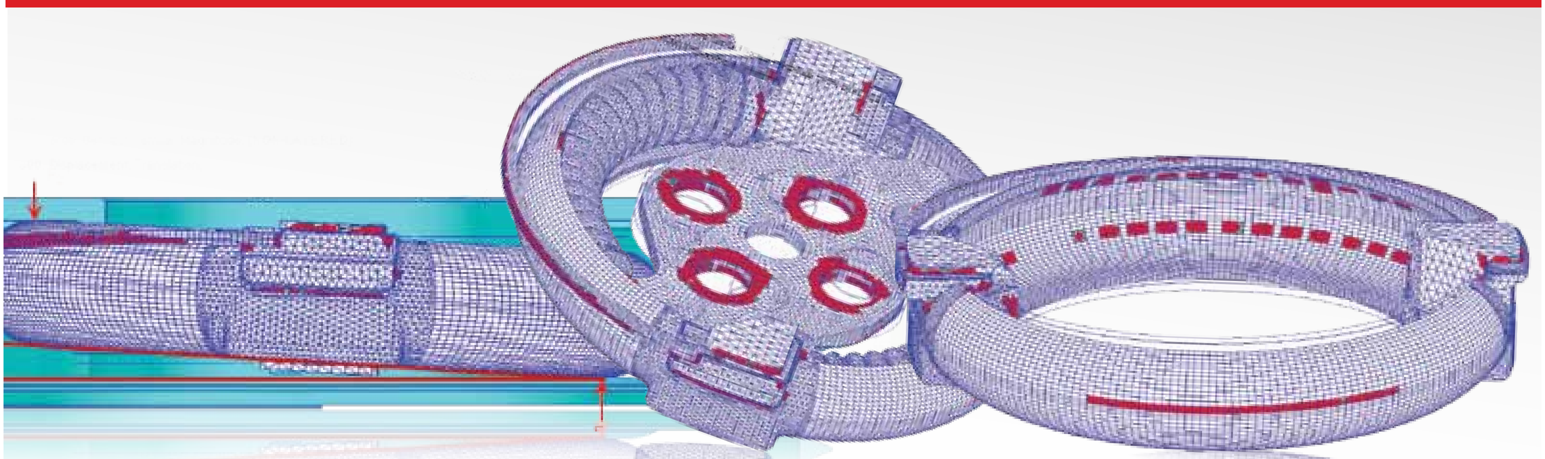
CASE STUDY

MSC Software: Case Study - Litens Automotive Group

Optimizing Engine Performance

Simulation Saves Millions per year by Getting Design Right the First Time



Litens Automotive Group's patented TorqFiltr crankshaft vibration control technology uses an arc spring isolator mechanism to decouple the accessory drive system inertia from the engine torsional vibrations. The product is dimensionally rather small but incorporates a complex mechanism consisting of a series of components that transmit power to each other through complicated frictional contacts rather than fixed connections. The product must frequently be customized to deliver optimal performance for a specific automotive engine. In the past, this involved a time-consuming and expensive trial and error process.

Recently, Litens has developed the ability to accurately simulate the operation of the TorqFiltr, making it possible to accurately evaluate performance of design alternatives and iterate to the optimal design before building the first prototype. "MSC Software's Marc nonlinear finite element analysis (FEA) software has been used to accurately predict how the design behaves, how components move and react against each other and what happens under dynamic loading conditions," said Dr. Steve Jia, Chief Engineer, CAE Technologies and Materials Engineering, for Litens. "It is difficult to accurately estimate the cost savings we have obtained through virtual product development (VPD) but we are certain that it amounts to millions of dollars per year across our complete product line."

Key Highlights:

Industry

Automotive

Challenge

To determine the magnitude, location and direction of the action-reaction forces and stress and deformation/deflection on each component and to investigate the contact mechanism in order to achieve an optimal design

MSC Software Solutions

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Benefits

- Cost and Time Savings
- Design Optimization
- Greater Understanding of Design Behaviors

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Dr. Steve Jia, Chief Engineer
CAE Technologies and Materials Engineering, Litens Automotive Group

Dynamic Tension Control

Figure 1: TorqFilter geometry

High static and dynamic accessory belt tensions reduce belt life, reduce accessory component bearing life, increase noise, waste fuel and add weight and cost through coping strategies. Litens specializes in delivering engineered control of pre-set (static) and running (dynamic) belt tension, resulting in accessory drive systems that are efficient, quiet and transmit maximum power under all conditions.

