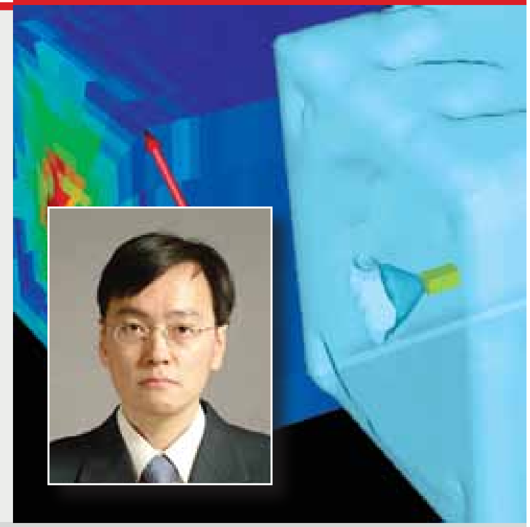
USER CASE STUDY

Agency for Defense Development

Customer Profile: Jong H. Kim



Jong H. Kim is Senior Engineer for the Agency for Defense Development (ADD) in Daejeon, South Korea. Kim and other members of the Aircraft Structural Team are responsible for, among other things, improving the survivability of airframes so that aircraft will be able to return to base after being hit by enemy fire. The primary method of assessing design alternatives in the past, live fire testing, is so expensive and time consuming that aircraft could not be tested for all of the likely damage scenarios.

Challenge

ADD needs to evaluate various wing fuel tank designs for their ability to withstand a high velocity projectile impact. Their goal is to predict and quantify the damage from impact so that subsequent survivability analysis, such as residual strength and structural/flutter stiffness can be performed on the remaining structure. This also provides understanding of how the aircraft should be flown to enable it to safely return to base. In order to accomplish these objectives, it is necessary to simulate the very complex phenomena of hydrodynamic ram which occurs when a projectile impacts a structure containing fluid and penetrates it or detonates near it to produce a blast wave.

Solution

Patran, MD Nastran, Flightloads, and Dytran finite element analysis software.

Benefit

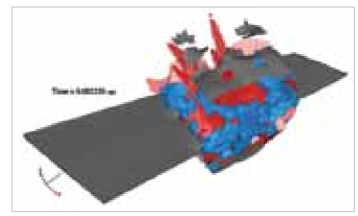
ADD has demonstrated the ability to simulate the damage to the airframe caused by the penetration and detonation of a projectile. This is expected to reduce the amount of live fire testing required and to make it possible to evaluate the effect of far more damage scenarios.

Case Study

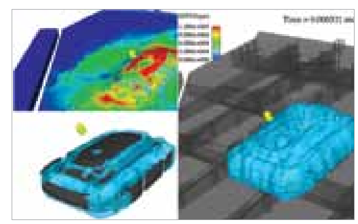
Seung M. Jun, Principal Engineer/Team Lead for the Agency for Defense Development (ADD)

Aircraft designers put considerable effort into designing aircraft that can withstand a direct hit by a projectile and return to base. Ensuring the survivability of aircraft requires assessment of various design alternatives based on their ability to withstand different damage scenarios. Another important aspect of survivability is understanding the structural characteristics of the aircraft after being hit so that techniques can be developed to safely fly the aircraft back to its base.

Kim and Jun set out to develop a method of accurately simulating the effects of hydrodynamic ram on fuel tanks. This problem is challenging because of the complexity of the physics involved including the need to account for the drag the projectile faces while traveling, the cavity behind the projectile, the pressure of the fluid in the tank, and the structural stress and deformation.



Fuel bursting through tank by internal detonation



Hydrodynamic ram on wing fuel tank

"We selected Dytran because its multi-material Euler solver works with multiple coupling surfaces and allows mass to flow from one coupling surface to another," Kim said. This feature made it possible to simulate both the Eulerian region of fluid and air and the Lagrangian region as the projectile penetrates and either detonates inside or passes through tank bays. Multiple adaptive Euler domains were defined to model three Euler materials: water, air and explosive.

These three meshes and the Lagrangian mesh of the tank interact and sometimes overlap with one another depending on how the explosive wave spreads inside the tank. Kim used adaptive master-slave contacts and the adaptive Euler mesh of Dytran to simulate the structural rupture by the projectile and to speed up the matrix calculations. "The use of general coupling instead of Arbitrary Lagrange Euler coupling made it possible to simulate both the structural rupture and the fluid burst at the same time," Jun added.

