Robust and Realistic LSDYNA Crashworthiness and Safety models by EASi-CRASH DYNA

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ABSTRACT

EASi CRASH DYNA can highly optimize the product development life cycle to meet the growing demand for robust and high quality products. Tough competition, strict mandatory regulations and global norms have forced the engineers and scientists to develop innovative ideas and solutions to meet the growing demand. The concept of Virtual prototyping, in the automotive sector, with the aid of FE-based analysis, has drastically reduced the life cycle of new car programmes and assessment.
The reliability of the output from any FE model is based on robust and realistic representation of physics of the model. To develop accurate models, the CAE engineers have a great necessity for innovative pre-processing and post-processing tools.
This paper will present necessary accessories required in pre-processing and post-processing tools, to develop robust, realistic, crash and safety models and to evaluate the results for simulation with LS-DYNA - exemplified with use cases from OEMs and major safety suppliers.

INTRODUCTION

In a virtual prototype environment, each subsystem has to be built and tested for its complete functionality and robustness. While analyzing a full car model, for crashworthiness and safety, each subsystem has to be built accurately to represent the physics of the subsystem. The Pre-processor tool plays a significant role in building and assembling the subsystems into a complete model. To stay competitive any automotive development organisation has to perform an increasing number of analysis in a short time. It is here, the productivity of CAE comes into focus. The need for increasing productivity in CAE for crash and safety analysis has never been greater and it will continue to grow.

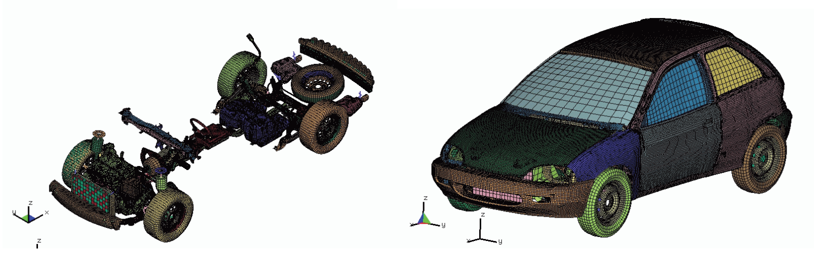

Figure 1: Robust full car model

Additionally, there are developments in the automotive business setting affecting how CAE is applied:

- increasing application of simultaneous engineering
- increasing product – process integration
- integration of structural crash and safety
- integration of active and passive safety
- transfer of innovation value-added between OEM and supplier
- increasing resource mobility in global organisations
- recent down-sizing of development organisations

In order to manage and benefit from these developments there are a number of measures which can be applied in pre-processing and post-processing for LS-DYNA. For example:

- introduce concept simulation earlier
- introduce faster hardware and solvers
- structure and manage simulation data
- automate assembly build-up and welding
- automate meshing
- automate load case build-up and best practices
- automate post-processing and report generation
- automate processes for regulatory test simulation
- introduce screening and optimization techniques

Before going in depth on the measures to build robust, realistic and increase productivity we will discuss and exemplify the potential of productivity gains in the environment supporting CAE in general.

IDEAL CAE PROCESS FOR CRASH AND SAFETY

An idealised CAE process for crash typically covers the following chain of tasks:

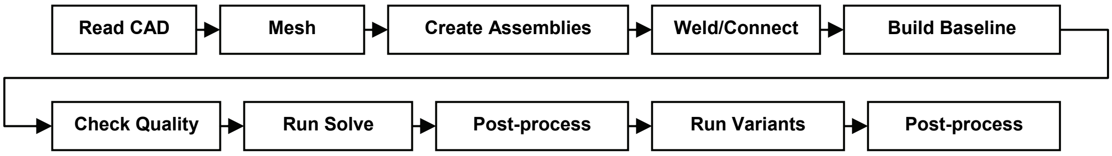

Figure 2: Productivity improvements can be integration of these tasks

When we implement productivity gains we automate the parts of this process or the complete process chain, or we introduce integration where applicable. This requires the underlying technical platform to be complete and process-driven. What this means is described in the next section.

A Platform for Productivity

Our platform for productivity is the Open Virtual Try-Out Space (The Open VTOS). The Open VTOS is complete and process-driven pre-processing and post-processing for NVH, safety and crash solvers, supported by PDM associativity and traceability. Common applications are conceptual crash, FE, coupled rigid body/ FE crash, and multi-body occupant simulation with solvers such as LS-DYNA, RADIOSS, PAM-CRASH and MADYMO.

