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Rewriting Introduction to Composite Materials Software to Function on 64-bit Windows Operating Systems

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Abstract

This paper will be used to describe the process I've taken into rewriting complementary software for the Introduction to Composite Materials Course at the University of South Florida. The program is entitled PROMAL and it has been used since 1990 to assist students in understanding and calculating various theoretical models of composite laminates. The software is unable to operate on 64 bit operating systems and needs to be rewritten with a newer programming language in order to remain compatible. I will describe my methods, the improvements and changes made to the PROMAL program, as well as objectives attained and future implementation of the software.

Introduction

In 1990 Dr. Autar Kaw from the mechanical engineering department of the University of South Florida developed the PROMAL program with help from several undergraduate students [4]. PROMAL, (acronym for PROgram for Micromechanical and Macromechanical Analysis of Lamina and Laminates), allows students with very little understanding of composite materials to begin analyzing how composites react to external mechanical and hygrothermal loads. As composite materials are found more prevalently in new products, it is important for engineers to understand their unique characteristics. By partnering a user-friendly software program with the introduction to composites course, students are able to develop their analytical skills and knowledge of conceptual theory in a more effective manner. It is necessary for me to give some background information on composite materials in order for the reader to better understand the unique abilities and characteristics which enable and restrict composites from operating in a manner we are more accustomed to expect from non-composite materials.

Composites

Composite materials have several defining characteristics which make them desirable to engineers, manufacturers, and product designers. Firstly a composite material is defined as such, "A structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other" [7]. A composite generally consists of a main base layer called a matrix and a second material inserted into it known as the fibers. One can think of a common composite known as fiber glass which has glass fibers inserted into an epoxy matrix. An important characteristic of composite materials is that if these fibers are aligned in a deliberate way the engineer can predict the expected strength of the composite material. You can think of composites similar to wood, a natural composite, which has a defined grain direction. Typically composite materials are strongest parallel to the fiber alignment and weakest in the direction perpendicular to the fibers. By carefully planning layers of composite materials with fibers positioned in optimized directions, engineers can achieve high strengths in multiple directions, while achieving vastly lower weights than equally strong metals.

Composite materials also have several undesirable traits associated with them. First, composite materials are prohibitively expensive for a large number of industries, generally costing many times more per pound than metal alternatives [11]. Manufacturing of composite materials is expensive due to material costs and complicated manufacturing processes. Another disadvantage of composites is that they are very difficult, if not impossible, to repair if they become disfigured or cracked, usually resulting in replacement. This is unlike metal counterparts, which are malleable and can easily be reshaped or repaired. Composites are also more difficult to work with because they have special characteristics as described above. This makes analysis of their reactions to loading complicated. Engineers require special education or training with composite materials in order to design components, not the case for simpler metals and ceramics.

PROMAL

Originally written in 1990 using Microsoft Basic on DOS, PROMAL has allowed students to analyze composite lamina and laminates while avoiding lengthy mathematical operations [4]. When it was first written PROMAL was able to accomplish tasks that generally fell under three categories within Composite Materials: Micromechanical analysis of a lamina, macromechanical analysis of a lamina, and macromechanical analysis of a laminate. I will briefly describe what these three sections of the program do and what they allow the student to solve.

The micromechanical analysis of a lamina is the study of the properties of a single lamina. A lamina is one single layer of composite material in which the fibers are aligned in a single direction. Here you supply the Young's moduli, Poisson's ratios and thermal expansion coefficients for the fiber and the matrix. Then you select a specified fiber volume fraction (ratio of fiber to matrix by volume), and PROMAL will output the mechanical properties and thermal expansion coefficients of the lamina at that fiber volume fraction [5]. This is useful for students to make up or insert properties of known matrix and fiber materials and see what properties a lamina consisting of them will possess.

The macromechanical analysis of a lamina already has all of the material properties for the lamina from a set list of materials. You simply apply load in specified directions and analyze the stresses and strains of the lamina. In addition you may consider at which loads a lamina will fail and under what conditions. This portion of the program is helpful for students to analyze under what conditions a specific lamina will fail. It also allows them to optimize a lamina and find the ideal direction the fibers should be positioned in order to maximize resistance to complex loading.

