# Optimisation Using Intermediate Response Function Approximations

This article may be found at
http://www.soton.ac.uk/~cedc/posters.html

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## Introduction

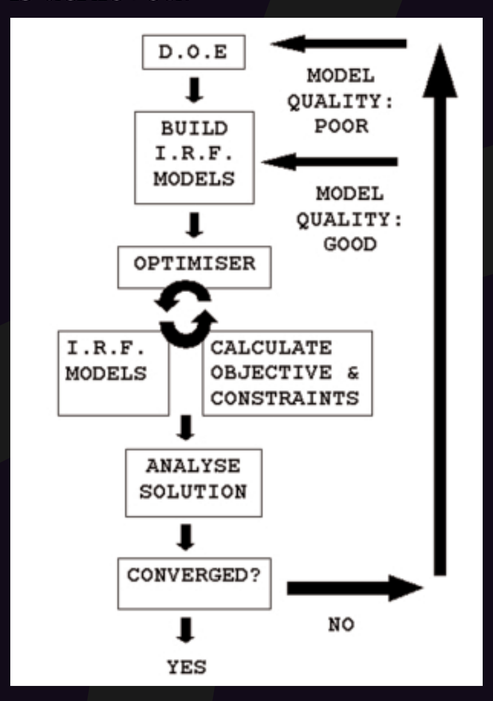
The assessment of the performance and reliability of a particular design concept often involves the execution of complex simulation codes. Direct coupling of these codes to an optimiser is usually impractical due to the prohibitive computational cost and hence much research has focused on the use of approximation models in the optimisation loop. A critical factor in the success of these methods is the accuracy of the approximation model over the search region.

## Intermediate response functions

In certain problems a designer may apply their understanding of the physical system to select analysis results which are amenable to low order approximation, e.g. by a 1st or 2nd order polynomial. These intermediate response functions are useful if they form the basis of simple explicit formulae for the non-linear objective and constraint functions. By introducing accurate low-order approximation models, the number of analyses necessary to identify an optimal design is reduced.

## Trust-region strategy

The low order approximation may not be valid over the whole design space and hence a trust region method is employed to limit the search to a region where the approximation is valid. The approximation model and the step size is updated after each optimisation loop until the selected convergence measure is achieved.

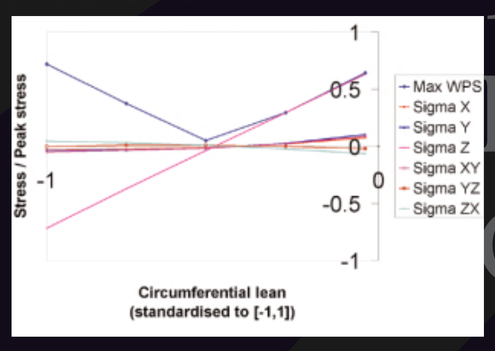



A trust region method with intermediate response functions is available in the SC03 plugin SC82.
This was developed for fan blade design but has been extended to other applications.

## Applications

### Fan Blade Leaning

In rotor blade design, the maximum steady stress over the aerofoil surface is often reduced by offsetting the stream-line sections from the radial line. The objective function, the peak worst principal stress, contains a number of slope discontinuities as the peak stress changes location, sign and direction.

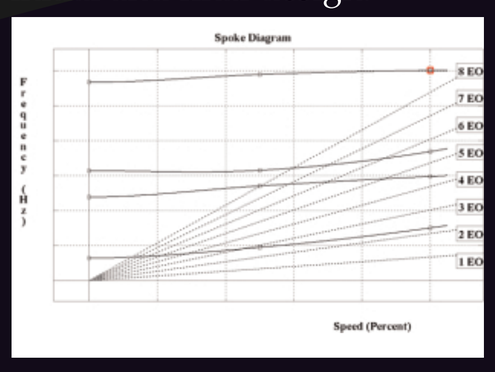


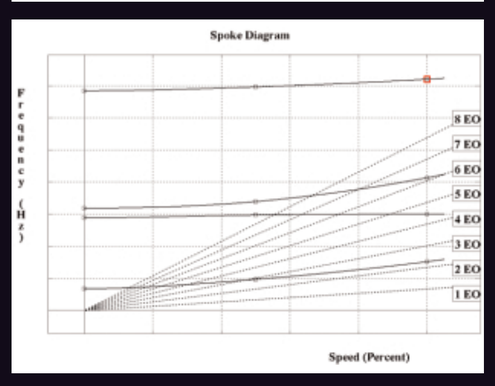

Selecting the 6 stress components at each surface node as an I.R.F. provides a significant reduction in the number of SC03 analyses required to identify the optimum design.
Test problem statistics:
4 sections perturbed on an aerofoil only model.

