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Experimental and Fe Analysis of Solid Particle Erosion Study of Glass/Epoxy Composite Laminates

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***Abstract:* Polymer network composites are picking up fame in numerous hello there tech regions because of their higher particular quality and module. With the expanded utilization of polymer network composites materials in erosive workplaces, it has turned out to be critical to research their disintegration attributes seriously in which they experience strong molecule disintegration. Subsequently investigation of strong particles disintegration conduct polymeric composites discovers significance and such studies are hardly reported in the open writing. In perspective of this, disintegration trials are did at different test condition, for this a plane sort crumbling test ring and Taguchi's orthogonal bunch are used. Basic control components influencing the erosive wear rate are recognized using ANNOVA (Analysis of Variance).**

The task plans to examine the strong molecule disintegration conduct of glass/epoxy covers utilizing orthogonal cluster test approach. The controllable parameter chose for the study are impingement speed (30, 45, and 60m/sec), effect edge (30°,60°and90°),erodent size(170,250,and420µm) and stand-off-separation (100,150,200mm) examination of difference was performed to locate the most noteworthy element. The bidirectional glass/epoxy overlay was described for disintegration harm. Among the four parameters chose for the study, impingement speed had the best impact on the erosive rate took after by effect point, the other two parameter r demonstrated minimal essentialness.

The morphology of disintegrated surfaces is inspected by utilizing checking electron magnifying lens (SEM) and conceivable disintegration instruments are examined. The examples that demonstrated most noteworthy disintegration rates in investigations showed fiber breakage method of harm in their SEM examination. These examples showed semi pliable disintegration attributes with the top disintegration wear happening at 600 impingement point.

Limited component models were created utilizing LS-DYNA for element contact examination. These models were utilized to reenact single molecule disintegration on bidirectional glass/epoxy cover and the resultant burdens and strains were seen on the dissolved surface, which is essentially an effect investigation. Von-Mises stresses, greatest shear burdens and plastic strains were anticipated.

I. INTRODUCTION

Composite is depicted as a mix of two or more materials that joined at a tiny of course without a doubt unmistakable level and are not dissolvable in one another. One constituent is called strengthening stage (particulates, filaments and so forth) furthermore, another as grid stage (polymers, metals, earthenware production and so forth.). Composite may be regular composites or manufactured composites. E.g. For characteristic composites coconut palm leaf, bones, bamboos with mud and for simulated composites like tars with glass filaments, epoxy with E glass strands and so on.

Composite materials have developing interest for applications in diverse ranges like aviation, car, marine, transportation and scaffolds in structural designing. Auxiliary Composite is a blend of two or more constituents (or stages) fiber and lattice with diverse physical/concoction properties at the plainly visible or minuscule scale. Strands are the main burden conveying constituents and Matrix will exchange the heap in the middle of them and grid will keep the filaments in a legitimate introduction and area. The successful properties of the fiber strengthened composites for the most part rely on the geometry of the filaments inside of the network. This plan is assessed by the volume division, perspective proportion, dispersing parameters and introduction of strands.

The designers are in search of materials which withstand the effect of all variety of loading conditions and at the same time at a very competitive price. The Composites are complex material and their properties vary as the constituents change in any of its parameters like fiber orientation, stacking sequence, fiber volume fraction or the matrix and the method of fabrication. Hence it is very much needed to characterize the composites by designing the testing equipment's, test procedures and more importantly careful conduction of tests. Polymer matrix composites are finding applications in many high tech areas. With the expanded utilization of these materials in erosive conditions, it has turned out to be critical to research their disintegration attributes seriously. Hence, study of solid particle erosion behaviour polymeric composites finds importance and such studies are scarcely reported in the open literature**.**

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II. EXPERIMENTAL METHODOLOGY

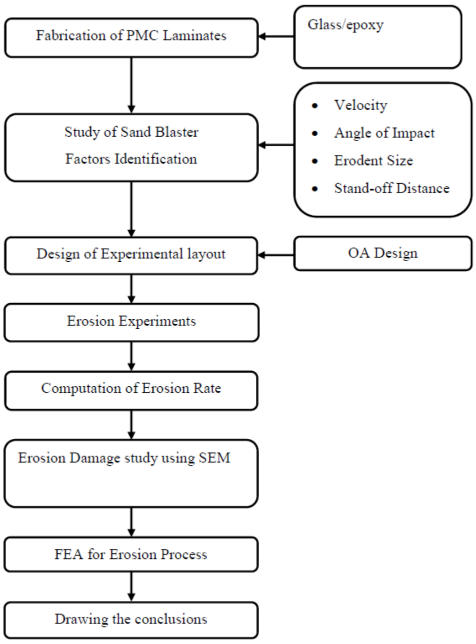

Fig.1 Project methodology

III. MATERIALS AND PROCESSES

This part portrays the points of interest of preparing of the composites and the test strategies took after for portrayal and tribological properties. The system identified with the outline of tests in view of Taguchi strategy is additionally displayed in this some portion of the venture work.

