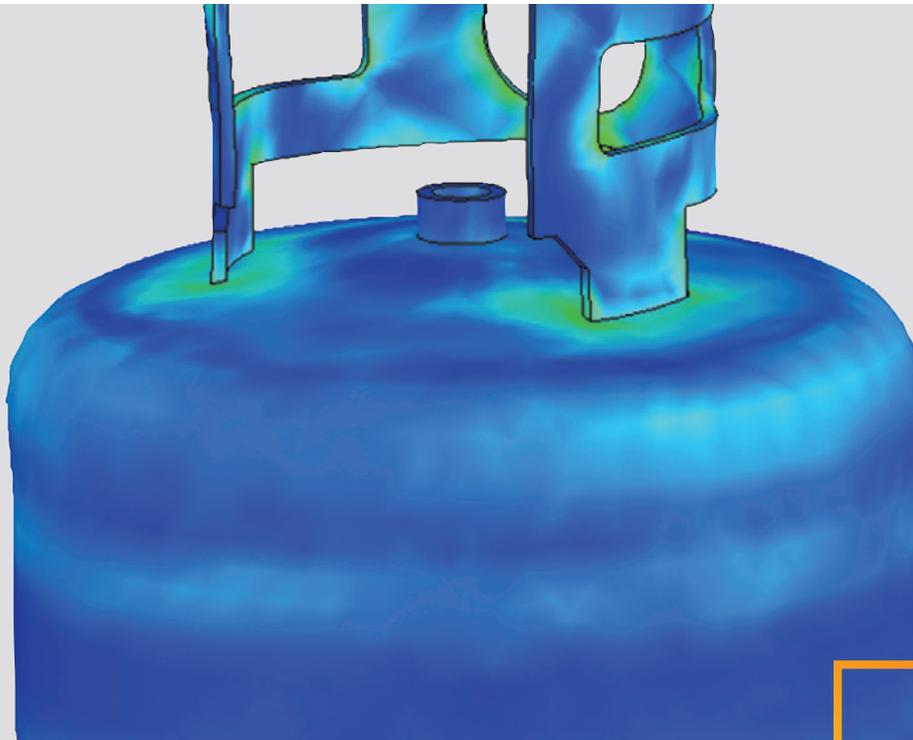


Simulating Drop Tests in SolidWorks



SUMMARY

SolidWorks® software now makes it possible for design engineers to run upfront drop tests on their designs easily and quickly, despite the fact that running them involves studying tens of thousands of very short time steps to capture the results within microseconds of the impact. This paper will look at what a user needs to do to perform such a test, the kinds of results he or she will obtain, and at the technology behind such simulations. For the user, running drop tests looks and feels just like doing any other SolidWorks analysis.

Defining a study

How can the working parts of your PDA or cell phone be protected if someone jars your arm while you're using it, and the device falls to the ground? Or, what happens to the structure of a storage tank if the crane putting it in place should drop it? Until now, learning the results of such accidents required running physical tests that destroyed the structures under study, or else performing very difficult nonlinear and dynamic response finite element analyses (FEA) better suited to simulating car crashes. In SolidWorks Simulation, you can set up a drop test just like setting up any other study.

SolidWorks software now makes it possible for design engineers to run upfront drop tests on their designs easily and quickly. Setting up a drop test is just like setting up any other study.

Step 1 - Define study and choose material

The user opens a study and names it "drop test." Then, if the material has not already been defined in the SolidWorks model, the user enters it. Different materials can be assigned to different components in an assembly. The user then goes to the setup menu.

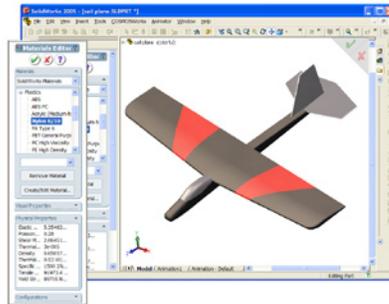


FIGURE 1:
MATERIALS THAT HAVE BEEN DEFINED IN SOLIDWORKS ARE IMMEDIATELY AVAILABLE FOR PERFORMING DROP TEST STUDIES, SAVING VALUABLE TIME.

Step 2 - Specify drop height, floor orientation, floor hardness

In setting up the study, the user chooses either to specify the drop height (that is, the distance to impact) or velocity at impact, which may be defined by a motion study conducted prior to the drop test. If he chooses a height study, he then defines whether to measure from the centroid (or center of the object) or from the bottom of the object, and also enters the direction of gravity or orientation of the object as it drops. When he specifies a drop height, the program automatically calculates the velocity just before impact ($(2Gh)^{1/2}$ (G stands for gravity, h is for drop height. Velocity is square root of $2 \times \text{gravity} \times \text{height}$). The default angle of the floor or other surface onto which the object drops is normal to gravity. However, the user can change that angle and, if desired, enter data about any friction the falling object would experience when hitting the floor. Such friction depends on the material of the surface on which it drops—say, asphalt or concrete. Also, the default floor is assumed to be relatively much harder (or rigid) than the object being dropped. Users can change the floor to

