Optimization & Robustness in MSC.SOFY

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Abstract

Structural optimization & robustness is often highly desired to support product development. Vehicle programs typically realize significant weight, cost, and performance improvements as a result of optimization. Unfortunately, this optimization is typically very complex resulting in the creation of highly specialized organizations and engineers that are capable of performing these analyses. This document proposes a "back-to-basics" approach to optimization that has been prototyped in MSC.SOFY. Simplifying the process to the point where the typical engineer can perform his or her own optimization & robustness studies should result in better enabling a Design for Six Sigma development process.

Introduction

1. Current State of Optimization & Robustness
2. Going “Back to Basics”
3. MSC.SOFY Software Prototype: Fleet Manager
4. Fleet Manager Process
5. Example Scenarios
6. Challenges
7. Next Steps

Current State of Optimization & Robustness

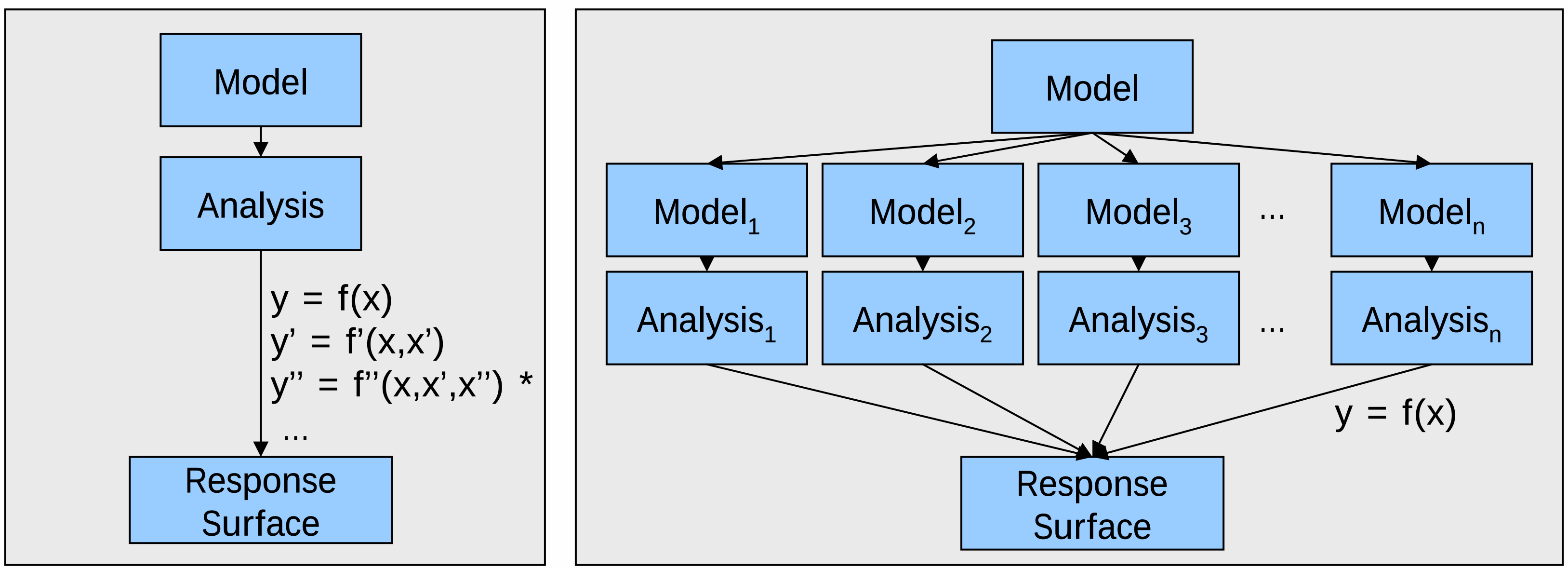
- Optimization & Robustness process often too complex for the typical engineer to support.
- Vehicle programs need the support of Optimization & Robustness specialists
- Studies are difficult to run analyses without scripting
- Proper interpretation of sensitivities requires years of experience (e.g. how far can a sensitivity be extrapolated?).
- Results often challenged for validity. Mathematics often very complex and difficult for the typical engineer to follow.
- Only the simplest design variables are supported (e.g. material thickness, bushing stiffness, damping, etc.). Many studies go unsupported due to only a limited number of supported variable types.