3.1 Material properties:

Material	Density (g/cm^3)	Volume fraction (%)	UTS (MPa)	E (GPa)	Poisson's Ratio
E-glass fiber	2.55	0.65	7500	260	0.3
Epoxy	1.2	0.35	85	25	0.28

Table 1: Material properties of glass fiber and epoxy

3.2 Specimen Calculation: glass/epoxy laminates

Laminates of 2mm thickness

ρ_f=1.35g/cc ρ_{resin}=1.15g/cc

W_{ff}=65% W_{fr}=35%

Density of laminates = (ρf×Wff) + (ρresin×Wfr)
= (2.54×0.65) + (1.15×0.35)
=2.053g/cc

Weight of laminates =ρlaminates×Vlaminates
=2.053×0.2×30×30
=369.54g

Weight of resin =Wfr×Wlaminates
=0.35×369.54
=129.33g

Weight of fiber =Wff×WLaminates
=0.65×369.54
=240.20g

Weight of hardener =Wresin×11/111
=129.33×11/111
=12.81g

300gsm

Weight of one ply =0.25kg=25g

No of layer required =wfiber/weight of one ply
=240.2/25
=9.608=10layer

3.3 Fabrication Procedure glass/epoxy laminates using hand layup technique.

Fig:2 Cutting of fibers to the size 300 X 300 mm

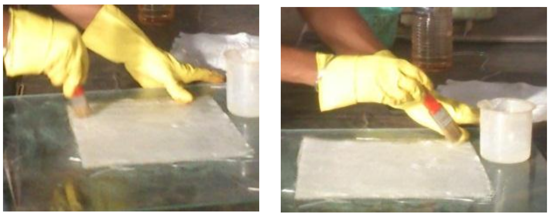

Fig: 3.layer by layer building of laminates

- ❖ Required number of Fibers of size 300mmX300mm was cut using scissors in fig 2.
- ❖ Sap hardener mix was joined with the Mylar sheet using a spreader and glass fiber utilizes was then put on the sheet in fig 3.
- ❖ Calculated amount of resin and hardener was weighed using a physical balance and poured into a container and the contents were mixed well.
  - ❖ Mylar sheet was put on the imaginative tile and wax was then joined to it.
  - ❖ Proper mixing of Resin-hardener mixture was applied to the ply until the entire ply gets uniformly distribute of resin and hardener.
  - ❖ The next ply was placed and the same procedure was repeated for all other plies.

Control Factor	Levels			
	I	II	III	Units
A	30	45	60	m/s
B	30	60	90	deg
C	170	250	420	µm
D	100	150	200	mm

- ❖ Another Mylar sheet was stacked on the highest utilize and the example was moved utilizing a roller.

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IV. EROSION TEST APPARATUS

The test set up utilized as a bit of this study for the strong particle separating wear test is readied for making reproducible erosive conditions for assess the disintegration wear resistance of the readied composite cases. It incorporates a compressor (Air sort), an air and sand molecule blending chamber and breathing life into chamber.

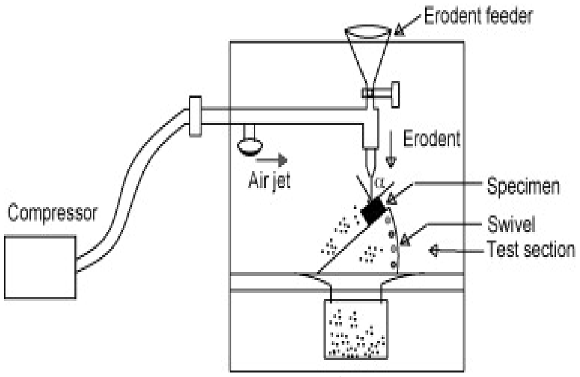

Fig: 4. Schematic diagram of the erosion test ring

4.1 Taguchi Experimental Design

Four parameters viz., impact speed, impingement point, erodent size, and stay off separation, each at three levels, are considered in this study. In Table 2, every piece relates to a test parameter and a line gives a test condition which is simply blend of parameter levels. Four parameters each at three levels would require 34 = 81 keeps running in a full factorial examination. Be that as it may, Taguchi's factorial examination method decreases it to 9 runs basically offering an astounding motivation behind excitement to the degree cost and time.

Controllable Factors		Fixed parameters	
Velocity of impact	Factor A		
Impingement angle	Factor B	Test temperature	RT
Erodent size	Factor C	Nozzle diameter (mm)	3
Stand-off-distance	Factor D		

Table 2: Parameters considered for erosion testing

Factors and Levels:

The following Table 3 depicts the various control factors and levels of erosion testing.

Test Run	Erodent Velocity (m/s) A	Impingement Angle (Degrees) B	Erodent Size (μm) C	Standoff Distance, mm D
1	30	30	170	100
2	30	60	250	150
3	30	90	420	200
4	45	30	420	150
5	45	60	170	200
6	45	90	250	100
7	60	30	250	200
8	60	60	420	100
9	60	90	170	150

Table 3: Levels for various control factors

Disintegration rate (Er) characterized as the proportion of mass lost because of disintegration to the mass of erodent:

$$\text{Erosion rate} = \frac{\text{Cumulative mass loss of target materials (mg)}}{\text{Impact particles weight (g)}}$$

Tabulated L9 orthogonal array for various control factors

Test Run	Erodent Velocity (m/s) A	Impingement Angle (Degrees) B	Erodent Size (μm) C	Standoff Distance, mm D
1	30	30	170	100
2	30	60	250	150
3	30	90	420	200
4	45	30	420	150
5	45	60	170	200
6	45	90	250	100
7	60	30	250	200
8	60	60	420	100
9	60	90	170	150

V. FEA RESULTS OF GFRP LAMINATES

The FEA was performed using LS-DYNA explicit software. The results are presented for all the nine experimental factor level combinations obtained as per L_9 lay-out.

