# Optimisation of morphing parameters using ANSA and VR&D genesis

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## KEYWORDS –

Conceptual Vehicle Design, PDP Decision Making, ANSA Morphing, ANSA parameterisation methods, VR&D Genesis optimisation, Reinforcement Derivation Method (RDM)

ABSTRACT –

Conceptual design studies usually consider a high dimensional design space of variables. These variables can be optimised to yield a defined solution space which can be used to decipher the most promising design configuration. A conceptual design can have a mixture of regular, irregular and complex geometrical shapes. As such they can expand or restrict the design space accordingly.

The process to formulate these shapes can be attained via ANSA parameterisation modelling processes. They can then be exported in Nastran format for optimisation within Genesis.

This paper summarises the assimilation of relevant ANSA & VR&D Genesis processes in order to establish an interdependent CAE framework capable of conceptual evaluation, development and optimisation. More so it facilitates the interactive design space evaluation. The effectiveness of this approach is evaluated within a BEV (Battery Electric Vehicle) battery pack design study which has shown significant success in physically realizable designs.

# TECHNICAL PAPER -

## 1. Introduction

Automotive OEMs use CAE approach extensively and in almost every aspect of the design and development process[1]. Within this process, conceptual design studies have become *the key* competitive advantage. Their purpose is to qualify and quantify an array of design ideas and solutions. Their function is to codify a high dimensional design space of variables in order to make their evaluation possible and therefore be able to gain an engineering insight.

Conceptual studies help to establish; adequate design space boundaries, fit for purpose conceptual configurations and explore geometric potential of a detailed design. CAE offers the ability to provide detailed information and evaluation means to underpin such studies. Technical articulation, elaboration and sophistication are attained through CAE qualification, quantification and optimisation methods. Out of these methods, the necessary knowledge and insight, to establish a plausible solution space, can be derived. This solution space can then be used to decipher the most promising design configuration.

ANSA parameterisation is a key enabler to conceptual studies. Complex geometric design variables, shapes and features can be parameterised to form an interpretation to a specific technical design idea (Figure 1). This technical idea can be explored further via optimisation processes, which can then provide an insight to a desirable solution space. VR&D Genesis supports these processes, utilising modern optimisation methods algorithms and techniques (Figure 1), to attain a desirable solution space. Therefore it plays an invaluable part on establishing plausible designs against known objectives, constraints and parameters. ANSA morphing then is subsequently used to form geometric interpretations of these findings (Figure 1) resulting to reliable CAE models for further technical evaluation and maturity.

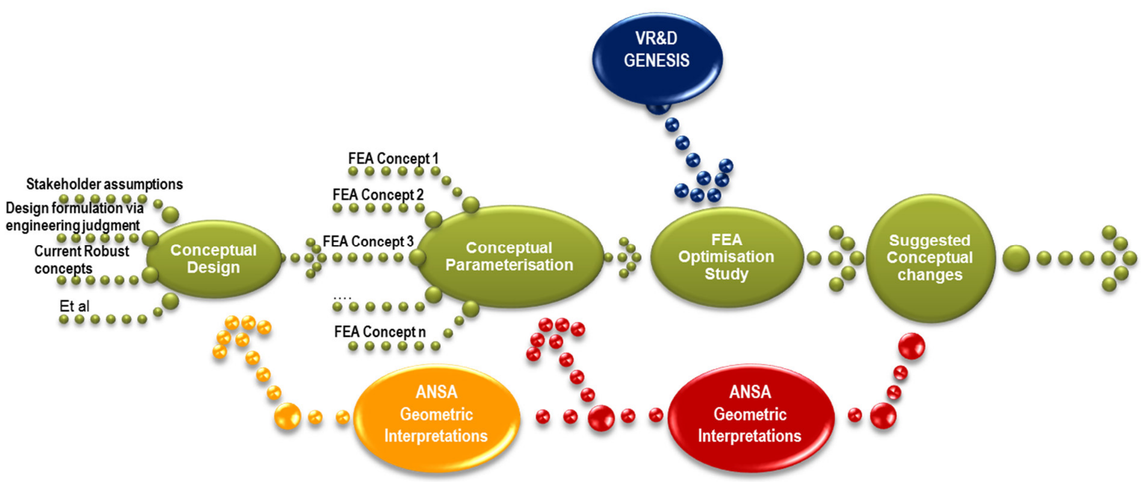


**Figure 1 - Process Description**

This paper summarises and illustrates the described approach i.e. ANSAs parameterisation to VR&Ds processes. It starts with the description of the ANSAs morphing techniques to compile a parameterised conceptual model. Then it describes the evaluation and optimisation phase to derive a desirable solution space via VR&D Genesis optimisation methods and techniques. This is an interdependent and iterative process. Its effectiveness is demonstrated on initial findings to a BEV (Battery Electric Vehicle) *Evoque-e project* battery pack design study.

