Knowing the System

It's more important than ever to understand the full system your individual components are going into. Here's the latest in how software developers are helping you do that.

Alex Cannella, Associate Editor

No component is ever made in a vacuum. No matter how big a gear you're making, it exists as part of a larger system, and understanding how it does so is paramount to making sure it fits a customer's demands. Whether you're manufacturing a specific gear or building entire gearboxes, your product's parameters are going to be defined at least in part by the other components it needs to interact with.

There's an awful lot to consider, too. There are basic considerations like the application, industry, how many copies you'll have to manufacture, and so on, that will inform design choices like what material and gear shape to use. Is the application mobile? What kind of temperature will it be operating at? How does it interface with the surrounding parts? Any shock loads?

But you also obviously have to consider the components a gearbox will be interacting with directly — the bearings, shafts, and anything else that might be crowding in and limiting design space.

"Your first focus is on the gears," Gunther Weser, general manager, technical support at GWJ, said. "But in the second step, you have to look of course to the shafts and to the bearings."

Part of that is making sure the shafts are strong enough to take the load coming from the gears, but you also need to consider deformation and the shaft's stiffness. And you also need to make sure whatever bearing is getting attached to your gearbox is strong enough, otherwise both components could suffer truncated service lives. In addition, a proper bearing can sometimes compensate for a poor shaft angle.

This is true no matter what you're looking to construct, be it a gearbox for a conveyor system or gear components for a transmission. SMT, whose MASTA software is primarily utilized for simulating transmission systems, be they for automotive, rail, aerospace or otherwise, also sees the industry push towards understanding the entire system said transmission is going to be a part of.

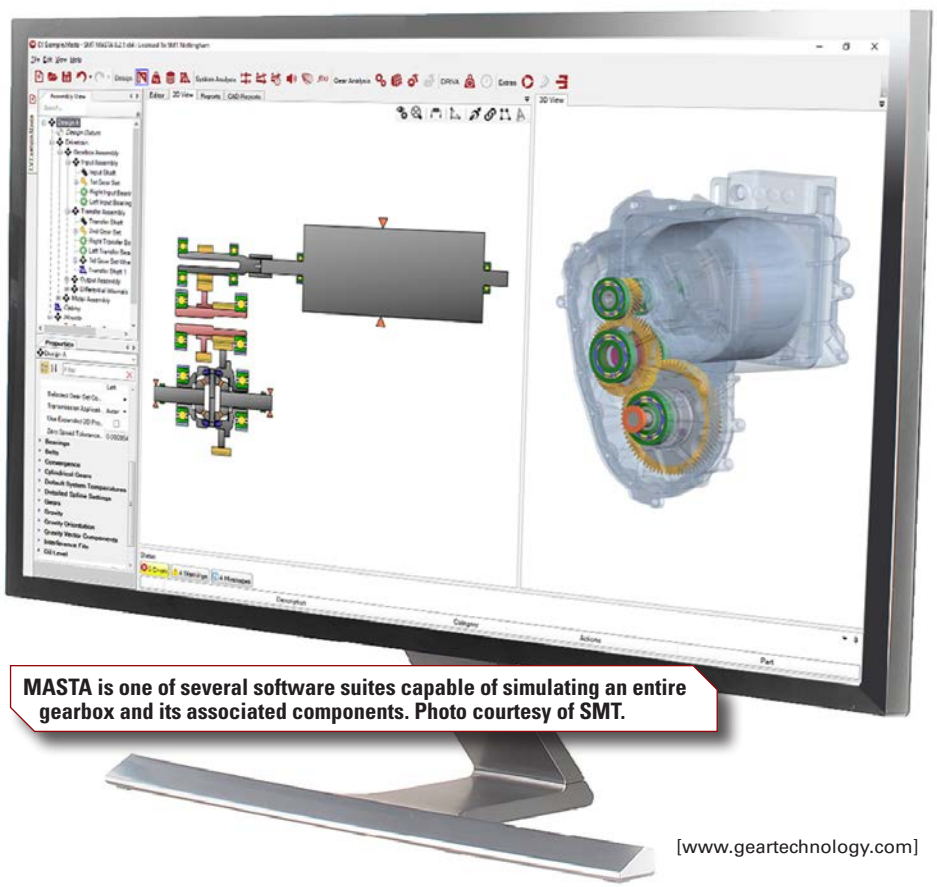
"When designing a heavy-duty automotive transmission, it is critical to understand the conditions it will be used in," Matt Sheridan, senior transmissions engineer at SMT, said. "These transmissions can experience a wide range of environmental temperature, operational gradient and shock loading; these factors need to all be accounted for from concept through to detailed design phases."

