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Development of Smart Composite for Aerospace Applications Using MWCNT-CNF

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Abstract: *Present Paper, Conductive Multi Walled Carbon Nano Tube (MWCNT) And Carbon Nano Fiber (CNF) Has Been Dispersed Between Nonconductive E Glass Fiber Sheets. MWCNT And CNF Mix With Epoxy Resin By Sonication Process And Vacuum Resin Transfer Molding (VRTM) Method Is Used For Fabrication Of Glass Fiber Sheet Polymer (GFRP). Equal Amount (50:50) Of MWCNT And CNF Has Been Mixed Together; 0.05 Wt. %, 0.1 Wt. %, And 0.5 Wt. % Used In This Paper. Nano Materials Neither Increase the Weight Of Composite (GFRP) Nor Downgrade Its Mechanical Properties. Mixture Of Nano Material (MWCNT And CNF) Acts As Sensing Material. Tensile Test Has Been Conducted On GFRP Specimen; Digital Universal Testing Machine Is Used For Tensile Testing. During Loading Condition, Electrical Resistance Of MWCNT And CNF Mixture Has Been Measured By Electrical Multi Meter. Stress And Strain Of GFRP Has Been Measured By Tensile Test And Graph Has Been Plotted Between It Including Change In Resistance Value Calculated. Damage Or Crack Of GFRP Is Sensed By Electrical Resistance.*

Keyword: *MWCNT, CNF, GFRP And Electrical Resistance*

I. Introduction

Now Day Composite Material Is Used Each And Every Field Due To Its Light Weight And Easy Maintenance. Composite Material Has High Resistance To Fatigue And Corrosion Degradation, Good Strength To Weight Ratio, Good Reliability, High Durability, Good And Smooth Aero Dynamics Profile, Good Resistance To Impact Damage, Easy To Manufacture And Assemble These Are Some Advantages Of Composite Material Which Make It Useful Rather Than Metal. Composite Material Is Generally Used In Aerospace, Automobile, Civil Construction, Sports, Marine Field Due To Its Large Application And Use It Is Also Introduced Super Material. Glass Fiber Has High Tensile Strength And Strain To Failure, Good Heat And Fire Resistance Property, Chemical, Thermal And Moisture Resistance, High Dielectric Strength Which Make It Different From Other Composite Fiber Material. It Has Some General Advantage Like Low Cost, Easy Availability, Easy Handling. Glass Fiber Is Used In Transportation, Sports, And Civil Construction. MWCNT Improves The Mechanical Properties Of Epoxy Resin. Long CNT Has Better Mechanical Properties Than Short CNT Shown In This Paper. Khalid R. Al Rawi Et Al Introduced The Effect Of Different MWCNT Type Based Upon Its Mechanical Property With Epoxy Resin. Long Multi Walled Carbon Nano Tube (LMWCNT) And Short Multi Nano Tube (SMWCNT) Both Mixed With Epoxy Resin By Ultra-Sonication Process For 30 Minute And Stirred For 2 Hour Than Vacuum System Used To Remove Bubble. Glass Mold Used To Cast This Mixture, Mixture Has Been Poured In The Mold And Left It For 72 Hours To Curing. Bending Test, Micro Hardness Test, Impact Test, Conducted For Checking Mechanical Properties Of Epoxy Resin Modified With MWCNT. Epoxy Resin Modified With LMWCNT Has Been Found Better Mechanical Property Than SMWCNT [1]. Inpil Knag Et Al Studied About Structural Health Monitoring By CNT Piezo- Resistive Strain Sensor. CNT And CNF Used With Electrolyte For Harvesting Power From Structural Vibration. CNT Bio Electronic Sensor Also Discussed CNT And CNF Has Elastic And Thermal Property, Electrical Conductivity, Magneto Resistive, Piezo Resistance, Electro Kinetics, Piezo Electric Property, Has Been Studied In This Paper. Different Weight Percentage Has Been Used In This Paper, 3% And 10% Weight Percentage Of SWCNT Has Good Sensitivity [2]. A. Martone Studied About Sonication Process, Two Type Of Dispersion Has Been Done In This Work One Is Solvent Solution And Another One Is Direct Mixed With Epoxy Resin. 0.1 Wt. % Of MWCNT Mixed With The Solvent(Acetone+ SDS+ Ethanol) By Ultrasonic Process Than Its Cooled With Ice At Room Temperature Epoxy Resin Is Added With Mixture In Mold. Second Process Epoxy Resin Mixed With MWCNT At Different Temperature. At 60º Temperature Magnetic Agitation Process Has Been Done For Mixture .If Compare Both The Result Second (Direct Mixing) Gives Better Result. Optical Microscopy Test Conducted. Mechanical Test (DMA, TMA) Test Has Been Done And Result Shown That Sonication Process Gives High Flexural Elastic Modulus [3]. Pilar Cortes Et Al Introduced About New Method To Preparation And Curing Of Epoxy Resin. Resin Mixed By Magnetic Stirrer For 30 Minute, Then Clay Mixed With Epoxy By Ultra-Sonication Process For One Hour. Thus 2 Wt. %, 5 Wt. %, 10 Wt. %Has Been Prepared After Adding Curing Agent Mixture Has Been Put In Vacuum For 24 Hour.Nano Structure Of The Cured Nano Composite