1st combination: Impact Velocity = 30 m/s, impact angle = 30 deg, erodent size = 170 μm and stand-off-distance = 100 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

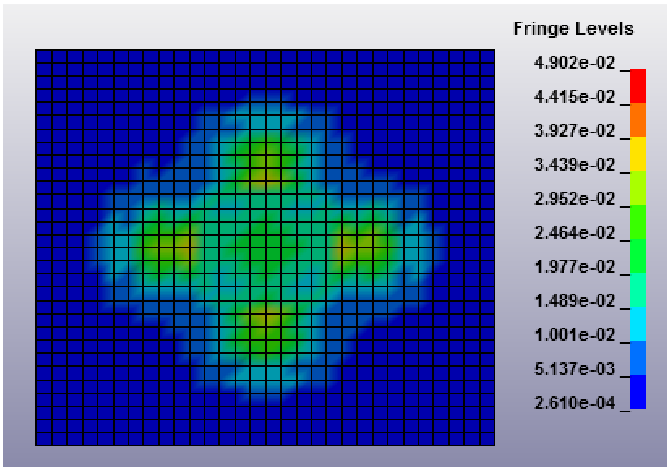

Fig 5: Von Mises stress plot v=30m/s, α=30 deg

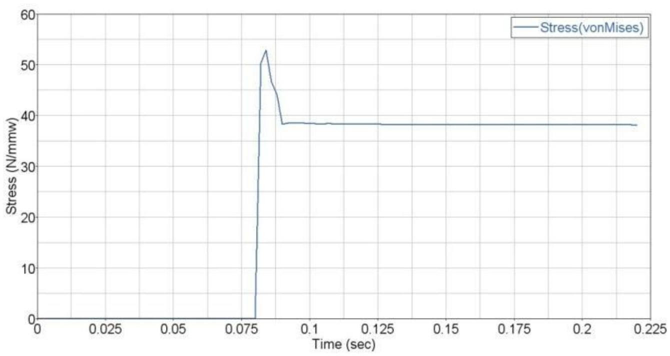

Fig 6: Variation of Von Mises stress v/s time

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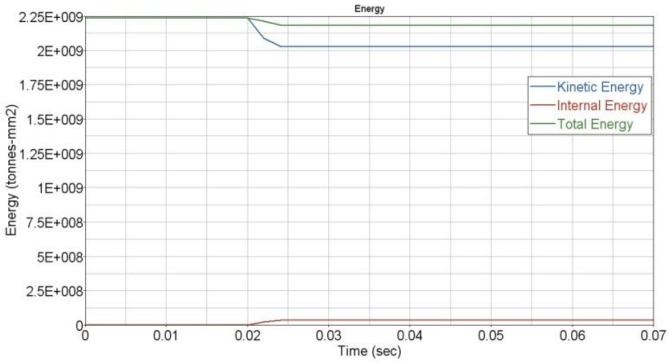

Fig 7: Variation of Energy v/s time

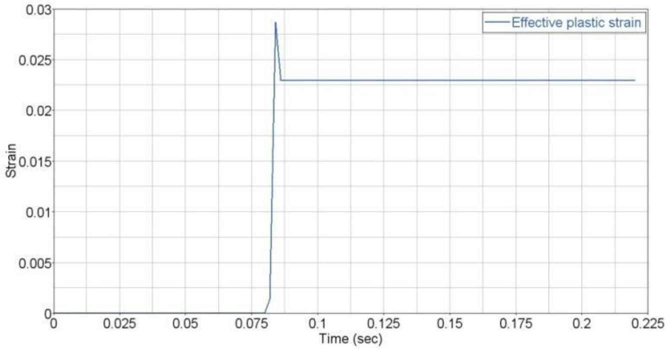

Fig 8: Variation of Effective plastic strain v/s time

2nd combination: Impact Velocity = 30 m/s, impact angle = 60deg, erodent size = 250 µm and stand-off-distance = 150 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

