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A Review of Recent Trends on Reinforcement of Fibre Metal Laminates with Nanoclay and Multi Walled Carbon Nanotubes

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Abstract: In this paper the Fibre-metal laminates have showed its great importance in high-performance, lightweight structures like aircrafts and military applications. Hybrid composite materials are built up from interlacing layers of Fibre reinforced adhesives and thin metals to form Fibre metal laminates. The combined effect of metals and Fibre-reinforced laminate offer merits like enhanced resistance to fatigue crack growth and impact damage for industrial applications. MWCNT, Nanoclay reinforced FMLs are economical than other FMLs like GLARE and CARALL. Using classical techniques Metallic layers and Fibre reinforced laminate can be bonded. Adhesively bonded Fibre metal laminates have shown more fatigue resistant than their equivalent mechanically formed laminates. FML's are chemically stable, conduct electricity and mechanically very strong. Due to these reasons they found their candidature to enhance the properties of FMLs.
Keywords : Nano clay, MWCNT, FML, GLARE, CARALL.

1. Introduction

Composite materials induce permanent interest during the last decades. Firstly, military applications in the aircraft industry have shown the commercial use of composites after the World War-II. Due to the use of composites considerable weight reduction in structural design could be achieved. Composites offer many advantages compared to metallic alloys in the applications that demand high strength and stiffness to weight ratio. Additionally, they provide superior corrosion resistance and fatigue properties. With all these advantages, during the past decades the aerospace industry gained usage in composite structures.

1.1. FMLs

Fibre metal laminates (FMLs) are plies of fibre reinforced polymeric materials and hybrid composite structures based on thin sheets of metal alloys.

FMLs combine the advantages of fiber reinforced matrix systems and metallic materials. Metals are generally isotropic, possess impact resistance and high bearing strength. They are also easy to repair.Full composites have high strength and improved fatigue characteristics. The poor corrosion and fatigue characteristics of metals and the low bearing strength, reparability of composites can be overcome by the FMLs [1,2]. These novel material systems are created by bonding composites.

1.2. Material behavior

FMLs have the following properties that are better compared to metals.

1. High fatigue resistance
2. High strength.
3. High fracture toughness
4. High impact resistance.
5. High energy absorbing capacity.

1.3. Physical properties

1. Low density: due to low density, FMLs comprising of Aluminium sheets and epoxy based polymer matrix, have overall low density compared to others.
2. Excellent moisture resistance: The absorption of moisture in FMLs is slow.
3. Excellent corrosion resistance: FMLs are highly corrosion resistant.
4. Lower material degradation: FMLs have excellent moisture absorption and improved corrosion resistance. Hence, degradation of FMLs is slower than other metallic or composite structures
5. Fire resistance: The high melting point of the fibres in FMLs does not allow fire to penetrate into the inner layers.
6. Cost saving: FMLs provide weight savings than their existing metallic parts. Less number of parts are needed to construct the same metal or alloyed component. Thus savings in labour and hence cost saving accrue from FMLs [3]

2. Types of FLMs

Name of FLMs	Reinforced Element	Benificial Properties
ARALL (Aramid Reinforced Aluminium Laminates)	7075-T6 Al cad steel, Aramid fibre	Superior fatigue strength and thermal stable [3]
GLARE(Glass Reinforced Aluminium Laminate)	Glass and epoxy resins [4]	Fatigue shear and high yield strength [4]
CARALL(Carbon Reinforced Aluminium Laminates)	Fibre and epoxy resins [5]	Toughness and resistant [1]
Titanium based FML	Sic coated boron [6]	High toughness ultimate and yield strength
Magnesium based FML	Boron, Carbon, Al_2O_3	Highly fire resistant and tough.

3. Reinforcement of Composites:

In reinforcement, a fibre composite or Nano material is added using bonding materials. Reinforcement usually increases rigidity and greatly restricts crack propagation. Thin fibres have very high strength and are mechanically well attached to the matrix thus greatly enhancing the overall composite properties. Reinforced materials will often provide a laminated structure.

3.1. MWCNTs

Carbon nanotubes (CNTs) based polymer composites have many enhanced applications due to their enhanced properties. Initial academic research on CNT nanocomposites has been focused on SWCNT because of they have simpler structure. Nowadays, the production of MWCNT has already taken up by the industries and therefore area of research is moving towards MWCNT based systems. Uniform dispersion of MWCNT still remains a great challenge. Several strategies such as ultra sonication, high shear mixing, surface oxidation have been used to overcome the problem of agglomeration [7–8]. The surface oxidation is most widely used to get the desired properties. Multiwall carbon nanotubes have an internal diameter of 2 to 10 nm, an external diameter of 20 to 75 nm and a length of 50. MWCNTs are produced by CVD synthesis. Multiwall carbon nanotubes are Nano scale carbon fibres with a high degree of graphitization.

