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Analysis of Elastic-Plastic Behavior of Fiber Metal Laminates Subjected to In-Plane Tensile Loading

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ABSTRACT

Fiber metal laminates square measure hybrid laminates consisting of skinny alternating warranted layers of Al and fiber/epoxy. ARALL (Aramid Al laminate) and GALARE (glass fiber bolstered Al laminate) square measure specific forms of fiber metal laminates that comprises skinny Al sheets together with Kevlar/Epoxy and Glass/Epoxy composite layers, severally. during this study, nonlinear tensile behavior of GLARE fiber metal laminates underneath in-plane loading conditions has been investigated. thanks to the elastic-plastic behavior of Al layers, elastic analyses aren't enough to accurately predict the tensile response. Thus, it's necessary to contemplate and make a case for the inelastic deformation behavior of GLARE laminates once yielding of Al alloy layers. 2 acceptable analytical approaches, the orthotropic physical property and changed classical laminated plate theories, are wont to predict the stress-strain response and deformation behavior of GLARE laminates. a suitable agreement was ascertained between the 2 models. Results show that the GLARE behavior is sort of additive underneath tensile loading condition and also the enduringness of simplex GLARE laminates square measure well stronger than Al alloys within the longitudinal direction.

1 INTRODUCTION

Fiber-Metal Laminates (FMLs) square measure hybrid laminates designed up from skinny Al alloy sheets warranted into laminates by intermediate skinny fiber/epoxy layers. Their behavior may be a mixture of metals and composites, they need high injury tolerance properties, and were primarily developed for part applications wherever smart fatigue properties and high strength square measure necessary [1]. style and development of advanced composite materials have invariably attracted nice interests to boost mechanical properties and their performance in advanced structures like craft structures [2, 3]. Recent advances exploitation composites in trendy craft construction were reviewed and carbon fiber composites were significantly argued in terms of style, manufacture and applications [4]. Fiber Metal Laminates were developed at earthenware University of Technology within the The Netherlands by L. B. Vogelesang [5]. the fundamental plan for the event of fiber metal laminates was to develop a fabric with a high crack growth resistance for fatigue prone areas of contemporary civil craft [5, 6]. it's reportable that FMLs originated at Fokker/TU earthenware within the The Netherlands concerning Seventies, and since then have undergone intensive development [7, 8]. Al alloys square measure most ordinarily utilized in FMLs as metal, and also the fibers is Kevlar or glass [9]. the primary business product of FMLs underneath the brand ARALL, together with Kevlar/Aramid as fibers, was launched by ALCOA in 1982 for craft wing application. A patent on GLARE was filed in Oct 1987 by AKZO that was composed of Al alloy sheets and simplex or biaxal bolstered high strength glass fiber/epoxy composite layers [10, 11]. the most reason for switch to glass fibers is that aramid fibers failing at some loading conditions. But, fiber failure is unacceptable for the wonderful fatigue resistance of FML. The fibre ply in GLARE doesn't have the disadvantage of failing fibers, and thus GLARE became the foremost necessary variant for FML [12]. Recently, GLARE laminate was selected for the higher body skin structures of airliner A380. this can be the primary structural application of GLARE laminate in an exceedingly business air-line. every A380 can have concerning 380 m of GLARE. The GLARE laminates are applied within the leading edges of the vertical and stabilizer planes of the A380 [9]. Limiting attention to the mechanical properties and above all to the tensile response, it's been shown [13, 14] that the stress-strain curve of Associate in Nursing FML is very nonlinear, chiefly reflective the physical property of the metal sheets. it's well documented that FMLs mix the sturdiness of metals with the spectacular fatigue and fracture properties of fiberreinforced composite materials [15, 16]. Krishnakumar [15] showed that the enduringness of the many fiber-metal laminates is superior thereto of ancient aerospace-grade Al alloys. Wu et.al investigated the in-plane mechanical properties of GLARE four with 2/1, 3/2 and 5/4 lay-up. The mechanical properties of GLARE4 were additionally foreseen exploitation the metal volume fraction approach supported a rule of mixtures [17]. Nahas conferred many models for nonlinear deformation of FMLs [18]. Since, GLAREs comprises Al layers and Al has nonlinear behavior, so elastic analysis isn't enough therefore a model for actual prediction of nonlinear tensile response should be conferred. to attain such a model, glass/epoxy composite ought to be sculptured as Associate in Nursing orthotropic linearly elastic solid Associate in Nursingd Al is assumed as an elasto-plastic solid. within the gift analysis, the nonlinear tensile response of GLARE laminate is investigated underneath static tensile loading condition. 2 approaches as orthotropic physical property and changed laminated plate theories square measure wont to predict the stress-strain response and deformation behavior of GLARE laminate. within the orthotropic physical property model, a 3 parameter plastic potential perform is employed. within the second theory, the composite layers and Al sheets square measure assumed to be linearly elastic and orthotropic elastic–plastic solids, severally.

