Metal and non metal Composite Materials a New Alternative for Materials: Review

[1]M. A. Boda, [2]R. V. Phand , [3]A. C. Kotali

[1]Assistant Professor, [2,3]U. G. Students
Department of Mechanical Engineering
VVPIET, Solapur, MH, India.

***Abstract*— In response to the marked increase in the research activity and publications in multifunctional materials and structures in the last few years, this article is an attempt to identify the topics that are most relevant to multifunctional composite materials and structures and review representative journal publications that are related to those topics. Materials play a significant role in the blooming of human civilization and country's infrastructure and growth. Composite materials have boundless engineering application where strength to weight ratio, low cost and ease of fabrication are required. Many of these recent developments are associated with polymeric composite materials and corresponding advances in nano materials and nanostructures. In this paper we present a relatively new approach of composite materials, its advantages, disadvantages and various applications.**

***Keywords*: Composite material, applications, metal and non metal, properties**

I. INTRODUCTION

Composite structures is developed and used in the aerospace, automobile, sports, a nd marine industries since the early 1940s. Composite materials have been using for thousands of years, example, they have manufactured bricks with the help of mud which is a thousand-year-old technology [7]. Compared to conventional metallic structures, newer high performance composite structures provide benefits such as decreased weight and reduced energy consumption [4, 11, and 13]. Composite materials are based on the concept that a combination of different materials can attain properties that constituent materials cannot attain individually by themselves [14]. This concept has been applied to create variety of composite materials. Typically, composite materials are "solid materials composed of two phases: 'Binder' and 'reinforcements' or 'fillers'. The development and use of composite materials has been increasing day by day. The matrix (or binder) binds the reinforcement-fibres together and gives shape to the composite [14]. Recently carbon nano tubes (CNTs), as a new type of advanced materials, has attracted a great deal of interest of researchers. Most investigations of carbon nanotubes-reinforced composites (CNTRCs) have focused on material properties [2]. Studies of mechanical, electrical and thermal properties of Nano composites are quite useful; the ultimate purpose of development of this advanced material [3]. Consequently the need to develop repair techniques and processes for composite components is readily apparent.The most common types of repairs carried out with composite materials in aerospace industry are external bonded patch repair and scarf repair [7]. Currently, Bacterial Cellulose composites are synthesized through numerous routes based on the nature and size of the reinforcement material [8]. Electrical discharge machining (EDM) is higher capability for cutting complex shapes with high precision for these materials [10]. Many of buildings of built heritage include a structure composed by timber elements like glass fibre composites to reinforce solid wooden beams [12]. Damages inside the composites are difficult to be perceived and to repair [16]. An important issue in the production of metal matrix composites is the chemical compatibility between the matrix and the reinforcement [27]. Micro cracking is one of the fatal deteriorations generated in service [28]. The design and development of high performance materials require a thorough understanding of microstructure and its effect on properties [31].

