White Paper

PTC®

Making Better Decisions, Faster: How Mechanical Engineers Are Improving Efficiency with Engineering Calculation Software

On March 28, 1979, America's worst nuclear accident took place at Three Mile Island – due in large part to a faulty valve that got stuck in the open position. According to writer Mike Gray, interviewed for the PBS program American Experience: Meltdown at Three Mile Island, the valve that sat on top of the pressurizer was "like a drawer that's too wide. You know how you pull on a drawer and, if it's wider than it is deep, it kind of – well, that valve had been designed that way. That was a mistake, an engineering error. So that instead of sliding freely, it had a tendency to twist. So it failed, and it failed in the open position and they didn't know it."

The same thing occurred at a plant outside Toledo, Ohio, a few months before. But fortunately someone closed the lower block valve on a hunch, which sealed the line and saved the plant. The accident from Toledo was never properly communicated to the operators of identical plants across the country, but that's another story.

The brush with nuclear catastrophe is a lesson for all mechanical engineering organizations that require precision, high performance and effective knowledge management for success. Can your engineering processes prevent a similar situation from developing? Are you able to provide sufficient documentation to mitigate your mistakes?

The right calculation software can be a powerful tool that enables engineering teams to more easily solve problems, generate ideas, share important data and catch mistakes before they have major consequences. Why then, do so many mechanical engineers rely on error-prone, limited and often paper-based legacy calculation methods, like Microsoft® Excel® spreadsheets or even a programming language like Fortran?

This short paper will explain some of the important reasons why modern mathematical software is a much better alternative for mechanical engineers – not only for performing complex calculations but also for understanding the intent behind them. You'll learn how more mechanical engineering enterprises are finding that their best interests lie not in the incidental information that spreadsheets provide, but in mathematics software that treats every calculation as a key business asset.

Ten Mechanical Engineering Calculations that Are Easier with Dedicated Software

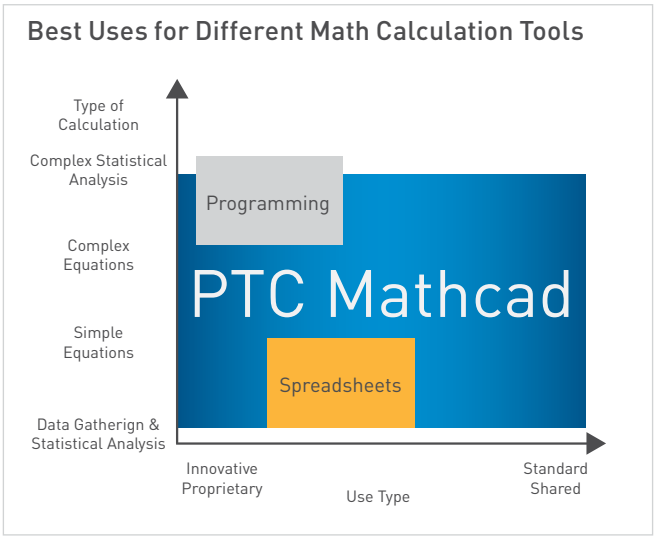
- Gear Speeds/Gear Sizing
- Power Output
- Torque and Speed
- Heat Dissipation
- Friction Loss
- System Dynamics and Responses
- Engine Performance
- Coil Spring Analysis
- Velocity and Acceleration
- Systems of Linear/Nonlinear Equations

Success Factor #1: Accelerate design time to market

"I have 30 people reporting to me," says an engineering manager for Arbor Networks, a company that designs Distributed Denial of Service (DDoS) protection for enterprise computer systems. "I'm under pressure to deliver projects on time and to ensure that our engineers have the resources necessary to do their job."

This should sound familiar to you, since most engineering-oriented companies have the same top-of-mind concerns. Engineers in all disciplines are struggling with decreasing time-to-market deadlines – and many don't even realize how much time they're wasting by trying to document calculations done in Excel.

Dr. Robert Phillips, an engineer who spent much of his career reverse engineering cars for General Motors, uses PTC Mathcad® software with his engineering team to save time on every project. When he first came to understand the benefits of the software over his old way of doing things, he realized that "if you can double productivity, you can reduce staff by a factor of eight and keep delivery constant – or keep those people and kill the time to market." Because many new products are variants of existing designs, it's important to capture and organize the original analysis tied to these products for others to find. Legacy calculation methods frequently lead to significant rework, which in turn creates longer development lead times, ties up valuable resources and ultimately results in a delayed time to market.