Proposal:
Going “Back to Basics”

Instead of relying on complex sensitivity based optimization & robustness, develop a general tool that generates a CAE model for every data point of interest, run analysis, and gather results.

Traditional Approach

Back to Basics



* second order derivatives are rarely used

Back to Basics – Pros & Cons

Pros

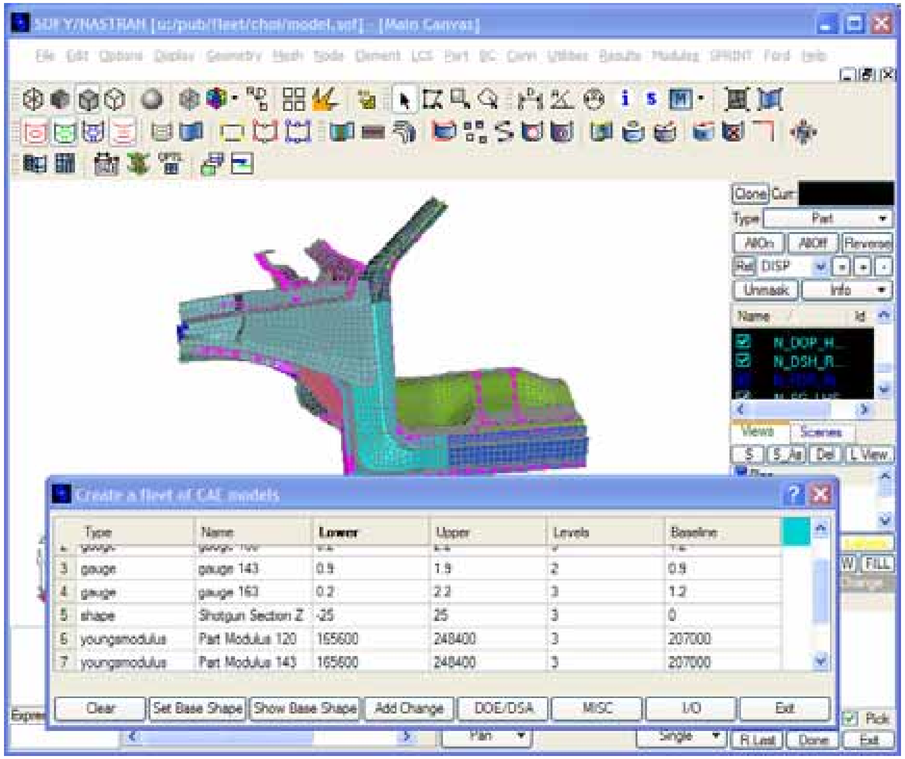
- The typical engineer will be able to do their own optimization & robustness analyses.
- Simple to understand and implement.
- Supports the creation of a general tool to manage the process (to be demonstrated in this presentation).
- Supports more advanced design changes (e.g. weld pitch, large displacement shape changes, part alternatives, topology changes).
- Results confidence much higher due to fewer assumptions (e.g. linearity assumptions).
- Especially effective with discrete variables.

Cons

- Inefficient use of compute resources. However… this con has been largely minimized since the implementation of **Desktop Clusters** (i.e. usage of hundreds idle desktop workstations).
- Only a limited number of design variables can be supported. At this time, around 1000 runs is feasible given a week (given a typical NVH structural analysis).