Litens TorqFiltr controls the system resonant frequency by tuning the spring stiffness to the system inertia. Because the spring stiffness is softer than traditional rubber isolators, vibrations from the engine are mostly absorbed before being transmitted to the accessory drive belt. This results in isolation of all components in the accessory drive, and any accessory drive system resonance has very small peak amplitudes since there is little excitation. TorqFiltr springs are made of steel and do not deteriorate like rubber. Additionally, the built-in automatic clutch system eliminates belt squeal associated with resonance of rubber dampers so no separate one-way clutch is needed.

The TorqFiltr device connects to the engine crankshaft through four bolts that connect to the holes in the driver shaft shown in the top half of Figure 1. The driver shaft has two wing tabs that compress the arc springs shown in red on the drawing. The arc springs connect to two shells shown in black in the drawing. Half of the shells have been removed for display purposes. The shells in turn connect to the clutch springs which are shown in gray in the drawing. The clutch springs have a frictional engagement with the pulley that drives the accessory belt.

Very complex engine vibration loading drives the device. The arc springs absorb most of the angular vibration energy of the engine and the clutch transmits power in only one direction, serving to decouple the engine from the accessory drive system. It's interesting to note that none of the components in the load path have a fixed connection each other and torque is transmitted only through frictional contacts rather than fixed connections. In addition, the contact conditions including the magnitude, location and direction of the contact forces are continually changing as torque varies or the device rotates.