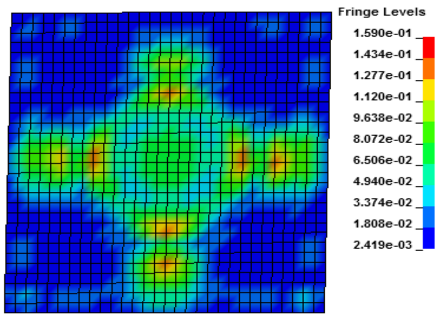

Fig 9: Von Mises stress plot v=30m/s, α=60 deg

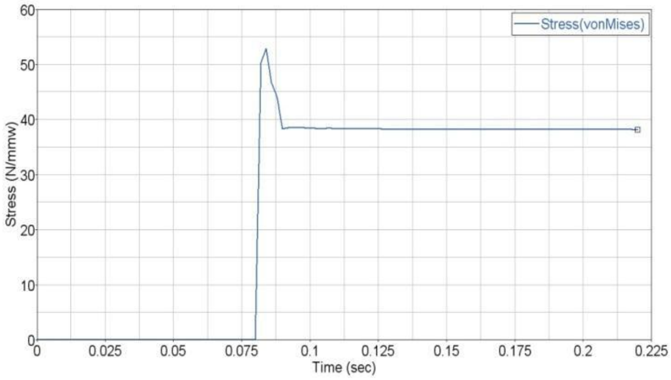

Fig 10: Variation of Stress v/s time

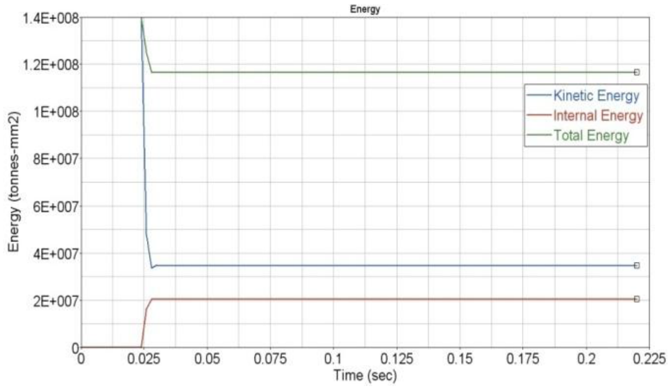

Fig 11: Variation of energy v/s time

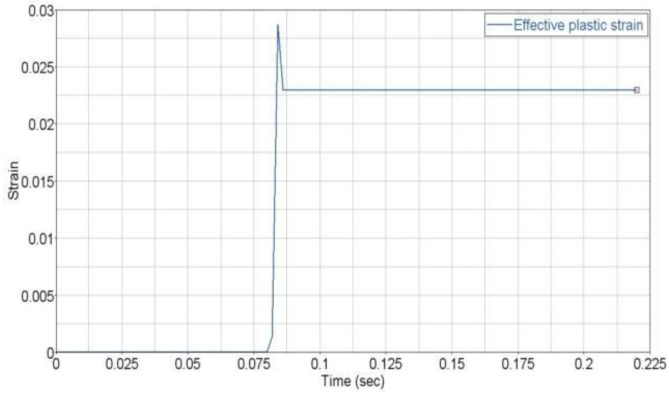

Fig 12: Variation of Effective Plastic strain v/s time

3rd combination: Impact Velocity = 30 m/s, impact angle = 90deg, erodent size = 420 µm and stand-off-distance = 200 mm. The Von-Mises stress plot, the variation of Von mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

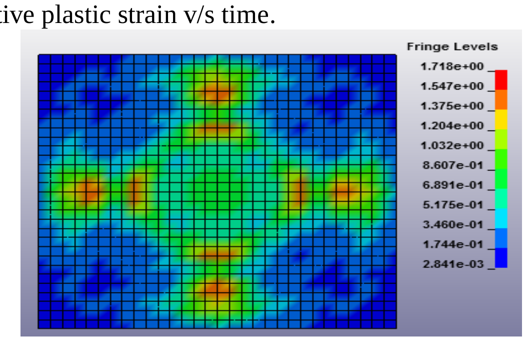

Fig 13: Von Mises stress plot v=30m/s, α=90 deg

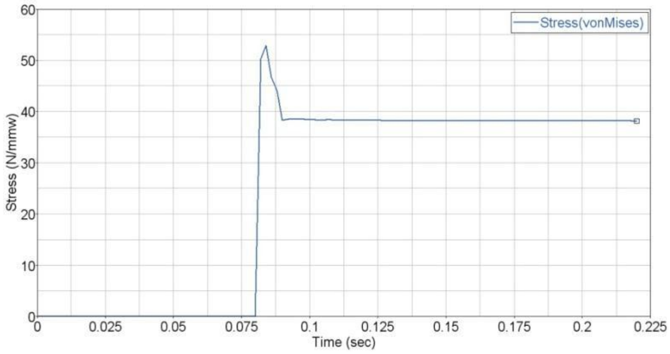

Fig 14: Variation of Von Mises stress v/s time

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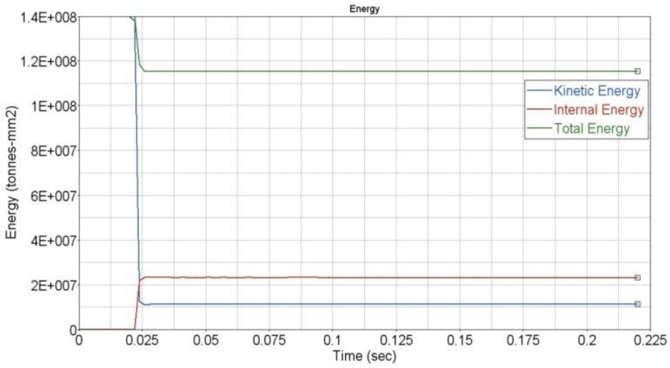

Fig 15: Variation of energy v/s time

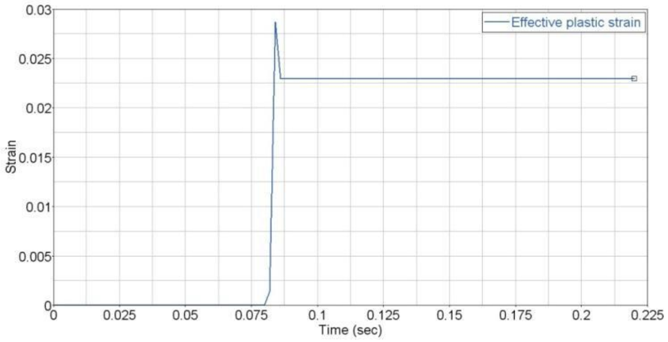

Fig 16: Variation of plastic strain v/s time

4th combination: Impact Velocity = 45 m/s, impact angle = 30deg, erodent size = 420 µm and stand-off-distance = 150 mm. The Von-Mises stress plot, the variation of Von mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