### 1.1 Evoque_e project

The Evoque_e project will design and develop innovative hybrid and electric propulsion systems, integrated structures, power electronics, electric drives and energy optimisation. This unique project develops an integrated approach to system development and optimisation from design to testing, encompassing three technology vehicle demonstrators: Mild Hybrid Electric Vehicle, Plug-in Hybrid Electric Vehicle and a Battery Electric Vehicle.

The project will deliver 3 scalable innovative vehicle technology platforms to comply with potential future global CO2 legislation whilst protecting performance attributes, capable of delivering benchmark performance in terms of cost, weight and sustainable use of materials.

Co-funded by the UK's innovation agency, Innovate UK, the collaboration of partners is led by Jaguar Land Rover, established large companies and 1st tier suppliers: GKN Driveline (GKN), Zytek Automotive, AVL Powertrain UK Ltd (AVL), TATA Steel and Williams Advanced Engineering (WAE). Three innovative SMEs: Delta Motorsport, Drive System Design (DSD) and Motor Design Ltd (MDL). Plus three leading Universities: Cranfield University, Bristol University and Newcastle University.

## 2. ANSA Morphing at the conceptual phase

Part of the challenge one is faced with, is the fact that at the beginning of the product development process the available designs are conceptual. Conceptual designs tend to be an aggregate of current or newly formed interpretations aspiring to meet a solution space. This translates to high level geometrical abstractions with basic features and detailing. However a CAE conceptual evaluation can only take place if these abstractions, features and detailing have been compiled onto a simulation model.

Whilst it is acknowledged that a simulation model is an efficient and effective tool to gather engineering evaluations and intelligence, somehow compiling one comes with immense challenges and high expectations. To proceed with such CAE studies one has to formulate a baseline conceptual design and explore, introduce or supress its influential features and geometrical details. In other words it has to be able to encapsulate a specific generic design and generate numerous variants out of it in order to lead its technical development, sophistication and maturity.

ANSA morphing technologies provide the necessary framework to formulate sophisticated and complex conceptual designs containing all the required features and geometric detailing without high CAD model demands. More so it provides a robust platform to generate numerous variants through its morphing parameterisation variables.

ANSA provides two main methods for morphing; box morphing and direct morphing. For box morphing, the user can be prescriptive, where in direct morphing, descriptive. In box morphing entities loaded to a user defined box will assume the shape changes of that box proportionally. In direct morphing shape changes are applied directly to the defined entities allowing a transition zone around them.

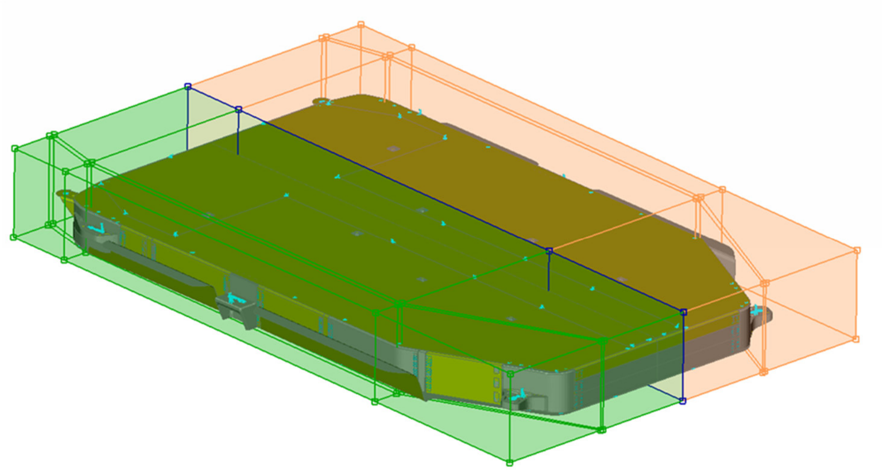

**Figure 2 – Basic Box Morphing Conceptual Parameterisation of a Battery Pack**

Whilst the proposed process can be applicable to both morphing methods in this paper study the box morphing approach was explored (Figure 2) and used for the following reasons;

