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We welcome you to a brand new edition of the **CADFEM eNewsletter** that shall update you some of our articles along with the latest news & events from the CAE industry. High performance computing is the order of today. It only makes sense to utilize the available computational power for running our simulation tasks. One of the key articles in this edition of the newsletter talks just about massive parallel processing (MPP) specifically for LS-DYNA users. Several other articles in eclectic analysis areas are also discussed. Hope you enjoy reading this edition too and find it informative. Please feel free to send us your suggestions for improvement. If you wish to contribute to the newsletter as a guest author, then please feel free to contact us.

## Massive Parallel Programming in LS-DYNA

There are two versions of LS-DYNA, Shared Memory Parallelization (SMP) and Massive Parallel Processing (MPP). The MPP version of LS-DYNA has been developed by LSTC throughout the 1990's. A primary goal for the code has been superior scalability, enabling many processors to work together efficiently in the execution of LS-DYNA.

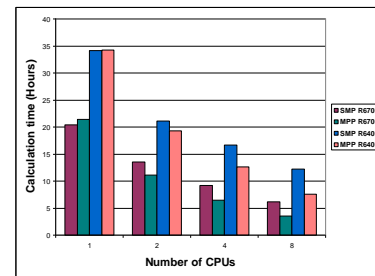


Illustration: Speed up using SMP and MPP

... (continued on page 8)

## Nonlinearities of Anisotropic Materials

### EVENTS

**2010 ANSYS India Conference**  
 October 26 – 27, 2010  
 Bangalore, India  
 October 29, 2010  
 Pune, India

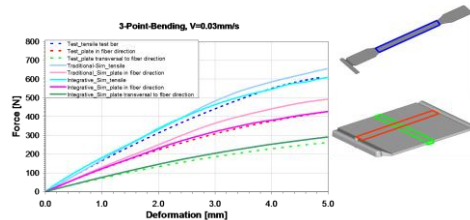


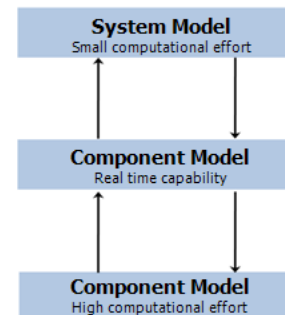
Illustration: 3-point bending – Force vs. deformation

The anisotropic, nonlinear, strain-rate dependency, the interface between polymer matrix and fiber, fiber length, fiber orientation in the composite makes the composite material complex enough for the engineering study. How one can model the material and ensure accurate structural modeling is discussed here.

... (continued on page 2)

## Hybrid Simulations for Hybrid Vehicles

It is a well known fact in the automotive industry that the future breed of vehicles will largely carry electric traction and hybrid-electric propulsion. With the improved technology there is no wonder that the high level of intricacy and wide variety of domains involved in this kind of design has appropriate simulation and analysis tools.



... (details on page 4)



**ANSYS Conference & 28<sup>th</sup> CADFEM Users' Meeting**  
 November 3 – November 5, 2010  
 Aachen, Germany

# Nonlinearities of Anisotropic Materials

## Multi-Scale Material & Structural Modeling using DIGIMAT

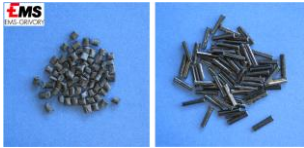


Fig 1: Comparison between 3 mm SFRT (left) and 11 mm LFRT granulate (right)  
Image courtesy: EMS Grivory AG

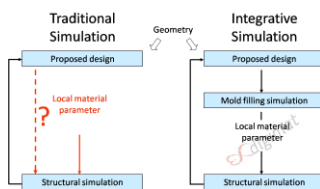


Fig 2: Traditional Simulation vs. Integrative Simulation

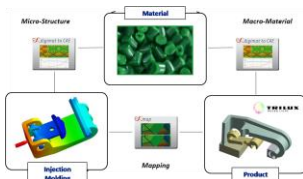


Fig 3: Multi-scale Material Modeling Platform - DIGIMAT

The accurate linear and nonlinear modeling of complex composite structures pushes the limits of finite element analysis with respect to element formulation, solver performance and phenomenological material models. The finite element analysis of injection molded structures made of nonlinear and/or time-dependent anisotropic reinforced polymer is increasingly complex. In this case, the material behavior can significantly vary from one part to another throughout the structure and even from one integration point to the next in the plane and across the thickness of the structure due to the fiber orientation induced by the polymer flow. The accurate modeling of such structures and materials is possible with LS-DYNA using LS-DYNA's Usermat subroutine to call the DIGIMAT micromechanical modeling software.<sup>(1)(2)</sup> In addition to enabling accurate and predictive modeling of such materials and structures, this multi-scale approach provides the FEA analyst and part designer with an explicit link between the parameters describing the microstructure (e.g. fiber-orientation predicted by injection molding software and the final part performance.

### Material Description

As material, which is investigated in this work, a PA66+PA6I/6T LGF50 is chosen. The material is supplied by the EMS-CHEMIE AG, where the material with the name GRIVORY GVL-5H can be characterized as a high performance long glass fiber reinforced thermoplastic for applications with medium temperature, high strength and stiffness requirements combined with excellent processing and low warpage behavior.

Long fiber reinforced thermoplastics (LFRT) have in comparison to short fiber reinforced thermoplastics (SFRT) longer fibers. For

example, the fiber length of a SFRT granulate is between 0.2 and 0.8 mm. On the other hand the fiber length of a LFRT granulates is app. 10 mm (see Fig. 1).