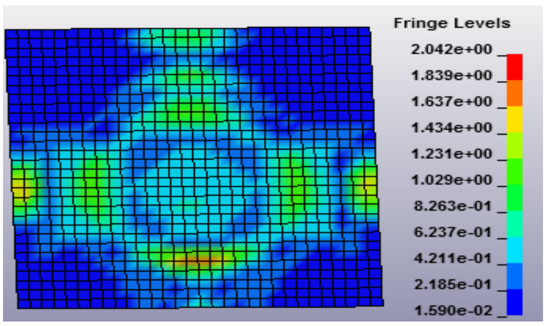

Fig 17: Von Mises stress plot v=45m/s, α=30 deg

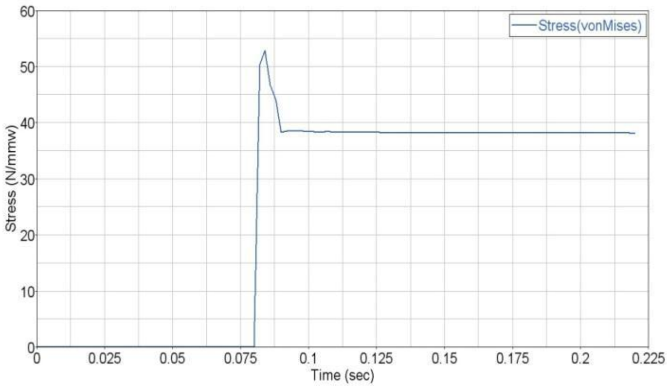

Fig 18: Variation of Von Mises stress v/s time

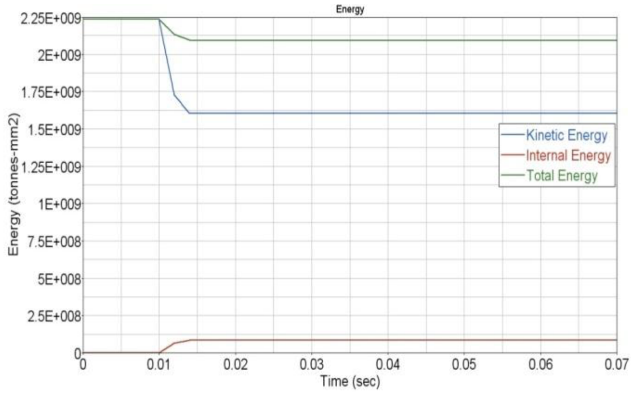

Fig 19: Variation of Energy v/s time

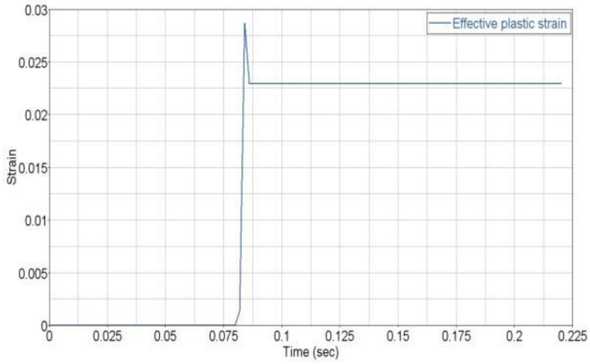

Fig 20: Variation of Plastic Strain v/s time

5th combination: Impact Velocity = 45 m/s, impact angle = 60deg, erodent size = 170 µm and stand-off-distance = 200 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