- Box morphing is similar to CAD feature based parameterisation approach
- Defined boxes can be named parameterised and applied to subsequent models
- Box morphing makes possible the introduction or suppression of geometric features
- Automation, categorisation and assembly is easier to implement throughout product development and maturity process

Note that at the end of each meshing procedure the connectivity of the mesh remains unchanged. However when large shape changes have been pursued within ANSAs morphings the resulting changes can yield very poor quality mesh. To alleviate this problem it is always advisable to use the reconstruct mesh process. In this way mesh quality standards can always be maintained. Also in this context welds, rivets, adhesives et al, need be considered, reviewed and realised accordingly.

## 3. ANSA morphing parameterisation to VR&D Genesis

ANSA morphings can be parameterised and exported in Nastran format for optimisation within VR&D Genesis. This can be accomplished by creating ANSA morph history states from which one can define DVGRID & DVAR(DESVAR) key words. These key words then can be considered as design variable data from which VR&D optimisation studies can take place once the necessary constrains and objectives have been added.

Each DVGRID defines a vector for every node in the model that, if applied, would create the morphing state created previously in ANSA. The initial location of each node at the start of each design cycle is defined by the original location plus the product of the current DVAR value and the DVGRID vector.

The DVGRID and DVAR keywords which have been exported from ANSA can be collated to an include file that contains all the conceptual parameterised design data. As such all the necessary variables and data can be logged and referenced as means to attain technical articulation, elaboration and maturity within the product development process.

## 4. VR&D Genesis optimisation

Conceptual designs are based on stakeholder experiences and as such they can be over or under engineered. To mature such designs the necessary detailing need to be added. An effective way to achieve this is to utilise the intelligence gained from a structural optimisation study. Such study will be able to highlight the over or under - utilised material at its corresponding region in the design.

Over the past 25+ years, VR&D have developed Genesis to be one of the leading and comprehensive structural optimisation CAE codes that can comfortably support such studies. It includes methods, algorithms and techniques developed by experts in the field.

GENESIS is a completely integrated finite element analysis and design optimisation software package, driven by its own environment in a software programme called Design Studio. This provides a complete pre & post-processing background for both the analysis and optimisation capabilities.

The Reinforcement Derivation Method (RDM®) provided as part of GRM's Design Toolkit module within Design Studio, enables users to automatically generate a design space and define optimisation studies to identify where to reinforce designs. By utilising existing models, a rapid design direction can be gained to focus the inevitably finite resources of the subsequent design studies. In this paper RDM® is used for the following reasons;

- Identify areas for load path improvement
- Define new load paths
- Identify optimal load paths and reinforcement patterns
- Locate and solve poor joint conditions
- Support the rapid development of optimum rib patterns for castings and mouldings

The basic premise of RDM is that it assumes that material properties are constant within each finite element. Each finite element property is treated as a design variable and combined with the corresponding boundary conditions and perimeter constraints. Solution for plausible optimised geometric space is derived via each elements mass density index. RDM employs a closed form expression for the effective Young's modulus and shear modulus in terms of phase properties and volume fractions[2].

## 5. VR&D Genesis optimisation from and to ANSA framework

The Genesis optimisation process is based on ANSAs meshed model extracted in Nastran format and the DVGRID and DVAR keywords. Note that unless fundmanetal changes have taken place to the meshed model, it is only necessary to export the DVGRID and DVAR kewords at it's subsequent iterations. The process within VR&D then will be to vary the DVAR (DESVAR) until the objectives and constraints have been satisfied.

The necessary geometric changes are applied to the variables with the largest influence on the considered response. Only the interesting DVAR response values are exported back to ANSA. The process is iterative (Figure 1) up until a feasible design can be found.

In this design study the general relationship of design variables to the objectives may be summarised by plotting the design variables with the DINDEX as illustrated in Figure X. One may see a clear relationship between the design variable and the DINDEX objective function.