The anisotropic, nonlinear, strain-rate dependency, the interface between polymer matrix and fiber, fiber length, fiber orientation in the composite makes the composite material complex enough for the engineering study.

In the traditional simulations (see Fig. 2), the material models will not consider the local material parameter in the simulation. This results in the study of the composite material at the macro level. In the multi-scale material modeling simulation (Integrative Simulation) the local material parameter will be considered. This helps to understand the behavior of polymer matrix, fiber material separately (micro scale) and also analyze the composite material (macro scale).

### Multi-Scale Material Modeling Platform

The software solution, DIGIMAT, offers the user a complete set of tools that allows the coupling between injection molding simulation and structural analysis for the fiber-reinforced plastic parts. DIGIMAT takes the locally different microscopic glass fiber orientations of the part into consideration. These differences are caused by the viscous flow of molten plastic during processing of the part leading to a variation of the microstructure over the plastic part which gets solidified after cooling to room temperature. The material is anisotropic because of the locally oriented fibers. In principle, for each element in the structural analysis an individual material description has to be used (see Fig. 3).

(continued in the next page)

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### Author

Chandra Sekhar Kattamuri

# Nonlinearities of Anisotropic Materials

## Multi-Scale Material & Structural Modeling using DIGIMAT

### Workflow of a coupled DIGIMAT analysis

The standard workflow of an integrated DIGIMAT analysis commonly starts with the reverse engineering of material properties within DIGIMAT-MF. In DIGIMAT-MF, the constitutive behavior of the matrix and the filler phase is defined separately through a set of parameters for predefined mathematical functions. These parameters are derived from the experimental stress strain curves for the respective material. Often only measurements for the complete composite material are at hand. In these cases the average microstructure of the test specimen is taken as a set value and the composite material parameters can be reverse engineered by the use of DIGIMAT-MF.

Once the parameters are known they are kept fixed and the influence of the microstructure on the material behavior can be investigated. It is this sensitivity towards a change in the microscopic fiber orientation which is taken into account by setting up a coupled analysis with results from injection molding simulations. MAP is a 3D mapping software used to transfer the fiber orientation, residual stresses and temperatures from the injection molding mesh to the structural analysis mesh.

Once the material parameters and fiber orientation files are ready, this information has to be linked with the structural simulation. DIGIMAT to CAE is the multi-scale structural modeling tool that groups the interfaces between injection molding software, DIGIMAT-MF and structural analysis software.

### Simulations

General purpose finite element software LS-DYNA is used for running traditional simulations. \*MAT\_MODIFIED\_PIECEWISE\_LINEAR\_PLASTICITY (\*MAT 123) material model has been

considered. This material model has been selected upon validating the test results with various material models available in LS-DYNA. In the automotive industry this is one of the most popularly used material models for FRP materials.

Three different tests have been considered – Uniaxial Tensile test, Three-Point Bending Test and Impact Test.

- Uniaxial Tensile test shows that both traditional simulation using LS-DYNA and integrative simulation using DIGIMAT to LS-DYNA interface produce good results. The simulation results fit very well with the experiment (see Fig. 4).
- The result of the Three-Point Bending test clearly shows that the traditional simulation is not able to capture the material behavior transversal to the fiber direction. This is because \*MAT\_123 is basically an isotropic material model and anisotropic material behavior cannot be captured. Results of the integrative simulation, on the other hand, fits well with the experiment (see Fig. 5).
- Traditional Simulation result of the Impact test tells us the material fails much earlier than what is seen in the experiment. With integrative simulation, the material behavior is captured properly (see Fig. 6).

### Conclusions

The material considered, GRIVORY GVL-5H, a long glass fiber reinforced thermoplastic is seen to be an anisotropic, nonlinear, strain-rate sensitive material. Traditional results do not give complete confidence which can otherwise be gained through integrative simulation. DIGIMAT is seen to be a proven tool for capturing material behavior in an accurate manner.

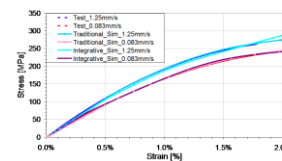


Fig 4: Uniaxial Tensile Test Results – Comparison between Traditional and Integrative Simulation

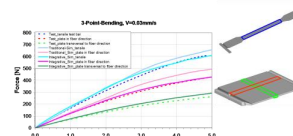


Fig 5: Three Point Bending Test Results – Comparison between Traditional and Integrative Simulation

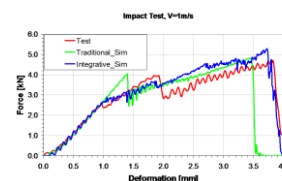


Fig 6: Impact Test – Comparison between Traditional and Integrative simulation

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# Hybrid Simulations for Hybrid Vehicles

## Importance of co-simulation for modeling vehicle propulsion

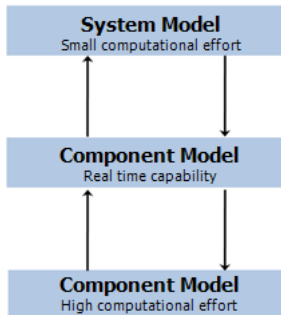


Fig 4: Different levels of modeling

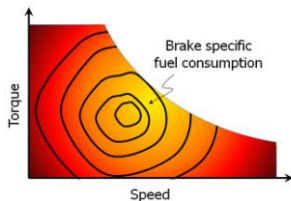


Fig 5: Calculation of efficiency maps of electric machines (component model with real time capability)

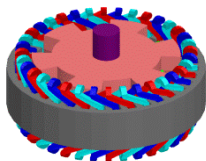


Fig 6: Motor design in RM-Expert (component model with high computational effort)

### Author

Sreekanth Nallabolu

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### Growing importance of Hybrid vehicles

It is a well known fact in the automotive industry that the future breed of vehicles will largely carry electric traction and hybrid-electric propulsion. These kind of propulsion are inherently more complicated than conventional vehicles which are built exclusively with internal combustion engines.

