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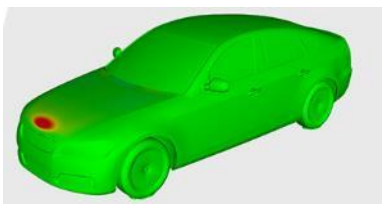
ANSYS



DYNAmore

ESI Group

Rescale

Livermore Software Technology, an ANSYS company

FEA Information Engineering Solutions

www.feapublications.com

The focus is engineering technical solutions/information.

FEA Information China Engineering Solutions

www.feainformation.com.cn

Simplified and Traditional Chinese

The focus is engineering technical solutions/information.

Livermore Software Technology, an ANSYS company

Development of LS-DYNA, LS-PrePost, LS-OPT,
LS-TaSC (Topology), Dummy & Barrier models and
Tire models for use in various industries.

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Platinum Particpants

Platinum Particpants

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About ANSYS, Inc.

If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge or put on wearable technology, chances are you've used a product where ANSYS software played a critical role in its creation. ANSYS is the global leader in engineering simulation. Through our strategy of Pervasive Engineering Simulation, we help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and create products limited only by imagination. Founded in 1970, ANSYS is headquartered south of Pittsburgh, Pennsylvania, U.S.A., Visit www.ansys.com for more information.

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Published on November 5, 2019 by Bill Kulp Automotive, Fluid Dynamics, Tips and Tricks
ANSYS Fluent, Adjoint Solver, Aerodynamics, Automotive

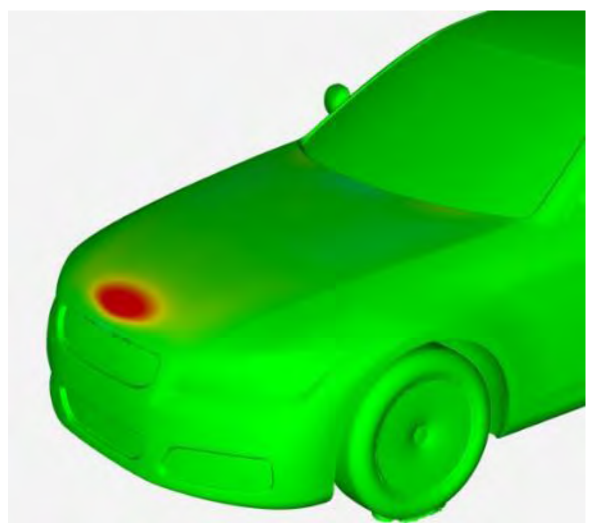
How Aerodynamic Shape Optimizations Simplify Car Body Design

Automotive engineers know the challenges of aerodynamic shape optimization. Some parts of the car body design are notoriously difficult to aerodynamically optimize, like a side mirror, because they have complex shapes that need to enclose mechanical components of a fixed size.

To keep a competitive edge, and to meet market demands, engineers need tools that can automate and simplify the shape optimization of car body designs.

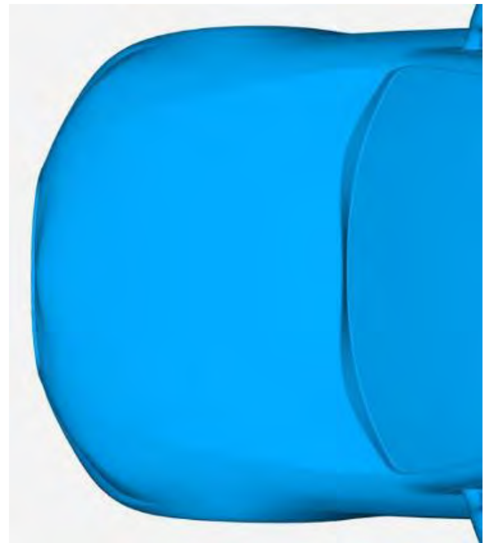
How to Automate Shape Optimization of Car Body Designs

Engineers can use the ANSYS Fluent adjoint solver to automate shape optimizations — especially those hard to optimize components.



The ANSYS Fluent adjoint solver is able to optimize the shape of components that are difficult for an engineer to optimize manually. Here, the adjoint solver is showing areas that can be morphed to improve the car's drag.

In this case, engineers need to set up a computational fluid dynamics (CFD) simulation and state that the optimization goal is to reduce the drag of the car body design. The adjoint solver then automatically morphs the geometry and mesh of the design, based on previous iterations, to improve the aerodynamic performance.



The ANSYS Fluent adjoint solver automatically updated the hood geometry to reflect the recommended changes to reduce the drag.

To demonstrate the capabilities of the adjoint solver, engineers used it to optimize the shape of one of the most complex, and challenging, parts of the car to aerodynamically design — the side mirror. These tests were performed on the DrivAer geometry from the Technical University of Munich.

Small features, mechanisms and mirrors need to fit into the side mirror enclosure without negatively affecting the rest of the car's aerodynamics.

The position of side mirrors is rather set. They tend to fit on the car's A-pillar to improve aerodynamics and a driver's ability to adjust the view. To improve the aerodynamics, engineers need to conduct a shape optimization of the side mirror's enclosure.

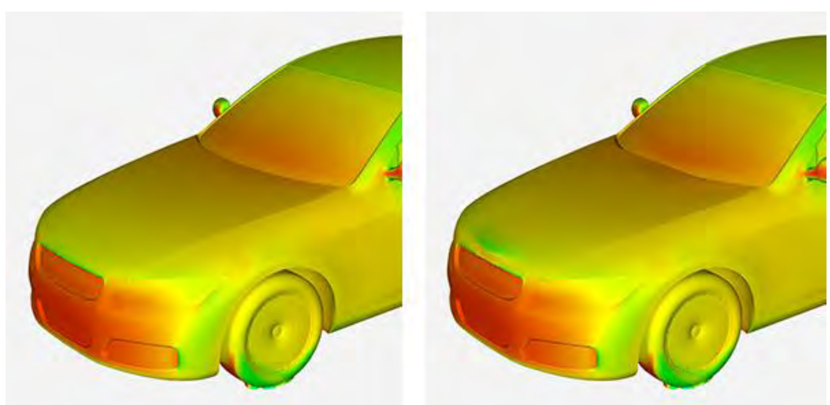
After only two iterations, the adjoint solver automatically morphed the geometry of the side mirror's enclosure to improve the drag coefficient from 0.299 to 0.286. That represents an improvement of 13 automotive drag counts (or 130 drag counts in the aerospace industry).

Adjoint Solver Optimizes the Shape of Car Body Designs Where it's Least Expected

There can be areas of a car body design that an engineer may not think to examine to improve the aerodynamics.

For instance, a car's hood is a large, smooth surface that doesn't typically add much drag. To save time, many shape optimization specialists focus on more problematic areas.

However, with the adjoint solver, another test showed that changing the geometry of the hood could reduce the car's drag coefficient, by another 4%, by changing from 0.299 to 0.287, or 12 automotive drag counts (120 drag counts in the aerospace industry).



Baseline pressure (left) compared to improved pressure (right) after the ANSYS Fluent adjoint solver optimized the geometry of the hood to reduce the drag coefficient.

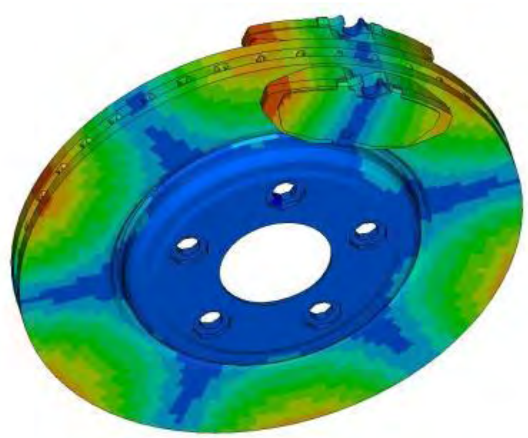
To learn more, read: Shape Optimization.

To learn how to speed up shape optimization using an automated and customizable workflow within ANSYS Fluent, join the webinar: ANSYS 2019 R3: Fluent Adjoint Solver Update.

Developing CAE software systems for all simulation disciplines. Products: ANSA pre-processor/ EPILYSIS solver and META post-processor suite, and SPDRM, the simulation-process-data-and-resources manager, for a range of industries, incl. the automotive, railway vehicles, aerospace, motorsports, chemical processes engineering, energy, electronics…

BETA CAE Systems announces the release of the v20.0.1of its software suite

October 1, 2019



About this release

BETA CAE Systems announces the release of the ANSA/EPILYSIS/META v20.0.1 series.
Apart from fixes for detected issues, this version also hosts noteworthy enhancements and implementations.
The most important enhancements and fixes are listed below:

Contents

Enhancements and known issues resolved in ANSA
Enhancements and known issues resolved in EPILYSIS
Enhancements and known issues resolved in META
Compatibility and Supported Platforms
New documentation

Download

Customers who are served directly by BETA CAE Systems, or its subsidiaries, may download the new software, examples and documentation from their account on our server. They can access their account through the "user login" link at our web site.
Contact us if you miss your account details. The Downloads menu items give you access to the public downloads.
Customers who are served by a local business agent should contact the local support channel for software distribution details.

Read more from website

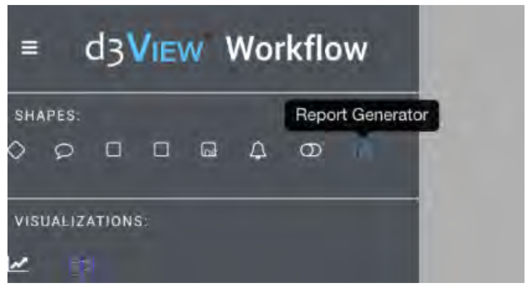
d3VIEW

www.d3view.com

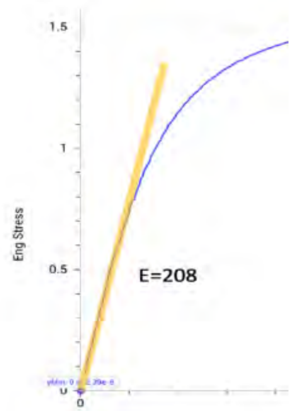
d3VIEW is a data to decision platform that provides out-of-the box data extraction, transformation and interactive visualizations. Using d3VIEW, you can visualize, mine and analyze the data quickly to enable faster and better decisions.

New Developments in Workflows

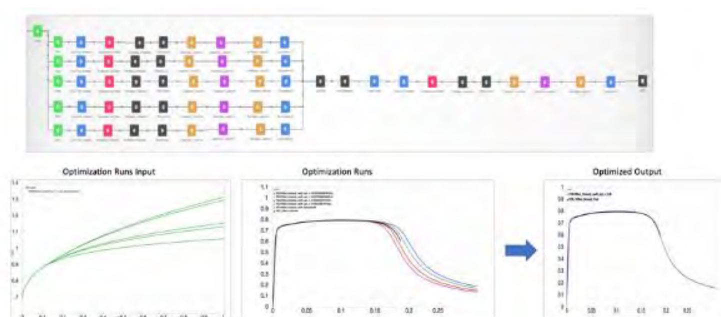
A new reporter worker added to fully automate report generation. The reporter worker allows pre-defining the format and its data.



Added worker to compute the initial elastic slope for the test Eng. Stress vs Eng. Strain. This value could help to validate test data to ensure the computed slope is within the bounds of accepted slope for a given material and to reject the test if falls outside of the bounds.



Fully automated workflow now available for calibrating post-necking behavior for metals and polymers.



www.d3view.com For more information email info@d3view.com

Author: Christian Frech christian.frech@dynamore.de

Playing with LS-DYNA

The Lego® Crash

The story

The German computer magazine c't in cooperation with the German Automobile Club ADAC crashed a LEGO® model of the Porsche GT3 RS. Consequently, some DYNAmore colleagues have asked themselves whether it is possible to do this virtually with LS-DYNA. A variety of urgent tasks and the sheer size of such a project made the idea fade into the background in the following months.

The challenge

Simply mesh all LEGO® bricks, assemble the model on the fly and check the ADAC result in the computer.

The realization

At Christmas Marko Thiele built a small crash test facility for his children. This revived the idea and over the Christmas holidays DYNAmore colleagues from Columbus (Ohio, USA), Versailles (France), as well as Stuttgart and Ingolstadt (Germany) have been competing with each other by meshing hundreds of LEGO® bricks based on publicly available CAD data. Thanks to the parallel development, the model was ready after a short time and delivered robust forecasts. Only the model size was slightly out of line: Due to the many geometric features of the LEGO® bricks, very fine discretization was required, which ultimately led to a model size of almost 20 million elements. This globally distributed cooperation was coordinated by the simulation data management system LoCo of Scale GmbH.

The result

The whole story and the result can be found at the DYNAmore website and on the corporate Youtube-Channel. Enjoy!

Author: Christian Frech christian.frech@dynamore.de

DYNA MORE Finite Elements Solutions

The company
DYNAmore GmbH – Gesellschaft für FEM-Ingenieursdienstleistungen – is one of the largest distributors of LS-DYNA simulation software worldwide. But we offer far more in the way of services: in addition to our guaranteed, expert support in all areas of application for the LS-DYNA and LS-OPT software packages, we offer FEM calculation services as well as general consulting on any questions concerning structural dynamics.

Engineering services
DYNAmore provides extensive services for numerous tasks in simulating nonlinear structures. Here, we mainly focus on both conventional and pilot projects and a variety of industries.

Portfolio

- Software solutions
- Method development
- Support and consulting
- Calculation services
- IT solutions for CAx and data management processes
- Training and information sessions
- Conferences

Facts

- Approx. 150 employees
- Subsidiaries in Germany, Sweden, Italy, France, Switzerland and the USA
- Offices in Ingolstadt, Dresden, Berlin, Langlingen, Wolfsburg, Linköping, Gothenburg, Turin, Versailles, Zurich and Dublin/Ohio
- 5 service centers at customers' sites
- More than 800 customers from industry and research, both in Germany and abroad (including almost all OEMs)
- Worldwide use of our ATD models
- FEM experience since the early 1980s.
- Ongoing development of LS-DYNA and LS-OPT

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Tel. +49 (0) 7 11 - 45 96 00 - 0
E-Mail:info@dynamore.de
www.dynamore.de

A leading innovator in Virtual Prototyping software and services. Specialist in material physics, ESI has developed a unique proficiency in helping industrial manufacturers replace physical prototypes by virtual prototypes, allowing them to virtually manufacture, assemble, test and pre-certify their future products.

Are You Reaping the Benefits of the Manufacturing 4.0 Transformation?

Monday, November 11, 2019 By Céline Gallerne

Attaining greater process efficiency through digital transformation is vital if you want to get ahead in today's manufacturing environment. In this interview, Dr. Fouad el Khaldi, discusses critical parts of the manufacturing 4.0 transformation which enable predictive maintenance, detection of early signals of deviation and prediction of future incidents with precision.

Why is the digital twin a critical part of manufacturing 4.0 transformation?

Today, manufacturing process design, process validation, and actual production are well optimized but remain disconnected. Thanks to recent developments (Big Data, Internet of Things, Artificial Intelligence, etc.), these three phases finally connect! Engineers can benefit from faster iteration loops and better assess the impact of process design decisions.

Data from real life performance offers opportunities for continuous learning, which will benefit the next generation of products by upgrading design assumptions. This becomes key as we speak increasingly of predictive maintenance and managing a product's performance throughout its lifetime (Product Performance Lifecycle™ - Management or PPL-M), rather than delivering a product that performs on day one (what conventional Product Lifecycle Management or PLM covers).

What role do you see for digital twins in Smart Factories?