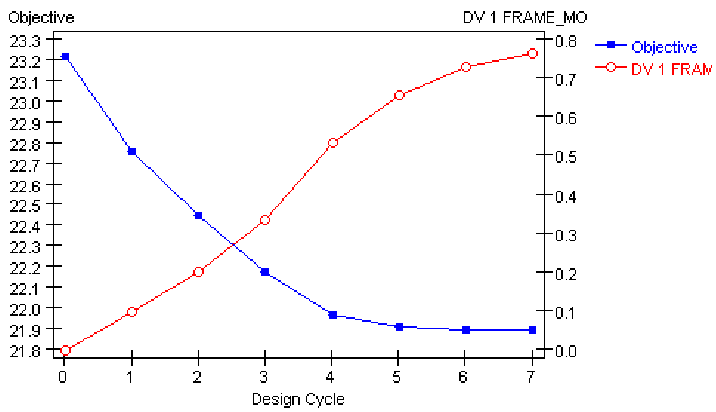


**Figure 3 - Optimisation Study using target values. In this graph it can be seen that most gains occurred by design cycle 5**

The acquired intelligence through this loop is that a large number of design variants can be studied. This leads to establishing a link between design variants (design space) to objectives (solution space). As a result product development can concentrate activities on the vital few design changes which have the highest influence to the overall objective.

## 6. Case study; Optimisation of battery pack structure

For this case study (mounting point optimisation) the goal was to optimise the structural performance of the battery pack within a desirable geometric morphing envelope. Initial studies had as their aim to develop an optimal load path from the vehicle to the battery pack. Figure 3 illustrates the initial morphing parameterisation and the 6 proposed primary mounting points

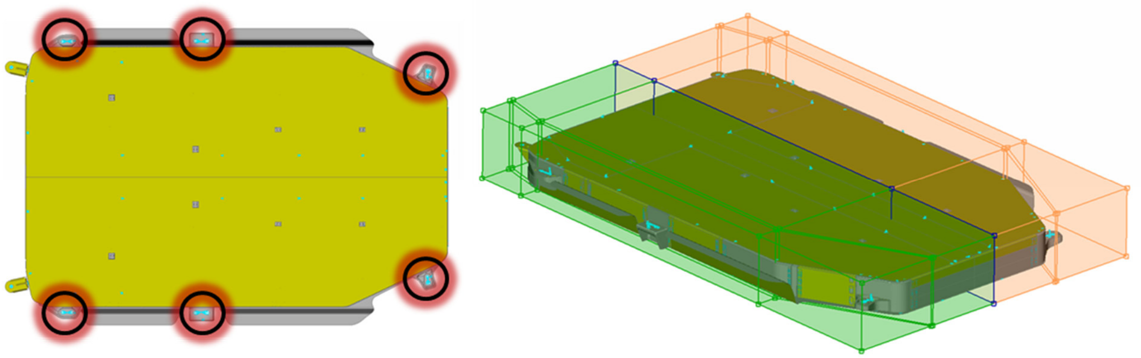

**Figure 4 - Morphing conceptual parameterisation to develop optimal mountings (6 highlighted)**

In this study the structural performance of the pack was used as the objective, constrained by the movement limits set within the DVAR keyword. The volumetric footprint was used as the design variable constraint in Z-axis – figure x. Since the outer surface of the pack design and the BIW footprint are difficult to change this bounds the decision space (constraint variable).

Considering the above and to achieve the desirable structural performance, two initial optimisation studies were contacted. The first was to confirm the general relationship of the design variable to the objectives and to find out which load cases are most affected by the design variable (Figure 5). The second was to optimise to stiffness targets for the load cases most affected by the design variable.

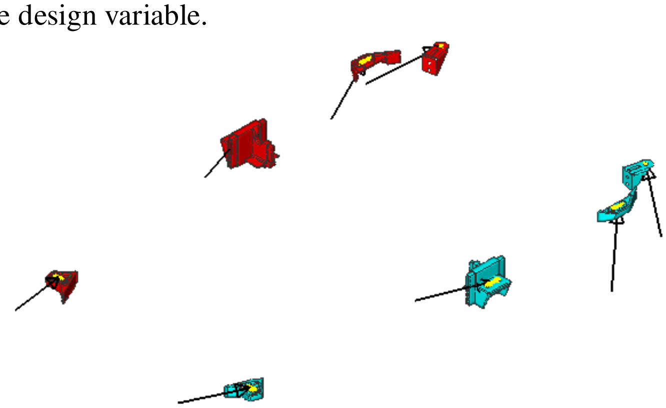

**Figure 5: Study to evaluate relationship between load cases and design variables. One iteration of forces acting on battery pack fixing points**

In the first optimisation the relationship of the design variable was derived using the amount of relative displacement between the 6 mounting points (Figure 5) defined as the standard deviation for each component of displacement. This was defined as a synthetic response, in solution space, for each component of displacement (X,Y,Z) and each loadcase. This yielded 30 unique synthetic responses linked to quantifiable relationships on specific design variables.

