

TIME SAVINGS IN PRODUCT DEVELOPMENT THROUGH CONTINUOUS SIMULATION

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Today's fast-paced economy and complex global market has made it difficult for manufacturing companies to maintain their competitive edge. Products being developed today must stand apart from others, and lead the market in the way they meet customer needs. Tools to reduce product development time have been in use for decades, but recently new tools have become available to make significant reductions in the product development cycle. Specifically, simulation tools are becoming very useful for saving time in the design-build-test phase of product development.

New simulation tools that compress the product development cycle change the way design errors are found and refined. Traditional product development would create a design, prototype that design, and test it for failures, then repeat the process until the performance was acceptable. A newly developed process combines CAD, CAE, and FEA simulation tools to create an interactive feedback loop in the front part of product development to significantly reduce development time.

DesignXplorer VT (DX-VT) uses CAD, CAE, and FEA to form an easy to operate virtual simulation tool that can be used by engineers and designers in multiple stages of product development. From generating innovative designs, to shedding light on how designs can be optimized for peak performance, DX-VT has tools to make product development easier. Using DX-VT in the concept design stage and throughout the CAE analysis and testing stage will give designers and engineers a complete breakdown of what design parameters need changed.

I have used DX-VT to create a benchmark test of how the software can be used for product development. I have used real world virtual prototypes from Technip Inc. to evaluate the realistic applications of this software. To capture this process a best practices guide was created to be a general guide on how to efficiently use Workbench Design Modeler, Simulation, and DesignXplorer for enhancing product development. This guide was tailored to Technip Inc. and their most recent project, the Red Hawk. The best practices guide demonstrates how to use the Ansys Workbench software to simulate actual components from the Red Hawk oil rig. The guide shows all the steps and features that were required to get this real life model to solve properly. The results of this product development process will cut development time at Technip by 1000's of man hours, and help in their goal to cut design costs by \$2 million per project.

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I dedicate this project foremost to my family. They have supported me for twenty years of education with love, admiration, and care packages. Their approval and encouragement has been essential to the completion of this project. They are my biggest fans, and I appreciate and love them for it.

1.0 INTRODUCTION

Today's fast-paced economy and complex global market has made it difficult for manufacturing companies to maintain their competitive edge. Products being developed today must stand apart from others, and lead the market in the way they meet customer needs. Whether the product excels in performance, value, durability, or any other attribute, it must compel consumers to select one product over another. Even more demanding are the time requirements necessary to develop these products. The time to market for a product very often determines its success or failure. Tools to reduce product development time have been in use for decades, but recently new tools have become available to make significant reductions in the product development cycle. Specifically, simulation tools are becoming very useful for saving time in the design-build-test phase of product development.

In his book, *The Virtual Engineer: 21st Century Product Development*, Howard Crabb remarks: "In a globally competitive environment where one lost opportunity can sound the death knell for an entire company, getting customer-focused, innovative designs to market fast is becoming an overriding determinant of whether a company thrives, survives, or dies." [1]

1.1 CUTTING PRODUCT DEVELOPMENT TIME

1.1.1 Better Engineering

Almost all manufacturers are under pressure to reduce time and costs in product development, while making improvements to product quality and performance. Managers of these firms have traditionally tried to pressure their engineering staff to be efficient as possible in an effort to shorten the time required to create engineering drawings, test design functionality, release products to manufacturing. All these efforts are done because of a need to increase profits by minimizing overhead costs and improve the return on investment.

Some of the ways that help engineers to be more efficient is to give them the proper tools to do their job. Using the most current technology helps engineers stay ahead of the curve of cost-effective product development. Gregory Roth, of Eaton Corp., talks about product development tools in his paper *Analysis in Action: The Value of Early Analysis*. He says:

Manufacturers have a wide range of computer-based tools available to support the product development process. Rapid prototyping systems quickly convert CAD models into physical prototype parts so users can hold, handle, fit together, and evaluate the appearance of components. Knowledge-based engineering captures technical standards, procedures, and other information in software to automate routine design tasks. Empirical testing systems utilize state-of-the-art, software-driven input equipment for duplicating real-world conditions, sensor technology for accurately measuring responses, and statistical methods for interpreting results. Solid modeling enables engineers to define parts and assemblies in 3D space and utilize this geometric and associated product data in a variety of downstream applications. CAE utilizes simulation and analysis technologies, such as finite-element analysis (FEA) used to study stress, deformation, vibration, temperature distribution, and other behavior in structures. [2]

Mr. Roth continues by talking about how these tools are used effectively in industry:

These tools do not act in isolation, but rather together in supporting the product development process, much like the underlying pillars of a bridge. Each has individual tasks and defined areas, but all are necessary for the total support needed. No single tool can effectively solve the entire problem; they all must be used in conjunction with one another to shave excess time and expense from the product development process. So work performed with one tool must always be tailored in consideration of the others. Otherwise, efforts are often counterproductive, delays are introduced, and important benefits are negated. [2]

1.1.2 Better Manufacturing

Similar to the efforts in the engineering departments, manufacturing departments have been re-organizing and streamlining production processes with an optimizing method known as lean manufacturing. Lean production tries to eliminate waste in every area of manufacturing. Its goal is to achieve the least possible manufacturing time, human effort, inventory, and shop space that can still produce top quality products in an efficient and economical manner. Popular lean manufacturing techniques have acronyms such as JIT, TQM, MRP, and KANBAN. Since the mid 1980's American companies have been using these techniques to push manufacturing to the limits of efficiency in an effort to compete in this difficult global market. Every dime and every second that can be squeezed out of the manufacturing process helps the bottom line for the company, and keeps them competitive. [3]

1.1.3 Better Marketing

More and more of today's companies now recognize that, even though running at peak operating efficiency is important, this alone does not guarantee success in the marketplace. Many firms are now focusing on time to customer, because market share can be directly related to who gets their products to buyers first. These manufacturers see that releasing products late has a direct correlation with lost market share. With this intense focus on getting products to customers quickly, companies need to know where market opportunities are the biggest so that product launches are in the right place at the right time. That is why businesses are spending large amounts of money in market research and forecasting to determine how their products will perform in the market place.

1.1.4 Better Managing

The way organizations are structured can have a huge impact on how efficiently they operate, how quickly they can change direction, or how flexible they are to new ideas. In product development teams all these issues are critical. Having good people in a team is important, but just as important is the way managers create a team that operates smoothly. Together each team member should feed off the others to stimulate new ideas and pool their talents to be as efficient as possible.

Product development teams today have come a long way from how they operated 20 years ago. Old manufacturing companies use to develop products with departments for each function. Products would go from the marketing department to design to development and testing and so on. The interactions between groups use to be called throwing the product "over the wall". A large amount of companies today are developing products with cross functional teams. This is where members from each

necessary department work closely together on a product to solve problems as a diverse team. The diversity of these teams often provides insight to problem solving that wouldn't be seen otherwise.

1.1.5 Future improvement to product development

With all these improvements happening in every corner of manufacturing companies, what is left to improve that will give a company's products an advantage in the market? The answer lies in the product development cycle, and how cutting edge virtual prototyping tools can compress the time it takes to develop a product and still cut costs from the expensive traditional product development cycle.

These tools that compress the product development cycle change the way design errors are found and refined. The latest virtual prototyping methods combine CAD, CAE, and FEA tools to create an interactive feedback loop in the front part of product development. The savings from this process are significant, and will be shown in the section: A New Virtual Prototyping Process to revolutionize Product Development

2.0 BACKGROUND

2.1 TRADITIONAL PRODUCT DEVELOPMENT CYCLE

The traditional product development cycle consists of stages that move a product from conception all the way through production. Figure 1 below is a generic template that focuses on how to develop engineered products.



Figure 1: Product development Cycle [4]

The mission statement for the cycle is generally devised by the owner and senior management of the company. The mission statement should describe the type of business the firm wants to enter, and what they want to objective of the company is (i.e. customer service, profit, environmentally friendly, etc.).

The concept development stage is a very important stage for marketing. This is where customer needs are identified, and market segments are defined. These types of key attributes are found through several methods including identifying lead users, analyzing competing products, etc. It is critical that this stage be well thought out, else perfect products could be produced for customers who don't want them , and won't buy them.

Other departments also have some tasks to address in this phase. Designers need to determine the feasibility of product concepts, and develop initial design concepts. Manufacturing should estimate manufacturing feasibility and costs of production. Patent issues should also be addressed to protect design concepts.

In the system level design phase, the design/engineering team has the most responsibility. Designers work with engineers to define the major sub-systems and interfaces for the product, redefine the initial design as more requirements or problems arise, and generate alternate product designs that may do a better job solving the stated requirements.

Other departments like marketing need to determine product options and ways to extended product life. Manufacturing should start moving to identify suppliers for key components, perform make-buy analysis of parts, and define final assembly scheme of assemblies.

Detail Design phase is another big focus for designers and also engineers, where they define lots of details from part geometry, to choosing materials, to even assigning tolerances. Marketers focus on developing a marketing plan. Manufacturing gets very involved as they design tooling, define quality assurance processes, begin procurement of long lead tooling, and make details of the piece-part production.

The testing and Refinement phase is a large engineering task where they perform analysis on everything from reliability testing, to life testing, to performance testing. Engineering implements any design changes, and also obtains regulatory approval where it is needed. Marketing develops promotional and launch materials, but also facilitates field testing and creates a sales plan. Manufacturing has several duties including supplier ramp-up, refining fabrication and assembly processes, train the work force, and refining quality assurance processes.

The final stage is production ramp-up, where manufacturing begins operation of the entire production system. This is also where engineers do analysis to test early production output, and marketing places early production sales with key customers.

2.2 TRADITIONAL PROTOTYPING PHASES

2.2.1 Manual

Manual prototyping is the first phase of prototyping. This method is centuries old, and is traditionally done by skilled craftsmen who specialize in making prototypes by hand. These models are normally made out of wood, metal, foam, or any material that can be molded and carved into a shape that accurately represents the concept being modeled. Manual prototypes normally take an average of four weeks to produce. [5]

2.2.2 Virtual

The second phase of prototyping is virtual (or soft) prototyping. This describes the process of using computer software, such as CAD/CAE/FEA, to model a design on the computer, and then test its durability based on what the computer knows about the models physical properties such as shape, material, and loading.

This process has become very widely used since the early 1980's, and has grown so swiftly that now a days just about every company who makes engineered products uses some sort of virtual prototyping package. The functionality of this technology has also been able to grow exponentially, due in part to advancements in computer processing power. Personal computers today are capable of designing and testing models that are so complex that three decades ago were not possible on the fastest mainframes in the world. The time required to create and test these models is also decreasing as programs are becoming more user friendly and offer more functionality. Simple parts can be modeled and tested in just a few hours, and it doesn't take a Structural Analyst to get good results. [5]

2.2.3 Rapid

Table 1: Rapid Prototyping History [5]

Year of Inception	Technology
1770	Mechanization
1946	First Computer
1952	First Numerical Control (NC) Machine Tool
1960	First commercial Laser
1961	First commercial Robot
1963	First Interactive Graphic System (early version of CAD)
1988	First commercial Rapid Prototyping System

Rapid prototyping (RP) is the third prototyping phase, and was started in the mid 1980's, but as you can see from Table 1 there have been a lot of necessary breakthroughs before RP could ever be conceived. Today's RP process involves three steps to creating a physical rapid prototype. First, a model is created on a computer with a CAD package. The model is created with only closed surfaces, and is best done by using solid modeling CAD software. The second step is to convert the CAD model into a Stereo Lithography format, or .STL file. This format approximates the surfaces of the model into polygons, which helps the computer better analyze the curves in the model's surfaces. The third step is to have the computer analyze the .STL file and slice the model into cross sections from the bottom up. In a rapid prototyping machine, these cross sections are systematically recreated one at a time out of liquids or powders. Each cross sectioned layer is created on top of the previous section and joined to create a 3-D model. This process takes an average of three weeks to physically create a relatively complex part. [5]

2.2.4 Advantages of Virtual Prototyping

Virtual prototyping has become very sophisticated in its recent advancements and has become superior to the other phases of prototyping. Simulation in virtual prototyping gives very good approximations of how models response to loads or other environmental factors. These prototypes can contain 100's of different materials and then be simulated to determine how these materials will perform. Other advantages to virtual prototyping include the ability to easily go back and change or fix design problems without physically rebuilding any prototypes. Simulations can be re-run even easier then the first time, because much of the setup work has already been done. Therefore tests are easily repeated.

When making presentations or reports, virtual prototyping is very convenient because all the results data is already on the computer and can be transferred into a presentation or cut and pasted into a report. Colorful presentations with motion or cross sectional views can also be utilized, by showing those results from the simulations. In Ansys Workbench products, reports are automatically generated and are a clear format for showing how results were obtained, and what the outcome was.

Virtual prototyping has become very necessary for manufacturing firms who need to reduce their reliance on physical testing. For example, by using virtual prototypes, Baker Atlas Inc. was able to reduce unnecessary hardware prototypes in the design of a new leak proof elastomer seal for oil-well drilling instruments. These units are used in deep wells five miles below the surface, where pressures exceed 25,000 psi and temperatures reach 400° F. [6]

At Baker Atlas, Eyad Ammari is the mechanical engineering analyst who developed the seal. According to Eyad, designs for several prototype seals of different shapes and sizes would ordinarily have been molded and tested, with each iteration taking at least six weeks. By using ANSYS Mechanical software to perform nonlinear hyper-elastic analysis, five seal designs were studied and the best one selected. Ammari explains: If those prototypes had been physically produced, the molding and

manufacturing costs for just on one project, “would have been tremendous. More importantly, we got all this work done in about a month, including the time needed to do reports and the usual exchange of information and change of design requirements. Using ANSYS analytical software was considerably faster.” [6]

2.3 HISTORY OF FEA

Finite Element Analysis (FEA) was created by R. Courant in 1943. Courant obtained approximate solutions to vibration systems by using the Ritz method of numerical analysis and minimization of variational calculus. In 1956, a paper published by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper focused more on the "stiffness and deflection of complex structures". [7]

FEA has improved tremendously since its early days in the 1950s and 1960s, where analysts were required to enter node and element locations by hand and sort hundreds of pages of computer printouts to decode the results. Today, automation and graphical tools make analysis much more efficient. FEA is much more user friendly in both pre- and post-processing with enhanced features and functions, and solvers can now handle a wider range of problems far more complex than ever before possible. Increases in computing power has also allows inexpensive personal computers and workstations to run problems in fractions of the time that older mainframe systems of the past would have taken. [7]

Over the years, FEA has become the most commonly used method for studying the stress, deformation, and other engineering parameters in mechanical parts. FEA uses complicated mathematical equations too accurately approximately how a complex structure reacts to a certain load or condition. FEA packages solve thousands or millions of these equations to find a solution for a model. Handling all these equations

as a whole would be difficult and mostly impossible to solve manually. Instead, FEA manages small pieces of the problem in a three step approximation technique, and then combines the results into a final solution.

The first step is known as pre-processing, this is where a mathematical model is created by dividing the structure into elements connected at nodes to form a mesh. In the second step, the solver performs the actual analysis on a computer to determine the behavior of the structure. In the third step, called post-processing, the computer converts the analysis results from raw data into a graphical display that the user can more easily interpret. [8]

Today's FEA packages have made great advancements in user interfaces, graphics, computing power, and automated features, but even with all these improvements FEA users have to be skilled analysts. A complex model can still take a significant amount of time to complete an analysis. For meaningful results, FEA software requires users to know how to pre-process CAD geometry. This may include applying proper boundary conditions, mesh densities, element types, and load types. Users also must know how to correctly interpret output information such as deformation, stress, and strain plots. Interpreting these results requires education and experience.

2.4 TRADITIONAL VIRTUAL PROTOTYPING PROCESS

The virtual prototyping process is an invaluable tool that helps manufacturing companies compete in their market with speed and efficiency. FEA is one of the most valuable of these tools as it analyzes structures for excessive stress, strain, deformation, vibration, etc. in critical areas. Because of the value in this type of analysis, FEA has become one of the most commonly used methods for studying structural reliability.