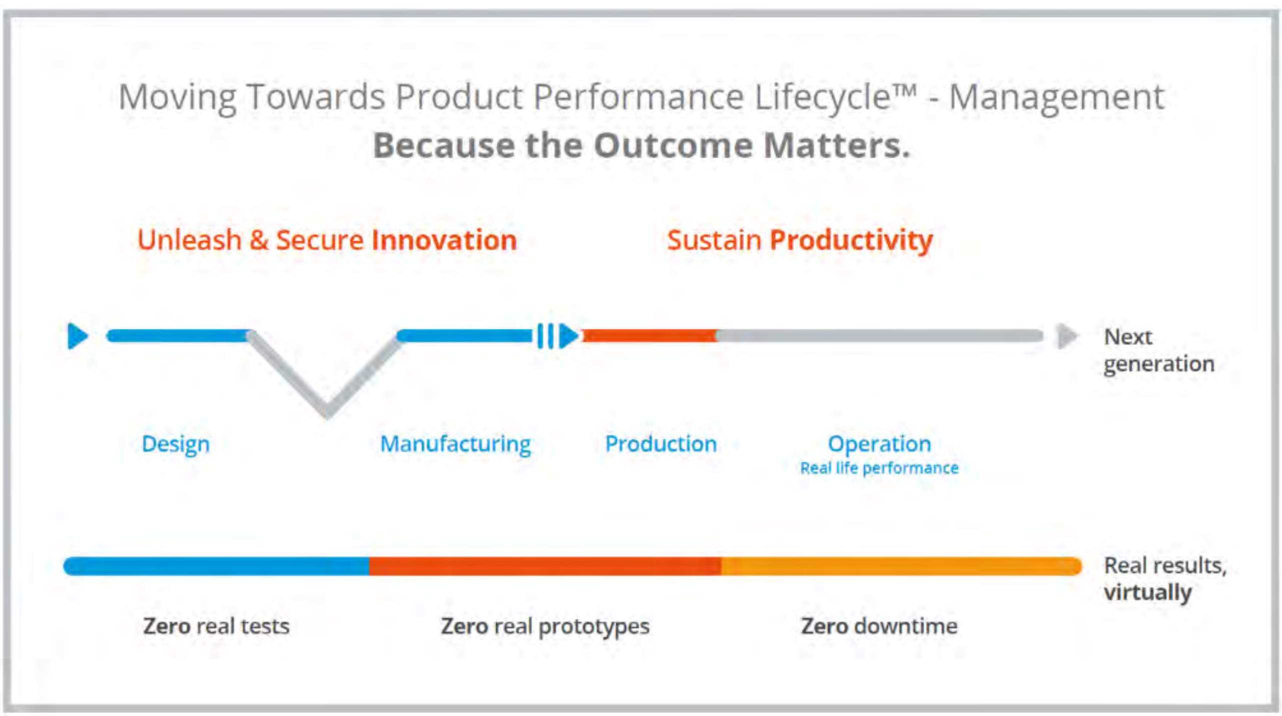
Virtual Prototyping is a powerful methodology enabling the design and validation of manufacturing processes. It's at the core of ESI's Hybrid Twin™ approach, where we combine the virtual prototype with the data coming from industrial plants to measure the real operational performance, to adjust the initial model to real life data and context, and to detect early signals of deviation. A Hybrid Twin™ enables asset managers to get the information necessary to assess cause & effect relationships, and to implement the appropriate corrective measures.

Why hybrid? This is crucial in overcoming the limitations of a digital twin: indeed, if we limit ourselves to data collected from historical and real-life operations, we can only predict behaviors that already took place. Whereas building on a virtual prototype that reproduces the asset as-good-as-real (capturing for instance its material characteristics after manufacturing and assembly) helps us predict almost any kind of future incident with precision, even in the case of changing parameters (materials variations, operating conditions, etc.).

How will simulation and modeling evolve to support optimization of manufacturing processes including forming, welding, additive manufacturing, and assembly?

Modern manufacturers rely on simulation and pilot tests to ensure that they're meeting various time, quality, cost requirements in their manufacturing process design and validation. However, they typically limit the use of simulation to the methods and the validation engineering departments and haven't deployed it into production for various reasons – mainly related to complexity and response time.

Good news for production managers: ESI's innovative Parametric Reduced Model technology enables the development of a Hybrid Twin™ with real time responses, derived from a predictive detailed 3D model built in the process design and validation phase (see graphic). The Hybrid Twin™ opens new opportunities to augment the PLC (Programmable Logic Controller) capacity for smarter machine control. The Hybrid Twin™ will be loaded on site as edge computing (small processors next to the machine) for obvious performance and security, benefiting from recent IoT advances, such as 5G. Factory production managers will be able to measure and predict production performance more efficiently to detect early signs of deviation and to anticipate troubleshooting - thus maintaining the required quality (reducing scraps) and ensuring optimal performance.



Early pilot projects are already demonstrating the feasibility of such a solution and showing manufacturers how the simulation capabilities will be adapted and streamlined to be implemented right at the heart of the factories – with very encouraging outcomes.

For more information visit Hybrid Twin™

ETA has impacted the design and development of numerous products - autos, trains, aircraft, household appliances, and consumer electronics. By enabling engineers to simulate the behavior of these products during manufacture or during their use, ETA has been involved in making these products safer, more durable, lighter weight, and less expensive to develop.

ETA's Technology Roadshow was an Epic Success!

It has been one busy year for the ETA team. This summer they kicked off the highly-anticipated release of their DYNAFORM 6.0 software, then soon began making preparations for a technology roadshow in Asia. The roadshow was arranged to support LSTC in China, Korea & India, visit with distributors and launch ETA's new software technologies – ACP OpDesign 1.0, DYNAFORM 6.0, and VPG Suite. Below are highlights from their journey -

China

The ETA team arrived in Shanghai for LSTC's 4th China LS-DYNA User's Conference on October 21st. They presented new products and technology solutions; ACP OpDesign 1.0, LUNAR (AI/ML), DYNAFORM 6.0 and VPG Suite within LSTC products to a crowd of over 500 attendees.

The ETA team pictured from left to right: Ming Zhang, Jenson (CC) Chen,

Dr. Akbar Farahani, Hui Ouyang and Divesh Mittal

A musical performance on stage during The 4th China LS-DYNA User's Conference

Korea

The team presented DYNAFORM 6.0 at the 24th Korean LS-DYNA Users Conference in Seoul Korea. Followed by visits with distributors to present ACP OpDesign.

DYNAFORM Project Manager, Jenson (CC) Chen presents DYNAFORM 6.0 at the LS-DYNA Users Conference in Seoul.

ETA's CEO, Dr. Akbar Farahani and ACP OpDesign Product Manager, Divesh Mittal attend a dinner with distributors.

Japan

Dr. Akbar Farahani and Jenson (CC) Chen enjoy a visit with local distributors.

India

The roadshow concluded with ETA-APME's (India) 1st Annual Disrupting Simulation with New Technologies ACP, AI, ML and EV's on Tuesday, November 5th. The conference hosted over 200 attendees from 60 companies - which included OEM's and suppliers. ETA officially launched ACP OpDesign, ODYSSEY, DYNAFORM 6.0 and VPG Suite in India.

The ETA APME & US team along with Kambiz Kayvantash,

CEO of CADLM France.

Shuhab Ahmed MD, ETA APME provided the opening ceremony

Dr. Akbar Farahani presented the ETA Overview

The ETA APME team speak with attendees during the break

The ETA team received rave reviews from customers, distributors and OEM's for presenting creative strategies and showcasing an innovative product portfolio. We would like to thank all of our distributors, customers and ANSYS/LSTC in China, Korea, Japan & India for their continued support and hospitality!

FEA Not To Miss

www.feantm.com

FEA Not To Miss, is a weekly internet blog on helpful videos, tutorials and other Not To Miss important internet postings. Plus, a monthly email blog.

Start your Monday with coffee or tea reading our engineering blog, at the FEA Not To Miss coffee shop.
Postings every Monday on what you have missed

www.feantm.com

Monday 11/11/2019 - Okay, I can hear the buzz in the room on today's simulation that it was in the email blog. BUT, it's a cauldron and I didn't have it on this site! AND I want one for the coffee shop to stir a new flavor! So, today we're having my great new Cauldron Cocoa Coffee with Cauldron Chocolate Chips. (notice all the C's)

Curt Chan - Happy Halloween! After the 'watercooler chat' with Yuki Okada & Ethan Thompson we thought how fast could we simulate a Witch's Cauldron in ANSYS Discovery?

Monday 11/04/2019 - And if you're having our delicious coffee with a hint of collapsing vanilla, you don't want to drink it in the below industrial building! GO to the nice park, or library or come visit the ranch to drink it!

LS-DYNA Seismic nonlinear dynamic analysis of one storey industrial building

LS-DYNA Demo License mv@feainformation.com

Monday 10/07/2019 - Okay, NO place would be safe for my to go coffee cups for below simulation. BUT we sooooo love Lego Crash cars by DYNAmore/SCALE. What flavor you ask? Crash Chocolate with a dash of bumper vanilla. Ouch!

Lego Crash 2019

Hengstar Technology

www.hengstar.com

Shanghai Hengstar & Enhu Technology sells and supports LSTC's suite of products and other software solutions. These provide the Chinese automotive industry a simulation environment designed and ready multidisciplinary engineering needs, and provide a CAD/CAE/CAM service platform to enhance and optimize the product design and therefore the product quality and manufacture.

Shanghai Hengstar & Enhu Technology

Sub-distributor and CAD/CAE/CAM consulting in China, especially for FEA needs for engineers, professors, students, consultants.

Contact us for our LS-DYNA training courses and CAD/CAE/CAM consulting service, such as

- Crashworthiness Simulation with LS-DYNA
- Restraint System Design with Using LS-DYNA
- LS-DYNA MPP
- Airbag Simulation with CPM
- LS-OPT with LS-DYNA

Our classes are given by experts from LSTC USA, domestic OEMs, Germany, Japan, etc. These courses help CAE engineers to effectively use CAE tools such as LS-DYNA to improve car safety and quality, and therefore to enhance the capability of product design and innovation.

Consulting - Besides solver specific software sales, distribution and support activities, we offer associated CAD/CAE/CAM consulting services to the Chinese automotive market.

Solutions - Our software solutions provide the Chinese automotive industry, educational institutions, and other companies a mature suite of tools - powerful and expandable simulation environment designed and ready for future multidisciplinary CAE engineering needs.

Shanghai Hengstar provides engineering CAD/CAE/CAM services, consulting and training that combine analysis and simulation using Finite Element Methods such as LS-DYNA.

Shanghai Hengstar Technology Co., Ltd

hongsheng@hengstar.com

http://www.hengstar.com

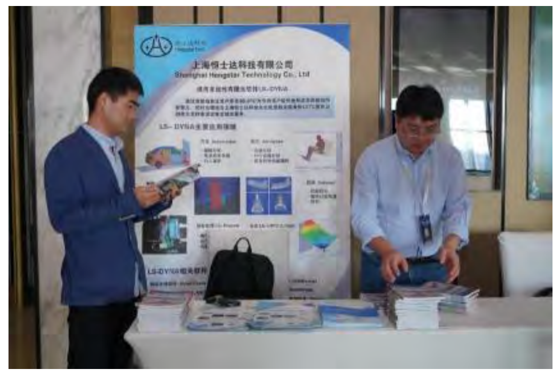
Shanghai Enhu Technology Co., Ltd

http://www.enhu.com

2019 4th LS-DYNA China Users' Conference was successfully held

The 4th LS-DYNA China user conference was successfully held in Pullman Shanghai South Hotel from October 21 to 23, 2019.The conference was sponsored by LSTC and Shanghai Fankun Software Technology Co., Ltd.. Shanghai Enhu & Hengstar Technology attended the conference as a platinum sponsor. As a sponsor, Enhu & Hengstar actively participated in the conference, and fully communicated with the CAE engineers.

More than 450 CAE simulation experts, scholars and development engineers from automobile, aerospace, civil, universities and scientific research institutes, and LSTC attended in the conference. At the conference, Dr. Yisheng Ye delivered the opening remark on the behalf of LSTC, with Dr. John o. Hallquist brought his thanks and blessings through a short video. Professor Wing Kam Liu from Northwestern University, Dr. Zhenliang Lou, from SAIC, Dr. Shoufeng Hu, from CAAR, Dr. Zhenglin Cao, from FAW Group, etc brought the advanced theories and applications of LS-DYNA in their respective professional fields. More than 100 presentations, including main applications of LS-DYNA in automotive crashworthiness, simulation technology and MPP, multiple solvers and applications, sheet metal forming and implicit analysis, innovation simulation methods, optimum design and Pre & post processing, are given in the two days conference.



Shanghai Enhu & Hengstar supported the JSOL CAE Forum 2019

The 2019 JSOL CAE Forum was successfully held at the Tokyo Convention Center on November 6, 2019. Shanghai Enhu & Hengstar Technology Co., Ltd. attended the forum as a sponsor. The conference has nearly 500 relevant technical personnel, experts and scholars. The conference has focused on the developments of CAE, especially in product design, material research, metal forming, LS-DYNA's new features, and cloud technology, etc. Experts in various fields provided the outstanding presentations.

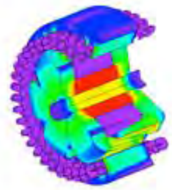
Dr. Jason Wang from LSTC, and Dr. Larry Williams from ANSYS provided the keynote lectures: "the Recent Development in LS-DYNA" and "ANSYS Simulation and Strategy". As LSTC joined to the ANSYS family, LS-DYNA，it will expand and bring more customers to use LS-DYNA and Ansys for their product design and simulation.

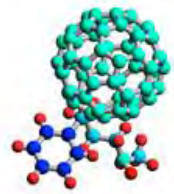
JSOL

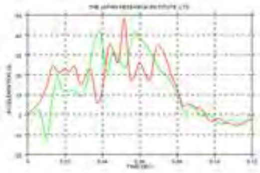
http://www.jsol.co.jp/english

JSOL supports industries with the simulation technology of state-of-the-art. Supporting customers with providing a variety of solutions from software development to technical support, consulting, in CAE (Computer Aided Engineering) field. Sales, Support, Training.

JSOL







Support tool design and process design for forming

Integrated forming simulation system JSTAMP

Sheet metal forming Simulation

JSTAMP@

- Dieface Design Support
- Blankline/trim line development
- Crack, wrinkle, and springback prediction
- CAD output of SB-compensated tool
- Material database as standard equipment

JSOL CAE Forum Website

J-OCTA Feature enhancement: Finite Element Method (FEM) simulation

Interface for LS-DYNA supports large-deformation simulation

Recently, it is in high demand to estimate and evaluate the behavior during large deformation of micro-structured composites which contain phase separation and filler, by performing simulations.

Existing FEM engine of J-OCTA, "MUFFIN-Elastica" is for elastic simulation and is specialized for the behavior during a small deformation.
To extend its applicability to FEM simulation, the updated J-OCTA 4.1 version will provide the interface for a multi-purpose nonlinear structural analysis engine "LS-DYNA".

The phase-separated structure computed by "COGNAC or "SUSHI" can be output as a mesh data for LS-DYNA simulation. After the user specifies the material properties for each component and deformation (boundary) condition, LS-DYNA simulation can be started from J-OCTA directly. As a material model being appropriate for nonlinear structural simulation, materials including elastoplastic, viscoelastic, and hyperplastic such as rubber are available for use.

From version 4.1, J-OCTA can deal a large-deformation FEM calculation of a multi-phase structure which contains phase separation and filler dispersed structure.

KAIZENAT Technologies Pvt Ltd is the leading solution provider for complex engineering applications and is founded on Feb 2012 by Dr. Ramesh Venkatesan, who carries 19 years of LS-DYNA expertise. KAIZENAT sells, supports, trains LS-DYNA customers in India. We currently have office in Bangalore, Chennai, Pune and Coimbatore.

Friction Welding

Friction welding (**FRW**) is also known as solid-state welding process that generates heat through mechanical friction between workpieces in relative motion to one another, with the addition of a lateral force called "upset" to plastically displace and fuse the materials. Friction welding is used with metals and thermoplastics in a wide variety of aviation and automotive applications.

Using LS-DYNA ,the friction welding process is simulated using the SPH method whereas the component's material behaviour is observerd during the contact. And also in addition to it, the temperature distribution in the process is studied which is obligatory in the friction welding process.

