Design Decision Documentation

Background Information

Throughout the design process, engineers must make numerous decisions which eventually lead to a completed design or other engineered work. It is important for engineers to properly document their decisions; explaining or providing justification for them. Typical mechanical engineering decisions may involve any of the following:

- determining the overall concept of a product (for example "the airplane should have wings mounted below the fuselage")
- selecting or specifying an existing product to be used in a design (such as a specific engine to be used in a vehicle or air conditioning unit to be used in a building)
- defining the form (geometry) and specific material of a component
- determining how parts should be manufactured or assembled
- et cetera

In order to make good decisions, engineers must rely on facts and data. Facts and data may be obtained from personal experience, experience of colleagues, literature search (journals, textbooks, handbooks, company reports, etc.), analysis, and experimentation or testing. **Engineers should remember that expert opinion, analysis or even testing do *not* provide *the* answer to a design question. They merely provide data to *help you* make a decision. Decisions require judgment and are based on the available data.**

The purpose of this document is to provide a guideline for students in regards to communication of incremental activities that assist with design decisions (such as analysis or testing). Such communication will be referred to as a "Design Decision Documentation." These may be stand-alone documents, part of a technical letter, an appendix in a design report, etc. Upper-division students should already be familiar with the spirit of a Design Decision Documentation, as it closely mirrors the standard problem solving format (given, find, etc.). However, Design Decision Documentation often requires even more detailed explanations. It is important that design decisions are properly documented in order to communicate with others as well as to serve as a record for future needs.

Design Decision Documentation

The engineer should keep in mind that Design Decision Documentation should be created to function as a "stand alone" document. It must be clear to anyone reading it what its purpose is, what data was created and how it was created, what data was obtained from other sources (including proper citation of those source), and what conclusions or decisions were reached based on the data. It must be clear that the design decisions are based on proper and thorough analysis of facts and data. Often, analysis must be explained. It may also require discussing what alternatives were considered but not selected.

It cannot be over emphasized that expert opinion, analysis nor even testing will provide *the* answer to a design question. They merely provide data to help the engineer (you) make a decision. Decisions require judgment and are based on the available data.

- Please, never justify a design decision by saying "I selected this option because Joe says it the best, and Joe knows!" You may use expert Joe's advice, but you must understand why it is best and are convinced yourself it is the correct decision. It is <u>your</u> decision – even if Joe is your boss.
- Please, never justify a design decision based on blind faith in analysis or test data. You must be convinced that the analysis or test data is correct and that you are interpreting it correctly. There is an example of a large corporation basing a significant decision on finite element modeling. The modeling was not properly validated through testing. It led engineers to an incorrect design which failed at just over half the expected load. This was a *hundreds of multimillion* dollar mistake that was caused by blind faith in analysis!

In general, Design Decisions Documentation should have the following format:

- Header identification information (name of individuals, team name, date, who's it for, and any other such information)
- Statement of purpose (what are you trying to determine and/or why are you trying to determine it)
- Declaration of information you are working with (criteria, given information, etc.)
- Assumptions being made (may be stated at the beginning of the document, or embedded in the document as assumptions are being utilized)
- Clear and logically organized work using the "given" information and assumptions. It must be clear where data being utilized comes from including equations and formulae (cite references).
- Conclusion stating what you conclude and why. In many cases, you should discuss any caveats of your conclusion. For example, you may include a discussion of assumptions – if they are not perfectly valid, would that change or affect your conclusion, and if so, how?

The following may serve as "check lists" or guidelines to help you create appropriate documentation:

<u>For analysis based decisions</u>

- Analysis is clear and easy to follow: purpose or objective clearly stated (may even be a restatement of a specific criterion), assumptions defined, "given" information provided, sketches (including FBD's, control volumes, etc.) are included, solution is clear, answer is underlined (or similar) with appropriate significant figures, sources of equations are cited, proper and consistent units are shown throughout the analyses, not just in the answer.
- For more extensive analysis, explanation (such as newly stated "objective, given, find," etc.) is provided at various steps where helpful so reader can follow your thoughts.
- Correct analysis is done, and done correctly.
- Sample calculations and/or explanation provided for spreadsheet or program-based calculations.
- Results (such as graphs) show parametric design "tradeoffs" if appropriate (ex. Stress vs. diameter, thickness…).
- Clear definition of final design and show that it satisfies the established design criteria.

- Proper organization: starts with criteria, which leads to clear analysis (or analyses), followed by results (such as graphs), and conclusion (answer(s)). May be iterative.
- **Bottom line: clear that design decisions are based on proper and thorough analysis of alternatives.**

For finite element method (or similar)

- Purpose or objective clearly stated (may even be a restatement of a specific criterion), assumptions defined, "given" information provided, sketches (including FBD's) are included.
- Assumptions must include such things as linear or nonlinear, small deformation or large deformation, etc.
- Software and version information provided for both the finite element model and the CAD solid model
- A description of the constraints or boundary conditions and a sketch or printout showing the constraints or boundary conditions is provided.
- Include an explanation of how the mesh was generated, and a printout showing the mesh.
- Include proper (meaningful, useful) printouts of the results.
- Provide an explanation regarding the significance of the analysis. May also explain what the analysis does not tell you.
- Clear definition of final design and show that it satisfies the established design criteria.
- **Bottom line: clear that design decisions are based on proper and thorough analysis of alternatives.**

For experimental or test based decisions

Most (hopefully, all) students are familiar with laboratory reports. Such reports, if done properly, serve as design decision documentation. It is appropriate to explain the significance of the testing and how it supports your design decisions.

Literature data (journals, handbooks, etc.)

Information obtained from reliable sources may be used as data in making a decision. Sources must be properly cited. Online data is not necessarily literature, thus websites selling a particular product, Wikipedia, patents, and other sources should only be used for reference information and not for design decisions.

For "expert opinion" based decisions

No design decisions should be based strictly on "expert opinion" no matter who the expert is. Expert opinions may be used (as data), but in all cases, other data is required to justify your decision. If you are using "opinion" as data, then you must give credit where credit is due.

Revision Information

Rev A, released October 2009
Rev B, added details to FEA requirements, February 2010
Rev C, emphasized the importance of decisions are the engineer's responsibility, August 2010
Rev D, added requirements to include header information (name, date, etc.), January 2012