Considering the findings from the first optimisation, the second optimisation pursued topology studies via the RDM method on the specific design variables. The development and maturity of these variables had the following design objectives:

1. Minimise mass: to achieved reduced overall vehicle weight and manufacturing cost
2. Stiffness: mountings should remain stiff for robust load transmission from the vehicle to the battery pack
3. Manufacturability: Feasibility studies and corresponding constraints
4. Permanent set: mountings should be within agreed permanent set at all of the considered load cases

The RDM process begins with the definition of the topology region (Figure 6). In this the RDM mesh is generated. There are several ways to choose each more or less have a direct impact to the breadth and depth of the optimisation results. In this particular case the projection technique was used. This technique creates new RDM node & element numbering in order to avoid conflict with the existing numbering ranges of the current model. The potential design space is then defined by ANSAs DVAR and DVGRID design variables including the material and gauge properties. Finally the specific objectives and constrains have been added.

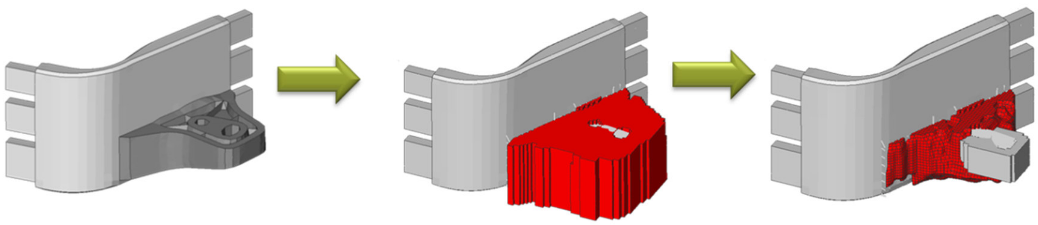

**Figure 6 – Overview of the RDM process for 1 of the 6 primary mounting points**

The RDM optimiser attempted to provide the 'best' solution i.e. set of design variables that meet the objective and constraint criteria. The optimiser initially yielded some hard convergence, meaning the best design variable values for the aimed solution space has been reached. These values are then become the new inputs in ANSA yielding a new geometrical interpretation (Figure 7). The process from ANSA to VR&D run again until soft convergence was reached. This concluded this study since a successful map between the design space to the solution space was defined.

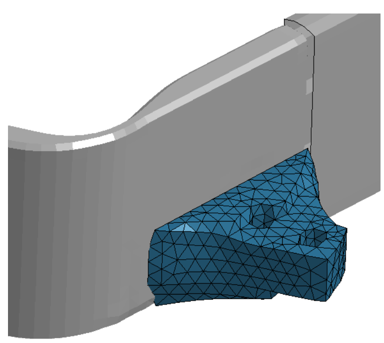

**Figure 7 - ANSA geometrical interpretation**

The same process was followed to optimise for several other factors and design variables. The acquired results are deemed to be accurate enough for the purpose and the assumptions required for this study.

## 7. Discussion / Conclusions

This paper presented a summary of relevant ANSA & VR&D Genesis processes able to establish a CAE framework for conceptual evaluation, development and optimisation. In general the proposed approach allows for quick study and evaluation of numerous design iterations derived from a conceptual design. Within ANSA parameterisation the important geometric design variables are easy to introduce. Subsequently VR&Ds optimisation technologies can use these parameters to process for a large range of objectives and constraints.

Although VR&D has parameterisation processes, these are limited. ANSA processes provide easier ways to introduce more refined and advanced parameterisations. Consequently the necessary conceptual design changes are easier to implement and therefore easier to be reflected to the design space.

Whilst VR&D can evaluate numerous design iterations and provide means to indicate new design features, it can't provide an updated geometric / simulation model. Geometric / simulation model changes are easier to derive within ANSA using its morphing parameterisation capabilities. ANSAs use provides for valid simulation models by adapting existing ones to new design variants. The potential for automation to this process can further enhance its use within this remit.

The application of this process was illustrated with a battery pack study (mounting point optimisation). The acquired results are deemed to be accurate enough for the purpose and the assumptions required for such study.

Overall the battery pack design (mounting point optimisation) used in this illustrated method is one of the many design iterations within the Evoque-e program. Therefore it should be seen as an example to demonstrate the potential and benefits one can gain from ANSAs parameterisation and VR&Ds optimisation for conceptual design studies rather than as an example to define an ideal battery pack mounting design.

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