**Probabilistic design of a rocket sandwich nozzle:**

**Introduction:**
During the design phase of a space nozzle, many different parameters have to be varied both design parameters but also the need of designing the nozzle robust with respect to variations in manufacturing process and loads. The general approach today when designing is to use extreme values and safety factors, instead of designing with real influence of variations and the relative importance of those values remain unclear.

A M.Sc.Thesis work [Karlén, 2007] was performed last semester, where design parameters were varied by using Design of Experiments and generating transfer functions and by Monte-Carlo simulations on parameter variations providing a probabilistic approach for determining on fulfillment on design criteria. The aim of this work is to provide a continuation of this work.

This work will be performed in collaboration between Mathematical Statistics, Chalmers and Volvo Aero.

**Goal of the study:**
This project proposal is a follow-up study of the Master project [Karlén, 2007]. The overall aim is to evaluate alternative methods for analyzing the uncertainty in life predictions, and modeling of the transfer function.

Also to perform with methods used in first thesis work, calculations and comparisons in another part of the sandwich nozzle that is regarded as even more marginal designed from the life point of view.

**Tools to be used:**
- TDK for Jet flame characteristics
- TCCOOL for aero-thermo computations
- ANSYS cross sections for maximum stress analysis
- CUMFAT for life analysis
- MINITAB for Design of Experiments
- Crystal Ball for Latin Hypercube simulations and visualization of the design space, optimization of the parameters and their distribution parameters etc.
- MATLAB to be used for statistical evaluations.
- VMEA -Variation Mode and Effect Analysis-procedure developed by FCC/Chalmers

**Modeling & work:**
The geometry will be a typical nozzle shape (or a cone) and the channel geometry will be decided in order to be representative but not corresponding to a real case.

The response parameters that will be studied are:

- life
- bulging (included in second part of the task)

Transfer function:

- Life & bulging vs. wall temperature/gradient through hot wall

The design parameters (control and noise) to be explored are:

- flame heat flux
- dump mass flow
- sandwich wall geometry parameters
- sandwich wall geometry outcome from manufacturing
- material properties
- inner roughness on the hot wall side

A certain dispersion of the parameters will have to be assumed.

The following steps will have to be performed:

- Recapitulation of results and modeling from previous Masters Work.
- Study and apply method developed at FCC/Chalmers of VMEA and a Design Practice created together with Volvo Aero.
- Conclude on differences in approaches between use of a probabilistic and an analytical approach.
- Apply conclusions on methodology on the same set of design parameters, but in a different part of the nozzle with more marginal design conditions.
- Evaluate tolerance setting of current manufactured development hardware to provide conclusion on design margins with respect to life on current manufactured hardware.

***Supervisor:***
Sören Knuts, Volvo Aero Corporation
mailto:Soren.Knuts@Volvo.com

***Supervisor and Examinator:***
Jacques de Maré, Chalmers Tekniska Högskola
mailto:demare@math.chalmers.se