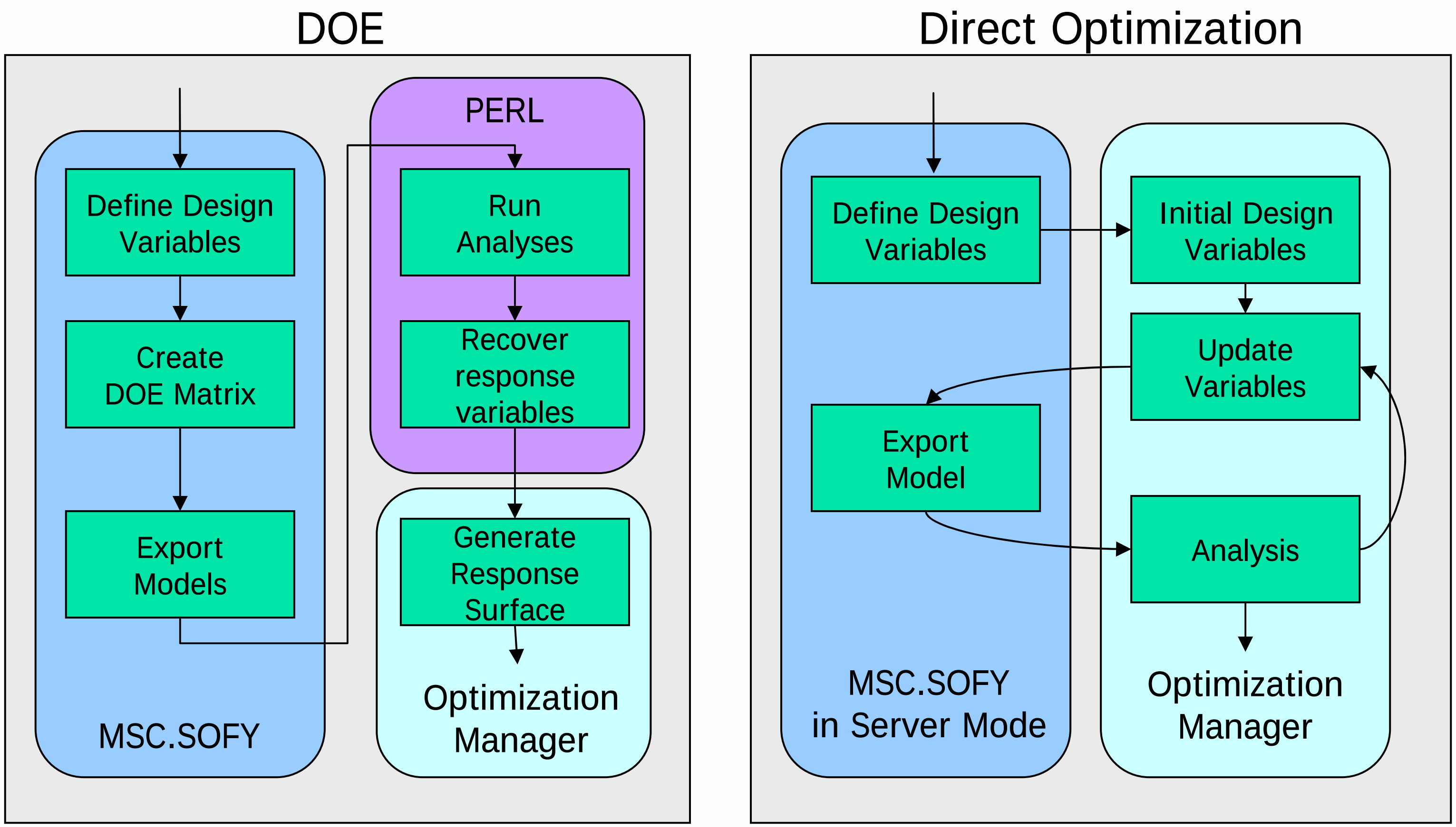
A Prototype Tool: Fleet Manager

The Fleet Manager was prototyped using RADE. It has supported several Optimization & Robustness projects that traditional approaches would have struggled with.



Note: The name Fleet Manager came from the idea of creating a “Fleet” of CAE models that represented manufacturing variability. Although originally created to estimate manufacturing robustness, it has grown into a general purpose Optimization & Robustness tool.