2 CASE STUDY

Several GLARE grades square measure commercially accessible (see Table (1)). each grade is designed up in many various thicknesses, e.g., the lay-up of a GLARE five variant with a alleged '2/1 lay-up' as shown in Fig. one is: 2024-T3 Al/ o zero glass fiber/ o ninety glass fiber/ o ninety glass fiber/ o zero glass fiber/ 2024-T3 aluminum during which the zero direction is that the longitudinal direction (i.e., the rolling direction) of the Al layers.

- it's the fatigue behavior of Associate in Nursing Al alloy, though the fiber layers of the fabric improve this behavior considerably.
- GLARE is plagued by hot-wet ageing underneath accelerated conditions, like composites. However, wet absorption (through the polished edges only) and property reductions square measure less compared to glass composites thanks to the big quantity of unaffected Al within the material.
- the particular weight of GLARE is close to 100% not up to that of Al.
- GLARE is formable to several single and double sickle-shaped shapes (Fig. 6).
- GLARE enduringness is considerably beyond one.5 × yield stress.
- GLARE blunt notch strength is commonly one among the governing style values.
- GLARE is machined exploitation similar tools (hard metal steel) and procedures as for Al alloys.
- GLARE is repaired exploitation Al kind repair configurations and procedures.

In this paper, the nonlinear tensile response of selected cross-plied GLARE four and GLARE five laminates is investigated underneath static tensile loading conditions. GLARE 4-3/2 consists of 3 layers of 2024-T3 Al alloy sheets and 2 layers of 70/30 glass prepreg with sixty seven of fibers within the 0˚ direction and thirty third fiber within the 90˚ direction.

3 ANALYTICAL PREDICTION BY CHANGED LAMINATED PLATE THEORY

An analytical model incorporating the elasto-plastic behavior of Al sheets of GLARE is employed to see the stress-strain relation of GLARE. the foremost necessary assumptions for composite analysis assessed by changed Laminated Plate theory square measure: composite fibers within the layers are parallel, distance between fibers in layers square measure equal, fibers square measure stretched on all layers and cross at some sections, and fibers square measure in excellent matrix bonding [19]. For a general orthotropic laminate subjected to in–plane loading, strain varies linearly in thickness direction however stress vary simply linear in thickness direction in any layer.

3.2. Constituent Model for 2024 – T3 Al

In this study, the 2024- T3 Al is taken into account to be orthotropic elasto–plastic solid. Thus, it's necessary to divide 2024–T3 Al alloy into 2 models, that the primary model denotes elastic deformation and also the second model describes plastic deformation behavior.
where a11 denotes the distinction between the plastic parts of longitudinal and cross directions. during this study, the ability law is employed to point out the link between the effective stress and also the effective plastic strain as outlined below used.

4 ASSOCIATE IN NURSING ORTHOTROPIC PHYSICAL PROPERTY MODEL

The Second approach for achieving a nonlinear GLARE response is Associate in Nursing orthotropic physical property model. The case being analyzed is Associate in Nursing, in plane plastic potential perform with 3 parameters [21].
To complete the stress-strain progressive plastic relation, the relation between the effective stress and effective plastic strain ought to be calculable. Thus, the ability law ought to be used as [21]

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5 RESULTS AND DISCUSSION

In order as an instance the behavior of the GLARE 4-3/2 and GLARE 5-2/1 underneath longitudinal and cross loading conditions, the subsequent table is conferred.

