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What Manufacturers Need to Know About Generative Design

A technology white paper for executives

ptc

DIGITAL TRANSFORMS PHYSICAL

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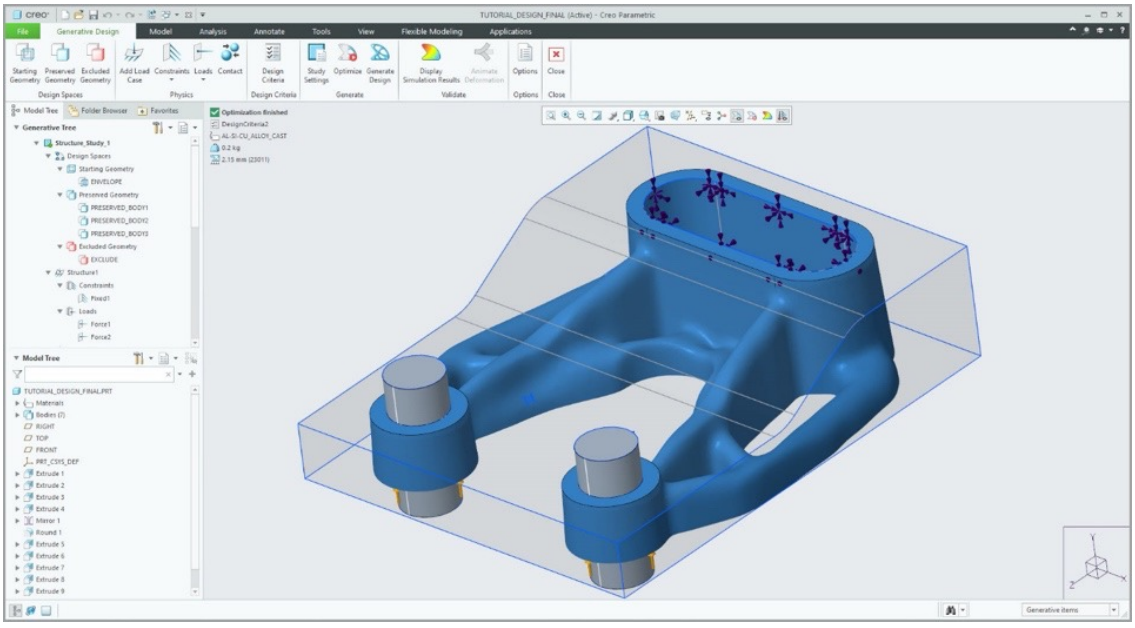
INTRODUCTION

BETTER PRODUCTS AT LESS COST – NOW.

It's the clarion call of today's marketplace and the prime directive for executives in any business that designs or produces physical goods, no matter how simple or sophisticated. Fortunately, every product can be improved and made at less cost. But how quickly a company can satisfy such demands – before, say, its competitors do, or the market moves on to something new – is largely a function of the product-development cycle. Shorten that cycle, and you can improve the numbers across the board, from customer satisfaction to market share to profitability.

However, one seemingly intractable barrier to faster product development lies within the traditional design process. That process starts with identifying a need in the market or within one's organization; it ends with the manufacture of a finished product, whether a massive, complex assembly or one tiny part. In between are multiple iterations of designs and tests: engineers sketch out a solution, prototype and test it (or run a computerized simulation), and then go back to the design to address any shortcomings. But trade-offs complicate matters each time the cycle repeats: make a part lighter and it's likely to become weaker, make it stronger and it will probably cost more, and so on. A workable, if not optimal, solution can usually be found. However, finding it often takes longer than the product-development timeline or budget will allow.

Generative design not only expedites design iteration cycle, but it also conceives designs an engineer would never dream of.



Shape optimization with PTC Creo. (Picture courtesy of PTC.)

In the simplest of terms, generative design is computer-aided design amplified by artificial intelligence and, sometimes, cloud computing. It takes much of the design-test-repeat cycle out of engineers' hands, performs it exponentially faster than humans can and produces optimized designs that meet all pre-established performance criteria. Need to design a lighter, stronger and less expensive item that's composed of a particular material and must be manufactured in a particular way? Generative design might be your most efficient solution.