II. LITERATURE REVIEW

Jin Zhang et al. [1] five types of composite laminates were investigated under static loading under tension, compression and three-point-bending. To effectively improve the tensile, compressive and flexural strength of the plain glass fiber composite, glass/carbon (50%: 50%) fiber reinforcement was used either by placing the carbon layers at the exterior or by placing different fiber types alternatively. **Z. X. Lei et. al. [2]** in this paper, the element free kp-Ritz method is successfully applied to buckling analysis of CNTRC plates. The plates are reinforced by SWCNTs and effective material properties of plates are estimated either by the Eshelby–Mori–Tanaka approach or the extended rule of mixture. Comparison studies were performed to verify the accuracy and efficiency of the present method and the results were found to be in good agreement with solutions available in literature. **Z.X. Lei et. al. [3]** They investigate free vibration of various types of CNTRC plates using the element-free kp-Ritz method. The effective material properties of CNTRCs can be estimated by either the Eshelby–Mori–Tanaka approach or the extended rule of mixture. Several numerical examples are provided to verify accuracy of present mesh-free method and results agree well with solutions available in the literature. **Qiang Liu et. al. [13]** a lightweight EV body structure made of CFRP was designed and evaluated using a multi scale approach. Prototype model was created according to microscopic structure of test samples. Thus the 3D material properties were predicted by using finite element based homogenization method. The prototype model was implemented. It is recommended that a multi scale analysis approach proposed here is in generic and can be used for other lightweight vehicle structure made of composites. **Nadir Ayrilmis. et. al. [15]** results showed that composites made with charcoal flour showed the better water resistance and mechanical properties compared to the composites made with wood flour or charcoal flour. The improvement in the mechanical properties was explained by the fact that the charcoal flour constrained mobility of the chains of a polymeric matrix. Better bending properties and internal bond strength could be attributed to the homogeneous dispersion of charcoal flour in WPC. Charcoal contains many pores and gaps in its structure. The improvement in the mechanical properties of WPC panels was significant by using charcoal flour. **Yingying Qu et. al. [24]** the morphology, structure and surface chemistry of the surface coating were evaluated and the influence of the process parameters was assessed. It was shown that for all temperatures two regions, an exterior and an interior one can be distinguished as having significant differences in the degree of oxidation. **Jeong- Ha You et. al. [25]** In this article, three most necessary Cu-matrix composite materials were reviewed in terms of thermal, mechanical and HHF performance as structural heat sink materials. Representative compressive stress–strain curves of Cu–Ta samples as a function of test temperature are displayed in the ultimate flow stress in the room temperature sample is 1154 MPa. The corresponding yield strength value of this specimen is 1048 MPa. Such strength levels are remarkably high. **C. Oikonomou et. al. [26]** their present study coated spherical FeSi powder particles with MnZn ferrite to electrically insulate the ferromagnetic particles Insulating material covers FeSi powder particles more or less completely, as indicated by the SEM micro graphs, they prepared several composite FeSi/MnZn ferrite samples with three different amounts of ferrite. **K. A. Darling et. al. [27]** they have conducted a series of quasi-static and high-strain rate compression experiments at various temperatures on a thermally stabilized nano structured Cu–10Ta composite. This composite consists of a uniform dispersion of nano scale Ta clusters and precipitates in Cu-rich matrix. The experimentally observed mechanical response indicates a material which exhibits the yield stress of 1.05GPa at room temperature, an approximate yield stress of 0.5GPa at 600°C, a linear temperature response and, with a very high degree of compressive plasticity. At higher strain rates, experiments showed greater strength levels and an unchanged deformation mechanism up to 600 °C. **N. Chawla et. al. [35]** Object-oriented finite element analysis (OOF) can be used as an effective tool for evaluating material behavior under thermal and/or elastic conditions, because it incorporates the inherent microstructure of material as an input to the model. OOF was successfully used to predict Young's modulus and CTE in two multi component systems, SiC particle reinforced Al matrix composites and WC DC Co matrix composites.

III. ADVANTAGE S, DISADVANTAGES AND APPLICATION OF COMPOSITE MATERIALS

Advantages

1. Part consolidation opportunities, design flexibility, reduced tooling cost, better damage and corrosion resistance, material anisotropy and improved internal damping, etc.
2. Important reasons for the growing adoption of polymer matrix composites are the reduced weight (30–40% lighter than steel parts of equal strength).
3. In aerospace approximately 50% of the airframe is made from composites due to their high specific strength, light weight and stiffness.
4. Composite materials used as an industrial material for their outstanding resistance to chemicals and most forms of corrosion.
5. Composites have four to six times tensile strength as compare to steel or aluminium (depending on reinforcements).
6. Composites have high fatigue strength, impact, environmental and reduce maintenance, higher fatigue endurance limit (up to 60% of ultimate tensile strength).

Disadvantages

1. While plastic and composite materials are used in automobiles today, they constitute only approximately 7.6% of total vehicle mass and the applications are generally not for the primary vehicle structure.
2. Concerns about high material costs, slow production rates and recyclability and auto-industry's lack of experience with composite materials, are the main problems automakers are facing currently.
3. The adhesive bonding of composite patches leads to cost effective and highly damage tolerant structural repairs in comparison with conventional mechanical fastened repair methods.
4. Composite materials have high cost of material, long development time, manufacturing difficulties, low ductility, temperature limits, solvent or moister attack, hidden damages and damage susceptibility.

