ANSA Kinematic Tool & Morphing – Enabling conceptual vehicle frontal design for pedestrian safety

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ABSTRACT –
Over the last decade, the pedestrian safety requirements for vehicle design have become increasingly important via legal regulations and consumer evaluation testing. However, a need for high pedestrian performance can have a significant influence on a vehicle's frontal design and structure.

Current reality is that PDP (Product Development Procedure) cycles get shorter, whilst the need to develop unique and sophisticated vehicle frontal design intensifies. A crucial enabler to address this is the ability to qualify and quantify pedestrian performance at the conceptual phase. To succeed in this, knowledge and understanding of vehicle frontal design and structure is essential. However such an approach is demanding on two fronts. The first is in relation to the detailed performance in terms of external geometry and generic load paths. The second is in relation to the detailed kinematic understanding, in terms of impact energy management, characterisation and implementation.

Vehicle frontal design knowledge acquisition and understanding at the conceptual phase can be problematic since detailed parts and assemblies are not readily available. However ANSA morphing and kinematic tools aid significantly this approach by providing some efficient and effective means to compile numerous conceptual studies. This paper reports initial experiences and findings from the application and use of ANSA kinematic tool and morphing to such pedestrian studies.

TECHNICAL PAPER -

1. Introduction

Over the last decade, accident studies, on vulnerable road users and in particular pedestrians, has led to several legal and consumer requirements [1, 2, 3, 4]. However such regulations and testing have a significant influence on a vehicle's PDP cycle, frontal design and structure.

Current automotive marketplace increasingly emphasises the need for shorter PDP cycles. However, shorter PDP cycles mean an increase in the need for greater breadth, depth and sophistication of the related product knowledge [5, 6] at the early PDP stages. PDPs true nature is the 'end products' specific knowledge acquisition, enrichment and maturity. In the case of frontal design, it implies detailed information obtained from a vehicle's particular design and structure on two fronts. First regarding the geometry's potential, and second, concerning the related kinematic performance.

CAE model studies are a key enabler for vehicle frontal design at the conceptual phase. Such studies offer the ability to provide detailed information, insight and reliable means for technical feedback, comprehension and knowledge creation. Typically, a CAE model requires detailed 3D CAD data. At the early conceptual PDP phase, these CAD data take a long time to compile and can be based on limited input. Arguably, this is time consuming and has no major significance to the overall CAE output. On the contrary, it detracts from the benefits of model parameterisation and shape variation in terms of styling cues and feature lines.

Without CAE modelling, technical assessment and feedback it is difficult if not impossible. ANSA morphing aids rapid CAE model iterations to a technical surface (i.e. bonnet, door, sunroof etc). More so, it offers the ability to compile additional models from the transition between two surface releases. Kinetics supports the articulation of such a technical surface release. This paper illustrates this approach using the bonnet design as an example.

2. Frontal Vehicle Design and PDP at the conceptual phase

A vehicle design accounts for product excitement and brand engagement. Therefore, most OEMs use vehicle design for product differentiation and as a key competitive advantage. A good design becomes a visual asset since it conveys the essence of the brand's forms, emotions and values. Global brands utilise their visual assets to increase customer engagement, appetite and potential for additional complementary products and / or services. Successful designs are developed on creative flexibility and uncompromising precision. Therefore, technical surfacing (aesthetic qualities) and CAE models (technical quantification of performance) are interlinked.

One of the great misconceptions regarding CAE models is that they are all about requirements engineering. Of course requirements are tremendously important but a CAE model is more than that. It is a styling enabler and a PDP facilitator. It is an efficient and effective tool (or system) for progressing meaningful and quantifiable styling or engineering interpretations. CAE models enhance comprehension and knowledge amongst all the PDP stakeholders through their rich visual and numerical outputs. Consequently, early conceptual CAE models are of high importance and value since they provide means for decision-making, design direction and development. Hence, it is pertinent to compile parameterised CAE models at the conceptual PDP phase.