The macromechanical analysis of a laminate does everything the previous section does in terms of inputting various loadings and finding resulting stresses and strains, but it does this with stacks of lamina creating a laminate. This allows the user to manipulate the laminate by placing lamina of different material combinations in different directions and analyzing resultant stresses and strains under varying mechanical and hygrothermal loads. This is useful because it allows students the ability to create complex laminates which can be designed for real applications. Students can solve complex applied problems which can put laminates under the same loadings real products and devices would experience, allowing a wide range of simulations to be recreated within PROMAL and tested with composites. Students can also calculate the properties of products if their common materials were replaced with composite laminates. It should be noted that all of these situations are intended for academic use and PROMAL in no way insures its accuracy or safety for commercial products to be made based on the calculations done in PROMAL. The program makes many assumptions in order to simplify calculations and allow students to gain the main concepts involved in the mechanics of composite materials.

PROMAL was updated in 1997 from Basic to Visual Basic 6. This was a major update allowing the operating systems of the time to utilize PROMAL. New features were also added to PROMAL making it more comprehensive and easier to use. Such features included a new graphical interface which was more intuitive for students to use, allowing them to navigate the menus of the program more easily. It allowed users the ability to click buttons on screen rather than solely using a keyboard's key presses to navigate through the program menus.

Need

Chances are the next new computer you purchase will be using a 64-bit operating system. Operating systems in most of PROMAL's life have been run on 32-bit systems, and it has been written as a 32-bit application. Windows 7 from Microsoft is an operating system that runs almost exclusively on 64-bit architecture. As more and more students use computers with 64-bit operating systems, there are more students unable to run the PROMAL program on their computer. When PROMAL was written in Visual Basic 6, it used many processes which are no longer supported by 64-bit systems and so it does not operate correctly if at all. This greatly reduces the number of students which can use PROMAL software, and as time goes on this number will only further reduce. Without a new version of PROMAL, students will be unable to use it concurrently with the introduction to composites class.

Objectives

Due to the large number of errors located within the original code of PROMAL it was decided by Dr. Kaw to rewrite the PROMAL program from scratch, salvaging certain subroutines which could be rectified to work within the new program. It was decided the new PROMAL program would be written using Visual Basic 2010, one of the newest programming languages released by Microsoft on the .Net framework. This would insure that the program will remain current for the longest amount of time without a required rewrite.

Since this was going to be a brand new version of PROMAL as opposed to a revision there were objectives included in the project which would have been impossible if modifying an older version of PROMAL. By planning ahead, the program could now be written differently to insure future adaptations will run more smoothly. In addition this would minimize the possibility of portions of the program becoming incompatible with newer versions of Windows operating systems. The list of objectives includes:

1. Insuring all values calculated from the previous version of PROMAL match those calculated by the new version. Previous calculations have been proven to be correct in all circumstances, therefore any deviations from these values are known to be incorrect. It is vital that all values under all circumstances are correct for the program to be acceptable. It is expected that in the first semester of classroom testing, any mistakes will reveal themselves and be corrected.
2. Improve readability and organization of programming code so future modifications are simplified. In Visual Basic 6, variable names within source code could only be eight characters long, resulting in variable names which were unintuitive. In addition the programs subroutines were mostly unlabeled so future modifiers of the program faced increase hardship in deciphering the roles of certain functions. This will be solved in the current version by maintaining good labeling and comments within code lines and subroutines so future programmers will understand the functions and subroutines within PROMAL. In addition, systematic naming will be issued to all variables. This means variables will have prefixes for their type as well as for their location within the program so they are easily identifiable.
3. Avoid as many third party software add-ons as possible. In previous versions of PROMAL, third party graphing software was used which later proved to be incompatible with new operating systems, as the owners of this software abandoned maintaining it. The objective will be to use only libraries from Microsoft so as to maintain compatibility with future operating systems.
4. Avoid using any form of database in PROMAL. The previous version of PROMAL was organized to store materials in a database which could be edited within the program. This

database was overcomplicated and created compatibility problems as it became unsupported within the .NET framework. The new version of PROMAL will store materials in a text file instead, which will maintain compatibility throughout the life of the program.

