Henkel Adhesive Technologies

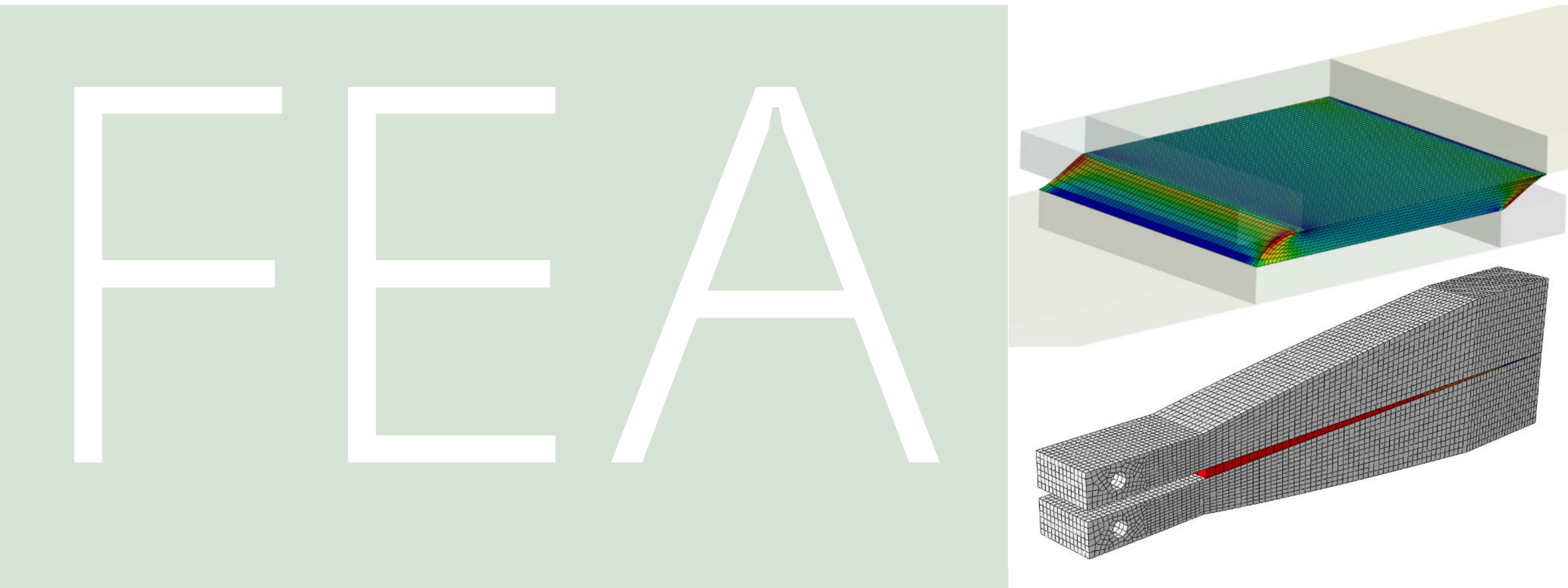
REIMAGINING PRODUCT DESIGN AND *ACCELERATING* TIME-TO-MARKET

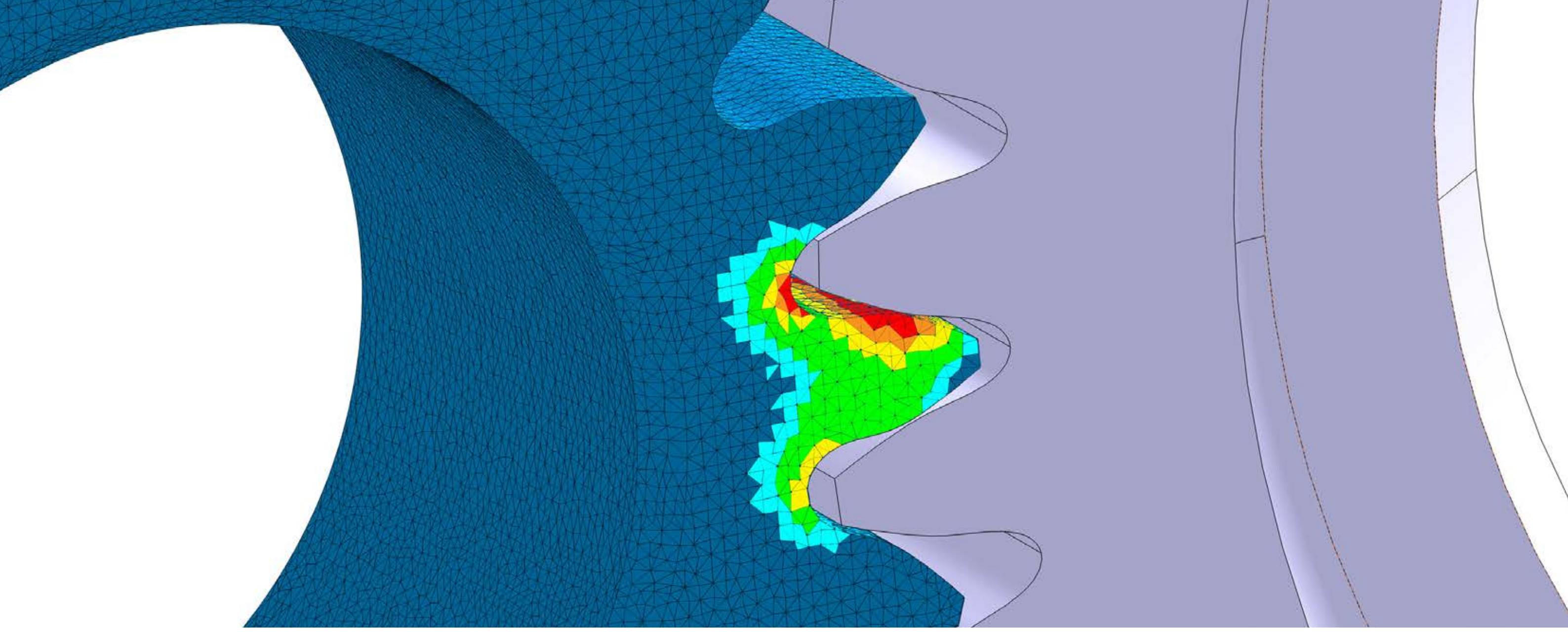
Finite Element Analysis is Making it Happen

Simon Stahl

Design engineers today are under immense pressure. Whether they're developing automated equipment, robotics, electric motors, vehicle structures, or seemingly simple products like a standard security camera, the demand for cost-efficient manufacturing, reliable function, and longevity is intense. Add to this the crucial need for product sustainability throughout lifecycles, and the challenges become even more daunting.

As product complexity increases and sustainability becomes a higher priority, traditional, time-consuming approaches to development, prototyping, and testing are no longer viable. This is especially true when considering shrinking time-to-market windows. Fortunately, Finite Element Analysis is a powerful method that can help. FEA can predict performance, optimize design elements, improve product quality, and achieve sustainability goals, all while minimizing waste and enabling exceptionally fast modeling and analysis. FEA is not a new technology, but its application in the materials sector is revolutionizing the design process.