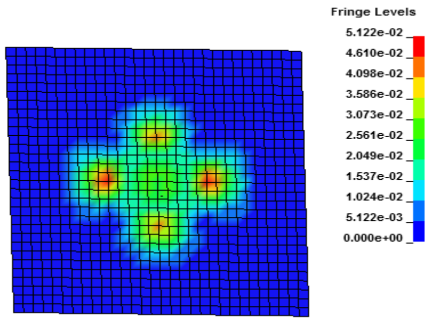

Fig 21: Von Mises stress plot v=45m/s, α=60 deg

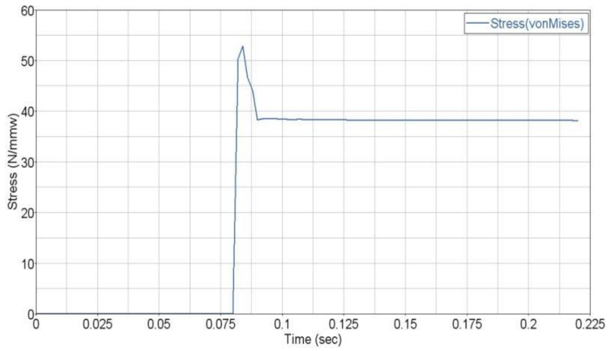

Fig 22: Variation of stress v/s time

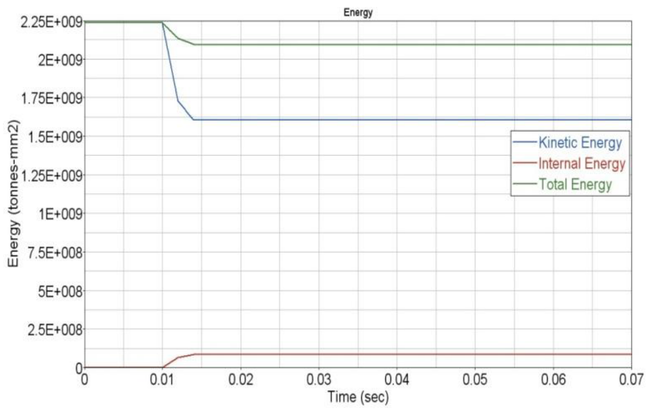

Fig 23: variation of energy v/s time

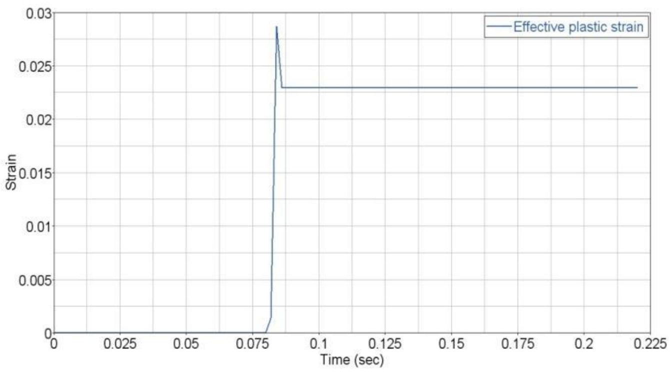

Fig 24: Variation plastic strain v/s time

6th combination: Impact Velocity = 45 m/s, impact angle = 90deg, erodent size = 250 µm and stand-off-distance = 100 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

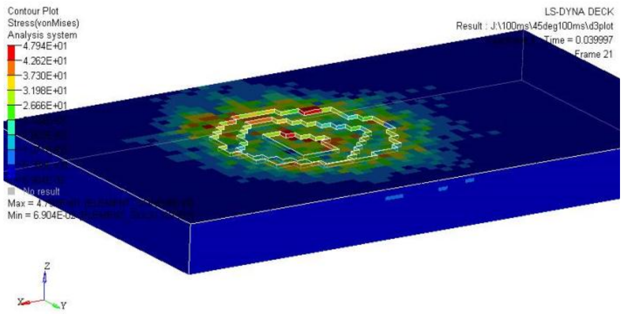

Fig 25: Von Mises stress plot v=45m/s, α=90 deg

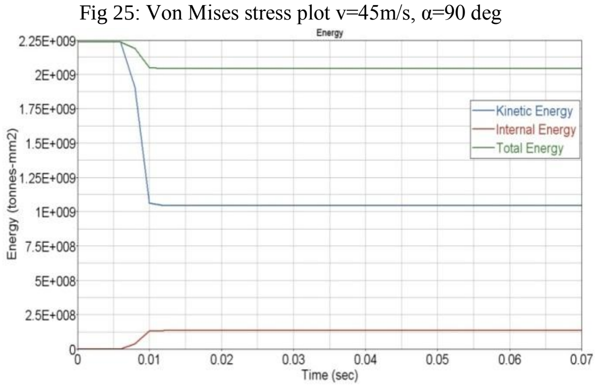

Fig 26: Variation of von mises stress v/s time

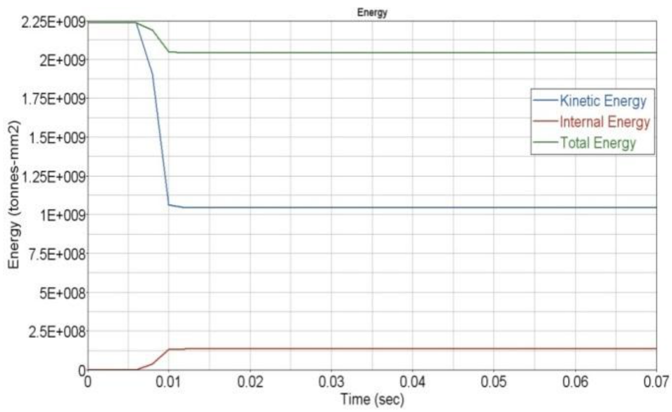

Fig 27: Variation of energy v/s time

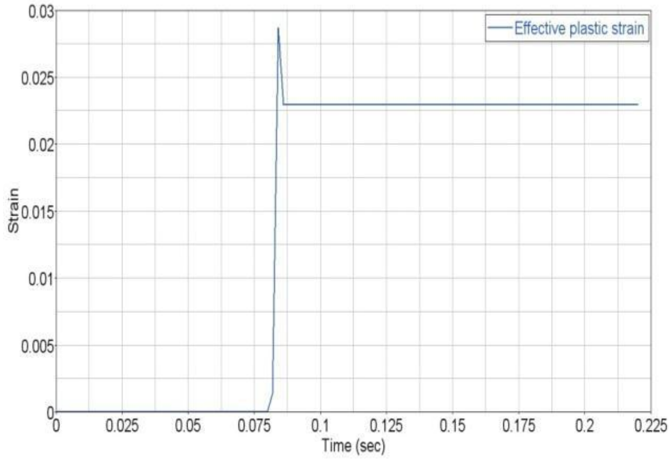

Fig 28: Variation of plastic strain v/s time

7th combination: Impact Velocity = 60 m/s, impact angle = 30deg, erodent size = 250 µm and stand-off-distance = 200 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