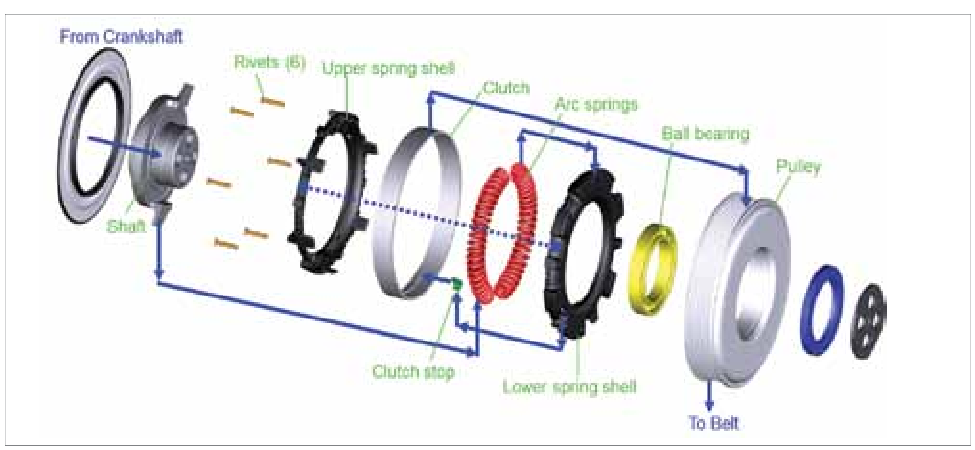


Figure 2: TorqFilter Mesh

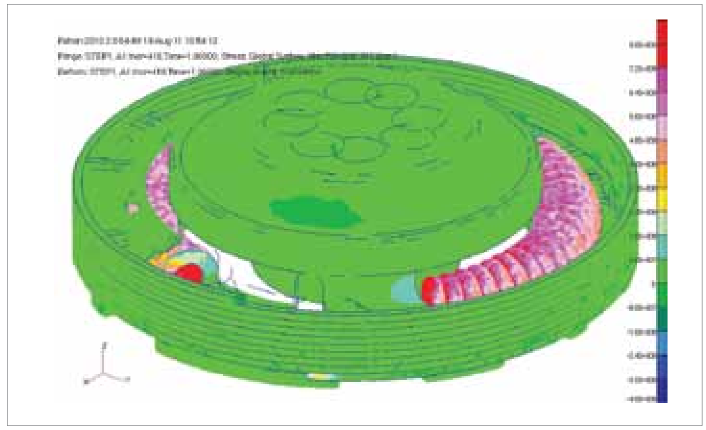


Figure 3: Maximum Principal Stresses

Design Challenge

"This device provides an enormous design challenge," Dr. Jia said. "We need to fully understand the behavior of the design under dynamic loading conditions in order to ensure that we will deliver the right products at right first time. We need to determine the magnitude, location and direction of the action-reaction forces and stress and deformation/deflection on each component and to investigate the contact mechanism in order to achieve an optimal design. Moreover, the automotive industry is very cost-competitive and weight-conscious so we also need to remove unnecessary material in the design in order to minimize the weight."

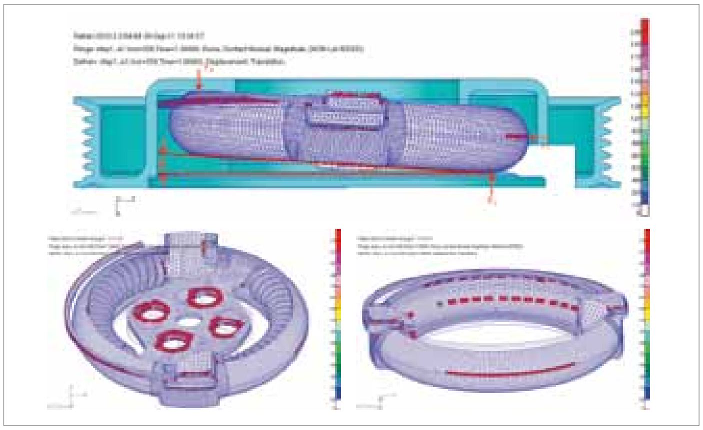
"We can determine the overall dynamic performance of a crankshaft decoupler through physical experiments but the information that can be gained from physical experiments is limited because there are no sensors available at a reasonable cost that can tell us what is going on inside that small assembly," Dr. Jia continued. "We are still left guessing as to what is happening inside such as contact locations and forces and stresses and deflections of the individual components."

Picking the Right Simulation Technology

Litens has evaluated a number of different simulation technologies. Large displacement dynamic simulation systems such as MSC's Adams software do a great job of simulating complex mechanisms, however, they are not designed to handle the elastoplastic nonlinearities seen in this application. There are a number of finite element analysis software programs on the market but most are limited to solving within the limits of linear material properties and displacements, small strains and small rotations. Some software packages claim to have nonlinear capabilities but are not able to consistently and reliably solve problems involving continually changing contact conditions between components, large rotational sliding frictional contacts and elastoplastic material behaviors.

On the other hand, Marc was built from the ground up to consistently obtain converged solutions for highly nonlinear problems involving nonlinear materials, large strain and displacement and contacts. Marc also provides multiphysics capabilities, enabling engineers to simulate coupling between structures, thermal, fluid, acoustics, electrical and magnetics.

Litens analysts receive a detailed computer aided design model from the company's design engineers. They import the geometry into Patran, the company's pre-processor of choice. The biggest challenge in pre-processing is to reconcile the detailed meshing required in areas such as where the clutch inserts into a slot in the lower spring shell with fillets of 0.2 mm with the need to keep mesh size as large as possible in areas with smaller transients to reduce solution times. Patran gives Litens analysts complete control over the mesh distribution. Analysts typically manually create a surface mesh in critical areas and use the automesher to fill in the less critical areas. The model is then sent to a high performance computing computer with 32 CPU/cores and 256 gigabytes of RAM for solution.