Complete means that it covers the complete pre-processing and post processing needs – from initial CAD cleaning through meshing, welding, dataset build-up, quality assurance, results evaluation and report generation. **Process-driven** means that any capability or function in the pre-processor and post-processor environment of the Open VTOS can be made a part of the workflow or a process. And the process module is seamlessly integrated in the standard as a part of pre-processor and post-processor functionality. How this is implemented is described in further detail below:

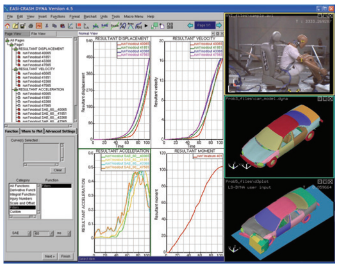

Figure 3: Seamless integration of input deck, plot, animation and test

The development of pre-processor and post-processor for LS-DYNA started 1993. In 1998 process automation technology was introduced. Today it is used in almost 200 organisations worldwide, especially in automotive OEMs and safety suppliers. The pre-processor and post-processor functionality of the Open VTOS covers standard functions such as:

- 1D, 2D, 3D element generation
- Modelling of surfaces, curves, node, points
- CAD cleaning, meshing, and welding
- Keyword editing
- Assembly and part management
- Plotting, animations and test video synchronization

But this paper focuses on how productivity gains, with LS-DYNA, are achieved. Therefore parts of the Open VTOS developed for LS-DYNA are used in this presentation, especially the capabilities of the pre-processor and post-processor EASi-CRASH DYNA delivering significant productivity gains.

Productivity Improvements through EASi-CRASH DYNA

In EASi-CRASH DYNA productivity improvements in safety and crash modelling are achieved at three different levels:

- **Productivity Features**
- **Time Savers**
- **Process Automation**

Productivity Features ease the modelling of a specific task in the model build-up or post-processing, for example:

- Coupling LS-DYNA FE with MADYMO Rigid Body Models
- Automatic Seatbelt Routing
- Dummy Positioning
- Weld Comparison
- Intersection and Penetration Removal
- Global Find and Replace

Time Savers ease the automation of a sequence of tasks, for example:

- FMVSS Test Block Position
- Replace Duplicate
- Model Quality Check
- IIHS Pre-processing Setup
- IIHS Intrusion Chart Plotting

Time Savers are also used to implement rapid customizations.

Process Automation is the complete process guidance for a specific process such as the development of the model and report for a regulatory test simulation. The process automation technology in EASi-CRASH DYNA is referred to as "Process Guidance" technology. This means that it is not complete automation – if this is not requested – but processes are broken down into tasks (or sub-processes) which can be executed in sequence. With this functionality the user follows a flowchart representing best practice or a regulatory test simulation. Examples of available template processes are:

- Pedestrian Safety (EUNCAP/ACEA)
- ECE-R 21 / FMVSS 201
- FMVSS 203
- FMVSS 208
- Bumper Test, FMVSS 581, ECE-R 42
- Pothole Analysis

How productivity features, time savers and process automation are implemented in the LS-DYNA environment is clarified in the following sections.

Productivity Features for LS-DYNA

EASi-CRASH DYNA is built to fit the requirements in safety and crash simulation with LS-DYNA. All keywords used in automotive safety simulation are completely supported in graphic modelling, the keyword editor, and in the explorer view. Additionally, EASi-CRASH DYNA has a large set of productivity features, which meet these requirements. For example:

- Coupling LS-DYNA with MADYMO Rigid Body Models
- Automatic Seatbelt Routing
- Dummy Positioning
- Weld Comparison
- Intersection and Penetration Removal
- Global Find and Replace

Coupling LS-DYNA with MADYMO Rigid Body Models

In EASI-CRASH DYNA, coupling DYNA and MADYMO models is made very simple and robust. All the systems of a MADYMO model can be coupled or uncoupled in one stroke. Coupling can also be done shape by shape, default materials, control cards and coupled materials can be defined automatically.

Automatic Seatbelt Routing

This feature allows the user to rapidly generate or edit a continuous FE-belt. With a minimum of interaction the user generates a quad, tria or seatbelt elements with automatic initial penetration removal (**Fig. 4**).

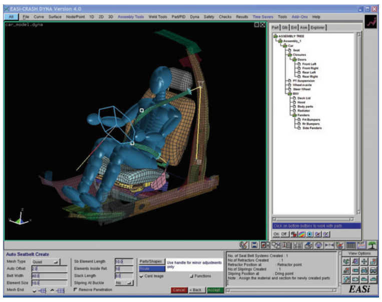

Figure 4: Generating FE seatbelt with minimum user interaction

Dummy Positioning

EASi-CRASH can handle LSTC, FTSS and MADYMO dummies. By editing the graphics the end user can easily perform body orientation and dummy positioning for any FE or rigid body dummy.

