STUDY AND RESEARCH ON ADDITIVE MANUFACTURING TECHNIQUES WITH FGM COMPOSITES FOR PRESSURE VESSEL- A REVIEW

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ABSTRACT:

Investigates a new technology to create functionally graded material (FGM) by additive manufacturing (AM). In particular, this paper focuses on creating grapheme-polymer composite FGM by laser-based sintering processes. Grapheme- polymer composites have received high attention in AM due to their excellent electrical conductivity, thermal stability and mechanical strength. However, AM of the grapheme-polymer composites have a huge challenge to overcome. The stress and strain solutions in laminated composite vessels are then investigated. Finally, modeling of FGM vessel reinforced by composite laminates with different lay-up is taken into consideration. The obtained results demonstrate that in the cylindrical shell reinforced by laminated composites, the maximum stress is considerably less than the maximum stress in the pressure vessels made of just composites or FGMs. Relevant to various aspects of theory and applications of FGM are reflected in this paper. They include homogenization of particulate FGM, heat transfer issues, stress, stability and dynamic analyses, testing, manufacturing and design, applications, and fracture. The critical areas where further research is needed for a successful implementation of FGM in design are outlined in the conclusions.

1.0 Introduction:

Functionally graded materials FGMs are composite materials formed of two or more constituent phases with a continuously variable composition. FGMs possess a number of advantages that make them attractive in potential applications, including a potential reduction of in-plane and transverse through-the-thickness stresses, an improved residual stress distribution, enhanced thermal properties, higher fracture toughness, and reduced stress intensity factors. A number of reviews dealing with various aspects of FGM have been published in recent years Proceedings of the international symposiums on FGM also shed light on the most recent research in these materials, their manufacturing, mechanics, thermal properties, and applications At present, FGMs are usually associated with particulate composites where the volume fraction of particles varies in one or several directions. One of the advantages of a monotonous variation of volume fraction of constituent phases is the elimination of stress discontinuity that is often encountered in laminated composites and accordingly, avoiding delamination-related problems FGM may also be developed using fiber-reinforced layers with a volume fraction of fibers that is coordinate dependent, rather than constant, producing the optimal set of properties or response In this review, our attention is concentrated on particulate-type FGM. While particulate composite materials may be locally isotropic, they are also heterogeneous due to spatial variations of volume fractions of the phases. An example of such material is where spherical or nearly spherical particles are embedded within an isotropic matrix.

Homogenization of Functionally Graded Materials:

In general, there are two possible approaches to homogenization of FGM. The choice of the approach should be based on the gradient of gradation relative to the size of a typical representative volume element RVE In the case where the variations of the material properties associated with gradation are relatively slow-changing functions of spatial coordinates, standard homogenization

methods can be applied. Accordingly, the material is assumed locally homogeneous at the RVE scale constant constituent phase volume fractions and homogeneous boundary conditions but it is globally heterogeneous on the macroscopic structural scale. The approach based on the assumption that the material remains homogeneous at the RVE scale and utilizing existing homogenization methods relies on their accuracy. The principal difference in the results available from various homogenization methods is related to a degree these methods account for the interactions of adjacent inclusions. The simplest approach, so-called dilute model, and neglects this effect altogether, while more advanced averaging techniques, such as MoriTanaka and self-consistent methods, include the interaction through various mechanisms.

Heat Transfer in Functionally Graded Material:

A typical FGM structure is affected by temperature both at the manufacturing phase and during its lifetime. Accordingly, it may be necessary to estimate postprocessing residual stresses due to thermal mismatch between the constituent materials, such as ceramic and metal phases in a ceramic-metal FGM. Such micromechanical stresses may cause initial damage, affect the lifetime stress distribution, and damage onset and propagation. For FGM in high-temperature environments, the temperature distribution in the material and associated thermal stresses at both macromechanical and micromechanical levels during its lifetime should also be considered.The closed form asymptotic solution was obtained by subdividing the strip into a number of homogeneous layers. The transient heat transfer problems for a FGM strip and for an infinitely long FGM cylinder subjected to stationary thermal loads and to thermal shock were solved by a local boundary integral method the transient heat transfer problem was also solved using the Galleria boundary element method for a number of configurations such as a 3D FGM cube subjected to a prescribed heat flux regime and a cylinder with a constant surface temperature Chen and Tong used a graded finite element approach to analyze the sensitivity in the problems of steady state and transient heat conduction in FGM The problem of optimization of FGM can be formulated using this solution yielding the rate of changes in the response with respect to design variables, i.e., performing a sensitivity analysis.

