Impact Analysis of Ergonomic Bicycle Helmet Made from Polymeric Foam Composite Strengthened by Coconut Fiber

Mahadi[1], A. Syahrul[1] and K. Tugiman[1]
[1]*Department of Mechanical Engineering, Faculty of Engineering, Universitas Sumatera Utara Padang Bulan Medan 20155 Indonesia*

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Abstract: This research contains report result manufacture and impacts analysis of bicycle helmet made from polymeric foam composite materials strengthened by coconut fiber. The ergonomic helmets are protective head gears wear by bicycle riders for protection against injury in case of the accident. Helmet standards require helmets to be tested with a simple drop test onto an anvil.The geometric helmet structure consists of shell and liner, both layers have sandwich structure. The shell uses matrix unsaturated Polyester BQTN-157EX material, chopped strand mat 300 glass fiber reinforce and methyl ethyl ketone peroxide (MEKPO) catalyst with the weight composition of 100gr, 15gr, and 5gr. The liner uses matrix unsaturated Polyester BQTN-157 EX material, coconut fiber reinforces , Polyurethane blowing agent, and MEKPO catalyst with the composition of 33% wt (181,5gr), 10% wt (55gr), 52% wt (285 gr) and 5% wt (27.5 gr). Layers of the helmet made by using hand lay-up method and gravity casting method. Mechanical properties of polymeric foam were the tensile strength (σ_t) 0,09MPa, compressive strength (σ_c) 0.51 MPa, flexure strength (σ_b) 0,52MPa, elasticity modulus (E) 2,76MPa, density (ρ) 140 (kg/m^3). Sample model helmet is the most ergonomic with the thickness 10 mm and the amount of air channel 5. Free fall impact test was done in 9 samples with the thickness of 10 mm with the height of 1.5 m. The result of the impact test was maximum impact force (Fi) 381,13N, maximum Impact Stress (σi) 5,71 MPa and maximum Impact Energy absorption (Ei) 493,41Joule.

1 INTRODUCTION

The appliance of laminated composites is improve in all sorts of engineering applications especially in bicycle sport. Function of helmets are protective head by bicycle riders for protection against injury in case of the accident (Peter A.Cripton 2014). Ergonomics is the study of the interaction between humans and system elements with the goal of increasing efficiency and compatibility. Through an understanding of the human form, muscle systems and human limitations, ergonomic principles can be applied to products used in business and personal settings. Ergonomic products are any goods designed to increase ease of use and reduce injuries.

The application of conservation of energy to a falling object allows us to predict its impact velocity and kinetic energy, but we cannot predict its impact force without knowing how far it travels after impact. The dynamic energy in a moving object can be expressed as follows:

$\frac{1}{2}$ Potential Energy, PE = mgh (2)

Kinetic Energy, KE = mv^2 (3)

The impact velocity, $v = \sqrt{2gh}$ (4)

2 MATERIAL PROPERTIES

The material used is Polymer Unsaturated Polyester BQTN-157 EX as the matrix, Coconut fiber as reinforces and polyurethane as Blowing Agent (BA). Unsaturated polyester resins are the condensation products of unsaturated acids or anhydrides and diols with/without diacids. The unsaturation present in this type of polyesters provides a site for subsequent cross-linking (Reinhold 1956). The properties of matrix was Modulus Young (E) 2 s/d 4,5 GPa, Density (ρ) 1,2 s/d 1,5 mg.mm^3 and Tensile Strength (σ_T) 90MPa.

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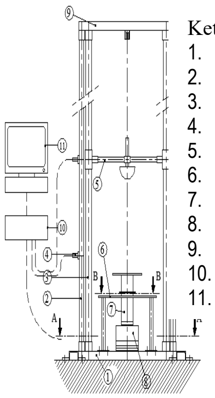
The research material is unsaturated polyester BQTN-157 EX resin as the matrix, oil palm empty fruit bunch fiber as reinforcement, polyurethane as blowing agent and MEKPO as catalyst. Polymeric foam helmet material is made using composition of fiber 10% wt (55gr), unsaturated polyester 157 BQTN-EX 33% wt (181,5gr), polyurethane blowing agent 52% wt (285 gr) and catalys methyl ethyl ketone peroxide (MEKPO) 5% wt (27.5 gr).

Table 1: Material helmet mechanical properties

Tensile Strength (σ_t) (MPa)	Compress Strength (σ_c) (MPa)	Flexure Strength (σ_b) (MPa)	Modulus of Elasticity (E) (MPa)
0,09	0,51	0,52	2,76

3 IMPACT TEST

The suitable utilization of protective helmets can minimalize the danger of interminable harm. A free-fall drop test construction as in Figure 1 was employed to drop sample helmets onto a flat anvil steel base which replicates a road surface. The drop height based of the helmet was 1.5 to 2 m, which coincides with the standard of Consumer Product Safety Commission (CPSC) drop height.



Ket:
1. *Framebase*
2. *Barrier*
3. Pipe launcher
4. Height sensor
5. *Testrig Arm*
6. *Supporttable*
7. *Anvilsupport*
8. *Loadcell*
9. *Upper*
10. *Power DAQ*
11. Computer

Figure 1: Free fall drop test impact

The three institutions most frequently used helmet testing standards are EN1078, CPSC, ASTM F1447 and Snell B-95. Table 2 demonstrates the correlations among each standard for helmet strength. The application of conservation of energy to a falling object allows us to predict its impact velocity and kinetic energy but cannot predict its impact force without knowing how far it travels after impact.

