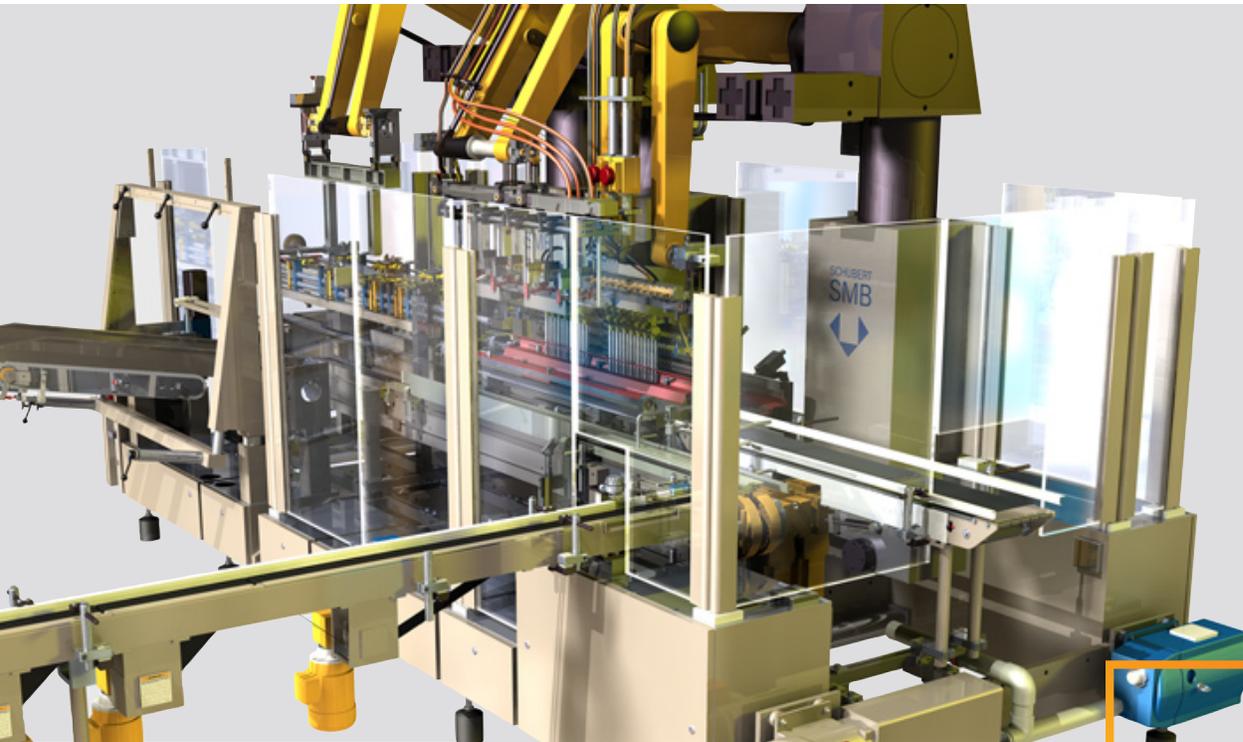# Analysis Guide for Machine Designers

real inspiration

SUMMARY

This guide describes the key design performance issues facing machine designers and manufacturers and identifies the benefits of using SolidWorks® analysis software in the product development cycle. SolidWorks software can be applied to almost any machine design field, from automation tooling to wrapping machines, to analyze a broad range of concerns. Its powerful analysis types—static, motion, thermal, vibration, fluid-flow, and nonlinear—will ensure that your product meets design requirements and is reliable in the field.

SolidWorks

Introduction

Analysis and simulation software is an indispensable tool in the development of large-scale machinery. These tools allow the developer to evaluate designs early in the design cycle, determine causes of premature failures in the field, quickly explore design changes aimed at reducing cost and weight, and determine the product's factor of safety. Use of analysis tools is of particular value to machine designers due to the size and complexity of the systems they are developing. Analysis tools can identify design issues that may elude a designer's review simply because of the dynamic nature of machinery's many moving parts.
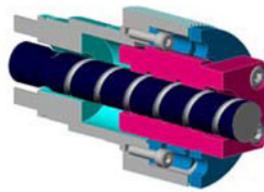
FIGURE 1:
INNER ARM OF ROBOT DESIGNED BY FANUC ROBOTICS

The unyielding demands upon machinery manufacturers by customers and the market to create systems that are cheaper, more reliable, and more productive necessitate that companies that wish to remain successful utilize all the tools available to them. These analysis tools reduce product development costs through a reduction of late engineering changes. They ensure products reach the market promptly, allowing the product to capture the largest piece of the market possible. Finally, it allows engineers to experiment with materials and designs that can result in products of minimal weight and cost. Analysis software enables engineers to simulate design performance and identify and address potential design problems before prototyping and production.

Analysis at the forefront of machine design product development

Regardless of the specific application, machine designers are under pressure from their customers: increase reliability and longevity; be quicker to market with new, improved products; reduce product weight and cost; and increase productivity. Working in this type of environment, engineers have little time to produce multiple prototypes and use trial and error to gain a better understanding of the physical behavior of their designs. Yet, that information is vital for producing innovative, high-quality products.
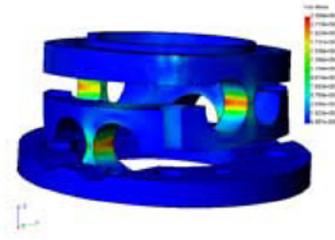
Analysis tools help machine designers understand the physical behavior of their designs quickly without resorting to expensive prototypes and physical tests that extend the product design cycle. Analysis tools can substantially reduce the number of ECOs, missed deadlines due to redesigns late in the design cycle, and costly redesigns at manufacturing time. All of these markedly decrease development costs and time-to-market. Further, these tools increase communication between design, sales, marketing, manufacturing, and the customer through their easy-to-read and -understand graphical results.

