JULY 2002 / VOLUME 54 / NUMBER 7

SPECIAL FOCUS: FIXTURES

Fixture Element ANALYSIS

Finite element analysis helps eliminate guesswork and overdesigned fixtures.

▶ A STAFF-WRITTEN FEATURE

Designing optimal fixtures in a timely manner can be a challenge. Fixtures must be large enough to hold one or more parts, rigid enough to withstand cutting forces, capable of locating parts accurately, able to provide machining datums and allow access to cutting surfaces from multiple machining axes. Their ability to perform all these functions properly impacts part quality and cycle time, which translates into profit or loss.

Validating fixture design prior to manufacture can be performed with relative ease using finite element analysis software. With FEA, a model of a fixture is created from CAD drawings. FEA then takes the model's complicated structure and reduces it to a series of discrete pieces by converting it into tiny triangles, or finite elements.

Once it is decided that FEA will be utilized, fixture designers should key on two factors: deflection and natural frequency. FEA computes fixture deflection by applying the known or calculated cutting forces.

FEA software shows exactly how the item will flex under the applied cutting forces through a color-coded output. Colors indicate the amounts and locations of deflection. If deflection is beyond allowable limits, the design can be modified to reduce deflection to acceptable levels. In this way, the designer knows the fixture is loaded exactly as it will be during the machining operation and how much it will deflect under actual applied clamping and cutting forces.

By examining the fixture's natural frequency with FEA, a designer can determine how the fixture will vibrate if subjected to a force that excites one of its natural frequencies or mode shapes. He or she can also determine in which direction the fixture is most susceptible to vibration.

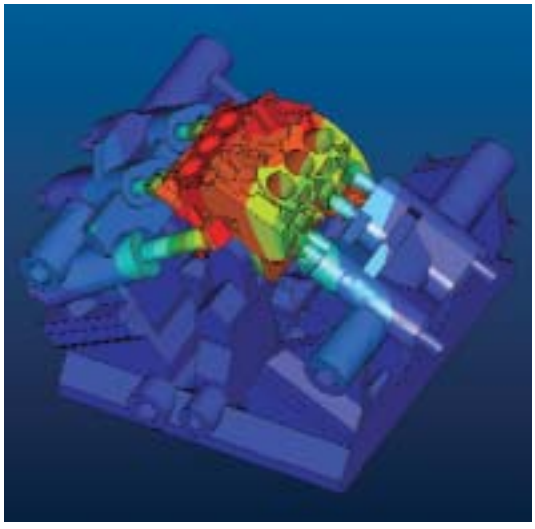
If a fixture vibrates at a natural frequency equal to or near the cutter frequency during machining, there could be a problem. For example, a fixture with a natural vibration frequency of 20 Hz would be troublesome if the spindle speed is 1,200 rpm, because 20 cycles per second, or 20 Hz, times 60 (the number of seconds in a minute) equals 1,200 cycles per minute. If the cutting tool frequency equals the fixture frequency, resonance is likely. On the other hand, the same fixture run at 5,000 rpm would not match the fixture's natural frequency.

The software uses the same information an engineer would examine if he were to crunch out the design with a pencil and slide rule. Usually, this means the fixture material's density, Young's modulus and Poisson's ratio (the ratio of the deflection in one direction when a force is applied in a different direction). These are commonly available in material specification sheets.

However, problems can occur in the application and interpretation of the units, constraints and loading conditions. For example, most FEA software packages don't convert units. Hence, if a CAD drawing is dimensioned in millimeters but material data for the model is entered in inches, the deflection, as calculated by the software, could be off by a significant factor.

Fixture Forces

Lamb Technicon Machining Systems, Warren, Mich., builds systems for the Big Three automakers and their Tier One and Tier Two suppliers. The company uses FEA to design fixtures for applications such as machining cylinder blocks and cylinder heads.



Lamb Technicon Machining Systems

This front view of a 6-cylinder engine block shows how cutting forces generate part and fixture distortion, as illustrated by the color bands that correspond to levels of displacement.

