SURVEY OF THE STATE OF THE ART COMPOSITES AND SANDWICH STRUCTURES**CORNEL Bucur,***Ph.D. student Technical University of Cluj-Napoca, Manufacturing Engineering Department, Cluj-Napoca, Romania, cornel_bucur85@yahoo.com***ANA MARIA Bucur,***Ph.D. student Technical University of Cluj-Napoca, Manufacturing Engineering Department, Cluj-Napoca, Romania, anamaria.varvorea@yahoo.com*

Abstract: *The objective of the work is to present some researches regarding composites. The aim is motivated by the new materials such as composites and structural concepts, sandwich construction that have resulted in lighter structural designs with superior performance. There are presented and discussed the types of matrix materials, sandwich construction, failure modes in sandwich structures and design considerations. It is not possible to cover every aspect of this vast subject. The purpose here is to impart the basic knowledge so that the people involved in the structural repairs will have better understanding of the processes.*

Key words: composite, matrix materials, sandwich construction

Introduction

A composite material consists of two or more constituent materials combined in such a way that the resulting material has more useful applications than the constituent materials alone. The constituent materials play a key role in the development of the final material properties. Advanced composite materials used in structural applications are obtained by reinforcing a matrix material with continuous fibers having high strength and stiffness properties. The selection of a composite material for any application will involve selection of reinforcing fiber and matrix, and their fractional volume in the resulting material. A properly selected combination will give a composite material with following advantages:

- High strength and stiffness-to-weight ratio;
- Low weight;
- Excellent corrosion resistance;
- Excellent fatigue resistance ;
- Can be “tailored to fit”.

New materials such as composites and structural concepts such as sandwich construction have resulted in lighter structural designs with superior performance[1]. The development of composite materials over last few decades has influenced every field of human life be it civilian or military. In military arena, one finds application of composites in almost every aerospace structure, ships, tanks, and marine structures. On civilian side one finds use of composites in bridges, sporting goods, repair of existing steel and concrete structures, enhancing earthquake resistance of existing structures, etc[2]. One of the most common composites is concrete. This material is made of loose stones and held together with a cement matrix. Concrete has superior properties than cement, being able to resist to higher compressive force. The main disadvantage remains the fact that it cannot sustain tensile loading. The solution to this problem is still the reinforcement with steel bars.[9]

2. Matrix materials

There are mainly three different types of matrix materials- organic polymers, ceramics and metals.

- First type of composite material is the ceramic matrix which is made of ceramic fibers put together in a ceramic matrix, resulting a reinforced ceramic fiber material(CFRC).[10]

- The composite that contains two constituent parts, that can be two metals, or one metal and another material are named metal matrix composites(MMC). The MMC's can be reinforced with another material resulting a composite with improved characteristics. A hybrid composite appears when more than two constituent parts are joined together. Depending of their application, the MMC can be composed of different metals, such as: aluminum, titanium, magnesium; nickel and cobalt can be used for a higher temperature resistance. The strong points of MMC's are the improved mechanical and thermal resistance, also higher electrical conductivity and better resistance to radiation effects.[10]
- The last type of matrix material is the polymer matrix composite(PMC). PMC's are mainly used because they have a simple and easy fabrication process. They are lighter than other composites, having a lower density, but still have good mechanical resistance, anticorrosive properties and good electrical conductivity. PMC's are divided in three categories: rubber, thermoplastic and thermoset.[10]

The majority of composites currently used are polymeric matrix composites. The selection of the matrix material is primarily governed by the service temperature. Polymeric matrices are useful up to temperatures of about 2500C. Most of the aluminum metal matrices are good for temperatures up to 2500C. Titanium matrices are good for temperatures up to 3500C. Ceramics can withstand temperatures exceeding 10000C. The MMC system is usually designated by the metal alloy, ceramic reinforcement and material type (fig. 1)[11]. Metals are extremely versatile engineering materials.[3]

Figure 1. Different kinds of reinforcement in composite materials

The manufacturing of composites involves several operations depending on available technology, facilities and personnel skills. A typical manufacturing process starts with receiving the materials that may include tapes, broad goods, and adhesives(fig.2). The materials are checked by quality assurance personnel to verify that the materials meet the necessary specifications. The materials are then stored in the freezer. As per the drawing requirements, the prepreg is cut to the required shape either manually with a knife or with a reciprocating cutter, or with a controlled knife. The required tooling is matched with the prepreg. The tooling undergoes preparation as per manufacturing requirements. The amount of time prepreg remains outside the freezer is closely recorded.