These are the main goals of the PROMAL program. Later I will discuss other changes made to the program, as well as the objectives we met.

Methods

I began working with Dr. Autar Kaw on rewriting the PROMAL program during the fall of 2011. I was taking Dr. Kaw's Introduction to Composite Materials class during the same semester, as it would be required later on that I fully understand the mechanics of composites and how these equations are developed in order to successfully write the program. We scheduled weekly meetings so as to monitor my progress and discuss where to continue and what problems I had encountered while working. The first semester would be unpaid work and the second semester would be paid at a rate of $10 per hour for ten hours per week. I worked an average of fourteen hours per week during the project, working on campus in either Dr. Kaw's lab or the CAD lab of the mechanical engineering department. We set a timeline to finish the project by the summer of 2012 so that Dr. Kaw could use the new program as a test run with his summer students. My previous programming experience only included MATLAB so Dr. Kaw lent me a book to learn the syntax and methods of the visual basic programming language [3].

Throughout the course of the project, I utilized several additional resources in order to clarify syntax and learn various subroutines and functions within Visual Basic 2010. Firstly there was the main Microsoft Visual Studio help library [9]. This is a library setup by Microsoft to assist programmers using its Visual Studio software in finding the correct syntax, as well as defining the purposes of different functions or subroutines.

A second website, dreamincode.net, had additional, well-developed solutions to various problems [10]. It allowed me to find answers and solve problems which involved several steps. They usually described multiple ways to solve a specific problem. With multiple options I would sometimes combine approaches in order to solve a problem as I would best see fit for PROMAL.

Without these two websites, it would have been extremely difficult for me to come close to completing this project. I will now describe in detail the progress and changes that were made to the PROMAL program.

Chapter 3

I began working on chapter 3, which involves the micromechanical analysis of a lamina. I began here because my knowledge of composites was limited and the equations for this chapter were fairly simple. Everything was recreated in chapter 3 as in the original PROMAL software. Maintaining correct units was challenging because the user has the option of changing their system of units between the SI and Imperial system of units. In addition, the user may choose their system of units for both the input values and the output values. Maintaining correct units was difficult at first but could be easily recreated once established. Dr. Kaw informed me to maintain correct units by making all background calculations occur in the SI system of units.

Therefore, if a value is in the Imperial system of units it must first be converted to SI and then used for calculations.

I was unable to insert the graphs in chapter 3 at this point but was instructed to reserve the challenges of graphing for the end of the timeline, once everything else in the program was complete.

Chapter 2

I then began working on chapter 2, the macromechanical analysis of a lamina. This section requires that you first select a material, because unlike Chapter 3, you do not need to put in the material properties; they are taken from a preselected list of materials. There will be five default materials already in PROMAL when it is installed, as well as the ability to create new materials and save them for later analysis. The five default materials are graphite/epoxy, glass/epoxy, boron/epoxy, aluminum, and steel. After selecting a material one can find the transformed reduced stiffness matrix and transformed reduced compliance matrix as well as their inverse matrices. These are used to find the stresses and strains at the applied load direction and the fiber direction as well as any angle which the user decides to evaluate. In addition, users may apply complex mechanical loads to find the strength ratio of the ply at a specified fiber angle.

Edit Material

PROMAL allows the user to input all of the properties of a material and save these properties as a customized material. PROMAL can store up to 25 different custom materials for which the user may analyze later. The user must first select the correct system of units with which they would like to input the information. Regardless of what the user selects all background storage and calculations are done in the SI system of units in PROMAL. So though a user may select the Imperial system when inputting the properties of a customized material, PROMAL first converts the data inputted into the SI system of units and then stores the customized material properties in a text file. The Edit Material section of PROMAL is very important to the user for customization and future analysis.

Resolution

It was at this time also that Dr. Kaw and I decided to upgrade the resolution of the PROMAL program. We didn't want it to take up too much space on the user's screen but at the same time the previous VGA standard sized resolution was becoming hard to read in several instances, in particular, large tables of values. The standard resolution of VGA is 640x480 pixels and so we decided to bump the program windows to 800x600 pixels. This allowed tables to become larger while not taking up too much space of the standard monitor. In addition this is the lowest resolution capable of most new computers and their monitors.