### Importance of simulations

Different technologies grow at different parts of the world, forming a decentralized design process. The complete assembly of a vehicle consists of several subsystems that must work together in the vehicle. Each of these subsystems are manufactured at different continents and finally assembled into a single vehicle. In this trend, it is logistically complex and tedious to bring the testing equipment together to validate the behavior of complete assembly. The only feasible method to explore design variations is numerical simulations. With the improved technology there is no wonder that the high level of intricacy and wide variety of domains involved in this kind of design has appropriate simulation and analysis tools.

### The hybrid vehicle propulsion

In particular, there has been much attention paid to the modeling of automotive drivetrains or powertrains. In hybrid vehicles, there is a dominating number of electrical systems. For example, a typical hybrid drivetrain consists of all the components that generate power, convert power and deliver it to the wheels. This includes the engine, transmission, energy storage device, motors and motor controller, driveshafts, differentials, and the wheels.

### Simulations at different levels

Numerical modeling and simulation of these subsystems can be carried out at different levels

of details. For example, there are simulations for calculation of efficiency maps of electric machines (fig. 2). In another way of modeling the motor which is at a system level the motor is just a black box that generates specific outputs in response to inputs.

### Simulating complete drivetrains

Many other vehicular subsystems such as electronic inverters, regenerative brakes, and various kinds of actuators can be modeled the same way. System level models can now predict how the overall system will behave. The system level simulation gets inputs and works with detailed electrical models of component parts (fig. 1). Use of these simulation packages lets automotive engineers work in a single integrated design environment. Software can help predict efficiency and fuel economy of vehicle designs, power management strategies, and guide the electrical design. Engineers can simulate complete drivetrains by combining fuel cells, batteries, power electronics, and electric motors in one environment. Most of such components are modeled and available for use as multiple designs.

### Complex vehicle details

The electrical components for vehicles can be extremely sophisticated due to the increased technology. They are manufactured with a lot of design features to minimize costs and optimize efficiency. Similarly, it is important for drivetrain simulations to accurately model these features to the level of electric field properties, torque qualities, and other details. These details provide a foundation for system level simulations allowing accurate simulation for the behavior of complete assembly.

(continued in the next page)

# Hybrid Simulations for Hybrid Vehicles

## Importance of co-simulation for modeling vehicle propulsion

### Capabilities for co-simulation

Due to the lack of a distinct comprehensive environment for combining all the models, one can synergize several simulation tools to give designers feel of how motors, drives, and other electromechanical systems will interact. The software, Rmxprt is a specialized software for the design of rotating electric machines (fig.2) which has the capability to calculate key performance metrics of electric motors. One can evaluate design tradeoffs early in the design process. It computes performance of specific designs through a combination of classical analytical motor theory and equivalent magnetic circuit methods. Rmxprt also can create statespace system models incorporating the physical dimensions of the machine being designed, winding topologies and nonlinear material properties. These factors can then be transferred to another simulation package called Maxwell 3D.

Maxwell3D uses finite-element methods to solve electromagnetic-field problems in the time and frequency domains. It is typically used to analyze the fields (fig.3) associated with electromagnetic actuators and components. Using Maxwell 3D, one can solve for electromagnetic-field quantities such as force, torque, capacitance, inductance, resistance, and impedance. One can also generate state-space models using this tool to help optimize design performance.

Engineers can use the Rmxprt state-space model to explore electronic control topologies, loads, and interactions with drive-system components in another simulation package called Simplorer (fig 5). Simplorer is a simulator specifically for system simulation including power electronics.

In Simplorer one can model at a system level using several standard languages like VHDL-AMS, SPICE, SML, C/C++ etc. VHDL-AMS is a language standard for the description and simulation of multidisciplinary mixed-signal systems. Rmxprt design and Maxwell can work in a Simplorer environment to define the behavior of rotational actuators in the hybrid drivetrain. Models developed this way can be configured in different design domains at different levels of abstraction. This sort of description also lets the model be co-simulated with specialized simulation packages and proprietary code, linking to Maxwell for high-fidelity modeling of electromechanical components.

Within Simplorer one can model components using several modeling techniques like Block diagrams, State machines or Circuits. One can also perform optimization at system level. In addition one can co-simulate with third party tools like Matlab Simulink, MathCAD etc.

Simplorer has a unique capability to combine different modeling techniques in a single environment. A very nice example is the integration of a Lithium-ion cell with the complete battery. One would like to model the complete battery pack using block diagrams in order to combine it with the other vehicle subsystems. But modeling the detailed electrochemistry at cell level is done using equivalent circuits or programming the physics using VHDL-AMS. One can then make this physics based cell model with the block diagram based battery model with in Simplorer seamlessly. All these examples gives a brief idea of the multidomain and multilevel capabilities possible with co-simulation, though there is much more to explore.

