
J	: Jute
GT	: Glass Fiber Fabric (Twill)
GBA	: Glass Fiber Fabric (Biaxial)
JGT	: Jute- Glass Fiber Fabric (Twill)
JGBA	: Jute- Glass Fiber Fabric (Biaxial)
TS	: Testing Standard
EN	: European Standard
ISO	: International Organization for Standardization
E	: Young’s Modulus
σ_{axial}	: Engineering Stress Along Loading The Axis
ε_{axial}	: Engineering Stress
σ_{u}	: Ultimate Stress
P_{max}	: Maximum Load
A_0	: Cross Sectional Area of The Sample For Tensile Test
t	: Thickness
E	: Impact Energy
HV	: Vickers Hardness Number
L_1	: Final Length

L_0	: Initial Gauge Length
ε	: Strain
A	: Area of The Specimen for Hardness Test
F_m	: Maximum Force
d^2	: Area
R_m	: Tensile Strength
R_{eH}	: Upper Yield Strength
σ_e	: Engineering Stress
N/mm^2	: Tensile strength
cm^3	: Cubic Centimeter
J	: Joule
g	: Gram

1. INTRODUCTION

Since 90's, hybrid composites have replaced many common materials in various applications mainly because of significant benefits which they offer better propeties in comparison to common materials. Generally, composite materials has great properties which they has low weight, low density, moderately high strength and great possibility to modify their properties (Gopinath et al., 2014).

In hybrid composites two or more reinforcements are used with matrix resin to have improve mechanical properties. These composites are generally used for low load nonstructural applications such as automobile parts. Hybrid composites provide the opportunity of taking the advantages of natural and synthetic fibers in single resin matrix (Niak et al., 2017).

Natural fiber composite materials are conceived as one of the new branch of engineering materials. Interest in this area is growing both in terms of their industrial applications and fundamental research as they are renewable, recyclable, economic and biodegradable. Among all the natural fiber reinforcing cheap and commercially available in the required shape. Glass Fiber Reinforced Polymers (GFRP) are fiber reinforced polymer, made of a plastic matrix reinforced by fine fibers of glass. Fiber glass is a lightweight, strong and tough material used in various industries according to their great properties (Sanjay and Yogesha, 2016).

The main purpose of this research thesis is focused on the utilize hybrid composite materials which was made of natural fiber and different weaved woven glass fiber fabrics. The objective of this thesis is developed and compared to what is mentioned above, and are the following:

- To show and analyze that natural fabrics can be composed clearly with glassfiber fabrics which have various weave directions.
- To observe the mechanical, microscopic-macroscopic structure and environmental behavior using a polymer matrix based on thermoset resin.

- One of the goal of this work will be the selection of the material and manufacturing process more suitable to our ecosystem.
- Environmentally friendly product design which includes the use of natural materials with the aim of reducing emissions in production and the product. The area of the applications are commonly interior and exterior panel and some additional parts (Wallenberg F. T. and Weston N., 2004).
- On this thesis, five different polymer matrix composites will be compared, to decide which material is more suitable for high volume production.
- Glass Fiber Composites (GFRC) are fiber reinforced polymers made of a plastic matrix reinforced by fine fibers of glass. Fiberglass is a light-weight, strong and resistant material which is used in various sectors and their applications due to their incredible properties. However, some mechanical properties such as strength, stiffness, brittleness are lower than carbon fibers (Kasama J and Nitinat S., 2009).
- When it is compared to metals the weight and strength specifications are very satisfying and it can be easily shaped during molding processes (UK D., Navin C.,2009).
- To prove that, it can be a remarkable alternative as the other hybrid composites for the industries.
- Natural fiber (such as jute) reinforced polymer matrix composites can be a good alternative for some industries or researchers because of their low costs, to be renewable, low health, toxicity and safety risks.
- Some materials such as glass and carbon fibers are not economic and the use of boron and carbon is suitable for aerospace applications (Kalaprasad G. and Thomas S., 1995).
- To introduce the polymer matrix composites and their reinforcement materials, matrix materials and manufacturing methods.

- In the all of reinforcing fibers, natural fibers have impressive as reinforcement in polymer based composites. Depends on the source of origin, natural fibers can produce from a plant, animal or some mineral fibers. These days due to the rising energy crisis and ecological risks, natural fiber reinforced polymer composite has attracted more by researchers. The positive sides of natural fibers are their low cost, low density, easy availability in nature, biodegradable, renewable, low density and high specific properties. A big deal of work has been carried out to measure the potential of natural fiber as reinforcement in the polymer such as jute, coir, bamboo, sisal and wood fiber has been reported (Xess, P.A, 2012).

2. LITERATURE REVIEW

2.1. Researches about Fibre Reinforced Polymer Matrix Composites

Nandaragi et al., (2016) performed an experimental research to observe some physical properties such as compressive, tensile and bending strengths according to ASTM standards. The glass fibre composite samples are manufactured by hand-lay up method. They objected to describe manufacturing, preparation of test specimens and also testing prcess woven glass fiber fabric epoxy composite material.

Cai et al., (2016) investigated the mechanical behaviours of uni-directional (UD), twill and plain woven glass fabric epoxy composites under the off-axis tensile loading. The aim of that experiment is to inspect the failure mechanics of the each composite laminates. Tsai-Wuu criteria used to inspect the UD, twill and plain woven fabric composites and multi-axial stress conditions. As a result, the failure types were discussed on the UD, twill and plain weave type composites. Also the surfaces were observed by SEM and the related failure mechansims were identified.

Kumar, (2017) examined the characteristics of E-glass fiber fabrics which they have 60, 65, 70% volume fractions to describe tensile loading, impact strength and hardness properties accroding to the ASTM standards. 70 % of woven glass fiber fabric has good mechanical properties after the performed tests.

Gopinath et al., (2014) studied with two type of polymer based resin for jute fiber reinforced composites, one of them is epoxy and the other one is polyester. The basic purpose of this work is comparison of polyester and epoxy matrix based jute reinfroced composites mechanical properties like flexural strength, tensile strength, hardness and impact strength. They found that epoxy based composite has better mechanical properties than jute fiber reinforced polyester matrix composite.

Kalagi et al., (2016), involved various natural fiber reinforced polymer matrix composites for wind turbine blades. The aim of this study is to replace natural fiber reinforced composites against carbon fibers and glass fibers. There is two different type of composites, one of them natural fiber reinforced polymer matrix hybrid composite and the other one is natural / synthetic reinforced polymer matrix hybrid composite. The designer named these composites as: ”ply construction 1” and “ply construction 2” . Each composites includes 5 layer fabric. Ply construction 1 contains on the first, third and fifth layers Sisal fabrics with 0°/90° angle orientation, second and fourth layers Flax. Ply construction 2 includes on the first and fifth layers Sisal with 0°/90° axis angle, second and fourth layers Flax with +45°/-45° axis angles, middle layer E-Glass with 0°/90° axis angle.

Table 2.1*Ply Construction-1 (Kalagi et al., 2016).*

Layers	**Angle**	**Fiber Type**	**Weight of Fabric(gram)**
Layer-A	0°/90°	Sisal	26.84
Layer-B	0°/90°	Flax	24.16
Layer-C	0°/90°	Sisal	26.84
Layer-D	0°/90°	Flax	24.16
Layer-E	0°/90°	Sisal	26.84

Table 2.2. *Ply Construction-2 (Kalagi et al., 2016).*

Layers	Angle	Fiber Type	Weight of Fabric(gram)
Layer-A	0°/90°	Sisal	26.84
Layer-B	45°/- 45°	Flax	24.16
Layer-C	0°/90°	E-glass	33.72
Layer-D	45°/- 45°	Flax	24.16
Layer-E	0°/90°	Sisal	26.84

After mechanical tests of composite specimens, it was reached that it is infeasible to use natural fibers without glass fibers for high strength required operations.

2.2. Studies on Hybrid Composites

In this study, Davoodi et al., (2010), investigated a hybrid of glassfiber / kenaf to increase physical properties for car bumper beams, this component is manufactured by modified sheet molding compund (SMC) method. The main purpose of this work is, hybridaztion of agro-based fibers with glassfibers and get better results from mechanical tests such as tensile strength, Young's modulus, flexural strength and impact test. The parameter is glass mat (GMT) which is common material for bumper beam. After ther performed tests, they found that felxural strength, flexural modulus, tensile strength and Young's modulus are almost same to GMT. Impact strength of hybrid natural fiber is still lower than GMT. It shows hybrid natural fiber (glass/ kenaf) reinforced epoxy composite has a good potantial for car components.

Jha (2017) fabricated E-Glass/ Jute fiber reinforced hybrid composite by using hand lay-up method. In this research, five different E-Glass/ Jute fiber hybrid composite combinations werer tested and E-Glass/ Jute fiber mechanical and wear properties was observed with different composition accroding to weight percentages.

The compostions are:

a) 100% epoxy + 0% sisal fiber
b) 70% epoxy + 30% jute fiber
c) 70% epoxy + 30% glass fiber
d) 70% epoxy + 18% jute fiber + 12% glass fiber
e) 70% epoxy + 18% glass fiber + 12% jute fiber

The test showed that high jute weight percentage has low wear rate than higher glassfiber weight percentage. Also jute/glassfiber shoed higher tensile properties.

Table 2.3: *Researches About Hybrid Composites-1.*

Composite		**Production Method**	**Measurements**				**References**
Matrix	**Reinforcement**		**Density (g/cm3)**	**Tensile Strength (N/mm2)**	**Impact Energy (Joule)**	**Hardness (HV)**	
Epoxy	Jute	Hand Lay Up					(Kumar and Srivastava 2017)
Epoxy	Jute			12.4-10, 5	2.63-2	44-41.67	(Gopinath et al. 2014)
Polyester				9.24- 7.92	3, 25-, 7	42-41	
Epoxy	Bamboo fibre	Hand Lay Up	1,6-1,25	87-165			(H.P.S. Abdul Khalil et al. 2012)
	Glass fibre		1,96-2,02	180-220			
Polyester	Jute fiber	Pultrusion	1,3				(Mohd Hafiz Zamri et al. 2011)
	Glass fiber		2,5				
Epoxy	Kenaf fiber+ GFRP	Hand Lay Up					(V.S. Srinivasan et al. 2015)
	Flax fiber+ GFRP						
Polyester	Sisal fiber	Compression Molding		78~95	7~8.5		(S.C. Amico et al. 2010)
	Glass fiber						

Table 2.4: *Researches About Hybrid Composites-2.*

Composite		Production Method	Measurements				References
Matrix	**Reinforcement**		**Density (g/cm3)**	**Tensile Strength (N/mm2)**	**Impact Energy (Joule)**	**Hardness (HV)**	
Polyester	Jute fiber	Resin Transfer Molding (RTM)					(Igor M. De Rosa et al. 2009)
	Glass fiber						
Polyester	Sisal fiber			31, 654		~209	(Anaidhuno U. P et al. 2017)
	Jute fiber						
Polyester	Jute fiber	Hand Lay Up		84,59	7,12		(Sanjay M R et al. 2014)
				71,57	5,77		
	Glass fiber			58,38	6,15		
Polyester	Hemp fiber			70,1			(Asim Shahzad 2011)
	Glass fiber			81,6			
Epoxy	Jute fiber	Lamination	0,95	29,52	3,44		R.A. Braga and P.A.A. Magalhaes Jr. 2015
			1,03	49,8	3,53		
			1,14	56,68	5,49		
	Glass fiber						
Epoxy	Banana fiber	Hand Lay Up		77			(K. Krishnakanth et al. 2016)
	Americana fiber						

Table 2.5: *Researches About Hybrid Composites-3.*

Composite		Production Method	Measurements				References
Matrix	**Reinforcement**		**Density (g/cm3)**	**Tensile Strength (N/mm2)**	**Impact Energy (Joule)**	**Hardness (HV)**	
Polypropylene (PP)	Jute fiber	Compression Molding		16			(Temesgen Berhanu et al. 2014)
				28			
				25			
Epoxy	Woven Jute	Compression Molding		82,58	3		(N O Warbhe et al. 2016)
	Kevlar			147,57	4		
				256,5	5		
Epoxy	Banana fiber	Hand Lay Up		16,39			(N. Venkateshwaran et al. 2011)
	Sisal fiber						
Epoxy	Jute fiber	Hand Lay Up		71,66			(M. Indra Reddy et al. 2016)
	Pineapple leaf						
	Glass fiber						

Jawaid (2011) developed tri- layered oil palm empty fruit bunches (EFB) / woven jute fiber reinforced hybrid composite with thermoset matrix material. The purpose of this study is to prove mechanical properties (tensile and flexural) of EFB. As fabrication technique, hand lay up was used and cured in a mold by using hot press at 105°C for 1 hour. Accroding to test results, the physical properties of jute fabriccomposite is higher thn EFB composites.

Ramesh et al., (2012), evaluated the flexural and tensile properties of hybrid glass fiber-sisal/ jute reinforced epoxy matrix composites.In this process hand lay-up method is used for material preparation.The length of raw jute and sisal is 35 mm and bi-directional woven glassfiber mat was used in the specimens. In reference to the test results, it was seen that Sisal-Glassfiber reinfroced composites performing better for tensile strength test and jute-Glassfiber reinforced composite materials are showed high flexural loading behave.