Suffice to say, just simulating a gear pairing doesn't cut it. In order to understand and calculate all these parameters, you need software capable of simulating the full system: gearbox, shaft, bearing, and all. Otherwise, you risk missing something that could critically hamstring your component's life expectancy and/or performance out in the field.

"A component's performance is very sensitive to its misalignments and deflections," Sheridan said. "As components are optimized based on their deflections, calculating these incorrectly can significantly impact the durability and noise of each component."

There are already plenty of products on the market that answer this need, as well — SMT's MASTA software being just one of them. MASTA's software is capable of analyzing full system performance, including, just to name a few things: gear, shaft, and bearing static, fatigue ratings, system stiffness and misalignments, and power loss and efficiency, both for individual components and the full system. It's also capable of tracking dynamic responses, modal behavior, and sound power levels of multiple components.

Similarly, MESYS already has extensive solutions for full-system calculations, allowing users to get information



MASTA is one of several software suites capable of simulating an entire gearbox and its associated components. Photo courtesy of SMT.

about contact pressures in bearings, understand load distribution in gear pairs, calculate deflections and housing stiffness, and analyze an entire shaft and/or gearbox system as a whole.

And GWJ offers its System Manager, a piece of software that expands on top of their other software suites to simulate entire gearboxes, including shafts, bearings and gears. Using it allows manufacturers to simultaneously track both system and individual component calculations all at once.

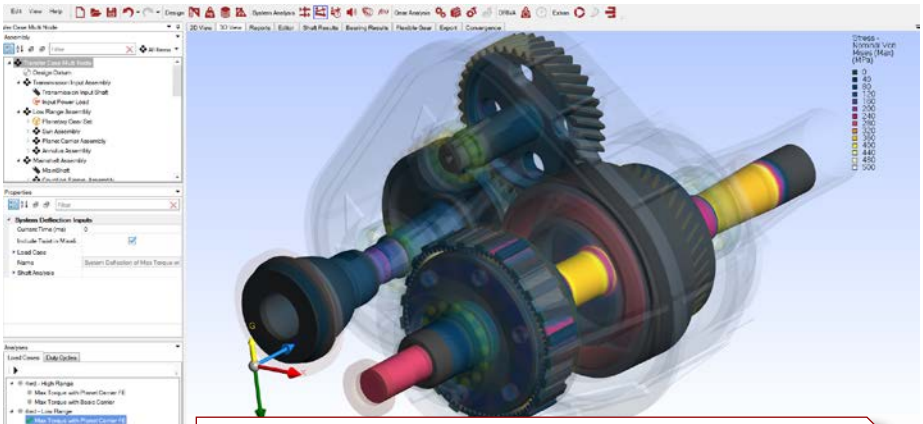
"This is an extension for both calculation software products," Gunther Weser, general manager of technical support at GWJ, said. "The System Manager is a true software application for complete systems of machine elements."

Many of these software suites are focused on speed and ease of use. Part of that is making it so that manufacturers can design components faster and more easily, but just as importantly, they're focused on reducing the computational time required on just a pure performance level, as well. It's all well and good to be able to simulate an entire system of interlocking components, but if it takes an entire day for a program to pump those calculations out, that significantly extends the development process. Cutting down on calculation time can reduce an iteration cycle from days to hours or just minutes.

"Focus for development of this system calculation was to develop an easy to use software that you can use to design very fast," Weser said.

"MASTA streamlines the modeling of transmission systems," Sheridan said. "At SMT we often see customers who, prior to learning about MASTA, are using complex FE modeling solutions which take a long time to run and are difficult to edit. MASTA removes a lot of these frustrations by allowing for analysis results to be calculated within seconds and [using] models that are easily configurable."

Sheridan also pointed to other ways a full system simulation can speed up development time outside of the software itself, as well as make the entire process more affordable, by taking on some of the responsibilities of physical testing.