3. The ANSA Morphing

Morphing in ANSA is a very powerful and intuitive tool, it can be used to reshape, redesign and detail a CAE model without the need for a 3D CAD model. In the case of frontal design, morphing can be used to retain and optimise vital styling cues and design features (Figure 1)

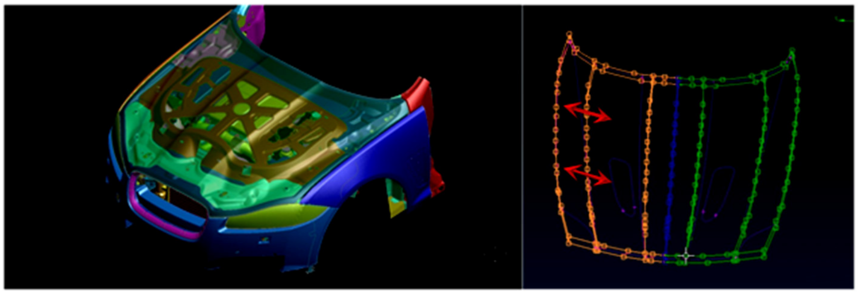

Figure 1 – Morphing according to styling cues

Morphing is based on the definition of special entities. These special entities can be defined to represent unique design or styling functions and features (Figure 2). The natural extension to the definition of these entities is shape, regional or topological definition. The culmination of which, can lead to a refined and detailed shape description. The control points of these entities can be moved freely or according to a specific curve. The 'degrees of freedom' to these control points ultimately can be assigned to parameters of a CAE model. Control changes to these parameters support the definition of a new CAE model, which can be aligned to a new technical surface release or a variation of it.

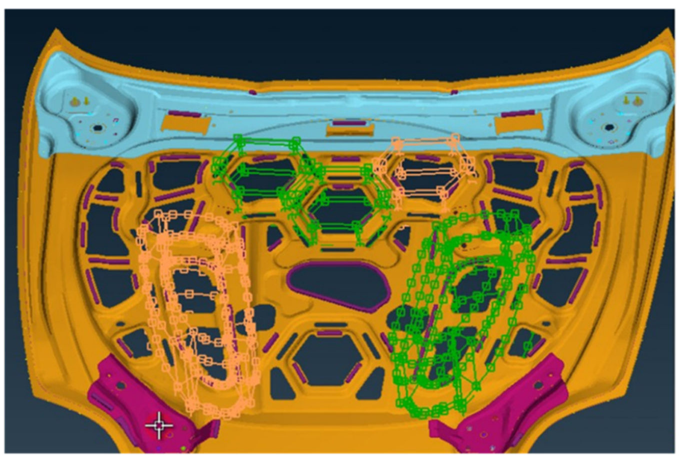

Figure 2 - Morphing entities representing unique design functions and features

The implementation of the described process expands the PDP body of knowledge on two fronts. The first is through morph entity definition and detailing from the technical surface releases (similar to a feature-based model). The second is in relation to the technical feedback of CAE model iteration. This feedback can be linked to a weighting factor in relation to the overall frontal design performance.

This approach offers a reliable framework for a traceable decision making process from which a system, product attribute, feature, part etc. has been derived. This leads to shorter overall PDP cycles, within a smoother and optimal knowledge acquisition and informational flow.

4. The ANSA Kinematic Tool

Pedestrian CAE studies, at the conceptual phase, over a deploying frontal vehicle design present many kinematic challenges compared to a passive system. These challenges are predominantly based on the vehicle's unique design and hinge assembly as well as to the specific deploying tuning factors. The deploying bonnet system is designed to reduce the risk of head injuries to pedestrians in certain accident situations by increasing crush space between the bonnet and the under bonnet hard components i.e. engine parts, expansion tank, air duct, etc. Such system is used in order to enable extra vehicle style and package space freedom.

The development of a sophisticated deploying frontal vehicle design requires a vast amount of kinematic factors and parameters to be considered. These need to cover the full interactions amongst all of the possible system design and assembly factors. The traditional route for the development and understanding of these factors is via crude CAD trajectory data and multi body model studies such as Matlab / Simulink (Figure 3). However, such an approach is demanding and strenuous.

