AC 2009-1670: INTRODUCTION TO REENGINEERED MATERIALS

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INTRODUCTION TO REENGINEERED MATERIALS

Abstract

In the recent years US aerospace, trucking, heavy equipment industry and civil infrastructure is facing with challenging problems of aging metal components. These components are typically made out of structural steel and aluminum. This paper discusses development of a new short course which introduces students with basic principles of reengineering design and manufacturing procedures for aging metal components. Special emphasis is placed on the use of lightweight high strength fiberglass and carbon composites. This course is specifically designed for the senior/first year graduate students from Mechanical, Civil, Architectural and Industrial engineering departments. Typically students taking this short course have prerequisites including strength of materials, machine design and material science. The proposed course will be useful in securing high tech jobs particularly where the reengineering skills are essential.

Introduction

This paper presents a new short course (typical duration of about three weeks), which introduces both seniors and first year graduate students from Mechanical, Civil, Architectural and Industrial engineering students a concept of reengineered materials. The course is typically divided into three sessions (one session per week). Each session runs approximately three times in a week, with duration of fifty minutes each. The details of the three sessions are provided below:

Session One - Overview of Composites

In the first lecture of Session 1, students are introduced to composite materials. Students learn that a composite material is made of two or more chemically different materials with a distinct interface between them. The individual constituents maintain their own properties. However, the combination of materials develops a material that has properties and characteristics different than those of the original constituents. The properties of the composite material depend on the properties and geometry of the constituent materials and the distribution of the phases. They also learn about high specific strength and high specific moduli, improved corrosion and wear resistance, low thermal conductivity, and increased fatigue life typical of composites. They also learn some specific disadvantages including cost, a lack of high productivity manufacturing methods, and clear-cut design rules. Some work is also devoted to the different fibers used such as glass, carbon, aramid, boron and alumina. They are also introduced to the more inexpensive and popular resins such as polyester, vinyl ester, cyanate ester and epoxy[1].

In the second lecture of Session 1, students are introduced to and the different manufacturing techniques. There are various methods that are used to manufacture composite laminates [2]. These methods include wet lay-up, prepreg method, autoclave processing, filament winding, pultrusion, resin transfer molding (RTM) and vacuum assisted resin transfer molding (VARTM). Students

are provided with a brief description of these methods and also students are presented with various advantages and disadvantages of these methods[3].

In the third lecture of Session 1, students are introduced to elastic behavior of composite lamina. In this students are taught micromechanics methods. They are also taught about elastic properties of composites using simple micromechanics approach.

Session Two – Introduction to Classical laminate Theory

In the first lecture of Session 2, students are introduced to concepts of strength of unidirectional lamina. In this lecture, students are introduced to longitudinal, transverse, in-plane shear and out of plane loadings as applicable to unidirectional lamina. This is purely based upon the micromechanics approach, which they have learned in Session 1 earlier.

In the second lecture of Session 2, students are introduced to strength of composite lamina and are based upon macro mechanics concept. They are introduced to various failure theories, including determination of lamina strength based upon Tsai-Wu Criterion.

In the lecture 3 of Session 2, students are taught elastic behavior of multidirectional laminates and emphasis is made upon the symmetric laminates, and in particular quasi isotropic laminates. At this point some of the fundamental principles of reengineering of the engineering parts are discussed. During this lecture, students are emphasized that during the reengineering process, the components are designed in such a manner that they have at least same or better fundamental material properties including modulii, strength etc. Furthermore, it is also stressed that the cost of materials and manufacturing, is comparable to the parts that are being reengineered.

Session 3: Reengineering of an actual engineering component made out of Aluminum

In the lectures 1 and 2 of Session 3, a replacement for a typical aerospace part made out of Aluminum 2024- T3 is considered as a reengineering project. First students are provided with physical properties of the aluminum and fiberglass/carbon composites. In general students follow the following procedure for reengineering the component using composite materials.

Reengineering procedure

- Tape properties are calculated using classical micro-mechanical theory for S-Glass fibers and Carbon fibers with Epoxy resin system.
- Mechanical Properties for plain weave pre-preg for both of the materials are calculated using Classical Laminate Theory.
- Arranging all the carbon/epoxy pre-pregs in quasi-isotropic lay-up (8 layers 0/45/90/-45-Symmetric) in conjunction with upper and lower face sheets with glass/epoxy zero degrees pre-pregs, a hybrid 10 ply laminate is designed.
- Mechanical properties for this hybrid laminates are calculated using Classical Laminate Theory.
- Ply-by-ply stresses are calculated for unit axial and flexural loading conditions.

- The same procedure is applied to find stresses for aluminum 2024 plate subjected to axial and flexural loading conditions.

During this reengineering procedure, students are also explained why quasi-isotropic layers are used and how the elastic properties and the strength of the composites are comparable to that of aluminum plate. Furthermore, students are also introduced to various failure theories in composites and how they are comparable to failures in metals like aluminum. In the Lecture 3 of the Session 3, students use reengineered panel to obtain test coupons, which are machined and tested for the fundamental properties including modulus, strength and Poisson's ratio and these properties are then compared with the aluminum material.

Assessment

In the present course in order to assess the skill and knowledge of students taking this short course, we have developed a written examination which consists of one hundred multiple choice questions. The approximate distribution of these questions is as follows:

- Composite Knowledge 10%
- Composite Manufacturing Processes 10%
- Composite Materials 10%
- Composite Laminate Theory 10%
- Composite Failure Theories 10%
- Composite Test Methods 10%
- Reengineering Principles 10%
- Reengineered Materials 10%
- Design Comparisons 10%
- Lessons Learned 10%

We plan to offer, this short course in the Fall 2009 and depending upon the student performance, the course will be modified. If the assessment indicates that students are performing below the expectation in certain parts of the examination, the modification may involve more emphasis on some of the topics with less emphasis on other topics. In addition we plan to get regular feedback from the students to get feel about how much reengineering principles they understood.

Conclusions

This paper presented a development of a new short course which introduces students with basic principles of reengineering design and manufacturing procedures for aging metal components. Special emphasis is placed on the use of lightweight high strength fiberglass and carbon composites. The proposed course will be useful in securing high tech jobs particularly where the reengineering skills are essential.

Bibliography

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