Application

1. Aerospace- Approximately 50% components of the airspace is made from composites like rudder, spoilers, airbrakes, elevators, doors, engine cowlings, keel beam, rear bulkhead, wing ribs, main wings, turbine engine fan blades, propellers, Interior components etc. The primary benefits that composite components are reduced weight and assembly simplification.
2. Automotive - Composites are being considered to make low weight, safer and more fuel-efficient vehicles like steering wheel, dashboard, seat, roof, hatch, mats, energy absorber, instrument cluster, interior and exterior panel, leaf spring, wheels, engine cover etc. fabricated by composite materials. A composite is composed of a high strength fiber (carbon or glass) in a matrix material (epoxy polymer).
3. Medical- A composite is a nonviable material used in a medical device and intended to interact with biological system. Composites in the form of sutures, bone and joint replacements, vascular grafts, heart valves, intraocular lenses, restore the function of disturbed or degenerated tissues or organs, to improve function, to assist in healing, to correct abnormalities and thus improve quality of life of patients.

4. Electrical field- Composite materials have strength, high modulus; electronic composites emphasize high thermal conductivity, low thermal expansion, lower electrical conductivity depending on the particular electronic applications. The application of composites in electronics includes interconnections, printed circuit boards, thermal interface materials, connectors, heat sinks, housings etc.
5. Sports- Composite materials are used in sports equipment because they offer ease of transport, less weight, less maintenance and high durability. The planning boats, sailing boats, sailboards tennis rackets, badminton rackets, softball bats, ice hockey sticks, bows and arrows etc.
6. Chemical Industry- Composites are extensively used in industrial gratings, scrubbers, ducting, piping, exhaust stacks, pumps & blowers, structural supports, storage tanks, columns, reactors etc. for alkaline & acidic environments.
7. Other- Composites have long been used in the construction for industrial supports, buildings, long span roof structures, tanks, bridge components and complete bridge systems. With the help of composite make light weight doors, window, furniture, building, bridge etc. for domestic and construction purpose.

IV. CONCLUSION

This article attempts a reasonably comprehensive review of representative journal publications covering developments in mechanics of multifunctional composite materials and structures. Composite materials have good mechanical, electrical, chemical properties, due to which we can use composite material in many various industries and domestic purpose. Various parts of automobile & aerospace are manufactured by composite material due to good properties that's why it is preferred mostly. Composites have been increasingly used in automotive industry because of advantages like less weight, more strength, and resistance to corrosion etc. Composites have four to six times tensile strength as compare to steel or aluminum. Composite materials have high cost of material, long developme*nt time, low ductility, temperature limits, solvent or moister attack, hidden damages and damage susceptibility. Composite materials are used for domestic purpose like furniture, window, door, civil construction etc. There is a wide scope of composite material in automotive, aerospace, wind energy, electrical, sports, civil construction, medical chemical industries etc. Composite materials have attractive aspects like the relatively high compressive strength, low weight, low density and corrosion and wear resistance. With the help of review, we conclude that composite materials have wide advantages & application in various fields.

REFERENCES

[1] Jin Zhang, Khunlavit Chaisombat, Shuai He and Chun H. Wang, "Hybrid composite laminates reinforced with glass/carbon woven fabrics for lightweight load bearing structures", Materials and Design: Elsevier, Vol. 36, pp. 75-80, 2012.

[2] Z. X. Lei, K. M. Liew and J.L. Yu, "Buckling analysis of functionally graded carbon nanotube-reinforced composite plates using the element-free kp-Ritz method", Composite Structures: Elsevier, Vol. 98, pp. 160-168, 2013.

[3] Z. X. Lei, K. M. Liew and J.L. Yu, "Free vibration analysis of functionally graded carbon nanotube-reinforced composite plates using the element-free kp-Ritz method in thermal environment", Composite Structures, Elsevier,Vol. 106, pp. 128-138, 2013.

[4] Keith A. Hunten , Allison Barnard Feeney and Vijay Srinivasan, "Recent advances in sharing standardized STEP composite structure design and manufacturing information", Computer-Aided Design, Elsevier,Vol. 45, pp. 1215-1221,2013.

[5] Ronald F. Gibson, "A review of recent research on mechanics of multifunctional composite materials and structures", Composite Structures: Elsevier, Vol. 99, pp. 2793-2810, 2010.

[6] Min Wu, BjornJohannes son and MetteGeiker, "Self-healing in cementitious materials and engineered cementitious composite as a self-healing material", Construction and Building Materials, Elsevier, Vol. 28, pp. 571-583, 2012.