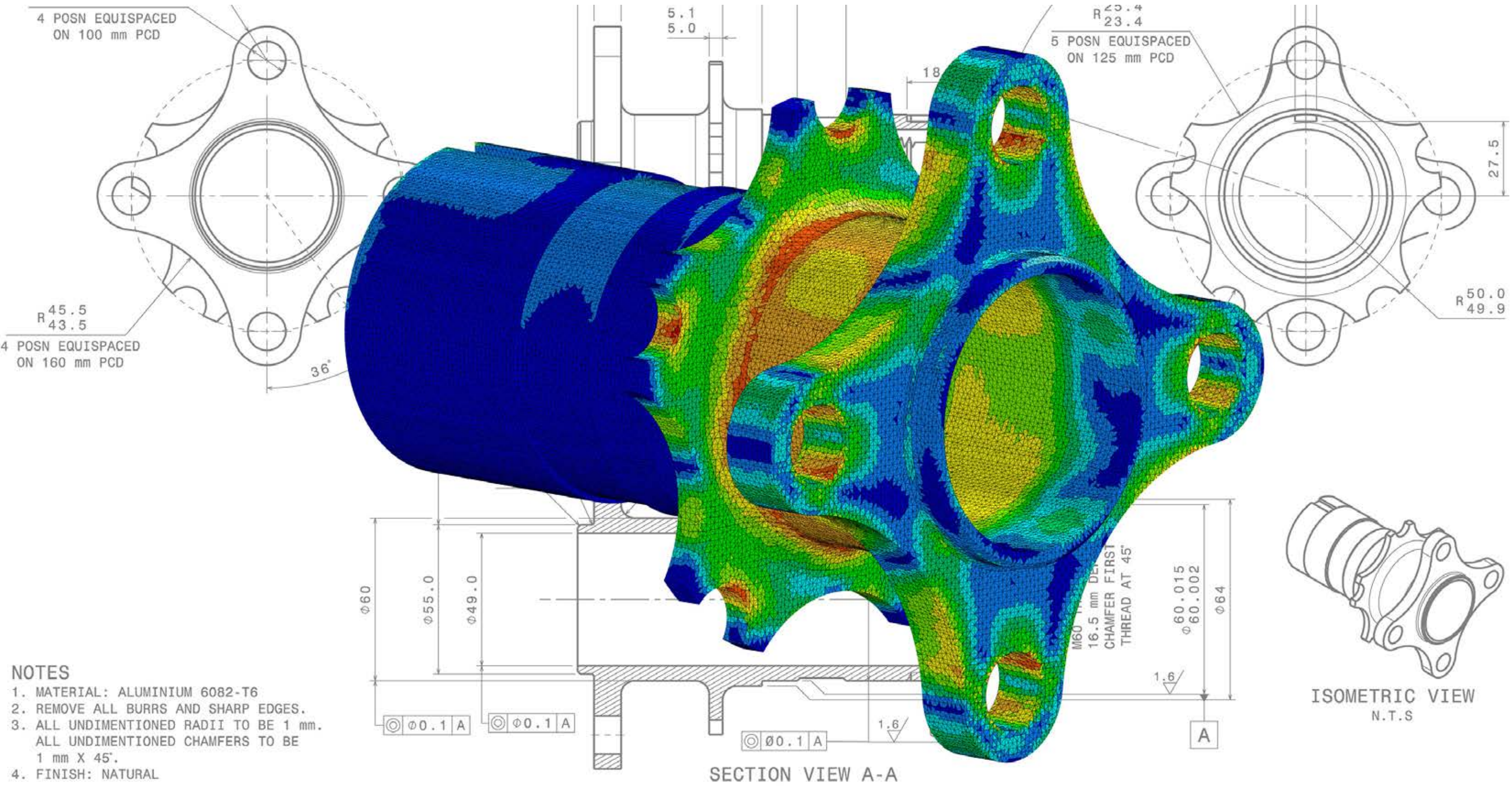
Moving Beyond the Perennial Prototype

With FEA, the days of the traditional product development process of design, build, test, redesign, build, test again, repeat, repeat, repeat ... until a successful outcome is reached are over. Finite element analysis is a modeling and simulation methodology that offers expedited and precise predictions of a structure's behavior, allowing significant reliability and time efficiency improvements. FEA applies mathematical equations to individual parts of the object, breaking down sophisticated, complex structures into a finite set of points to understand and analyze each element. Then, mathematical equations within each element are solved, providing the load impact on the entire system, while enabling isolation of the stress or strain in individual elements. Which is not possible with physical testing. FEA facilitates a comprehensive assessment before more expense, time, and risk are incurred. To be clear, FEA's aim is not to replace physical prototyping but to model, simulate—and then build—a prototype for which there is confidence that it will meet its performance objectives.