Fleet Manager Supports both DOE & Direct Optimization

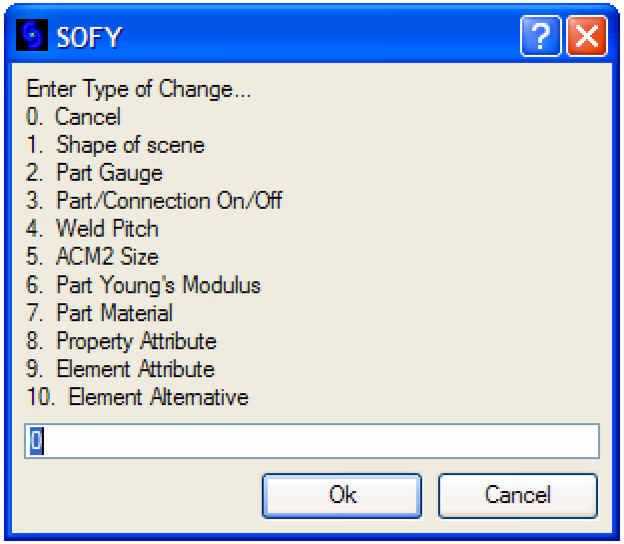


Design Changes Supported

Some of the more important design changes.

- Shape – very effective when used in combination with Morphing!
- Part Gauge - Material Thickness
- Part On/Off & Element Alternative – Supports design alternative studies.
- Connection On/Off – supports a weld manufacturing robustness study.
- Weld Pitch –weld respacing
- Property/Part Attribute –change any attribute that SOFY supports.

Note that all these variable types may be mixed within the same study.

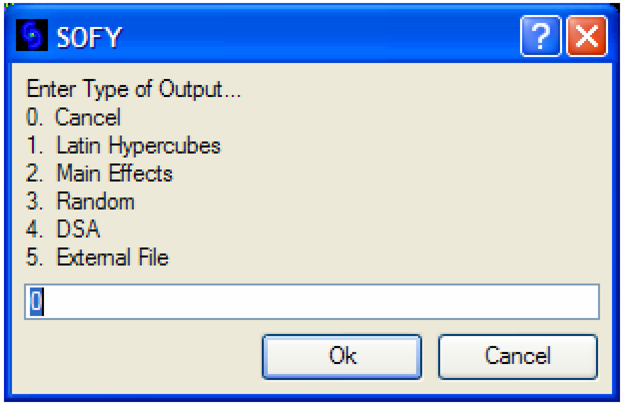


Creating the DOE

Once the design variables are established, the next step is to create a DOE matrix (or create SOL200 DSA cards).

Fleet Manager supports a variety of simple DOE matrices

- Latin Hypercube
- Main Effects (One at a time)
- Random (for Monte Carlo)
- DSA (will export MSC.Nastran DESVAR cards for those support design changes such as shape and properties variables
- External (ability to import a DOE matrix from another source such as Minitab, iSIGHT, or Insight)



Reviewing the DOE Matrix

Once a DOE matrix is created, the user may review and potentially make any necessary changes. The user may also select a row apply all changes applicable to that run to the SOFY database.

If desired, the user may save all runs in one click (if there are 100 runs, the Fleet Manager will save 100 models).

Runs / Models

DOE Iterations

	Gauge 118	Gauge 117	Gauge 143	Part Modulus 103	Part Modulus 117	Part Modulus 118
R1	0.300000	0.863333	0.400000	233333.333333	166666.666667	166666.666667
R2	0.633333	1.196667	1.066667	233333.333333	100000.000000	233333.333333
R3	0.966667	0.863333	0.400000	100000.000000	100000.000000	166666.666667
R4	0.300000	0.530000	1.066667	166666.666667	100000.000000	100000.000000
R5	0.300000	0.863333	0.733333	166666.666667	166666.666667	166666.666667
R6	0.300000	0.863333	0.733333	166666.666667	100000.000000	166666.666667
R7	0.966667	1.196667	0.733333	100000.000000	233333.333333	233333.333333
R8	0.966667	1.196667	0.733333	100000.000000	166666.666667	100000.000000
R9	0.966667	0.530000	1.066667	233333.333333	233333.333333	233333.333333
R10	0.633333	0.863333	0.400000	100000.000000	233333.333333	100000.000000
R11	0.633333	0.530000	1.066667	100000.000000	100000.000000	233333.333333
R12	0.300000	0.530000	0.733333	233333.333333	233333.333333	233333.333333
R13	0.633333	0.530000	1.066667	166666.666667	166666.666667	233333.333333
R14	0.966667	0.530000	0.733333	166666.666667	233333.333333	166666.666667
R15	0.633333	0.863333	0.400000	100000.000000	166666.666667	233333.333333

Save Iterations in Volume | Save Iterations in Files | Save Current | Exit

Save all models

Solving the “Storing Many Models Problem”

Efficient model storage is essential to the success of the Fleet Manager. Storage of 500 models at 50 MB comes to 25 GB!