No. of SC03 analyses:
IRF method = 15
Objective approx. = 82
Direct search = 251

### Fan Blade 'Tuning'

This application concerns the design of a minimum weight aerofoil which meets the resonance and flutter avoidance criteria.
A test case from the RC104B Rotor 2 preliminary design process is presented. The following plots illustrate the Campbell diagram for the initial and final design.



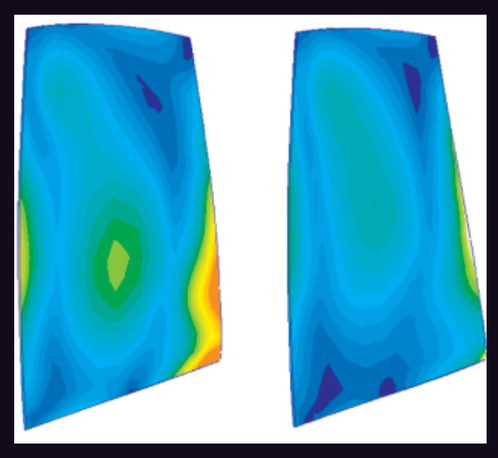




The aerofoil shape was modified by varying the chord at 3 sections and the maximum thickness at 5 sections, using JC14.
In this problem I.R.F.'s were introduced to model the frequency for each mode at 3 speeds. The Campbell diagram may then be re-created based on the approximate frequency data to determine the engine order and modal separations.

IRF Method = 61
Obj & Constraint Approx. = 321
Direct search = 495

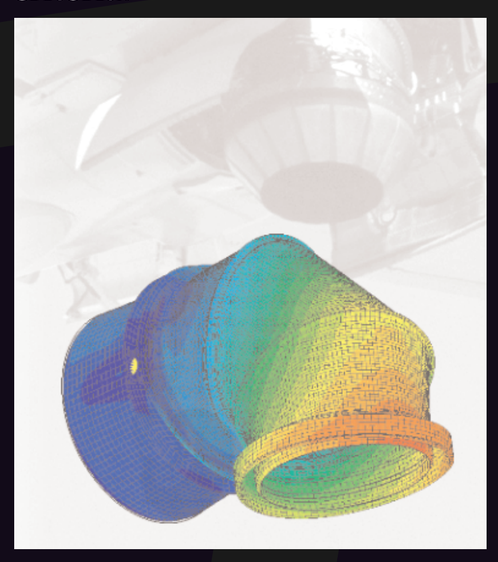
### RC104B Rotor 2

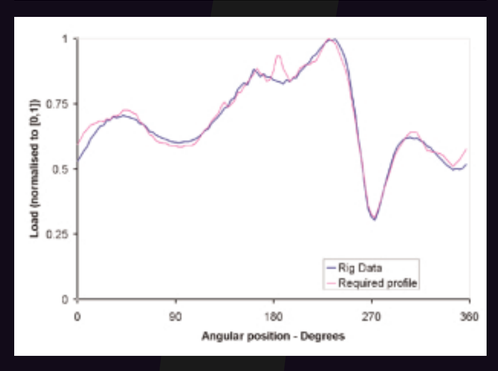
The Fan blade optimisation system was used to assist in improving the af strength for the 1T mode. A 215% increase in af strength was achieved with no increase in mass.
HCF endurance contours:



### JSF 3 Bearing Swivel Duct test design

This method is being applied to select the jack loads for the 3BSD structural rig test. The project aim is to optimise the jack loads to achieve the required load profiles at each bearing plane. Constraints are imposed on the jack loads based on the proof stress criteria.



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