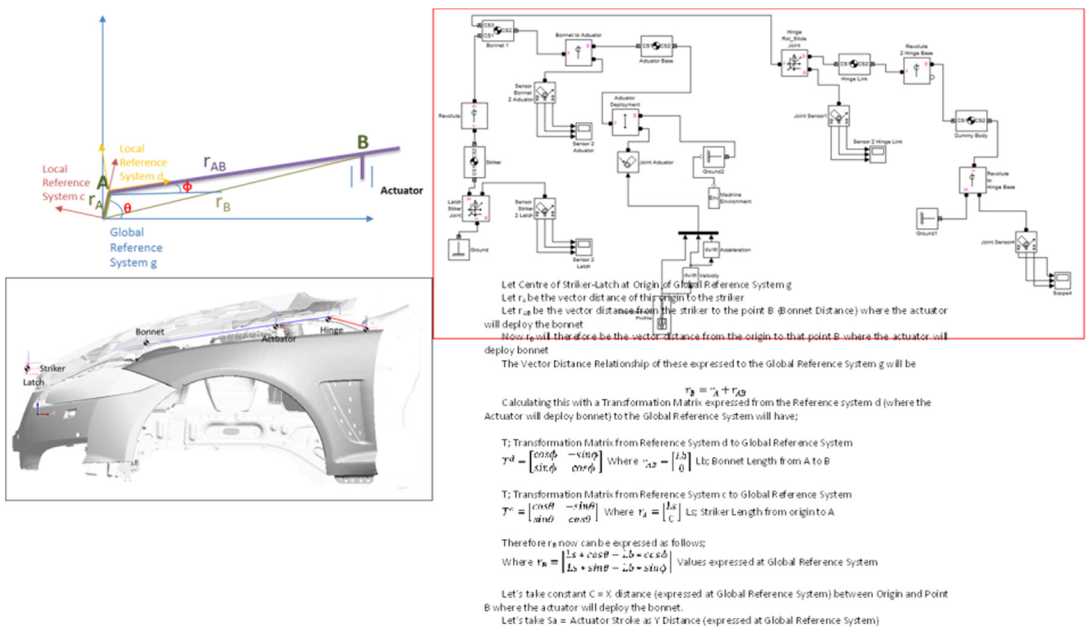

Figure 3 - Traditional Multi-Body Analysis

ANSA kinematic tool is an intuitive and quick alternative. It offers a rich library of joint types, bodies and forces. Additionally numerous kinematic motion definitions can be used covering a wide spectrum of motions on joints or on bodies. Physical deploying parts represented by their meshed elements can be kinematically described. ANSA can calculate mechanism motions in a multitude of ways according to the user requirements.

As an example the mechanism of a deploying bonnet consists from many parts such as;

- The actuator which is utilized for bonnet lift. This was modelled as a kinematic motion entity
- The hinge is positioned at the rear end of the bonnet. A hinge has a dual function; the normal bonnet opening to access the engine compartment and the deploying function which is used in order to increase crush space between the bonnet and the under bonnet parts. All of the hinge components were modelled using a combination of revolute and translational joint types
- The latch or latches with a pivot / hinge on an active (deploying) bonnet is represented in the model with a revolute joint. Typically, simple kinematic

configurations, modelled as a revolute joint. For more refined kinematic configurations, a combination of revolute and translational joints may be required.

ANSA Kinematic tool offers the benefit of a multi body numerical codification and characterisation to a wide range of physical factors. These factors are dimensionally very close to the physical parts and systems. Such an approach is intuitive and less volatile to factors that may be hidden within the assumptions of the traditional multi body model. The direct implication of this is that it has the potential to provide detailed understanding and characterisation to the physical parts and systems.

As an example **HIC** (**H**ead **I**njury **C**riterion) is one of the main metrics to measure and report on Pedestrian frontal vehicle design performance. HIC is a quantifier depicting kinematic and mechanical response under a specific impactor and test requirement. This mechanical response is governed and influenced by numerous design and assembly factors. One of these main factors is the bonnet energy state at the time of impact (Figure 4).