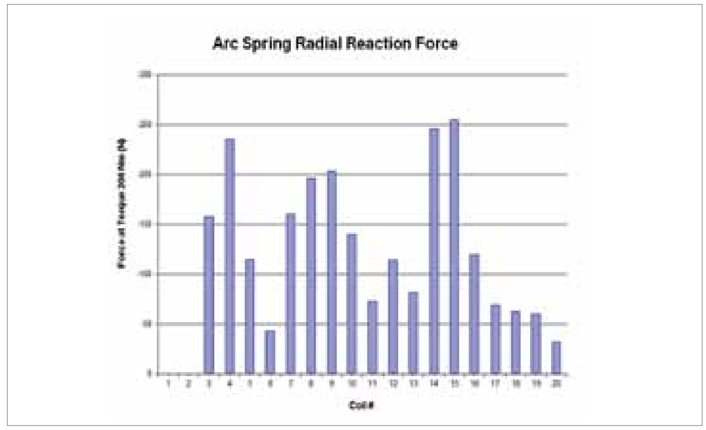


Figure 4: To virtually measure - Tilting angele vs. torque; Contact Force vs. torque; Contact location vs. torque

Understanding How the Design Behaves

The simulation results enable Litens to understand how the design behaves, how the components affect each other and what happens as the product rotates through large angles of displacement. “We can see how every component moves and reacts against other components as the product rotates through its full range of motion,” Dr. Jia said. “We can determine contact locations, contact forces, stresses and deflections, many things we need to know to optimize the design of the product. For example, our clutch was originally designed in an S-shape based on previous experience, but the FEA results showed us that a C-shape provided much better performance at no increase in cost. Simulation results with Marc are consistently within 5% to 10% of physical testing results, and even less than 5% in some cases, giving us confidence to use simulation to drive the design process.”

Figure 3 shows the maximum principal stresses at one point in the rotation. The figure shows that the highest stress is in the arc springs. The ability to view stress on each location of each component makes it possible to identify hot spots so they can be corrected to avoid premature failures. At the same time, areas where stresses are low present the opportunity to remove material to save costs. By the way, for this plot the scale was set to 900 Megapascals in order to easily view stresses in the arc spring in relation to other components. Litens analysts lower the scale in order to distinguish differences in stresses among the components with stresses that are so close to each other that they all show up as green in Figure 3.

Figure 4 highlights the ability of Marc to determine the contact locations and forces. The colored areas show the location of the contact and the magnitude of the contact forces. Analysts can determine these values at any point in the rotation or can generate an animation that visually shows the contact locations and forces changing as the device rotates.

“It’s not practical to obtain this type of information using physical testing,” Dr. Jia said.

“Marc has been widely used in our everyday VPD to simulate the complete mechanism and to virtually measure everything we need to optimize the designs. Marc not only substantially reduces development time and cost, but also is the only tool that enables us to investigate how the proposed design works and how the product behaves when a physical part is not available during conceptual development stage or a physical experiment is not practical or cost-prohibitive,” Dr. Jia said. “Over the years, we have developed great confidence in both the Marc software platform as well as our own ability to apply the tools in an accurate and consistent method. Obviously this approach saves money and time and has become such an embedded part of our engineering process that I cannot see us developing any new product without this capability.”

About MSC Software

MSC Software is one of the ten original software companies and the worldwide leader in multidiscipline simulation. As a trusted partner, MSC Software helps companies improve quality, save time and reduce costs associated with design and test of manufactured products. Academic institutions, researchers, and students employ MSC technology to expand individual knowledge as well as expand the horizon of simulation. MSC Software employs 1,000 professionals in 20 countries. For additional information about MSC Software's products and services, please visit www.mscsoftware.com.

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About Marc

Advanced Nonlinear & Multiphysics

Marc is a powerful, general-purpose, nonlinear finite element analysis solution to accurately simulate the response of your products under static, dynamic and multi-physics loading scenarios. Marc's versatility in modeling nonlinear material behaviors and transient environmental conditions makes it ideal to solve your complex design problems. With its innovative technologies and modeling methodologies, Marc enables you to simulate complex real world behavior of mechanical systems making it best suited to address your manufacturing and design problems in a single environment.

With the solution schemes that are smarter and designed to provide the performance that you need by taking full advantage of your hardware combined with an easy to use modeling solution, you can truly discover and explore nature's inherent nonlinearities. Whether your problems involve large deformation and strains, nonlinear materials, complex contact or interaction between multiple physics, you have reached the end of your search and with Marc, you can now focus on improving your designs.

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