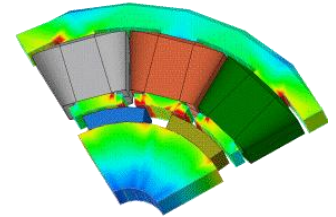


Fig 4: Electro-magnetic analysis of electric machine design (component model with high computational effort)

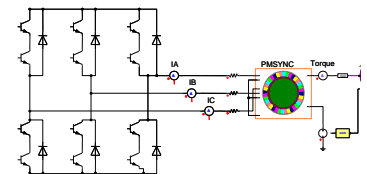


Fig 5: Co-simulation in Simplorer

### Images courtesy

Fig. 3, 4 & 5 – Ansoft Inc.

### Author

Sreekanth Nallabolu

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# Electro-thermal simulations for batteries

## A review

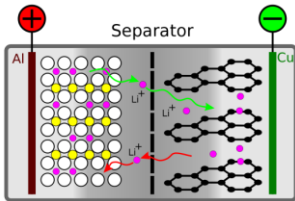


Fig 7: Electrochemistry in Lithium-ion cell

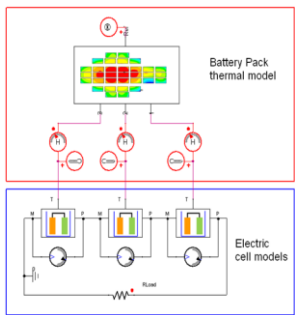


Fig 8: Electrothermal simulation of battery

### Introduction

Electrochemical batteries are of significant importance in electrical power systems since they give a means for energy storage in a way that is immediately available and pollution free. Few key applications that have grown fast during the last decade are: Batteries within Uninterrupted Power Supplies (UPS), Battery Energy Storage Plants (BESP) to be installed in power grids, electric vehicles. There are several battery technologies that are currently being used, the more widespread being the lead-acid and Li-ion technologies.

### Simulation driven development of Battery

One would like to simulate a battery at two different levels. The first being detailed cell level simulation involving the electrochemistry and the other being system level simulation of the entire battery consisting of several cells. On battery cell level, the focus is on detailed heat generation and temperature distribution within a battery cell. This type of study is pursued mainly by battery manufacturers and battery researchers. Experimental data reveals that the rate of heat generation varied substantially with time over the course of charging and discharging. Heat can be generated from internal losses of Joule heating and local electrode overpotentials, the entropy of the cell reaction, heat of mixing, and side reactions. Considering only Joule heating and local electrode overpotentials, heat generation can be expressed by open circuit potential and potential difference between the positive and negative electrodes.

One can model the cell either as a detailed physics based model or as an equivalent circuit. Physics based electrochemistry model, can be used to investigate the impact of battery design parameters on battery performance, which includes the geometry parameters, properties,

and temperature. Equivalent circuits are a workaround for detailed time consuming physical modeling.

### Challenges in Battery design

The lithium-ion battery is ideally suitable as a power source for hybrid electric vehicle (HEV) and electric vehicle (EV) due to its uniqueness such as high energy density, high voltage, low self-discharge rate, and good stability among others. There are several causes of failure of a battery. Heat is a major battery killer, either excess of it or lack of it, and Lithium secondary cells need careful temperature control to avoid thermal runaway. Due to the likelihood of significant temperature increase in large batteries during high power extraction safety is currently one of the major concerns confronting development of lithium batteries for electric vehicles. A properly designed thermal management system will be crucial to prevent overheating and uneven heating across a large battery pack, which can lead to degradation or mismatch in cell capacity. Design of the thermal management system requires knowledge about the cooling system as well as the amount of heat that will be generated by cells within the battery pack.

The so-called battery aging is also one of the interesting aspects for battery specialists. Battery life and reliability forms a key feature of interest in the automotive industry. For product designers, an understanding of the factors affecting battery life is vitally important for managing both product performance and warranty liabilities particularly with high cost, high power batteries. Offer too low a warranty period and you won't sell any batteries/products. Overestimate the battery lifetime and you could lose a fortune. In spite of being so important decision maker modeling of battery aging is still ambiguous in the market.

### Author

Sreekanth Nallabolu

### Interested?

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# Robustness Study – Automotive application

## Stochastic studies to determine robustness of NVH of a Brake System

The automotive industry is one of the drivers of CAE-based virtual product development. Due to a highly competitive market, development of innovative, high quality products within a short time is necessary and it is only possible by using virtual prototyping. It is important to note that increased application of virtual prototyping itself increases the necessity to perform robustness studies.

Brake noise is one of the most important problems in the automobile industry due to the high warranty costs. The generation of brake noise is due to the development of instabilities in the brake system. The analysis of brake squeal is highly complex, which is very sensitive to the operation conditions. Robustness analysis is primarily carried out to determine the variation range of significant response variables and their evaluation by using definitions of system robustness due to the imperfections of design parameters. The imperfections are usually modelled by either random variables that are constant in space or random fields that vary in space.

Occurrence of squeal is intermittent or perhaps even random. Many different factors appear to affect squeal. Out of which, one of the factor is existence of tolerances in material of the brake system (see Fig. 1) in reality. Therefore, robustness analysis has been carried out by considering the material tolerances for thorough understanding of brake squeal. Robustness analysis is carried out by stochastic modelling of material tolerances by random variables by software called optiSLang.