Spreadsheets and programming languages are optimized for specific types of calculations, while engineering math software like PTC's Mathcad are good for virtually all types of calculations – from the simplest to the most complex.

Success Factor #2: Get your creative juices flowing more freely

Exploring multiple design concepts and what-if scenarios early in the design process is important for projects that demand innovation and design optimization. It can be mission-critical for mechanical engineers to solve challenging problems in key disciplines such as mechanics, thermodynamics, robotics and mechatronics.

Design studies and trade-off analyses are best practices that help engineers make better design choices faster, knowing that they've evaluated all the best options. Using mathematical models to establish performance envelopes and cost trade-off curves,

engineers can quickly identify the design solution that most effectively meets product requirements. A well-documented study or analysis should make it clear why the proposed design offers the best tradeoff between performance and cost – and give reviewers a high degree of confidence that a better solution has not been overlooked.

By using mathematical calculation software, mechanical engineers can predict the performance of designs before modeling the physical geometry. Calculation software can be used early on to determine the appropriate physical design dimensions and parameters used in CAD models. Unlike spreadsheets that require complex formulas to convert measurements, the right mathematical calculation software provides built-in unit conversion and unit intelligence so that engineers can spend their time creatively solving problems rather than on mundane tasks.

Success Factor #3: Improve precision and minimize costly mistakes

Speed and creativity don't mean much if your designs aren't accurate and easy to understand. Calculation software can also improve the precision and thus performance of individual engineers and engineering teams. Robert Phillips acknowledges that he "can generally clear things up as I work through a Mathcad model, instead of saying, 'Oh no, what's wrong here?' later in the process."

Spreadsheet expert Raymond Panko points out that "every study that has attempted to measure errors, without exception, has found them at rates that would be unacceptable in any organization." Rick Butler, an auditor who writes and speaks widely on the error-prone nature of spreadsheets, concurs, asserting that spreadsheet developers miss more than 80 percent of their own errors, and outside testers miss more than 50 percent of design logic and 34 percent of application errors.

[1]Panko, Raymond R (2009). "What We Know About Spreadsheet Errors," Spreadsheet Research (SSR. 2 16 2009), University of Hawaii, February 27, 2009.

[2]Powell, S. G., Baker, K. R., and Lawson, B., (2007b), "Impact of Errors in Operational Spreadsheets." Proceedings of the European Spreadsheets Risks Interest Group, 2007b.

Spreadsheets and programming languages essentially hide the logic behind engineering decisions, which makes it much more difficult for complex work to be quickly and properly verified. With legacy calculation methods, errors are more likely to show up downstream in a project, when the costs of rework are multiplied exponentially. Or worse, the errors may make their way into the final product. Even honest mistakes pose a serious risk to most product development organizations, and calculation software does a much better job of keeping them to a minimum.

A Disaster Waiting to Happen: Why Risk Your Most Important Calculations to Spreadsheets?

- According to researcher Raymond Panko, 94 percent of spreadsheets have errors, and the average cell error rate (the ratio of cells with errors to all cells with formulas) is 5.2 percent[1];
- Out of 25 operational spreadsheets studied by S.G. Powell, 10 had an error impact ranging from $216,806 to $110,543,305[2];
- Olson & Nilsen found a 21 percent cell error rate among experienced spreadsheet users[3].

Success Factor #4: Collaborate with less friction

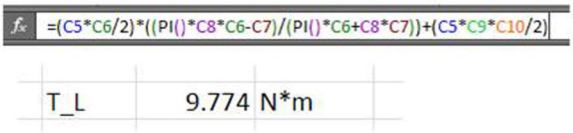
By standardizing the way calculations are solved and documented, organizations can make valuable engineering information visible and accessible to key people throughout the organization. This makes it easier to check another engineer's calculations, reuse calculations without having to rewrite them, gain management approval and otherwise collaborate more effectively.

The calculation methods available for solving engineering problems are not always the best tools for capturing and sharing intellectual property. Calculations are valuable to engineering organizations not only because of the end results, but also because of the assumptions, methods and values behind the results.