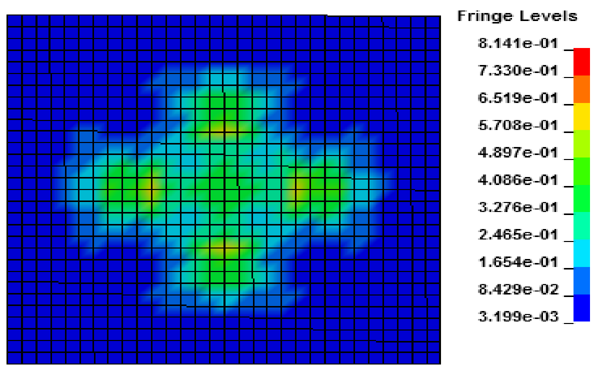

Fig 29: Von Mises stress plot v=60m/s, α=30 deg

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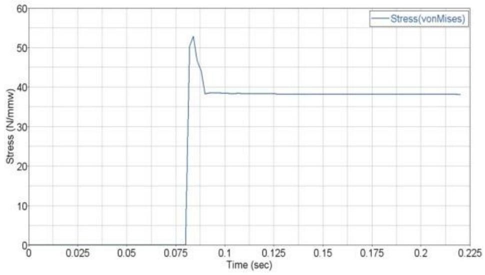

Fig 30: Variation of von Mises stress v/s time

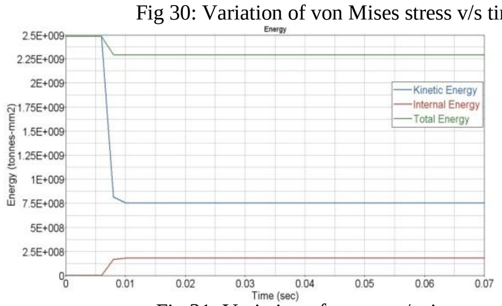

Fig 31: Variation of energy v/s time

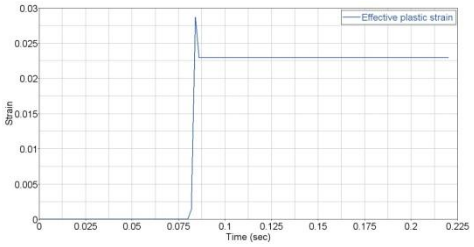

Fig. 32: Effective plastic strain v/s time

8th combination: Impact Velocity = 60 m/s, impact angle = 60deg, erodent size = 420 µm and stand-off-distance = 100 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time, variation of Energy v/s time and variation of Effective plastic strain v/s time.

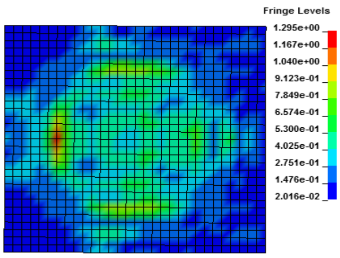

Fig 33: Von Mises stress plot v=60m/s, α=60 deg

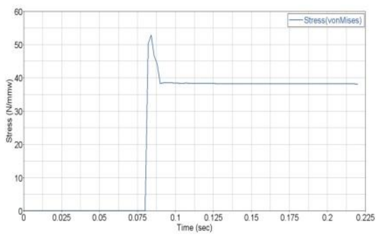

Fig 34: Variation of Von Mises stress v/s time

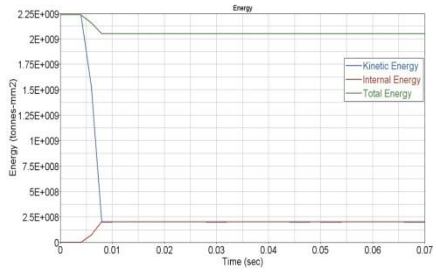

Fig 35: Variation of energy v/s time

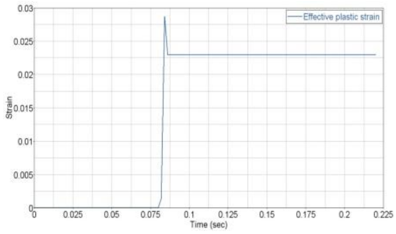

Fig 36: Variation of effective plastic v/s time

9th combination: Impact Velocity = 60 m/s, impact angle = 90deg, erodent size = 170 µm and stand-off-distance = 150 mm. The Von-Mises stress plot, the variation of Von Mises stress v/s time and variation of Energy v/s time.