**Keywords:** Stochastic Finite Elements, Robustness Analysis, Brake Squeal.

### Robustness Analysis Using Material Tolerances

Design parameters are the Young’s modulus of each component. Components and there tolerances of Young’s modulus are given in Table 1. The coefficient of variation and distributions of Young’s Modules of different components is selected based on engineering experiences. The truncated normal function is chosen as the PDF for all parameters with the bounds equal to two times coefficient of variation.

Robustness analysis is carried out for 100 designs in this case, to get a clear idea about the variation of response parameter w.r.t the variation of design parameters. From Fig. 2 it is observed that the variation of design parameters leads to a high variation in the response parameter which is the squeal propensity.

From analysis Pad G33, which means stiffness of pad in out of plane direction is the most influential design parameter and it has linear correlation with the response. The mean of damping ratio (from Fig. 3) for all designs is 0.048 which is high in terms of squeal noise. It is also observed that the coefficient of variation (CV) is about 45% which in turn indicates that the brake system is not robust.

### Summary

In the virtual model, the phenomenon which is found in the tests could be retrieved by robustness analysis. Primary result of the robustness evaluation is the estimation of the scatter of important result variables. Furthermore sensitive scattering input variables can be identified as well as the determination of result variables can be examined.

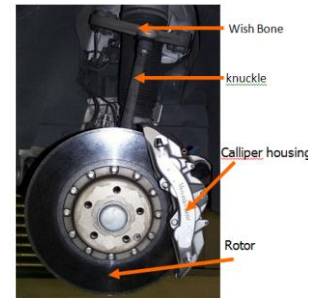


Fig 9. Complete brake system

Component	Coefficient of variation (%)	Scattering (%) Function - Truncated normal
Knuckle	2,50	+/- 5
Rotor	7,50	+/- 15
Calliper	2,50	+/- 5
Calliper Beam	4,00	+/- 8
Steering Rod	2,50	+/- 5
Tension Strut	2,50	+/- 5
Lower Arm	2,50	+/- 5
Wish Bone	2,50	+/- 5
Bolts, Bearings and Hub	2,50	+/- 5
Brake Pad	25,00	+/- 50
Backing Plate	2,50	+/- 5
Steel	2,50	+/- 5
Cast Iron	7,50	+/- 15
Aluminium	2,50	+/- 5

Table 1. Components and their Respective Material Tolerances

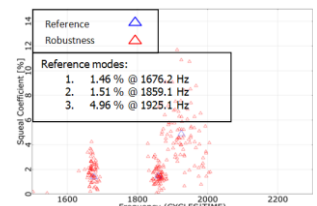


Fig 2. Squeal Propensity for all Designs

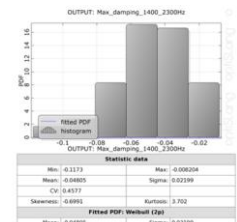


Fig 3. Histogram of Squeal Propensity

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**Author**  
Karthik Chitpetu

# Massive Parallel Programming in LS-DYNA

## Fundamentals and basic steps of MPP version of LS-DYNA

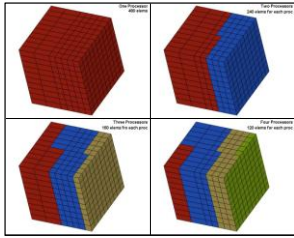


Fig 1. Domain decomposition based on element count with different number of processors

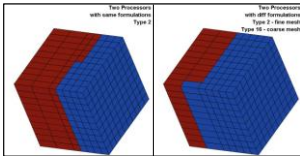


Fig 2. Domain decomposition based on element formulation with two processors

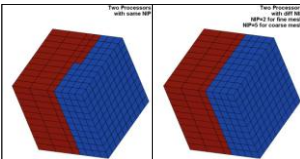


Fig 3. Domain decomposition based on number of IPs with two processors

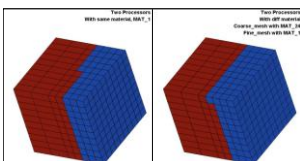


Fig 4. Domain decomposition based on type of material model with two processors

There are two versions of LS-DYNA, Shared Memory Parallelization (SMP) and Massive Parallel Processing (MPP). The MPP version of LS-DYNA has been developed by LSTC throughout the 1990's. A primary goal for the code has been superior scalability, enabling many processors to work together efficiently in the execution of LS-DYNA.

### Why MPP?

- More number of algorithms in the code can be run in parallel
- Communication time between the processors is less
- Memory is distributed among the processors
- MPP code can run a task in one or more computers each with one or more processors
- MPP results are quite scalable and the performance is very effective

### How MPP works?

- A domain is divided into sub-domains based on number of processors; it is so called domain decomposition which is the major step of MPP code
- Each processor is responsible for solving its sub-domain
- MPP code needs to communicate to other processors only two times at each timestep.
  - When the contact forces are being calculated
  - When the nodal forces are being updated
- The computational efficiency will go up if the ratio of elements located at boundaries of sub-domains to internal elements is reduced

Some important aspects which affect performance of the MPP version are processor speed, model characteristics (size, number of elements and type of element formulations), communication, and load balance. But model characteristics are not included in this study because it is mainly depend upon the type of problem. Processor performance has a very

direct impact on MPP LS-DYNA elapsed time, but only two processors are considered for this study.