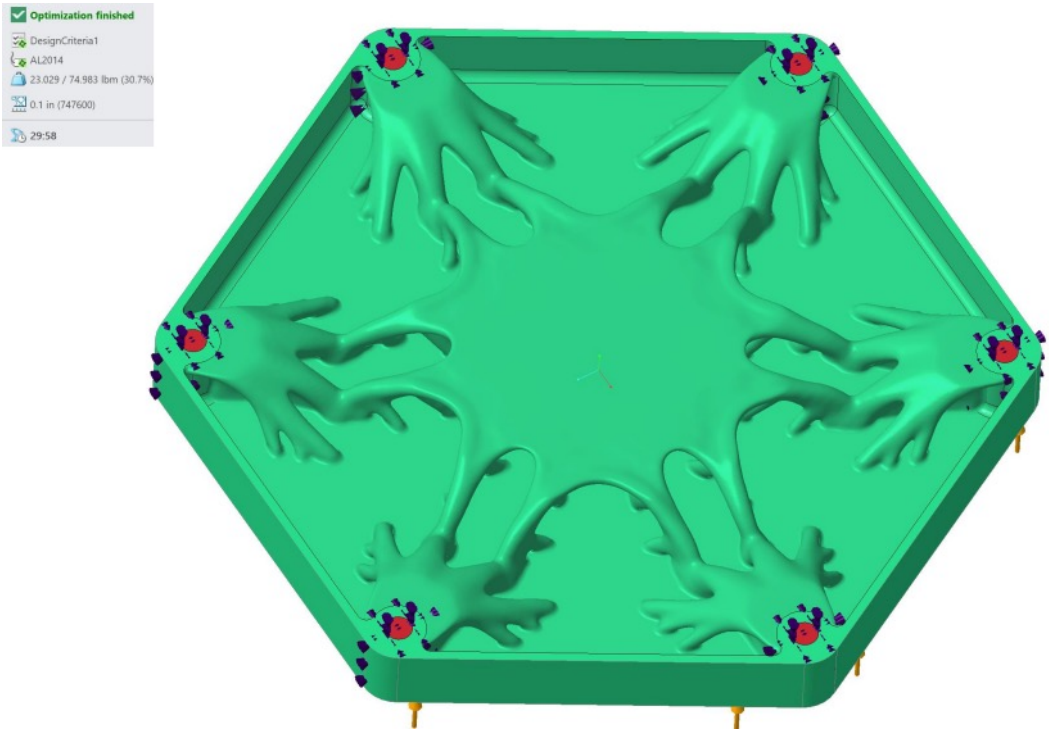
As more organizations learn to work with generative design, executives must develop a basic knowledge of this emerging technology, understand the business case for its adoption and explore how their own companies can deploy generative design to gain competitive advantage.

GENERATIVE DESIGN 101

A good starting point for understanding generative design is the infinite monkey theorem. It states that a monkey hitting typewriter keys at random for an infinite amount of time will, eventually, type any given text (even the contents of this whitepaper). Similarly, a monkey with a sketchpad could randomly draw shapes until it arrived at the optimal design of a specified object – although neither the monkey nor an observer would know when the optimal state had been achieved.

Generative design is not the infinite monkey in computer form. Although some randomization is involved in both cases, the similarities end there: generative design tests its designs on the fly and uses the results of those tests to make further optimizations to the model.

The process begins with a design space or "bounding volume" in which the desired product or part must fit. (For ease of reading, we'll use "part" to cover any object being designed.) The bounding volume can be a cube of specified dimensions or something more complex, such as the shape of an existing part being redesigned. The design space will contain other parameters, both geometric and non-geometric – say, how the part will be held in place (restraints), the forces it must resist (loads), its maximum weight, the material it will be made of, and how it will be manufactured. The generative design system (i.e., software and hardware) then uses algorithms to produce and test (virtually, of course) countless design permutations in search of one that jibes with all the user-defined constraints.



Optimized shape created by Andreas Vilhanos.

As each permutation is tested, the software learns from the results and applies those lessons to the next iteration of the design. When a shape finally meets the prescribed design criteria and is optimized, it's presented to the user as a valid design option.