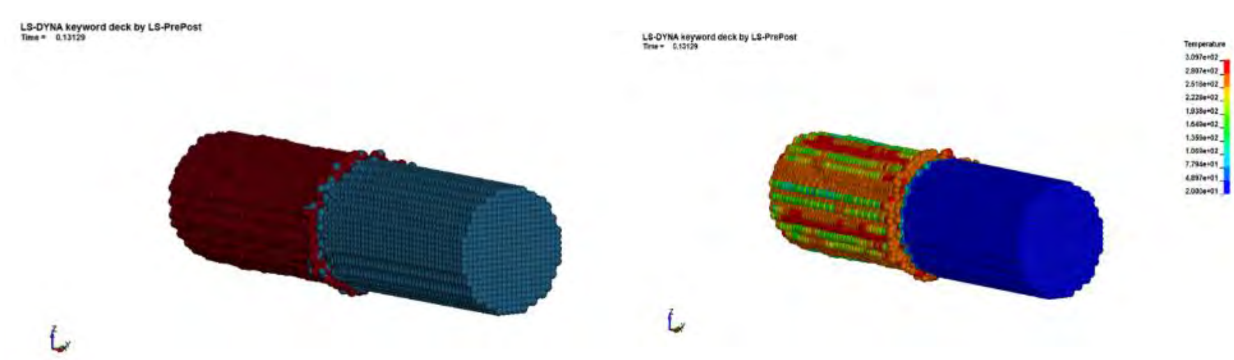


Figure: **Friction Welding** Simulation in LS-DYNA

To know more about the simulation, please contact support@kaizenat.com

A team of engineers, mathematicians, & computer scientists develop LS-DYNA, LS-PrePost, LS-OPT, LS-TaSC, and Dummy & Barrier models, Tire models.

LS-DYNA® EFG, Peridyanmics, X-FEM & RVE

Intelligent Manufacturing, Advanced Material Design & Integrated Structural Analysis

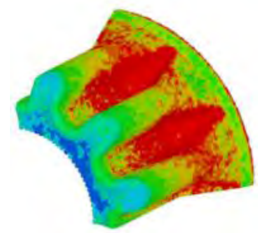
LS-DYNA® integrates the advanced finite element methods for solving some of the most challenging problems in manufacturing processes, material design, and structural analysis. Such problems typically involve large deformations, material failure, crack propagation, and composite materials. Some of these methods are coupled with the thermal, fluids, and electro-magnetic solvers in LS-DYNA to perform multi-physics analysis as needed.

Applications

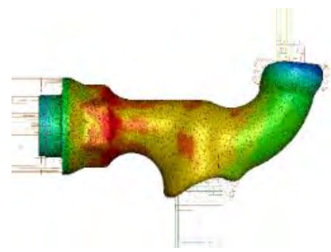
- Manufacturing: forging, extrusion, 3D printing, compression molding
- Structural analysis: crack propagation, bird strike, fluid-structure interaction
- Material design: representative volume element (RVE), reduced-order modeling, deep material network

Features

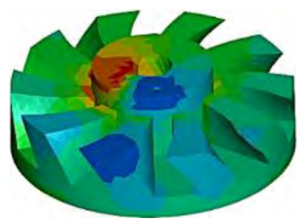
- Solid formulation: meshfree-enriched FEM, element free Galerkin (EFG), peridynamics
- Shell formulation: EFG, eXtended FEM
- Adaptivity: adaptive EFG and FEM
- Materials: brittle, semi-brittle, ductile, rubber
- Explicit and implicit solvers
- Multi-physics analysis
- Multi-scale composite modeling
- Material data processing
- Small to extremely large deformations
- Low to very high strain rate loadings
- Physics-based failure mechanism
- Material failure and separation



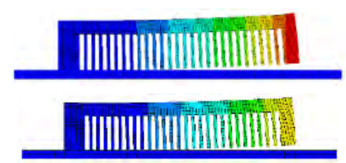
Gear forging



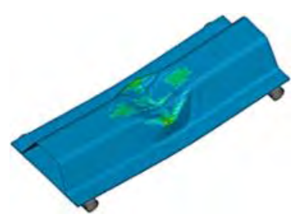
Extrusion of plastics



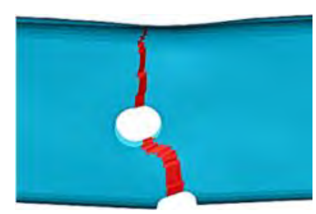
3D printing



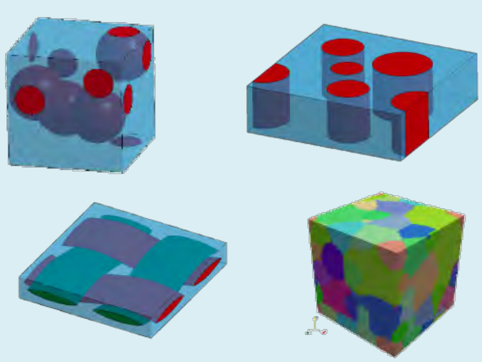
Distortion prediction of 3D printed components



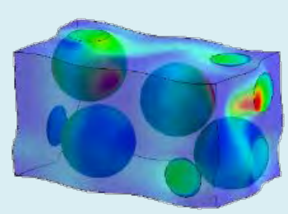
Carbon fiber reinforced polymer



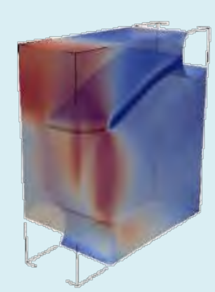
Ductile cracking in shell



RVE models



Nano-particle reinforced rubber



Crack in double-notched coupon using data clustering

Group Website: https://www.lstc-cmmg.org

LS-DYNA® SPG & SPH

Intelligent Manufacturing, Advanced Material Design & Integrated Structural

LS-DYNA® integrates the advanced finite element methods for solving some of the most challenging problems in manufacturing processes, material design, and structural analysis. Such problems typically involve large deformations, material failure, crack propagation, and composite materials. Some of these methods are coupled with the thermal, fluids, and electro-magnetic solvers in LS-DYNA to perform multi-physics analysis as needed.

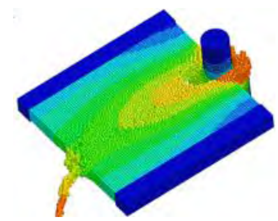
Applications

- Destructive manufacturing:
  Blanking, drilling, machining, grinding, self-piercing riveting (SPR), flow drill screwing (FDS), friction stir welding (FSW)
- Impact penetration:
  Projectile impact (concrete and metal targets), bird strike, FSI (water jet impact)
- Structural analysis:
  Joint strength analysis (cross-tension, lap shear, coach peeling), tube crushing

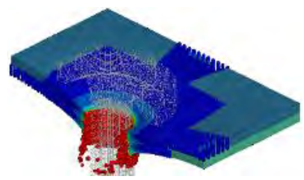
Features

- Solid formulation:
  Smoothed Particle Galerkin (SPG)
  Immersed SPG
  Coupled FEM-SPG
- Discrete formulation:
  Smoothed Particle Hydrodynamics (SPH)
- Materials:
  Brittle, semi-brittle, ductile, rubber
- Solvers:
  Explicit, SMP and MPP
- Multi-physics analysis:
  Thermal mechanical coupling
  Coupled SPG/SPH analysis
- Multi-scale modeling:
  Two-scale for structural responses
- Applicable problems:
  Small to extremely large deformations
  Low to very high strain rate loadings
- Material fracture:
  Physics-based bond failure mechanism
  Material failure and separation

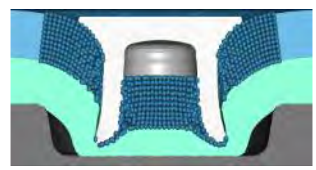
Bird strike



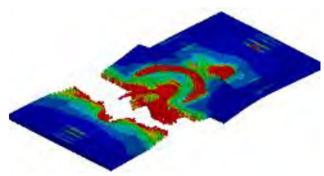
Friction stir welding



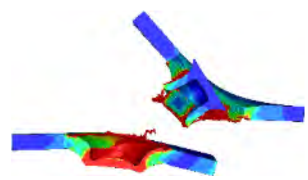
Flow drill screw



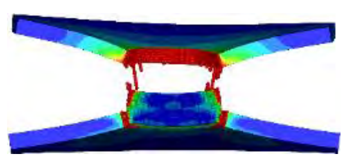
Self-piercing riveting



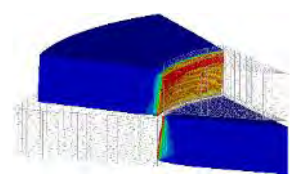
Lap shear of FDS



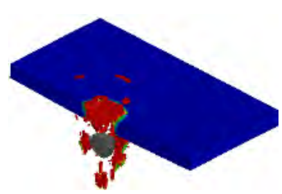
Lap shear of SPR



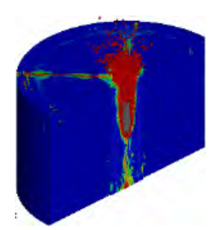
Cross tension of spotweld



Metal blanking



Perforation of Aluminum



Penetration of concrete

Group Website: https://www.lstc-cmmg.org

Providing engineering services to the composites industry since 1970. During this time, we have participated in numerous programs that demonstrate our ability to perform advanced composite design, analysis and testing; provide overall program management; work in a team environment; and transition new product development to the military and commercial sectors.

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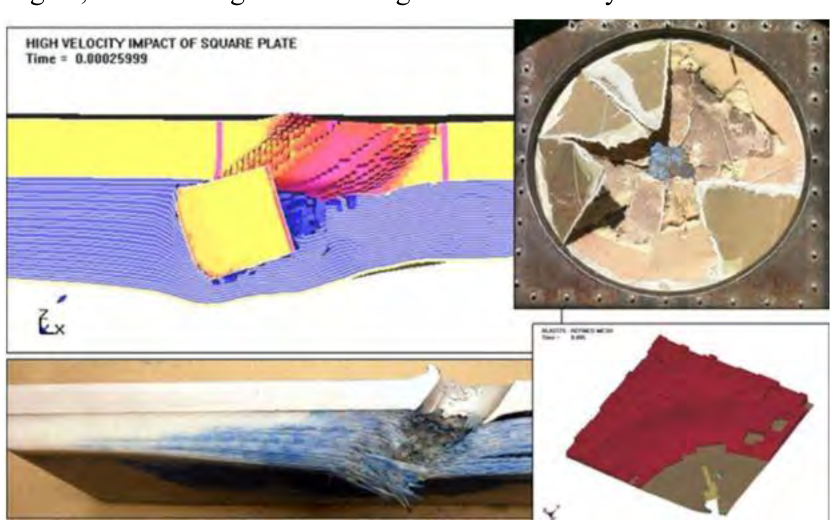
Bottom photos courtesy of TPI Composites, Inc. (left) and Seemann Composites, Inc. (right)

Engineering Services

MSC brings a long-range perspective to its engineering services clients. We understand the history of our core technologies, and can project likely new developments, and seek to provide innovation. A keen appreciation of the materials and structures state-of-the-art gives us the ability to create a development roadmap that efficiently reaches the clients goal, while taking full advantage of what already exists. We have an unusually broad exposure to materials applications; we have been involved with everything from infrastructure applications to spacecraft. This broad perspective allows us to draw on approaches and trends in one application area, and apply it to another. This helps our clients avoid pitfalls, and make exceptionally rapid technological progress. The same broad reach allows us the opportunity to interact with, and evaluate a wide range of suppliers.



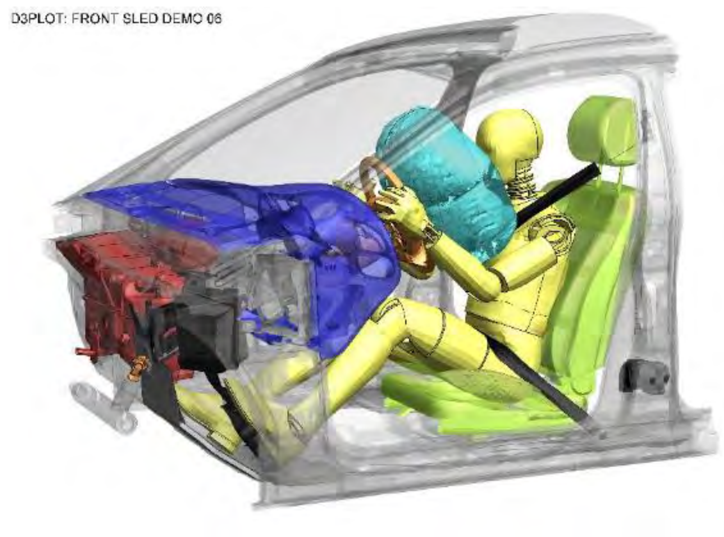
OASYS

www.oasys-software.com/dyna

Oasys Ltd is the software house of Arup and distributor of the LS-DYNA software in the UK, India and China. We develop the Oasys Suite of pre- and post-processing software for use with LS-DYNA.

Webinars

Oasys and LSDYNA team offers free webinars



Next webinar:

LS-DYNA: introduction to contacts

Emily Owen, MEng, Engineer at Arup will present this webinar:

12:30 PM (GMT) on 7th January 2020

For more information and to register click here.

Events

SIMBIO-M conference

June 18th -19th 2020 in Turin, Italy

Hosted by Dr Christophe Bastien (Coventry University), Dr Alessandro Scattina (POLITO), Dr Michel Behr (IFSTTAR), Prof Kambiz Kayvantash (CADLM);

This conference is aiming at introducing new technologies, advances and tools in the fields of Biomechanics and Biomedical engineering. Focus is on research and in particular introduction of young researchers into the applications world.

Paper submission: **February 28th 2020**

SIMBIO-M website and brochure .

Predictive Engineering provides FEA and CFD consulting services, software, training and support to a broad range of companies.

NEW CFD case study posted on simulation of recovery boiler combustion

Posted By: Webmaster November 9, 2019

Analysis: CFD

A CFD analysis was performed on a newly built recovery boiler to estimate operational temperatures, CO emissions, and NOx emissions.

Predictive Engineering has been working closely with SHB Power Plant Engineering on the modeling of bio-fuel power generation in STAR-CCM+. SHB is a local company in Portland, Oregon that specializes in upgrading boilers to increase efficiency and reduce emissions. This has been a unique project that has involved software support for Simcenter STAR-CCM+, engineering consulting services, and technology transfer so that SHB can run the models in-house for further design exploration.

Combustion is one of the most challenging types of analysis to solve through CFD and the analysis requires a highly capable code with strong multiphysics capabilities. Predictive Engineering developed a model of a recovery boiler for SHB in support of on-going efforts to evaluate performance and identify areas of improvement. Recovery boilers are used in the paper-mill industry and are fueled by black liquor, which contains wood lignin from the pulping process. Although the black liquor is a highly viscous liquid, we utilized the coal combustion model in STAR-CCM+ to simulate the multistage combustion process of solid biomass fuel from drying, devolatilization, char burning, and reduction to ash/inert components. Combustion of the devolatilized gases within the lower furnace is handled by an eddy-break up model utilizing reversible reactions to provide a quick estimate of flame locations, energy release, and CO production. The model utilizes a built-in thermal NOx model utilizing the Zeldovich mechanisms to predict NOx formation from the combustion process. Radiation and conjugate heat transfer to the surrounding tube walls was modeled utilizing gray gas, participating media models.

One of the most challenging aspects to modeling black liquor combustion is to capture the unique swelling that occurs during combustion. As the injected black liquor droplets dry and devolatilize, the particles can swell 4 to 5 times the original size. This size expansion causes the lighter particles to lift up within the lower furnace. Once char burning commences, the particles shrink back in size and fall to the char bed below. To capture this effect, standard drag models were customized and tuned to meet the desired behavior.

