Crash & Impact Analysis Using Abaqus

Target Audience

This course is designed for mechanical, aerospace, and automotive engineers with basic FEA knowledge who want to specialise in crash and impact simulation using Abaqus/Explicit. It suits practising CAE engineers, postgraduate researchers, and engineering graduates targeting roles in automotive OEMs, Tier-1 suppliers, aerospace structures, defence, and consumer electronics testing. A background in static FEA is recommended; no prior explicit dynamics experience is required.

Course Outcomes

- **Understand** the theoretical basis of explicit time integration, stability limits, and energy balance governing Abaqus/Explicit
- **Understand** the physics of crash, impact, penetration, and high-strain-rate material behaviour
- **Apply** professional meshing strategies, element selection, hourglass control, and mass scaling for crash models
- **Apply** Johnson-Cook plasticity and damage, ductile/shear damage, and Hashin composite criteria
- **Apply** general contact, self-contact, spotwelds, and friction in multi-part crash assemblies
- **Create** five portfolio-grade simulation models across crash box, drop test, composite impact, automotive crash, and ballistic penetration
- **Optimize** simulation runtime and accuracy using mass scaling, symmetry, and parallel processing
- **Troubleshoot** hourglass energy, negative volumes, contact instability, and model blow-up
- **Prepare** professional simulation reports and energy balance validations aligned with industry standards

Course Objectives

- To deliver rigorous understanding of Abaqus/Explicit solver architecture and explicit time integration for crash and dynamic events
- To develop proficiency in element selection, meshing, hourglass control, and section definitions for crashclass models

- To build competence in industry-standard material cards including Johnson-Cook plasticity, damage initiation, damage evolution, and Hashin fibre/matrix failure
- To train participants in all contact forms — general contact, self-contact, spotwelds, and tied constraints — for multi-body assemblies
- To reinforce every module with hands-on labs and deliver five industry-grade projects as portfolio deliverables
- To develop post-processing skills including energy curves, damage contours, deformation animation, and benchmark validation
- To equip participants with systematic troubleshooting skills for professional explicit analysis failures
- To prepare participants for senior CAE roles through portfolio-ready crash simulation projects

Course Outline

The course comprises **40 hours** of theory and labs and is divided into **10 different chapters**. Each chapter will be followed by hands-on lab exercises to reinforce learning and gauge understanding of the topics covered.

Table of Contents

Section 1 — Foundations & Theory

- What is Crash & Impact Analysis — real-world scope and applications
- Explicit vs. Implicit solvers — when to use which and why
- Central-difference time integration — the math behind Abaqus/Explicit
- Stability limit, critical time step, and the CFL condition
- Energy balance — the most important check in any explicit run
- Mass scaling — concept, types, and when it's acceptable

Section 2 — Abaqus/Explicit Environment Setup

- Tour of Abaqus/CAE for explicit analysis
- Creating and importing geometry for crash models
- Step module — Dynamic Explicit step settings
- Setting up field and history output requests
- Job management, parallel processing, and solver settings

Section 3 — Meshing for Crash Simulations

- Element types for explicit — shells, solids, beams compared
- Shell elements in depth — S4R, S3R, reduced integration and hourglass control
- Mesh quality rules — aspect ratio, warping, Jacobian for explicit
- Mesh size and its direct effect on stable time increment
- Adaptive meshing and mass scaling strategies
- Workshop — meshing a crash box (thin-walled steel tube)

Section 4 — Material Models for High-Rate Events

- Elastic and elastic-plastic materials — review and setup in Abaqus
- Rate-dependent plasticity — why strain rate matters in crash
- Johnson-Cook plasticity model — theory, parameters, calibration
- Ductile damage initiation and evolution — DUCTCRT, SHRCRT ■
Element deletion — when and how to use it correctly
- Johnson-Cook damage model — combined plasticity + damage
- Material models for composites in impact — Hashin criteria
- Workshop — defining a full Johnson-Cook material card for steel

Section 5 — Contact in Abaqus/Explicit

- General contact vs. contact pairs — which to choose
- Surface definitions — element-based vs. node-based
- Contact properties — normal behavior (hard, softened) and tangential (friction)
- Self-contact — critical for folding and crushing structures
- Tied constraints and spot welds in crash assemblies
- Common contact errors and how to fix them
- Workshop — setting up full-body general contact for a car frame

Section 6 — Loads, Boundary Conditions & Initial Conditions

- Applying initial velocity — the correct way in Abaqus/Explicit
- Rigid body definition and rigid wall setup
- Prescribed displacement vs. velocity loading
- Gravity and body forces in dynamic events

- Symmetry in crash models — reducing compute cost

Section 7 — Post-Processing & Result Validation

- Visualising deformation — animation, contour plots, section cuts
- Force-displacement and energy-time curves from history output
- Energy balance interpretation — internal, kinetic, artificial strain energy
- Validating results against physical test data
- Writing a simulation report — what industry expects

Section 8 — Troubleshooting & Best Practices

- Diagnosing excessive artificial strain energy (hourglass)
- Fixing negative volume errors — element distortion
- Contact penetration and instability fixes
- When your model explodes — common causes and cures
- Checklist before every crash simulation run

Section 9 — Advanced Topics & Career Path

- Implicit-Explicit co-simulation — pre-stressing then crashing
- Introduction to Abaqus Python scripting for automation
- Connecting to LS-DYNA — similarities and differences
- Where crash engineers work and what they earn
- Building your simulation portfolio

Section 10 — End to end Project

- End to end project for the whole course to understand the practical usage and industrial application of thus course.