Of course, computers do this work thousands of times faster than humans can. That does not mean a final design will be achieved thousands of times faster, because generative design is used at the beginning of the design process to produce optimized shapes, one or more of which an engineer can choose to refine using other CAD tools. Still, by taking the laborious task of basic shape creation and optimization out of human hands, generative design accelerates the design cycle.

Why is refinement needed at all? Generative design will optimize for all of the supplied parameters, placing material only where it needs to be to handle the prescribed loads. Any desired trade-offs or remaining criteria, such as a unique manufacturability requirement or some undefinable aesthetic standard, will be addressed by human designers after generative design phase.

THE WIDESPREAD BENEFITS OF GENERATIVE DESIGN

Successful technology deployments are commonly characterized by efficiency gains among those who use the technology, which trickle down to the bottom line and satisfy corporate finance departments. However, the impacts of generative design can be more widespread, directly benefiting HR, sales, and public relations.

POWER THROUGH THE PEOPLE

Typically, engineers begin a design job with some notion of the required shape, informed by their knowledge of what's likely to work and what's not. They apply that expertise to every iteration of the design. Although many workable designs can be produced by relatively inexperienced engineers, some jobs call for an engineer with decades of experience. For example, the ability to identify load paths almost intuitively – and, therefore, quickly – is gained through years of stress analysis.

The above scenario presents two business challenges. First, highly experienced engineers command salaries that can stretch product-development budgets. Second, such seasoned pros could be getting harder to come by. According to a 2018 report by the National Science Board, between 1993 and 2015 the proportion of U.S. scientists and engineers aged 51 to 75 rose by 20 percent. The same report identified a rapid decline in full-time work among the group, starting at age 55.

If a manufacturer loses a substantial amount of experience to retirements, generative design can help fill the void. It requires no specialized expertise and little training to operate, allowing companies to entrust a significant part of the design cycle to greener engineers assisted by generative-design tools. Lower labor costs are a happy coincidence of this shift.

Even a company overflowing with experience can benefit from extracting their veteran engineers from the conceptual stages of the design process. Why expend high-priced talent on tasks that lower-cost employees can perform, especially if there's higher-value work to do?

A NEW STORY FOR SALES

Few things excite salespeople more than a new product or feature they can discuss with customers. They're equally jazzed by a product improvement that helps them overcome objections or win product-comparison battles against competitors.

Unfortunately for the sales team, it's not easy for designers to come up with new ideas that are both feasible to produce and likely to seize the attention of buyers. Their thinking tends to stay in the orbit of the familiar, particularly if a part is commonplace or if they've designed something similar before. Moreover, a designer is always under time constraints, and the fastest way to gain momentum on a design job is to start with a design they've created before. After all, why waste time and energy fixing a part that isn't broken?

Generative design can give sales teams something to talk about, because its "thinking" isn't limited by pre-conceived notions of a part. It simply churns out design after design, constrained only by the parameters prescribed by the user. As explained previously, a human might default to a geometric solid for a part, whereas generative design is more likely to create a shape found in nature.

Because of its incredible efficiency, generative design can also be used to optimize existing parts that wouldn't otherwise merit the time and attention of a human designer. A given part might leave great room for improvement, particularly if it was designed before the advent of certain materials or manufacturing methods. A part that inhibited sales prior to optimization by generative design could suddenly become a salesperson's favorite talking point.

ENVIRONMENTAL ACTIONS SPEAK LOUDER THAN WORDS

For manufacturers who want to reduce their environmental footprint and achieve sustainability in their operations, generative design can be an important enabler. Recall that generative design puts material only where it's needed. When applied to the redesign of an existing part, the process is almost guaranteed to result in a design that uses less material and, therefore, weighs less – two outcomes with clear benefits to the natural environment. Generative design also makes it easy to create and test designs using alternative materials that are sustainably acquired and result in fewer greenhouse gas emissions over their lifetime of use. Public relations, regulatory affairs and other communications personnel can communicate such measures to customers, business partners, investors, and governments.

ADDITIVE OR SUBTRACTIVE: IT'S YOUR CHOICE

A persistent misconception of generative design is that it's made exclusively for additive manufacturing. It's simply untrue that molders, casters and machinists need not enquire into generative design.