2.0 Objectives:

- To review the different researches made manufacturing techniques with FGM composites
- To understand the behavior of FGM composites.
- To non-graded composite under mixed mode loading conditions.

3.0 Literature review:

[1]**A. Mortensen and S. Suresh(1995)**presented in two sections an overview of the processing techniques, the performance and the thermo-mechanical analysis of functionally graded materials. The first section concentrates on constructive & transport-based production processes. Constructive methods represent FGM gradients by selectively stacking of two or more base materials and allowing programmed composition gradient control since they mainly employ powder consolidation processes such as solid state powder metallurgy or reactive sintering and coating methods such as plasma spraying and vapour deposition. Whereas in transport-based processes, natural transport phenomena such as the transport of heat, mass or fluid are used to develop compositional and micro-structural gradients during the production of FGM. A time scale analysis is carried out for the corresponding transport phenomenon and validation studies are carried out to test the role and importance in both methods of FGM production.

[2]J. N. Reddy (2000)presented analytical Napier's solutions for rectangular FGM plates, and third-order shear deformation plate theory was used for developing finite element models. The formulation assumes

the parameters of the thermo-mechanical coupling, the time dependency and the geometric non-linearity of Karman. A simple Power-law distribution with respect to the volume fractions of the constituents is used to vary the material properties of the FGM plate. It is found that fundamental response of FGM plates is not necessarily between ceramic and metal. For all types of boundary conditions, it is concluded that without thermal stress, the response of FGM plate is in between the metal and ceramic plates, but this does not apply when thermo-mechanical stresses are applied. The gradation in the material properties plays an important role in the determination of the response of FGM plates.

[3]P. Xu, J.Y. Zheng , P.F. Liu, (2009) Carbon fiber/epoxy composites have been increasingly used to develop the lightweight high pressure hydrogen storage vessel in areas of the hydrogen fuel cell vehicle. In this research, a 3D parametric finite element model is proposed to predict the damage evolution and failure strength of the composite hydrogen storage vessels, in which a solution algorithm is proposed to investigate the progressive damage and failure properties of composite structures with increasing internal pressure. The maximum stress, The birth-to-death element technique in the finite element analysis is used to describe the mechanical properties of carbon fiber/epoxy composite elements. Parametric studies in terms of the effects of different failure criteria are performed and the calculated failure strengths of composite vessels are also compared with the experimental results.

[4]A.R Ghasemi, A. Kazemian (2013)stress and strain in vessels made of FGMs is studied first. It is assumed that the elasticity modulus follows a power law distribution in the thickness direction and Poisson's ratio considered to be constant for simplicity.The stress and strain solutions in laminated composite vessels are then investigated. Finally, modeling of FGM vessel reinforced by composite laminates with different lay-up is taken into consideration. The obtained results demonstrate that in the cylindrical shell reinforced by laminated composites, the maximum stress is considerably less than the maximum stress in the pressure vessels made of just composites or FGMs.

[5] D. V. Kubair (2013) worked on closed-form expressions for the elastic fields (stresses, stress-gradients, strains, and displacements) in radially graded continua without andwith circular holes are derived. The stress concentration factor increases when the rigidity modulus progressively decreases away from the center of the hole (softening materials). The stress concentration desirably reduces in hardening materials in which the rigidity modulus progressively increases away from the hole. In hardening materials, the propensity of damage reduces with increase in the in homogeneity length-scale due to the stress dilution.