Fleet Manager leverages the UNIX commands associated with RCS (Revision Control System), which was created to manage multiple versions of software code. RCS efficiently stores many versions of a file by only recording the differences between one version and the next. This proves to be extremely efficient for the purposes of storing many CAE models.

<u>Example Shape DOE</u>

Baseline File Size: 17.6 MB

27 Iterations w/o RCS: 475 MB
27 Iterations with RCS: 20.3 MB *

For RCS, it took 17.6 MB to save the first run, and 2.7 MB to save the other 26 iterations. In most cases, RCS does even better.

Example RCS File - UNIX

```
RCS file:       testing.dat,v;   Working file:    testing.dat
head:           4.0
locks:
access list:
symbolic names:
comment leader:  ""
total revisions: 5;    selected revisions: 5
description:
Sofy Changer Manager
----------------------------
revision 4.0
date: 2003/04/08 13:48:07;  author: bhuf1;  state: Exp;  lines added/del: 1391/1811
Iteration 4
----------------------------
revision 3.0
date: 2003/04/08 13:47:53;  author: bhuf1;  state: Exp;  lines added/del: 1810/1490
Iteration 3
----------------------------
revision 2.0
date: 2003/04/08 13:47:38;  author: bhuf1;  state: Exp;  lines added/del: 1490/1400
Iteration 2
----------------------------
revision 1.0
date: 2003/04/08 13:47:26;  author: bhuf1;  state: Exp;  lines added/del: 3043/7
Iteration 1
----------------------------
revision 0.0
date: 2003/04/08 13:47:16;  author: bhuf1;  state: Exp;
DOE Matrix 4x10
=========================================================
```

Job Submitting & Response Recovery

- A PERL script was written that can submit all models within an RCS *,v file. Analysis jobs will be routed to unused workstations or placed into a queuing system (manage by a cluster).
- Special care needs to be taken when recovering results from the solver. Only the most important data should be written out & kept.
- The most general way to extract response variables from all the runs is to use MSC.Nastran sol 200 and create a DRESP for each response of interest (e.g. max displacement, max stress, frequency, etc). Another PERL script has been created to extract NASTRAN sol 200 responses into a table (given a many .f06 files).

Example Scenarios

- Morph driven shape optimization
- Adhesive optimization
- Weld pitch optimization
- Shape and stiffness optimization
- Design alternatives

Morph Driven Shape Optimization

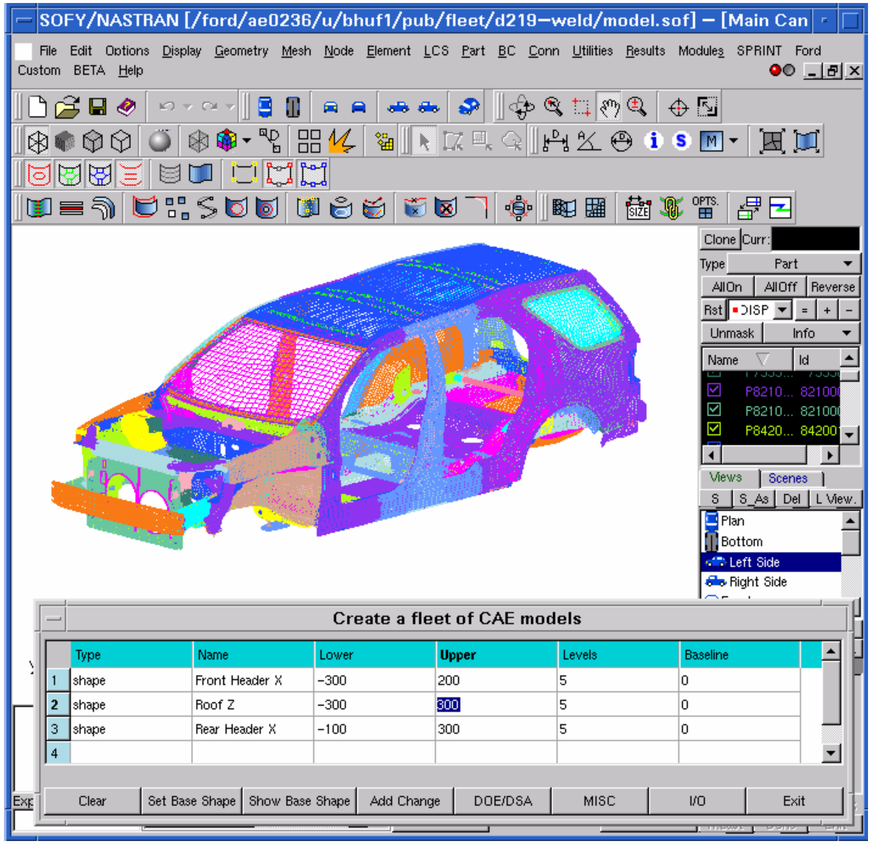
Three vehicle level shape design variables were created using Domain Morphing:

Front Header X (windshield angle)

Roof Z (Roof Height)

Rear Header X (backlight angle)

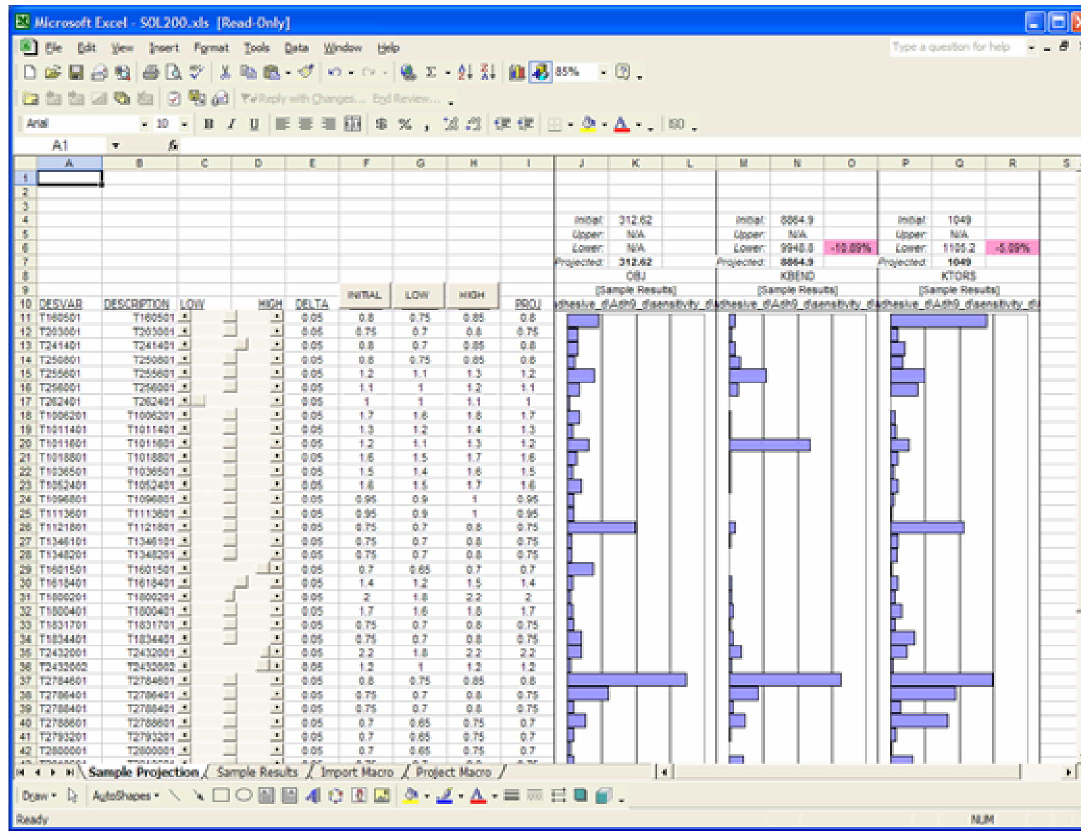
All three design variables can be adjusted simultaneously.