Although designs produced by earlier generations of the technology required manufacture by 3D printing or other additive manufacturing processes, the latest generative design software includes manufacturing method among its user-defined constraints. Designs for CNC machining, molding and casting are all possible, unlocking opportunity for a huge swath of the manufacturing sector.

WHICH BUSINESSES WILL BENEFIT MOST?

Generative design is an option for any company for which the weight, size or strength of parts and the time to design them has a material impact on business performance. Lighter parts require less power to move, meaning lower energy costs. Stronger parts translate into lower repair and warranty costs, not to mention increased safety. Reducing the size of a single component might not make a noticeable difference, but an assembly of smaller parts could form a rightsized whole that enables new applications and attracts new buyers.

Perhaps the greatest strength of generative design is its ability to conceive functional parts that use less material than predecessor designs. For any manufacturer where the cost of materials is significant, this alone makes the technology worth careful consideration.

Given generative design's most obvious applications, it's no surprise to learn which industries are early adopters of the technology.

AEROSPACE

Thanks to its natural ability to trim the fat off parts, generative design is a no-brainer for the aerospace industry. The cost of launching material into space increases with the material's weight. NASA's Space Shuttle's launch is said to have cost more than $50,000 per kilogram. Competition may have reduced the expense of parts by a factor of 20, but even at $2,750 per kilogram of payload on a SpaceX Falcon 9 rocket, the cost remains considerable.

NASA contracted the 5,000-employee Jacobs Engineering space group of Dallas, Tex., to service the International Space Station, prepare the Orion crew capsule, and stack and integrate the Artemis rocket-launch system and the next generation of "space backpacks," the Exploration Portable Life Support System (xPLSS).

The xPLSS may weigh nothing in space but pulling it away from Earth's gravity exacts a considerable cost. With the help of generative design technology, Jacobs engineers have reduced the weight of the parts in the xPLSS by up to 50 percent, according to Jesse Craft, Senior Design Engineer and Innovation Project Manager at Jacobs. Generative design saves design time, too – as much as 20 percent, according to PTC. But Craft is most appreciative of the creativity generative design can unlock.

"The most exciting thing about generative design to me is it challenges my biases," says Craft. "As an engineer, I like right angles, flat surfaces, round dimensions, and generative design says that may not be the best solution. So, if I want to be the best possible engineer at my job, I look to generative design to find those kinds of solutions."

AUTOMOTIVE

While the lightweighting of space freight illustrates the cost-cutting power of generative design most dramatically, the ubiquity of freight in transit on the Earth's surface translates into far greater savings potential. Volvo's SuperTruck program aims to reduce fuel consumption with lightweighting and improved aerodynamics. Generative design makes it more feasible to explore designs that incorporate less material not only by volume but also by density, like when aluminum or titanium substitute for steel.

A bulky bracket that holds the SuperTruck's engine fan motor firmly in place is a perfect candidate for lightweighting. The bracket was optimized for weight for three types of manufacturing: 3D printing, CNC machining and then for molds and casts – with full consideration of parting lines and angles.

