

Homework 4 – Spring 2019

AE 6220: Rotorcraft Dynamics

Prof. Dewey H. Hodges

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1 Introduction

Composite materials have revolutionized the field of structural and aeroelastic analysis due to their tailorability arising from their directional nature. This makes them an obvious choice in several critical load carrying members of an aircraft, and one such example is rotor blades. In this HW, you will determine the effect of the fiber layup angles and rotor speed on the natural frequencies and mode-shapes of a realistic rotor blade. The tools needed for this purpose, which will be provided to you are VABS (Variational Asymptotic Beam Section) and GEBT (Geometrically Exact Beam Theory), which when coupled with a pre-processor unit borrowed from a 3D FEM tool like ANSYS or ABAQUS, essentially constitute a package for the structural analysis of a rotor blade. The foundation theory for these tools as well as some related developments are detailed in [2].

2 Rotor Blade

The airfoil that is to be used for this study is the MH-104. The coordinates describing the airfoil can be found on the interwebs, for example, in the UIUC airfoil database. The remaining details of the blade section, i.e., the materials used and layup configuration, are detailed in section 4.5 of [1]. The pertinent information is that corresponding to station 1's (st1) blade section configuration. The length of the blade is 8.82 m. For simplicity, we will assume the blade has zero initial twist and curvature, and that the hinge offsets are zero. The VABS results in [1] are outdated and should not be used for comparison purposes at any stage during the analysis.

3 Problem Statement

Determine the first five natural frequencies of the rotor blade described above for six cases which are listed by the following variations:

- Rotor Speed: 0, 400 RPM
- Layup angle of material 1 (in all occurrences of segment 3 of both top and bottom surface only): -30° , 0° and 30° . Note that this angle has been specified to be 30° in [1]. You will need to do the analysis for the other two angles as well.

Also, for the case determined by option 2 for rotor speed and option 3 for the lamina lay-up angle, study the mode shapes obtained. If possible, for each mode-shape identify the dominant structural modes of deformation, i.e., extension, twist, bending (flap or lead-lag), or shear.

4 Solution Procedure

Before using any of the tools, it is advised that the student is familiar with what exactly each tool does. In a nutshell, VABS performs the cross-sectional analysis (2D problem) and GEBT solves the 1D problem. Due to the complicated nature of the material and configuration of the rotor blade cross section, a pre-processor, a Graphic User Interface (GUI) specially designed for use in either of the commercially available tools such as ANSYS or ABAQUS aids the user in generating the input files for VABS. It is also recommended that the student reads the instruction manual for each of these softwares (VABS & GEBT) and for the use of GUI available (described in Sec.5, especially the parts describing the preparation of input files and reading the output files for VABS. For GEBT, the manual is self-sufficient to prepare an input file.

The entire solution procedure is depicted in Fig. 1. The file names used in the schematic are for illustration purposes only and students are free to name the files as per convenience. Once the student is familiar with the functionalities of each tool, the information provided in Sec. 2 is sufficient to construct the input files for VABS with the help of a GUI. Student may pick any one of the options listed in Sec. 5 to generate an input file for VABS. Use of ABAQUS-VABS GUI is recommended for the sake of simplicity and less chances of running into errors. A student may choose to use ANSYS based GUI if he/she is an experienced user of ANSYS, however it may be noted that the GUI developed to generate a VABS input file has almost no connection to having an experience using ANSYS.

5 Running VABS

VABS tool along with the information to generate an input file for VABS can be obtained on cdmHUB. Following the steps listed below, would help a student in accessing VABS for academic use. For distance learning students, it would be advised that use of VABS on cdmHUB is restricted to academic use such as the project assigned in AE6220. For use of VABS outside AE 6220, you may inform the group admin before doing so, in order to obtain clearance and avoid any copyright infringement issues.

Steps:

1. Create an account on cdmHUB using their personal details e.g. choice of a username, email id (use of school email id is preferred), password and name of organization (Georgia Tech.).
2. To access VABS, a student is required to get added to the VABS Group on cdmHUB.
3. Click on “Apps” from the menu bar on top. Further, select “Composite Beams” from the list in the first column. The second column will show access to the tools “VABS”