[3]Olson, Judith Reitman and Nilsen, Erik. "Analysis of the Cognition Involved in Spreadsheet Interaction."Human-Computer Interaction, Volume 3 Issue 4, December, 1987

Mathematical software provides engineering teams with sharable documents that explain everything they need to know about the design process, including text, interactive math calculations, graphs, and actual drawings and models. Reusable worksheets can be saved in several formats, including Microsoft Word, Adobe® PDF, HTML and XML, making it easy to share information with a variety of stakeholders, even if they're using different document management applications, CAD programs and PDM solutions.

Natural Math Notation Enables Collaboration



The logic of engineering calculations can get buried in spreadsheets, while it is perfectly clear in calculation software.

Using standard math notation, integrated text and graphical displays, calculation software can automatically generate readable documents that are easily understood up and down the management chain and across diverse teams.

Success Factor #5: Reduce the stress of regulatory reporting

In addition to facilitating knowledge transfer internally, calculation software makes it easy for organizations to report to regulatory agencies and clients responsible for auditing vendor quality processes.

Spreadsheets lack the controls and documentation capabilities needed for proper traceability. Calculation software, on the other hand, simplifies and streamlines documentation that's critical to communicating and to meeting business and quality assurance standards. All engineering information is in one place with appropriate annotations: Calculations, methods and values can be shared as the company sees fit with a wide variety of parties outside the engineering division.

Case Example: Evaluating Yield Strength in Candidate Materials for Robotic Armature

The engineering team at an industrial equipment manufacturer is asked to evaluate the yield strength and cost trade-offs for robotic 'finger' materials under different gripping forces. The materials evaluated include steels like ASTM A36, ASTM 514, and stainless steel ANSI 302, along with high-density polyethylene (HDPE).

Using calculation software, engineers quickly formulate a series of visual trade-off equations and plots to calculate the area moment of inertia for bending of the armature model.

The built-in equation editor enables the team to express component solutions in familiar, natural math notation, with automatic unit checking for accuracy. The team can focus on the design experiments and analysis itself, rather than laboring to "program in" formulas that are hard to read and difficult to communicate.

Evaluating maximum stress as a function of material thickness is given a jumpstart by the calculation software's open architecture. Collected in an earlier project, the yield strength, ultimate strength, and density values for the materials under evaluation were imported from a Microsoft Excel spreadsheet.

The team can easily incorporate this information into the worksheet they're using to conduct their trade-off analysis. The team minimizes the thickness for each material within a safety factor of yield strength, and generates a graph that visually displays the trade-off between materials.

Considering all the constraints and stated goals, the team concludes that the optimal material is HDPE. There's ample room in the design envelope to accommodate the thicker armature, which also meets the tensile and yield strength requirements. The resulting mass is 37.5 percent of the equivalent A36 steel structure, and the cost of HDPE is less than the steel.

The entire analytic process is automatically documented, step-by-step, in the calculation software worksheet, and can easily be reviewed or reused by subsequent teams on different projects. The team could also import armature dimensions and gripping geometry directly from a CAD model into the calculation worksheets. With everything tied together, any changes to the calculation software model would dynamically modify the CAD model.

Conclusion: Finding the right math calculation software for mechanical engineering

Engineers in all disciplines are struggling with decreasing time-to-market deadlines – and many don't even realize how much time they're wasting by trying to document calculations done in Excel.

Spreadsheet developers miss more than 80 percent of their own errors, and outside testers miss more than 50 percent of design logic and 34 percent of application errors.

Using standard math notations, integrated text and graphical displays, calculation software can automatically generate readable documents that are easily understood up and down the management chain.

Modern calculation software is a much better alternative for performing complex calculations and understanding the intent behind them. Your best interests lie not with the incidental information that spreadsheets provide, but with calculation software that treats your calculations as key business assets.

Those who do step up to modern calculation programs, like Robert Phillips did with PTC Mathcad, are often amazed at the results – and how easy it is to hit the ground running. All engineers owe it to themselves to at least take advantage of the free 30 day trials that the major math calculation packages offer, just to see how the software can take their performance to new levels of success.

Sources

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PTC Mathcad is the Industry Standard Software for Engineering Calculations.

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