This type of technology has been advancing in leaps and bounds since it became well known in the 60's and 70's. However, even with this remarkable improvement, experienced FEA analysts are generally in short supply because of the skills, training, and background required. Many organizations cluster FEA analysts into centralized groups, so the group can handle all the analysis tasks for the firm. This type of arrangement has traditionally let to a separation between engineers and designers. As designers finish their model, they then throw the designs "over the wall" to the analysts. When analysts complete their results, any failures or product recommendations are thrown back "over the wall" for the designers to address. This process of going back and forth can waste long periods of time that companies can't afford.

In most manufacturing companies, this swap between designers and analysts is so slow that FEA is typically done only for critical components with possible risk of failure. Otherwise it is used as an after thought in the final phases of product development. In worst case scenarios engineers will use FEA if hardware has failed somewhere during final testing or production, when fixes are already very expensive.

The conventional build-test-fail cycle can chew up large amounts of time and effort. The act of modifying designs, getting approval, issuing engineering change orders (ECO), and re-submitting plans, can turn into a long process of red tape that only negatively affects companies. In addition, these new designs may be less optimal due to quick fixes inserted hastily to meet manufacturing deadlines. These quick fixes often result in parts being over designed with added size, weight, and materials that can hurt the appearance and function of the product.

3.0 A NEW VIRTUAL PROTOTYPING PROCESS

To create a new process that compresses the product development cycle, new tools and methods have been developed to change the way in which design errors are found and refined. Traditional product development will create a design, prototype that design, and test it for failures. This process can be repeated until the performance and design of the parts are acceptable. The newly developed process combines CAD, CAE, and FEA to create an interactive feedback loop in the front part of product development.

The process begins as soon as a basic CAD model is developed. With that model, a preliminary analysis is conducted where the CAD model is modified and re-analyzed until an optimal product is found. The time spent in up-front analysis will help reduce the number of physical prototypes so that it could be possible that the first design built will pass all empirical tests the first time.

If analysis is performed in the early stages of product development for the conceptual design process, engineers will be able to explore a variety of product configurations, experiment with different materials, and perform tradeoff studies that normally don't happen until later in the product development cycle. By addressing these issues early, such difficulties could be avoided later in the cycle where the issues become more complex to fix. With these extra resources dedicated to the early stages of design, costs during this phase will be higher than normal. The designs studied in the conceptual phase will take longer to release, but this added time and cost is greatly offset in later stages through savings in prototype building, testing, and fewer engineering changes. The writers on Leveraging Simulation: The Design Innovation

Process shown in Figure 2 that spending this extra time in Concept design can lead to a 30% reduction in product development time. [6]

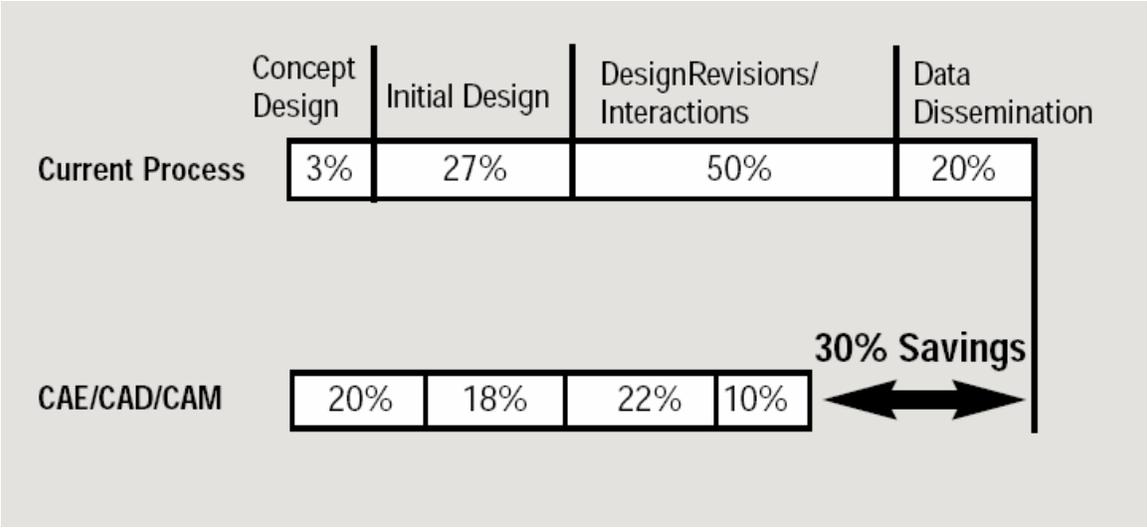


Figure 2: Compressed product development cycle [6]

This condensed product development cycle decreases the time for all later stages in the cycle, including physical testing at the end of design. This is because the new virtual prototyping process gives engineers added time earlier in development to research and develop innovative concepts. Additionally, correcting problems before the designs are sent to the build-test-redesign stage, ensures these design innovations are carried through to the final product design.

According to Dr. David Cole, President of the Center for Automotive Research at the Altarum Institute “The use of computer-aided engineering (CAE) and virtual prototyping technology is critical in reducing reliance on physical prototypes, reducing cost and shortening the overall product development process.” [6]

3.1 TOOLS ARE BECOMING COMMONLY USED

Dr. James Croscheck, a retired structural engineer with Deere and Company and now head of the consulting firm Effective Engineering Solutions notes:

Until now, analysis has been done almost as an afterthought at many companies, performed apart from design and out of the product development loop. Advances in technology and processes notwithstanding, the single most important factor bringing simulation into the mainstream of product development is a radical shift in attitude. In engineering departments, simulation tools are now more commonly being regarded as an integral part of design instead of an outside service used only on a limited basis. And at the executive level, simulation is today being taken into account as part of corporate strategy in bringing more innovative products to market and more revenue to the company's bottom line. [6]

Stefan Thomke, author of the Harvard Business Review article Enlightened Experimentation: The New Imperative for Innovation, says "the process of systematically testing ideas early in new product development is referred to as "enlightened experimentation"". [9] According to Thomke, "simulation technologies increase the number of breakthroughs by trying out a greater number of diverse ideas." [9]

3.2 TOOLS GIVE MORE CREATIVITY TO DESIGNERS

Stefan Thomke commented in his article: "Computer simulation doesn't simply replace physical prototypes as a cost-saving measure; it introduces an entirely different

way of experimenting that invites innovation”. [9] And later in the Article: “The rapid feedback and the ability to see and manipulate high-quality computer images spur greater innovation: many design possibilities can be explored in real time yet virtually, in rapid iterations.” [9]

These tools given to designers are sometimes referred to a “first pass tools”. The designers use the tools to do their own analysis, and in effect can save time for designers and engineers, who can devote more time to creative facets of the product design. These facets include exploring innovative ideas that otherwise would be skipped in favor of more traditional designs. That is why first-pass tools are valuable in helping point designs in the right direction. The best time to research innovative concepts is in the early stages of product development, not the later part of the cycle. In the later in the cycle, designs can be refined with more advanced simulation software.

In the early stages of development designers and engineers use a feedback loop to gain insight from CAE analysis. This is shown in Figure 3, where a large design and CAE analysis stage interact to create an innovative product that doesn’t require multiple redesign steps.

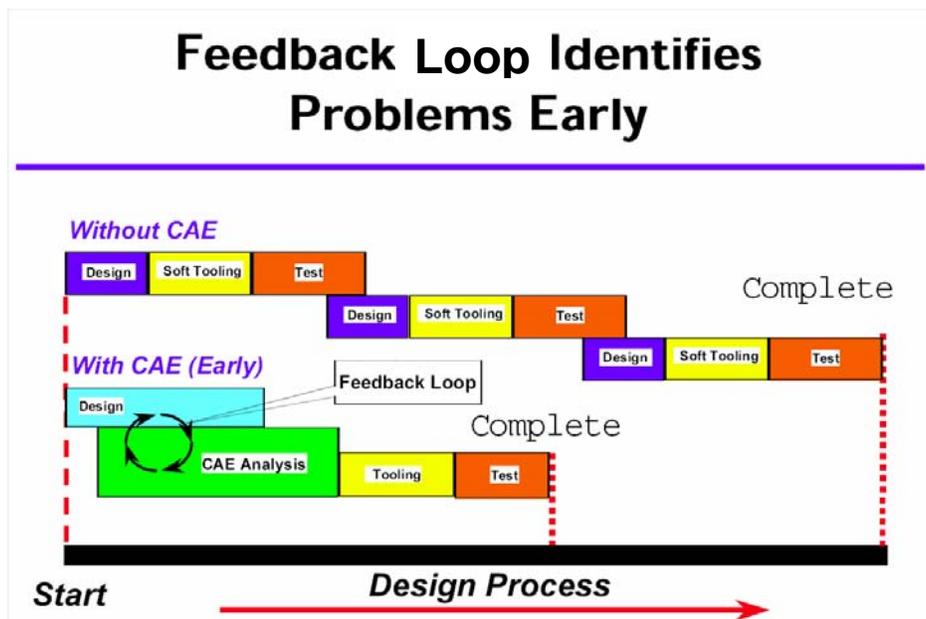


Figure 3: Feedback Loop in Early Product Development [6]

3.3 TEST IDEAS EARLY, ELIMINATE INFERIOR DESIGNS

The cost of a change in product design increases exponentially with each stage of development. For example, if changes cost \$100 during detailed design, they will cost \$10,000 during prototype testing, \$1M during production, and if a recall is issued it could cost \$100M. All for a simple change that could have been made back in the design phase.

Often, if parts fail in the testing phase, a quick-fix may be made to the part so that certain schedules can be met. Unfortunately, these quick-fixes are less than optimal, and can weaken the performance of the product. Products that are over designed with extra material to simply pass a stress test, can be cumbersome, more expensive to produce, and the performance may not satisfy customer demands. All this hurts the company's chances of survival, and could be avoided with earlier simulation tests.

The use of virtual prototyping tools early in the development cycle, such as FEA, CAE, and advanced optimization, assists engineers in developing innovative designs. Gordon Willis, president of Vulcanworks Inc. believes: "Simulation-based design optimization can be used in automating routine, repetitive tasks in evaluating the influence of many different variables, leaving the engineer more time and energy to devote to the original, creative, and inspirational parts of the product development process," [6]

3.4 STILL A NEED FOR RAPID PROTOTYPING AND PHYSICAL TESTING.

Virtual prototyping cannot be thought of as a way to eliminate physical testing. Instead, simulation-driven product development should be used to guide the design and decrease the number of physical testing that are done late in development. This approach can create better physical prototypes that have less problems to address, and can be used to verify the intended design.

4.0 RESULTS OF THIS NEW VIRTUAL PROTOTYPING PROCESS:

This new process has already begun to revolutionize the auto industry in the product development of several mechanical systems. Systems such as suspensions, engine components, steering assemblies, and body structures. Gordon Willis, president of Vulcanworks Inc., cites benchmarks where this “design synthesis process” has compressed development time significantly. In the redesign of an automotive body structure to lengthen the wheelbase and raise occupant seating, for example, 720 person-days (12 people for 12 weeks) were required to complete the project compared to only six person-days (two people for three days) using automated design synthesis. Similarly, work on a suspension system that normally takes 60 person days was done in only two person-days. [6]

Dr. David Cole, President of the Center for Automotive Research at the Altarum Institute remarks, “The use of analytical methods more than doubling over the next five years will likely translate into significant savings for automotive manufacturers and their suppliers,” [6]. According to Cole, one manufacturer was able to cut product development time and cost significantly by reducing the number of physical prototypes by nearly 50 percent. The automotive industry is primarily interested in shortening the time to market from concept to product launch. Cole says that “The key to this level of product development time reduction is math-based engineering – the world of virtual prototyping using modeling, analysis, and simulation.” [6]

Advancements in virtual prototyping processes have become famous, due in part to the auto makers. Chrysler Corp. impressed television viewers with flashy computer graphics in its advertising campaign for the 1998 Dodge Intrepid, where they affirmed that the car was designed digitally and tested in the "virtual world" until it was "virtually

perfect". Chrysler touted that the Intrepid was "the world's first car designed, assembled, and proven on computers." Promotions like this have given fame to virtual prototyping, and in turn has created a huge demand for software tools that will revolutionize product development for every industry.

5.0 ANSYS DESIGNXPLORER VT TOOLS

Until now, virtual prototyping has been a tedious process performed only by experienced FEA engineers and structural analysts. Virtual prototyping tools have always been useful, but only a handful of people have been experienced enough to use them. Companies developing virtual prototyping tools have been seeing a heavy demand for tools that are less complicated, so that simulations can be finished faster and done by a diverse group of users. Companies such as Ansys Inc. has seen that customers need software that directly impacts how product development is performed, and therefore has developed DesignXplorer-VT to help reduce time and money spent in the product development cycle.

DesignXplorer VT (DX-VT) is used by engineers and designers in the product development cycle for multiple tasks. From generating innovative designs not thought of before, to shedding light on how designs can be optimized for peak performance, DX-VT has tools to make product development easier. DX-VT and all of the Ansys Workbench family of software has been created with a totally user friendly design. This simulation software is one of the first available packages that is so intuitive that even high school students are able to create useful simulations.

This powerful yet easy to operate software is perfect for the concept design stage of product development, where concepts can be tested quickly with virtual prototyping to see where the designs need to be modified. Using DX-VT in the concept design stage and throughout the CAE analysis and testing stage will give designers and engineers a complete breakdown of what design parameters need changed. The DX-VT software even recommends new designs that will best meet the goals for the project.

DX-VT analyzes the response of parts and assemblies in a simulation model. DX-VT was created from several optimization methods including Design of Experiments (DOE). Through these methods, DT-VT uses parameters from Ansys Simulation, Design Modeler, and various supported CAD packages as the inputs for solving an optimization. Users are able to select input and response parameters as the main variables used to find an optimal solution.

DX-VT uses variation technology to provide a much more efficient and timely solution. By using mesh morphing and the Taylor series expansion approximation, DX-VT can provide a response surface that is based on a single finite element solve. This is done by calculating the derivatives of the FEA solve. The creates an “extended” finite element analysis that takes longer than one FEA solve, but much less time than the multi-solution runs that are required for a regular DX solve.

The program can quantify and graph multiple performance responses as a function of design parameters for parts and assemblies. The response variable changes as the input design variable is adjusted. This change can be seen in a 3-D graphical display of the assembly.

The goal-driven optimization (GDO) feature of the software is able to generate designs that are based on goals the user has for certain parameters. By evaluating 1000's of sample designs all from one solution, GDO arrives at an optimal design for what the user is interested in. For example, is a user is interested in minimizing deformation of a design but also wants to minimize the thickness of certain parts, GDO will find an optimal solution for these conflicting demands.

The Trade-off Study allows the user to explore the calculated response surface of a response variable based on two competing input variables. By selecting two competing input and one output parameter in the left column, the main window will display a 3D plot of input and response parameters. The chart shows sample input parameters values, and the response parameters values, which is useful to show where response parameters reach a min, max, or more importantly inflection point. For example, this chart would help find the ideal input parameter values to minimize Max Principle Stress

The final optimized design is displayed in a 3-D parametric solid model or through the DX-VT report, which quantifies the optimal design with values of each design point. Plots are also produced for both the sensitivity of the design to key variables and the trade-offs made among parameters. DX-VT features bi-directional associativity with many popular CAD packages, which allow optimal designs to be immediately translated into solid models with speed and accuracy. Having designs quickly transfer into CAD models allows designs to be turned into a physical prototype without manually the computer models needed for CNC machining or rapid prototyping.

6.0 IMPLEMENTING SIMULATION TOOLS

Every company is different in the way they utilize simulation tools, so there is no clear cut method suited to fit every company. If a company is planning on implementing new virtual prototyping and simulation tools, they should perform a self-assessment of how they execute their product development process and where they need to improve. During this evaluation, companies look at where simulation would add the most value. Some companies have to realign or expand where they use their simulation tools, while others don't use simulation yet, and need to introduce the technology to the proper teams.

Whichever the case may be, using virtual prototyping tools with combined links between CAD, CAE, and FEA like Ansys DesignXplorer VT, can help propel a company to the front of its industry. Making an investment in these type of tools can also help a company's long term potential. These types of investments can be easily justified with the return of investment a company gets from savings in reduced man hours and cost of development.