Adhesive optimization

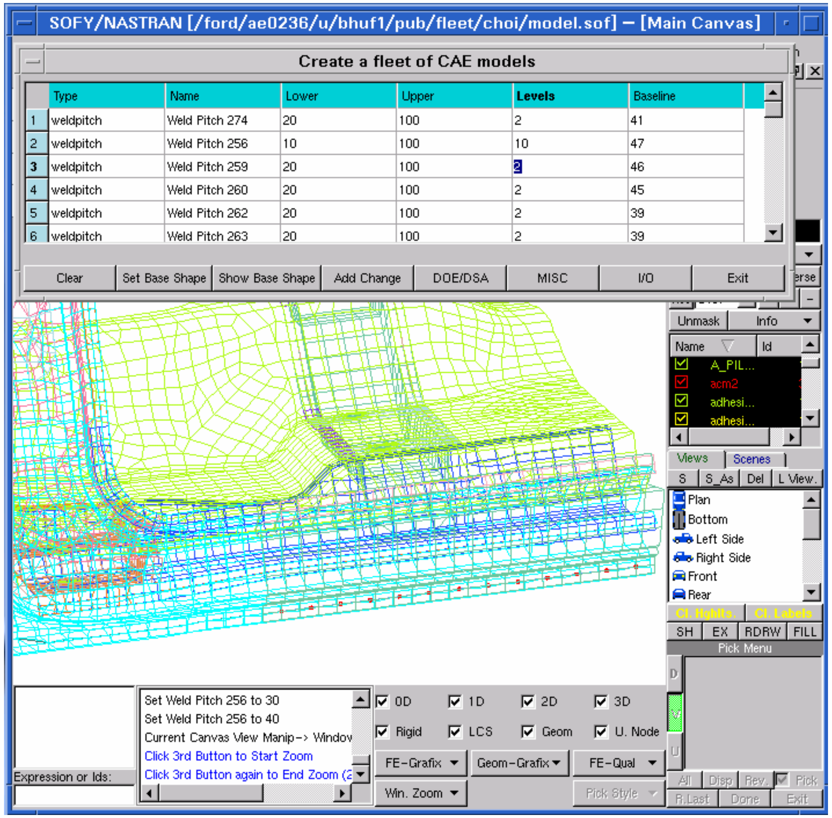
Approximately 50 adhesive strips were studied, resulting in around 200 model iterations.

An Excel surrogate model was then created to optimize the placement of adhesive.



Weld Pitch Optimization

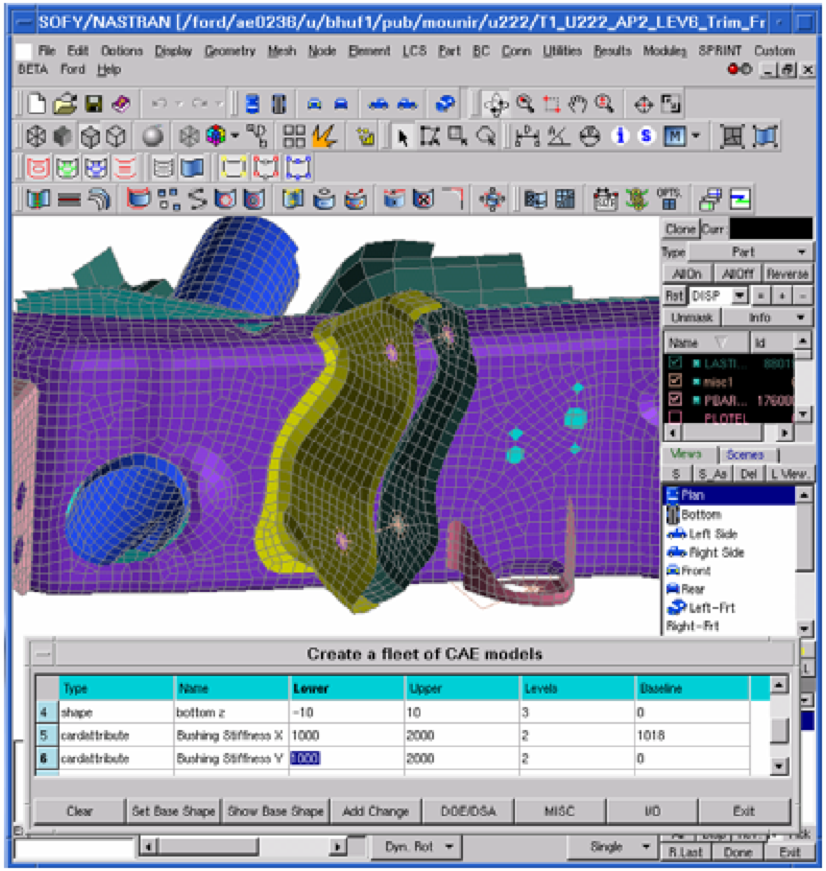
A weld pitch design variable will re-generate all the welds on a particular weld line. This supports the usage of any type of spot elements (e.g. Mesh Independent Solids or RBE2's).