Chapter 4

I began working on chapter 4, macromechanical analysis of a laminate, at the beginning of the spring semester. The only goals left to accomplish were the following: insure that all values obtained by the PROMAL program are correct, that chapter 4 is completed, and that graphs are implemented. As stated earlier, the macromechanical analysis of a laminate does not have any new material implemented except for now the calculations need to be made over an entire laminate of differing materials and angles. The extra complexity comes with making sure PROMAL reads all user created materials correctly as well as correctly implementing the specified stacking sequences.

A stacking sequence is the sequence in which a composite laminate's plies are stacked. In PROMAL the stacking sequence is denoted by the material number followed by a comma, then followed by the angle at which the fibers in the composite are aligned. The first pair listed is the top ply, and the laminate descends from there. The total number of plies in the laminate can be found by adding the number of pairs in the stacking sequence.

Replace Corrupted Database

A button on the main menu of PROMAL allows the user to replace a corrupted database. This is available in case a user has in some way altered the default material text file or the user created materials text file. If these text files are not edited by the PROMAL program itself, there is a chance for error, which could cause the program to incorrectly read the text file. The replace corrupted database button first deletes both the user material and default material text files. A backup default material text file and an empty user material text file are stored within the PROMAL files folder. These backup text files are copied and renamed so that PROMAL can read from them correctly. Now the default materials have been restored correctly and the user created materials have been deleted to restore functionality to the program.

Graphs

We had saved graphs last for the project because we were hoping to find some tools within the Visual Studio software that would allow us to include simple graphs. Because we were unable to find embedded commands for creating graphs within Visual Studio we chose to use third party software. The particular software we used was entitled ZedGraph and was chosen for being open source and simplistic [1]. ZedGraph's library needed to be imported into Visual Studio and afterwards it integrated easily with the PROMAL code. I needed to search for examples in order to understand the syntax of working with zedgraph [2] but afterwards I was able to implement it fairly easily. Graphs were inserted to both the macromechanical analysis of a lamina and the micromechanical analysis of a lamina sections.

Further Work

Currently the PROMAL program is complete but is still in the debugging phase. Calculations in isolated circumstances are returning incorrect values and some operations have the possibility to return errors. Dr. Kaw and I will continue to work through the summer of 2012 to insure the program is free of errors and completed to a level which we are comfortable with its stability. Particular problems identified are as follows.

1. When steel is used in a hybrid laminate under complex mechanical loads, incorrect stresses and strains are obtained. This has been isolated to an error in the way PROMAL is reading the default material text file when multiple material types are present, causing steel to be read as a different material.
2. When a user tries to edit a stacking sequence there is a possibility for PROMAL to read the stacking sequence incorrectly and close the program due to error. The causes of this have not yet been identified but are isolated to stacking sequences which have

already been loaded by the PROMAL program and are trying to be edited. New stacking sequences do not seem to be suffering from this same error.

3. More comments need to be included within the body of the PROMAL code. This is to insure that future programmers who try to improve the PROMAL program will be able to easily understand the purpose and function of the code.
4. Verify that PROMAL deploys correctly on all operating systems which it is intended to operate on. Currently Windows 7 64-bit operating systems have been proven to deploy correctly but there are other variations which we have yet to test including Windows Vista and Windows XP.

Conclusion

In conclusion the PROMAL program has been successfully rewritten using Visual Basic 2010 with the above exceptions. It is expected to be complete by the fall semester of 2012 and used in the classroom at that time. There have been huge gains in organization of the PROMAL program code. With the systematic naming of variables and forms, in addition to the comments describing functions and subroutines, future programmers will be much more prepared to make adjustments to the PROMAL program.

It is unfortunate that Visual Studio does not yet support a library for simple graphing to utilize for a project such as this. Resorting to an outside software program to develop the graphs was meant to be avoided, but unfortunately was our most timely option for the project. There may be implications in the future as this graphing software may become incompatible, but for the foreseeable future it is an adequate solution.

The most important factor is that students will be able to start using the PROMAL software again in the fall of 2012. This will complement the Introduction to Composite Materials course and allow users of the program to gain a better understanding of the academic material.

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