CFD CASE STUDY - Simulation of Recovery Boiler Combustion

FINITE ELEMENT ANALYSIS
Predictive Engineering

Who We Are

We are experienced simulation engineers that have successfully analyzed and validated hundreds and hundreds of finite element analysis (FEA) projects. With decades of experience in FEA and CFD, we know how to optimize your design to deliver every last bit of performance and to ensure that it will meet your service requirements whether in Aerospace, Marine, Energy, Automotive, Medical or in Consumer Products.

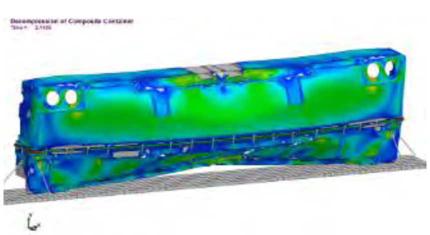
Our History

Since 1995, Predictive Engineering has continually expanded its client base. Our clients include the total spectrum from large Fortune 500 companies to start-ups looking to launch the next generation of satellites. We are also proud of work in the renewable energy fields from wind to solar. Over the years, one of our core strengths is in the vibration analysis of composite structures, aerospace electronic components and large industrial machinery. What has set us apart from the competition is our experience in the successful completion of more than 800 projects.

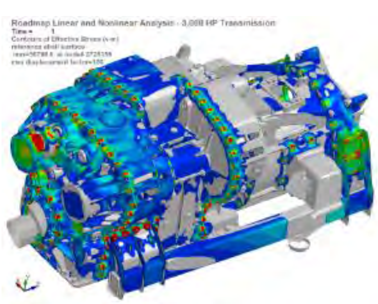
View our portfolio

FEA, CFD and LS-DYNA consulting projects

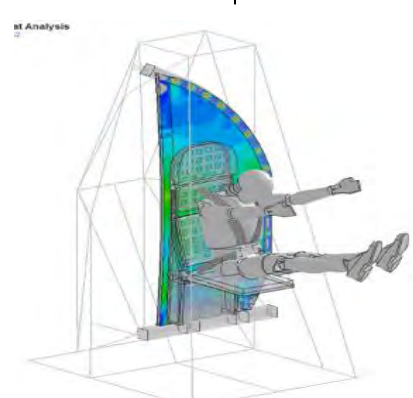
Composite Engineering



Nonlinear Dynamics



Aerospace



Offering industry-leading software platforms and hardware infrastructure for companies to perform scientific and engineering simulations. Providing simulation platforms that empower engineers, scientists, developers, and CIO and IT professionals to design innovative products, develop robust applications, and transform IT into unified, agile environments.

Siemens Lift-and-shift to Rescale is here, and in force

October 25 Robert Combier

Rescale expands Siemens Simcenter software capability on its platform to include Simcenter Amesim and Simcenter 3D.

Substantial additions to Siemens SaaS on Rescale

Siemens has teamed up with Rescale to expand their SaaS offering in the cloud, bringing distinct advantages to both large enterprises and smaller organizations. In this blog post we'll look at the details of this program and the benefits provided.

Substantial price decreases have arrived

First, let's look at what has changed in the SaaS offering on Rescale. For years, customers of Rescale and Siemens have been able to purchase on-demand licenses for batch solving of Simcenter Nastran and Simcenter 3D products. Those products are still offered, but the price has been reduced by up to 60%! That's not all: Simcenter Amesim is now also available for batch solving on Rescale with the same parallel solve pricing that comes with Simcenter Nastran and Simcenter 3D. This is absolutely great news for Rescale users, and I'll get into a bit later.

GUI now available on subscription

In addition to expanding the batch solve offering on Rescale, we are excited to offer a SaaS option for GUI usage as well. GUIs, or Graphic User Interfaces, are used to interact with your model for pre-processing activities prior to solve as well as post-processing activities following the solve. This required a user to purchase or lease a license from Siemens directly. With the new SaaS offering, Rescale offers a monthly concurrent GUI subscription service for anyone looking to access Simcenter 3D or Simcenter Amesim pre and post-processing tools. Each GUI offers three different subscription levels; Basic, Advanced, and Premium; to allow users to only pay for what they need. Customers can select which GUI level they need, for how many months, and for how many concurrent users.

The expansion of the Rescale batch solve offering along with the introduction of GUI subscriptions allows users to easily expand every aspect of their Simcenter 3D or 1D environment while also allowing customers to run fully zero-footprint when needed, meaning no local software or hardware resources are required. This provides the ultimate in portability and flexibility.

Example use case for the enterprise: from weeks to hours

Now let's look at some use cases for two customers at opposite ends of the spectrum: The large enterprise user and the small startup.

First, the large enterprise user. This customer likely already owns licenses for many Siemens products and uses them on a daily basis. Sound familiar? But, those licenses are purchased on an annual basis and there will be times when more analysis capability is needed. This demand could result from a lack of hardware resources, a lack of software licenses, or both. Let's assume this enterprise customer has entered a part of their product development process where they need to run a large number of Simcenter Nastran analysis in order to determine the best design path to take.

The analyst team has several design options they are considering and needs to test multiple load cases against those options using Simcenter Nastran. For this example, let's say they have 3 different design options and they need to test each them against 25 different load cases. If every load case takes 5 hours to process and they only have 1 Simcenter license they will have all results back in 375 hours. That is over 15 days of continuous analysis processing, during which time their local resources are not usable for anything else and their annual license is fully tied up. However, if this same situation is moved to Rescale, not only can all three jobs can be run simultaneously, but all load cases can also be run in parallel. This means the results for this simulation can be returned to the analysis team in just over 5 hours.

The licensing cost for this run, assuming the requirements are satisfied by a Simcenter Nastran Basic license, would be $275.25. This figure does not include the charges for the Rescale hardware to run the application, but if we assume the customer was running each solve using 8 cores the hardware cost would be roughly the same as the software cost at around $275-$300 total. Spending less than $600 to free up a license, the hardware, and the engineer's time as well as deliver a result in 5 hour instead of 15 days is an incredible advantage.

Example use case for the startup: extreme cost optimization

Next, let's take a look at the smaller company. This company doesn't have as intense of a design cycle and may only occasionally need high level design analysis. Due to this, this company has not invested in simulation software. As a result, they are seeing increased failures and warranty claims in the field, but not enough to justify the cost of an annual license.

Instead, this customer could subscribe to a Simcenter 3D GUI to perform their model pre/post activities in the cloud and use the same batch solve techniques as the the large enterprise customer (above) to get results even faster. Instead of having to invest in an annual licenses or short-term lease, the customer can subscribe to the Simcenter 3D GUI for between around $590-$1,764 per user, per month, depending on the capability level required for their simulation.

Rescale offers a wide range of desktop capabilities to serve this usage, including GPU accelerated desktops. The user selects the desktop they need for the task at hand and only pays for the time they use it, down to the second. Standard desktops start at $1* per hour and GPU enabled desktops start at $3 per hour. This allows the smaller company that only has occasional usage needs to deliver the same results as the large enterprise.

They are able to do so at a fraction of the cost because they only need the software for small time periods and not as frequently as the enterprise user. If the smaller company's usage increased they may want to speak with their Siemens representative about purchasing a perpetual or lease license and augmenting with Rescale SaaS licenses.

Siemens and Rescale: a partnership where customers win

The new Siemens SaaS offering available on Rescale offers customers the ability to augment their current solve capability and/or enter the market at a very reasonable price with all the capabilities needed to ensure the best possible results.

Go to website to read

Shanghai Fangkun

http://www.lsdyna-china.com/

LS-DYNA China, as the master distributor in China authorized by LSTC, is fully responsible for the sales, marketing, technical support and engineering consulting services of LS-DYNA in China.

仿坤软件 LS-DYNA China

Shanghai Fangkun Software Technology, Ltd.

Shanghai Fangkun Software Technology Co., Ltd. was established in May 2018. It is fully responsible for sales, marketing, technical support and engineering consulting services of LS-DYNA software in China. It will meet this responsibility through the integration and management of various resources of LS-DYNA's Chinese sub-distributors and partners, providing expert technical support services for China's LS-DYNA users, helping customers to use LS-DYNA software more efficiently and effectively for product design and development, thereby improving the efficiency and effectiveness of LS-DYNA software usage by the customers.

The sub-distributors under Shanghai Fangkun are ARUP-China, ETA-China and Shanghai Hengstar. Through cooperation with sub-distributors and partners, Shanghai Fangkun will provide customers with a full range of LSTC products: LS-DYNA, LS-OPT, LS-PREPOST, LS-TASC and LSTC's dummy and barrier models. Shanghai Fangkun Software Technology Co., Ltd. brings together a group of top application engineers of LS-DYNA software, focusing on sales and technical support in various industries such as automotive, aerospace and general machinery.

- **Website**: http://www.lsdyna-china.com
- **Sales Email**: sales@lsdyna-china.com
- **Technical support Email:** support@lsdyna-china.com
- **Customer Service Number**: 400 853 3856 021-61261195
- **Address**: Room 2219, Building No.1, Global Creative Center Lane 166, Minhong Road, Shanghai, China 201102

Successful Conclusion of the 4th LS-DYNA China Users' Conference

102 papers, 80 presentations in 8 sessions, 8 training courses and workshops and about 450 participants

On Oct. 21-25, 2019 the 4th LS-DYNA China users' conference was successfully held in Shanghai by LSTC and Shanghai Fangkun Software Technology Ltd. There were one main session and five technology and application sessions. About 450 participants who came from various application fields of 8 countries and regions such as vehicle OEMs, components factories, aerospace and electronics industries, machinery, shipbuilding, structural and universities and research institutions participated in the event.

In the morning of October 22, Dr. Isheng Yeh gave an opening speech on behalf of John O. Hallquist, Member of National Academy of Engineering, founder and president of LSTC, and bring us greeting video from Dr. John O. Hallquist.

Prof. Wing Kam Liu from Northwestern University, Dr. Zhenliang Lou from SV Dept. SMTC, Dr. Shoufeng Hu from Chinese Aeronautical Establishment, Shanghai Branch, Dr.Cao Zhenglin from China FAW R&D Center CAE Research Institute, Dr. Ping Xin from Japan Chinese Society of Automotive Engineers, Dr. Changping Yi from Swebrec presented the lecture on main session.

Through two days' event on the Technology and Application Session, more than 80 lecturers shared the advance experience, knowledge, and the new features and various applications in different industries of LS-DYNA.

Shanghai Fangkun hold a welcome banquet in the evening of October 22 to thank all attendees. In the traditional Chinese instruments folk music, attendees enjoy a feast of magic show and sand painting show. Meanwhile, best paper winners received the certificate and prize issued by LSTC experts.

The 4th LS-DYNA China users' conference was a great successful. It provides a platform for LS-DYNA customers, developers, and researchers and experts from all fields of applications. Shanghai Fangkun will keep mission firmly in mind, devote to improving user satisfaction of LS-DYNA and providing high-quality technical support and engineering consulting services for users.

Terrabyte

www.terrabyte.co.jp/english

CAE software sale & customer support, initial launch-up support, periodic on-site support. Engineering Services. Timely solutions, rapid problem set up, expert analysis, material property test Tension test, compression test, high-speed tension test and viscoelasticitiy test for plastic, rubber or foam materials. We verify the material property by LS-DYNA calculations before delivery.

CAE consulting - Software selection, CAE software sale & customer support , initial launch-up support, periodic on-site support.

Engineering Services - Timely solutions, rapid problem set up, expert analysis - all with our Engineering Services. Terrabyte can provide you with a complete solution to your problem; can provide you all the tools for you to obtain the solution, or offer any intermediate level of support and software.

FE analysis

- LS-DYNA is a general-purpose FE program capable of simulating complex real world problems. It is used by the automobile, aerospace, construction, military, manufacturing and bioengineering industries.
- ACS SASSI is a state-of-the-art highly specialized finite element computer code for performing 3D nonlinear soil-structure interaction analyses for shallow, embedded, deeply embedded and buried structures under coherent and incoherent earthquake ground motions.

CFD analysis

- AMI CFD software calculates aerodynamics, hydrodynamics, propulsion and aero elasticity which covers from concept design stage of aerocraft to detailed design, test flight and accident analysis.

EM analysis

- JMAG is a comprehensive software suite for electromechanical equipment design and development. Powerful simulation and analysis technologies provide a new standard in performance and quality for product design.

Metal sheet

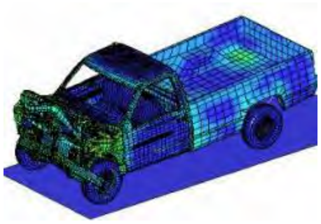
- JSTAMP is an integrated forming simulation system for virtual tool shop based on IT environment. JSTAMP is widely used in many companies, mainly automobile companies and suppliers, electronics, and steel/iron companies in Japan.

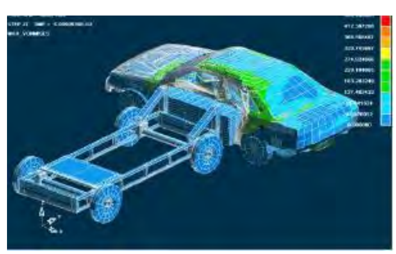
Pre/ Post

- **PreSys** is an engineering simulation solution for FE model development. It offers an intuitive user interface with many streamlined functions, allowing fewer operation steps with a minimum amount of data entry.
- **JVISION** - Multipurpose pre/post-processor for FE solver. It has tight interface with LS-DYNA. Users can obtain both load reduction for analysis work and model quality improvements.

Biomechanics

- **The AnyBody Modeling System™** is a software system for simulating the mechanics of the live human body working in concert with its environment.





Aerospace News - Boeing aims for Moon landing

Artwork: Boeing plans to build a lander split into two stages

Boeing aims for Moon landing in 'fewer steps'

By Paul Rincon
November 6,2019
Science editor, BBC News website

Aerospace giant Boeing has unveiled its proposal for a lander that could take humans to the Moon's surface.

Under a programme called Artemis, the White House wants to return humans to the Moon by 2024.
Its approach, named "Fewest Steps to the Moon", would use the huge Space Launch System (SLS) rocket.

The company says its plan reduces the complexity involved in sending several different bits of hardware into space on multiple launches.

For most robotic space missions, all the hardware needed for the mission is launched on one rocket. Likewise, the crewed Apollo missions to the Moon in the 1960s and 70s required only one lift-off.

However, the Artemis missions are expected to involve several flights to loft all the hardware needed. For example, the lander elements are likely to be launched separately from the Orion capsule carrying crew.

Bezos floats 'national team' to build Moon lander
To the Moon and Beyond

Boeing says it can land astronauts on the Moon with only five "mission critical events" - such as launch, orbit insertion and others - instead of the 11 or more required by alternative strategies.

Artwork: The lander would use the power of the SLS Block 1B configuration for launch

Nasa previously said its preferred option was a lunar lander split into three stages, but it left the door open to "alternative, innovative approaches".

Boeing's proposal uses just two stages - a descent element that gets astronauts down to the surface, and an ascent element to get the crew off the surface and back into lunar orbit at the end of a mission. They are designed to be launched as one unit.

Aerospace News - Boeing aims for Moon landing

The lander will make use of technologies developed for the CST-100 Starliner spacecraft

The company says its lander can carry itself from lunar orbit to the surface without an additional transfer element, or "tug", as previously specified by Nasa.

This, it said, would further reduce the launches needed for a mission and simplify the steps required for a successful landing.

The company says its lander would be ready for the 2024 mission, called Artemis-3. But Boeing's plan would depend on a more powerful variant of the SLS rocket called Block 1B.

Under current Nasa plans, the Block 1B version of the rocket wouldn't be ready until 2025.

However, Nasa's procurement process allows for the use of two separate landers from different companies on the Artemis-3 and Artemis-4 missions (Artemis-4 is due to fly in 2025).

"Whether serving in Nasa's 2024 or 2025 mission slot, Boeing's approach maximises return from agency investments in previous and ongoing programs to allow for the simplest and therefore highest probability path back to the lunar surface," the company said in a statement.