Was Characterized By Small Angle X- Ray Scatting (SAXS) And Transmission Electron Microscopy (TEM) Mechanical Property Was Determined By Dynamics Analysis (DMA) [4]. Majid R. Ayatollahi Et Al Worked On Sonication Process And Concluded The Mechanical And Electrical Properties Of Epoxy Resin Modified With MWCNT. Modified Epoxy Resin With Nano Clay And MWCNT Mixture Improves Mechanical Strength As Well As Electrical Property. Modified Epoxy Resin Mixture Improves Young Modulus And Fracture Toughness But It Reduces The Tensile Strength [5]. M.J. Kadhim Et Al Discussed Mechanical Properties Of Epoxy Resin Modified With AL_2O_3. In This Process AL_2O_3 Mixed By Homogenizer. AL_2O_3 Particle Divided Into 1,2,3,4,5,6,7 Wt. %. Three Point Bending And FE-SEM Test Carried Out. 7 Wt. % Of AL_2O_3 Gives Better Result In Case Of Young Modulus But 4 Wt. % Gives Good Better Result In Case Of Flexural Strength [6]. Najiba Abdullah Al- Hamadani Evaluated The Electrical Properties Of Epoxy Resin Modified Functionalized CNT, Dielectric Properties Of MWCNT Has Been Calculated And Found MWCNT Has Better Dielectric Constant Than U-MWCNT And Pure Epoxy Resin. MWCNT Treated With Acetone 0.2 % F-MWCNT Gives Less Dielectric Loss And 0.2 % F-MWCNT Shows Good Impedance [7] But In This Paper Ultra- Sonication Process Has Been Used To Mix MWCNT And CNF Are 50:50 Used; This Different Wt. % Used 0.05%, 0.1%, And 0.5%. Vacuum Resin Transfer Molding Method Is Used To Fabricate Of Glass Fiber Reinforced. ASTM D3039 Has Been Followed And Laminate Has Been Cut By Water Jet Cutting Machine. Mechanical Test Has Been Carried Out During Loading Condition Electrical Resistance Of The Prepared Glass Fiber Laminate Has Been Measured.

II. Material

(1) Glass Fiber- E Glass Fiber Is Used In This Work. It Is Bidirectional And Gram Square Meter (Gsm) Is 360. (2) Carbon Nano Tube - Multi Wall Carbon Nano Tube Is Used. Its Length Is 10-20 Nm, Outer Diameter Is 10-30 µm And Assay Is 95%.It Is In Black Color And Powder Form. It Manufactured By Chemical Vapor Deposition Method And Supplied By Sigma Aldrich.(3) Carbon Nano Fibers- Powder Form Of CNF Used In This Work, Diameter Of CNF Is 100nm, And Length Is 20-200µm. (4) Resin-ARALDITELY LY556 Used In This Work Supplied By Huntsman.It Is In Liquid Form. (5) Hardener-ARAUR HY 951used In This Work Supplied By Huntsman.(6) Silver Paste-Adhesive Type Of Silver Paste Used. It Is Containing Into Two Different Containers. It Has To Mix With 1:1 Ratio. Glass Rod Was Used For Spreading The Mixture On The Glass Fiber.