Weld Comparison

Complementing the already powerful welding capabilities of EASi-CRASH DYNA is Weld Comparison. This feature identifies and displays the difference between two models. The user can view matching/un-matching weld points, and delete or copy weld points from one model to another (**Fig. 5**).

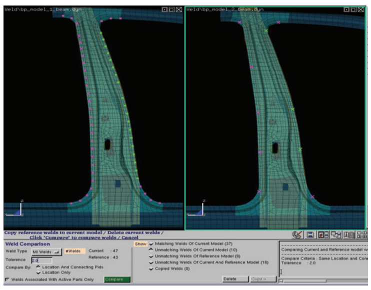

Figure 5: Weld comparison of matching/un-matching welds

Intersection and Penetration Removal

Through this feature the user detects intersections and penetrations in the model. Intersections are defined based on part – part, while penetrations are defined based on part – part or contact thickness (**Fig. 6**). Through semi-automatic or automatic corrections productivity is dramatically increased. In semi-automatic mode, nodes/elements are moved, along a node normal, a vector, through node alignment, or dropped on a plane. The automatic penetration removal can be left to run over night to use hours when out of office.

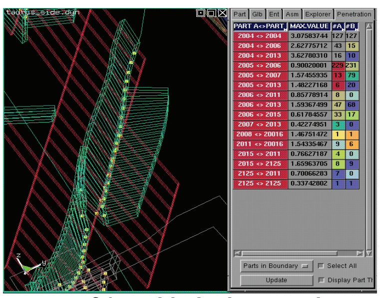

Figure 6: Users estimate a productivity increase of 1:4 with the Intersection and penetration check

Global Find and Replace
In the Explorer view, any field value in a keyword can be searched and replaced. The editing will only be applied to selected values. Besides editing, this feature increases productivity in debugging significantly.

Time Savers
Through the automation of smaller sequences significant improvements can be made in terms of productivity. In EASi-CRASH DYNA this is implemented as Time Savers. Times Savers are either introduced by the end user or by the ESI development team.
The End users typically have their own functions, scripts, or code (in JavaScript, JAVA, Fortran, Python, C or C++) and they want to apply this on the model/models, animations, results currently loaded in EASi-CRASH DYNA.
Additionally, ESI continuously introduces new Time Savers. Based on requirements or requests from the users who rapidly need a specific functionality in EASi-CRASH DYNA these Time Savers are introduced throughout the year. Recent examples are specific routines for “model check” to check the solver entities and to post any possible errors. The examples listed as Time Savers often have a significant impact on the productivity in the organisations, which introduce them, even though they might be limited in scope. The typical development lead-time for introducing a new Time Saver is from a few minutes to a few days. For example:

- FMVSS Test Block Position
- Replace Duplicates
- Model Quality Check
- Cross Section Copy
- IIHS Pre-processing Setup
- Plot IIHS Intrusion Chart

FMVSS Test Block Position
This program positions the test blocks as per FMVSS 207 / 210 requirements.

Replace Duplicates
With this Time Saver, the user can easily search for and replace duplicate Materials, Load Curves, Sections, Mat Type 24, Material and Hourglass.

Model quality check
Before running LS-DYNA, this Time Saver checks the model for errors and warning. Reports are generated with information on the model, issues, warnings and errors.

Cross section copy
This function allows the user to either automatically or interactively copy all cross sections from for example a baseline model to all its variants. In interactive mode the parts on which the C/S definition is to be applied to can be reselected (**Fig. 7**).

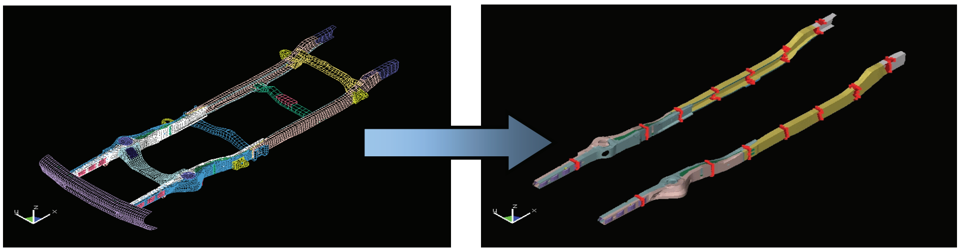

Figure 7: All C/S are copied from one model to another, or exported as *.gif

IIHS pre-processing setup
With this Time Saver, the user selects nodes for plotting the Insurance Institute for Highway Safety (IIHS) intrusion chart.

Plot the IIHS intrusion chart
When the nodes are defined, this program computes and plots the intrusion values for the salient points on interior structures of a vehicle according to the guidelines of IIHS for the front offset crash test, recorded on 50th percentile male Hybrid III driver dummy.