Noi et al., (2017), utilized fiberglass (FG), kenaf (K) and jute (J) reinforced hybrid composite materials with 4 different layers of reinforcements. The main purpose of this work is to examine dynamic response of the natural fiber reinforced hybrid composites under low velocity impact energy. Also some mechanical tests such as; tensile and impact test was performed by researcher. The configurations of composites are; FG-J-K-J-FG, FG-K-K-K-FG, FG-J-J-J-FG,. FG-K-J-K-FG The best two designs were picked accroding to their impact energy levels from 10 J to 40J.Theses designs are FG-J-J-J-FG and FG-J-K-J-FG. The designs showed better results than the other two. The third sample reached the highest tensile test result which is 124,05 MPa. From the performed tests, the both designs has linearly increasing impact force as well as absorbed energy. The third design has a lower peak force compared to fourth design. Therefore, fourth sample has better impact resistance.

Magarajan et al., (2017), compared static mechanical properties for Glass Fiber (GF) and Glass-Jute (GJ) Fibre reinforced composites. The static mechanical tests namely hardness, tensile strength, impact test, yield strength, flexural loading. Each tests were obtained according to ASTM standards. In this study, GF and GJ reinforced polymer composites were manufactured using Hand Lay-Up method. They reached some results as below after static mechanical tests:

1. GJ composite has lower tensile strength than GF composite (80,15 Mpa-209,51 MPa)
2. The hardnesses are almost same (GF:42,2 BHN- GJ: 36,22 BHN)
3. The impact strength of the both composites is nearly equal.
4. As an addition to the conclusion; on GJ composite, a good increasement was observed in flexural strength such as 178,52 Mpa

Zhao et al., (2017), performed an experimental research investigate flexural behaviour of needle punched jute/fiberglass fabric reinforced polymer hybrid composite. Four different compoosites was setted for this work such as Jute (J), Jute(J)/ Glass fiber (GF), Jute (J)/ Glassfiber (GF)/ Glass fiber (GF), Jute(J)/ Jute(J)/ Glassfiber (GF). The composite made by hand lay-up method with polyester resin after needle-punched treatment. Subsequently, bending test was performed. Accroding to flexural modulus there was not wid difference observed except Jute composite, it has the lowest flexural strength (approximately 37 Mpa) among the tested composites. The jute composite showed an indicating brittle characteristic and a low deflection. They found that J/ GF and J/ J/ GF has higher flexural strength when the GF layer located on the bottom side compare3d to test results of jute.

Bajpai et al., (2017), developed a hybrid glass-jute reinforced epoxy composite for safety helmets.The aim of this work is to show glass-jute reinforced composites can be a good alternative to Acrylonitrile butadiene styrene (ABS) based safety helmets. They designed five different composite depending on weight percentages of matrix and varied fiber layers by using hand lay up method. They manufactured jute percentages from less to more. The first sample is completely 4 layered jute and the fifth sample is completely 4 layered glass; between the 1.and 5.composites are showed below:

A. 3 Layer Glass + 1 Layer Jute + Epoxy (%32+ %6+ %62)
B. 2 Layer Glass + 2 Layer Jute + Epoxy (%20+ %10+ %70)
C. 1 Layer Glass + 3 Layer Jute + Epoxy (%12+ %20+ %68)

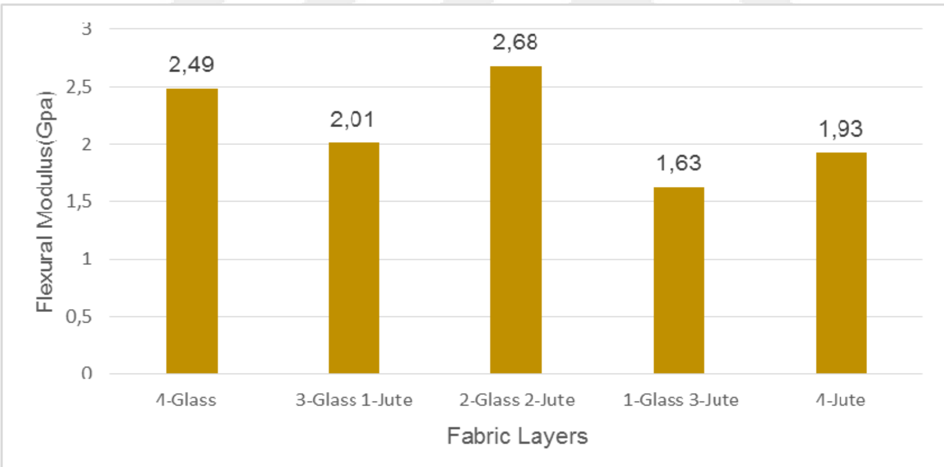


Figure 2.1. *Flexural Modulus Test Results (Bajpai et al., 2017).*

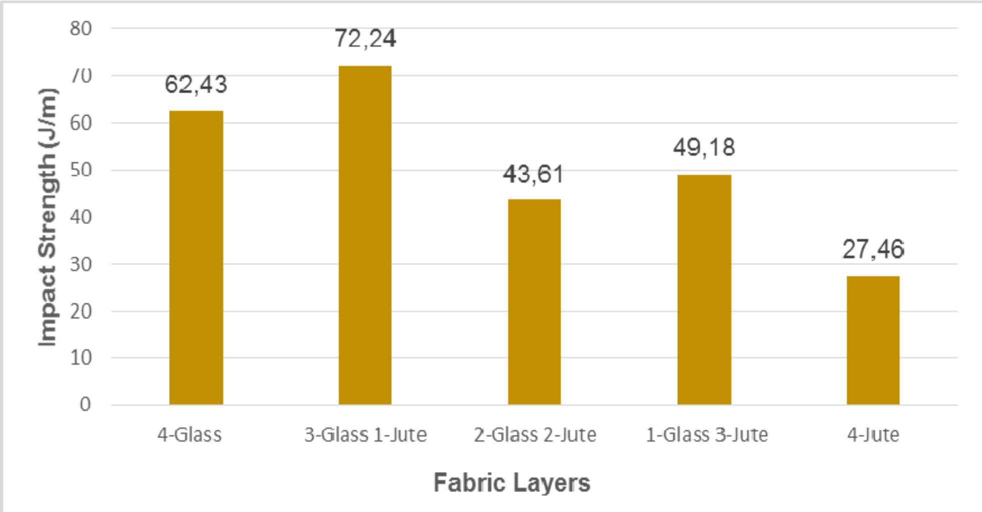


Figure 2.2. *Impact Strength Test Results (Bajpai et al., 2017).*

The C type composite reached to maximum flexural strength. The A type composite reached to maximum impact strength. Accroding to test results the A type composite can be used to replace ABS based safety helmets.

3. COMPOSITE MATERIALS

3.1.Introduction

Composite material is made by two or more different material that consist of the reinforcement phase and the matrix phase. Composite materials have been utilized to figure out some engineering problems.Since 1960's, composite materials have become one of the most common engineering materials (Song K. Et al., 2013). Composite materials are fabricated for aerospace, automotive, sport equipments and marine. The first composite was discovered in the nature. For instance, the shell of invertbrates, such as snails and oysters, is a good example to primitive composite. In some countries husks or straws mixed with clay have been used to build houses for centuries. In general a composite material contains a matrix material (matrix phase). The reinforcement materials shaped into the matrix material. The type of reinforcements can be fibers, particulates or whickers and the matrix maaterials can be plastics, ceramics or metals (Mandalgiri P.D., 1999).

3.2.Biocomposites

Biocomposites are obtained from a biological environment; these may be reinforcements (jute, hemp, flax, sisal and kenaf or recycled wood and paper) or organic substances, for instance, soybean resins and polylactic acid (PLA) (Fowler P.A. et al., 2006) (Christian S. And Billington S., 2009), (John M. J. And Thomas S., 2008). By the commercialization, synthetic materials like carbon fibers, glass fibres and aramid fibers in tweintieh century caused reduced of the usage of the natural fibers with various factors. " This was a time of robust industrial and technological development that required use of highly reliable materials with consistent properties; a test well passed by the newly engineered fibers and somehow failed by the natural fibers as physical and chemical properties had big variations and fluctuations stemming from weather, harvesting methods, transportation, storage, and processing." (Taub A. I. Et al., 2007).

Since 1953, glass fibers and the other conventional fibers have been incomparable composite reinforcements in automotive industry. GM started to supply glass fibers for using in Chevrolet Corvette which are hand rolling polyester resins on open molds, from Molded Fiber Glass Company of Ashtabula, Ohio. These fibers were used in the assembly of a prototype car; after hundered's were made. As a conclusion glass fiber composites rapidly rised in automotive sector with their a few superiority such as better mechanical properties, easy processing and lightness (Taub A.I.Etal.,2007).

Ever since, glass fibers has satisfied attributes; low cost, good mechanical properties, and reliable performance that makes them take a place alongside steel in car body building using up to 15% of the world's steel, 25% of the world's glass, and consuming 40% of the annual world oil output. (Bilefeldt K. Et al., 2007).

3.3.Hybrid Composites

The meaning of "Hybrid Composite", is containing of two or more different type of reinforcements in the matrix. It has also called such as "Fiber Hybrids" or "Fiber Hybrid Composites". Presence of fiber hybrid composites are started from a few decades ago. By the invention of carbon fibres in 1960's (Shindo A., 1964), (M. M. Tang and Bacon R., 1964) the high price was their biggest obstacle. In an attempt to decrease the price, while still exploiting the exceeding features of carbon fibre, hybridization became a highly active research area in the 1970's and 1980's. After reduction of carbon fibers researchers focused on investigate their production techniques and understand the mechanical behaviours of non- hybrid composites (Fitzer E., 1989).

Generally, the purpose of bringing two fibre types in a single composite is to keep the advantages of both fibers and lower some disadvantages. For example, replacing carbon fibres in the middle of a laminate by cheaper glass fibres can significantly reduce the cost, while the flexural properties remain almost unaffected. If a hybrid composite is loaded in the fibre direction in tension, then the more brittle fibres will fail before the more ductile fibres. This fracture behaviour can be used for health monitoring purposes (Wu Z.S. et al., 2006) or as a warning sign before final failure (Czel G. And Wisnom M.R., 2013).

3.4. Polymer Matrix Composites

The polymer matrix composites are consists of two components; polymer resin as the matrix phase and fibers as the reinforcement phase. Polymer matrix based composites are applied in wide range areas due to the thier properties, ease of manufacturing and low investment cost (Callister W., 2007).

Polymer based materials such as epoxy and polyester have low mechanical properties in comparison to metals, that causes low usage on structural operations. On the other hand, the mechanical properties can be enhance if reinforced with strong materials. Polymer matrix reinforced materials have good tensile and compressive properties but these are non-effective on surface damages. The solution of this problem is, combination of strong reinforcements with resin to manufacture composite with optimum properties. The combination of reinforcements with various type of resins with proper mechanical properties may positively effect the environment (Roylance D., 2000).

Polymer materials consists long chain molecules and these chains are constitued by repeating units. They unfiltrates so easily which is suitable for use. The matrix materials of polymers are classified two; thermosets and thermoplastics by their response to heat treatment (Pickering S., 2006).

3.4.1. Matrix Material

Polymers have good chemical resistance in compoarison to metals and ceramics, however they have low strength and modulus. Some solvents and UV lights can cause structural degradations on polymers. Polymer materials have covalent bonded carbon molecules and it includes macromolcules and huge chain molecules. Both of these cahin molecules create backbone structure of the polymers. By the pressure of polymerization, small chains and big organic molecules (which they have low molecular weight) are linked together with this process polymer material occurs. According to bond structure polymer materials are classified as linear polymer and cross- linked polymers. Linear polymers are includes long chains and cross- linked polymers are formed as three dimensional network, each molecules of chain bond those of another (Asthana et al., 2006).

Cross- linking poloymers are rigid and strong because the structure of cross linking blocks sliding molecules. In other respects metals melt at constant temperature, in some range of high temperatures polymers shows crystallinity vanishes on heating up. Liquid polymers contraction just as metals during cooling process. Under the melting point the contraction continues for amorphous polymers. T_m as crystalline polymer and T_g is glass transiton temperature. On T_g, the structure is supercooled and ultra rigid in consequence of the viscosity is extremely high. Under the T_g polymer structure is disrodered such as a liquid. Various physical properties of T_g is change like thermal expension heat capacity and viscosity. (Asthana et al., 2006).

Molecular weight(MW), degree of polymerization(DP) are curicial for polymers which they are effects mechanical properties. MW can be calculated by MW= DP x $(MW)_u$. The meaning of $(MW)_u$ is molecular weight of the repeating unit. Each polymers has different molecules, when DP and MW has various values. (Asthana et al., 2006).

3.4.1.1. Characteristics of Matrix Materials

On applied stress glassy polymers are showed linear elastic behave and also follows Hooke’s Law. Elastomers are non linear unlike the elasticity of glassy polymer is lower than %1. According to Figure 3.1. below elastomers has high strain ratio that cause tangle of the molecular chains under a performed stress. Some thermoset resins which they have high cross- linked, such as epoxies, polyesters and polyamides have high strength and modulus unlikely they are very brittle. Thermoset resins has more or less better fracture energy than organic glasses (Asthana R. et al., 2006).