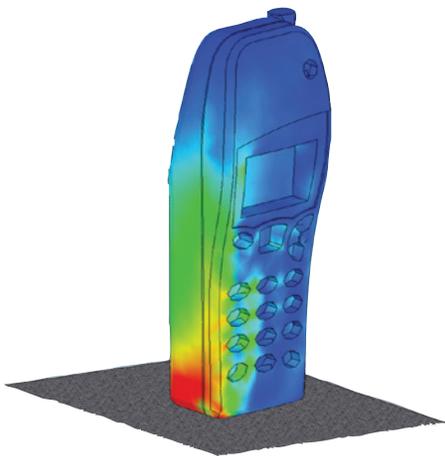


FIGURE 2:
SIMULATION OF A CELL PHONE ASSEMBLY DROP TEST USING SOLIDWORKS

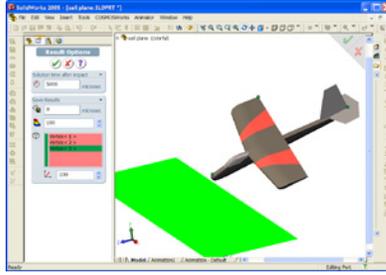


FIGURE 3:
YOU CAN EASILY DEFINE THE ORIENTATION OF THE MODEL AS WELL AS THE HEIGHT IT IS BEING DROPPED FROM.

Simulating a drop test is as easy as 1-2-3.

1. Define a study and choose materials
2. Specify drop height, floor orientation, floor hardness
3. Run the analysis and study results

be flexible and specify a hardness to it—wood floor has a different hardness than carpeted floor for example. Users can simulate interaction between components within an assembly (see Figure 4) after impact by specifying the faces or surfaces of various components which are likely to come in contact with each other.

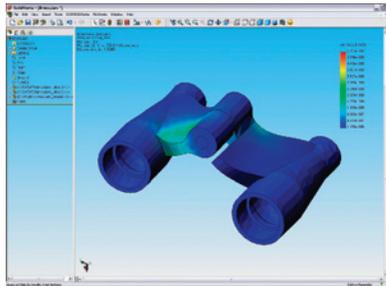


FIGURE 4:
THIS BINOCULAR ASSEMBLY SHOWS THE TRANSFER OF STRESS FROM ONE SIDE OF THE ASSEMBLY, THROUGH A PIN CONNECTOR, TO THE OTHER SIDE OF THE ASSEMBLY.

Step 3 - Run analysis and study results

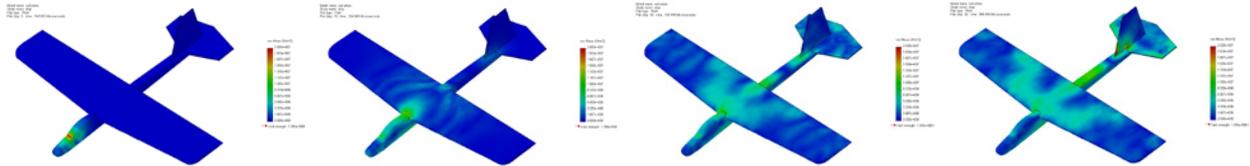
To get the most out of the simulation, some questions should be addressed before running the analysis:

A. For how long after impact should one observe or capture the solution?

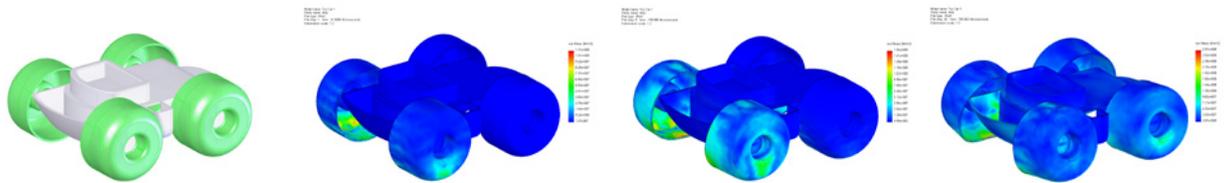
Solution time after impact is measured in microseconds. The total duration depends on how much time elapses before the object experiences all the likely impact stress it will undergo after it bounces. If a user wants to account for any secondary impacts, that time will add to the duration. When the object under study hits the floor, a stress wave originates from the point of impact and travels through the length of the object and then travels back. This effect is similar to the ripple effect when a stone hits water in a pond. SolidWorks Simulation software internally calculates the time it would take this wave to travel through

the length of the body a few times—and assumes that all major stress events would occur and be captured within that time.

Think of a toy glider impacting nose first onto the floor. The stress wave generates from the nose of the glider hitting the floor and then travels towards the wing and the tail.



The simulation needs to be run for a considerably longer time to study secondary impacts. An easily visualized example is the toy car shown below, which drops so that the rear wheels hit the floor first, and then are followed by the front wheels, causing an initial and secondary impact.