[6] G. Romeo, F. Danzi, E. Cestino, F. Borello (2013) presented work on designing Very-Long Endurance Solar Powered Autonomous Stratospheric UAV. This UAV could play the role of a pseudo satellite and could offer the advantage of allowing a more detailed land vision due to its relative closeness to land (17-20 km) at a much lower cost than a real satellite. Two different configurations are under investigation in order to decide on the best solution that will completely satisfy the a priori imposed constraints. In recent years, the aeronautical community has increasingly focused on the design of solar powered platforms and zero emission airplanes; a coupled system (solar array and hydrogen fuel cells) can be used to supply energy throughout the entire day in order to ensure the continuous flight for several months. As known, a fuel cell system requires at least a couple of external tanks for fuel storage. Hydrogen and oxygen are stored using a pressure vessel installed inside the wing. In this way, the stored gases are subjected not only to pressure loads but also to in-flight

loads that can abruptly change the optimum layout required to satisfy regulation requirements. A parametric analysis has been performed to define the optimum layout and the number of tanks necessary to supply the required power.

[7]Avinash R. Kharat, V. V. Kulkarni (2013) reviewed some of the current developments in the determination of stress concentration factor in pressure vessels at openings. The literature has indicated a growing interest in the field of stress concentration analysis in the pressure vessels. The motivation for this research is to analyze the stress concentration occurring at the openings of the pressure vessels and the means to reduce the effect of the same. Most of the researchers have worked on the stress concentration occurring at circular and radial openings in the shell under internal pressure. Also some of the researchers have worked on holes in the end covers. In this paper the recent developments, theories for estimation of stress concentration are presented and the scope for future studies is also presented.

[8] M. Tajik , F. Pellicano (2014) The present research aims to investigate the vibration characteristics of stiffened composite cylindrical shells using experimental, numerical and analytical techniques. The specimens are fabricated from continuous glass fiber (GFRP) using a specially-designed filament winding setup. The theoretical formulation is established based on Sanders' thin shell theory. In the analytical approach, a smeared method is employed to superimpose the stiffness contribution of the stiffeners with those of shell in order to obtain the equivalent stiffness parameters of the whole panel. Using the Ritz method, the governing eigenvalue equations are obtained and will then be solved for evaluating the natural frequencies of the GFRP stiffened composite shells. In order to validate the analytical achievements, experimental modal analysis is conducted on a stiffened cylinder.

[9] Kim, Seul-kee Kim, Dong-Man Ryu, Jae-Myung Lee (2014) In the present study, an evaluation method for the initial and progressive failure of composite laminates was proposed based on the Puck failure criterion and damage mechanics, respectively. In other words, the initial failure (crack initiation in the fiber and/or matrix) and progressive failure (crack growth in the fiber and/or matrix) were evaluated using the Puck failure criterion, and fiber- and matrix-dependent damage variables, respectively. In addition, the Surer-defined subroutine UMAT was developed based on coupling theories for the failure criterion and damage mechanics in order to efficiently analyze the progressive failure phenomenon in glass/carbon fiber-reinforced composite laminates.

[9] AvinashR.Kharat, V. V. Kulkarni (2014) presented work on the analysis of variance method which is used to serve the relation between nozzle size and stress produce in the nozzle area. To reduce the errors in the experimental result the randomize sequence method is used. To test the influence of the both parameters that is opening diameter and internal pressure on each other the randomized test sequencing is generated and experimental test is conducted to investigate the stress distribution near opening area.

[10] Dr.SabahKhan(2015)A functionally graded material (FGM) is a two component composite characterized by a compositional gradient from one component to other. In a traditional composite, which is basically a homogeneous mixture of its constituents the pure identity of each constituent is altogether lost and thus we have to make a compromise between the desirable properties of the constituent materials and our requirement.FGM are becoming one of the potential advanced materials for most of the tribological applications. Since the FGMs are produced to achieve a certain property requirement in particular positions of a component, it is better to work out an inverse design in developing

the functionally gradient materials for the specific application or component. There is vast potential for the development of new functionally graded composites as well as new processing methods.

[11] M.A. Caminero , G.P. Rodríguez, V. Muñoz (2015) worked on the characterization and the assessment of the damage in CFRP composite laminates with different stacking sequences subjected to low velocity impact and flexural loading. Chirpy impact test and three-point bending test were used in order to obtained the impact response and flexural behavior of different laminates. An experimental test series was carried out to determine impact energy absorption, flexural strength and stiffness and failure mechanisms of composite laminates made from M21E=IMA, an unidirectional prepreg used in Airbus A350 XWB primary structures.