Table 2: Helmet Test Criteria (CPSC 1998)

	CPSC	ASTM F1447	Snell B-95	EN 1078
Flat anvil (m)	2.0	2.0	2.2	1.5
Hemispherical anvil (m)	1.2	1.2	1.5	N/A
Head form weight (kg)	5	5	5	4
Failure threshold (g)	300	300	300	250

4 RESULTS

The results of impact test on nine helmets thick 10 mm and drop height on flat anvil 1.5m and impact area 119 mm^2 is shown in Figure 2 up to 4.

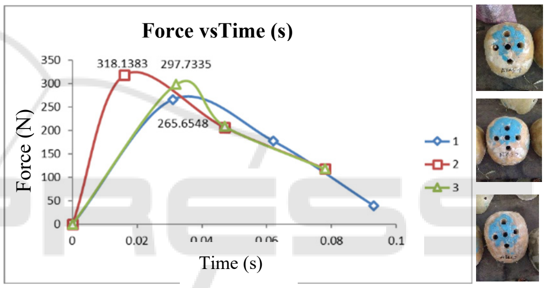


Figure 2: F vs. t Top

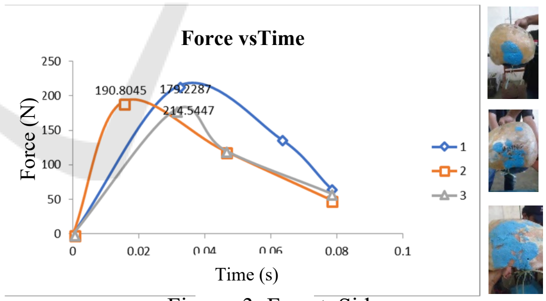


Figure 3: F vs. t Side

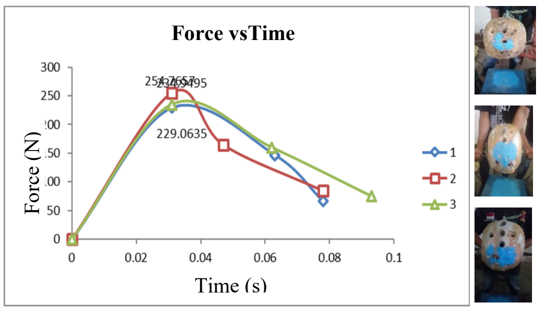


Figure 4: F vs. t Front

Table 3: Result of Helmet Impact Test

Helm	Impact Point	Mass (Helm+Rig) (kg)	Impact Force (F_i)(N)	Impact Time (T_i)(det)	Impact Stress (σ_i) (MPa)	Condition
1	Top	5,38	265,65	0,03	3,98	Fracture
2	Top	5,32	381,13	0,02	5,71	Fracture
3	Top	5,35	297,73	0,03	4,46	Fracture
4	Front	5,37	229,06	0,03	3,43	Fracture
5	Front	5,36	254,76	0,03	3,82	Fracture
6	Front	5,38	234,94	0,03	3,52	Fracture
7	Side	5,35	179,23	0,03	2,68	Fracture
8	Side	5,34	190,80	0,03	2,86	Fracture
9	Side	5,37	214,54	0,02	3,21	Fracture

Table 4: Impact Energy Absorption

Helmet	Weight Helmet + Test Rig (kg)	Theoretical Impact Energy Et = m.g.h (Joule)	Impact Force (F_i)(N)	Experimental Impact energy Ee = F_i.h (Joule)	Impact Energy Absorption E_i=Ee-Et (Joule)
1	5,38	79,16	265,65	398,47	319,31
2	5,32	78,28	381,13	571,69	493,41
3	5,35	78,72	297,73	446,60	367,88
4	5,37	79,02	220,92	331,38	252,36
5	5,36	78,87	185,61	278,40	199,53
6	5,38	79,16	106,04	159,06	79,90
7	5,35	78,72	159,12	238,68	159,96
8	5,34	78,57	167,85	251,77	173,20
9	5,37	79,01	260,48	390,72	311,71

Tabel 5: Force (F) and Impact Energy (Ei)

Average Force (F) and Impact Energy (E_i)					
Top		Front		Side	
Force (N)	Impact Energy (J)	Force (N)	Impact Energy (J)	Force (N)	Impact Energy (J)
314,83	393,53	170,85	177,26	195,81	214,95

Tabel 6: Result of free fall drop impact test

Parameter	Helmet	Commercial	CPSC
Impact Force (F_i) (max)	381,13 N	441,84 N	-
Impact Energy (E_i) (max)	493,41Joule	555,64 Joule	110 Joule
Impact stress (σ_i) (max)	5,71 MPa	3,78 MPa	-
Mass (m)	357,7 g	300 g	300

5 CONCLUSIONS

Base on data of research can be concluded as the impact energy of the helmet is greater than the standard and technique of making helmet is shell layer with hand lay up method, liner with cast method and the both layers are sandwich structured. The shell helmet uses matrix unsaturated Polyester BQTN-157EX material, chopped strand mat 300 glass fiber reinforced, and Methyl Ethyl Ketone Peroxide (MEKPO) catalyst. The liner composition is matrix unsaturated Polyester BQTN-157 EX material 33% wt (181,5gr) , coconut fiber reinforces 10% wt (55gr), Polyurethane blowing agent 52% wt (285 gr), and catalyst MEKPO 5%wt (27.5 gr). The results of the free fall impact test shows that there are different parameters of the helmet with a sample, commercial and CPSC standard.

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