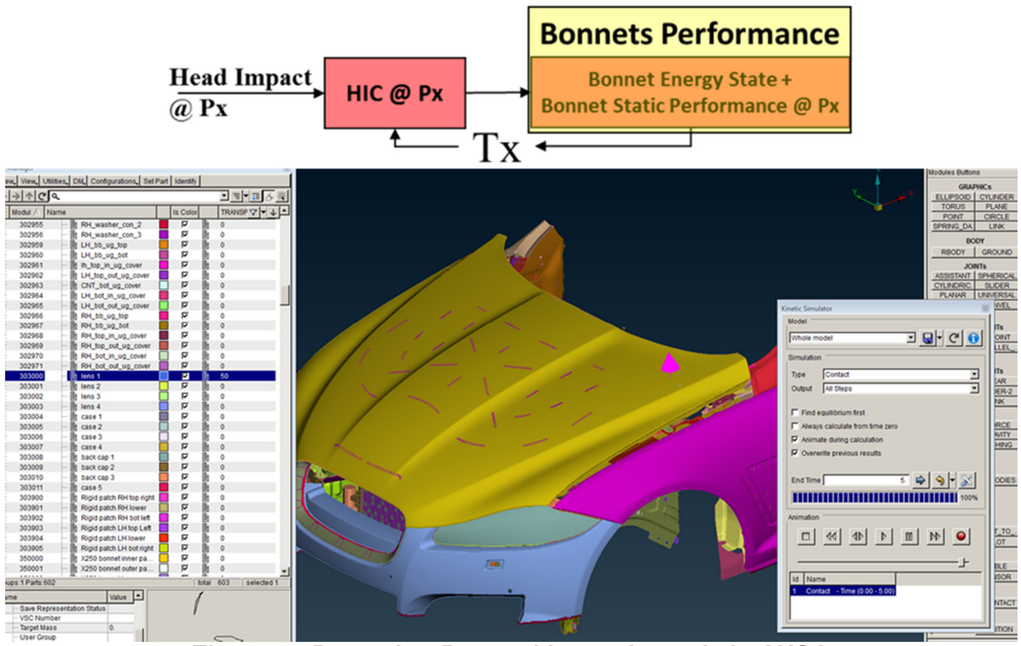

Figure 4 - Deploying Bonnet kinematic study in ANSA

However the bonnet energy state varies with the deploying time and the head time to contact. Evidently there is a relationship between HIC performance, Head impact location and Bonnet Velocity (Bonnet Energy State). ANSA kinematic tool yields quick deploying kinematic characterization with the following beneficial output and understanding;

- Apply a quick kinematic analysis to measure and characterise a specific bonnet region for energy state Vs time to contact
- Conceptual Study on a new deploying bonnet system
- Optimal Hinge, Latch selection point & trajectories
- Apply system model analysis to first establish and then optimise which of the hinge and actuator factors are kinematically the best choice for maximum HIC performance – (Optimal time to deploy, minimal velocity across bonnet A-Surface for specific time to contact)
- Increase understanding on hinge performance requirements and specifications
- Pursue further detailed kinematic studies on the results to investigate for further significant findings i.e hinge soft stop, actuator pulse performance requirements etc.

ANSA's kinetic tool allows for the organization of the kinematic components such that the mechanism expert can **predefine** different movement configurations. These configurations can then be made widely available to system engineers for further kinematic visualisation and interaction. This is important because kinematic visualisation and interaction requires less mental determination to understand before being able to contribute to it.

Finally ANSA demonstrates a seamless and tight integration between it's kinematic and morphing tool. Mechanism of part's can be reshaped and controlled by the morphing tool such that the full mechanism geometric envelop can be realised.

5. Discussion / Conclusions

This paper reported initial experiences from the application of ANSAs morphing and kinematic tools to pedestrian studies. The application of these tools was illustrated with a deploying bonnet study. Deploying bonnet studies at the conceptual PDP phase present many CAE challenges. These challenges are based on limited CAD input (technical surfacing), the kinematically unique hinge assembly and the specific deploying tuning choices.

ANSAs morphing toolset offer an explicit approach to capture a wide range of CAE model iterations between two technical surface releases. However, additional remarks for it's application can be made as follows;

- No detailed CAD model is required.
- Model & Styling shape parameterisation is possible. This is a very quick and effective means to compile numerous conceptual studies.
- Major PDP time saving can be realised since many surface and shape variations can be formed and analysed .
- A CAE lead design and development is possible

ANSA kinetics supports the mechanism articulation of a system design such as a deploying bonnet system. ANSA kinetic study helps to study many different but yet important facets in the development and realisation of a mechanism. As such, the following remarks can be made;

- Quick kinematic differences can be compiled and studied with the following benefits;
    - Kinematic / Trajectory result easier to compile, visualise and comprehend
    - Many Multi Body counterintuitive results or assumptions can be further studied and or analysed
    - Once the basic premises of kinetic element model and representation are compiled then a vast array of parameters and variables can be assigned and tested within ANSA. Such a possibility is prohibitive within the current explicit CAE model (and is time consuming).
- Deploying Bonnet Performance and Part Characterization;
    - From a Product Development viewpoint and considering the requirements cascade process, System Modeling and simulation can be implemented and utilized at the early conceptual phases.

Overall the kinetic model simulation was proven to be accurate and informative to all of the studied scenarios. ANSA kinetic studies have helped to enhance confidence levels to the deploying bonnet mechanism even further. The acquired results are deemed to be accurate enough for the purpose and the assumptions required for the current study.

DECLARATION

Any ideas, opinions, findings and conclusions or suggestions regarding styling understanding and interpretation, are those of the authors and do not necessarily reflect JLR's views on this subject.

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