[12] K. Swaminathan, D.M. Sangeetha (2016) presented a comprehensive review of developments, applications, various mathematical idealizations of materials, temperature profiles, modeling techniques and solutions methods that are adopted for the thermal analysis of FGM plates. An attempt has been made to classify the various analytical and numerical methods used for the stress, vibration and buckling analyses of FGM plates under one-dimensional or three-dimensional variation of temperature with constant/linear/nonlinear temperatures profiles across the thickness. An effort has been made to focus the discussion on the various research studies carried out till recently for the thermal analysis of FGM plates.

[13] Yogesh Kumar Bhardwaj1 ,VikasBansal (2016) Functionally graded cylindrical shell is analyzed which is subjected to the internal pressure. In most of studies its thermal aspect is studied but here we analyze how it respond to the pressure loading.To eliminate the effect of boundary condition on stress, the stress results are read far from the vessel edge. The element to the model in simulation used is triangular with fine meshing with total degree of freedom 2064. For the simulation perform by 2D – axissymmetric physics with stationary solution is selected.

[14] IkHyeon Choi (2016) analyzed the transient response and damage of pressurized vessels subjected to a drop impact or foreign object impact; we must consider the change in stiffness due to pre-stress. The pre-stress condition induces a phenomenon where thin plates with in-plane pre-stress show different stiffness during out-of-plane deflections compared to the original plate without the in-plane pre-stress. Because the cylindrical wall of a pressurized vessel is under in-plane pre-stress induced by the vessel's internal pressure, we must consider the 'change in stiffness' to accurately analyze the impact response and damage. In this study, we investigated the low-velocity impact response of a composite laminated cylinder wall of a pressure vessel with high internal pressure. The shear deformation theory of a doubly curved shell and von Karman's large deflection theory, as well as a newly proposed strain–displacement relation including initial strain terms to consider the stiffness change induced by cylinder stress due to internal pressure,

[15] Young Chang Kim, Sang Won Lee (2017)investigates a new technology to create functionally graded material (FGM) by additive manufacturing (AM). In particular, this paper focuses on creating grapheme-polymer composite FGM by laser-based sintering processes. Grapheme-polymer composites have received high attention in AM due to their excellent electrical conductivity, thermal stability and mechanical strengthmixing grapheme and polyethylene powders before sintering, and depositing the different material powders separately and sintering them. This study identified that the two methods led to different mechanical and electrical properties of the created parts.

[16] AvinashKharatSuyash Kamble (2017) The literature has indicated a growing interest in the field of stress concentration analysis and progressive failure analysis in the pressure vessels. The motivation for this research is to analyze the stress concentration, Stress and failures occurring at the openings of the pressure vessels and the means to reduce the effect of the same.Stress analysis is one of the important factors to be studied in the pressure vessels openings. A review of the literature related to the stress concentration and progressive failure in pressure vessels is presented. Majority of the researchers have worked on cylinders/shell and laminated plate.

[18] Pankaj Bohra1, Dr. Manish Bhandari (2017)studies are reported for predicting the vibration characteristic of Functionally Graded Material plate subjected to both mechanical and thermal loadings. This article presents a complete review of application of FGM, various processing methods of FGM, developments, different mathematical idealizations of functionally graded materials, modeling techniques, temperature profiles and various solution methods and techniques which are adopted for the vibration analysis of FGM plates.FGM plates and therefore the effect of transversal displacement terms of higher order must be used for an accurate prediction of responses.

[19] Yang Dai, MiaolinFeng, Min Zhao (2017) presented solution for the topology structures of composite laminates with design-dependent loads. The methodology is based on the isoline method, the sensitivity filter with density gradient weighting, and the solid isotropic material with penalization (SIMP) method. In addition, the element stiffness matrix for composite layups is derived. Two- and three-joint constraint examples of the topology optimization design for composite structures are presented. The work efficiency of the isoline method and the distance regularized level set evolution (DRLSE) method are compared; five other filtering methods are also studied. The distribution rule of solid material and the relationship between the minimum compliance of optimal structures and the principal angle of composite layups are discussed.