[7] M. A. Caminero, S. Pavlopoulou, M. Lopez-Pedrosa, B.G. Nicolaisson, C. Pinna and C. Soutis, "Analysis of adhesively bonded repairs in composites: Damage detection and prognosis", Composite Structures, Elsevier,Vol. 95, pp. 200-517, 2013

[8] Nasrullah Shah, Mazhar Ul-Islam, Waleed Ahmad Khattak and Joong Kon Park, "Overview of bacterial cellulose composites: A multipurpose advanced material", Carbohydrate Polymers: Elsevier, Vol. 98, pp. 1585-1598, 2013.

[9] E. Carrera, M. Filippi and E. Zappino, "Free vibration analysis of rotating composite blades via Carrera Unified Formulation", Composite Structures: Elsevier, Vol. 106, pp. 317-325, 2013.

[10] R. K. Garg, K. K. Singh, AnishSachdeva, Vishal S. Sharma,KuldeepOjha and Sharanjit Singh, "Review of research work in sinking EDM and WEDM on metal matrix composite materials", Metal matrix composites, Vol. 50, pp. 611-624, 2010.

[11] Prachi Singh, Nitesh Kumar, Richa Singh, Kamini Kiran and Shailesh Kumar, "Overview and recent advances in composite resin: A review", Vol. 3, (Issue 9), pp. 169-172, Dec.2015.

[12] Pilar de la Rosa Garcia, Alfonso Cobo Escamilla and M. Nieves González Garcia, "Bending reinforcement of timber beams with composite carbon fibre and basalt fibre materials"

[13] Qiang Liu ,Yongzhou Lin, ZhijianZong ,Guangyong Sun and Qing Li, "Lightweight design of carbon twill weave fabric composite body structure for electric vehicle", Composite Structures, Elsevier,Vol. 97, pp. 231-238,2013.

[14] Gourav Gupta , Ankur Kumar , Rahul Tyagi , Sachin Kumar ,Gourav Gupta ,Ankur Kumar ,Rahul Tyagi and Sachin Kumar, "Application and Future of Composite Materials: A Review", Vol. 5, Issue 5, pp. 6907-6911 May 2016.