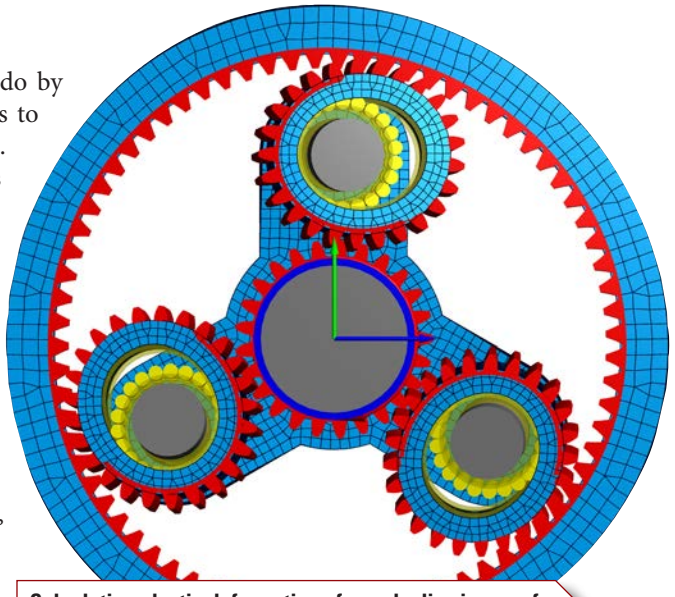


When designing a gearbox, you also need to consider how the bearings and shafts will affect your component. Photo courtesy of SMT

"Whilst it can seem like a large upfront investment to model a full transmission the benefit can be found later in the design and development process when the engineer has greater knowledge and confidence in their system performance," Sheridan said. "Developing a more robust model can reduce the need for expensive physical testing and last-minute development."

One of the most recent advances a lot of software suites have started adopting is in the field of simulating 3d elastic components. MESYS is just one example. But the most recent update to the program has expanded those capabilities further. The focus for this update was on expanding how well the software could simulate 3d elastic parts, namely creating finite element models for elastic bearing rings and gear bodies.

According to Raabe, this expansion has been a while coming. While elastic bearing calculations weren't directly requested as a feature, Raabe had come across customers curious about them, as well as elastic planetary gears. Up until recently, it was already possible to simulate an elastic bearing ring in MESYS, but it could only be done as a standalone calculation. This most recent update expands that functionality, which streamlines the amount of work one needs to do by allowing these bearings to be calculated in-system.



Calculating elastic deformation of gear bodies is one of the capabilities of MESYS software.

In particular, this new feature helps calculate potential deformations in a part.

"If you have [a non-cylindrical shape] gear body for whatever reason, it's difficult to take into account the deformations of the part," Raabe said. "Either you do a full finite element calculation or you just assume it's stiff enough and you don't have to consider that."

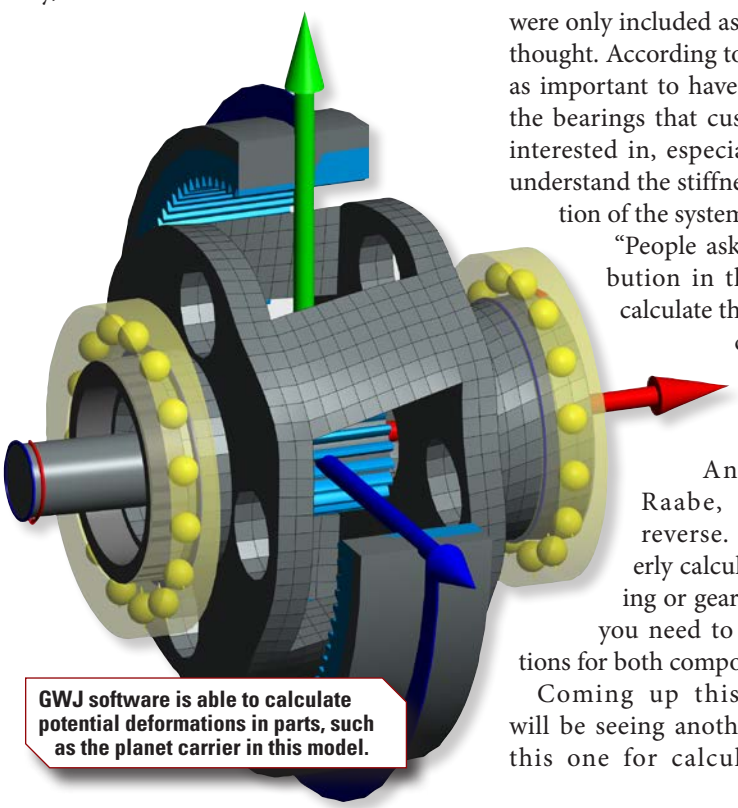
The focus for the update was foremost on the elastic bearings, as they were a topic that regularly came up in both the wind and automotive industries. Elastic gear bodies then also got included due to their similar shape, which allowed the software to calculate them similarly. Because both bearings and gears are cylindrical parts that deform, the same basic principles, and thus the same calculations, could apply to both.