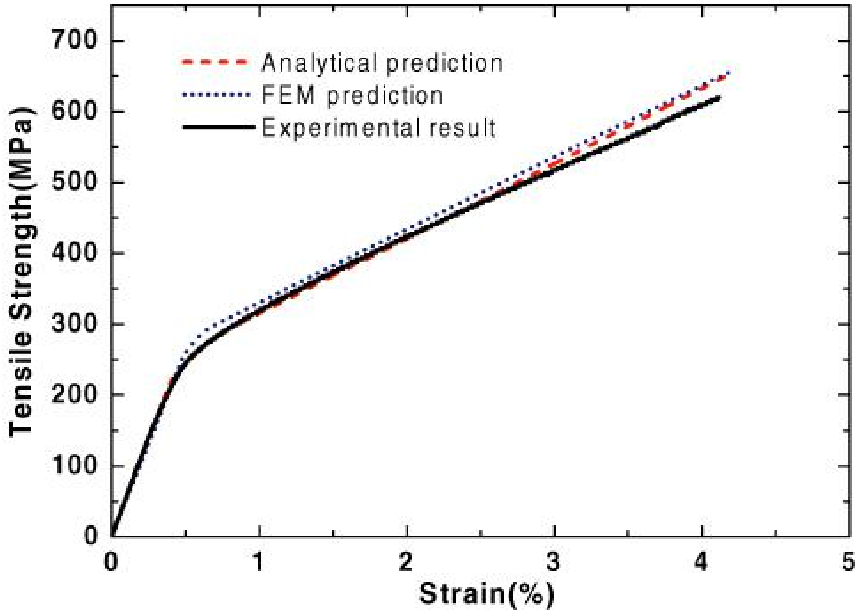

Fig:-1 The Poisson's ratio response in longitudinal direction for GLARE 4, 5

The tensile response of GLARE 4-3/2 and GLARE 5- two/1 square measure conferred in figures 2 and three. As delineated within the mentioned figures, it is all over that each GLAREs' behavior vary nearly linearly in plastic half just like elastic region within the longitudinal loading. within the cross loading, the same stress-strain response to the longitudinal direction is obtained. This explains that GLARE 4-3/2 and GLARE 5-2/1exhibit a additive stress-strain behavior within the each longitudinal and cross directions. Results show that the stress–strain relation of GLARE 5-2/1 is analogous thereto of GLARE 4-3/2. However, GLARE 5-2/1 exhibits constant modulus in each the longitudinal and cross directions thanks to the 0˚/90˚/90˚/0˚ Glass/epoxy layers. Of course, the stress-strain response specifications like yield stress, hardening modulus and tensile fracture stress within the cross loading square measure not up to longitudinal direction thanks to 0˚/90˚/90˚/0˚ orientation of fibers. It is seen that each GLAREs has 2 completely different slopes in elastic and plastic components.

5.1. Elasto–plastic deformation of GLARE via Orthotropic physical property Model

By considering the orthotropic physical property model for the GLARE laminate, all longitudinal stress-strain curves ought to get replaced by one curve indicating effective stress and effective plastic strain. this can be the premise for determinant the values of eleven twelve a ,a and a66 within the plastic potential perform. From Eq.

6 CONCLUSIONS

In this paper the nonlinear behavior of GLARE 4-3/2 and GLARE 5-2/1 underneath in–plane tensile loading has been investigated. 2 approaches specifically orthotropic physical property and changed laminated plate theories were wont to predict the elastic-plastic behavior of GLARE laminates. within the changed laminated plate approach, Al layers in GLAREs are sculptured as orthotropic elasto-plastic solids and Glass/epoxy layers are thought-about as orthotropic linearly elastic solids. Results showed that GLAREs square measure stronger than Al alloy and stress-strain relations square measure nearly additive in each longitudinal and cross directions. The stress-strain response indicates that each GLAREs have additional strength in longitudinal direction compared to cross direction. Analytical predictions by changed laminated plate theory showed smart agreement with results of orthotropic physical property model. it's been seen that Poisson's quantitative relation response in GLARE five is not up to the similar case in longitudinal loading of GLARE four thanks to o o o o zero /90 /90 / zero orientation of fibers.

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