7.0 TECHNIP CASE

While conducting preliminary research for the topic of my thesis, I was introduced to Jim Maher who was interested in performing virtual simulation on CAD models where all features could be set as parameters and easily changed. Jim Maher is a chief technical advisor for Technip Inc., and his underlying interest was in virtually designing a complete oil rig and then changing any parameter needed to meet the performance goals of that project. Technip could save a large amount of design time if they could reuse existing oil rig designs and merely change parameter settings to meet the unique demands of each project. Additionally, if Technip engineers could analyze these new designs before extensive testing and structural analysis was performed, inferior designs could be quickly eliminated without wasted man hours.

Technip is a world class player in engineering, technologies and construction services for oil and gas, petrochemical and other industries. With a workforce of 19,000 people worldwide, Technip ranks among the biggest full-service engineering and construction groups in the field of hydrocarbons and petrochemicals.

One of Technip's newest projects is a deep water offshore gas rig. Their first ever cell spar was named the Red Hawk project. The 560-foot long hull structure composed of seven 20-foot diameter rolled steel tubes, was engineered and built in the United States in several sections at Technip's Gulf Marine Fabricators in Ingleside, TX (see Figure 4). Kerr-McGee ordered the spar, and has installed it in 5,300 feet of water in Kerr-McGee's deepest field development to date. Kerr-McGee was also the first one to use the classic spar at the Neptune field in the Gulf of Mexico.



Figure 4: Red Hawk model

Technip completed delivery of the Red Hawk in record time of 22 months from contract award in September 2002. The design of the Red Hawk took approximately 57,000 man hours, half the time of previous designs (of comparable complexity)(see Figure 5). They attributed this efficiency to three factors: keeping all the detailed analysis work in one office instead of two, turning support structures from a ship type structure into simple ring stiffeners, and turning complicated load cases into simple governing criteria.

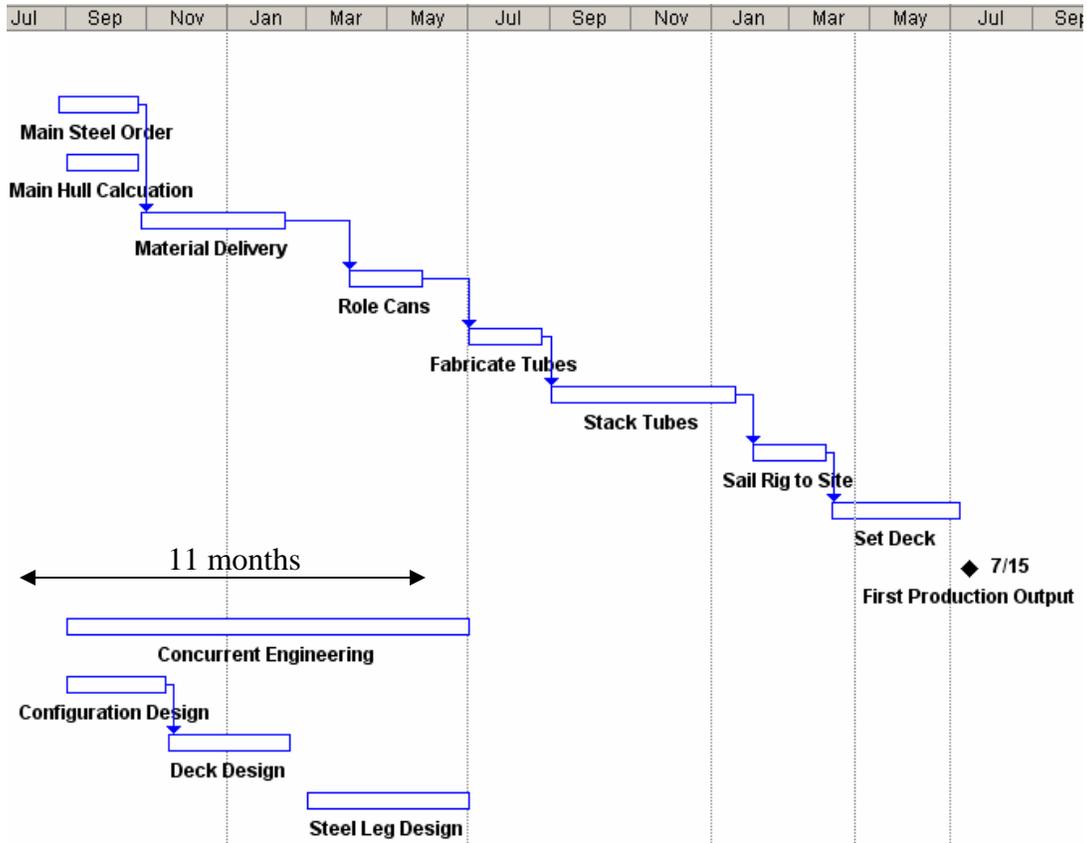


Figure 5: Gantt Chart of Original Red Hawk Project

In designs being created in the last three months, engineering design time has been cut by another 50%. Complete designs for offshore oil and gas rigs over 500 feet tall can be created in under 29,000 hours. This is now possible since Technip has created global models that can be used as the base for each new project. The global models can have any parameter changed quickly to meet the demands of each project. One engineer can complete the drawings for a custom oil or gas rig in about 12 hours. The final design just needs to be analyzed for static and dynamic loading. Now Technip engineers are highly interested in what techniques are available to reduce their product design time even further.

8.0 SOLUTIONS FOR TECHNIP

Managers at Technip were interested in trying new creative ideas for saving time in product design, so I evaluated tools that could meet their demands and recommend specific strategies for them to follow. With this very interesting dilemma, I began evaluating possible solutions to meet their needs. My solution to their problem involved a software package called DesignXplorer VT which was being developed by Ansys Inc. I believed that this product showed significant promise for use in the Technip case. I decided to evaluate to see if it would meet the needs of Technip.

Once a potential case study was found, I created a case study that would be very relevant to Technip. Therefore, I selected components from the Red Hawk project to use as a proof of concept test. I modeled an entire bulk head in Autodesk Inventor for this test (see Figure 6). Inventor was used because it is the primary CAD software used by Technip engineers. With this package I created CAD assembly drawings of a bulk head that mimicked the ones used on the Red Hawk oil rig. I also set key geometry dimensions as parameters which could be changed later.

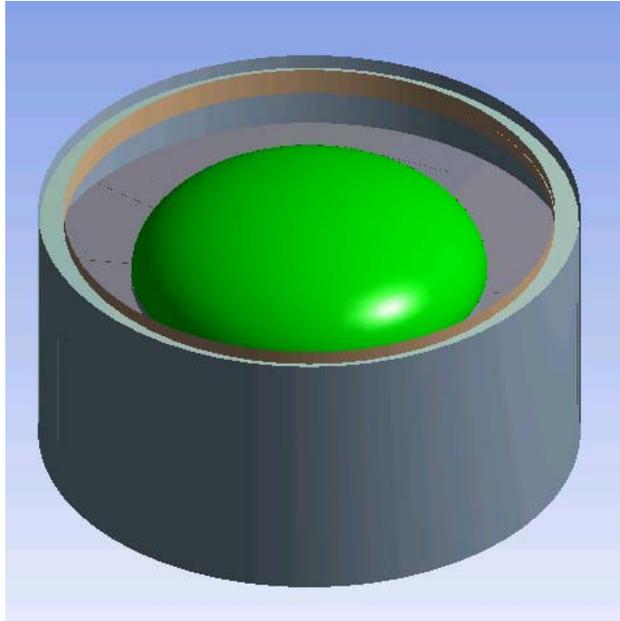


Figure 6: Bulk Head model in Autodesk Inventor

Next, the completed CAD model assembly was then imported into Workbench through Design Modeler. In Design Modeler, the mid-surfaced tool was used so that the structure could be analyzed with shell elements, instead of the default solid elements. Figure 7 shows a view of the mid-surfaced bulk head. Shell elements are more accurate for solving models like this where pressure is the main loading.

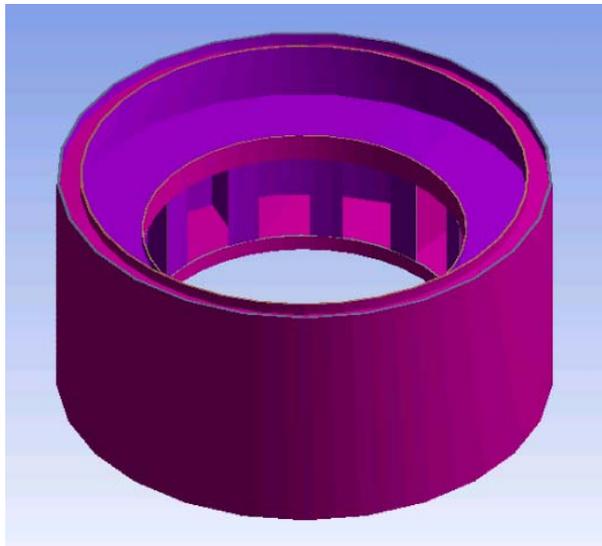


Figure 7: Mid-surfaced Faces

I assisted Ansys Inc. in the development of the mid-surface feature through testing and soliciting customer feedback. The mid-surface feature was not available when I started development. My work with this project helped determine and correct bugs that tool would cause the mid-surface feature to fail. I was able to report these bug and recommend solutions to developers.

The bulk head model that I created for this project also became a benchmark test for Ansys Workbench Mesher. The mesher was initially unable to process some of the complex features in the model I created. By submitting this model to Ansys as a benchmark test, I was able to work with developers to improve the capability of the Workbench mesh tools to handle this model. Processing this model in the Workbench mesher was an important priority for Ansys developers because the model was a good representation of parts that Ansys customers would need to analyze on a regular basis. Solving issues with model would immediately help other Ansys customers that have similar problems.

When the simulation was complete, the model was run in Ansys DesignXplorer. I decided to evaluate Ansys DesignXplorer because it was ideal for reusing existing oil and gas rig designs and merely changing parameter settings to meet the unique

demands of each project. DX-VT analyzed several key geometry parameters, such as wall thickness or size of support structures, to optimize the model for the most important response parameters. One optimizing goal, for example, involved minimizing the thickness of the inner bulk head supports, known as web stiffeners, until an idea max. principle stress was obtained. Goal driven optimization became very quick and helpful to perform tests like this because one solution already solved for all these possible scenarios.

When all the analysis was completed, all the steps were captured to explain how to repeat the process. Therefore I took procedure and made it into a best practice guide for Technip engineers to follow (see Appendix A). The guide that shows the easiest way for Technip, or any company needing to reduce product development time, to virtually prototype and optimize designs with DesignXplorer software. This demonstration shows how to design and test components for their oil rigs in a new and innovative fashion. This best practice guide is accompanied by three interactive demonstrations which go step by step to show how a Technip product can be analyzed with FEA and CAE simulations to find weak points and recommend design changes to better meet there performance needs.

The best practices guide was created to be a general guide on how to efficiently use Workbench Design Modeler, Simulation, and DesignXplorer for enhancing product development. This guide was tailored to Technip Inc. and their most recent project, the Red Hawk. The best practices guide demonstrates how to use the Ansys Workbench software to simulate actual components from the Red Hawk oil rig. The guide shows all the steps and features that were required to get this complicated model to solve properly.

I distributed the best practices guide to engineers at Technip, and shortly thereafter went to Technip's main US office in Houston, TX to train engineers on how to use DesignXplorer, and its advanced features. While there I also made a proposal on the value of Workbench and DesignXplorer, and how Technip will prosper from using these tools. The training was well received by the Technip engineers. And they called the best practice guide "invaluable" for getting them up to speed with the new Workbench tools. After the training onsite in Texas, I have been frequently consulted as

a technical support advisor to the Technip engineers. They have asked me for dozens of recommendations on how to best perform specific tests that they want to analyze. My recommendations come from my experience and from suggestions of the Ansys development staff, and have always proven useful to Technip.

Because of my link between Technip and Ansys, Technip engineers have become beta testers of Ansys products. And this has proven to be a good relationship because of how Technip pushes the software to its limits with large models, extensive parameters, and heavy use of advanced functions. All these tough requirements from Technip have given Ansys a clear understanding of what their customers demand from their products. Having customers work so closely with the development of Ansys products has been a huge help for driving the products success.

The interaction that I have made with Technip and Ansys has benefited both companies. Technip has had a chance to pursue new product development techniques that are very innovative for their type of products. While Ansys has seen a closer look at what their customers software needs are. This interaction has provided active feedback for Ansys on how there newly developed tools are working for their customers. Technip continues to be a beta tester of the newest Ansys features, and this relationship will hopefully last in the future to benefit both companies.

9.0 CONCLUSION

Through my work on the project, Technip is trying to implement DesignXplorer VT in an effort to save 40% on design time. Based on the average salary for structural engineers, this savings would account for up to \$750K per project. DesignXplorer VT is will be able to save time by automating repetitive processes required to do a simulation. Also, savings will come from full integration with parameterized models from Autodesk Inventor, where bi-directional associativity is possible. Figure 8 shows the proposed reduced time in production, from 22 months to 18.5 months. Figure 9 is more impressive, because it shows the decrease in design time from 11 months to 6 months. That equals a savings of 45%.