[20] Gargano, K. Pingkarawat, Mouritz (2017) presented an experimental investigation into the explosive blast response of fiber-reinforced polymer laminates used in naval ship structures. Blast tests using plastic explosive charges were performed in air on square target plates made of carbonpolyester, glass-polyester, carbon-vinyl ester or glass-vinyl ester laminates, which are composite materials used in naval ships. The laminates were dynamically loaded by shock waves of increasing pressure and impulse, and the deformation, damage and residual mechanical properties were determined. The amount of blast-induced damage and the post-blast mechanical properties depend on both the fibre reinforcement and polymer matrix. E-glass laminates have higher resistance to blast-induced delamination cracking and tow rupture than carbon fibre composites. Furthermore, glass or carbon fibre laminates with a vinyl ester matrix have superior blast damage resistance compared to composites with a polyester matrix.

4.0 Results and discussions

References	Year	Study	Results
Gargano, K. Pingkarawat, Mouritz	**2017**	investigation into the explosive blast response of fiber-reinforced polymer laminates used in naval ship structures	Amount of blast-induced damage and the post-blast mechanical properties depend on both the fibre reinforcement and polymer matrix.
Pankaj Bohra1, Dr.	**2017**	complete review of	FGM plates effect of

Manish Bhandari		application of FGM, various processing methods of FGM, developments	transversal displacement terms of higher order must be used for an accurate prediction of responses.
AvinashKharatSuyash Kamble	**2017**	field of stress concentration analysis and progressive failure analysis in the pressure vessels	the stress concentration and progressive failure in pressure vessels is presented.
AvinashR.Kharat, V. V. Kulkarni	**2014**	Presented work on the analysis of variance method which is used to serve the relation between nozzle size and stress produce in the nozzle area.	Generated and experimental test is conducted to investigate the stress distribution near opening area. .
M. Tajik , F. Pellicano	**2014**	present research aims to investigate the vibration characteristics of stiffened composite cylindrical shells	solved for evaluating the natural frequenciesof the composite cylindrical shells
Avinash R. Kharat, V. V. Kulkarni	**(2013)**	developments in the determination of stress concentration factor in pressure vessels at openings.	developments, theories for estimation of stress concentration are presented and the scope for future studies is also presented

Discussions:

FGMs have revolutionized the field of modern materials science by incorporating graded microstructure and have proven to be a multifunctional material in the management of extreme conditions more effectively. The flexibility in the design and its performance in thermal environments are the main reasons for its possible applications in various sectors. Therefore, the modeling and analysis of FGM are extremely important for the development of this new emerging material.In general, the material properties in FGMs vary across the thickness of the plate while the in-plane is homogeneous. Therefore, it is assumed that the temperature fluctuations occur only in the thickness direction and are evaluated in different ways.Most helicopters, combat aircraft, armor, weapons and armor are made of FGMs. These have good damping properties with thermal and chemical inertness and are therefore used in hull tanks, stabilizers, rotor blades, aircraft wings, low temperature fuel tanks, gas turbines, nozzles and compressor components of combat aircraft and aircraft engines Helicopter. Ultra-light FGMs are used in the defense sector to develop weapon platforms, armor plates, barrier materials, bullet-proof jackets, etc. Military submarine components such as Sonar Dome Composite piping systems are manufactured with Glass / Epoxy FGM, Drive Shafts with Carbon / Glass Fiber FGM, Cylindrical Pressure Sleeves with Graphite

Conclusions:

In this study, a new method to reinforce the FGM cylindrical pressure vessel by the composite laminates is presented. Analysis of the stress and the strain in the pressure vessel made of functionally graded material are studied, analytically and numerically. The results of the FEM are in good agreement with the exact solution. This results show that the FEM is sufficiently accurate for modeling the FGM vessel. In the FGM vessel the radial stress increases and the circumferential stress decreases with increasing of in-homogeneity constant results show that in the hybrid vessel stress distribution depend on stacking sequences of composite cylindrical vessel, directly, so that if the layup stacking sequence is being symmetric/unsymmetrical, the stress distribution is symmetric non symmetric, respectively. Also, the stress values of composite layers usually are very high.Although experimental investigation methods for predicting the individual thermo physical material properties, microscopic investigations have to be carried out and quantitative relationships have to be determined for the precise assessment of the physical and thermal properties of graded materials. These relationships are used with different theories for the analytical or numerical evaluation of different FGM plate reactions. In this paper, various theories and mathematical idealizations techniques for the stress, vibration analysis of FGM plates exposed to thermal stresses

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