Process Automation
The Process Automation Technology, integrated in EASi-CRASH DYNA, is a proven key technology for increasing productivity with LS-DYNA. Through the process the user is guided through a best practice or complete processes - from model build-up to report generation - for regulatory test simulations.
Since the process automation technology is integrated in EASi-CRASH DYNA, the user can at any time switch between conventional pre-processing and post-processing to the process executive view. In the executive view, the current model is applied in the test process selected from the library of templates, for example, FMVSS 201 / ECE-R 21 (for head impact), FMVSS 208 (for frontal crash) or FMVSS 581 / ECE-R 42 (for bumper test). The process executive can cover any functionality available in EASi-CRASH DYNA, and processes are rapidly prototyped and built for customized processes for model assembly with meshing.

In the process executive view the user has access to:

Process Modelling and Execution Area
- Model Area
- Audit Trail
- User Interaction Area

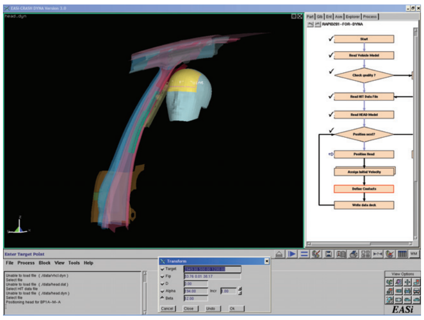

Figure 8: FMVSS 201 / ECE-R 21 Process Executive in EASi-CRASH DYNA

When the user selects the desired process template, in this case the FMVSS 201, its process flow template is imported in the **process modeling and execution area**. The execution area has the capability to run the complete process automatically or step through or undo individual steps. The user can choose to pause, bypass, step through the process, or run the complete or parts of the process in automatic mode.
The model is displayed in the **model area**. This is the area where users can input FE entities, screen select FE components, nodes, and elements, and this is where animations or reports will be displayed.
The audit information of each step is given in the **audit trail area** as the process is executed step-by-step. The trail may be exported as a log in the report, useful for a supervising engineer to verify if the process was executed properly. This area also provides the key note, intermediate computed results to the users with necessary comments and feedback.
The **user interaction area** will be activated whenever the user interaction is needed (text input, query response or option selection). In the example in **Fig. 8** the user has a menu to edit the approach angles. At any time during the process execution, the user can request more information or guidance by picking the appropriate task block. A knowledge advisory capturing the corporate best practice with hints and suggestions is provided for each task block.
To generate reports, standard functionality in EASi-CRASH DYNA, is used to prototype the report layout. This report template is then introduced in the process.
The productivity improvements achieved with the Process Automation Technology are substantial. Continuously, since its introduction in 1998, OEMs and safety suppliers have reported productivity improvements in the range from 12:1 to 25:1 per process iteration. Examples are:

- Inertia Relief Analysis
    - **From 14 days to 5 hours**
- Body Mount Static Stiffness
    - **From 16 days to 6 hours**
- Full Body Static Stiffness
    - **From 48 hours to 2 hours**
- FMVSS 201 (Free Motion Head Form)
    - **From 3 hours to 10 minutes**
- FMVSS 201 (Head Impact on IP)
    - **From 1 hour to 5 minutes**

In Europe, the processes showing the most impressive productivity gains are the processes for pedestrian safety with the EU NCAP/ ACEA test templates (**Fig. 9**).
The productivity improvement has a value in itself with reduced lead-time. Additionally, for the end users it is perceived as a release of unproductive work spent on time-consuming administration, repetitive modelling, and documentation. The process automation technology allows them to focus on what makes them productive - bringing real engineering value.

The current development is that organisations, which earlier introduced process automation, now combine the established processes with screening techniques, optimisation and DoE schemes. These processes do not only increase the level of automation, but takes them one step further by using the technology to remove time consuming trial-and-error searches and introduce CAE-driven robust design. Many organisations confirm that robust system design for vehicle safety or large-scale multi-disciplinary optimization will not be possible before the basic process automation is established.

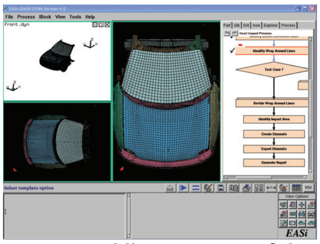

Figure 9: Defining wrap around lines as part of the Pedestrian Process

Summary and Conclusions

Most European automotive OEMs and safety suppliers have substantial potential for improving the productivity of pre-processing and post-processing for LS-DYNA. This paper has presented what this potential is and highlights how productivity improvements are achieved through the Productivity Features, Time Savers and Process Automation Technology in EASi-CRASH DYNA. Even though the presented solutions have proven a significant improvement in relation to a conventional approach or current practice there is still additional potential, especially through the combination of process automation technology and screening, optimisation and robust systems design techniques.

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