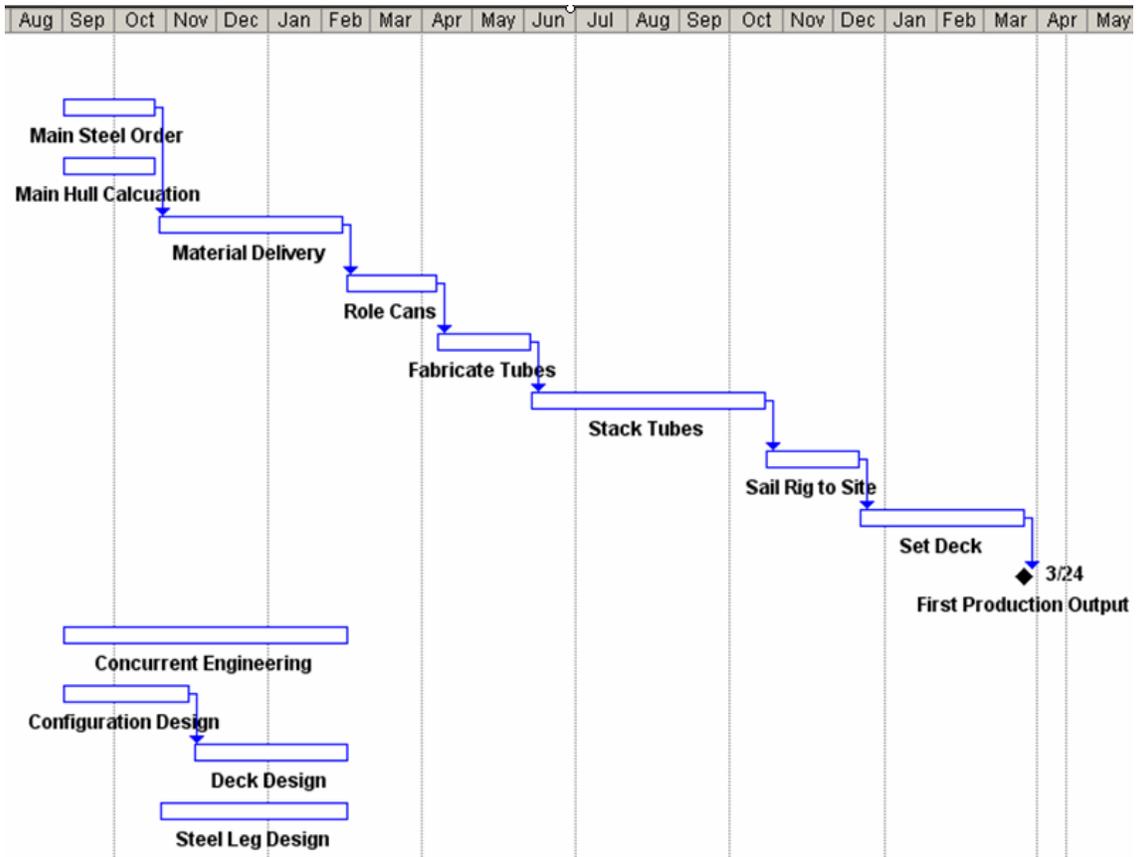


Figure 8: Gantt Chart of reduced production time

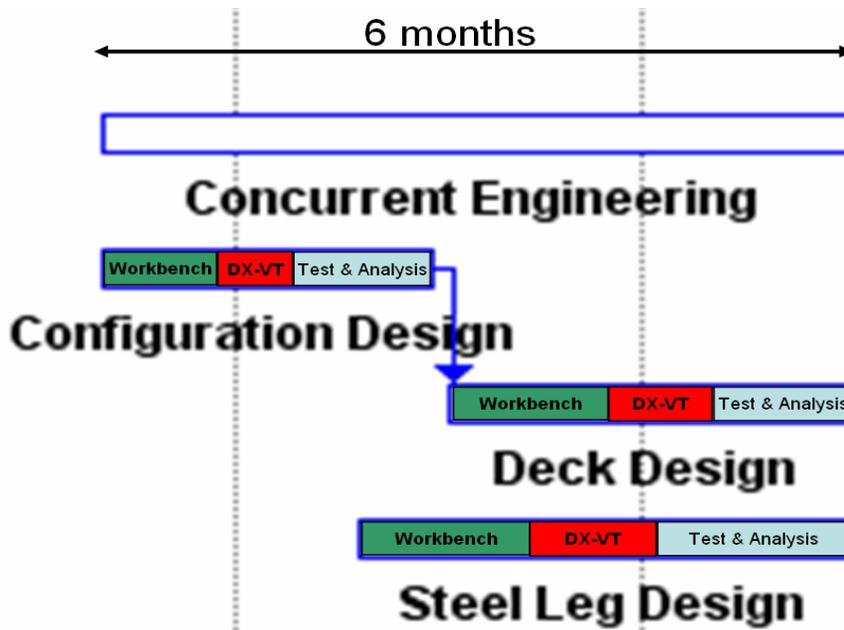


Figure 9: Reduced engineering and design time

Technip is currently evaluating how well they can integrate Ansys Workbench products into their product development cycle. If they incorporate my proposed ideas, Technip will be the first in their industry to implement this type of innovative solution for reducing product development time. Technip recognizes opportunities for DX-VT in the Accessories department, where add on features that go on top of the oil rig platform. These accessories tend to be more unique and innovative, and would benefit greatly if DX-VT could help shape their design. Also, the sizes of these accessories CAD models are well suited for the capabilities of DX-VT, so they won't overwhelm the program by being too large.

Engineers who are already using Ansys Workbench and DesignXplorer at Technip have learned how by using the best practice guide I created. They commented that the guide proved "invaluable" in getting them up to speed with learning the program, and figuring a step by step plan to get analysis done. The technical support that I have given to the Technip engineers has been well appreciated, and definitely used. Previously my technical support recommendations would come from my experience and from suggestions of the Ansys development staff. Question that Technip engineers are

asking recently, are more difficult than I can solve. These days I resort to forwarding questions directly to Ansys Tech-support group, who have more experience and more personnel to handle Technip's advanced problems.

In the future, when Technip implements these tools, the company should make a re-evaluation of how their product development process is performing. In a fast paced company such as Technip, it can easily take three months or more to become familiar with the DesignXplorer tools. Therefore, after a three month trial period Technip should evaluate what the product development bottlenecks are at that point. They should evaluate how productive DesignXplorer has been for them, and determine what other road blocks are slowing their product development cycle. Streamlining their process will give them a notable advantage in their industry.

APPENDIX

BEST PRACTICES GUIDE

DESIGN MODELER

To get started in Design Modeler, run ANSYS Workbench and choose open “New Geometry” in the first screen (Figure 10). This will open a new instance of Design Modeler. Go to the top toolbar and select File > Import External Geometry File > (Figure 11). This Import External Geometry File will allow the user to import a desired model from Autodesk Inventor or other CAD programs. Select the desired CAD model and click OK. The part will not appear on the screen until the user clicks Generate Part from the toolbar (Figure 12).

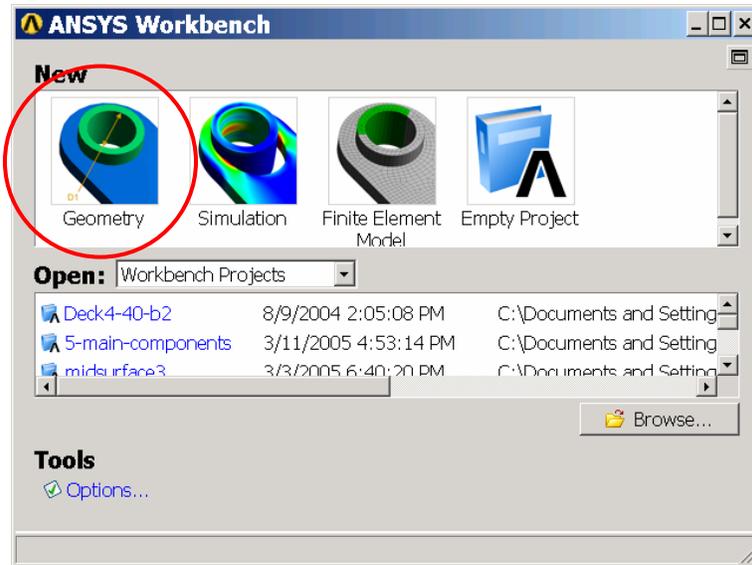


Figure 10: Ansys Opening Screen

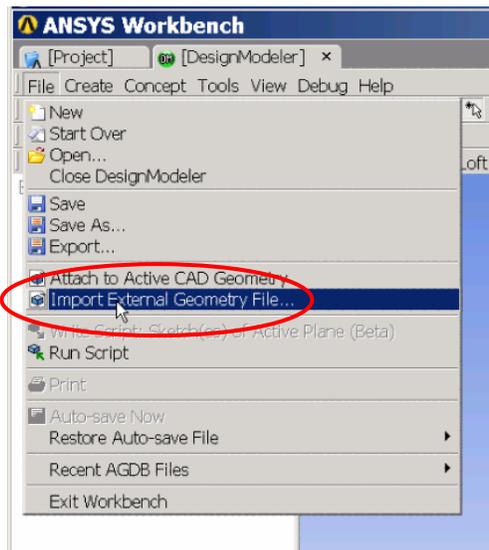


Figure 11: Import External Geometry

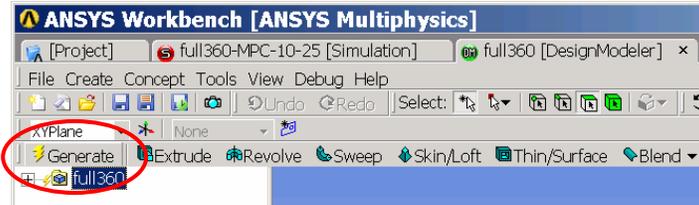


Figure 12: Generate button

Mid-surface Extraction

Mid-surface Extraction can be used to create shell elements out of existing solid elements. This feature is very common when analyzing medium to thin walled structures such as pressure vessels. To use this feature in ANSYS Workbench 9.0, the user must turn on Beta Features. This is done by going to Tools > Options > Common Settings > User Interface > (Figure 13). Set Show Beta Options = Yes, and click OK (Figure 14).

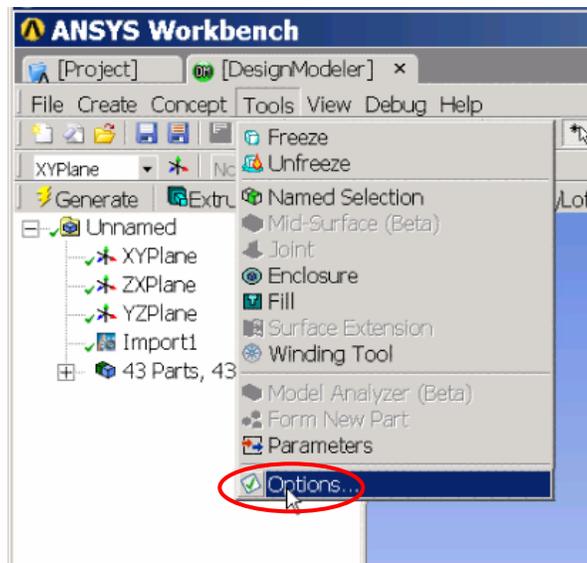


Figure 13: Options Button

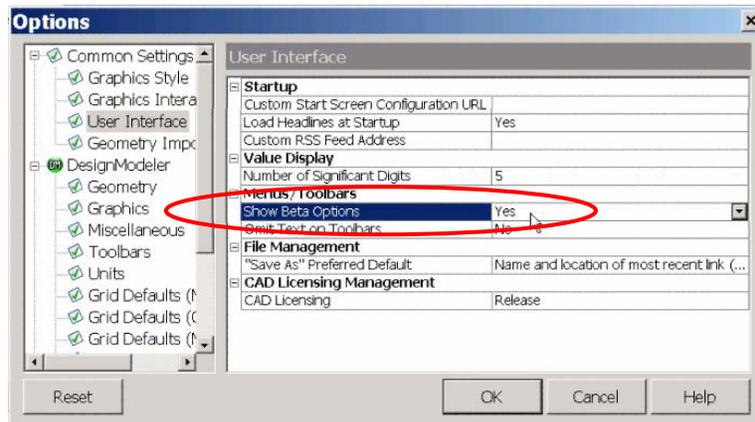


Figure 14: User Interface Options

To use the Mid-surface tool, go to Tools > Mid-surface > (Figure 15). The mid-surfacing features will come up in the lower left toolbox. For quick mid-surfacing of all parts, use Auto Select (Figure 16). Auto Select will ask the user to set the minimum and maximum thresholds for determining the min and max thicknesses of geometry surfaces that will be mid-surfaced into planes. These thresholds are important so that Workbench does not reduce a part into a plane in the wrong (probably perpendicular) direction. Next, set Automatic Detection to: ON, and all relevant parts will be highlighted with one side pink and the other side purple (Figure 17). Select generate part to finish the mid-surfacing feature.



Figure 15: Mid-Surface button

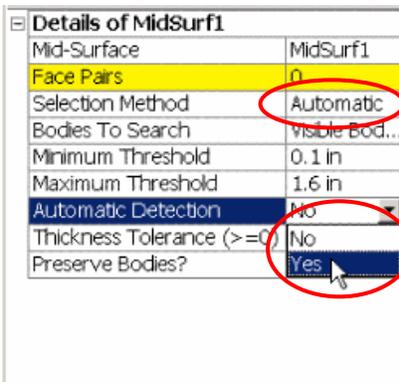


Figure 16: Mid-Surface Features

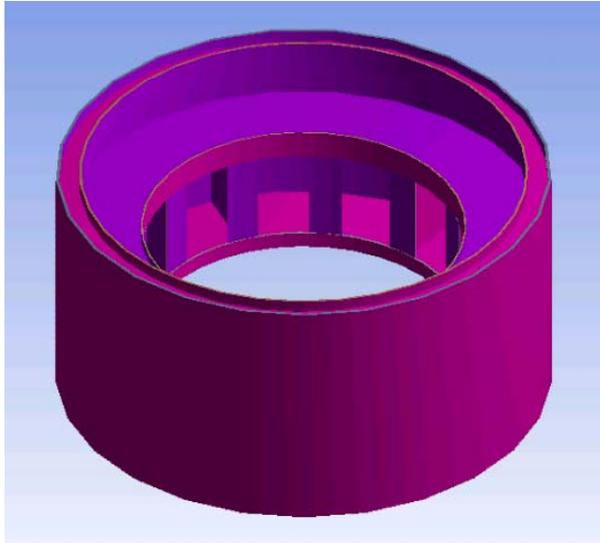


Figure 17: Mid-surfaced Faces

Surface Extension

The Surface Extension tool is typically used after the mid-surface tool to correct any gaps between joining surfaces where walls thinned to the mid section are no longer touching joining surfaces, and a gap is created.

To use this tool, go to Tools > Surface Extension (Figure 18). The Surface Extension features will come up in the lower left toolbox, where the user should click on the Edge button (Figure 19). Next, select all edges that you wish to extend by holding the Ctrl key and picking each edge from the geometry. It is also possible to select multiple edges at once by holding the left mouse button down, and rolling over edges that need to be selected. Now go back to the lower left toolbox, and select Apply on the Edge to Extend feature. Set Extend to: To Surface (Figure 20). Then select all surfaces to extend edges to, and then click the Target Face feature and hit Apply. Finally, select Generate Part in the top toolbars.

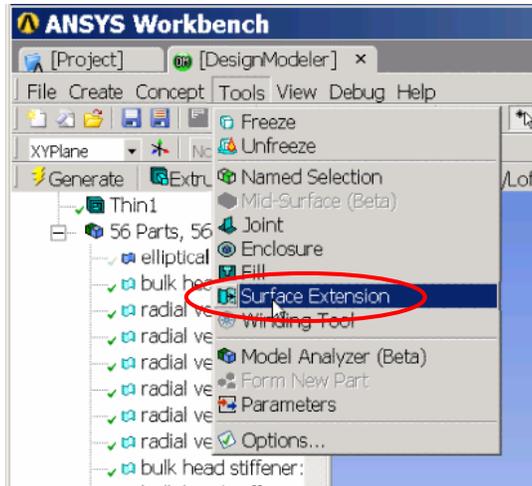


Figure 18: Surface Extension Button

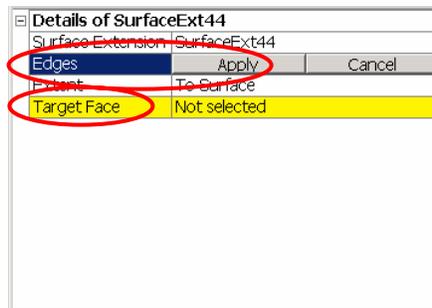


Figure 19: Surface Extension Features

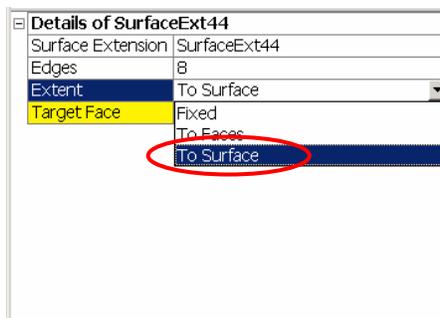


Figure 20: Additional Surface Extension Features

Thin Wall feature

The Thin Wall feature is used as an alternative operation if the geometry of a part is too complicated for the Mid-surface tool to calculate. The Thin Wall feature reduces the thickness of a solid part to zero. This allows ANSYS Workbench to think the solid elements have no thickness, and can thus be treated as shell elements.

To use this Thin Wall feature, select the Thin/Surface button from the top toolbar (Figure 21). Select the surface of geometry desired to make thin. In the lower left toolbox change Thickness to equal zero (Figure 22). Select Generate Part in the top toolbars to create this thin feature. This will allow parts to mesh as shell, and thickness of shell can be determined later in simulation mode.

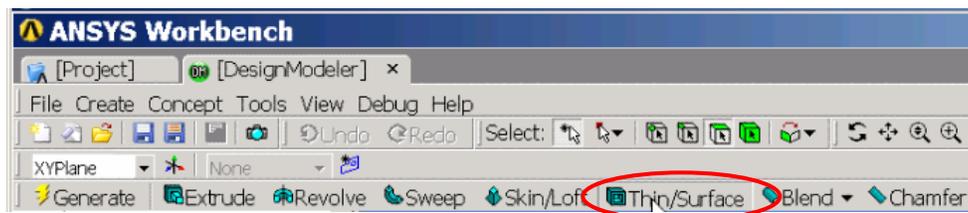


Figure 21: Thin/Surface Button

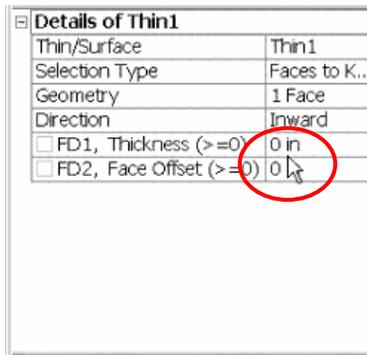


Figure 22: Thin/Surface Features

Joint feature

The Joint feature is a very helpful tool that can be used to join different parts, and resolve possible contact problems in the simulation. If contact fails between two parts in simulation, it might be useful to come back to Design Modeler and add joints between the two parts. With a joint between parts, contact is not necessary to constrain these parts to each other.

