Enhanced equipment design using EDEM co-simulation

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During operation, a wide range of aspects of equipment performance – from stresses on load arms, to the hydraulic forces, to the traction of the tyres and delivery of power – is dependent on the bulk material being handled.

This article demonstrates how Discrete Element Modelling (DEM) simulation can be combined with other computer-aided engineering (CAE) methods – such as Finite Element Analysis (FEA) and Multi-Body Dynamics (MBD) – to provide engineers with enhanced insight into their equipment designs.

Examples are provided for EDEM-Adams and EDEM-ANSYS co-simulation.

The challenge of equipment design

Understanding how a design will perform in a particular material environment is critical to ensuring an optimal design that combines strength and durability, with performance efficiency.

Real bulk materials – such as gravel, clay, and mined ores – are complex in their behaviours. For some materials, like sand, moisture plays a significant factor in how they behave. One day they may be the free-flowing but, after a heavy rain shower, may become highly cohesive and very difficult to handle. The variability and complex nature of materials means that it is very difficult for engineers to predict exactly how they will behave.

FEA and MBD are commonly used simulation tools in the design of heavy equipment and when using such tools an engineer has to tackle the problem of material loads head on. In order to iterate to the best possible design, an engineer needs to be able to define with confidence the material loads acting on their equipment and understand how these loads impact on the performance of the equipment.

Traditional approaches to get representative load data include hand calculations to approximate the load, reliance on prior experience, or assumption of the anticipated material behaviour. However, because of the difficulty in predicting material behaviour using hand calculations and assumption, an engineer may only be able to assess a small set of conditions.

One alternative to hand calculation methods is physical prototyping; however, such prototyping is typically expensive and time-consuming. As a result it is often reserved for late stage design assessment, rather than as a regular design iteration check.

Enhanced design using EDEM co-simulation

The landscape of the CAE market is evolving. Internet based software, off-site cloud computing resource, and pay-as-you-go methods are on the rise and, increasingly, users are demanding that their CAE solutions can be found ‘in one place’.

Compared to FEA and MBD, Discrete Element Modelling (DEM) is a relatively new CAE method, but it is one that provides engineers with the ability to simulate bulk material behaviour as part of their analysis. EDEM is a simulation tool based on DEM that provides engineers with the tools to create realistic material behaviours for a wide range of different material types. It provides the analysis tools needed to solve complex problems in the design and optimization of heavy equipment and is used by engineers around the world.

Driven by the evolving demands on CAE and the material challenges faced by engineers designing heavy equipment, DEM Solutions has been working closely with other CAE companies to provide co-simulation solutions that combine the insight from EDEM with the powerful analysis of MBD and FEA methods.

These co-simulation solutions give engineers the opportunity to reduce their reliance on hand calculations and assumption by instead using realistic material models and associated load patterns provided by EDEM.

In the design of heavy equipment, CAE tools such as FEA and MBD are commonly used. However, to use effectively, engineers need to understand what material loads are going to be applied during operation.

Using EDEM-Adams co-simulation, engineers are able to combine realistic material behaviour with realistic system dynamics.
EDEM-MBD co-simulation: dynamic system analysis

During co-simulation with MBD codes, EDEM will calculate the material force and loads during a machine operation. These loads are then shared with the MBD code which uses this information to calculate the effect on the system dynamics of the equipment assembly. These motions are then fed back to EDEM and the process can continue.

In the example shown here, an excavator bucket is being simulated going through its digging cycle. All the motion is controlled by Adams (MSC Software) and the performance of the equipment is being evaluated for two different material types: one dry with low levels of cohesion, the other wet with high, sticky, cohesion levels. The excavation cycle has three stages: digging, rotating and unloading, and the material models for the EDEM simulation have come from DEM Solutions’ ‘Generic EDEM Material Model (GEMM) Database’.

The image shows the total pressure that is acting on the excavator bucket during the loading cycle. Initially, the load is zero. As the bucket enters the material bed, the pressure on the bucket begins to increase. Due to the moisture content in the cohesive material, the pressure rises to a higher level than during the same period in the dry material.