Sample Preparation

Resin Solution Preparation

MWCNT-CNF According To Wt. % Has Been Measured And Well Grinded. Required Amount Of Epoxy Resin Has Been Taken And Put In The Homogenizer And Mixed It For 2 Minute After That Small Amount Of MWCNT-CNF Powder Has Been Added In The Resin Solution And Mixed It By Homogenizer For 10 Minute. Required Amount Of MWCNT-CNF Has Been Divided Into 6-7 The Batches Each Batch Has Been Subjected In The Resin Solution At 10 Minute Interval To Get Well Dissolve And Homogenous Resin And MWCNT-CNF Solution. The Whole Mixing Process Has Been Carried Out In Presence Of Ultra-Sonic Bath. Ultra- Sonic Bath Is A Technique To Reduce The Temperature Of The MWCNT-CNF And Resin Mixture; Which Is Overheated By Homogenizer Probe. In This Process Whole Mixing Experiment Has Been Taken Place In One Tub That Should Be Filling By Ice And The Mixture Of MWCNT-CNF, Resin Has Been Kept Between In Ice; Remember That Ice Should In Plastic Packet. Plastic Is Insulator, It Seal The Moisture Of Ice So That MWCNT-CNF Won't Affect By Any Ice Moisture. After Sonication Process Hardener Has Been Added In The Resin Mixture And Mixed It By Homogenizer For 5 Minute.

Fabrication of Specimen

Glass Has Been Cut Into Ten Pieces. Modified Epoxy Resin Has Been Dispersed Between 9^{th} And 10^{th} Layer. Silver Paste Applied On Top And Bottom Of 10^{th} Layer Glass Fiber Sheet For Conductivity Medium. Vacuum Resin Transfer Molding Method Is Used To Fabrication Glass Fiber Alone With Modified Epoxy Resin. All Glass Fiber Kept Together, Modified Epoxy Resin Has Been Dispersed Between 9^{th} And 10^{th} Layer By Roller Fabrication Area Was Closed With Bagging Material Then Vacuum Was Created Through Pump Resin And Hardener Mixture Infused By Infusing Pipe.100:12 Resin Hardener Mixtures Has Been Taken. Curing Time Is 24 Hour; Fabrication Has Been Left For 24 Hour At Room Temperature.

III. Experimental Method

After Curing Temperature, Fabrication Has Been Taken Out And Cut Accordingly ASTMD3039 By Water Jet Machine. Length, Width, and Thickness of Specimen Should Be 250mm*25mm*2.5mm.Outer Surface Of Specimen Scratched And Wire Placed On The Surface With The Help Of Silver Paste. Multi Meter Attached To Wire The Record The Reading This Reading Denotes Initial Resistance Value. Servo Hydraulic

Instron 50KN Used As Tensile Testing Machine For Specimen. One End Of The Wire Has Been Attached By 9V DC Battery And Another End Connected To Multi Meter.

IV. Result And Discussion

Mechanical Test

Tensile Test Has Been Carried By Digital Universal Testing Machine; This Machine Has Capacity To Measure Up To 50KN Load. Load Was Applied On The Specimen As 10 Mm/Min. Initially One Specimen Has Been Tested And Fracture Stress Of It Recorded. This Fracture Stress Divided Into 20%, 35%, 45%, And 100%. For Each Loading Condition Resistance Has Been Measured By Multi Meter That Could Be Considered As Final Resistance, So That Ratio $\Delta R/R_0$ (-) Calculated**.**

$\Delta R/R_0$ = Initial Resistance – Final Resistance/Initial Resistance Corresponding Of Each Loading Condition Stress And Strain Has Been Recorded. For Each Loading Condition Graph Was Plotted Between Stress, Strain And $\Delta R/R_0$ (-). Graph Shown Blow Represent The Mechanical Behaviour Of GFRP Modified By Nano Particle. Resistance Of Nano Particle Increased With Load, Which Is Shown In Graph. Resistance Value Increased With Amount Of Nano Particle, It Shown In The Graph 0.05 Has Less Resistance Value Than 0.1% And 0.5%; Then 0.5% Has High Resistance Value.

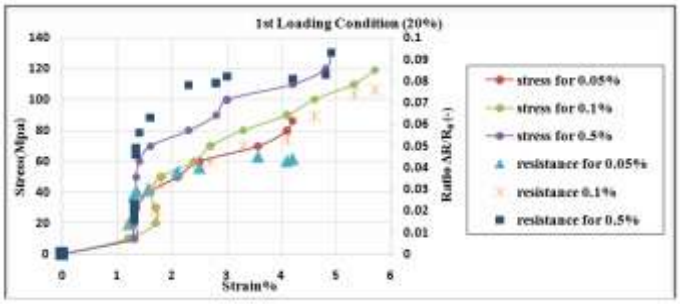

Fig 1: Graph Represents Curve Between Tensile Stress And Electric Resistance Corresponding To Stress of GFRP Modified With MWCNT-CNF For 1st Incremental Loading.