To use the Joint feature, go to Tools > Joint, and select Joint from the pull down tab (Figure 23). In the lower left toolbox, select Target Bodies (Figure 24). Now manually select all features that you wish to contain joints. Again, to select multiple bodies at once, hold the left mouse button down and roll over edges that need to be selected. Then select Apply in the Target Bodies area. All selected bodies that touch another selected body will contain a joint at their intersection and the pair will have a shared topology.

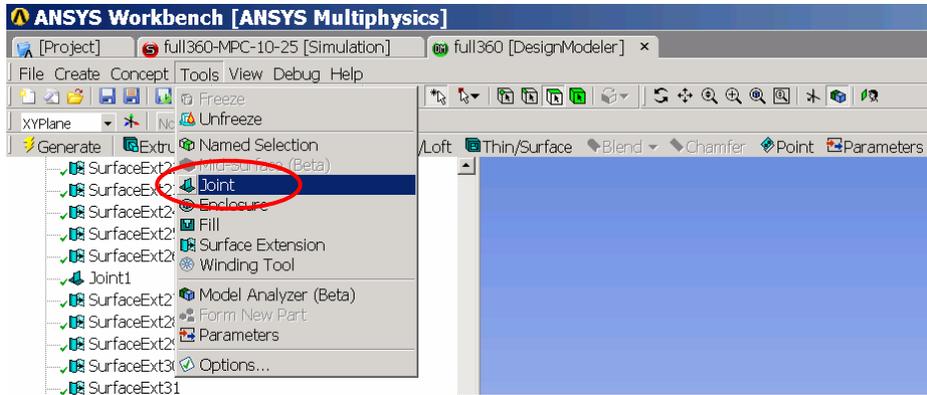


Figure 23: Joint Button

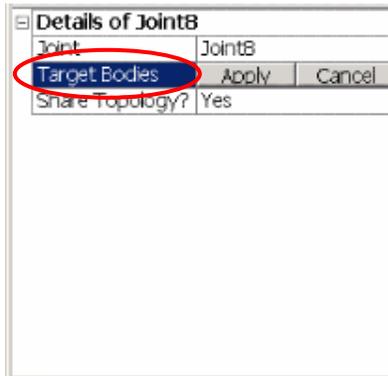


Figure 24: Joint Features

Form New Part

The Form New Part feature may be used to create one part out of several joining parts. This feature is similar to the joint tool in that it can be useful in eliminating contact problems later in simulation mode.

To use the Form New Part feature, select the parts that are to be joined from the geometry tree on the left side of the window (Figure 25). Now select Form New Part

from Tools > Form New Part (Figure 26) after all the desired parts are chosen. A new part will be automatically generated in the part tree.

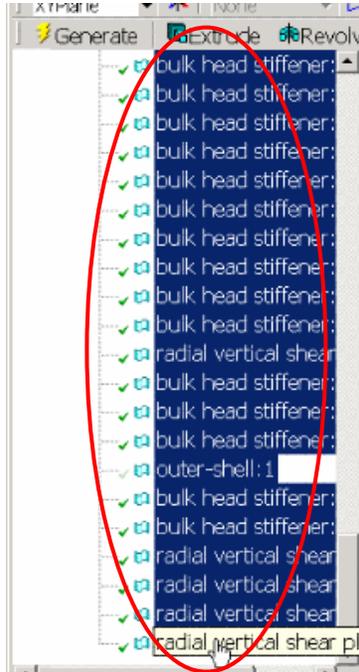


Figure 25: Select Parts from Geometry Tree

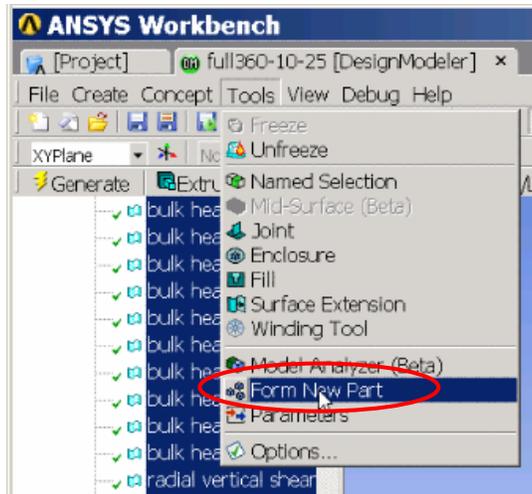


Figure 26: Form New Part Button

Parameters

Parameters can be used to transfer changes in parameters from CAD program to workbench. To make a geometry dimension or other design variable a parameters, in the lower left window click the box to the left of each feature, which puts a “P” next to it (Figure 27). These features will become parameters that can be varied in the simulation or DX-VT mode.

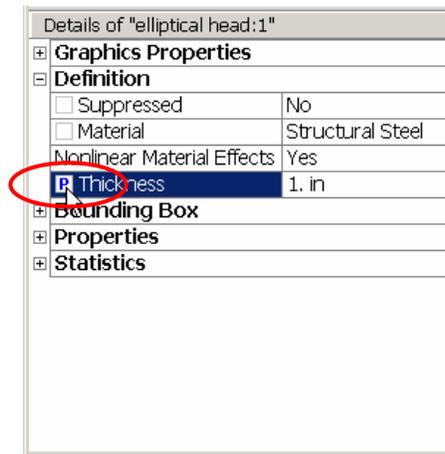


Figure 27: Set Parameters

SIMULATION

Whence a Design Modeler file (.agdb) is created and saved, the next step is to create a new simulation from the DM file. By going to the Project tab at the top of the

window, the user can click New Simulation to create new simulation from existing geometry in the Design Modeler file (Figure 28).

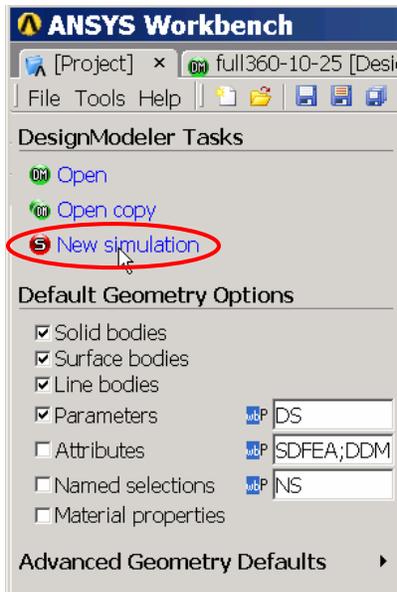


Figure 28: Start New Simulation

Contact

Contact between all the bodies is automatically generated when the new simulation is started. Although the automatic contact can be very thorough, it is important to inspect the contact automatically selected. A good aid to this process is to rename to contacts after the two bodies it refers to. Just right click on Contact in the project tree on the left side of the window, and select Rename Based on Geometry (Figure 29). Now go through the list and verify that contact between parts is correct.

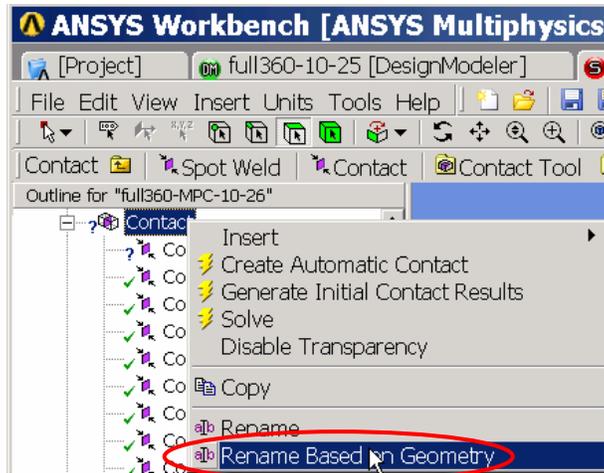


Figure 29: Rename Contact Based on Geometry Button

There are two notable things to check for. First check that there aren't duplicate contacts. These are easier to find when the contact in names after the parts, and sorted alphabetically. Delete duplicate contact regions (Figure 30). These contacts may have been created because two bodies may have same edge-to-surface and surface-to-edge contact point. It is only necessary to keep one of those contacts.



Figure 30: Deleting Duplicate Contact

The second thing to inspect the contact for is that correct parts are mating in each contact pair. When contact is automatically generated Workbench uses a tool called a “pinball” to determine which bodies should be in contact. Workbench puts two bodies in contact if their distance apart is less than or equal to the size of the pinball. However Workbench may not place contact between to bodies intended to be mating if the gap between them is larger then the size of the pinball. The opposite of this is also true, two bodies may be coincidently close together, but are mistakenly given a contact point because their relation to each other was smaller than the pinball size. It is these situations that the user needs to look for, and change the pinball size as necessary. To change the pinball size, click on Contact in the project tree. Contact details will appear in the lower left toolbox. The pinball size can be changed by entering a new value into the Tolerance Value field (Figure 31).

Details of "Contact"	
Auto Detection	
Generate Contact On Update	Yes
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	2.3044e-002 m
Face/Face	No
Face/Edge	Yes
Edge/Edge	Yes
Priority	Include All
Same Body Grouping	Yes
Transparency	
Enabled	Yes

Figure 31: Setting Contact Pinball Size

Another helpful tool for managing the contact for the simulation is the Contact Tool. Simply right click on Contact in the project tree, and go to Contact > Insert > Contact Tool (Figure 32). This tool gives the user a description of contact types, allows user to change contact types, and allows user to delete inactive contacts (Figure 33). All of which are good tools to use if the simulation fails for contact reasons.

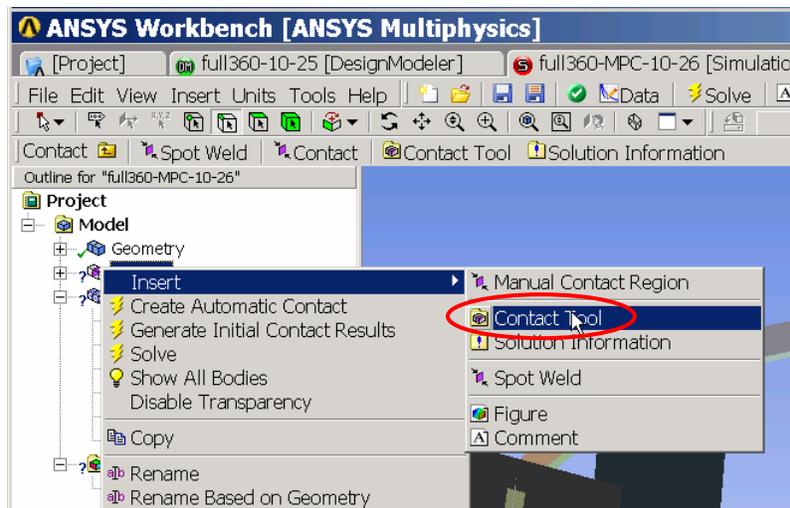


Figure 32: Inserting Contact Tool

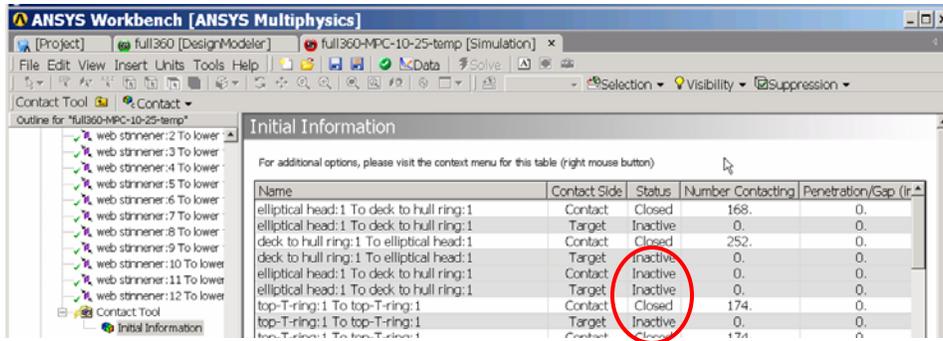


Figure 33: Deleting Inactive Contact

Material

Workbench offers several preset materials that can be chosen to represent each part of the model. In addition, the user can specify the properties of their own material they wish to use in their analysis. To select a material, click on geometry in the project tree. Now highlight all the parts that will have the same material. Go to the lower left toolbox, and click on Material. The user has the choice of selecting a predefined material, creating a new material, or importing a material that has already been created (Figure 34). The user should select one of these options for all the different parts in the model. All parts need to be made of some type of material so that Workbench knows how the material will react in the analysis.

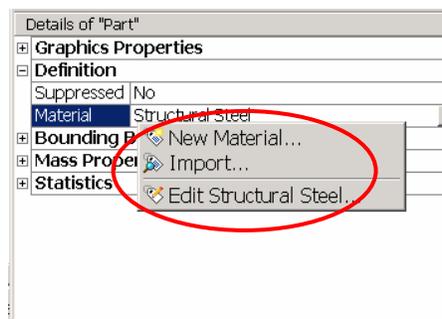


Figure 34: Setting Material Properties

Meshing

A good mesh of the geometry can make all the difference in the world when Simulation is trying to find a solution to the model. Key steps such as minimizing the overall number of elements, refining the mesh around critical features, or mapping the mesh with a standard pattern on simple bodies; all can have a large effect on the success and accuracy of the solution. Several important modifications to the mesh will be discussed here.

The first step for meshing is to allow Workbench to create a mesh for the user to review. Use Preview Mesh to have Workbench generate a mesh of the model (Figure 35). For this, right click on Mesh in the project tree and click on Preview Mesh. Workbench will automatically generate a mesh for the model based on preset criteria in the mesher.

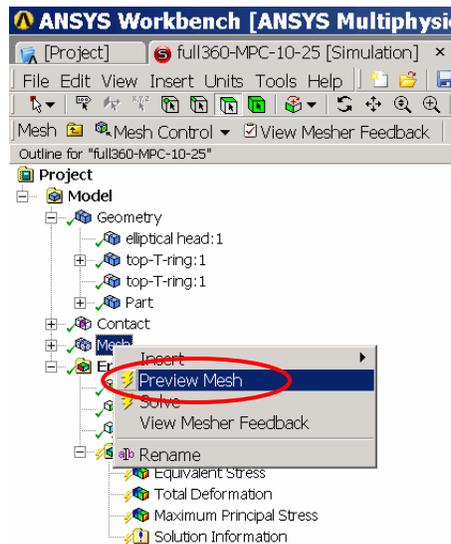


Figure 35: Preview Mesh Button

When the model is meshed, modifications can be made where the mesh is too coarse or too fine. The tool for this is called Mesh Sizing. For this, right click on Mesh in the project tree and click on Insert > Sizing (Figure 36). This tool refines the mesh on selected bodies, surfaces, or edges; and makes the elements all roughly the size, which the user specifies. The element size is set in the Element Size field in the lower left toolbox (Figure 37). It is important to note that although this tool refines the mesh on selected bodies, surfaces, or edges; using bodies for resizing tends to be more successful when meshing solid bodies.