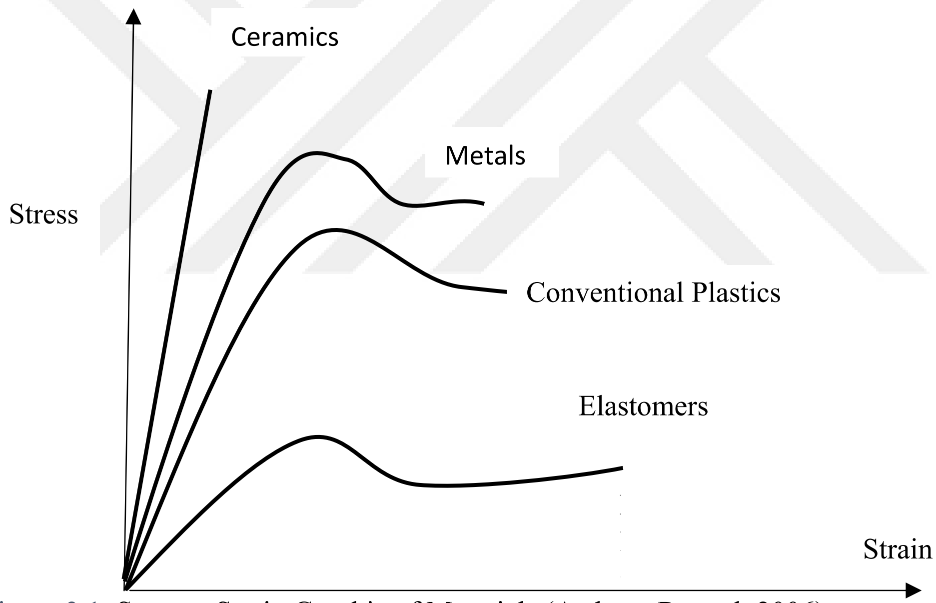


Figure 3.1. Stress – Strain Graphic of Materials (Asthana R. et al, 2006).

Thermoplastics and thermosets are applied for polymer composites as matrix materials. The most common matrix materials are; epoxies, polyester and polyamides. Epoxies has good moisture resistance, low shrinkage value, around three percent, high working temperature. Polyesters have fair chemical resistance also shrinks more than epoxies during curing process. Polyamides are brittle and they have low fracture energies besides of these polyamides high service temperature, it is around 300 ° C (Asthana R. et al., 2006).

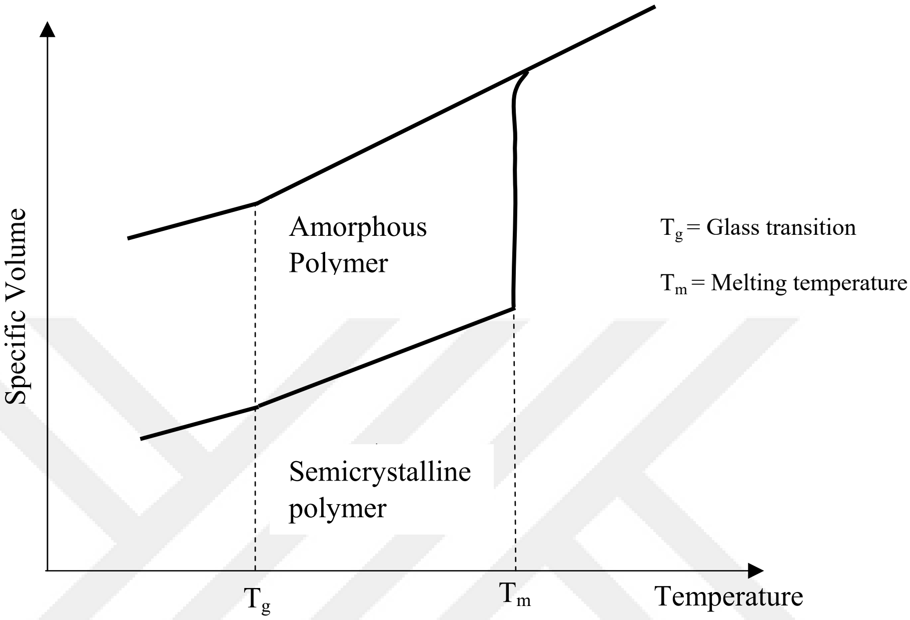


Figure 3.2. Specific Volume- Temperature Graphic (Asthana R. et al, 2006).

3.4.1.2 Thermoset Resins

Thermosets are cross- linked materials, they one time cured and after it cannot be remelted or reshaped. The quantity of cross- linkings are important for rigidity and thermal resistance. In elastomers, the density of cross- linkings are lower than thermosets thus elastomers are elastic. Thermosets has great electrical and chemical resistance with good rigidity. The most common thermosets are; polyesters, polyamides and epoxies (Mazumdar S., 2002).

Epoxy: epoxies are most popular resin materials and they are used in vaious areas from aviation to some sport materials. There many variety of epoxy resins, it may change according to use of the area with different formulas. When the formulas changes; curing, toughness, thermal resistance will be changed. Epoxy resins are expensive in comparison to polyesters and vinylesters. Epoxies are widely used for hand lay up method, RTM and filament winding. (Mazumdar S., 2002).

Polyester: Polyesters are low cost resins and resistant to corrosive environments. On the other hand polyester have lower themal properties than epoxy resins. Polyesters are mostly used on RTM, pultrusion and filament winding (Mazumdar S., 2002).

Vinylester: Vinylester are low cost and have great corrosion and chemical resistance. They are mostly used in the chemical applications and batch productions. The cross linked vinylesters offers high touhgness and ductility when they are cured (Mazumdar S., 2002).

3.4.1.3 Themoplastic Resins

The properties of thermoplastic polymers can be changed by changing length of chains, changing the strength of bonds between chains. Linear polymers are quite flexible but molecular rings in the chain andside groups on the chain have a stiffening effect. Side groups on chains, molecular rings in the backbone and strong Van der Waals forces between chains all increase the melting temperature. Crystallinity is influenced by the nature of the molecular chains and the ease with which they can be packed together, linear chains with no side groups on the chain crysatllise most easily. Crytallinity also increases the melt temperature. Non-Crystalline polymers have excellent transparency but, since the crystals in a polymer scatter light, crystallinity reduces tranparency. Polymer transparency thus ranges from highly transparent to completely opaque to visible light. Moisture absorption by polymers is largely dependent on the atoms maling up the polymer. The presence of oxygen and chlorine atoms gives rise to some absorption while nitrogen considerably increases the absorption. For example, nylons contain nitrogen and so have significant water absorbing properties. Moisture absorption increases the volume of a polymer and generally reduces the strength and stiffness. It also causes an increase in the electrical conductivity and dielectric constant.

Solvents attack thermoplastics by separating the molecular chains. The most popular thermoplastic resins are; polyethylene, polypropylene, polyvinylchloride and polystrene (Philip M. And Bolton B., 2002).

Polyethylene(PE):Polyethylenes are classified as high density polyethylene (HDPE) and low density polyethylene (LDPE0). HDPE has linear molecular chains, LDPE has branches on the molecular structure. Both polyethylene types has great chemical resistance, LDPE is more flexible but HDPE is more stiffer. The two types of polyethylene can be easily shaped by extruder and several molding techniques(Philip M. And Bolton B., 2002).

Polypropylene(PP): Polypropylene properties depends on the crytallinity. Any addition to the polymer chains by side groups, it improves the strength and physical properties. Polypropylenes can be easily shaped such as PE (Philip M. And Bolton B., 2002).

Polyinylchloride(PVC): Polyvinylchloride is a stiff material but it can be flexible by adding plasticisers. There are four methods to manufacture PVC, these are; injection molding, rotational molding, blow molding and thermoforming. PVC is produced for constructions to waste water and soil drainage. Some soft(plasticized) polyvinylchlorides are used for hoses, bottles and plastics coats(Asthana R. Et al., 2006).

3.4.2.Reinforcements

Reinforcements are used for to exhibits rigidity and toughness. Mostly reinforcements has more strength and stiffness in comparison to matrix phase. Reinforcements are divided two; particulate (discontinous) and fiber. Continous fiber composites are stiffer than particulate compsites, it has more strength. According to contents, fiber are classified as; synthetic (glass, carbon, aramid) and natural which can be contious or discontinous (Campbell F, 2010).

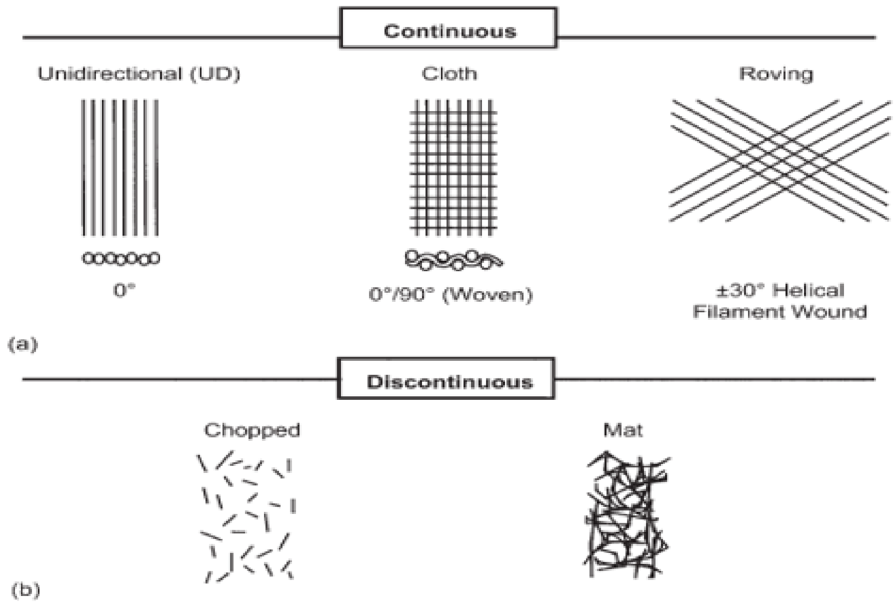


Figure 3.3. Typical Reinforcement Types (Campbell F., 2010).

3.4.2.1.Natural Reinforcements

Natural reinforcements are used as fiber in the aerospcae and automotive industry (Table 3.1). Natural fibers can offer good mechanical properties. Also these fibers can support vibration damping and thermal insulation. Natural fibers are recyclable, biodegredable and sustainable. Natural reinfoced composites can be beneficail for the environment and economy. The most used natural fibers are; jute, hemp, ramie and flax(Chegdania F. Et al., 2018).

Table 3.1. Some popular applications of natural fiber in automotive industry (Suddell B., 2009).

Automotive Manufaturer	**Model applications**
AUDI	A8, A6, A4, A3, Roadster, Coupe Seat backs, side and back door panels, boot lining, hat rack, spare tyre lining
BMW	3, 5, 7 series Door panels, headliner panel, boot lining, seat backs, noise insulation panels
FIAT	Punto, Brava, Marea, Alfa Romeo 146, 156
FORD	Modeo CD 162, Focus
LOTUS	Eco Elise, Body panels, Spoiler, Seats, Interior carpets
PEUGEOT	406 Seat backs, parcel shelf
RENAULT	Clio, Twingo, Rear parcel shelf
ROVER	2000 and others Insulation, rear storage shelf
TOYOTA	Brevis, Harrier, Celsior Raum, Door panels, seat backs, spare tyre cover
VOLKSWAGEN	Golf, Passat, Bora Door panel, seat back, boot lid finish panel, boot liner
VOLVO	C70, V70 Seat padding, natural foams, cargo floor tray

Jute: Jute is one of the most popular fiber to produce eco- friendly composite material. The origin of jute fiber is bast and it is very common material in the continent of Asia. Jute is preferred by various industries because of their low-cost, high volume, low extension break despite all they have poor moisture, UV and chemical resistance. The mechnaical properties of jute fibers are showed in Table-3.2 (Singha H. Et al., 2017).

Hemp: The origin of hemp is Cannabis family and it grows in warm climates. EU consider to use for further developments (Faruk O., et al., 2012).

Ramie: Production of ramie is limited as a textile fiber, ramie has required extensive pre- treatment in comparison to the other natural fibers (Faruk O., et al., 2012).

Flax: Flax is grown in warm climates which is beongs to the bast family. These days flaxes are mostly used as reinforcements in composite materials (Faruk O., et al., 2012).

Table 3.2. Properties of some natural fibers and E-glass (Koronis G. et al., 2012).

Fibers	**Density (g/cm^3)**	**Diameter (mm)**	**Tensile strength (Mpa)**	**Young Modulus (Gpa)**	**Elongation at brake (%)**	**Price ($/kg)**
Flax	1,5	40- 600	345- 1500	27- 39	2,7- 3,2	3,11
Hemp	1,47	25- 250	550- 900	38- 70	1,6- 4	1,55
Jute	1,3- 1,49	25- 250	393- 800	13- 26,5	1,16- 1,5	0,925
Kenaf	1,5- 1,6	2,6- 4	350- 930	40- 53	1,6	0,378
Ramie	1,5- 1,6	0,049	400- 938	61,4- 128	1,2- 3,8	2
Sisal	1,45	50- 200	468- 700	9,4- 22	3,7	0,65
Curaua	1,4		500- 110	11,8- 30	3,7- 4,3	0,45
Abaca	1,5	Eki.30	430- 813	31,1- 33,6	2,9	0,345
E-glass	2,55	15-25	2000-3500	70- 73	2,5	2

3.4.2.2. Synthetic Reinforcements

***Carbon Fibers* :** Carbon fibers are one of the most common material in automotive, electronics and aerospace industry. The high mechanical properties, service temperature, thermal,electrical conductivities and low moisture absorption makes carbon fiber popular in industries. Carbon fibers has the highest mechanical proeprties among all reinforcement fiberrs. (Prashanth S., et al., 2017).

Kevlar fibers*:** Kevlar fibers are light- weight, stiff, damage resistant, durable materials. The application areas of kevlar fibers are; automotive, construction, military, marine and aerospace (Wu Z.S. et al., 2006). ***Glass fibers: Now a days, glass fibers are produced in various industries (Loewenstein, 1993).The properties of glass fibers are; rigidity, strength and flexibility. Glass fibers are mainly used in comopsite manufacturing and numerous products for special purposes (Wallenberg, 1994,p129-168).