### Automatic Domain Decomposition

The domain decomposition is the main function of MPP LS-DYNA, as it determines the final load balance on each of the compute nodes. The default (and most widely used) decomposition method is Recursive Coordinate Bisection (RCB), which recursively halves the model using the longest dimension of the input model. Apart from the longest length, it also considers the following aspects to achieve better load balance among the processors

- Weighting of element count, each processor will result with equal number of elements as shown in Fig 1.
- Weighting of element formulation, it also considers the type of element formulations to achieve perfect load balance as shown in Fig 2.
- Weighting of integration points (IPs) along the thickness as shown in Fig 3.
- It also considers the complexity of material model to achieve perfect load balance as shown in Fig 4.

### Manual Domain Decomposition

The default decomposition (automatic) may not be the optimum one for every case, so the end user has an opportunity to decompose the model manually with additional commands. The following commands are used for manual decomposition:

```
*CONTROL_MPP_DECOMPOSITION_TRANSFORMATION
```

By default, RCB method finds the longest dimension and halves the model and again finds the longest dimension in each half model and halves them.

(continued in the next page)

### Interested?

For details, you may contact our consulting division at [info@cadfem.in](mailto:info@cadfem.in)

# Massive Parallel Programming in LS-DYNA

## Fundamentals and basic steps of MPP version of LS-DYNA

The final decomposition contains 'n' number of sub-domains where 'n' number of processors is used. But by the above command, one can scale the desired dimension. The option to scale the initial dimensions of the model is purely related to decomposition and the calculation is not at all affected.

\*CONTROL\_MPP\_DECOMPOSITION\_CONTACT\_DISTRIBUTE

Computations involving contacts in LS-DYNA usually consumes 20-40% of total computational cost of most simulation models. To improve load balancing, contact definitions must be distributed for all processors. This is usually done for contacts large number of entities in either slave or master side. This can be achieved by the above keyword.

\*CONTROL\_MPP\_DECOMPOSITION\_CONTACT\_ISOLATE

To reduce the communication between processors, smaller contacts need to be isolated to individual processors. This can be achieved by the above keyword.

### Output files in MPP LS-DYNA

For performance reasons, MPP-LS-DYNA creates new binary format files instead of ASCII output files. There is a special post-processing program 'l2a', which reads binary files and convert to corresponding ASCII files. For this, one must set the option BINARY=2 or 3 (3 is recommended) in \*DATABASE\_OPTION. The files are named as *binout.nnnn*, where *nnnn* represents the processors number. For example, if 4 processors are used to calculate a simulation, then one can see *binout.0000*, *binout.0001*, *binout.0002* and *binout.0003*. LS-PREPOST and Hyper View are able to read the binout files directly. For LS-PREPOST the option is located as shown in Fig 5. It is also same with *d3dump* (*d3dump.nnnn*) and message (*mesnnnn*) files. *d3hsp* and *d3plot* are written as usual like in SMP

### Restart in MPP version of LS-DYNA

Restart capability is also available in MPP LS-DYNA, but slightly different than the SMP code. Each time a restart file *d3dump* is written, a separate restart file is also written with the base name *D3FULL*. The main difference between *d3dump* and *d3full* is, *d3dump* is written one for each processor but *d3full* is a single file. For example, if one writes *nth* restart file, *d3dump0n* is writtenn(one for each processor, *d3dump0n.0000*, *d3dump0n.0001*, etc) and single file *d3full0n* is also written. For restart or extension of a calculation, one can use both files. But by using *d3full* file there might be some instabilities in the calculation, so it is not recommended.

### Memory allocation in MPP LS-DYNA

Memory required to run a problem can be specified on the command line using the keyword, *memory=XXX*, where 'XXX' represents the number of words of memory to be allocated. 1word=4Bytes for single precision and 1word=8Bytes for double precision problems. One processor of 'n' processors has to perform the decomposition of the problem. This requires significantly more memory than will be required once execution has started.

There is a second memory command line option, *memory2=YYY*. If the second memory is used with the memory keyword, the decomposing processor will allocate XXX words of memory, and all other processors will allocate YYY words of memory. For example, in order to run a 250,000 element crash problem on 4 processors, you might need *memory=80m* and *memory2=20m*.

CFD	Cgat	Stereo
Binout	Skid	AleMat
Subsys	PTravel	PTrim
Renum	Refchk	MatDB
ElGen	Detach	
ElEdit	Curves	Offset
Movcpy	DupNod	Normals
Trnsfrm	Reflect	Project
Translt	Rotate	Scale
1	2	3
4	5	6
7	D	

— BINOUT file operations —

Fig 5. To load binary output files using LS-PrePost

### Interested in more details?

Email us at [info@cadfem.in](mailto:info@cadfem.in) for further information.

(continued in the next page)

**Author**  
Krishna Chaitanya Kusupudi

# Massive Parallel Programming in LS-DYNA

## Fundamentals and basic steps of MPP version of LS-DYNA

To run the same problem with 16 processors, you still need *memory=80m*, but can set *memory=6m*. The value for *memory2* drops nearly linearly with the number of processors.