FEA and Materials Modeling

While FEA has been widely used in multiple industries – especially those with somewhat high risk like automotive or aerospace – the obvious advantages of the technology are now being leveraged for other applications, including material analysis. Henkel, a longtime user of FEA, has intensified its efforts, bolstering its expert staff and internal capabilities in recent years, as the company sees this as essential to helping customers achieve product performance and sustainability ambitions.

Material exploration that previously would have taken weeks or months is reduced to mere days – and often with better results. In Henkel's case, using FEA to model bonded joints and the performance of various adhesive chemistries allows predictive performance of bonded parts for unlimited scenarios such as strength or crash simulations. With FEA, product safety, reliability, sustainability, and longevity can be enhanced.



The models used for adhesive materials analysis include:

VISCOELASTIC—As a linear material model, viscoelastic is generally used for small strains to understand the strain rate, strain frequency, and temperature impact to evaluate material behavior when deformation's impact is limited.

ELASTOPLASTIC—This continuum-based model employs elastic and plastic characteristics to evaluate the effect of high stress and strain levels and non-linear behavior in adhesives under varied mechanical conditions.

FINITE STRAIN—Typically used to simulate adhesives experiencing significant deformation, finite strain models mechanical responses under tension, compression, and shear.

COHESIVE ZONE—A fracture mechanics-based material model, cohesive zone replicates crack separation within a bond line and is valuable for predicting cohesive failures with adhesive bonds.

While FEA is an incredibly powerful tool that is becoming more intuitive with advances in AI, its proper application requires precise, informed inputs and expert guidance. Professional collaboration with FEA experts to achieve effective outcomes is imperative. Selecting the appropriate model based on the project's specific requirements and analysis objectives is crucial, as is executing the routines and evaluating the data. This requires know-how and underlines the importance of expert guidance in the FEA process.

Sustainable Results: Strengthening Bonds, Reducing Emissions

Though product design objectives vary, one of FEA's more notable advantages is its contribution to sustainable design. These benefits go beyond waste reduction, time-to-market expediency, and cost efficiency. FEA has also been instrumental in facilitating complex designs with emission reduction as a core objective. One inspiring example is Henkel's work with a customer to redesign a vehicle cabin frame. This project aimed to replace welding with bonding while reducing the frame's weight by 50% and involved using a different base material – moving from standard stainless steel to thinner, high-strength steel. The thinner steel typically cannot be welded, so adhesive bonding is the only option.

Using FEA, Henkel conducted deep analysis of all the bonded joints, made modification recommendations, and the epoxy adhesive was analyzed using the elastoplastic model.
In the end, the new design resulted in emission reductions of 42%, while delivering a robust and durable structure able to pass the stringent ROPS rollover vehicle testing.

Seeing the Future of Design

Finite element analysis, when applied in collaboration with design engineering expertise and material science know-how, helps industrial design professionals visualize product robustness and performance, customize designs to precise specifications for waste reduction, improve safety and reliability, analyze infinite temperature and condition scenarios, significantly reduce cost, enhance sustainability, and speed market introductions. FEA as applied to materials performance will continue to play an increasingly important role in product development processes, driving the future of design and delivering a competitive advantage.

Simon Stahl

The Author

Simon Stahl is a mechanical engineer with over 15 years of experience in testing and simulation. Currently serving as a Lead Application Engineer for Simulation in the Industrials business unit of Henkel Adhesive Technologies, he has developed deep expertise in advanced engineering technologies, including 3D printing.

Throughout his career, he has been dedicated to driving innovation and solving complex customer challenges, constantly seeking new solutions and methods to enhance performance and collaboration. Passionate about the future of engineering, he remains committed to advancing technology and improving industry practices. Based in Germany, Simon holds a diploma degree in mechanical engineering from TU Dortmund University.

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