E- glass (Electical resistant) is the most used glass fiber type, it contains alumina borosilicate glass and trace amount of alkali oxides. The other types are; A-glass (Alkali- lime), C-glass (for insulation), D- glass (low Dielectric constant), R-glass (Reinforcement for high mechanical conditions) and S-glass (Strength) (Fitzer et al., 2000) .

3.4.3. Some Manufacturing Techniques of Polymer Composites

3.4.3.1. Sheet Molding Composite (SMC) and Bulk Molding Composite (BMC)

On this process, semi finished sheet product which contains fibers, resins, fillers and unsaturated polyesters (Mortazavian and Fatemi, 2015). The semi finished products are pressed with heated steel molds between temperature of 140 °C and 160°C (Boylan and Castro, 2003). (Fig 3.4).

BMC is similar process to SMC except a few differences such as; length of fibers and alternatively injection molding can be used by BMC method. This application şs used by chemical, textile, automotive, electronics and construction industries (Boylan and Castro, 2003).

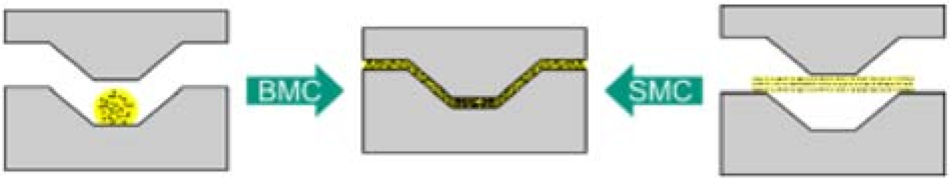


Figure 3.4. *SMC and BMC production (Flesicher J. et al., 2018).*

3.4.3.2.Preforming

The first step of this process is preparation of semi finished three dimensional shape for infiltration. For the following steps are seperated as direct preforming process and sequential process (Peng and Cao, 2005; Zhang et al., 2017).

For direct preforming, fiber rovings are used as reinforcement. Recently, researchers are focused on to reduction of cost and time of the process (El-Dessouky et al., 2016).

In sequential preforming, woven and non woven fabrics are shaped into three dimensional form. The differences between two processes are forming and fixation (Fleischer et al., 2018).

3.4.3.3.Resin Transfer Molding(RTM)

The process of resin transfer molding (RTM) is quite simple, the preform is placed between female and male mold.These elements are constitued the close molding system and preform is pressed by male mold to give a required shape(Figure 3.5), (Fleischer et al., 2018).

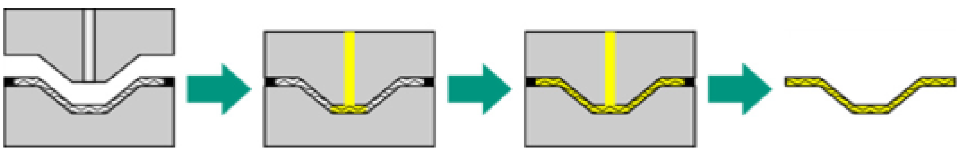


Figure 3.5. RTM process Flesicher J. et al., (2018).

3.4.3.4. Vacuum Assisted Resin Transfer Molding(VARTM)

The vacuum assisted resin transfer molding is a different type of RTM. This process is not performed in closed mold instead of this, vacuum bag is placed onto the preform. VARTM method is easy to apply, the sealing is provided and vacuum is turned on. The resin flow is begun by required pressure (1 atm) and complete distribution is ensured. After the preform completely wet out, the vacuum it turned off and the preform is cured in the oven of at room temperature. VARTM is low cost method because on this process the male mold is not used. Figure 3. 6.

Besides of this the large scale projects can be applied by VARTM (Song, 2003).

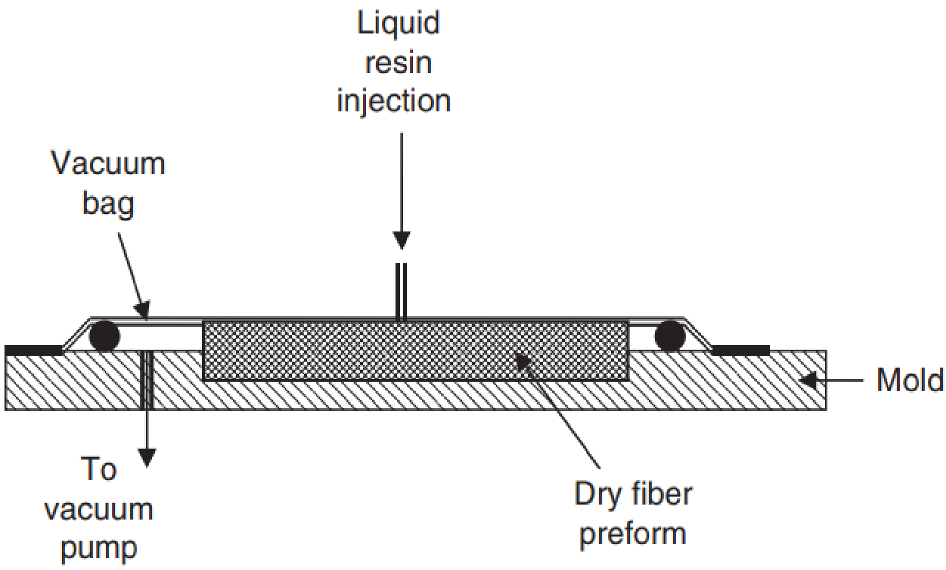


Figure 3.6. *VARTM process (Mallick P., 2007).*

3.4.3.5.Thermoforming

Thermoformed reinforced thermoplastics are widely used in automotive industry (Chen, 2011; Tanaka et al., 2016). Thermoforming has many advantages such as; short process time, easy surface treatment, possibility to repair the surface (Boisse et al., 2014).

The preform is placed on the mold and presses by heat. The melting of thermoplastic matrix is begun to distribute inside of the preform (Bargende, 2016).Thermoforming process is illustrated in Figure 3.7.

On this technique, glass and woven carbon fibers and as matrix resin; polypropylene (PP) and polyamide (PA) are mostly used materials. (Chen et al., 2011; McCool et al., 2012).

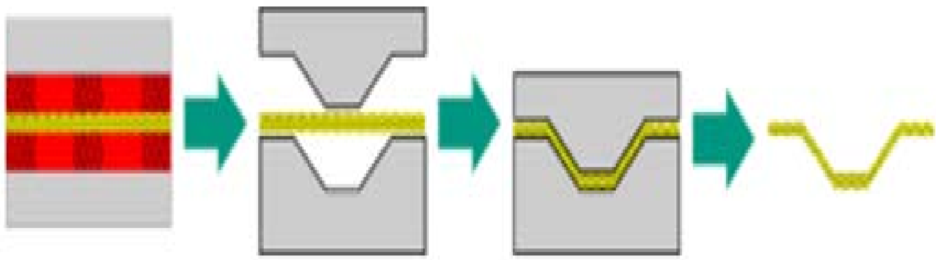


Figure 3.7. *Thermoforming process (Flesicher J. et al., 2018).*

3.4.3.6. Pultrusion

By pultrusion method different shape of materials are continousşy produced with low cost (Flemming et al., 2013; Henning and Moeller, 2011). In automotive industry various parts can be produced such as parts of car body and bumpers (Miazza, 2014; Othman et al., 2014). Pultrusion process is shown in Figure 3.8.

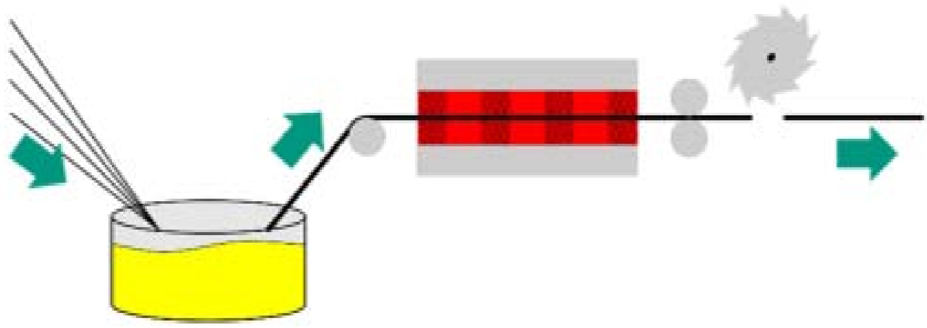


Figure 3.8. *Pultrusion process (Flesicher J. et al., 2018).*

The fibers are pulled into the resin bath, wet fibers are shaped by guides. The final guide determines the final shape of the profile (Srinivasagupta, 2003). During this process mositure absorption and air circulation must be blocked (Grigor'ev, 2015). Thermosets and thermoplastic resins can be used on this process (Raper et al., 1999).

3.4.3.7. Filament Winding

This method is diversified many different types such as; classical design, machine kinematic, rotational mandrel and translationally winding unit (Groover, 2010). By the all methods rotationally summetrical parts and non- axisymmetric parts can be produced (Finkenwerder, 2017; Fleischer and Schaedel, 2013; Fu et al., 2017; Li et al.,2005; Minsch et al., 2017; Vargas et al., 2014).(Figure 3.9).

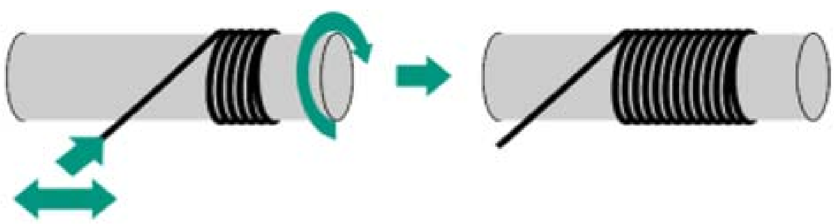


Figure 3.9. *Filament winding process (Flesicher J. et al., 2018).*

4.MATERIAL AND METHOD

4.1. Material

In this study, jute fiber fabric (country of origin: İstanbul, TURKEY) and two types of E-Glass fiber fabrics (country of origin: İstanbul, TURKEY) which has different weavings types were used as reinforcement materials. The properties of the reinforcements are shown Table 4.1.

Table 4.1. *Fabric Properties.*

Fabric	Spinning System	Weave	Weight (g/m^2)	Fabric Thickness(mm)	Warp (tex)	Weft (tex)
Jute	Ring	Plain 1/1	265	±1	312,5	312,5
Glass Fiber	Filament	Twill 2/2	300	±0,23	220	110
Glass Fiber	Filament	Biaxial 0-90 stitch	300	±0,25	300	300/600

The matrix materials are available as liquid form and they can cure at room temperature, L160 as an accelerator (country of origin: İstanbul, TURKEY) and LH160 as a hardener (country of origin: İstanbul, TURKEY) these components are constituted the epoxy resin for the matrix material system. Epoxy resin has outstanding properties such as; high dimensional stability, excellent adhesion to different materials and high mechanical properties. Besides it is odourless and totally non-toxic (Sakthivela R. and Rajendranb D., 2014).

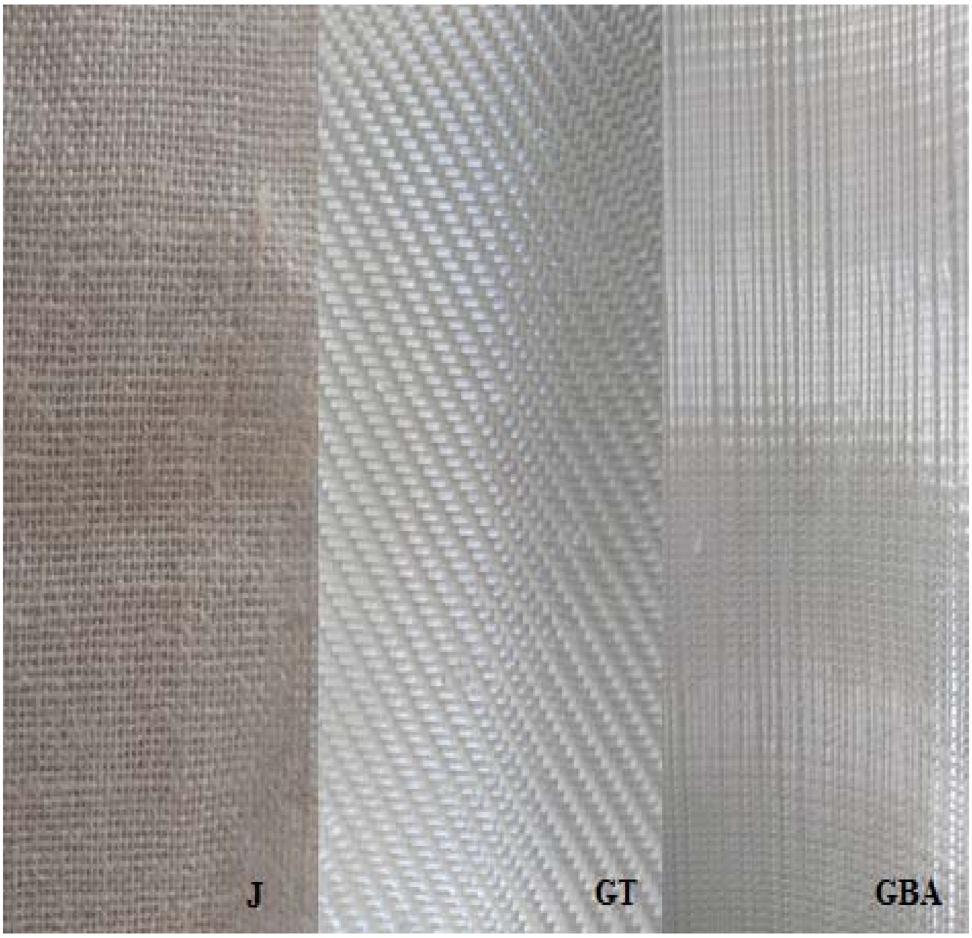


Figure 4.1. *Left to Right; Jute- Glass fiber fabric (Twill)- Glass fiber fabric (BA).*

Table 4.2. *Physical Properties of Fibers (Koronis G. Et al., 2012)*

Fiber	**Density (g/cm2)**	**Diameter (mm)**	**Tensile Strength (Mpa)**	**Young Modulus (Gpa)**	**Elongation at brake (%)**
Jute	1,3–1,49	25–250	393–800	13–26,5	1,16–1,5
E-Glass	2, 55	15–25	2000–3500	70–73	2,5–3,7

4.2. Method

4.2.1. Design

In this survey, five unique types of composites were manufactured. Three of fifths were %100 Jute and Glass fiber fabric and two of fifths were glass jute hybrid composites also glass fiber fabrics are divided in eachother according to their weaving styles. During this process each composite type was coded, the codes of the designed composites are shown table below:

Table 4.3. *Composite Codes.*

Code	Composite
J	Jute
GT	Glass Fiber Fabric (Twill)
GBA	Glass Fiber Fabric (Biaxial)
JGT	Hybrid (Jute- Glass Fiber Fabric (Twill))
JGBA	Hybrid (Jute- Glass Fiber Fabric (Biaxial))

4.2.2. Manufacturing of Hybrid Composite by VARTM

Vacuum resin transfer molding method is used for hybrid composite preparation. The steps of manufacturing as follows:

I. The surface is cleaned by cellulosic thinner or any similar products.

II. One layer release agent is applied by a brush, after thirty minutes if it needs one more layer can be applied to the surface.