The lander will use key technologies from Boeing's CST-100 Starliner capsule, designed to carry astronauts to the International Space Station (ISS).

The Boeing lander would be able to dock with the Gateway, a planned space station in lunar orbit, but it would not require it. It could instead dock with Nasa's Orion spacecraft directly for a simpler mission profile.

Last month, Amazon founder Jeff Bezos announced the formation of a "national team" that would make a separate bid to build the lander for 2024.

Bezos' space company Blue Origin has teamed up with aerospace giants Lockheed Martin, Northrop Grumman and Draper to put together a proposal for a three-stage lander.

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2020 Chrysler Voyager Launches With Five-star Safety Rating

November 6, 2019
Auburn Hills, Mich

2020 Chrysler Voyager

- 2020 Chrysler Voyager minivan earns five stars overall – the highest possible rating in NHTSA's vehicle evaluation program
- Highest possible rating – five stars – in each of NHTSA's crash test modes
- High-strength steel accounts for 72 percent of Chrysler Voyager's body structure
- Chrysler Voyager starts at a U.S. Manufacturer's Suggested Retail Price (MSRP) of $26,985
- Voyager joins Chrysler Pacifica in receiving five-star safety rating

The 2020 Chrysler Voyager, the latest addition to Chrysler brand's legendary minivan lineup, has earned a five-star overall safety rating from the U.S. National Highway Traffic Safety Administration (NHTSA).

Five stars is the highest possible rating awarded by NHTSA. Voyager is the latest Chrysler brand minivan to earn the rating, joining Chrysler Pacifica in the five-star category.

"The 2020 Chrysler Voyager definitely comes to market on a high note," says Tim Kuniskis, Head of Passenger Cars – FCA North America.

The new minivan's overall five-star rating was achieved, in part, because it received five-star ratings in a full range of crashworthiness evaluations:

- Front driver-side impact
- Front passenger-side impact
- Overall frontal impact
- Front seat combined barrier and pole side impact
- Rear seat combined barrier and pole side impact
- Driver side barrier impact
- Rear passenger side barrier impact
- Side barrier impact
- Overall side pole impact

"The new Voyager benefits from the same engineering discipline and innovative spark that led to our invention of the minivan segment," Kuniskis said. "We dominate the segment because the features and performance minivan customers want most are baked right in to our vehicle designs."

Automotive News - 2020 Chrysler Voyager

The 2020 Chrysler Voyager's crashworthiness benefits from thoughtful application of steel shaping technologies such as hydroforming, a process that transforms steel tubes by injecting them with fluid at extreme pressures. The result: intricately molded load beams that afford greater strength and stiffness than welded components.

In addition, the new minivan's door ring is assembled from tailor-welded blanks – sections of hot-stamped steel that vary in thickness. This strategy helps maintain structural integrity in certain crashes.

High-strength steel (HSS) accounts for 72 percent of the new Voyager's body structure. Its cradle and front rails are made of Advanced High-strength Steel (AHSS) and are configured to help steer crash energy away from the passenger compartment.

Arguably more important, the Voyager also features several available safety and security features to help drivers avoid collisions in the first place. The minivan's Blind-spot Monitoring system alerts the driver to vehicles entering his/her blind spot.

Such warnings help accommodate safer lane changes.

Meanwhile, an available Rear Cross Path detection system assists the driver with hard-to-see angles when backing out of tight parking spots where field of vision may be hindered.

And the available ParkSense rear park assist with stop detects objects in the path of the Voyager when the vehicle is in reverse. While sensors help the driver maneuver into tight parking spaces, they also prompt automatic braking when the system deems contact is imminent.

The Voyager is produced at FCA's Windsor Assembly Plant in Windsor, Ontario, Canada.

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OASYS	www.oasys-software.com/training-courses
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Training - Dynamore

Author: Christian Frech christian.frech@dynamore.de

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Selection of trainings for December/January

Introduction	
Introduction to LS-DYNA	10-12 December (V)
	10-12 December
	27-29 January (V)
Introduction to Simulation Technology	2 December
Nonlinear Implicit Analyses	13 December
Crash	
Crash Analysis	3-6 December
Metal Forming	
Hot Forming with LS-DYNA	21-22 January
Applied Forming Simulation with eta/DYNAFORM	23-24 January
Multiphysics	
ICFD Incompressible Fluid Solver	16-17 December
Pre- and Postprocessing	
Introduction to PRIMER for LS-DYNA	13 December

Information days (free of charge)

Information day: Human Modeling	9 December

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V = Versailles, France; T = Turin, Italy, Tr = Traboch, Austria, Z = Zurich, Switzerland

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December 2019

Date		Location	Course Title	Instructor(s)
Dec 10	Dec 13	MI	Introduction to LS-DYNA®	R. Chivukula

January 2020

Date		Location	Course Title	Instructor(s)
Jan 28	Jan 31	***MI***	Introduction to LS-DYNA®	H. Devaraj

February 2020

Date		Location	Course Title	Instructor(s)
Feb 4	Feb 5	***MI***	Passive Safety	A. Gromer
Feb 5	Feb 6	CA	Comprehensive LS-DYNA® ALE and S-ALE Applications Seminar	I. Do, H. Chen
Feb 10		***MI***	CAE for Non-CAE Engineers	N. Karajan
Feb 11	Feb 2	***MI***	Implicit Analysis in LS-DYNA®	N. Karajan
Feb 18	Feb 19	CA	Methods & Modeling Techniques: Pre-requisites for Blast and Penetration	P. Du Bois, L. Schwer
Feb 20	Feb 21	CA	Blast Modeling with LS-DYNA®	P. Du Bois, L. Schwer
Feb 24		CA	Explosives Modeling for Engineers	P. Du Bois, L. Schwer
Feb 24		***MI***	Overview of Contacts in LS-DYNA®	S. Bala
Feb 25		***MI***	Material Characterization for Metals, Polymers, & Foams	S. Bala
Feb 25	Feb 26	CA	Penetration Modeling with LS-DYNA®	P. Du Bois, L. Schwer
Feb 27	Feb 28	***MI***	Occupant Simulation in LS-DYNA®	H. Devaraj

Numerical prediction of residual deformation and failure for powder bed fusion additive manufacturing of metal parts

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ABSTRACT

In this paper, a numerical approach in predicting residual distortion, stress and failure in AM products is presented. This approach consists of three simulation steps including a detailed process simulation in small-scale, a one-time static mechanical finite element analysis in part-scale, and a material failure analysis. First, the inherent strains are calculated from a thermo-mechanical process simulation in small-scale, which considers AM process parameters, such as laser power, scanning speed and path. The physical state in deposited materials including powder, liquid and solid states are taken into account in the simulation by specifying the solidus and liquidus temperature and corresponding material properties. Then the inherent strains are applied layer by layer to the part-scale simulation, where the residual distortion and stress can be predicted efficiently. Finally, a Lagrange particle method is utilized to study the failure characteristics of AM products. Numerical examples are studied to investigate the effectiveness and applicability of present approach.

Keywords: Inherent strain, Residual deformation, Failure, Powder bed fusion additive manufacturing.

1. INTRODUCTION

Additive manufacturing (AM), also referred to as 3D printing, has received significant attention and interest from the industrial and academic communities worldwide. AM uses 3D digital design data to build up a near-net-shape component in layers by depositing material. In the powder bed fusion (PBF) process, a laser selectively melts the powders according to the sliced three-dimensional model data. Once the powder layer is melted, another layer of powder is spread on the previous layer with a roller, and subsequently the part geometry is fused by selectively melting the powder. The process repeats itself until the entire part is built completely. A manifold of physical effects, such as heat radiation, conduction, and Marangoni convection occur during PBF process [1], which affect the process stability and the final component quality. Undesired residual distortion and stress have been a critical issue that hinders the wide application of AM process in automotive, aerospace and biomedical industries.

To optimize the AM process without expensive trial-and-error iterations to control the residual deformation and failure in the build product, efficient and reliable simulation tools are needed. The available simulation tools can be roughly divided into three main categories in terms of accuracy and computational efforts. Detailed fine-scale thermo-mechanical modeling lies into the first category, which is the most accurate but expensive method. This class of methods simulates the progressive building of the part layer by layer [2,3,4]. Considering the fact that strong thermo-mechanical reactions take place locally in the build part over a very short time, this class of simulation methods always require a very fine resolution and thus immense computational power is needed, which hinders its usage for the part-scale simulation in industrial applications. To reduce the computational cost, a volume by volume or layer by layer method [5,6] has been developed, where a representative heat flux or thermal history is extracted from a detailed microscale laser model and then applied to a layer or a hatching volume for a representative time. Since this class of methods only requires transient thermo-mechanical simulations in the part scale, it is computationally more efficient than the previous class of methods, and thus has wide applications. Commercial software such as Pan Computing (now Autodesk) [7,8] has successfully applied this approach to efficiently simulate the residual deformation in AM products. However, the main drawback of this approach is the neglect of influence of different scanning patterns and thus is not practical.

The third class of simulation tools is developed based on the inherent strain method. The inherent strain method was proposed originally to estimate the residual deformation in metal welding applications [9] and has been adapted and modified for the AM simulation [10,11]. This method consists in performing a high resolution thermo-mechanical analysis to determine the plastic strain tensor. The plastic strains are then assigned to the macroscale model as material thermal properties by a one-time static mechanical finite element analysis in a layer by layer fashion. Unlike two other classes of methods, this method can dramatically reduce the computation time from several days or even weeks to few hours in industrial applications. However, its application under different scanning pattern is also limited. Alternatively, Setien et al. [12] developed a method based on the Classical Laminate Theory (CLT) to empirically determine the inherent strain in the PBF AM process.

The prediction of failure in AM products is another challenging research topic. To the best of authors' knowledge, the existing literature in the study of material failure in AM products is still not available. This mainly because the mesh-based numerical methods such as finite element method are ineffective to model the moving discontinuity in three-dimensional cases. The Smoothed Particle Galerkin (SPG) method introduced by authors [13,14,15] is a new particle method specifically developed to model the material failure. These observations prompt application of SPG in modeling the material failure of AM products.

In this paper, an effective numerical approach consisting of three simulation steps is presented to predict two critical issues, the residual distortion and material failure, in additive manufacturing of metal products. First two simulations steps including a detailed process simulation in the small-scale and a one-time static mechanical finite element analysis in the part scale are developed to predict the residual stress and part distortion. In the small-scale simulation, the thermo-mechanical analysis is first performed, which considers the influence of PBF process parameters such as laser power, scanning speed, scanning path, and hatch space. Then inherent strains extracted from the small-scale simulation are applied layer by layer in the part-scale using the static analysis, where the residual distortion and stress can be predicted. Different laser scanning patterns are also considered. In the last numerical step, a Lagrangian particle method is utilized to study the failure characteristics of AM products.

2. FRAMEWORK OF SIMULATION-BASED INHERENT STRAIN METHOD

2.1 Theory of inherent strain for the AM process

The inherent strain method was proposed originally to estimate the residual deformation in metal welding [9, 16]. Following the theory of Yuan and Ueda [16], the definition of inherent strain is briefly overviewed here. In the welding process, the material along the welding path will experience different thermal states in a very short time, which will generate different thermal strain, elastic strain, plastic strain, creep strain and strain due to the phase change. However, there are two main differences of AM process compared to the welding process. First of all, the reheating process occurs in the AM process when the new layer or the new track deposits on the previous layer. Secondly, newly deposited layers or tracks will become mechanically constrained to the previously deposited layers or tracks, which implies the elastic strain will evolve and cannot be fully released when the manufactured part cools down to ambient temperature [17]. Therefore, the following definition of inherent strain is given:

$$\varepsilon^{in} = \varepsilon_c^p + \varepsilon_c^e - \varepsilon_s^e \tag{1}$$

where ε_c^p and ε_c^e denote the plastic strain and elastic strain respectively when the laser just passes through the point and the amplitude of plastic strain reaches the maximum value at this time. ε_s^e is the elastic stain at steady state, which is used to consider the effect from constrained boundaries.

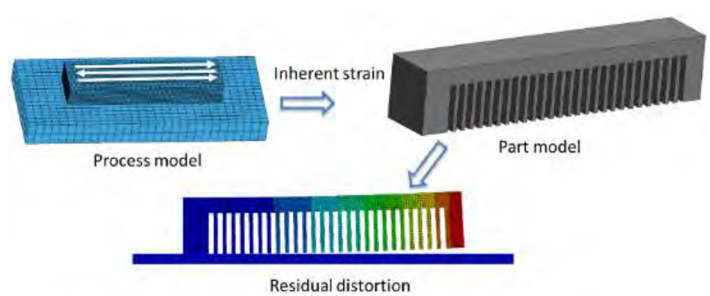

Fig. 1 Simulation framework based on inherent strain method.

2.2 Simulation framework

Fig. 1 shows the flowchart for this simulation framework. Briefly speaking, the first step of this simulation framework is to analyze a small-scale process problem and to extract the inherent strains from the result. Thermo-mechanical analysis is used in this detailed process analysis, in which the heat loss due to thermal radiation and convection are taken into account.

After the thermo-mechanical analysis is completed, inherent strain components are calculated according to Eq. (1) in the second step. After that, the inherent strains are applied to part scale model in a layer by layer fashion to predict the residual distortion.

3. MODELING APPROACH AND PROBLEM SETUP

3.1 Setup of small-scale model

To extract the inherent strain from the small-scale process model, the thermo-mechanical simulation needs to be conducted first. The material constitutive model is using the standard elastic-plastic material with kinetic hardening.

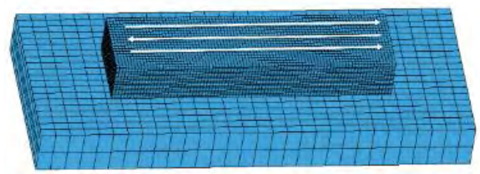

Fig. 2 Finite element model for deposition layers and substrate.

Due to rapid heating and cooling change in PBF AM process, the physical state of build material experiences a transformation from powder, liquid to solid states. The transformation of different physical states in the cross section along the laser moving direction can be characterized by the solidus temperature (T_s) and liquidus temperature (T_L) of material in this study. Computational Welding Mechanics (CWM) model is adopted in this paper to characterize effective material properties for different material states [18,19].

As mentioned in Section 2, the small-scale process model should consist of multiple layers in order to consider the influence of reheating. Here a three-layer process model is proposed. The dimension of three deposition layers is 1.8mm*0.45mm*0.3mm and the element size has the dimension of 0.02mm*0.05mm*0.015mm (Fig. 2), in which a small element size has used to capture the high thermal resolution. The process parameters in this study are given in Table 1. The printing process of small-scale model is shown in Fig. 3. Elements of the small-scale model is activated layer by layer. The material properties of the elements are changed from powder to liquid when the temperature exceeds the liquidus temperature (T_L) of AlSi10Mg.

Table 1 Building process parameters for AlSi10Mg.

Parameter	Value
Laser power	195*W*
Scanning speed	800*mm/s*
Hatch space	150*um*
Laser thickness	100*um*

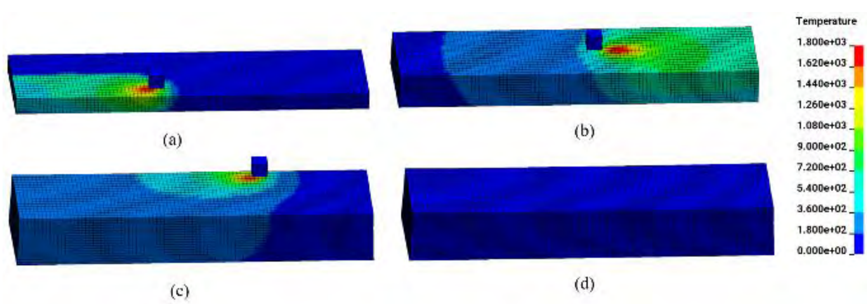

Fig. 3 Printing process of thermal analysis snapshots (a) the first layer, (b) the second layer, (c) the third layer, and (4) completely printed model.

