Nonlinear Simulation Provides More Realistic Results

When parts interact and experience large deflections and extreme conditions, nonlinear technology is required to simulate real-life situations.

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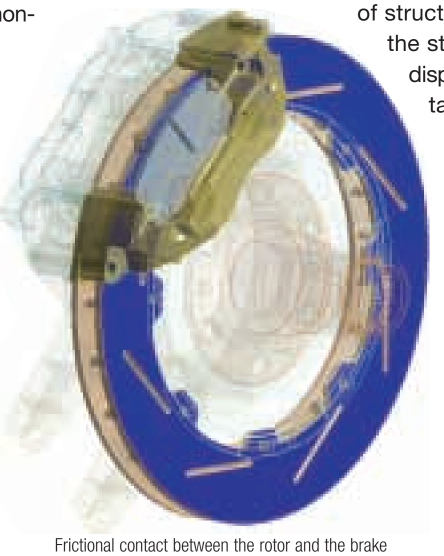
In today's competitive environment in which everyone strives to develop the best design with the best performance, durability and reliability, it is unrealistic to rely on linear analysis alone. Analyses must be scaled from single parts and simplified assembly-level models to complete system-level models that involve multiple complex subassemblies. As more parts get added to a simulation model, it becomes more difficult to ignore the nonlinear aspects of the physics, and, at the same time, expect realistic answers.

In some situations involving single- or multiple-part models, analysis with linear assumptions can be sufficient. However, for every assumption made, there is some sacrifice in the accuracy of the simulation. Ignoring nonlinearities in a model might lead to overly conservative or weak design in certain situations, or might result in the omission of unexpected but valuable information about the design or performance of the model. It is essential to understand when and when not to account for nonlinearities. The following are some situations in which nonlinearities are commonly encountered.

Contact

Currently, auto-contact detection in ANSYS Workbench *Simulation* allows users to quickly set up contact (part interactions) between multiple entity types (solids, sheets, beams). However, in cases in which two parts interact with each other, the parts might stick or slide against each other instead of remaining static. Also, their stiffness might change depending upon whether they touch each other or not, as is seen with interference or snap-fit cases. Ignoring sliding may be acceptable for a large class of problems, but for those with moving parts or that involve friction, it is unwise to make this assumption.



Frictional contact between the rotor and the brake pad in a brake assembly

Geometry

In certain situations, the deflections of a structure may be large compared to its physical dimensions. This usually results in a variation in the location and distribution of loads for that structure. For example, consider a fishing pole being bent or a large tower experiencing wind loads. The loading conditions over the entire body of the structure will change as the structure deflects.

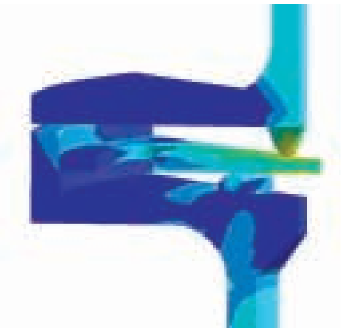
Top-loading simulation of a plastic bottle

Also, in certain slender types of structures, membrane stresses may cause the structure to stiffen and, hence, reduce displacements. One example of this is fuel tanks used for satellite launchers and spacecraft. If accurate displacements are to be computed, geometry nonlinearities have to be considered.

Material

Material factors become increasingly important when a structure is required to function consistently and reliably in extreme environments — such as structures that must operate at high temperatures and pressures, provide earthquake resistance, or be impact-worthy or crash-worthy. Plastics, elastomers and composites are being used as structural materials with increasing frequency. These materials do not follow the linear elastic assumption of stress–strain relationships. Structures made with these materials may undergo appreciable changes in geometric shape before failure. Without accounting for this material behavior, it can be impossible to extract meaningful and accurate information from their simulations.

In the past, nonlinear analysis was associated with heavy investment in training, resources and manpower. For many, the software appeared cumbersome, challenging and intimidating. It was acceptable and often preferable to get by with physical testing alone. That is not the case today, however. Nonlinear structural simulation is no longer an intimidating tool, but rather one that ANSYS has made available to all engineers by fusing its complex physics into an easy-to-use interface in the ANSYS Workbench environment. ■



Medical check valve

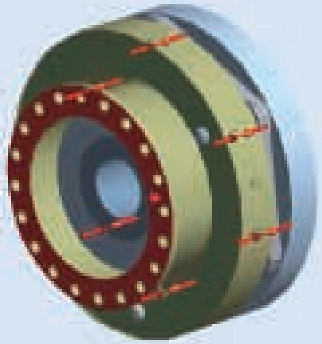
Turbomachinery Coupling

Bibby Transmissions Group — a long-time ANSYS DesignSpace user — has been a world leader for many years in the design and manufacture of couplings for use in industrial markets. The company's high-speed disc couplings, designed by its TurboFlex division, have been a popular choice for transmission couplings among the power, chemical, steel and water treatment industries.

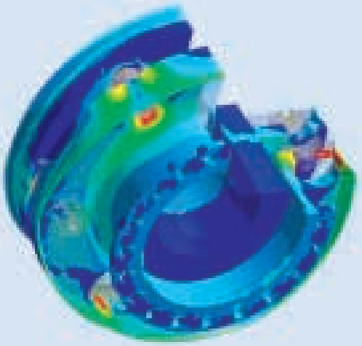
Engineers at Bibby found that with linear analysis assumptions, material yielding occurred around clearance holes where the flexible coupling was mounted and also when the coupling was rotating near its operating speed. Knowing that they were not capturing material behaviors related to contact and preloading conditions, engineers at Bibby felt a need to model the material plasticity and calculate plastic strains and deflection. This analysis was undertaken to ensure that the loading-induced plasticity was localized and did not induce global failure for the coupling. The simulation required nonlinear modeling of contact in which the couplings used an interference fit, material behavior for the hub and spacer, and bolt preloading for the couplings.

Bibby engineers successfully set up this model within the ANSYS Workbench *Simulation* tool using the previously mentioned nonlinearities and were able to accurately predict the observed behavior. In addition, they were able to identify operating speed — not torque as had been previously believed — as the dominant factor that influenced the observed plastic deformation. This valuable information could not have been obtained by physical testing alone.

Thanks to Wilde FEA Ltd. for assistance with this article.



The assembly model includes pretension bolted joints and BISO material for the hub and spacer.



The von Mises stress exceeds the yield limit of 700 MPA, and yet it is localized.

"Through the ANSYS Workbench platform, we have a tool that allows us to increase the performance of our products. Drastic reductions in weights and inertia of the couplings have been achieved without compromising the strength of the unit. Lateral vibration of couplings is now being estimated to a level of confidence previously unattainable without days of computation and cost."

— Ron Cooper, Technical Director
Bibby Transmission, U.K.