III. Fabrics are laid on the surface and respectively peel ply, infusion mesh is placed on end.

IV. The infusion and vacuum hoses are attached to infusion mesh by sealant strip to stabilize the position of the structure.

V. The frame is specified by sealant tape.

VI. Two hoses are sticked on the frame as inlet and outlet.

VII. The vacuum bag is sticked carefully around the frame for the prevention of any air leakage.

VIII. Epoxy resin is prepared as the calculated amount and the vacuum machine is started up (the gauge must show -760mmHg).

IX. The infusion is started until gotten all surface wet.

X. The process is done, all hole must be closed and the vacuum machine should be switched off.

XI. After twenty four hours, the vacuum bag is opened and infusion mesh, peel ply is separeted from the composite, steps of the manufacture are shown below, respectively:

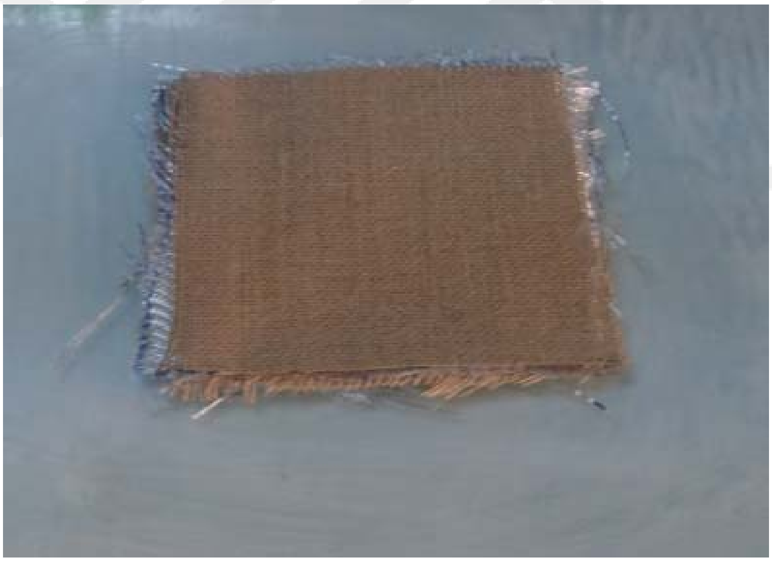


Figure 4.2. *Layered Fabrics.*

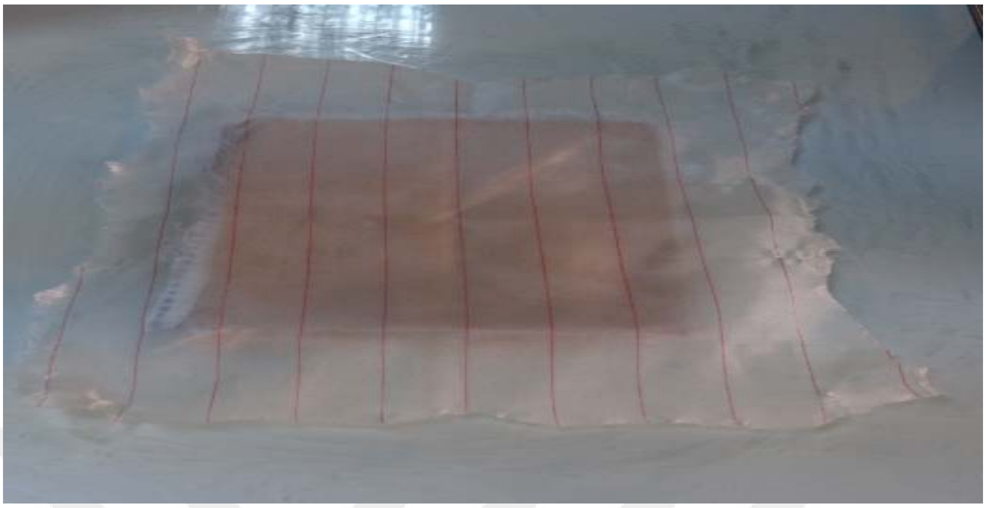


Figure 4.3. *Peel Ply on Fabrics.*

Figure 4.4. *Infusion Filter on Peel Ply.*

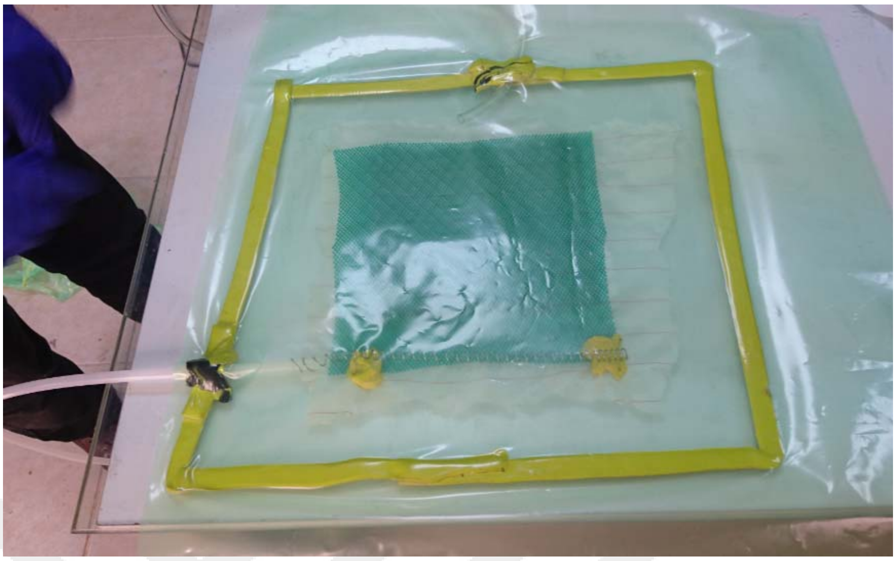


Figure 4.5. *Attached Vacuum Bag.*

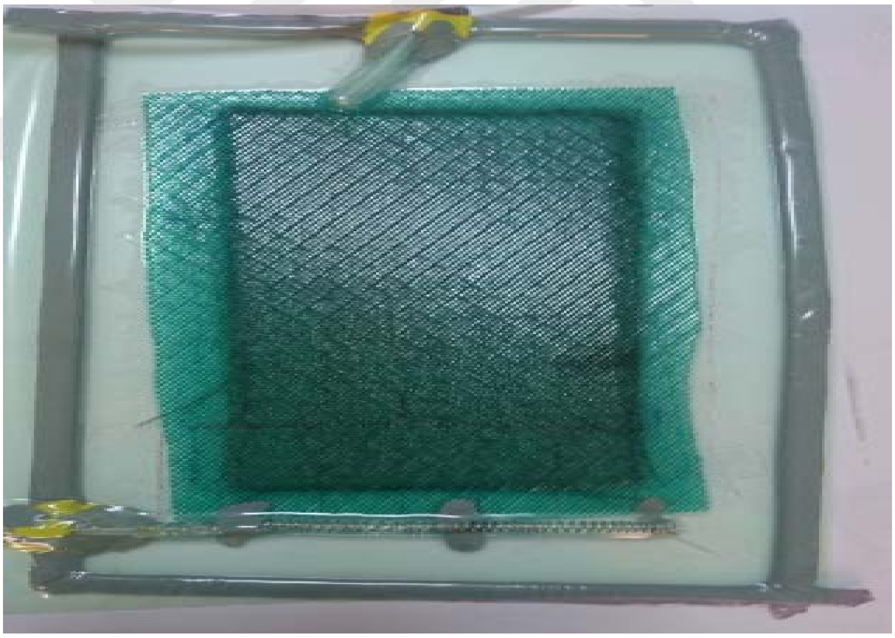


Figure 4.6. *Vacuumed Material.*

4.2.3. Preparation of Test Specimens

The tests specimens were prepared at Çukurova University Mechanical Engineering workshop. The specimens were shaped according to;

- On the tensile test, three specimen is prepared from each composite type. The samples are prepared accroding to ASTM standards D 3039 for tensile test.

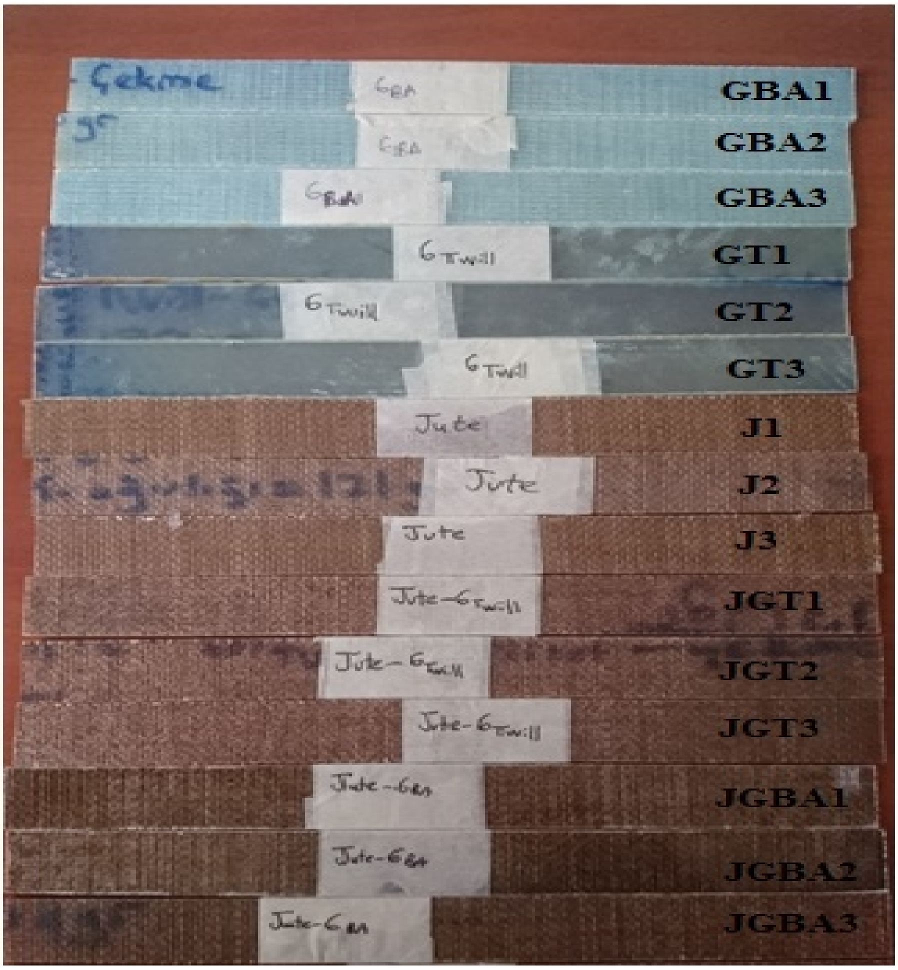
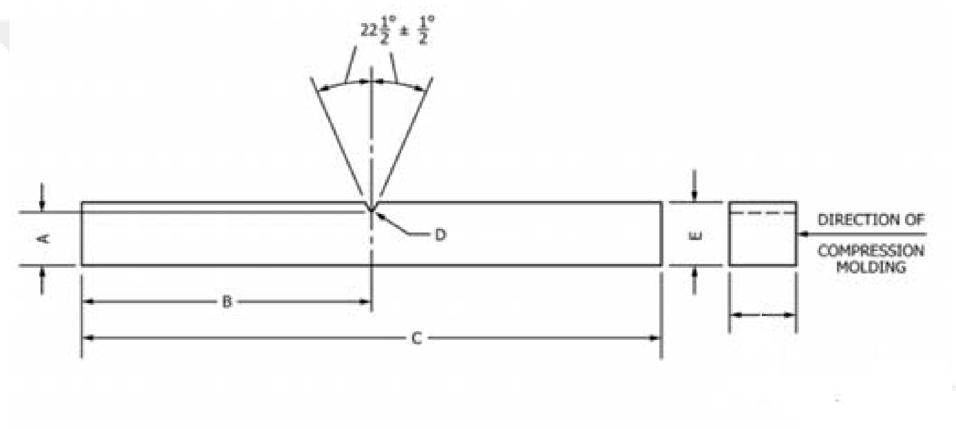


Figure 4.7.*Tensile Test specimens.*

- For Charpy Impact Test, a rectangular specimen with the sample size of 125x 12,5x 10 mm. A ‘V’ notch of 2.0 mm and angle of 45° is prepared for per sample accroding to the ASTM D 61610-10 standard. (Figure 4.8). 15 composite samples are taken for each type of composite samples for analysis of impact strength. The notches were opened at the middle of each sample by a notching apparatus (Figure 4.9). The related dimensions of the samples is shown on drawing below Figure 4.8.



	mm	in.
A	10.16 ± 0.05	0.400 ± 0.002
B	63.5 max	2.50 max
	61.0 min	2.40 min
C	127.0 max	5.00 max
	124.5 min	4.90 min
D	0.25R ± 0.05	0.010R ± 0.002
E	12.70 ± 0.15	0.500 ± 0.006

Figure 4.8. *Sample of Charpy Impact Test according to ASTM D 6110-10.*

Figure 4.9. *Notched Charpy Impact Test samples.*

4.2.4. Experimental

4.2.4.1. Tensile Test

The tensile test is carried out by ALŞA Hydrolic Test Machine at KOLUMAN Automotive Industry Corporation (Figure 4.10). Before testing, all dimensions and types of samples are registered to tensile test program. By the tensile test; Tensile Strength, Young's Modulus, Stress-Strain diagram of hybrid composites is calculated.