3.2. Nanoclay

Nanoclay is the most widely investigated nanoparticle. The origin of betonite (natural clay) is formed by the in-situ alteration of volcanic ash and hydrothermal alteration of volcanic rocks. Molten rock within the planet, magma, under extreme pressure, forced its way through the earth's crust and exploded into the atmosphere in a volcanic eruption.

3.2.1. Properties of Nanoclays

1. Effective barrier properties
2. Heat retardant
3. Enhance mechanical properties
4. Resistant to fracture

4. Bonding Elements (Epoxy Resins)

These are often referred to as curatives or hardeners. Epoxy has a wide range of applications in industries, like metal coatings, use in electronic and high tension electrical insulators, structural adhesives and fibre-reinforced plastic materials are commonly used in boat-building.

4.1 Types of epoxy resins

1. Bisphenol-A
2. Novolac
3. Aliphatic epoxy resins

5. Dispersion Methods

1. Optical microscopy
2. Micro Raman spectroscopy
3. Multi-wavelength anomalous dispersion[9]

Optical micrographs and Raman images showed a uniform distribution and reduced assemblage of MWCNTs in the epoxy matrix.

5.1.Dispersion of MWCNT and Nanoclay in FMLs

Method 1: Ultrasonic Sonication Followed by Three Roll Milling

Sonication of the Nanoclay/MWCNT and resin is done over a coolant bath for 1 h. For this amplitude of 25% and pulse rate of 50:25 were used. In the ultrasonic process “peeling off” the individual nanoparticles from the clay bundles is done. The clay-resin mixture was further processed using three roll milling. The three roll milling machine have three rollers side by side , running at different velocities. The resin was fed into the rollers.As a resultNanoclay dispersed into resin. Three roll milling was done using different passes with gap setting between the rollers from 35 µm down to 15 µm, in three passes [10].

Method 2: Thinky Mixing (Planetary Centrifugal Vacuum Mixer) Followed by Three Roll Milling

The thinky mixing process uses rotation of the Nanoclay/MWCNT epoxy mixture under vacuum pressure and centrifugal force. The semi uniform paste of the Nanoclay/MWCNT and resin was thinkymixed for 1 h at pressure of 30 psi and speed of 1200 rpm. A further mixing was carried out using different passes with gap setting between the rollers from 35 microns down to 15 microns [10].

Method 3: Magnetic Stirring Followed by Three Roll Milling

The partial uniform paste of Nanoclay/MWCNT and resin and were stirred using magnetic stirring for 24 h. The vortex effect produced partial dispersion of the clay in the epoxy resin. A final mixing using the three roll mill was then carried out using different passes with gap setting between the rollers from 35 microns down to 15 microns, in three passing in steps of 15 microns [10].

6. Inspection Methods

1. SEM (Scanning Electron Microscopy)
2. Mechanical testing (Bending test, tensile test)
2. Volume resistivity measurement test [11]
3. Transmission Electron microscopy (TEM) [12]
4. Atomic force microscopy (AFM)
5. Wide angle X-ray diffraction (WAXD) for determination of clay %
6. Differential Scanning Calorimetry (DSC) for thermal analysis

7. **Effect of Reinforcing with MWCNTs and NANOCLAY:**

1. Increase in barrier properties
2. Increase in electrical conductivity properties
3. Increase in mechanical properties i.e. impact and hardness values [12]
4. Increase in thermal insulation properties/high thermal resistant
5. Light weight
6. Increase in flexural strength [7]
7. Increase in storage modulus [13, 14]

7.1. Application of MWCNT and Nanoclay Reinforced FMLs

1. In aerospace vehicle parts
2. In automobile parts eg; where more mechanically strong part is required
3. In PCB circuit boards
4. In the parts which are exposed to high temperature and perfect insulation is required.

8. Conclusion

Reinforcement of MWCNT enhances mechanical properties of fibre metal laminates. The FML becomes more rigid and tough. Reinforcing of MWCNT enhances the electrical conductivity to a great extent. The flexural strength increases two times compared to the value of pure epoxy at 2% MWCNTs concentration. Increase of the impact strength and hardness values with increase MWCNTs concentration was noted. Reinforcement of Nanoclay enhances flexural strength of FMLs. The flexural modulus increased by about 90 % at 7.5 wt% Nanoclay. However, with an increased load of clay in the nanocomposite, the mechanical properties decreased due to the agglomeration of excessive Nanoclay. The storage modulus was significantly increased at high temperature with increasing the load of Nanoclay.

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