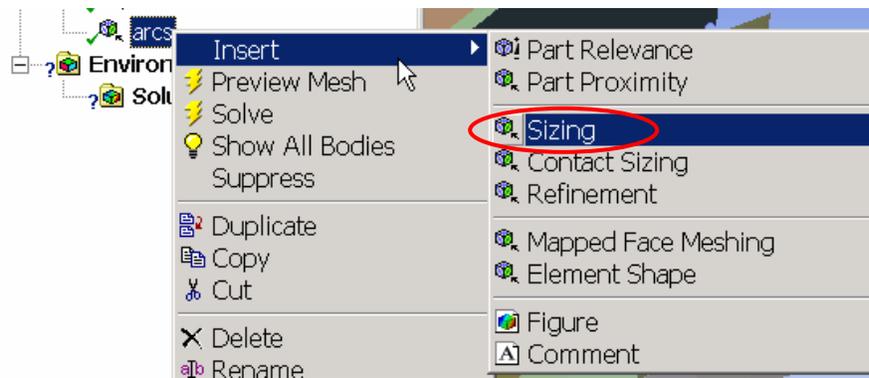


Figure 36: Insert Mesh Sizing

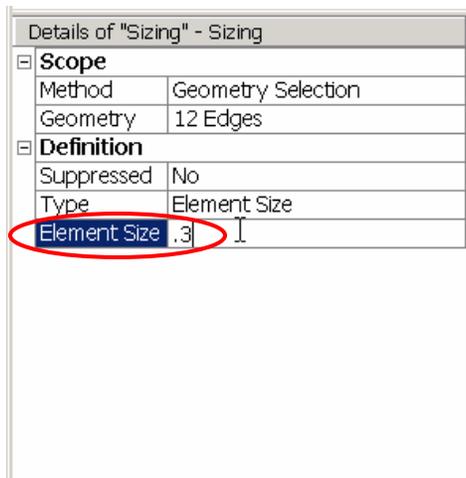


Figure 37: Mesh Sizing Details

Refinement is another tool that can be used to generally refine bodies or surfaces to be meshed. This tool is helpful when a key feature or region wants to be analyzed and the solution at these points needs to be most accurate and precise. To use this tool, right click on Mesh in the project tree and click on Insert > Refinement (Figure 38).

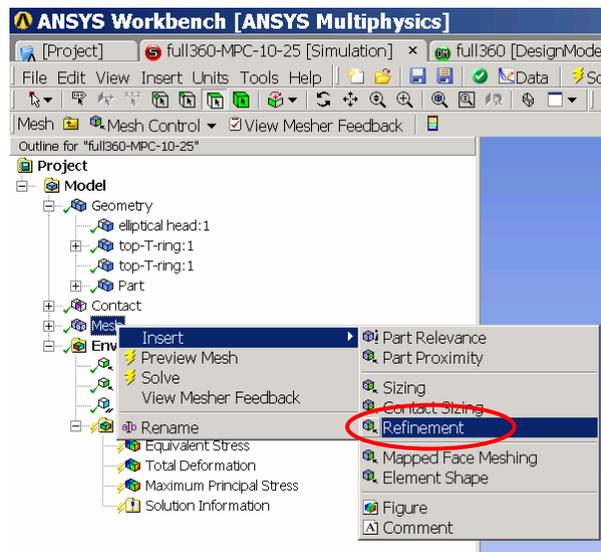


Figure 38: Insert Mesh Refinement

The Mapped Face Meshing tool is used to pattern the mesh in areas where the geometry is simple and mesh symmetry is possible or preferred. Having a mapped mesh makes the elements the same size and shape, and contain similar attributes. The mapped mesh will also reduce the total number elements in most cases. These features allow the Workbench solver to run faster, with less processing time required. This feature is found under Insert > Mapped Face Meshing when one right clicks on Mesh in the project tree (Figure 39).

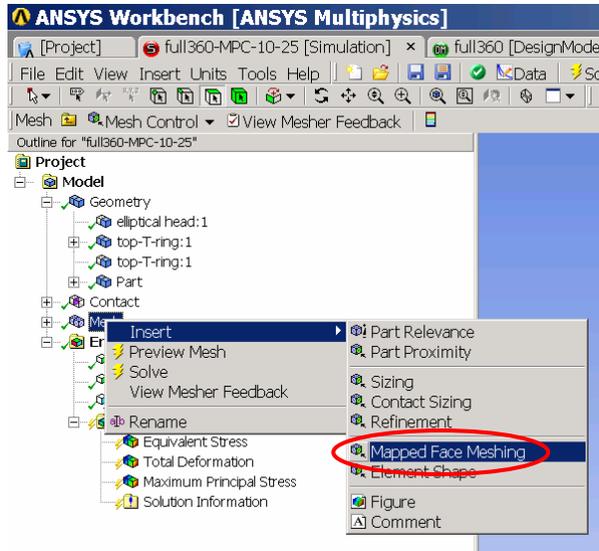


Figure 39: Insert Mapped Face Meshing

Environment

The Environment of the simulation gives the model actions to react to. Actions such as pressure, forces, acceleration, convection, heat flux, etc. can be used. In addition the environment has the constraints that keep the model constrained in space. Constraints such as fixed supports, frictionless supports, given displacements, etc. This guide will focus on loads and supports that enable the user to do a structural analysis. These features are only a small number of what is available in the environment section.

Loads can be inserted for the appropriate loading conditions of the model. When doing a structural analysis, pressure loads on a surface give less local stress concentrations than a force at a single point. To insert a pressure load right click on Environment in the project tree, and go to Insert > Pressure (Figure 40).

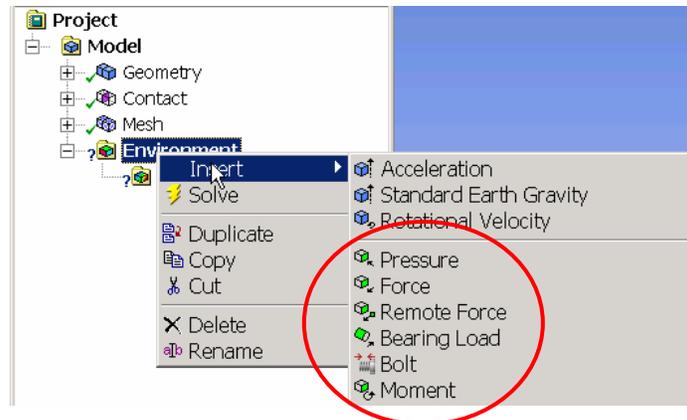


Figure 40: Insert Structural Loads

Fixed Supports are necessary in a structural analysis to keep the model from “flying away” when a force is applied to it. The user must insert appropriate supports to keep model fully constrained. This is done by right clicking on Environment in the project tree, and go to Insert > Fixed Support (Figure 41).

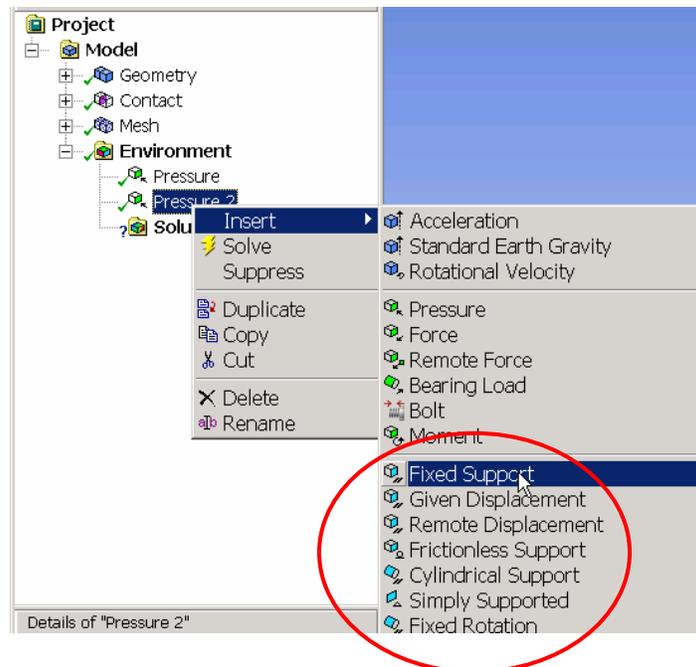


Figure 41: Insert Supports

Solution

Under the Environment section of the project tree is Solution section. This solution section is where the user specifies what Workbench is supposed to solve for. The user can insert various solution tools to solve for: Max. Equivalent Stress, Total Deformation, VonMises Stress, etc. (Figure 42). All these tools and more are found by right clicking on Solution in the project tree, and go to insert to see a list of various tool available.

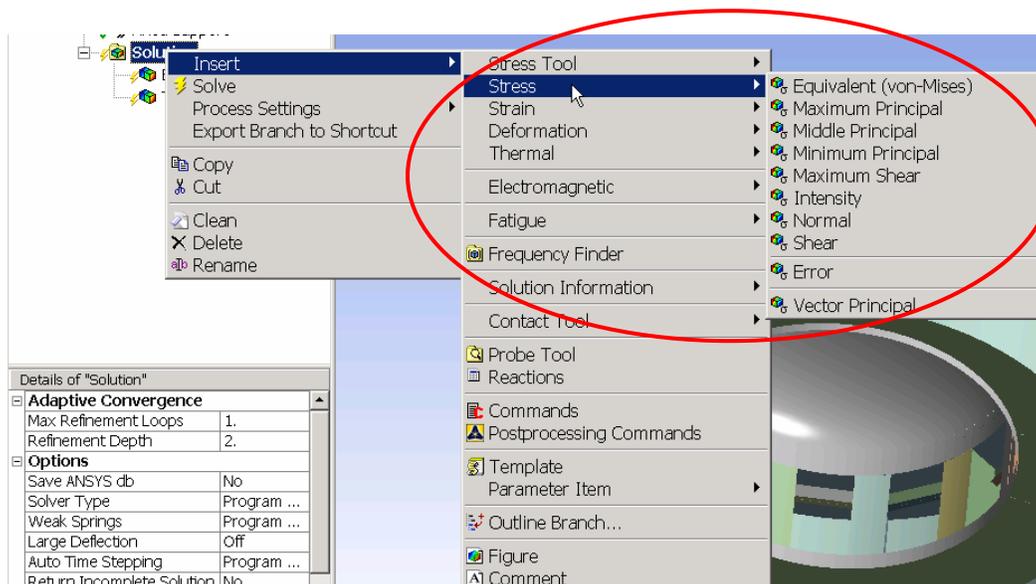


Figure 42: Insert Solution Criteria

For experienced Ansys classic users, the Insert Solution Information tool is available to show the Ansys output window, which contains all solver messages, warnings, or errors. To use this tool right click on Solution in the project tree, and go to Insert > Solution Information > Solution Information (Figure 43).

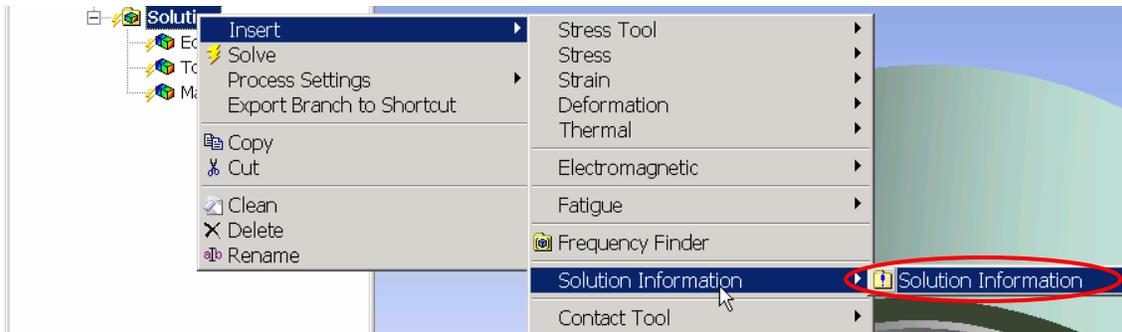


Figure 43: Insert Solution Criteria

Parameters

Parameters set in the Simulation stage of Workbench can be passed from application to application within Ansys. The parameters allowable in Simulation include CAD parameters and engineering parameters, such as dimensions of a part, geometry mass, pressure, maximum stress, material properties, etc. To select parameters, there is an empty box next to allowable parameters in the toolbox on the lower left side of the window.

For example, to select a geometry parameter, go under the Geometry section of the project tree, where each Geometry part is listed. Select a geometry part, and in the lower left box there are geometry features. Click the box next to each geometry feature that you wish to make a parameter (Figure 44). A “P” will appear in the box to show it is set as a parameter. You may also select the box next to the solution criteria that you wish to optimize, such as shear stress, total deformation, etc. (Figure 45). A “P” will appear in the box to show it is also set as a parameter.

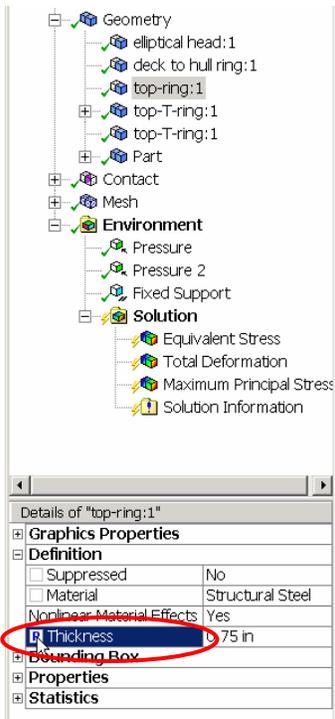


Figure 44: Set Input Parameters

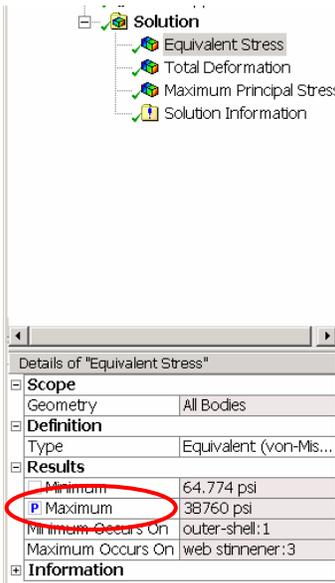


Figure 45: Set Output Parameters

These parameters selected will now be available in the DX-VT parameterization, which is able to optimize designs based on the parameters selected here.

Solve

One final setting that needs to be made for the purpose of this guide, is to set the type of solution formulation. Certain types of solution codes are more accurate than others, and Ansys Workbench offers five types, each with a specific purpose. The default formulation is Pure Penalty, but for our purposes of using DesignXplorer VT in this guide, we must use Multi Point Contact (MPC) formulation. To change these settings, click on solution in the project tree, look under Advanced in the lower left toolbox. Under Formulation, change the default to MPC (Figure 46).

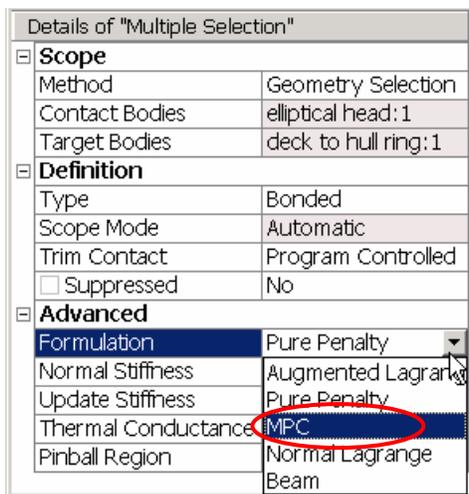


Figure 46: Solution Settings

When all the aforementioned information has been entered for the model, the solver may be started by hitting Solve on the top tool bar (Figure 47). Depending on the size of the model this process could take a long period of time. Unless otherwise

specified, all analysis is done of the desktop computer where the Workbench software is running. When the solution is finished, the user should review results for accuracy. Solving a model is traditionally an iterative process where mistakes are found in the solution, the input information (such as mesh detail) is corrected, and the solver is run again.



Figure 47: Solve Button

When the solution for the model is reached, the user will be able to analyze all the information that was solved for. Analyzing the areas of highest deflection (Figure 48) or stress (Figure 49) may prompt the designer to made design changes in those areas of focus. Also, seeing areas of little deflection may prompt the user to subtract material from over designed areas. If a user makes any changes to the model, they would next re-run the simulation to verify that their changes produced acceptable results.