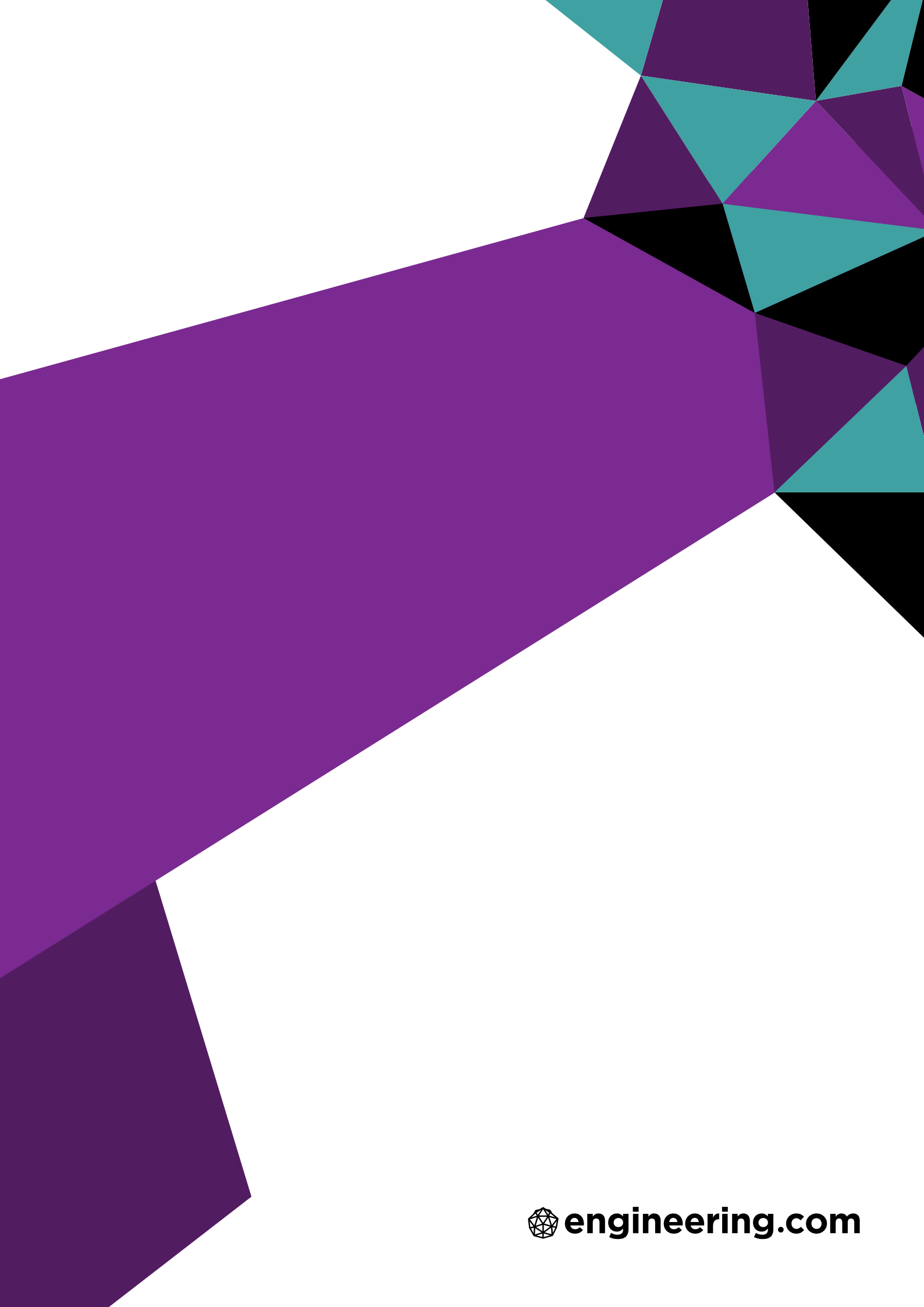
Machine design and operation also can benefit from minimal weight. Cummins, a large diesel- and gas-engine manufacturer headquartered in Columbus, Ind., has enough rotating and reciprocating parts on its factory floors to make their optimization worthwhile – not only to reduce the company's energy costs, but also to improve its environmental sustainability. As part of Cummins' ambitious PLANET 2050 initiative, the company aims to reduce its greenhouse gas emissions by 50 percent by 2030. Since generative design assures a part can withstand its loading, Cummins expects its engineers to explore the use of materials with lower carbon footprints. Already, Cummins has used generative design to reduce the material needed for a part by 10-15 percent, according to PTC.

"We're taking very seriously the amount of material that we put into our new designs and the amount of water that is required to manufacture them," says David Genter, Technical Project Leader and former Director of Design Engineering at Cummins. "Given that most of the CO2 footprint is determined within an item's design phase, if you don't utilize generative or if you choose a suboptimal material that can't be recycled, reused or remanufactured, that ship sails very early in the whole design and development process."

IN CONCLUSION

Like any emerging technology that proves its worth and gains a foothold among its intended user base, generative design will receive the attention and investment required to continue its evolution. It will become more powerful and easier to use; it will be developed for new applications and, conceivably, users will discover new applications for it.

Getting the most out of generative design will require companies to invest in strategic planning, education and the tools themselves. Some companies are already using generative design to significant advantage. For other organizations trying to meet the demand for better products at less cost *now*, there might be no better time that the present to seriously explore the potential of generative design.



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