Figure 4.10. *Tensile Testing.*

For the determination of the tensile strength and Young Modulus we need the following equations, respectively.

$$E = \frac{\sigma_{axial(elastic)}}{\varepsilon_{axial(elastic)}} \tag{4.1}$$

E is Youngs's Modulus,

σ_{axial} is engineering stress along loading the axis, ε_{axial} is engineering stress

$$\sigma_u = \frac{P_{max}}{A_0} \tag{4.2}$$

σ_u is tensile strength is calculated by division of the maximum load to cross sectional area of the sample.

4.2.4.2. Charpy Impact Test

TOTOMAK Charpy Impact Test Machine was used to carry out the impact resistance of the composite specimens according to ASTM D 6110-10 standard (Figure 4.11).

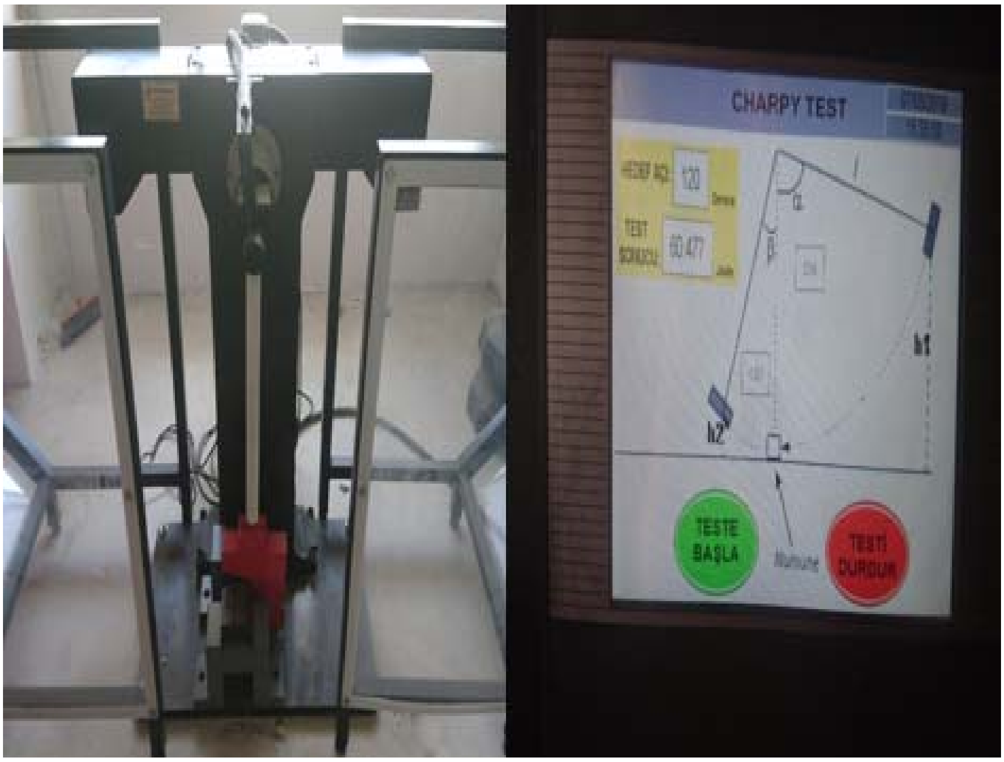


Figure 4.11.*Impact Test Machine.*

Figure 4.12.*Charpy Impact Test Process.*

The notched specimen was placed on the testing machine and the notched side was set to be at the level of the pendulum of the impact machine (Figure 4.12). Then, the pendulum was tacked at the top of the machine and then released.

The impact strength can be calculated from the equation below:

$$\text{Impact strength} = E/t \times 1000$$

'E'- Energy used to break (J)

't' – Thickness in mm

(4.3)

(Sakthivela R. and Rajendranb D., 2014).

4.2.4.3. Vickers Hardness Test

The hardness test was performed by JGTT and THV-1MD model numbered machine to estimate the degree to which the material resists scratch, cutting or indentation. The principle of this test is that it uses a diamond indenter to make an indent which is measured and converted to a hardness value. A square based pyramid shaped diamond is used for testing in the Vickers scale. The hardness tester and the pyramid shape is shown in Figure 4.13.

Figure 4.13.*Vickers hardness Test and Pyramid Shaped Sample.*

The HV number (Vickers Hardness number) can be determined by the following formula:

$$HV = \frac{F}{A} \approx \frac{1.8544F}{d^2} \tag{4.4}$$

where F is in kgf and d is in millimeters (Maharana A., 2015).

4.2.4.4. Water Absorption

By this test, it was aimed that the capacity of absorbed water for each composite type. Wate saturated the composites through the surface of the samples depending on time intervals. This process causes changes on macroscopic and microscopic extents. In the testing carried out, the tap water was used for water immersion and the test was perfored at room temperature. Five samples were placed in PET containers with tap water and the samples were taken out periodically and weighed in turn by digital balance (Figure 4.14).

Figure 4.14.*Water Absorption Test.*

5.RESULTS AND DISCUSSIONS

5.1. Tensile Properties

Tensile properties of a composite material are mostly depending on fibre strength, modulus, fillers, weavings and fibre/matrix interfacial bonding. The Table 5.1 shows the tensile test results with details. The GBA composite produced the highest tensile value compared to the other four composite specimens, also the strain was the highest among all. The comparison of tensile stress for each composite types can be seen in Figure 5.2 as below. The data shows that the GBA composite has the highest tensile stress. The best two configurations that are GT and JGBA configurations according to test results. The Figure 5.2 show the similarity between GT and GBA , the difference of the tensile stress is %30,8 and the difference the strain is %1,27. It was found that glass fibers has similar tensile properties even if they have different weavings. It is observed from the Figure 5.1 that Hybrid composite JGT and JGBA has similar tensile behaviours with small differences. The tensile strength of JBT is 93,19 N/mm^2 and the strains is %6,7 besides JGBA has 115,72 N/mm^2 tensile strength and %6,56 strain. Jute composite has the lowest stress-strain (54,7 N/mm^2 -%4,96) behave between glass fiber composites and hybrid composites as natural reinforced composite.

Figure 5.1.Tensile test specimens after the test.

Table 5.1. Tensile Test Results.

Composite Type		E (N/mm^2)	ε (%)	L_0 (mm)	L_1 (mm)	F_m (kg)	A (mm^2)	R_m	R_{eH}	σ_e
Jute	J1	954	4,3	80	83,42	428,49	77,81	54	0	5,506
	J2	1149	5,3	80	84,25	457,79	82,83	54,2	0	5,526
	J3	1161	5,3	80	84,21	457,79	80,32	55,89	0	5,7
Glass Fiber	GT1	3571	10,4	80	88,31	2581,9	88,02	287,7	0	29,33
	GT2	3610	10,1	80	88,08	2490,4	85,34	286,2	34,93	29,18
	GT3	4147	9,3	80	87,47	2373,2	84,08	276,8	0	28,23
Glass Fiber	GBA1	4897	11,2	80	88,97	3131,3	82,83	370,7	363,4	37,8
	GBA2	4842	11,2	80	88,97	3109,3	85	358,7	352,4	36,58
	GBA3	5064	11,2	80	88,94	3406	87,15	383,3	379,6	39,08
Hybrid	JGT1	1387	6,4	80	85,11	791,06	83,16	93,29	0	9,512
	JGT2	1325	7,1	80	85,7	816,7	87,85	91,17	0	9,296
	JGT3	1382	6,6	80	85,27	827,69	85,34	95,11	0	9,698
Hybrid	JGBA1	1613	6,2	80	84,94	900,93	80,32	110	0	11,22
	JGBA2	1710	7	80	85,62	1040,1	84,08	121,3	0	12,37
	JGBA3	1726	6,5	80	85,18	937,56	79,36	115,9	0	11,81

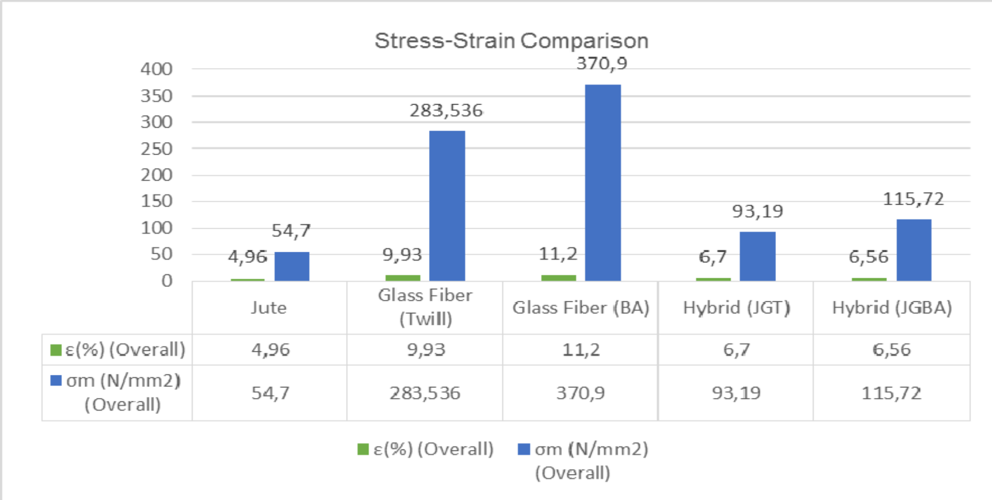


Figure 5.2.The Stress- Strain Comparison of The Composites.

As it is seen the Young's modulus (the modulus of elasticity) values (Figure 5. 3), Glass Fiber (BA) had the highest elasticity modulus. It was investigated that the elasticity modulus of JGBA thirty percent had better values than JGT. These value was showed that GBA had improved more the elasticity modulus of hybrid composites with respect to GT. Another point should be underlined that Jute reinforced composite material has the lowest Young's modulus among the all composites, because Jute fibers has lower elasticity values when compared with Glass fibers (13~26.5GPa, 70~73GPa).

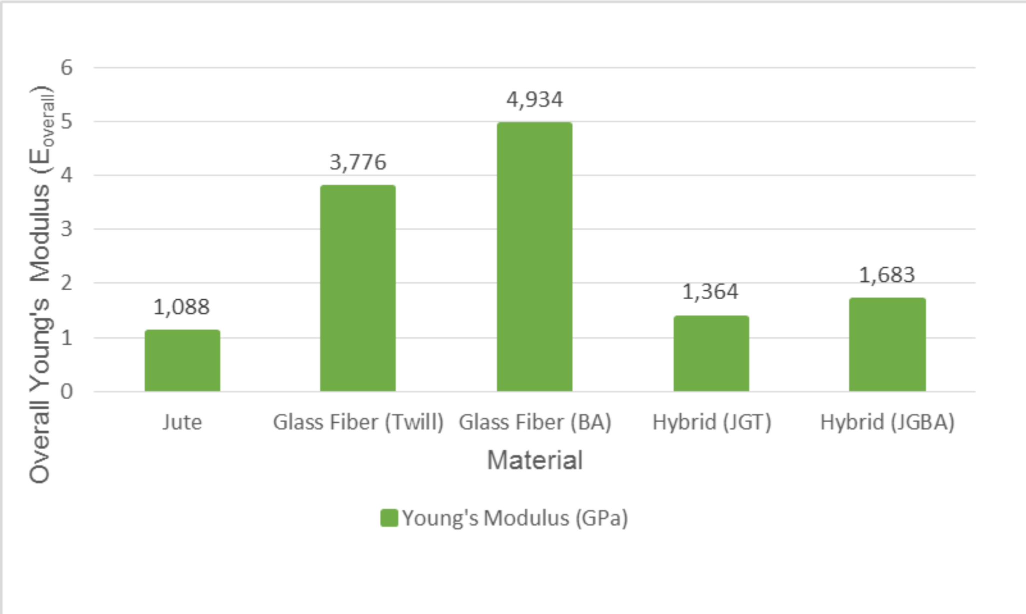


Figure 5.3.Young's Modulus values according to composite type.