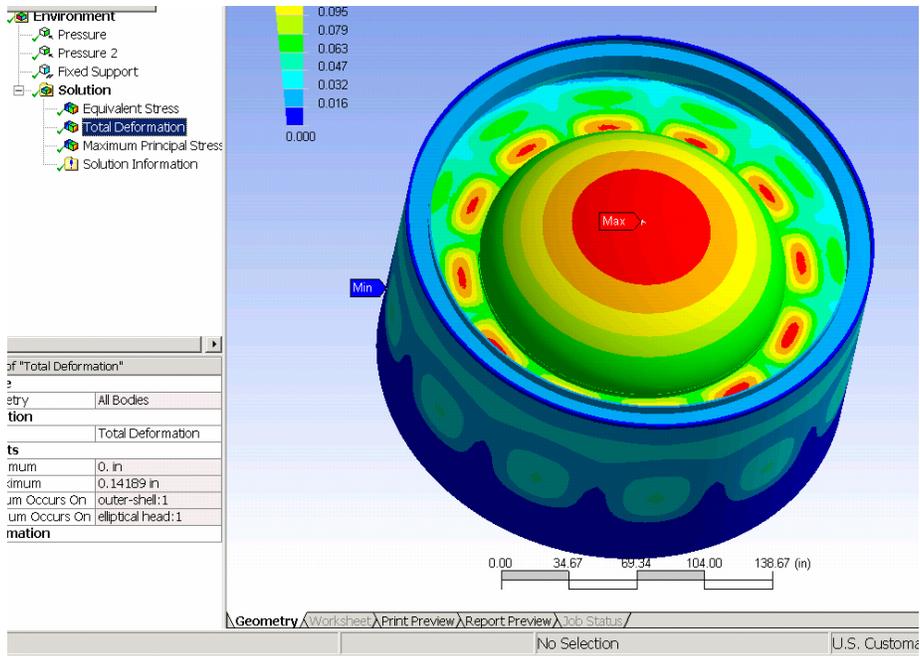


Figure 48: View of Total Deformation Solution

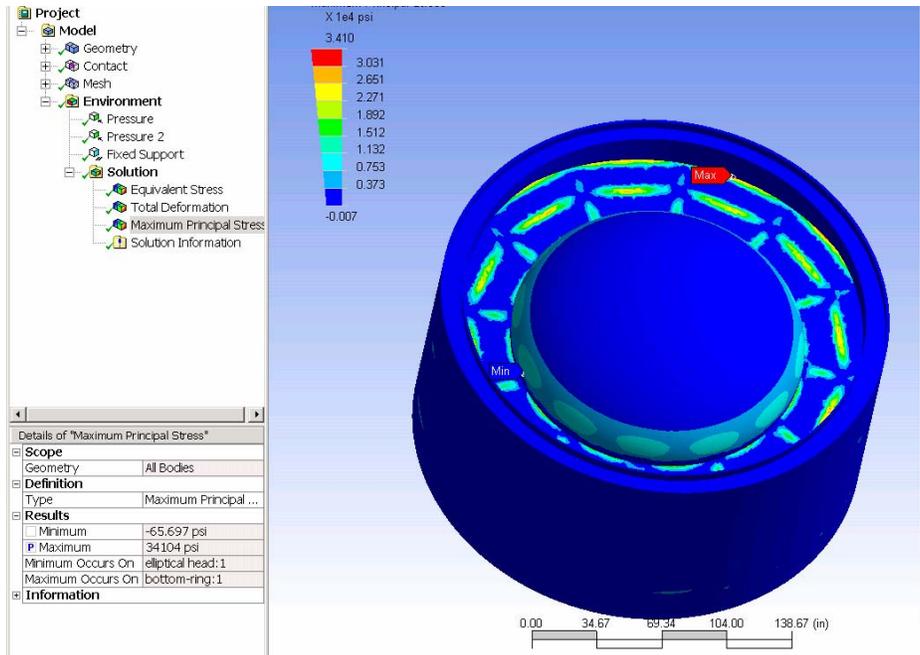


Figure 49: View of Maximum Principle Stress Solution

Reports

A very nice feature that Workbench offers is the reports section. Workbench can automatically generate a Design Report for the user, in which The Design Report shows summaries of all parameters, design sets, and response charts saved as snapshots. To generate a design report, click the Report Preview tab at the bottom of the main window (Figure 50). You can also use Publish Report to write the report as an HTML file in a designated directory.

The image shows a screenshot of an ANSYS Report Preview window. At the top, the ANSYS Report logo is displayed. Below it, the word "Project" is written in a large, bold, blue font. The report details are listed in a structured format:

- Author:** Andrew Martin
- Subject:** Bulkhead 4
- Prepared For:** Technip Inc.
- Project Created:** Monday, October 25, 2004 at 12:58:43 PM
- Project Last Modified:** Friday, October 29, 2004 at 8:09:01 PM
- Report Created:** Friday, March 25, 2005 at 1:27:03 PM
- Software Used:** [ANSYS 9.0](#)
- Database:** C:\Documents and Settings\amartin\Desktop\Technip\Red Hawk\New part\Workbench tests rev 8\full360-MPC-10-25.dsd

1. Summary

This report documents design and analysis information created and maintained using the ANSYS® engineering software program. Each scenario listed below represents one complete engineering simulation.

At the bottom of the window, a tabbed interface is visible. The tabs include "Geometry", "Worksheet", "Print Preview", "Report Preview", and "Status". The "Report Preview" tab is currently selected and is circled in red.

Figure 50: Simulation Design Report

Decreasing Solving time

If the desktop computer where Workbench is installed is part of a larger Ansys server, it is possible to run solutions on the server for faster processing. By going to Tools > Options in the top toolbar, an Options window appears. Click on Simulation > Solution to see where Workbench currently runs the Solver (Figure 41). In the right box of this options window are settings to change the location of process settings. Change these settings to the location of the server, and workbench will use that server for processing the simulation analysis.

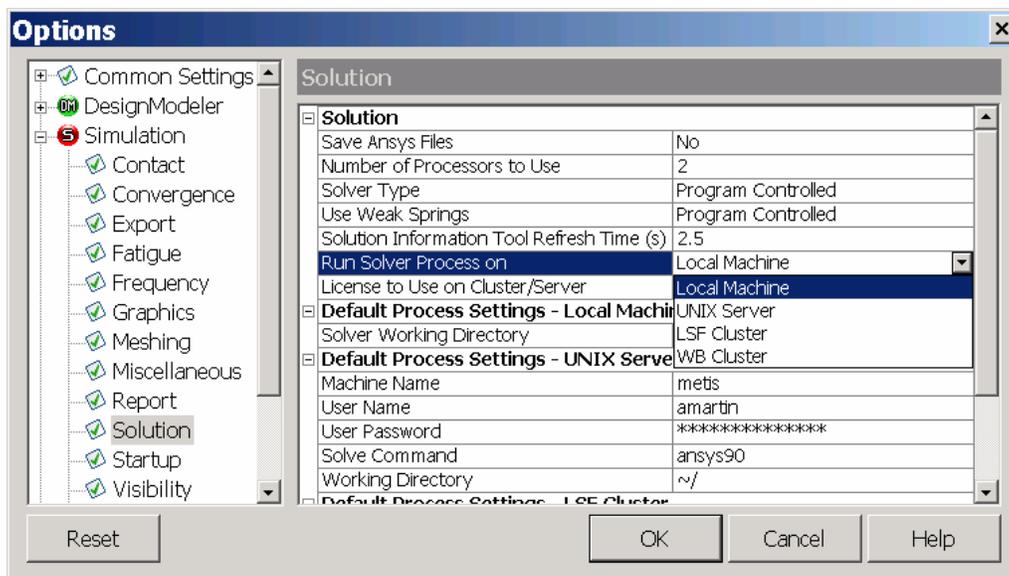


Figure 51: Solution Settings

DX-VT

DesignXplorer VT (DX-VT) is used for analyzing the response of parts and assemblies in a simulation model. DesignXplorer was created from various optimization methods such as Design of Experiments (DOE). Through these methods, DX-VT uses parameters from Simulation, Design Modeler, and various supported CAD packages as the inputs for solving an optimization. Input and response parameters are the main variables used to find an optimal solution.

The variation technology in DesignXplorer VT helps provide a much more efficient and timely solution to these problems. By using mesh morphing and the Taylor series expansion approximation, DX-VT can provide a response surface that is based on a single finite element solve. This is done by calculating the derivatives of the FEA solve. The effect of this is an “extended” finite element analysis that takes longer than one FEA solve, but is much shorter than the multi-solution runs that are required for a regular DX solve.

8.3.1 Begin & Select Parameters

To run a DX-VT study, follow these steps: Begin by having a Workbench Simulation session open with all the parameters specified. See Simulation- Parameters above for details. Open a DX-VT study by selecting New DesignXplorer VT study from the project tab in Workbench (Figure 42). When the DX-VT window opens, select the input parameters from the left column that are important to this particular study (Figure 43). Input parameters normally include geometry dimensions, material properties, or suppressed features. Response parameters are all included from those chosen in Simulation, and could be parameters such as geometry mass, total deformation, shear stress, etc.

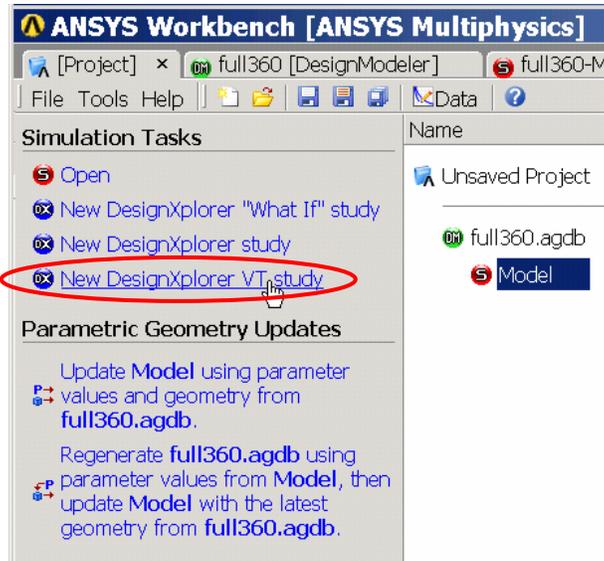


Figure 52: Start New DesignXplorer VT Study

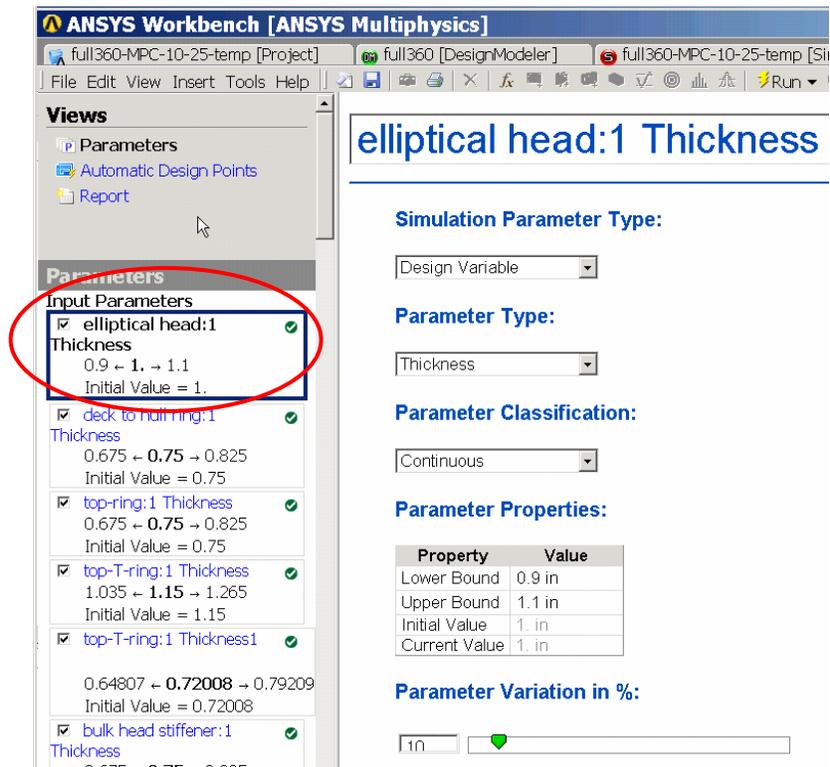


Figure 53: Select Input Parameters

Define Parameter types

When selecting each parameter there are pull down tabs in the middle of the screen to choose the proper Simulation Parameter Type, Parameter Type, and Parameter Classification (Figure 44). The Simulation Parameter Type may be a design variable or uncertainty variable. Use design variable if you know the parameter is a key part to the design. The Parameter Type (for geometry parameters) specifies how the parameter is used in the part, length, angle, thickness, etc. The Parameter Classification can be set to continuous (for continuous variation of value) or usability (for discrete use or non-use of the parameter).

Simulation Parameter Type:
Design Variable

Parameter Type:
Thickness

Parameter Classification:
Continuous

Parameter Properties:

Property	Value
Lower Bound	0.675 in
Upper Bound	0.825 in
Initial Value	0.75 in
Current Value	0.75 in

Parameter Variation in %:
1.0%

Figure 54: Parameter Details

Also in the main window as the last parameter setting is a place to change the Parameter Variation. Changing this variation allows DX-VT to solve for a larger or smaller range of values for that parameter. Larger variation ranges give more design points to experiment with, but also increase the time it takes to reach a solution.

Run Solve in ANSYS

When the parameters are all selected and defined, run the DX-VT solve by going to the top toolbar and selecting Run > Solve in ANSYS (Figure 45). This will perform the ANSYS solve with variation technology so that one solution will be sufficient for analyzing hundreds or thousands of design points.

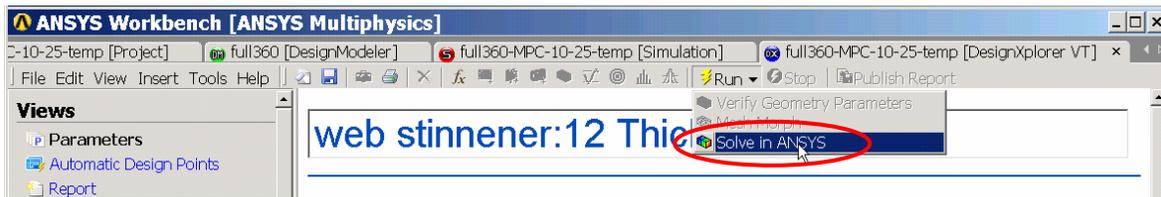


Figure 55: Solve in ANSYS Button

Responses

After the solution has finished, new views will become available in the left column of the window. The Response button on the left column (Figure 56) shows each response variable, and allows the user to vary the input parameters by moving the slider bar between the extreme points of that particular study (Figure 57). The response variable changes as the input variable is adjusted. This change can be seen in the graphical display of the assembly on the main section of the window.

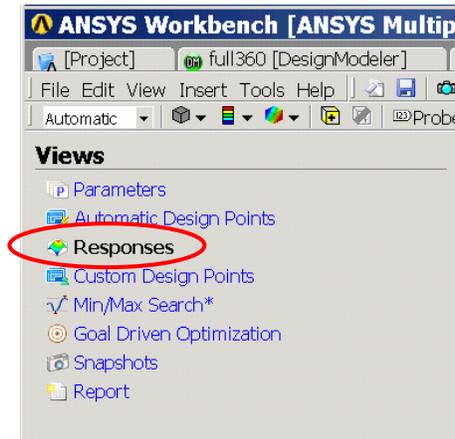


Figure 56: Responses Button

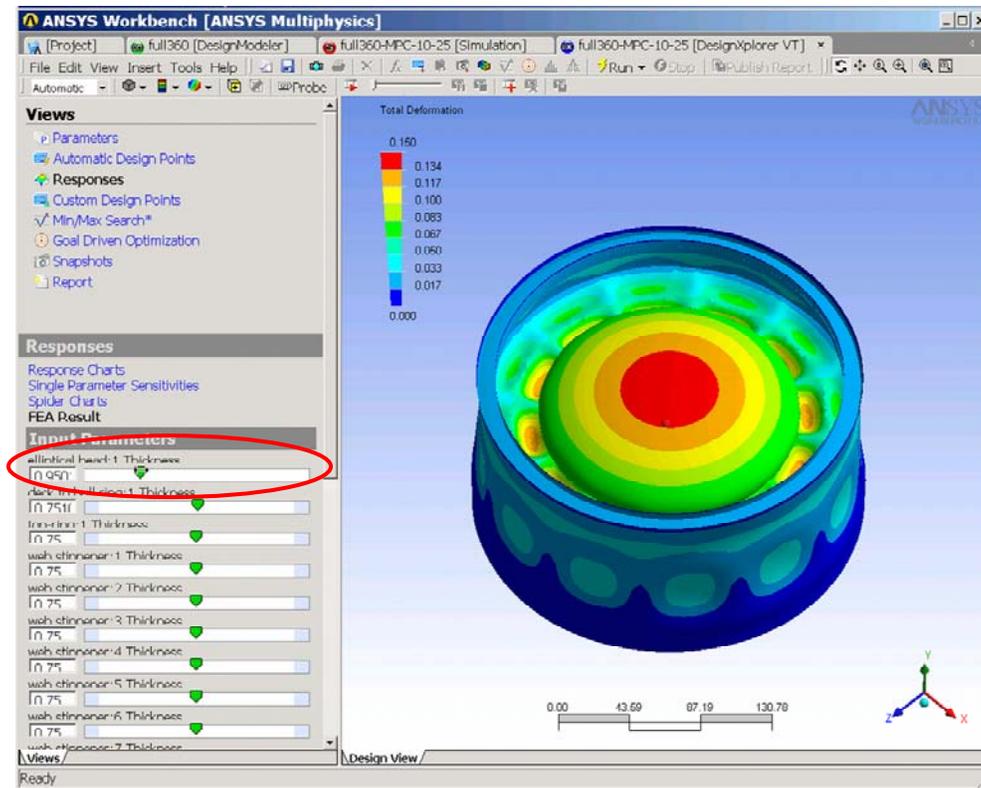


Figure 57: Response to Input Parameters

Goal Driven Optimization

By using Goal-Driven Optimization (GDO), DesignXplorer will create multiple of robust design points through sample generation. To generate samples, pick or enter the number of samples in the Sample Generation box in the lower left part of the window (Figure 58). Sample size should be based on complexity of analysis, the more complex the model, the longer it will take to generate these samples from the solution data. Therefore it might be time efficient for a larger model to have less samples. A good size for completeness is 1000 samples, if the model is moderately complex (under 20,000 elements).