3.2 Inherent strain determination

According to the results of process model and Eq. (1), the inherent strain components are extracted and plotted in Fig. 4. The inherent strain components in three directions are stable in the middle region of specimen, and varying values can be observed in the boundary region. The steady values in Fig. 4 are used as the inherent strain components which are (-0.0026, -0.0013, 0.0013). This inherent strain will be used in the part scale simulation for the residual deformation prediction of 3D printed AlSi10Mg products.

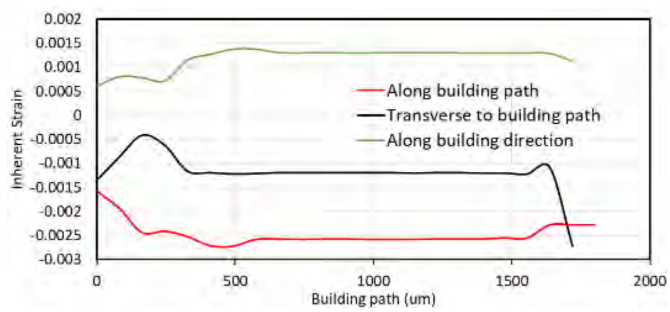

Fig. 4 Inherent strain components distribution of bottom layer.

4. NUMERICAL EXAMPLES

4.1. The double cantilever beam model

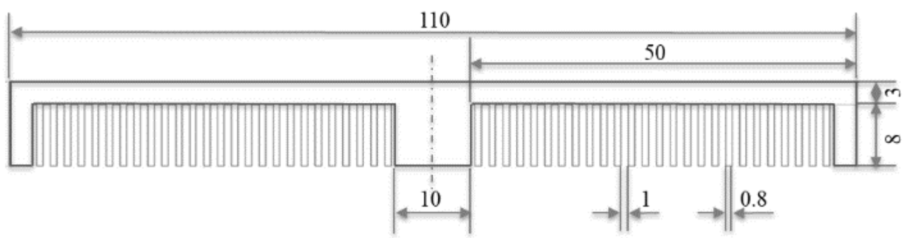

Fig. 5 Geometry of the double cantilever beam with the thickness of 10mm (unit: mm).

In this section, residual distortion and stress of a 3D printed double cantilever beam are predicted based on the inherent strain method. The geometry and dimensions of double cantilever beam are shown in Fig. 5, and the thickness of this beam is 10mm. Considering the symmetry of this geometry, half of the model is considered as shown in Fig. 6, which consists of 11 layers and each layer is characterized with different color. The layer thickness is 1mm and the substrate thickness is 2mm.

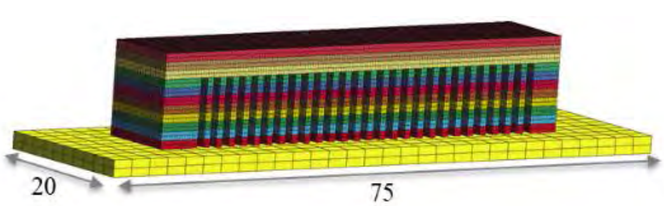

Fig. 6 Finite element mesh for deposition layers and substrate where the substrate thickness is 2mm (unit: mm).

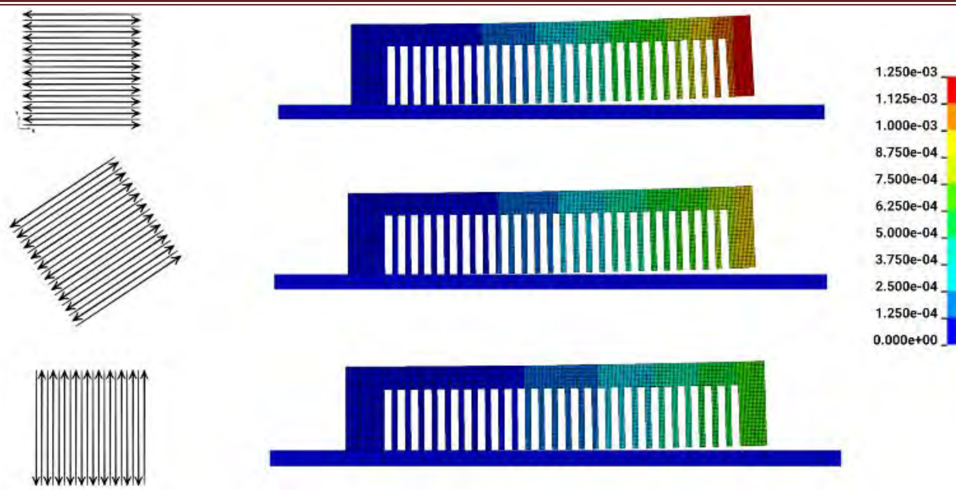

Fig. 7 Distortion comparison of double cantilever beam with (a) horizontal (b) 45° (c) vertical scanning patterns (unit: m).

The inherent strain components from Section 3 are applied as anisotropic thermal coefficients, and the layer is activated one by one. The inherent strain components are rotated by 45° and 90° to predict the residual deformation with different scanning patterns. The residual distortions with different scanning patterns are compared in Fig. 7. The horizontal scanning pattern has the largest distortion value of (1.25mm), followed by 45° scanning pattern (0.97mm) and the vertical scanning pattern (0.72mm). The influences of scanning patterns on the distortion are in agreement with the results in Keller and Ploshikhin [10].

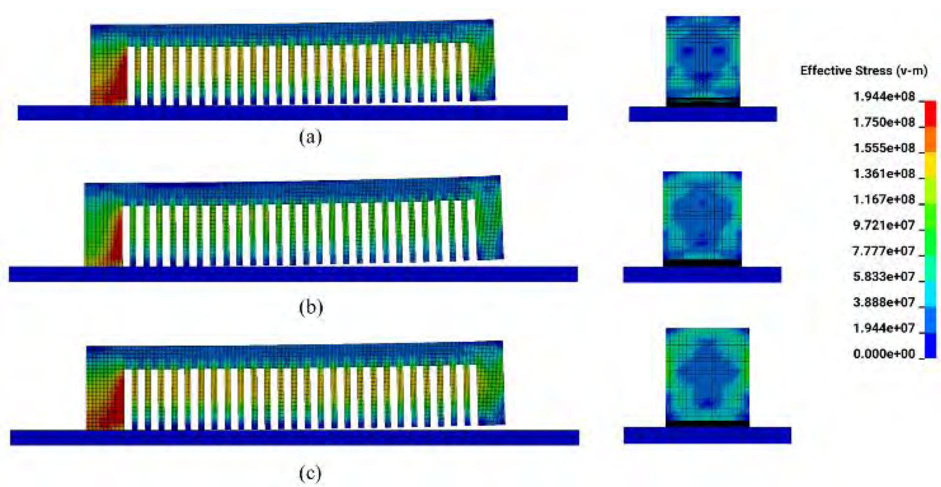

Fig. 8 Residual stress comparison of double cantilever beam after cutting off the supports with (a) horizontal (b) 45° (c) vertical scanning patterns (unit: Pa).

The residual stress after cutting off the supports are plotted in Fig. 8. The effective stress inside the right boundary and middle area are released, while these around the left boundary are still kept due to the fixed left boundary conditions.

4.2. The gear model

In this section, residual distortion and stress of a 3D printed gear model are predicted based on the inherent strain method. The geometry and dimensions of the gear are shown in Fig. 9(a), and the thickness of this model is 10mm. This gear has 12 teeth. The mesh of the gear model is provided in Fig. 9(b), which consists of 5 layers and each layer is displayed with different color. The 6-node hexahedron elements are employed to discretize the gear model. The layer thickness of gear model is 2mm and the substrate thickness is 10mm.

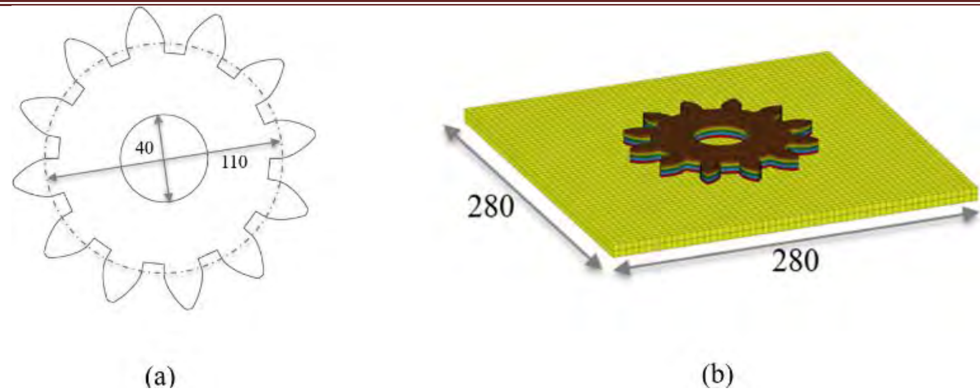

Fig. 9 (a) Geometry of gear model and (b) finite element mesh for deposition layers and substrate, substrate thickness 10mm (unit: mm).

Similar to example 4.1, the inherent strain components are applied as anisotropic thermal coefficients, and the layer is activated one by one. The residual distortions with different scanning patterns are compared in Fig. 10. The maximum distortion with horizontal scanning pattern and vertical scanning pattern has the same value of 0.2mm, while that with $45°$ scanning pattern is 0.13mm. Considering that this gear model has unlimited symmetric axis that passes through the center of gear model, the maximum distortion is expected to be very similar with different scanning patterns. The distortion with $45°$ scanning pattern has a difference by 35% compared to the results with horizontal and vertical scanning pattern. This inconsistence may result from the size of the small-scale process model used in this paper, which has a length-to-width ratio of 4.0. This leads to the difference of inherent strain component in the direction along the build path and its transverse direction. These issues may be investigated by establishing the small-scale process model with different sizes in the future study.

The residual stress with the horizontal scanning pattern before and after cutting off the supports are plotted in Fig. 11. With a support on the substrate, high effective residual stress occurs around the middle area and the teeth bottom of gear. As one expected, the high effective stress is released after the gear is cutting off from the substrate as seen in Fig. 11(b).

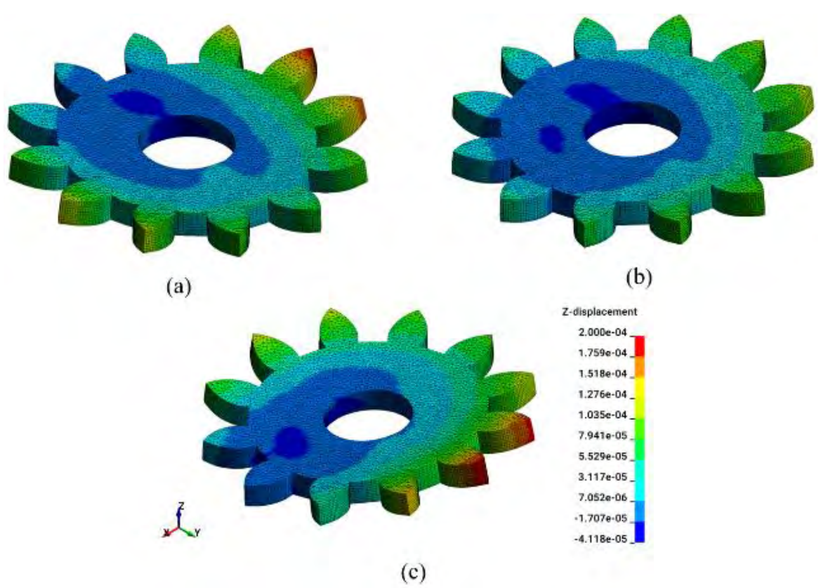

Fig. 10 Distortion comparison of gear with (a) horizontal (b) $45°$ (c) vertical scanning patterns (unit: m, displacement scale factor: 50).

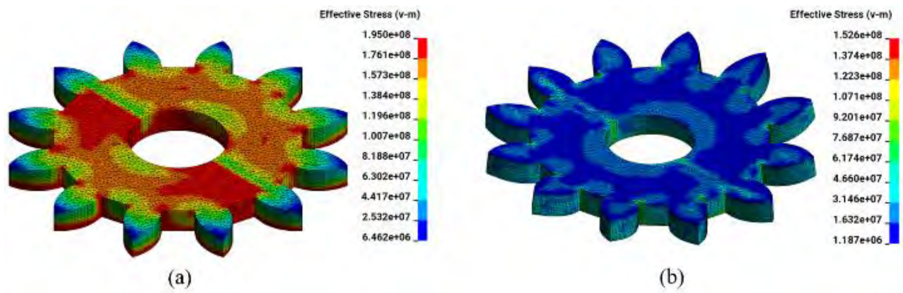

Fig. 11 Residual stress of gear model before (a) and after (b) cutting off the supports with horizontal scanning patterns (unit: Pa).

4.3 Failure prediction of gear model

In this example, failure of 3D printed gear model is simulated using the SPG method recently developed by authors. Unlike the finite element method, SPG utilizes the bond-failure mechanism to model the metal failure process without eroding the elements. The SPG method prevents the loss of conservation property in mass and momentum that often observed in conventional finite element methods. The theory and numerical formulation of SPG method can be found in existing literatures [13, 15, 20, 21], and is thus omitting in this paper.

The first step of this analysis is to covert the finite element mesh in Example 4.2 into a particle-based gear model [22]. In essence, only the nodal information is retained for the SPG analysis. This leads to a gear model containing 43876 particles in this analysis. The gear model is under a fixed boundary condition along the interior wall as shown in Fig. 12. A rigid block (size 5mm $\times$ 10mm $\times$ 20mm) is in contact with one of gear teeth and moving with a uniform velocity of 2.0m/s along the direction as shown in Fig. 12 to study how the 3D printed gear will fail under external loading conditions in operation.

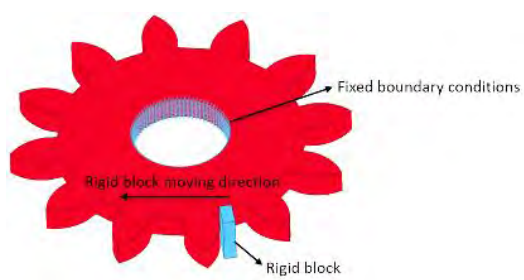

Fig. 12 Geometry and boundary conditions of gear model.

In terms of failure criterion for this analysis, a phenomenological strain damage model with a failure effective plastic strain equal to 0.01 and a stretching parameter equal to 1.1 [39] is used. Fig. 13 shows the history of effective plastic strain distribution as rigid block moves. As expected, the damage in the tooth begins at the connection part with the root (Figs. 13 (a) and (b)). The tooth is then totally damaged and separated from the root of the gear as shown in Fig. 13 (c). Finally, second damage of adjacent tooth occurs as shown in Fig. 13 (d) when two teeth collide with each other.

5. CONCLUSIONS AND DISCUSSIONS

This paper introduces an effective approach for the simulation of residual distortion and failure in the AM product. The approach consists of three major simulation steps. The first simulation step is a small-scale computation in which a thermo-mechanical process simulation is performed, which takes into account of PBF process parameters. In addition, the physical state in deposited materials including powder, liquid and solid states are considered by specifying the solidus and liquidus temperature and corresponding material properties. In the second simulation step, the inherent strains extracted from the small-scale computation are applied to the residual distortion and stress analysis of cantilever beam and gear model in the part-scale. In the last simulation step, failure characteristics of gear model are predicted using the SPG method.