As the excavator finishes the dig phase and moves to rotate away from the material bed, the pressure on the bucket decreases. During rotation of the boom arm, the cohesive wet material has a greater fill level and as a result there is greater pressure acting on the bucket.

By using EDEM as part of the usual MBD analysis, engineers here are able to understand how their design will perform when faced with different, challenging materials. It allows optimisation of a design so that it will perform effectively across a range of different operating and site conditions.

EDEM-FEA case study: Austin Engineering

Austin Engineering designs and manufactures some of the world’s leading truck bodies for use in off-highway environments. Each site where its equipment is deployed is different, and Austin Engineering has to customise its designs for each client to cope with the local environmental challenges and meet productivity requirements. Optimised durability and performance efficiency is key part of all Austin Engineering custom truck body designs. Physical prototyping at this scale is expensive, and so each custom design needs to be tested virtually to guarantee performance at each site.

Austin Engineering deploys EDEM and ANSYS software to evaluate each of their truck body designs. EDEM, with its realistic material simulation, provides engineers with accurate pressure distributions of material acting on their equipment. Then, using the ‘EDEM Add-In for ANSYS Workbench’, these loads are used as inputs into structural and fatigue analysis in ANSYS Mechanical for FEA analysis.

Using EDEM instead of hand calculations and guesswork allows engineers to broaden the operational conditions that can be reviewed, without the cost and time of physical prototyping.

Using the EDEM Add-In, Austin Engineering performs extensive ‘what-if’ analysis of operational scenarios such as alternative tray loadings and cornering conditions (see images).

The EDEM Add-In for ANSYS Workbench enables Austin Engineering to improve the durability and performance of each truck body design. The realistic material loads from EDEM significantly improve accuracy compared to traditional approaches and mean truck body designs are strong, efficient and will perform in a range of operational conditions. Combining EDEM insight with ANSYS tools allows Austin Engineering to show their clients how a design will perform on-site, and ensure that their needs are met before it is sent for fabrication.

Summary

Co-simulation between CAE tools allows engineers to reduce the reliance on hand calculation and assumption when designing heavy equipment and address the challenges of how their equipment will perform when dealing with bulk materials.

The realistic loads provided by EDEM combined with the...
structural and dynamic analysis capabilities of FEA and MBD tools, means that engineers are able to design with greater confidence and ensure that their designs are structurally sound, efficient and safe.

Co-simulation is becoming increasingly popular in the CAE market and by combining methods companies are able to enhance their equipment design process. This means benefits of shortened design times, lower costs through reduced prototyping, and the ability to provide optimal solutions to meet project requirements.

Real bulk materials are complex in their behaviour and to be able to make design decisions with confidence engineers need to know that the virtual material they are simulating is linked with real-world behaviours.

To enable engineers to access suitable material inputs quickly and easily, DEM Solutions has developed the GEMM Database. The GEMM Database is free to use and contains 1,000s of individual material models for use in EDEM simulation.

To choose the materials they need, engineers need to answer three questions:

• What is the bulk density of their material?
• What is the size of their application?
• What is the angle of repose of the material?

The GEMM database

Software for conveyors

Alex Harrison, best known to ABHR readers for his work in remotely accessible steel cord belt monitoring technology, has formed a new company in Australia called ConveyorScience Pty Ltd, which develops software applications for the mining and bulk handling sectors.

In Australia, ConveyorScience promotes the use of in-house developed programs to maximize the effectiveness of conveyor designs and operations,” explained Harrison. Harrison has spent over 30 years developing systems for the remote monitoring of steel cord conveyor belts, including 20 years in the USA. At the same time, and in parallel, he has long worked more broadly on software aimed at conveyor operators.

Harrison, a Conjoint Professor at the University of Newcastle, said that his software developments have evolved significantly over the past 15 years with improved coding platforms and internet availability.

“Today, cloud-based programming is becoming a norm, although dedicated software packages are still developed on in-house computers,” he said.

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