Phil Szuba, the company's director of research and new product development, recommends that analyses be performed by degreed mechanical engineers.

The systems Lamb Technicon builds can have up to 100 different stations, and each station can have its own fixture. Since errors compound as the number of fixtures increases, FEA helps to eliminate error accumulation that could occur due to part and fixture deflection as workpieces are transferred through the manufacturing process.

After the machining system is specified and tooling is set up, the metal-removal rate is determined. Tool layouts incorporating speed, feed, thrust, power requirement and mrr are then created.

"At this point, we know what the expected forces are on the fixtures," Szuba explained.

After the fixtures are designed, an analyst models the fixtures, applies the forces through FEA and interprets the results, modifying the fixtures if necessary.

"Only after fixtures meet design parameters and constraints will they be manufactured," Szuba said.

Another company that uses FEA software is Royal Machine & Tool Corp., a Berlin, Conn., manufacturer of modular fixtures and tombstones. John Darling, chief engineer, stressed that the software is not just for "the big guys," particularly given the growing use of high-speed machine tools.

"Getting maximum production from these machine tools is critical," Darling said, "and a fixture such as a tombstone has to be lighter. As such, there's been a migration toward thinner sections in cast iron and aluminum fixtures."

Darling pointed out that if, for example, part arrangement on a lighter-weight tombstone calls for three or four parts per side, one side can experience a high level of stress, causing it to deflect as parts are mounted on the opposite side. "That means the fixture moves. As a result, machined parts might not meet specifications. FEA allows us to predict and eliminate those problems.

"Furthermore," Darling added, "when tooling engineers and programmers don't have the information provided by FEA, like fixture deflection and resonant frequencies, they can have a very difficult time producing parts that meet finish requirements or tolerances."

Not surprisingly, FEA helps ensure that tooling in the most stringent of applications holds to the tightest tolerances. For example, Los Angeles-based Stadco recently completed a proposal for Lockheed Martin for the wing and forward fuselage assembly tooling for the $200 billion X-35 Joint Strike Fighter. FEA was used in conjunction with the jet's wing tooling, which is 25' high, 50' long and 54" deep.

"As the components are assembled into the tooling and then machined during the assembly process, the tooling and wing must maintain dimensional integrity, so that when that the wing is complete and removed from the fixturing, it has the dimensional requirements Lockheed intended," said Bob Wiederrick, Stadco's manufacturing engineer. "FEA software identified where we needed to beef up the structure or reduce it. FEA is the instrument that led us to success."

Don't Jump to Cost Conclusions

Undoubtedly, FEA makes sense for shops that are proficient with CAD and have designers or engineers on staff. Shops with a low volume of work or those using handprints or hard-copy prints and no one trained in CAD, though, may presume it's difficult to cost justify the purchase and use of the software. That assessment may be mistaken.

While it is true that the price of FEA software can drift up into the five-figure range for stand-alone systems, depending on the individual company's situation, it can also cost as little as several hundred dollars if a company is already running CAD software and can add on programming to that.

No matter the complexity of the application, smaller job shops can reap the benefits of FEA without purchasing software themselves. The answer: contract fixture designers and FEA software providers. Some software providers share their software through rental agreements, and others allow clients to submit CAD files for analysis. All a shop needs is access to the Internet.

Local universities with mechanical engineering programs are usually capable of performing FEA, too.

John Buchowski, product line manager for Needham, Mass.-based PTC concurs and added, "The answer is relative. If a shop runs into problems meeting tolerances because a fixture flexed too much, it might consider using FEA sooner than if it had not run into problems, or FEA may be a customer requirement."

FEA for fixture design is a change in how things have been done, and therein lies another hurdle—overcoming resistance to change. Some people will have to be convinced that a few days extra for FEA on the front end of a job can save 5 weeks of tweaking on the back end.

The following companies contributed to this article:

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