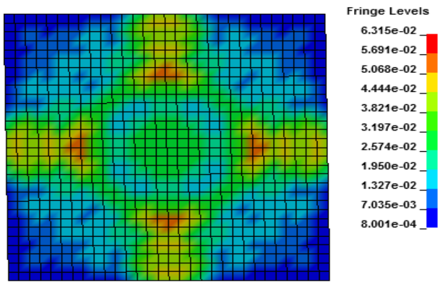

Fig 37: Von Mises stress plot v=60m/s, α=90 deg

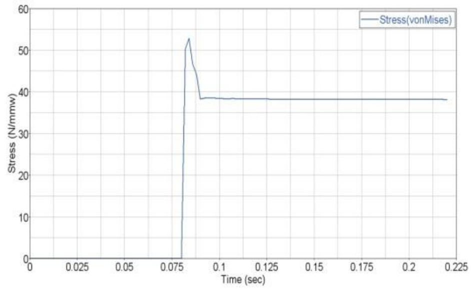

Fig 38: Variation of Von Mises stress v/s time

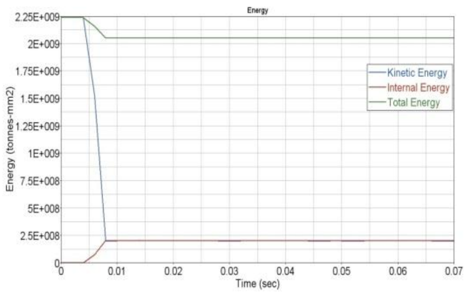

Fig 39: Variation of energy v/s time

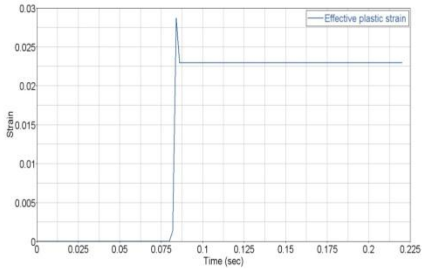

Fig 40: Variation of effective plastic v/s time

VI. Experimental Results and Discussions

Test Run	Impact Velocity(m/s) A	Impact Angle (deg) B	Erodent Size (µm) C	Stand-off Distance (mm) D	Experimental Erosion Rate E_{rr} (mg/kg)
1	30	30	170	100	520.38
2	30	60	250	150	526.52
3	30	90	420	200	516.39
4	45	30	420	150	465.43
5	45	60	170	200	498.68
6	45	90	250	100	471.80
7	60	30	250	200	457.19
8	60	60	420	100	402.97
9	60	90	170	150	523.16

Table 4. Erosion rates for glass/epoxy with bidirectional laminate

Trial No	Response "Y"	Impact velocity			Impact Angle			Erodent size			Stand-off distance		
		1	2	3	1	2	3	1	2	3	1	2	3
1	520.38	520.38			520.38			520.38			520.38		
2	526.52	526.52				526.52			526.52			526.52	
3	516.39	516.39					516.39			516.39			516.39
4	465.43		465.43		465.43				465.43				465.43
5	498.68		498.68			498.68				498.68	498.68		
6	471.80		471.80				471.80	471.80				471.80	
7	457.19			457.19	457.19					457.19		457.19	
8	402.97			402.97		402.97		402.97					402.97
9	523.16			523.16			523.16		523.16		523.16		
Total	**4382.52**	**1563.3**	**1436**	**1383.32**	**1443.00**	**1428.17**	**1511.35**	**1395.15**	**1401.29**	**1472.26**	**1542.22**	**1455.51**	**1384.79**
No. of values	9	3	3	3	3	3	3	3	3	3	3	3	3
Average	486.95	521.10	478.64	461.11	481.00	476.06	503.78	465.05	467.10	490.75	514.07	485.17	461.60
Effect		59.99			27.73			25.70			52.48		

Table 5: ANOVA result table

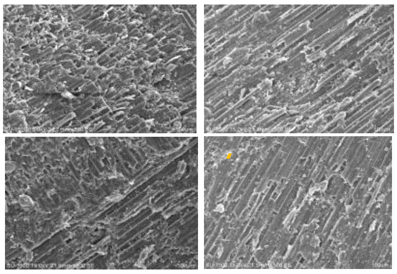

Fig: 41: SEM of GFRP (bidirectional) eroded laminates

(a) V: 30m/s, α: 90^0, erodent size: 420µm, SOD: 200mm, Er: 516.39 mg/kg
(b) V: 60m/s, α: 30^0, erodent size: 250µm, SOD: 200mm, Er: 457.19 mg/kg
(c) V: 30m/s, α: 60^0, erodent size: 250µm, SOD: 150mm, Er: 526.52 mg/kg
(d) V: 30m/s, α: 30^0, erodent size: 170µm, SOD: 100mm, Er: 520.38 mg/kg

CONCLUSIONS

- Glass/epoxy bidirectional covers were created with hand lay-up strategies and the covers were portrayed for mechanical properties.
- Erosion experiments were conducted using Taguchi's Orthogonal Array technique and erosion rate was computed for different factor level combinations.
- The results demonstrate that effect speed, impingement edge, erodent size and remain off-separation are the critical components in a declining arrangement influencing the disintegration wear rate.
- SEM studies uncover that material evacuation happens by smaller scale cutting, plastic misshaping, and miniaturized scale splitting, introduction of filaments and evacuation of the fiber.
- The composites display semi-malleable disintegration attributes with the crest disintegration wear happening at a 60^0 impingement edge. This has been clarified by breaking down the conceivable harm component with the assistance of SEM micrograph.
- From the finite element analysis, it was concluded that erosion process solely depended on the impact velocity of the erodent and the angle of impact. The erosion was found to be maximum at 60^0angle of impact and at impact velocity 60 m/s. There was some interactive effect on the erosion model when the two or more parameters were combined.

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