*"Computations involving contacts in LS-DYNA usually consumes 20-40% of total computational cost of most simulation models.*

*To reduce the communication between processors, smaller contacts need to be isolated to individual processors."*

### Results

Name of the System	Type	CPU	RAM (GB)	Frequency (GHz)
TRTCAECLN01	R670	W5580	48	3.2
TRTCAECLN02	R640	W5365	8	3
TRTCAECLN03	R640	W5365	8	3
TRTCAECLN04	R640	W5365	8	3
TRTCAECLN05	R670	W5580	12	3.2
TRTCAECLN06	R670	W5580	48	3.2
TRTCAECLN07	R670	W5580	48	3.2
TRTW3009	V380	Opt285	8	2.6

Fig 6. Resources used for this study

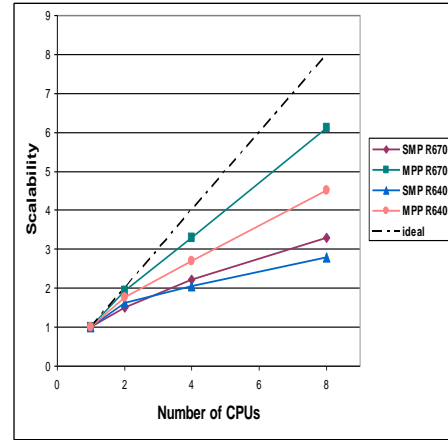


Fig 9. Scalability vs. Number of CPUs for SMP and MPP with different type of processors

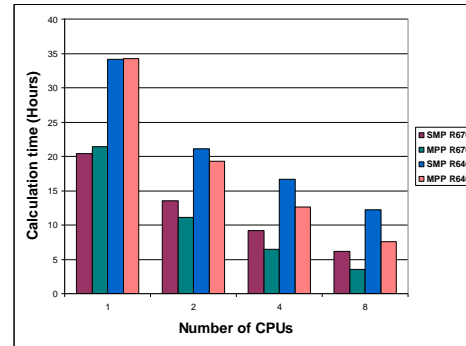


Fig 7. Comparison of calculation times for SMP and MPP with different type of processors

Conventional Oven (120ms termination time, 248800 nodes and 315467 elements)		
LS-DYNA Code	Time for calculation	System
SMP with 4 processors	9h 12min	TRTCAECLN06
MPP with 4 processors	6h 30min	TRTCAECLN06
MPP with 8 processors	3h 32min	TRTCAECLN06

Refrigerator (50ms termination time, 342255 nodes and 656423 elements)		
LS-DYNA Code	Time for calculation	System
SMP with 4 processors	6h 55min	TRTCAECLN01
MPP with 4 processors	4h 33min	TRTCAECLN01
MPP with 8 processors	2h 33 min	TRTCAECLN01

Fig 8. Calculation times with SMP and MPP

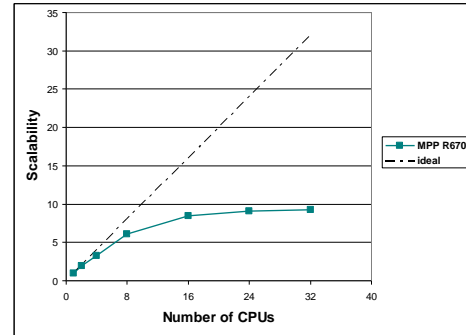


Fig 10. Scalability vs. Number of CPUs for MPP code with R670 processor

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## News & Events

From the world of CAE

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### Author

Praveen Mokkalapati

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### Terrafugia's "Roadable Aircraft" Engineered with Virtual Prototyping using ANSYS Software

Massachusetts-based Terrafugia used ANSYS® engineering simulation software to design and verify its new production prototype of the Transition® aircraft that also can drive on the highway, which was unveiled at the EAA AirVenture airshow. Terrafugia engineers conducted whole-vehicle airflow tests that assessed the effects of design changes on overall performance -- working in parallel across the various transition components. The simulations were used to maximize wing lift in the air and to minimize the effects of crosswinds along the road.

For more information:

[Press Release](#)

### Componering release new version of ESAComp, the composite design and analysis software

A few months ago, a new and improved version of ESAComp was released. The 4.1 version also comes with a new add-on module for cylindrical structures for the design of pressure vessels, pipes and shafts. For stiffened cylindrical structures, an add-on developed to meet the demands of the aerospace industry is now available.

For information on new features/updates, please [click here](#) (PDF).

### CADFEM congratulates ANSYS for having completed 40 Years of Innovation!



### DIGIMAT Users' Meeting

Luxembourg

October 5, 2010 – October 7, 2010

The DIGIMAT Users' Meeting is The Material Modeling Conference that provides CAE Engineers and Managers from all over the world with state-of-the art information on the latest simulation technologies for the accurate modeling of composite materials and structures. Complementary activities such as exhibition & training are also included in the agenda.

### Weimar Optimization & Stochastic Days - WOST 7.0

Weimar, Germany

October 21, 2010 – October 22, 2010

The annual Weimarer Optimization and Stochastic Days will be held for the seventh time. Come, join the symposium for CAE-based parametric optimization, stochastic analysis and robust design optimization (RDO) in the virtual product development. The slogan for this symposium will be *'optiSLang meets easySLang'*.

### 2010 ANSYS India Conference

October 26 – 27, 2010, Bangalore, India

October 29, 2010, Pune, India

**Meet us here!!**

Join the 2010 ANSYS India Conference to see how leading companies are using smart simulation tools from ANSYS to drive innovation in product development. Whether you're a designer, engineer, analyst, manager or from academia, the 2010 ANSYS India Conference can help you design smart new products in a smart way, leading to innovation, efficiency and product success.

