

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 crash-class 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 **64 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 — Industry Projects

- **Project 1 — Axial Crush of a Crash Box** (*Beginner–Intermediate*)

- Setting up a thin-walled square tube under axial crushing load, observing progressive folding, energy absorption, and force-displacement response

■ **Project 2 — Drop Test Simulation** (*Intermediate*)

- Simulating a product dropped from height onto a rigid floor — initial velocity setup, contact, deformation, and stress peaks

■ **Project 3 — Low-Velocity Impact on a Composite Panel** (*Intermediate–Advanced*)

- Impact of a rigid impactor on a CFRP plate using Hashin damage — predicting delamination, damage extent, and residual strength indicators

■ **Project 4 — Automotive Frontal Crash (Full Frame)** (*Advanced*)

- Full vehicle front-end crash at 56 km/h into a rigid barrier — general contact, spotwelds, multiple materials, energy balance validation, and result post-processing

■ **Project 5 — Ballistic Penetration / Bird Strike** (*Advanced*)

- High-velocity impact — Johnson-Cook damage, element deletion, penetration depth, and residual velocity calculation

Section 8 — 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 9 — 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 10 — 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