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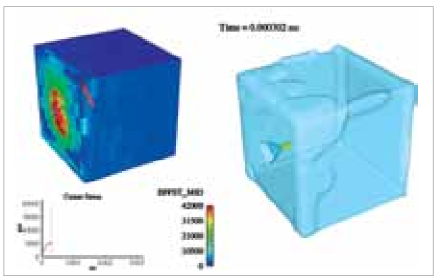
The results show that a detonation that starts at the center of the fuel bay expands the tank and finally ruptures it. These results match ram physics calculations, proving that Dytran can accurately simulate the complicated physics of hydrodynamic ram. "The result presents the promising future of saving time and money by reducing the need for live fire testing to evaluate airframe structures and of developing strategies to return aircraft to base under a much wider range of damage scenarios," Kim concluded.

MSC Software

MSC Products Used:

Dytran

- Explicit nonlinear solver technology for simulating short duration dynamic events
- Robust and efficient 3D contact
- Complete finite element model library that includes beams, shells, solids, springs and dampers
- Nonlinear material models
  - Metals
  - Composites
  - Soils
  - Foam rubber
  - Liquids
  - Gases
- Coupled fluid-structure interaction
- Parallel processing for improved productivity
  - Shared memory parallel
- Distributed memory parallel



Projectile penetrating water tank

Patran

Pre-processing

- Standard Geometry Access from
  - Parasolid
  - STEP 203 and 209
  - IGES
  - VDA
  - I-DEAS
- Parametric Modeling Capabilities
- Wireframe and Solid Geometry Creation and Modification
- Mesh Generation
  - Automatic 2-D surface meshing
  - Automatic solid mesher
  - Generalized 1-D, 2-D, 3-D mapped mesher
  - Mesh on Mesh
  - Mesh editing and modification
- Comprehensive Element Library
- Element Property Creation and Edit
- Material Property Creation and Edit
- Load and Boundary Creation and Edit
- Easy Contact Definitions
- Model Visualization and Verification
- Support for multiple FEA solvers
  - Marc
  - Dytran
  - MSC Nastran
  - MD Nastran
  - 3rd party solvers

Post-processing

- Results Access
  - Nastran
  - Dytran
  - Marc
  - 3rd party solvers
- Results Visualization
  - Contours
  - Vector arrows
  - Fringe plots
  - Isosurfaces
  - Data History / Animation
  - X-Y plots
  - Imaging
- Results Templates

Flightloads

Integrated Nastran/Patran based solution for aerodynamic/aeroelastic models used for calculation of external structural loads that can be applied to a structural model for a detailed stress analysis.

Pre-/Post-Processing

- Support for user preferred CAD applications
- Define aerodynamic models
  - Flat plate aero modeling
  - Control devices
  - Aero and structural monitor points
  - Model management for lifting surfaces and bodies
- Steady and unsteady aerodynamics
- Couple aerodynamic and structural models to perform aeroelastic analysis
- Produce external loads for detailed design and verification
- Store intermediate results for subsequent retrieval in further analyses
- Integrated visualization tools

Analysis
(MSC Nastran and MD Nastran)

- Subsonic, supersonic aerodynamics
  - Steady
  - Unsteady
- Support for multiple aerodynamic theories
  - Doublet-Lattice subsonic
  - ZONA51 and Constant Pressure Method supersonic
  - Subsonic wing-body interface
- Static aeroelastic trim analysis
  - Redundant controls
  - Control surface modeling
  - Nonlinear aerodynamic forces
- Aeroelastic stability derivatives
- Hinge moments
- Flutter analysis
- Transient aeroelastic response using Fourier Transform methods
- Frequency domain aeroelastic response
- Discrete and harmonic gust analysis
- Aeroservoelastic analysis
- Numerous flutter algorithms
- Design sensitivity and optimization (SOL200)

Company Profile

Agency for Defense Development(ADD) was established in August 1970 under the banner of the self-reliable defense. ADD is the one and only national agency for R&D in defense technology contributing to enforcing the national defense, to improving the national R&D capacity, and to fostering the domestic industry through research, development, test and evaluation of weapons, equipments and related technologies. ADD succeeded in domestic development of the most advanced weapon system and reached to the 10th world-level in the defense technology.

Refer to http://www.add.re.kr (and click English language) for more information.

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