[Call for papers](#)

### ANSYS Conference & 28<sup>th</sup> CADFEM Users' Meeting

Eurogress, Aachen, Germany

November 3, 2010 – November 5, 2010

**Meet us here!!**

Experience today's simulation technologies for tomorrow's products at the ANSYS Conference & the CADFEM Users' Meeting, featuring ANSYS products and complementary solutions. For three days, CADFEM & ANSYS Germany will present a diverse range of technical information for specialists and interested beginners at one of the largest specialist conferences on simulation.

Call for papers: [www.usersmeeting.com](http://www.usersmeeting.com)

# About Us

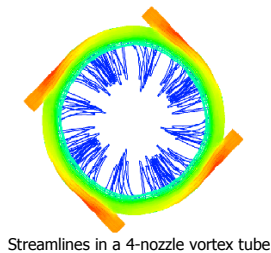
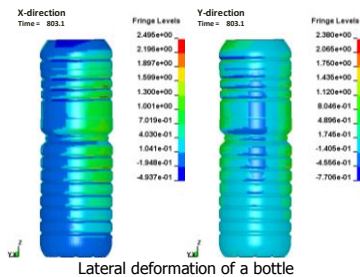
Software – Consulting – Seminars – Support

## Software & Support

Today's simulation engineers demand for software products that offer the best-in-class solutions to the problems in the industry. At CADFEM, we offer CAE software products that can solve your simulation problems. Talk to one of us to know how one of the below products can be useful to you.

- **LS-DYNA** - The leading explicit code for mainly simulating highly nonlinear dynamic problems
- **optiSLang** - An algorithmic toolbox for sensitivity analysis, optimization, robust design & reliability analysis
- **Diffpack** - Object-oriented tools for the numerical modeling and solution of partial differential equations
- **ESAComp** - Software for the analysis and design of composite laminates and laminated structural elements
- **DIGIMAT** - The nonlinear multi-scale material & structure modeling platform
- **VirtualPaintShop** - Paint simulations for the automotive industry

Hand over your support questions to our **Technical Support** team and relax. Our highly experienced and well-trained experts ensure a competent and reliable support to the simulation-based product development team in your organization. Contact us if you are interested in seeking our assistance.



## Consulting

CADFEM India has engineering expertise in a broad variety of disciplines. Our experience, in the CAE industry, of over 25 years will strive to provide you with the solution to your problems. Contact us to discuss your problems with us.

- Statics/Dynamics
- Strength Assessment (Static/Fatigue)
- Crash Analysis
- Passenger & Pedestrian Safety
- Drop Test
- Metal Forming
- Meshless Methods (SPH)
- Computational Fluid Dynamics (CFD)
- Fluid-Structure Interaction (FSI)
- Materials/Composites
- Design Optimization
- Robustness/Reliability Analysis

## Seminars

Today's simulation problems require engineers to keep themselves updated and informed on a constant basis. At CADFEM, we have training programs designed to meet your needs. You have the option of attending one of our periodic training programs or have us conduct the training at your organization. Please let us know the topic of your interest and we shall facilitate the training process.

- Introduction to ANSYS Workbench - DesignModeler & Simulation
- Introduction to LS-DYNA
- Contact Simulation with LS-DYNA
- Material Models in LS-DYNA
- Introduction to CFD - Modeling, Meshing, Solving & Post-Processing
- Meshing for CFD Analysis - Tetra, Prism & Hexa Meshing
- Fluid Structure Interaction (FSI) - Introduction, one-way & two-way coupling

Visit our website or contact us for next available dates for the training seminar of your interest.

We're on the Internet!

[www.cadfem.in](http://www.cadfem.in)

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**CADFEM Engineering Services India Pvt. Ltd.**

6-3-887, MCP Arcade, 4<sup>th</sup> floor  
Raj Bhavan Rd., Somajiguda  
Hyderabad 500082

Tel: +91 40 64543579  
Email: [info@cadfem.in](mailto:info@cadfem.in)  
Web: [www.cadfem.in](http://www.cadfem.in)

# Training Calendar

S.No	Training title	Dates*	Venue**	Attending?
1	Introduction to ANSYS Workbench - Design Modeler & Simulation	Oct. 7-8 Nov. 4-5 Dec. 9-10	Hyderabad	<input type="checkbox"/>
2	Introduction to LS-DYNA	Oct. 21-22 Nov. 18-19 Dec. 23-24	Hyderabad	<input type="checkbox"/>
3	Contact Simulation & Material Models in LS-DYNA	Nov. 25-26	Hyderabad	<input type="checkbox"/>
4	Introduction to CFD - Modeling, Meshing, Solving & Post-processing	Oct. 14-15 Nov. 11-12 Dec. 2-3	Hyderabad	<input type="checkbox"/>
5	Meshing for CFD Analysis – Tetra, Prism & Hexa Meshing	Oct. 28-29	Hyderabad	<input type="checkbox"/>
6	Fluid Structure Interaction (FSI) – Intro, One-way & Two-way Coupling	Dec. 16-17	Hyderabad	<input type="checkbox"/>

\* In case of very few registrations, training seminars will be postponed  
 \*\* We can provide trainings at specified/client locations as well

Training title of Interest (Either enter here or tick box above)	
Name (First Name & Surname)	
Designation	
Department	
Organization	
Contact Number	
E-mail address	
Preferable contact mode	
Remarks	

Due to limited number of seats, please turn in your registrations one week before the scheduled training course. Please feel free to contact us at [info@cadfem.in](mailto:info@cadfem.in) for further clarifications on any of the above courses.

For other dates, please keep checking our website for the [latest schedule](#).