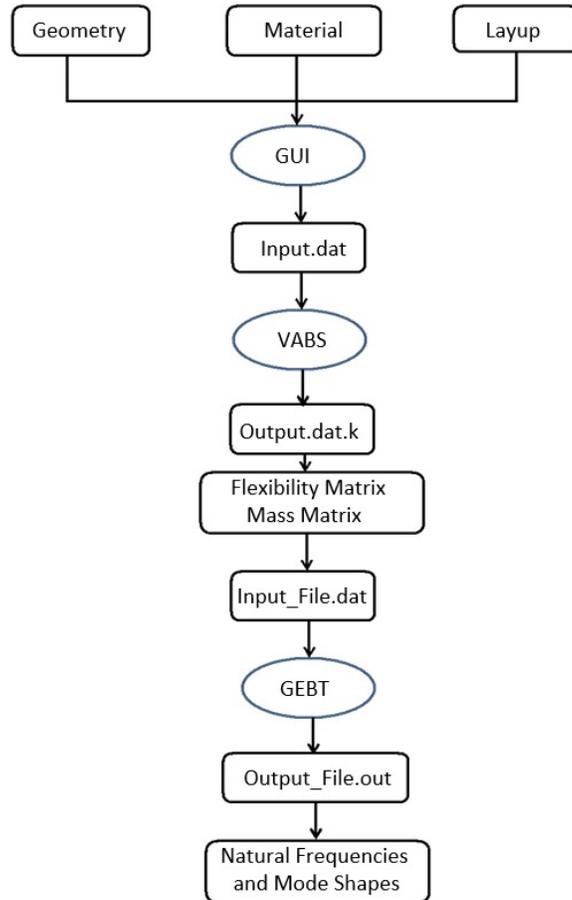


Figure 1: Solution procedure to obtain the mode-shapes and natural frequencies of a rotor blade

and “Geometrically Exact Beam Theory” for use in this course. The tool can be launched by clicking the “Launch Tool” button in the third column after choosing the desired option in the second column. If you don’t find the ‘Launch Tool’ button for VABS even after getting added to the group, click here to proceed.

4. Map network drive (webdav) on your system using the information provided on this link and transfer the VABS and GEBT input files in the webdav network drive mapped.
5. To run an input file through VABS, directly type `vabs input_file` with extension to execute the code. A sample input file (example.dat) for running VABS can be downloaded by clicking here. Download example.dat from the link and place it in the webdav mapped network drive. Go to VABS on cdmHUB and click “Launch Tool.” Type `vabs example.dat` in the terminal window and VABS will execute to generate output files within the same directory in webdav.
6. A similar process is required to be followed for running input files of GEBT.

As mentioned, information provided in Sec. 2 is sufficient to generate input file for VABS. To generate input files for VABS, a student may choose to use any of the three options provided below in the order of preference. It is highly recommended that the students use PreVABS for generating their VABS input file.

5.1 Using PreVABS

A student may download the PreVABS version along with supporting documents from the link provided. The downloaded folder would contain both the application as well as supporting documents such as examples and the manual.

5.2 Using the GUI in ANSYS

A student may download the ANSYS-VABS GUI alpha version along with supporting documents from the link provided. A brief video tutorial on using the GUI in ANSYS can be obtained by clicking [here](#).

5.3 Using the GUI in ABAQUS

A student may download the ABAQUS-VABS GUI alpha version along with supporting documents from the link provided. There is no video tutorial for this GUI, however, a self supporting instruction manual can be downloaded.

Finally, the input file for VABS is generated (*input.dat*) which can be fed into VABS directly using the step described in Sec. 5.

6 Running GEBT

If GEBT on cdmHUB doesn't work as expected, an executable file (contained in .zip folder) to run GEBT on your respective local machines can be obtained by clicking [here](#). To run that file on local machine, the FORTRAN dynamic link library MA28.dll provides the solver for GEBT. If you are using the solver on your local machine, please make sure all the .dll files present in the .zip are in the same folder as *gebt.exe* for proper functioning.

7 Expected results

If VABS doesn't execute properly, the .ech file generated would have additional information for you to process your VABS input file again and the same goes with GEBT. A list of very common errors that students make and the solution for those are compiled in an errata which can be accessed by clicking [here](#).

Once VABS has executed it outputs the flexibility and mass matrices for the blade section, which are needed for *input_file.dat*, an input file for GEBT. GEBT on executing will produce an output file (*output_file.dat.out*), in which the eigenvalues and their corresponding eigenvectors are generated and from which one can obtain the natural frequencies and mode shapes. Finally, following results are expected:

1. Five plots corresponding to the variation of each natural frequency with the layup angle; each plot should contain the results for the rotating and non-rotating case.
2. Plots of the mode shapes for the particular case described in Sec. 3. Note that this is a composite beam, so the stiffness matrix is fully populated with significant couplings. Hence, the description of each mode shape may need to include the plot of more than one variable among u_1 , u_2 , u_3 , θ_1 , θ_2 and θ_3 along the length of the beam.

References

- [1] Hui Chen, Wenbin Yu, and Mark Capellaro. A critical assessment of computer tools for calculating composite wind turbine blade properties. *Wind Energy*, 13(6):497–516, 2010.
- [2] Dewey H Hodges. *Nonlinear composite beam theory*. American Institute of Aeronautics and Astronautics, 2006.