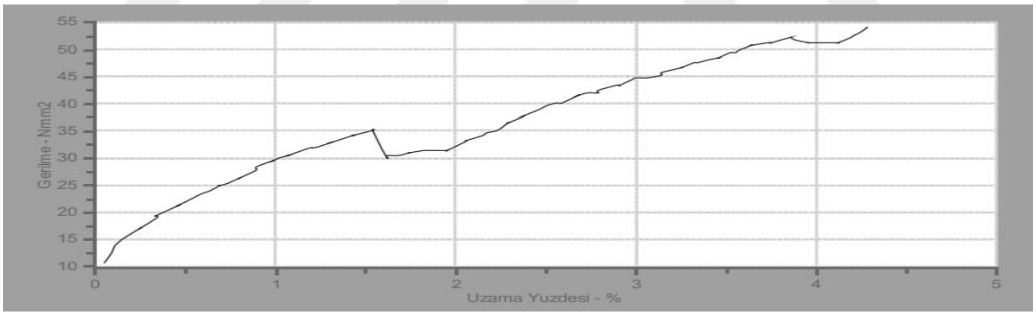


Figure 5.4.Stress-Strain results of first sample of the Jute Composite(ε (%):4,3, σ_m: 54 MPa).

Figure 5.5. Stress-Strain results of second sample of the Jute Composite (ε (%):5,3, σ_m: 54,2 MPa).

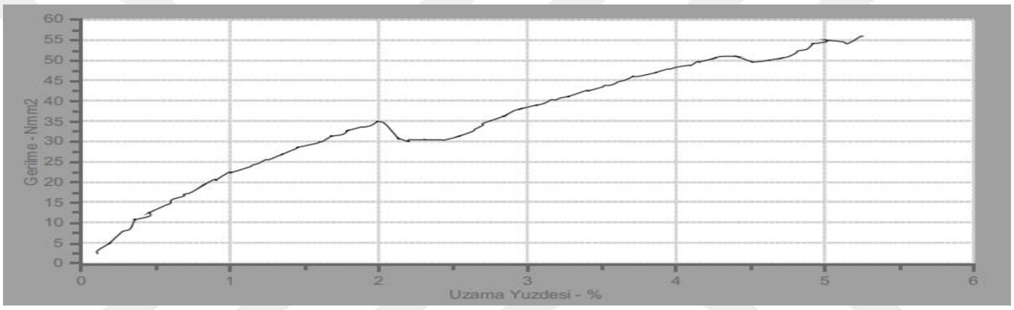


Figure 5.6. Stress-Strain results of third sample of the Jute Composite (ε (%):5,3, σ_m: 55,9 MPa).

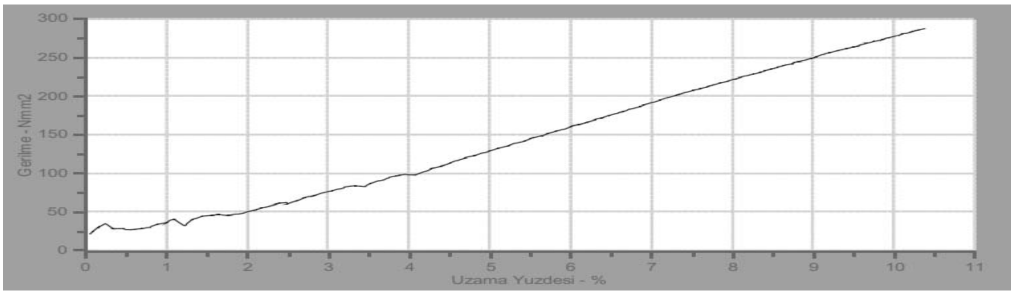


Figure 5.7. Stress- Strain results of first sample of the GT Composite(ε (%):10,4, σ_m:287,65 MPa).

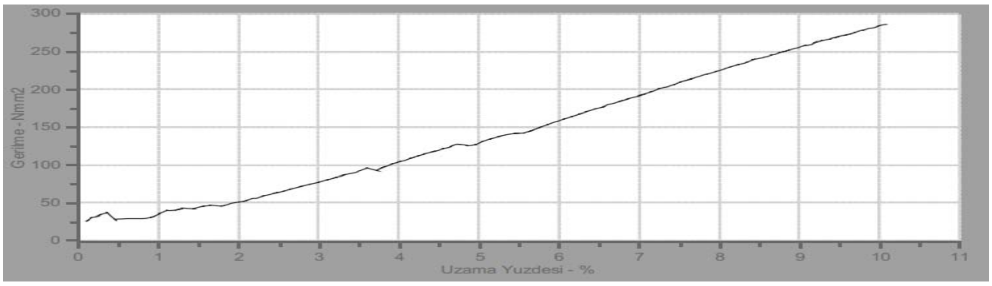


Figure 5.8. Stress- Strain results of second sample of the GT Composite (ε (%):10,1, σ_m: 286,18 MPa).

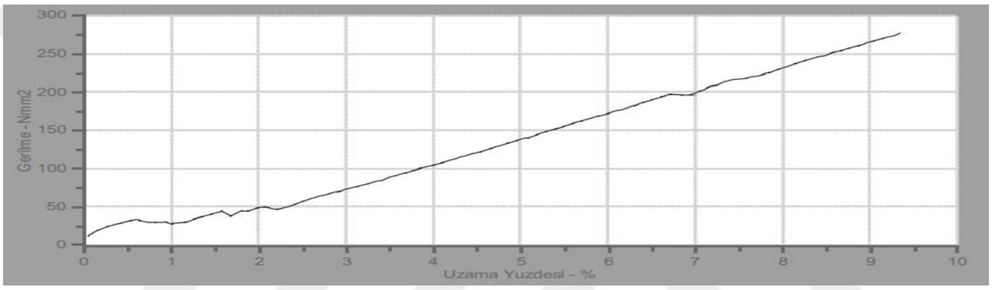


Figure 5.9. Stress- Strain results of third sample of the GT Composite (ε (%):9,3, σ_m:276,78 MPa).

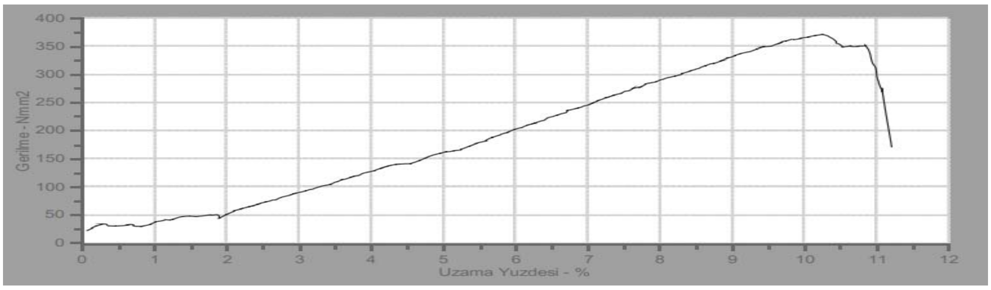


Figure 5.10. Stress-Strain results of first sample of the GBA Composite (ε (%):11,2, σ_m:370,73 MPa)..

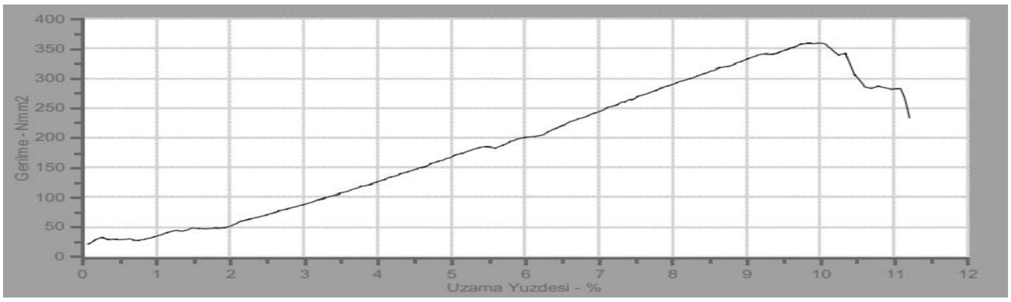


Figure 5.11. Stress-Strain results of second sample of the GBA Composite (ε(%):11,2, σ_m:358,73 MPa).

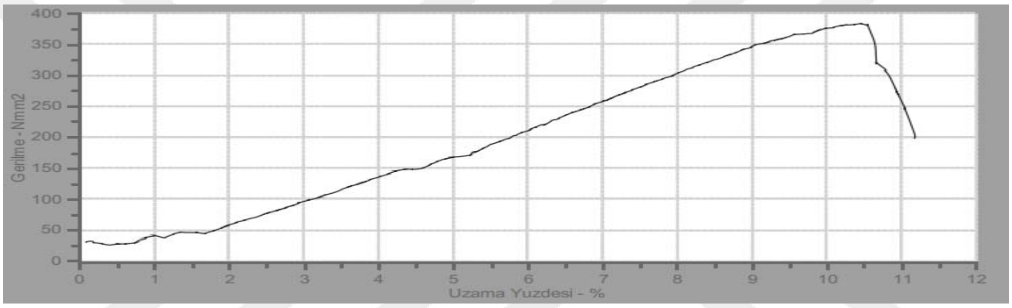


Figure 5.12. Stress-Strain results of third sample of the GBA Composite (ε (%):11,2, σ_m:383,26 MPa).

Figure 5.13. Stress-Strain results of first sample of the JGT Composite (ε (%):6,4, σ_m:93,29 MPa).

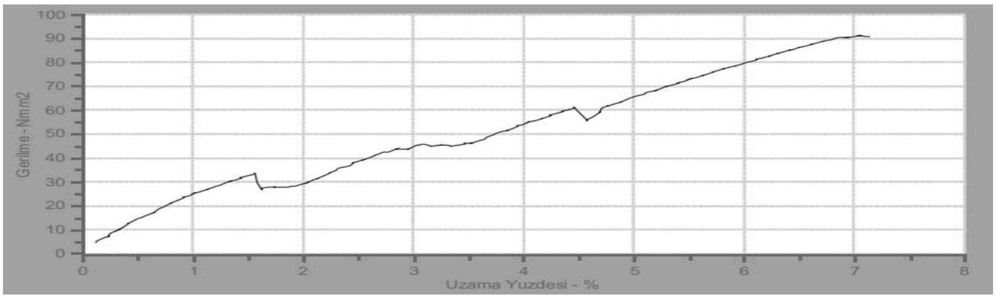


Figure 5.14. Stress-Strain results of second sample of the JGT Composite (ε (%):7,1, σ_m:91,17 MPa).

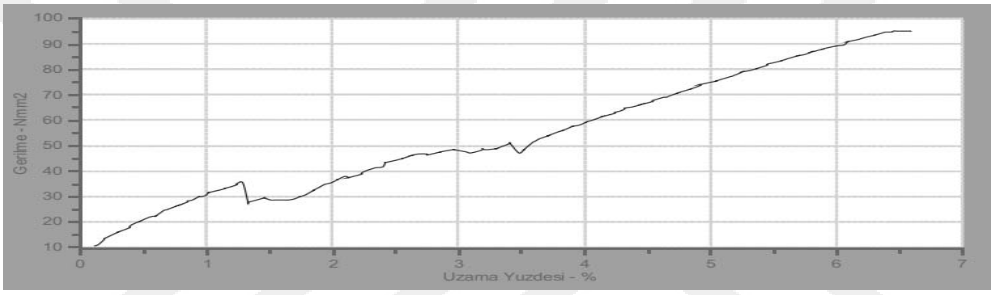


Figure 5.15. Stress-Strain results of third sample of the JGT Composite (ε (%):6,6, σ_m:95,11 MPa).

Figure 5.16. Stress-Strain results of first sample of the JGBA Composite:110 MPa).

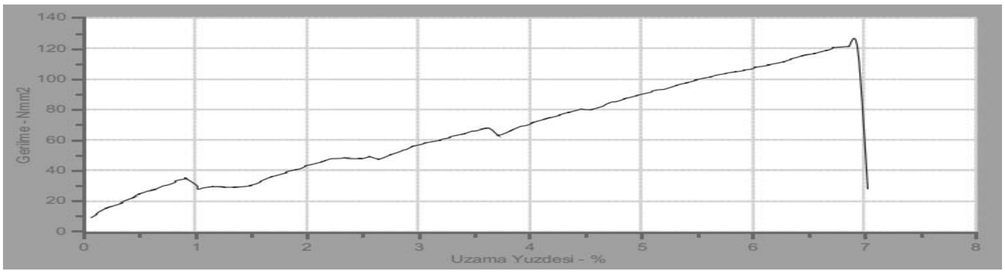


Figure 5.17. Stress-Strain results of second sample of the JGBA Composite (ε (%):7, σ_m:121,3 MPa).

Figure 5.18. Stress-Strain results of third sample of the JGBA Composite (ε (%):6,5, σ_m:115,86 MPa).