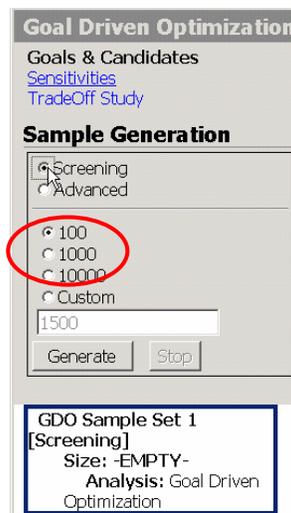


Figure 58: Sample Generation

The next step is to set Goals for Input and Response Parameters. In the main window, click on each parameter that needs to be optimized in this study (Figure 59). In the row of each parameter there are pull down lists to set Desired Value and Importance for each parameter. In the Response Parameters a target value can also be set, which can be very useful for certain goals such as target mass, etc (Figure 60). When all the

desired parameters are set, click Generate set at the bottom of the Sample Generation box (Figure 61).

GDO Sample Set 1

■ A Goals Driven Study uses a calculated set of sample design points. Click the "Generate Sample Designs" button to generate these points.

Input Parameter Goals
Click rows in this table to assign design goals to input parameters.

Name	Lower Bound	Upper Bound	Target	Desired Value	Importance
elliptical head:1 Thickness	0.9	1.1		No Preference	Default
deck to hull ring:1 Thickness	0.675 in	0.825 in		No Preference	Default
top-ring:1 Thickness	0.675 in	0.825 in		Near Lower Bound	Default
web stinnener:1 Thickness	0.675 in	0.825 in		Near Midpoint	Default
web stinnener:2 Thickness	0.675 in	0.825 in		Near Upper Bound	Default
web stinnener:3 Thickness	0.675 in	0.825 in		No Preference	Default
web stinnener:4 Thickness	0.675 in	0.825 in		No Preference	Default
web stinnener:5 Thickness	0.675 in	0.825 in		No Preference	Default
web stinnener:6 Thickness	0.675 in	0.825 in		No Preference	Default
web stinnener:7 Thickness	0.675 in	0.825 in		No Preference	Default
web stinnener:8 Thickness	0.675 in	0.825 in		No Preference	Default

Response Parameter Goals
Click rows in this table to assign design goals to response parameters. Defining a target value is optional.

Name	Target	Desired Value	Importance	TradeOff
Geometry Mass	-	No Preference	Default	-
Equivalent Stress Maximum	-	No Preference	Default	-
Total Deformation Maximum	-	No Preference	Default	-
Maximum Principal Stress Maximum	-	No Preference	Default	-

Candidate Designs
Generate or update candidate designs based on the current goals

Figure 59: Goals for Input Parameters

Response Parameter Goals
Click rows in this table to assign design goals to response parameters. Defining a target value is optional.

Name	Target	Desired Value	Importance	TradeOff
Geometry Mass	<input checked="" type="checkbox"/>	Less Than Target	Default	<input type="checkbox"/>
Equivalent Stress Maximum	-	Minimum Possible	Default	On
Total Deformation Maximum	-	Minimum Possible	Default	On
Maximum Principal Stress Maximum	-	Minimum Possible	Default	On

Candidate Designs
Generate or update candidate designs based on the current goals

[About Parameter Ratings](#)

Figure 60: Goals for Output Parameters

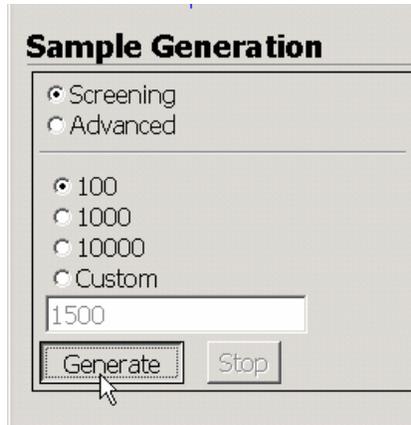


Figure 61: Sample Generation Button

When the samples have been generated click on the button under Candidate Designs at the bottom of the main window (button reads: Generate or update designs based on current goals) (Figure 62). Under Candidate Designs, three candidates will be generated that rank best with the goals selected for this sample. The candidates have each parameter listed with a number of stars or X's bases on how well or poor each parameter came to meeting the goal set. Choose a Candidate Design with the most acceptable parameter attributes (Figure 63). Insert selected candidate as a soft design by clicking the button labeled: "Insert selected as a soft design" at the bottom of the main window (Figure 63).



Figure 62: Candidate Designs

Candidate Designs

Generate or update candidate designs based on the current goals

Parameter	Candidate A	Candidate B	Candidate C
elliptical head:1 Thickness	0.919 in ★★	0.907 in ★★★	0.831 in ★★
deck to hull ring:1 Thickness	0.76012 in —	0.78825 in ××	0.81637 in ×××
top-ring:1 Thickness	0.68131 in ★★★	0.69242 in ★★	0.71464 in ★
web stinnener:1 Thickness	0.80175 in —	0.76575 in —	0.69375 in —
web stinnener:2 Thickness	0.72167 in —	0.74004 in —	0.7033 in —
web stinnener:3 Thickness	0.79848 in —	0.71666 in —	0.73154 in —

Insert selected candidate as a soft design

About Parameter Ratings

Design View

Figure 63: Best Candidate Designs

Sensitivities

Under the Goal Driven Optimization bar in the left column, click Sensitivities (Figure 64). This feature shows charts of significant input parameters. The charts show how significant each input parameter is on any response parameter such as Total Deformation. Click the different response parameters at the bottom of the left column to see what input parameters affect the response parameters and by how much.

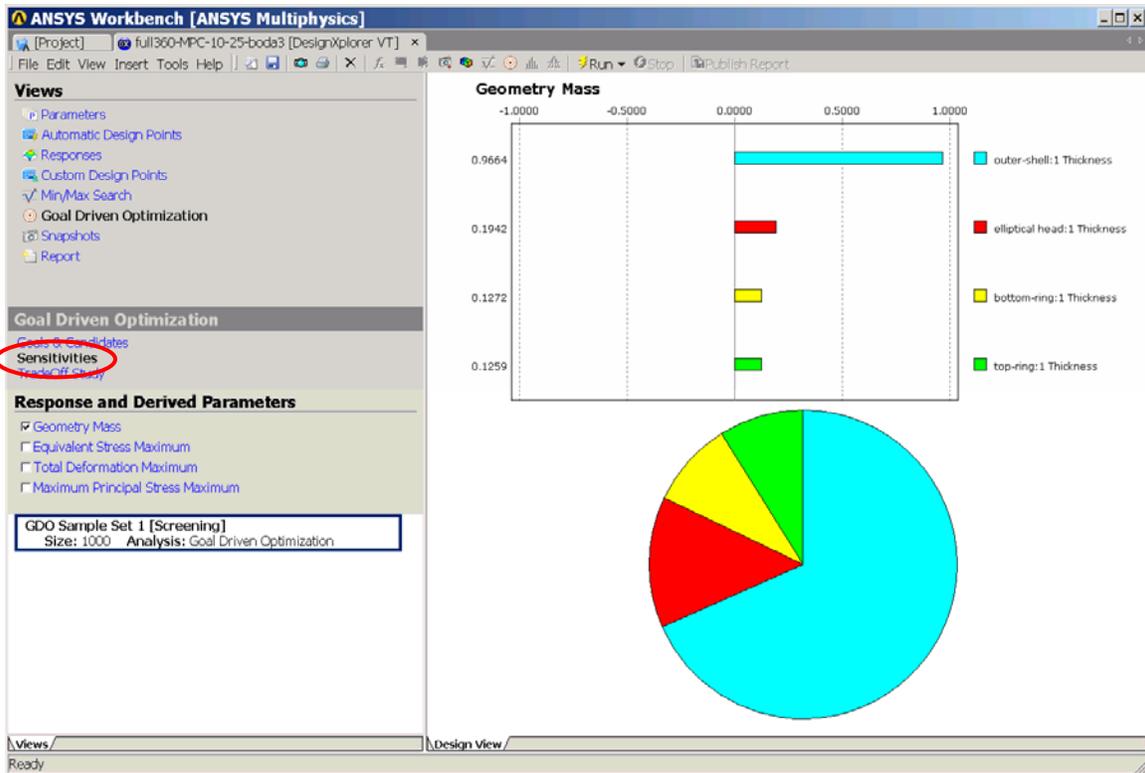


Figure 64: Sensitivities

Trade off study

The Trade Off Study allows the user to explore the calculated response surface of a response variable based on two competing input variables. By selecting two competing input and one output parameter in the left column, the main window will display a 3D plot of input and response parameters (Figure 65). The chart shows sample input parameters values, and the response parameters values, which is useful to show where response parameters reach a min, max, or more importantly inflection point. For example, this chart would help find the ideal input parameter values to minimize Max Principle Stress.

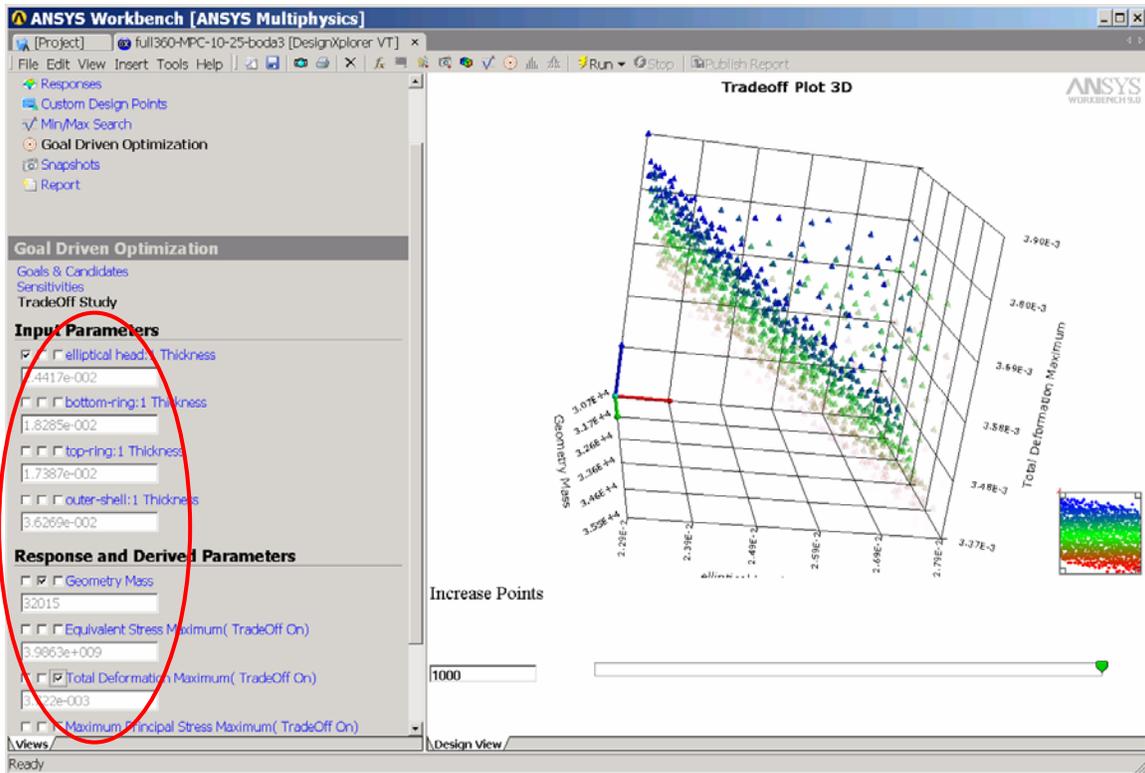


Figure 65: Tradeoff Plot 3D

Reports

DesignXplorer offers a sophisticated reports section similar to those produced by Workbench Simulation. DX-VT automatically generates a Report for the user that summarizes: Design Parameters, Min/Max Search Results, Design Goals, Custom Design Points, Automatic Design points, Responses, Sensitivities, Goal Driven Optimization Sets, and Trade-off Studies to name a few. To generate this report, click the Report button on the left column of the window (Figure 66).

ANSYS Workbench [ANSYS Multiphysics]

full360-MPC-10-25-boda3 [DesignXplorer VT]

File Edit View Insert Tools Help Run Stop Publish Report

Views

- Parameters
- Automatic Design Points
- Responses
- Custom Design Points
- Min/Max Search
- Goal Driven Optimization
- Snapshots
- Report**

Report

Subject: Bulkhead 4

Company: Technip Inc.

Prepared By: Andrew Martin

Prepared For: Technip Inc.

Created On:

Last Modified On:

Software Used: ANSYS DesignXplorer 9.0



Design Parameters

TABLE 1
Continuous input parameter definitions

ID	Name	Lower Bound	Upper Bound	Usable Values	Initial Value	Type
P1	elliptical head:1 Thickness	2.286e-002 m	2.794e-002 m	Continuous	2.54e-002 m	Thickness
P2	top-T-ring:1 Thickness	2.6289e-002 m	3.2131e-002 m	Continuous	2.921e-002 m	Thickness
P3	top-T-ring:1 Thickness1	1.6461e-002 m	2.0119e-002 m	Continuous	1.829e-002 m	Thickness
P4	lower flange ring:1 Thickness	2.286e-002 m	2.794e-002 m	Continuous	2.54e-002 m	Thickness
P5	deck to hull ring:1 Thickness	1.7145e-002 m	2.0955e-002 m	Continuous	1.905e-002 m	Thickness
P6	bottom-ring:1 Thickness	1.7145e-002 m	2.0955e-002 m	Continuous	1.905e-002 m	Thickness
P7	top-ring:1 Thickness	1.7145e-002 m	2.0955e-002 m	Continuous	1.905e-002 m	Thickness
P8	outer-shell:1 Thickness	3.429e-002 m	4.191e-002 m	Continuous	3.81e-002 m	Thickness

TABLE 2
Response parameters and calculated extrema

ID	Name	Minimum	Maximum	Type
P9	Geometry Mass	30721 kg	35870 kg	Mass
P10	Equivalent Stress Maximum	3.4879e+009 Pa	4.2296e+009 Pa	Equivalent Stress
P11	Total Deformation Maximum	3.3444e-003 m	3.9041e-003 m	Displacement
P12	Maximum Principal Stress Maximum	1.7806e+008 Pa	2.5082e+008 Pa	Principal Stress

Min/Max Search Results

Views / Design View / Ready

Figure 66: DX Reports

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