B. How do you select the time steps to save from your results?

By default, SolidWorks saves detailed results for 25 steps and location results for 20 steps within every major step. Because each simulation can have tens of thousands of time steps, it makes sense to save only the important ones, rather than wasting computer resources on the entire series. A user may be able to cut more time from analysis runs by performing a first pass run, using default settings, to obtain initial results. Those may indicate time windows that need to be refined—and the user can choose which windows to refine—saving time in the overall solution.

SolidWorks is capable of showing both primary and secondary impact results.

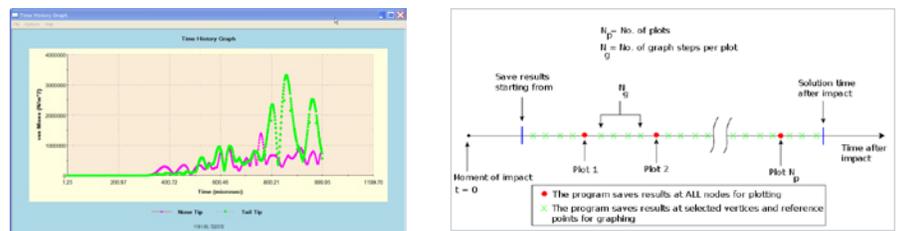


FIGURE 5: STRESS VARIATION WITH TIME AFTER AN IMPACT AT TWO DIFFERENT LOCATIONS ON A MODEL

C. Why do you want to run drop tests inside SolidWorks?

As illustrated in the propane tank shown in Figure 6, running a drop test in SolidWorks makes it easy to study the impact on objects dropped in different orientations. Containers that carry hazardous materials, for example, have different design requirements to account for being dropped in different orientations.

SolidWorks makes it easy to study the impact on objects dropped in different orientations.

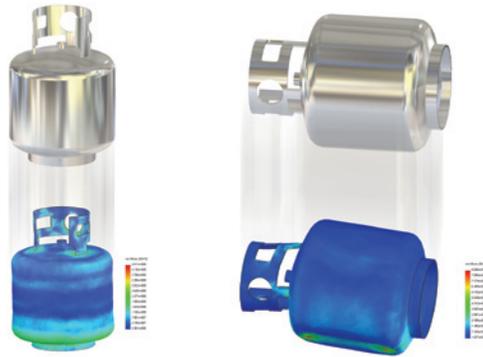


FIGURE 6:
PROPANE TANKS DROPPED IN DIFFERENT ORIENTATIONS SHOW SIGNIFICANTLY DIFFERENT STRESS RESULTS.

SolidWorks drop test simulations also support plasticity, so that engineers can determine such permanent deformations as dents after impact. Plastics and metals exhibit permanent deformations—the definition of plasticity—when stressed beyond their yield points. For example, a paper clip will lose its shape when bent beyond a certain point. The drop tests discussed here can account for such material behavior coupled with impact analysis.

The technology behind fast drop test analysis

Although experienced SolidWorks users will find the steps involved in running drop tests familiar, the technology behind them is more complex than it looks. To simulate an object dropping and hitting a hard surface, the simulation software has to solve the following equation iteratively, because as the object falls and hits the floor, the forces and stiffness keep changing.

$$[M]\{a\} + [C]\{v\} + [K]\{x\} = \{F\}$$

Where:

M = Mass matrix

a = acceleration vector

C = damping matrix

v = velocity vector

K = Stiffness matrix

x = displacement vector

F = external force vector

FEA can use two approaches for solving drop test equations. They are called implicit and explicit solutions. The drop test simulation in SolidWorks uses the explicit solution technology. Although both approaches are equally accurate, implicit solutions of impact problems such as dynamic drop tests take longer to solve.

FEA can use two approaches for solving this equation. They are called implicit and explicit solutions. The drop test simulation in SolidWorks uses the explicit solution technology. Although both approaches are equally accurate, implicit solutions of impact problems such as dynamic drop tests take longer to solve. Here's why: Implicit solvers first compute displacement "x," causing them to invert the stiffness matrix. All computers have to work harder and longer on matrix inversion than on matrix multiplication—the approach used by explicit solvers.

The explicit approach computes accelerations, and thus has to invert only the mass matrix, much easier because this is a diagonal matrix. On the other hand, explicit techniques have the drawback of requiring very small time increments to provide a good, stable solution.

Real-life problems generally can be solved with either approach. But depending on the nature of the problem, one method will be faster than the other. Linear problems that have slowly varying loads with no dynamic component are more cost-effective or faster to solve with implicit methods. However, problems with short-duration loading—such as impact or drop tests—are more economical to solve with explicit methods. Problems with gross nonlinear behavior that requires a constant update to the stiffness matrix are also more economical to solve with explicit methods.

Conclusion

The speed gained through technology and through SolidWorks software's ease of use makes it simple for users to run drop tests on their designs, and adds another dimension to overall upfront simulation. Design engineers can run upfront drop tests on their designs easily and quickly, despite the fact that running them involves studying tens of thousands of very short time steps to capture the results within microseconds of the impact. For the user, running drop tests looks and feels just like doing any other SolidWorks analysis. Setting up a drop test is just like setting up any other study.



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