[15] Nadir Ayrilmis, Jin HeonKwon, ***Tae***Hyung Han ***and*** Ali Durmus, "Effect of Wood-derived Charcoal Content on Properties of Wood Plastic Composites", Vol. 18 (3), pp. 654-659, 2015.
[16] Tao Yin, Min ZhiRong, Ming Qiu Zhang and Gui Cheng Yang, "Self-healing epoxy composites – Preparation and effect of the healants consisting of microencapsulated epoxy and latent curing agent", Composites Science and Technology, Vol. 67, pp. 201-212,2007.
[17] Venkata Ramana Gedela and Vadali V.S.S. Srikanth, "Electrochemically active poly aniline nano fibers coated grapheme Nano sheets/PANi NFs composite coated on different flexible substrates", Synthetic Metals, Vol. 193, pp. 71-76,2014.
[18] Oisik Das, Ajit K. Sarmah and Debes Bhattacharyya, "Bio composites from waste derived bio chars: Mechanical, thermal,chemical, and morphological properties", Waste Management:Elsevier,pp. 1-11, 2015.
[19] Vijayadurga Nallathambi, Jong-Won Lee, Swaminatha P. Kumaraguru, GangWu and Branko N. Popov, "Development of high performance carbon composite catalyst for oxygen reduction reaction in PEM Proton Exchange Membrane fuel cells", Journal of Power Source, Elsevier,Vol. 183, pp. 34-42,2008.
[20] Reza Mahmoodian , M.A. Hassan ,M. Hamdi , R. Yahya and R.G. Rahbari, "In situ TiC–Fe–Al2O3–TiAl/Ti3Al composite coating processing using centrifugal assisted combustion synthesis", Composites: Part B, Elsevier,Vol. 59, pp. 279-284,2014.
[21] N. Chawla, R.S. Sidhu and V.V. Ganesh, "Three-dimensional visualization and microstructure-based modelling of deformation in particle-reinforced composites", Acta Materialia: Elsevier, Vol. 54, pp. 1541-1548, 2006.
[22] Marianna Kouzeli, Christopher San Marchi and Andreas Mortensen "Effect of reaction on the tensile behaviour of infiltrated boron carbide-aluminium composites", Materials Science and Engineering, Elsevier, Vol. A337, pp. 264-273, 2002.
[23] Oisik Das, Ajit K. Sarmah and Debes Bhattacharyya, "A novel approach in organic waste utilization through bio char addition in wood/polypropylene composites", Waste Management: Elsevier, Vol. 38, pp. 132-140, 2015.
[24] Yingying,Qu,WenboZhang,KunDai,GuoqiangZheng,ChuntaiLiu,JingboChenandChangyuShen,"Tuning of the PTC and NTC effects of conductive CB/PA6/HDPE composite utilizing an electrically superfine electro spun network", Materials Letters, Elsevier,Vol. 132, pp. 48-51,2014.
[25] Jeong-HaYou, "Copper matrix composites as heat sink materials for water-cooled diverter target", Nuclear Materials and Energy, Elsevier,Vol. 5, pp. 7-18, 2015.
[26] C. Oikonomou, R. Oro, E. Hryha and L.Nyborg, "Effect of heat treatment in air on surface composition of iron-phosphate based soft magnetic composite components", Materials Science and Engineering, Elsevier,Vol. B189, pp. 90-99, 2014.
[27] K. A. Darling, E. L. Huskins, B. E. Schuster, Q. Wei and L. J. Kecskes, "Mechanical properties of a high strength Cu–Ta composite at elevated temperature", Materials Science & Engineering, Elsevier,Vol. A638, pp. 322-328, 2015.
[28] J. Füzer, M. Lauda, P. Kollar , M.Streckova, R.Bures , J.Kovác , M.Batkova and I.Batko, "Magnetic properties and loss separation in FeSi/MnZnFe_2O_4 soft magnetic composites", Journal of Magnetism and Magnetic Materials, Elsevier,Vol. 411, pp. 12-17,2016.
[29] S.D. Green, M.Y. Matveev, A.C. Long, D. Ivanov and S.R. Hallett, "Mechanical modelling of 3D woven composites considering realistic unit cell geometry", Composite Structures: Elsevier, Vol. 118, pp. 284-293, 2014.
[30] Tao Yin, Min ZhiRong, Ming Qiu Zhang,Gui Cheng Yang, "Self-healing epoxy composites – Preparation and effect of the healants consisting of microencapsulated epoxy and latent curing agent", Composites Science and Technology: Elsevier, Vol. 67, pp. 201-212, 2007.
[31] Lars Böger, Malte H.G. Wichmann, Leif Ole Meyer, Karl Schulte, "Load and health monitoring in glass fibre reinforced composites with an electrically conductive Nano composite epoxy matrix", Composites Science and Technology: Elsevier, pp. 1-23,2011.
[32] Franka Stahl, Stephen H. Ashworth, Klaus D. Jandt and Robin W. Mills, "Light-emitting diode (LED) polymerisation of dental composites: flexural properties and polymerisation potential", Biomaterials: Elsevier, Vol. 21, Elsevier,pp. 1379-1385, 2000.
[33] J. J. Williams, Z. Flom, A.A. Amell, N. Chawla, X. Xiao and F. De Carlo, "Damage evolution in SiC particle reinforced Al alloy matrix composites by X-ray synchrotron tomography", Acta Materialia, Vol. 58, pp. 6194-6205,2010.
[34] R. V. Silva, D. Spinelli, W.W. Bose Filho, S. Claro Neto, G.O. Chierice and J.R. Tarpani , "Fracture toughness of natural fibers/castor oil polyurethane composites" , Composites Science and Technology: Elsevier, Vol. 66, pp. 1328-1335, 2006.
[35] N. Chawla, B.V. Patel, M. Koopman, K.K. Chawla, R. Saha,B.R. Patterson, E.R. Fuller and S. A. Lang, "Microstructure-based simulation of thermo mechanical behavior of composite materials by object-oriented finite element analysis", Materials Characterization : Elsevier, Vol. 49, pp. 395-407, 2003.
[36] Vijay Kumar Thakur and Manju Kumari Thakur, "Processing and characterization of natural cellulose fibres/thermoset polymer composites", Carbohydrate Polymers: Elsevier, Vol. 109, pp. 102-117, 2014.
[37] Maria A. Lopes, Fernando J. Monteiro, Jose H D. Santos, "Glass-reinforced hydroxyapatite composites: fracture toughness and hardness dependence on microstructural characteristics" Biomaterials: Elsevier, Vol. 20, pp. 2085-2090, 1999.