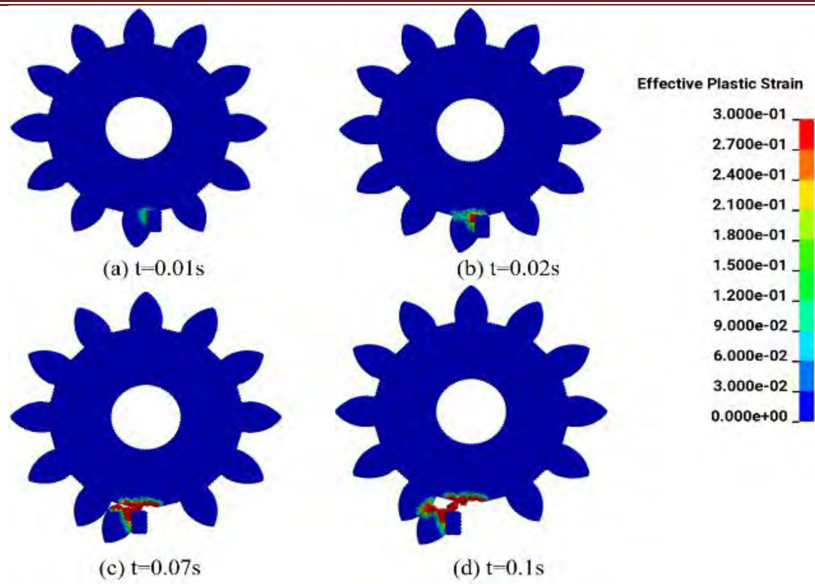

Fig. 13 Effective plastic strain distribution of gear model at different time instant.

The numerical results suggest that the variation of residual distortion of the double cantilever beam with different scanning patterns are in agreement with experimental results. The prediction of residual stress also correlates well with experimental results and other numerical results in literatures. The inherent strain computation for the double cantilever beam and gear model in the part-scale are finished within 2.5 hours and 1.0 hours, respectively using LS-DYNA with 8 CPUs. Therefore, the inherent strain method performs well in balancing the accuracy and the efficiency in the part-scale simulation. The failure analysis of 3D printed gear model under external loading conditions is also studied. The failure pattern predicted by the SPG method is reasonably well. This is the first time in the literature we are able to effectively model the failure in the AM product using the particle method.

To enhance the high fidelity of process simulation and the inherent strain computation in the future, process parameters and heat source parameters in the small-scale simulation need to be further validated by comparing the temperature history and the size of the molten pool from experiment. Meanwhile, it is worth mentioning that the layer at different height of AM part may also experience different thermal history due to different layer geometry and varied reheating process from subsequent deposition layers. Thus, instead of assigning a uniform inherent strain to every layer, different inherent strains in different layers should also be considered. This difference leads to the inconsistency in predicting the maximum distortion of gear model under different scanning patterns as observed in the numerical example. To tackle those issues, more detailed process simulations with different sizes and layers need to be performed in the future. Finally, the developments of a position-dependent inherent strain method as well as the consideration of residual stress in the failure simulation are also required for a more general analysis.

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REFERENCES

1. Markl, M. and Körner, C., “Multiscale modeling of powder-bed-based additive manufacturing,” *Annual Review of Materials Research*, **46**, pp. 1–34 (2016).
2. Kruth, J. P., Froyen, L., van Vaerenbergh, J., Mercelis, P., Rombouts, M., and Lauwers, B., “Selective laser melting of iron-based powder,” *Journal of materials processing technol*ogy, **149**, pp. 616–622 (2004).

3. Fu, C. H. and Guo, Y. B., "3-dimensional finite element modeling of selective laser melting Ti-6Al-4V alloy," 25th Annual International Solid Freeform Fabrication Symposium, pp. 1129–1144 (2014).
4. Megahed, M., Mindt, H.W., N'Dri, N., Duan, H. and Desmaison, O., "Metal additive-manufacturing process and residual stress modeling," Integrating Materials and Manufacturing Innovation, 5, pp. 61–93 (2016).
5. Papadakis, L., Loizou, A., Risse, J., Bremen, S. and Schrage, J., "A computational reduction model for appraising structural effects in selective laser melting manufacturing: a methodical model reduction proposed for time-efficient finite element analysis of larger components in Selective Laser Melting," Virtual and Physical Prototyping, 9, pp. 17–25 (2014).
6. Li, C., Liu, J.F., Fang, X.Y. and Guo, Y.B., "Efficient predictive model of part distortion and residual stress in selective laser melting," Additive Manufacturing, 17, pp. 157–168 (2017).
7. Denlinger, E.R., Irwin, J. and Michaleris, P., "Thermomechanical modeling of additive manufacturing large parts," Journal of Manufacturing Science and Engineering, 136, pp. 061007 (2014).
8. Denlinger, E.R., Gouge, M., Irwin, J. and Michaleris, P., "Thermomechanical model development and in situ experimental validation of the Laser Powder-Bed Fusion process," Additive Manufacturing, 16, pp. 73–80 (2017).
9. Ueda, Y., Fukuda, K., Nakacho, K. and Endo, S., "A new measuring method of residual stresses with the aid of finite element method and reliability of estimated values," Journal of the Society of Naval Architects of Japan, 138, pp. 499–507 (1975).
10. Keller, N. and Ploshikhin, V., "New method for fast predictions of residual stress and distortion of AM parts," Solid Freeform Fabrication Symposium, pp. 1229–1237 (2014).
11. Alvarez, P. et al., "Computationally efficient distortion prediction in powder bed fusion additive manufacturing," International Journal of Engineering Research & Science, 2, pp. 39–46 (2016).
12. Setien, I. et al., "Empirical methodology to determine inherent strains in additive manufacturing," Computers and Mathematics with Applications, DOI: 10.1016/j.camwa.2018.05.015 (2018).
13. Wu, C.T., Koishi, M. and Hu, W., "A displacement smoothing induced strain gradient stabilization for the meshfree Galerkin nodal integration method," Computational Mechanics, 56, pp. 19–37 (2015).
14. Wu, C.T., Wu, Y. and Koishi, M., "A strain-morphed nonlocal meshfree method for the regularized particle simulation of elastic-damage induced strain localization problems," Computational Mechanics, 56, pp. 1039–1054 (2015).
15. Wu, C.T., Chi, S.W., Koishi, M. and Wu, Y., "Strain gradient stabilization with dual stress points for the meshfree nodal integration method in inelastic analyses," International Journal for Numerical Methods in Engineering, 107, pp. 3–30 (2016).
16. Yuan, M.G. and Ueda, Y., "Prediction of residual stresses in welded T-and I-joints using inherent strains," Journal of engineering materials and technology, 118, pp. 229–234 (1996).
17. Liang, X., Cheng, L., Chen, Q., Yang, Q. and To, A.C., "A modified method for estimating inherent strains from detailed process simulation for fast residual distortion prediction of single-walled structures fabricated by directed energy deposition," Additive Manufacturing, 23, pp. 471–486 (2018).
18. Lindström, P.R.M, "DNV Platform of Computational Welding Mechanics," Proceedings of International Institute of Welding 66th Annual Assembly, (2013).
19. Lindström, P.R.M., "Improved CWM platform for modeling welding procedures and their effects on structural behavior," Ph.D. Dissertation, Production Technology, University West, Trollhättan, Sweden (2015).
20. Wu, C.T. et al., "Numerical and experimental validation of a particle Galerkin method for metal grinding simulation," Computational Mechanics, 61, pp. 365–383 (2018).
21. Pan, X., Wu, C.T., Hu, W. and Wu Y., "A momentum-consistent stabilization algorithm for Lagrangian particle methods in the thermos-mechanical friction drilling analysis," Computational Mechanics, 64, pp. 625–644 (2019).
22. Hallquist, J., LS-DYNA Users' Manual, Livermore Software Technology Corporation, U.S.A. (2019).

BETA CAE Systems. www.beta-cae.com

BETA CAE Systems - ANSA

An advanced multidisciplinary CAE pre-processing tool that provides all the necessary functionality for full-model build up, from CAD data to ready-to-run solver input file, in a single integrated environment. ANSA is a full product modeler for LS-DYNA, with integrated Data Management and Process Automation. ANSA can also be directly coupled with LS-OPT of LSTC to provide an integrated solution in the field of optimization.

BETA CAE Systems μETA

Is a multi-purpose post-processor meeting diverging needs from various CAE disciplines. It owes its success to its impressive performance, innovative features and capabilities of interaction between animations, plots, videos, reports and other objects. It offers extensive support and handling of LS-DYNA 2D and 3D results, including those compressed with SCAI's FEMZIP software.

Solutions for:

Process Automation - Data Management – Meshing – Durability - Crash & Safety NVH - CFD - Thermal analysis - Optimization - Powertrain
Products made of composite materials - Analysis Tools -
Maritime and Offshore Design - Aerospace engineering - Biomechanics

ETA – Engineering Technology Associates **www.eta.com**
etainfo@eta.com

Inventium Suite™

Inventium Suite™ is an enterprise-level CAE software solution, enabling concept to product. Inventium's first set of tools will be released soon, in the form of an advanced Pre & Post processor, called PreSys.

Inventium's unified and streamlined product architecture will provide users access to all of the suite's software tools. By design, its products will offer a high performance modeling and post-processing system, while providing a robust path for the integration of new tools and third party applications.

PreSys

Inventium's core FE modeling toolset. It is the successor to ETA's VPG/PrePost and FEMB products. PreSys offers an easy to use interface, with drop-down menus and toolbars, increased graphics speed and detailed graphics capabilities. These types of capabilities are combined with powerful, robust and accurate modeling functions.

VPG

Advanced systems analysis package. VPG delivers a unique set of tools which allow engineers to create and visualize, through its modules--structure, safety, drop test, and blast analyses.

DYNAFORM

Complete Die System Simulation Solution. The most accurate die analysis solution available today. Its formability simulation creates a "virtual tryout", predicting forming problems such as cracking, wrinkling, thinning and spring-back before any physical tooling is produced.

ESI Group www.esi-group.com

get it right®

Visual-Environment is an integrative simulation platform for simulation tools operating either concurrently or standalone for various solver. Comprehensive and integrated solutions for meshing, pre/post processing, process automation and simulation data management are available within same environment enabling seamless execution and automation of tedious workflows. This very open and versatile environment simplifies the work of CAE engineers across the enterprise by facilitating collaboration and data sharing leading to increase of productivity.

Visual-Crash DYNA provides advanced preprocessing functionality for LS-DYNA users, e.g. fast iteration and rapid model revision processes, from data input to visualization for crashworthiness simulation and design. It ensures quick model browsing, advanced mesh editing capabilities and rapid graphical assembly of system models. Visual-Crash DYNA allows graphical creation, modification and deletion of LS-DYNA entities. It comprises tools for checking model quality and simulation parameters prior to launching calculations with the solver. These tools help in correcting errors and fine-tuning the model and simulation before submitting it to the solver, thus saving time and resources.

Several high productivity tools such as advanced dummy positioning, seat morphing, belt fitting and airbag folder are provided in **Visual-Safe,** a dedicated application to safety utilities.

Visual-Mesh is a complete meshing tool supporting CAD import, 1D/2D/3D meshing and editing for linear and quadratic meshes. It supports all meshing capabilities, like shell and solid automesh, batch meshing, topo mesh, layer mesh, etc. A convenient Meshing Process guides you to mesh the given CAD component or full vehicle automatically.

Visual-Viewer built on a multi-page/multi-plot environment, enables data grouping into pages and plots. The application allows creation of any number of pages with up to 16 windows on a single page. These windows can be plot, animation, video, model or drawing block windows. Visual-Viewer performs automated tasks and generates customized reports and thereby increasing engineers' productivity.

Visual-Process provides a whole suite of generic templates based on LS-DYNA solver (et altera). It enables seamless and interactive process automation through customizable LS-DYNA based templates for automated CAE workflows.

All generic process templates are easily accessible within the unique framework of Visual-Environment and can be customized upon request and based on customer's needs.

Visual*DSS* is a framework for Simulation Data and Process Management which connects with Visual-Environment and supports product engineering teams, irrespective of their geographic location, to make correct and realistic decisions throughout the virtual prototyping phase. Visual*DSS* supports seamless connection with various CAD/PLM systems to extract the data required for building virtual tests as well as building and chaining several virtual tests upstream and downstream to achieve an integrated process. It enables the capture, storage and reuse of enterprise knowledge and best practices, as well as the automation of repetitive and cumbersome tasks in a virtual prototyping process, the propagation of engineering changes or design changes from one domain to another.

JSOL Corporation www.jsol.co.jp/english/cae/

HYCRASH

Easy-to-use one step solver, for Stamping-Crash Coupled Analysis. HYCRASH only requires the panels' geometry to calculate manufacturing process effect, geometry of die are not necessary. Additionally, as this is target to usage of crash/strength analysis, even forming analysis data is not needed. If only crash/strength analysis data exists and panel ids is defined. HYCRASH extract panels to calculate it's strain, thickness, and map them to the original data.

JSTAMP/NV

As an integrated press forming simulation system for virtual tool shop the JSTAMP/NV meets the various industrial needs from the areas of automobile, electronics, iron and steel, etc. The JSTAMP/NV gives satisfaction to engineers, reliability to products, and robustness to tool shop via the advanced technology of the JSOL Corporation.

JMAG

JMAG uses the latest techniques to accurately model complex geometries, material properties, and thermal and structural phenomena associated with electromagnetic fields. With its excellent analysis capabilities, JMAG assists your manufacturing process.

Livermore Software Technology, an ANSYS Company www.lstc.com

LS-DYNA
A general-purpose finite element program capable of simulating complex real world problems. It is used by the automobile, aerospace, construction, military, manufacturing, and bioengineering industries. LS-DYNA is optimized for shared and distributed memory Unix, Linux, and Windows based, platforms, and it is fully QA'd by LSTC. The code's origins lie in highly nonlinear, transient dynamic finite element analysis using explicit time integration.

LS-PrePost
An advanced pre and post-processor that is delivered free with LS-DYNA. The user interface is designed to be both efficient and intuitive. LS-PrePost runs on Windows, Linux, and Macs utilizing OpenGL graphics to achieve fast rendering and XY plotting.

LS-OPT
LS-OPT is a standalone Design Optimization and Probabilistic Analysis package with an interface to LS-DYNA. The graphical preprocessor LS-OPTui facilitates definition of the design input and the creation of a command file while the postprocessor provides output such as approximation accuracy, optimization convergence, tradeoff curves, anthill plots and the relative importance of design variables.

LS-TaSC
A Topology and Shape Computation tool. Developed for engineering analysts who need to optimize structures, LS-TaSC works with both the implicit and explicit solvers of LS-DYNA. LS-TaSC handles topology optimization of large non-linear problems, involving dynamic loads and contact conditions.

LSTC Dummy Models
Anthropomorphic Test Devices (ATDs), as known as "crash test dummies", are life-size mannequins equipped with sensors that measure forces, moments, displacements, and accelerations.

LSTC Barrier Models
LSTC offers several Offset Deformable Barrier (ODB) and Movable Deformable Barrier (MDB) model.

Material Sciences Corporation www.materials-sciences.com

Materials Sciences Corporation has provided engineering services to the composites industry since 1970. During this time, we have participated in numerous programs that demonstrate our ability to: perform advanced composite design, analysis and testing; provide overall program management; work in a team environment; and transition new product development to the military and commercial sectors. MSC's corporate mission has expanded beyond basic research and development now to include transitioning its proprietary technologies from the research lab into innovative new products. This commitment is demonstrated through increased staffing and a more than 3-fold expansion of facilities to allow in-house manufacturing and testing of advanced composite materials and structures.

Materials Sciences Corporation (MSC) MAT161/162 - enhanced features have been added to the Dynamic Composite Simulator module of LS-DYNA.

This enhancement to LS-DYNA, known as MAT161/162, enables the most effective and accurate dynamic progressive failure modeling of composite structures to enable the most effective and accurate dynamic progressive failure modeling of composite structures currently available.

MSC/LS-DYNA Composite Software and Database -

Fact Sheet: http://www.materials-sciences.com/dyna-factsheet.pdf

- MSC and LSTC have joined forces in developing this powerful composite dynamic analysis code.
- For the first time, users will have the enhanced ability to simulate explicit dynamic engineering problems for composite structures.
- The integration of this module, known as 'MAT 161', into LS-DYNA allows users to account for progressive damage of various fiber, matrix and interply delamination failure modes.
- Implementing this code will result in the ability to optimize the design of composite structures, with significantly improved survivability under various blast and ballistic threats.