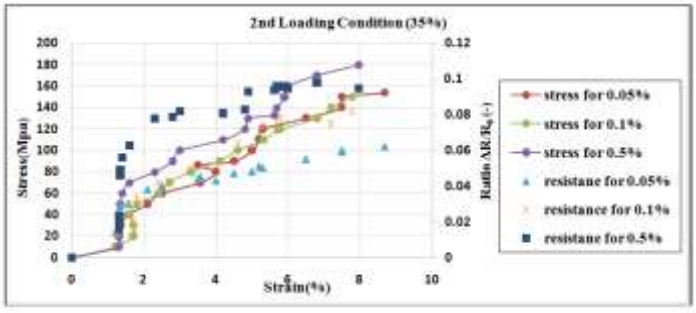

Fig 2: Graph Represents Curve Between Tensile Stress And Electric Resistance Corresponding To Stress of GFRP Modified With MWCNT-CNF For 2nd Incremental Loading.

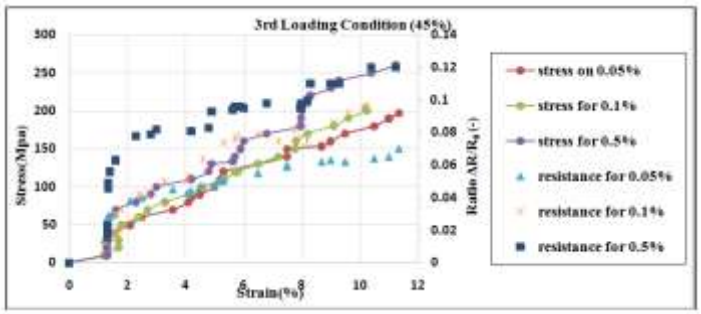

Fig 3: Graph Represents Curve Between Tensile Stress And Electric Resistance Corresponding To Stress of GFRP Modified With MWCNT-CNF For 3rd Incremental Loading.

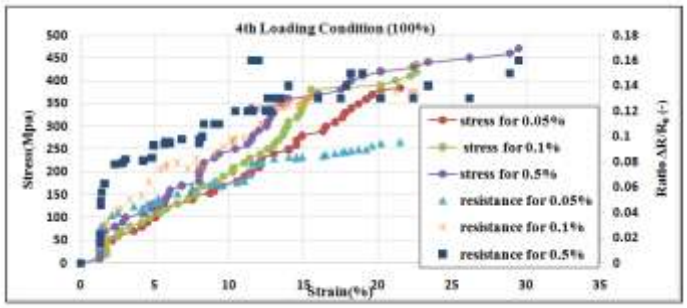

Fig 4: Graph Represents Curve Between Tensile Stress And Electric Resistance Corresponding To Stress of GFRP Modified With MWCNT-CNF For 4th Incremental Loading.

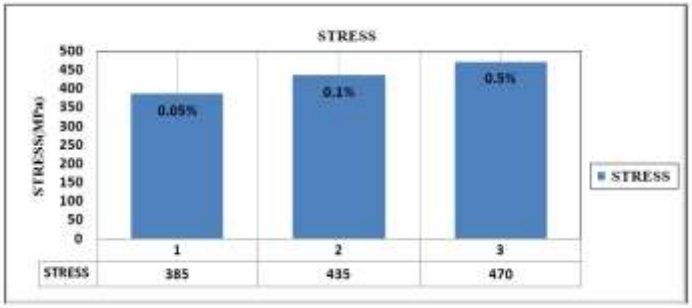

Fig 5: Typical Bar Graph Represents Tensile Stress Increasing Value of GFRP Modified With MECNT-CNF

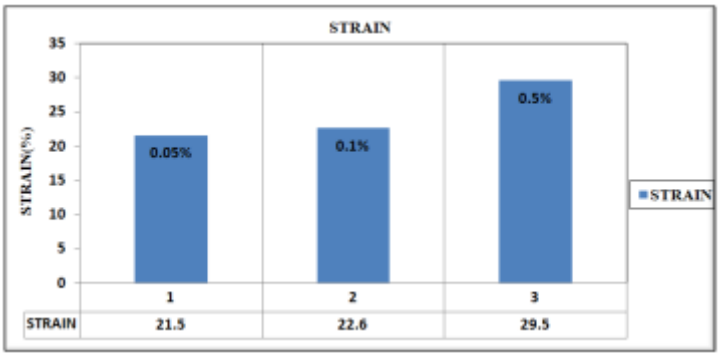

Fig 6: Typical Bar Graph Represents Strain Increasing Value of GFRP Modified With MWCNT-CNF