But that's not to say that elastic gears were only included as a convenient afterthought. According to Raabe, they're just as important to have calculations for as the bearings that customers were more interested in, especially if you want to understand the stiffness or load distribution of the system.

"People ask about load distribution in the bearing, but to calculate that, you also need to consider the elastic gear in case of planetary gears," Raabe said.

And according to Raabe, it's also true in reverse. In order to properly calculate either the bearing or gear's load distribution, you need to know the calculations for both components.

Coming up this month, MESYS will be seeing another update, as well, this one for calculating the effects of dynamic displacement, such as, for example, vibrations generated by transmission error. Once the update goes live, MESYS will be capable of calculating the dynamic forces placed on both gears and bearings by such vibrations, something that will be helpful for some high-speed applications. The only vibrations it won't cover are vibrations from the housing itself. According to Raabe, the software is capable of calculating vibrations from the housing, but doesn't offer outputs that "could be used easily."



GWJ software is able to calculate potential deformations in parts, such as the planet carrier in this model.

Another company now offering accurate simulations for 3d elastic parts is GWJ Technology. In a February update for their System Manager software, they introduced calculations for 3d elastic and meshed parts. Much like with MESYS, gear bodies and bearings are the central focuses when introducing elastic component simulation, but GWJ's System Manager is also branching out to simulate a gearbox's housing. And here again with GWJ, one of the primary uses for the new simulations is planetary carriers.

Each of these three software suites have seen a positive reception out in the wild. It unsurprising, perhaps, since understanding the full system has become so centrally important to developing an individual component, but each software suite has individually received such a positive reception due to its ease and speed of use.

"Reception to MASTA has been overwhelmingly positive," Sheridan said. "Our

customers really value the ease of use of the software. MASTA is quick to learn and we would normally expect an engineer to be creating and analyzing transmissions within their first day of use."

Additionally, Sheridan noted that SMT's consulting staff have been a boon to their customers, which of course means these support staff have also become a central selling point for their software.

"We believe this is an essential part of our business," Sheridan said. "Supporting our customers ensures they are satisfied with our software and engineering services as well as having the additional benefit of allowing SMT to stay abreast of new demands and developments in the field of transmissions."

Weser at GWJ echoed those sentiments with some anecdotal evidence of his own about an application their software was used for. The System Manager was utilized for designing a hoisting gear unit for a crane transporting metal liquids. And in order to properly simulate the entire system, GWJ's software sure had its work cut out for it.

"Comparing the work effort of [each individual component] and the calculation of the entire system, we had 38 calculation files in total generated…" Weser said. "That means we had 12 shaft files, 12 gear calculation files, and 14 calculations of rolling bearings. And all 38 calculations needed to be handled and updated accordingly."

It didn't end there, either, as they also had to track four different torques and two speeds. According to Weser, going through and making all those calculations one component at a time took almost two hours for a single load case. The System Manager calculated all of that in three minutes. And needless to say, the customer appreciated two whole hours of time savings per design iteration.

"The customer was very happy with this calculation because [the development went so quickly]," Weser said. "And on the other side, he had no idea how to calculate all these things with single calculations."

Ultimately, however, more than speed or ease of use, the greatest boon these software suites will provide you is knowledge. Knowledge that prevents breakdowns or malfunctions. Knowledge that will let you adjust designs ahead of time before they're proven faulty in physical testing, or worse, the field. Knowledge that speeds up the iterative design process. The system your component fits into informs so many of the parameters required for that component, and programs like these are how you understand it.

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