Shape & Stiffness Optimization

The vehicle program wanted to understand how a body-to-chassis attachment point affected a full vehicle noise response.

Both shape and bushing stiffness were studied.

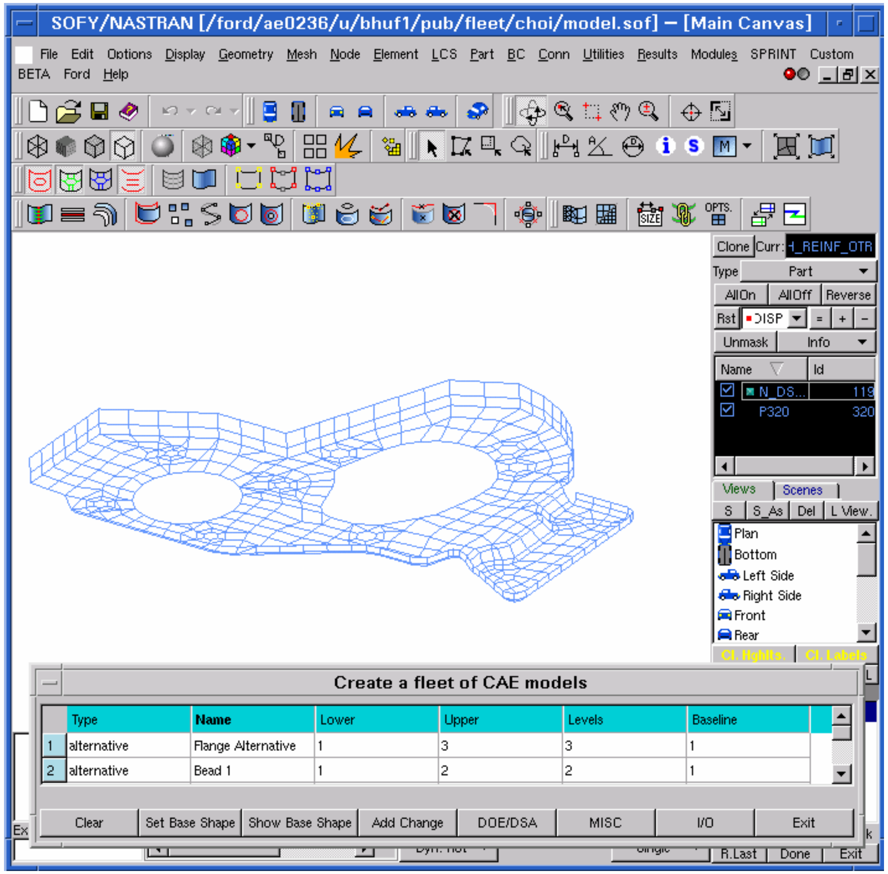


Design Alternatives

Here's a simple example of the recently added Element Alternative design variable.

This supports discrete design changes that can represent topological changes. In this case, two design variables were created:

1. Flange Alternative has 3 levels – no flange, small one-element flange, and full sized two-element flange.
2. Bead 1 has 2 levels – with and without a bead



Challenges

- Although usable, the Fleet Manager needs to developed into a production ready tool.
- PERL scripting was used for both job submitting and response recovery. This functionality should be built into our Job Submitting and/or Optimization tools.
- We still need help from the optimization expert to develop the DOE matrix.
- Creating the surrogate model takes took much time and often requires the support of an optimization expert.