Figure 2: Overview of Manufacturing Process

2.1 Sandwich construction

Sandwich construction has found extensive application in aircraft, missile and spacecraft structures due to high strength to weight ratio. This type of construction consists of thin, stiff and strong sheets of metallic or fiber composite material separated by a thick layer of low density material as shown in figure 3. The thick layer of low density material commonly known as core material may be light foam type (e.g. Nomex core or Rohacell fig. 3a) or metallic honeycomb as shown in fig. 3b or corrugated core as shown in fig. 3c. The core material is generally adhesively bonded to the face sheets[6].

Figure 3- Honeycomb Construction

In some sandwich construction the core may be made of metallic or composite material corrugations. The corrugated core may be adhesively bonded, rivet bonded or weld bonded if the face sheets are metallic material. For sandwich construction using composite face sheets, the core may be bonded or co-cured with face sheets. A sandwich construction has following advantages:

- High ratio of bending stiffness to weight as compared to monolithic construction.
- High resistance to mechanical and sonic fatigue.
- Good damping characteristic.

- Improved thermal insulation.
- No mechanical fasteners, hence, no crack initiation sites.

The main disadvantages of honeycomb construction are:

- In-service trapped moisture in the core material causes corrosion problems.
- A good quality control is needed during the fabrication process to make sure that there is no disbonding in the adhesive layer.

2.2 Failure mode

Failure modes in sandwich structures are different from those in monolithic structures. The general failure modes that might occur in sandwich structures, depending on the design and core material, are shown in fig.4

Figure 4- Failure Modes in Sandwich Structures

General Buckling- The general buckling of a panel might occur if the panel thickness is not sufficient or core rigidity is insufficient.

Shear Crimping- This occurs as a consequence of general buckling. It is caused by low core shear modulus or low adhesive shear strength.

Face Wrinkling- In this failure mode, a face sheet buckles acting as a “plate on an elastic foundation” with core acting as an elastic foundation. The wrinkling of face sheet may occur inwards or outwards depending on relative strength of core in compression and adhesive strength in tension. **Intracell Buckling (Dimpling) -** This failure mode occurs in panels with cellular cores due to thin face sheets or large core cell size. This failure mode may propagate in adjoining cells and thus causing face sheet wrinkling.

Face Sheet Failure- This failure mode is caused by insufficient panel thickness, face sheet thickness or face sheet strength.

Transverse Shear Failure- This type of failure mode is caused by insufficient core shear strength or panel thickness.

Flexural Crushing of Core- This is caused by insufficient core compressive strength or excessive panel deflection.

Local Crushing of Core- This failure mode is caused by low core compressive strength.

2.3 Design Considerations

A sandwich structure is designed to make sure that it is capable of taking structural loads throughout its design life. In addition, it should maintain its structural integrity in the in-service environments[8]. The structure should satisfy the following criteria:

- The face sheets should have sufficient stiffness to withstand the tensile, compressive, and shear stresses produced by applied loads.

- The core should have sufficient stiffness to withstand the shear stresses produced by applied loads.
- The core should have sufficient shear modulus to prevent overall buckling of the sandwich structure under loads.
- Stiffness of the core and compressive strength of the face sheets should be sufficient to prevent the wrinkling of the face sheets under applied loads.
- The core cells should be small enough to prevent inter-cell buckling of the face sheets under design loads.
- The core shall have sufficient compressive strength to prevent crushing due to applied loads acting normal to the face sheets or by compressive stresses produced by flexure.

Conclusions

From the theoretical research from this paper it can be take out the next important conclusions:

- composite materials technology has made tremendous strides in last couple of decades. Advanced resin systems, fibers, manufacturing technology, and new design concepts have been developed
- the selection of a composite material for any application will involve selection of reinforcing fiber and matrix, and their fractional volume in the resulting material
- the metal matrix is reinforced with the other material to improve strength and wear
- a sandwich structure is designed to make sure that it is capable of taking structural loads throughout its design life. In addition, it should maintain its structural integrity in the in-service environments.
- sandwich materials (face sheet, core and adhesive) should maintain the structural integrity during inservice environments.

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