MSC's LS-DYNA module can be used to characterize a variety of composite structures in numerous applications—such as this composite hull under blast.

Oasys Ltd. LS-DYNA Environment

www.oasys-software.com/dyna

The Oasys Suite of software is exclusively written for LS-DYNA® and is used worldwide by many of the largest LS-DYNA® customers. The suite comprises of:

Oasys PRIMER

Key benefits:

- Pre-Processor created specifically for LS-DYNA®
- Compatible with the latest version of LS-DYNA®
- Maintains the integrity of data
- Over 6000 checks and warnings – many auto-fixable
- Specialist tools for occupant positioning, seatbelt fitting and seat squashing (including setting up pre-simulations)
- Many features for model modification, such as part replace
- Ability to position and depenetrate impactors at multiple locations and produce many input decks automatically (e.g. pedestrian impact, interior head impact)
- Contact penetration checking and fixing
- Connection feature for creation and management of connection entities.
- Support for Volume III keywords and large format/long labels
- Powerful scripting capabilities allowing the user to create custom features and processes

www.oasys-software.com/dyna

Oasys D3PLOT

Key benefits:

- Powerful 3D visualization post-processor created specifically for LS-DYNA®
- Fast, high quality graphics
- Easy, in-depth access to LS-DYNA® results
- Scripting capabilities allowing the user to speed up post-processing, as well as creating user defined data components

www.predictiveengineering.com

Predictive Engineering provides finite element analysis consulting services, software, training and support to a broad range of engineering companies across North America. We strive to exceed client expectations for accuracy, timeliness and knowledge transfer. Our process is both cost-effective and collaborative, ensuring all clients are reference clients.

Our mission is to be honest brokers of information in our consulting services and the software we represent.

Our History

Since 1995, Predictive Engineering has continually expanded its client base. Our clients include many large organizations and industry leaders such as SpaceX, Nike, General Electric, Navistar, FLIR Systems, Sierra Nevada Corp, Georgia-Pacific, Intel, Messier-Dowty and more. Over the years, Predictive Engineering has successfully completed more than 800 projects, and has set itself apart on its strong FEA, CFD and LS-DYNA consulting services.

恒士达科技

Hengstar Tech.

Shanghai Hengstar www.hengstar.com

Center of Excellence: Hengstar Technology is the first LS-DYNA training center of excellence in China. As part of its expanding commitment to helping CAE engineers in China, Hengstar Technology will continue to organize high level training courses, seminars, workshops, forums etc., and will also continue to support CAE events such as: China CAE Annual Conference; China Conference of Automotive Safety Technology; International Forum of Automotive Traffic Safety in China; LS-DYNA China users conference etc.

On Site Training: Hengstar Technology also provides customer customized training programs on-site at the company facility. Training is tailored for customer needs using LS-DYNA such as material test and input keyword preparing; CAE process automation with customized script program; Simulation result correlation with the test result; Special topics with new LS-DYNA features etc..

Distribution & Support: Hengstar distributes and supports LS-DYNA, LS-OPT, LS-Prepost, LS-TaSC, LSTC FEA Models; Hongsheng Lu, previously was directly employed by LSTC before opening his distributorship in China for LSTC software. Hongsheng visits LSTC often to keep update on the latest software features.

Hengstar also distributes and supports d3View; Genesis, Visual DOC, ELSDYNA; Visual-Crash Dyna, Visual-Process, Visual-Environment; EnkiBonnet; and DynaX & MadyX etc.

Consulting

As a consulting company, Hengstar focuses on LS-DYNA applications such as crash and safety, durability, bird strike, stamping, forging, concrete structures, drop analysis, blast response, penetration etc with using LS-DYNA's advanced methods: FEA, ALE, SPH, EFG, DEM, ICFD, EM, CSEC..

Contact: **JSOL Corporation Engineering Technology Division** cae-info@sci.jsol.co.jp

Cloud computing services
for
JSOL Corporation LS-DYNA users in Japan

JSOL Corporation is cooperating with chosen cloud computing services

JSOL Corporation, a Japanese LS-DYNA distributor for Japanese LS-DYNA customers.

LS-DYNA customers in industries / academia / consultancies are facing increased needs for additional LS-DYNA cores

In calculations of optimization, robustness, statistical analysis, we find that an increase in cores of LS-DYNA are needed, for short term extra projects or cores.

JSOL Corporation is cooperating with some cloud computing services for JSOL's LS-DYNA users and willing to provide short term license.

This service is offered to customers using Cloud License fee schedule, the additional fee is less expensive than purchasing yearly license.

The following services are available (only in Japanese). HPC OnLine:

NEC Solution Innovators, Ltd. - http://jpn.nec.com/manufacture/machinery/hpc_online/

Focus - Foundation for Computational Science
http://www.j-focus.or.jp

Platform Computation Cloud - CreDist.Inc.

PLEXUS CAE
Information Services International-Dentsu, Ltd. (ISID) https://portal.plexusplm.com/plexus-cae/

SCSK Corporation - http://www.scsk.jp/product/keyword/keyword07.html

Cloud - HPC Services - Subscription RESCALE

www.rescale.com

Rescale: Cloud Simulation Platform

The Power of Simulation Innovation
We believe in the power of innovation. Engineering and science designs and ideas are limitless. So why should your hardware and software be limited? You shouldn't have to choose between expanding your simulations or saving time and budget.

Using the power of cloud technology combined with LS-DYNA allows you to:
- Accelerate complex simulations and fully explore the design space
- Optimize the analysis process with hourly software and hardware resources
- Leverage agile IT resources to provide flexibility and scalability

True On-Demand, Global Infrastructure
Teams are no longer in one location, country, or even continent. However, company data centers are often in one place, and everyone must connect in, regardless of office. For engineers across different regions, this can cause connection issues, wasted time, and product delays.

Rescale has strategic/technology partnerships with infrastructure and software providers to offer the following:
- Largest global hardware footprint – GPUs, Xeon Phi, InfiniBand
- Customizable configurations to meet every simulation demand
- Worldwide resource access provides industry-leading tools to every team
- Pay-per-use business model means you only pay for the resources you use
- True on-demand resources – no more queues

ScaleX Enterprise: Transform IT, Empower Engineers, Unleash Innovation
The ScaleX Enterprise simulation platform provides scalability and flexibility to companies while offering enterprise IT and management teams the opportunity to expand and empower their organizations.

Cloud - HPC Services - Subscription RESCALE

Rescale Cloud Simulation Platform www.rescale.com

ScaleX Enterprise allows enterprise companies to stay at the leading edge of computing technology while maximizing product design and accelerating the time to market by providing:

- Collaboration tools
- Administrative control
- API/Scheduler integration
- On-premise HPC integration

Industry-Leading Security
Rescale has built proprietary, industry-leading security solutions into the platform, meeting the needs of customers in the most demanding and competitive industries and markets.

- Manage engineering teams with user authentication and administrative controls
- Data is secure every step of the way with end-to-end data encryption
- Jobs run on isolated, kernel-encrypted, private clusters
- Data centers include biometric entry authentication
- Platforms routinely submit to independent external security audits

Rescale maintains key relationships to provide LS-DYNA on demand on a global scale. If you have a need to accelerate the simulation process and be an innovative leader, contact Rescale or the following partners to begin running LS-DYNA on Rescale's industry-leading cloud simulation platform.

LSTC - DYNAmore GmbH JSOL Corporation

Rescale, Inc. - 1-855-737-2253 (1-855-RESCALE) - info@rescale.com

944 Market St. #300, San Francisco, CA 94102 USA

ESI Cloud Based Virtual Engineering Solutions www.esi-group.com

ESI Cloud offers designers and engineers cloud-based computer aided engineering (CAE) solutions across physics and engineering disciplines.

ESI Cloud combines ESI's industry tested virtual engineering solutions integrated onto ESI's Cloud Platform with browser based modeling,

With ESI Cloud users can choose from two basic usage models:

- An end-to-end SaaS model: Where modeling, multi-physics solving, results visualization and collaboration are conducted in the cloud through a web browser.
- A Hybrid model: Where modeling is done on desktop with solve, visualization and collaboration done in the cloud through a web browser.

Virtual Performance Solution:

ESI Cloud offers ESI's flagship Virtual Performance Solution (VPS) for multi-domain performance simulation as a hybrid offering on its cloud platform. With this offering, users can harness the power of Virtual Performance Solution, leading multi-domain CAE solution for virtual engineering of crash, safety, comfort, NVH (noise, vibration and harshness), acoustics, stiffness and durability.

In this hybrid model, users utilize VPS on their desktop for modeling including geometry, meshing and simulation set up. ESI Cloud is then used for high performance computing with an integrated visualization and real time collaboration offering through a web browser.

The benefits of VPS hybrid on ESI Cloud include:

- Running large concurrent simulations on demand
- On demand access to scalable and secured cloud HPC resources
- Three tiered security strategy for your data
- Visualization of large simulation data sets
- Real-time browser based visualization and collaboration
- Time and cost reduction for data transfer between cloud and desktop environments
- Support, consulting and training services with ESI's engineering teams

VPS On Demand

ESI Cloud features the Virtual Performance Solution (VPS) enabling engineers to analyze and test products, components, parts or material used in different engineering domains including crash and high velocity impact, occupant safety, NVH and interior acoustics, static and dynamic load cases. The solution enables VPS users to overcome hardware limitations and to drastically reduce their simulation time by running on demand very large concurrent simulations that take advantage of the flexible nature of cloud computing.

Key solution capabilities:

- Access to various physics for multi-domain optimization
- Flexible hybrid model from desktop to cloud computing
- On demand provisioning of hardware resources
- Distributed parallel processing using MPI (Message Passing Interface) protocol
- Distributed parallel computing with 10 Gb/s high speed interconnects

Result visualization

ESI Cloud deploys both client-side and server-side rendering technologies. This enables the full interactivity needed during the simulation workflow along with the ability to handle large data generated for 3D result visualization in the browser, removing the need for time consuming data transfers. Additionally ESI Cloud visualization engine enables the comparisons of different results through a multiple window user interface design.

Key result visualization capabilities:

- CPU or GPU based client and server side rendering
- Mobility with desktop like performance through the browser
- 2D/3D VPS contour plots and animations
- Custom multi-window system for 2D plots and 3D contours
- Zooming, panning, rotating, and sectioning of multiple windows

Collaboration

To enable real time multi-user and multi company collaboration, ESI Cloud offers extensive synchronous and asynchronous collaboration capabilities. Several users can view the same project, interact with the same model results, pass control from one to another. Any markups, discussions or annotations can be archived for future reference or be assigned as tasks to other members of the team.

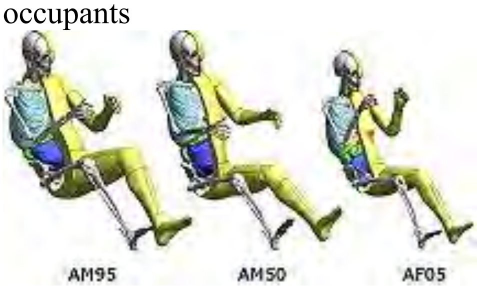
Key collaboration capabilities:

- Data, workflow or project asynchronous collaboration
- Multi-user, browser based collaboration for CAD, geometry, mesh and results models
- Real-time design review with notes, annotations and images archiving and retrieval
- Email invite to non ESI Cloud users for real time collaboration

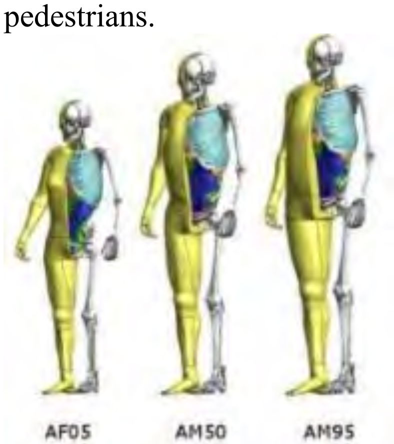
TOYOTA - Total Human Model for Safety – THUMS

The Total Human Model for Safety, or THUMS®, is a joint development of Toyota Motor Corporation and Toyota Central R&D Labs. Unlike dummy models, which are simplified representation of humans, THUMS represents actual humans in detail, including the outer shape, but also bones, muscles, ligaments, tendons, and internal organs. Therefore, THUMS can be used in automotive crash simulations to identify safety problems and find their solutions.

Each of the different sized models is available as sitting model to represent vehicle occupants



and as standing model to represent pedestrians.



The internal organs were modeled based on high resolution CT-scans.

THUMS is limited to civilian use and may under no circumstances be used in military applications.

LSTC is the US distributor for THUMS. Commercial and academic licenses are available.

For information please contact: THUMS@lstc.com

THUMS®, is a registered trademark of Toyota Central R&D Labs.

LSTC – Dummy Models

LSTC Crash Test Dummies (ATD)

Meeting the need of their LS-DYNA users for an affordable crash test dummy (ATD), LSTC offers the LSTC developed dummies at no cost to LS-DYNA users.

LSTC continues development on the LSTC Dummy models with the help and support of their customers. Some of the models are joint developments with their partners.

e-mail to: atds@lstc.com

Models completed and available
(in at least an alpha version)

- Hybrid III Rigid-FE Adults
- Hybrid III 50th percentile FAST
- Hybrid III 5th percentile detailed
- Hybrid III 50th percentile detailed
- Hybrid III 50th percentile standing
- EuroSID 2
- EuroSID 2re
- SID-IIs Revision D
- USSID
- Free Motion Headform
- Pedestrian Legform Impactors

Models In Development

- Hybrid III 95th percentile detailed
- Hybrid III 3-year-old
- Hybrid II
- WorldSID 50th percentile
- THOR NT FAST
- Ejection Mitigation Headform

Planned Models

- FAA Hybrid III
- FAST version of THOR NT
- FAST version of EuroSID 2
- FAST version of EuroSID 2re
- Pedestrian Headforms
- Q-Series Child Dummies
- FLEX-PLI





LSTC – Barrier Models

Meeting the need of their LS-DYNA users for affordable barrier models, LSTC offers the LSTC developed barrier models at no cost to LS-DYNA users.

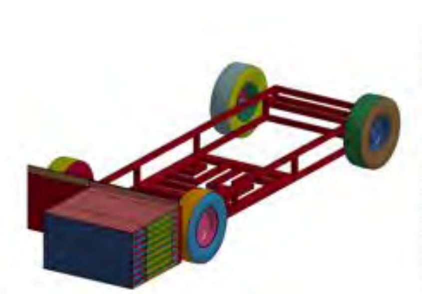
LSTC offers several Offset Deformable Barrier (ODB) and Movable Deformable Barrier (MDB) models:

- ODB modeled with shell elements
- ODB modeled with solid elements
- ODB modeled with a combination of shell and solid elements
- MDB according to FMVSS 214 modeled with shell elements
- MDB according to FMVSS 214 modeled with solid elements
- MDB according to ECE R-95 modeled with shell elements
- AE-MDB modeled with shell elements
- IIHS MDB modeled with shell elements
- IIHS MDB modeled with solid elements
- RCAR bumper barrier
- RMDB modeled with shell and solid elements

LSTC ODB and MDB models are developed to correlate to several tests provided by our customers. These tests are proprietary data and are not currently available to the public.

All current models can be obtained through our webpage in the LSTC Models download section or through your LS-DYNA distributor.

To submit questions, suggestions, or feedback about LSTC's models, please send an e-mail to: atds@lstc.com. Also, please contact us if you would like to help improve these models by sharing test data.



Social Media

FACEBOOK

- BETA CAE Systems
- CADFEM
- ESI Group
- Lenovo

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- BETA CAE Systems
- ESI Group
- ETA
- CADFEM
- Lenovo

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- DYNAmore Nordic
- ETA
- ESI Group

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ESI Group	www.esi-group.com
ETA	www.eta.com
Lancemore	www.lancemore.jp/index_en.html
Lenovo	

GOOGLE+

- BETA CAE Systems