VISITOR RESEARCH REPORT

Visitor Name: **Gerhard Venter**

Area of Research: **Research in Reliability Based Design**

Period of Visit: **January 24, 2011 – May 6, 2011**

Goal:
The goal of the research visit at NASA Langley was to investigate the use of proof or acceptance test data during the reliability based design optimization process. The special case where the actual component that enters service passed the proof test was considered. For this case, the proof test in effect reduces the strength uncertainty of the component. Translating this reduction in uncertainty into a weight saving was the desired outcome of the research project.

Strategy:
The research started by simulating the current design process at NASA. There are three key points of interest regarding the current design process that were considered:

1. Mostly a deterministic design process is followed
2. A relatively small number of components are manufactured
3. Virtually all components are proof tested before entering service

Currently, NASA proof tests virtually all components before the components enter into entering service. However, the results from these proof tests are not used during the design process. The proposed methodology integrates the results from the proof tests directly into the design process. The result is a simultaneous design of the structural component and the proof test, with direct control over the probability of failing the proof test itself.

The proposed methodology starts by performing a deterministic design using a safety factor approach to deal with uncertainty, similar to what is currently done at NASA. The probability of failure associated with this deterministic design is then calculated and used as a constraint during the reliability based design process. The result is a probabilistic design with the same reliability as the deterministic design.

Finally, the proof test data is incorporated by calculating a conditional probability of failure when evaluating the reliability of the structure. This conditional probably of failure can be stated as: "The probability of failure provided that the component has passed the proof test". In the design problem definition, this conditional probability of failure is constrained to be less than the probability of failure obtained for the deterministic design. Two additional components are added to the design problem definition. The first is an extra design variable that controls the level at which the structure is proof tested (in other words the magnitude of the proof test load) and the second is an extra constraint that controls the probability of failing the proof test.

The design problem then optimizes both the structure and the magnitude of the proof test simultaneously, while maintaining the same probability of failure as the deterministic design and controlling the probability of failure for the proof test.

In the work done so far, trade-off graphs were generated for different probabilities of failing the proof test. These trade-off graphs allow the designer to select a weight saving, based on the risk of failing the proof test.

Accomplishments:

At this point, the proposed concept outlined above was developed and a set of software routines that can be used to design simple structures were created. Currently, three analytical examples were considered: (1) a cantilevered beam, (2) a spherical pressure vessel and (3) a stepped cantilevered beam.

The example problems considered to date are straightforward in nature. The example problems were selected to allow the development and illustration of the proposed methodology, rather than to represent real life applications. The developed methodology is however general an nature and can handle multiple proof loads and failure criteria.

The results obtained so far shows that significant weight savings are possible while maintaining high levels of reliability.

Future Work:

Future work will include finalizing a journal paper that is currently in draft form. The work will also be expanded to include several important enhancements. Some of these can be summarized as:

1. Including non-normal and dependent random variables
2. Considering approaches other than FORM to evaluate the probability of failure
3. Appling the methodology to real life examples
4. Investigating the influence of different probability density functions for the strength distribution on the final result

The future research will be conducted on two levels. The first will be direct collaboration between myself and Dr Steve Scotti from NASA Langley. The second level will be in the form of post-graduate students at Stellenbosch University.

Pending Publications:
There is currently a first draft of a journal paper titled:

Accounting for Proof Test Data in a Reliability Based Design Optimization Framework

The authors are Dr Steve Scotti from NASA Langley and myself. We are currently working on finalizing this draft before submitting the paper to an appropriate journal in the near future.

Seminar Presented:
Two seminars were presented at NASA Langley during my visit. The first was at the Uncertainty Based Methods community forum on April 26, 2011 and the second was a general meeting that was advertised to the structures and materials group on May 5, 2011.

I also had to the opportunity to present the research as a research seminar at the University of Florida on April 12, 2011 and will present a short summary of the research at a mini-conference organized by the Department of Mechanical and Mechatronic Engineering at Stellenbosch University on May 19th, 2011.