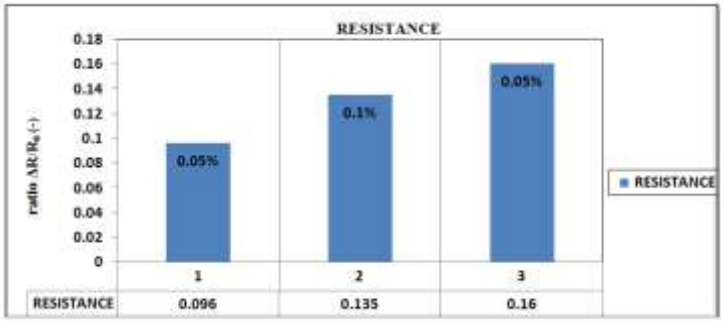

Fig 7: Typical Bar Graph Represents Electrical Resistance Increasing Value of GFRP

Modified With MWCNT-CNF

Electrical Conductivity

Electrical Resistance Obeys Mechanical Response (Stress-Strain Graph) Of The GFRP. Graph Shows The Relationship Between Fracture Stress And Resistance. Nano Particle Has Tendency To Measure Electrical Resistance Without Help Of Any Additional Sensor, This Nano Particle Behave As Self- Sensing Material In GFRP. This Nano Particle Is Very Sensitive and Also Capable To Measure Minor Defect Such As Inter Fiber Failure Or Any Other Micro Type Of Failure.

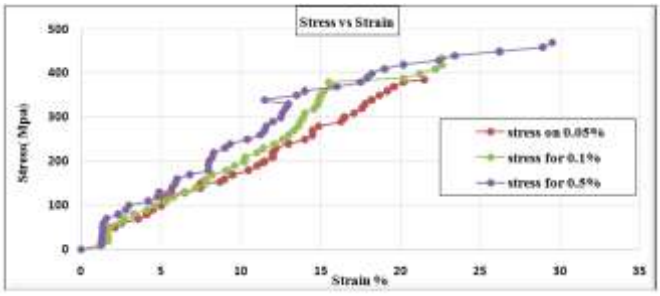

Fig 8: Mechanical Result of GFRP Modified With MWCNT-CNF

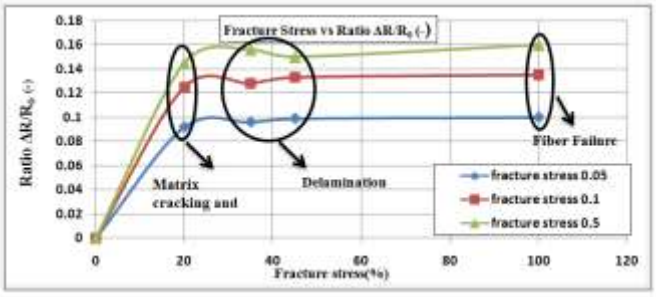

Fig 9: Relation of Loading Condition with Residual Resistance of MWCNT-CNF Epoxy Resin

V. Conclusion

In This Paper Nano Particle Has Been Dispersed Over Glass Fiber Reinforced Composite This Nano Particle Increase The Mechanical And Electrical Properties Of GFRP. Nano Makes GFRP To Sense Structural Defect Of GFRP And Behave As Sensing Material.

- GFRP Modified With Nano Particle Increased The Load Capability Against Stress And Strain.
- Nano Particle Increase The Tensile Strength Of GERP Without Affecting Its Mechanical Performance. 0.5% Modified GFRP Showing High Tensile Strength In The Above Graphs.
- These Nano Particles Are Capable To Measure Electrical Resistance Without Downgrade Any Mechanical Properties And Without Use Of Any Additional Sensor. Electrical Resistance Increase with the Applied Load Shown In the Graphs.
- Nano Particle Sensitive To Electrical Resistance And It Is Capable To Measure Minor Crack Or Failure Such As Fiber Failure; It Also Acts As Self- Sensing Material.
- 0.5% Modified GFRP With Nano Particle Shows High Value Of Resistance Mentioned In Graphs.
- Co-Relation Between Stress, Strain, And Resistance With Different Loading Condition Has Shown In The Graph.

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