5.2. Charpy Impact Test Results

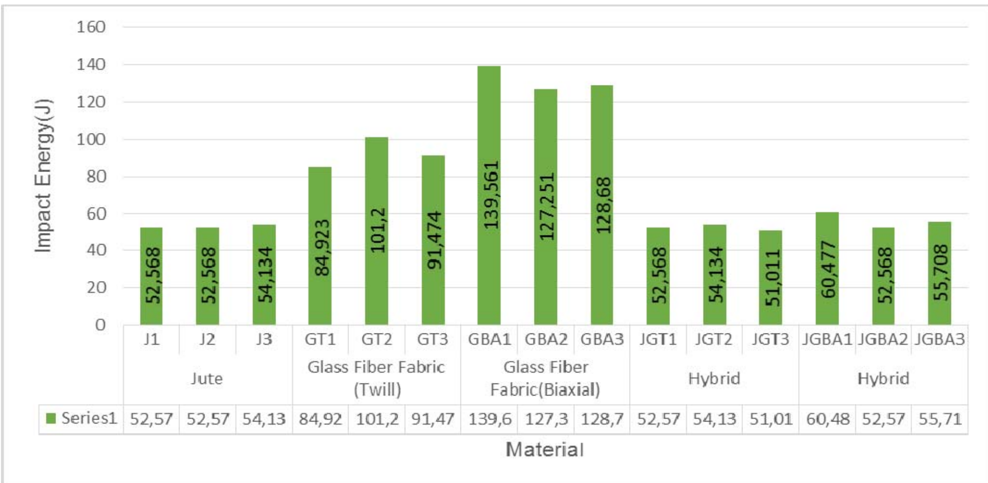


Figure 5.19.Impact Energies of the Composites.

Figure 5.20. Charpy Impact Test Samples (After Test).

After Charpy Impact Test the specimens are designated in Figure 5.20 also Figure 5.19 shows the impact energies of the composite specimens. As it is seen from the values, glass fiber fabric had the highest impact energy which has biaxial weaving type (139,561-128, 68 J), while the hybrid composite which has composed by jute and glass fiber fabric (twill) had the lowest value (54,134-51,011J). From the graph, we can see that pure jute, glass fiber fabric (twill) reinforced hybrid and glass fiber fabric (biaxial) hybrid has similar impact energies. This situation could be explained by the mechanics of the fabric layers between jute and glass fibers and adhesion between jute, epoxy and glass fiber layers.

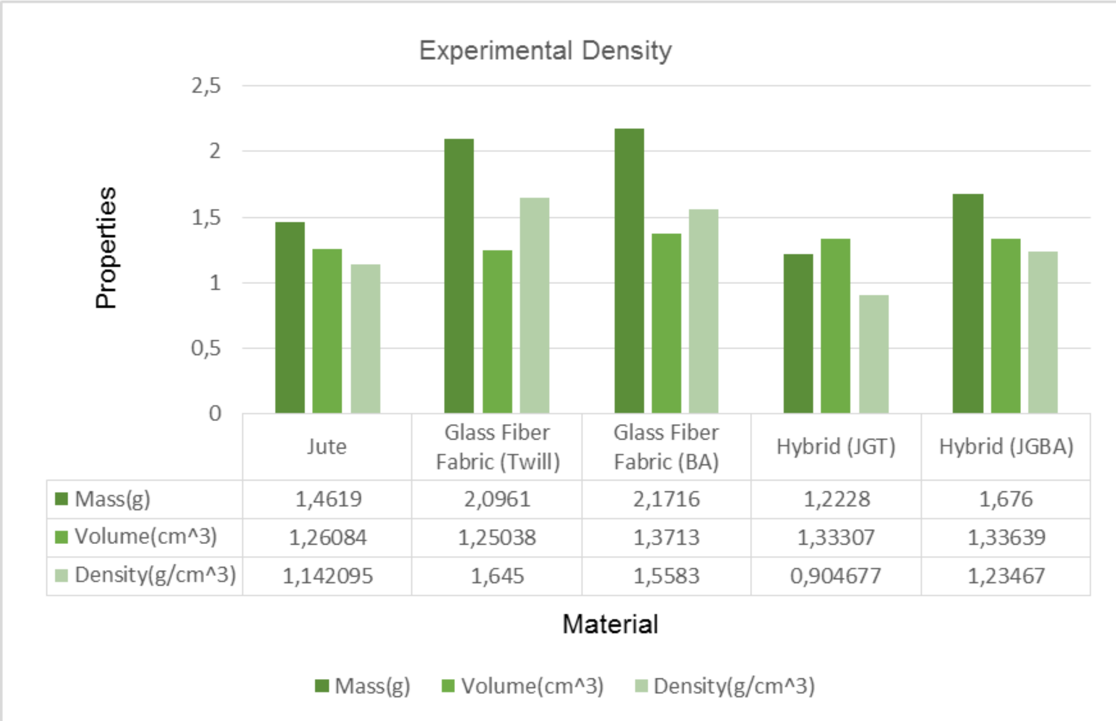


Figure 5.21.Experimental Density.

According to Energy-Density comparison graph (Figure 5.22), it was seen that, the glass fiber fabric (biaxial) has the highest impact energy although the experimental density of the GT has higher than GBA. The JGT hasthe lowest experimental density with the lowest impact energy. Hybrid composites JGT and JGBA has 0,33 g/cm^3 experimenral density difference however they have similar impact energy behave and consequently there is no strict relation between impact energy and experimental density.

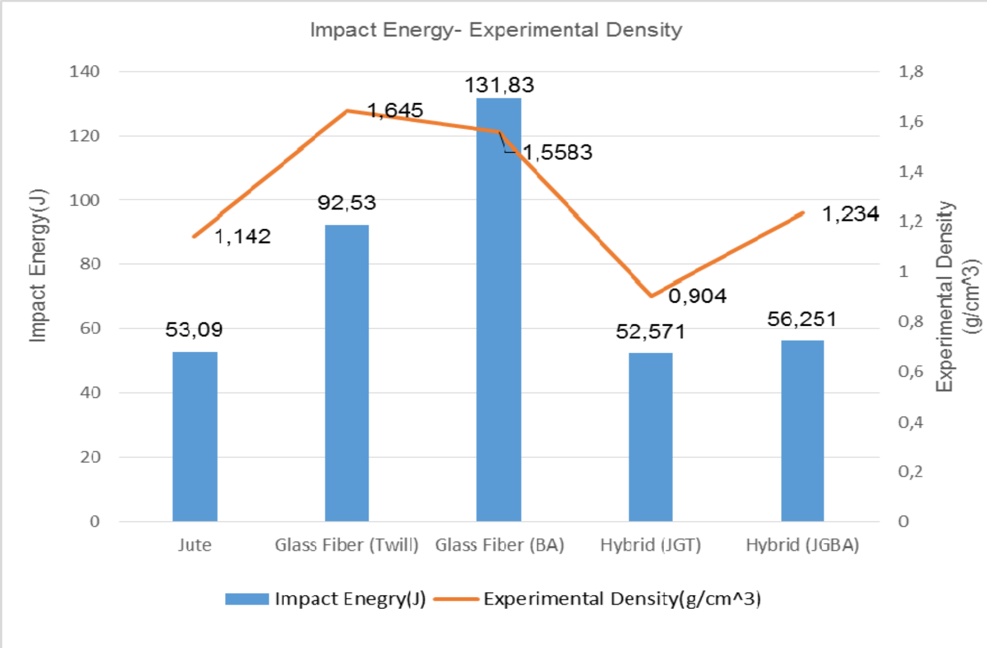


Figure 5.22.Impact Energy - Experimental Density.

5.3. Hardness Test Results

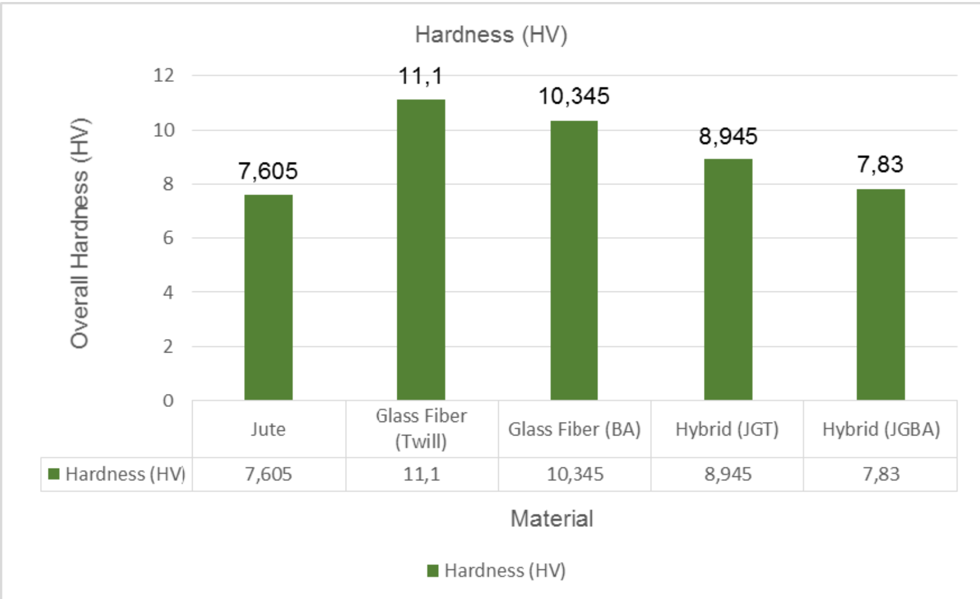
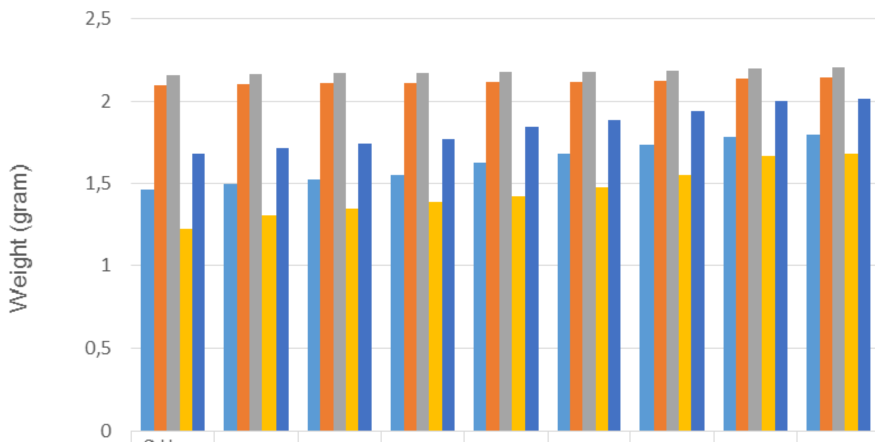


Figure 5.23.Overall Hardness Values of the Composites.

In Figure 5.23 show the overall hardnesses of the manufactured composites. As a result of Vickers hardness tests, it was observed that GT composite has the highest hardness value, Jute has the lowest hardness value among all the manufactured composite types. The graphs explains Hybrid composites have similar hardness properties with significant difference (%24). The hardness of values of pure glass fiber composite were found to be nearly same. As a conclusion, twill weaved glass fabrics enhanced the hardness properties of the composites.

5.4. Water Absorption Test Results



	0 Hour (Dry weight)	1 Hour	2 Hour	4 Hour	16 Hour	24 Hour	48 Hour	72 Hour	96 Hour
Jute	1,4646	1,502	1,5276	1,5535	1,6252	1,6759	1,7348	1,7776	1,7966
Glass Fiber (Twill)	2,0948	2,1044	2,1076	2,1084	2,1175	2,119	2,1258	2,1388	2,1422
Glass Fiber (BA)	2,1618	2,1686	2,1719	2,1733	2,1765	2,1779	2,1831	2,1991	2,2051
Hybrid (JGT)	1,2221	1,3059	1,3483	1,3909	1,4206	1,4796	1,5507	1,6611	1,6779
Hybrid (JGBA)	1,6789	1,7147	1,7369	1,7676	1,8438	1,8857	1,9415	1,9992	2,0161

Time (Hour)

Figure 5.24.Water Absorption Amounts of Composites.

The water absorption test was completed at the end of 96 hours and the weight changes were noted, the values were tabulated in Figure 5.24 also it shows the amount of the water absorption of J, GT, GBA, JGT and JGBA. After the periodic calculations, it was observed that GBA has the lowest absorption ratio by %2. GT was closely followed GBA with %2,6 and the different weavings are not demonstrably changed the water absorption abililty. The natural fiber fabric (J) water absorbed by % 22,66 at the end of the test and as can be seen hybrid composites (JGT- JGBA) has rather different water absorption abilities (%37,3 and %20,08) even similar raw materials used during manufacturing.

6.CONCLUSIONS

In the scope of this work, the properties of natural reinforced (J), pure glass fiber fabrics with two different weaving types (GT- GBA) and hybrid composites were designed, manufactured and tested. The results that were obtained throughout this work, can be listed below;

- The Glass Fiber Fabric reinforced (GT and GBA) composites has higher tensile properties than natural reinforced (Jute) and hybrid composites.
- The hybrid composites produced with GT and GBA as reinforcements gives great tensile properties as compared with jute reinforced composite. This composite can be applied in automobile industry as body parts and industrial apllications.
- It was found that GBA has the highest tensile strength (ε (%):11,2, σ_m:383,26 MPa).
- As a result of the Charpy Impact Test, the glass fiber fabrics (GT and GBA) has the highest toughness. The impact energies of both hybrid composites are also same with a variation of only %7. This confirms that the addition of jute fiber fabric does not improve the toughness of the material.
- The hardness of GT composite is 11,1 HV and the hardness of GBA composite is 10,345 HV. Both of the materials hardnesses are looks to be same with a negligible difference of % 7,3.
- It has been understood that the GT and GBA increased the water absorption abilities of the hybrid composites.
- It is clearly observed from results that glass fibers more enchanced the mechanical properties of composites than jute.

- By the incorporation of jute fiber fabric makes the composite, environmentally friendly material.

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