Application areas

- Production Equipment: Hallmark Cards, food production

- Industrial Robots and Robotic Systems: design optimization, failure analysis

- Industrial Food Machinery

- Packaging Equipment

- Electromechanical Systems: heating

- Printed Circuit Boards: semiconductors, heat sinks, MEMS

- Cooling Systems: fans, motors, air flows

- Electronic Systems: antennas, transmitters, switches

- Automation Tooling

- Aerating Machines, for beverages

- Bag Opening, Filling, and Closing Machines

- Bottling Machinery: washing, sterilizing, filling, capping, and labeling

- Bread-wrapping Machines

- Carton-packing Machines

- Label Moisteners, industrial type

- Labeling Machinery, industrial type

- Wrapping Machines

Analysis tools help machine designers understand the physical behavior of their designs quickly without resorting to expensive prototypes and physical tests that extend the product design cycle.

Scope of analysis

- Design verification/validation: Will this design work? Will this design behave the way I think it will?

- Relative merit: Which of these candidate designs is the best? How can I weed out and eliminate poor-functioning designs?

- Proof of concept: Testing radical new concepts without producing prototypes

- Durability and reliability: Fatigue/failure analysis, drop tests, shake simulations

Tight integration with 3D CAD

The SolidWorks 3D CAD system, the standard for 3D design, is tightly integrated with all major CAD software. This means that engineers can use SolidWorks analysis software directly on the CAD model and do not need to remodel designs to take advantage of analysis technology.

FIGURE 3:
HALLMARK CARDS DESIGNS CARD-MANUFACTURING MACHINERY USING SOLIDWORKS SIMULATION.

"What if" studies

A clear advantage of performing "virtual" testing using computer simulations over physical testing, beyond the cost and time savings, is the ability to quickly compare many designs incorporating different materials, part geometries, assembly configurations, subsystems, and more. Using analysis to conduct "what if" studies—what if I tried this material, or what if I used this type of mechanism—can help engineers identify the best material and mechanical design for a particular function. Using computational model and analysis software to perform "what if" evaluations saves time and money and can help to improve design performance. By coupling analysis studies with SolidWorks Configuration Management, the designer can quickly converge on the best-form design solution over many degrees of freedom.
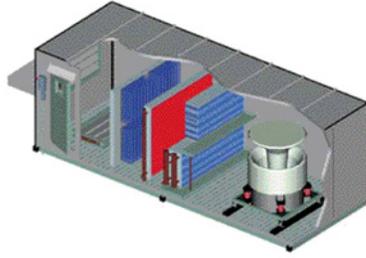
Using computational model and analysis software to perform "what if" evaluations saves time and money and can help to improve design performance.

Powerful analysis types—static, motion, thermal, vibration, fluid-flow, nonlinear

Machine designers must work with systems of amazing complexity and variability. The kinematics and dynamics of all of the system's moving parts and their potential for interference requires a great amount of design effort. Thermal effects of the heat-producing components upon the rest of the systems can be difficult to predict and design around. Vibration and other structural issues can lead to part failures, poor performance, and other operational issues. Companies that use analysis to address these issues at the design state develop a clear advantage over their competitors. SolidWorks analysis software helps to ensure that these considerations are addressed early in the product development cycle, enabling manufacturers to accelerate time-to-market and reduce development costs while producing higher-quality products with fewer warranty issues. Using a range of analysis technologies, SolidWorks software helps engineers to ensure that a product's behavior will be within design limits, reliable, and free of the risk of thermal, electromagnetic, or stress-induced failures.
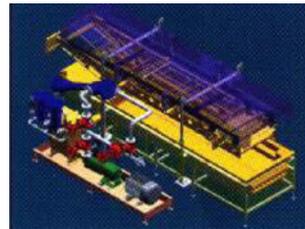

FIGURE 5:
CALCULATING THE CRITICAL FORCES OF A ROLLER ON A SHEETER HEAD TAKES JUST MINUTES FOR CASA HERRERA.

Companies that use analysis to address these issues at the design state develop a clear advantage over their competitors.

- Static analysis is a tool that empowers the machine designer to avoid catastrophic immediate or long-term failure modes and determine if redesign of one or more of the core elements is necessary. Designers can study the stresses or deflections in the device and compare it against allowable levels to predict failure. SolidWorks Simulation has the ability to analyze shells using SolidWorks surfaces and by extracting mid surfaces of thin-walled structures, particularly useful in machines that incorporate sheet metal in their designs. Through static analysis, designers can optimize geometries, minimize weight and material usage, and determine the factor of safety built into each of their machines.

- Motion analysis is also extremely valuable in the development of machinery in that they are by their nature extremely complex, dynamic assemblies. Running motion analysis allows designers to perform "virtual testing" before manufacturing physical prototypes, saving time and money during the iterative design cycle. Changes prior to "cutting metal" are far cheaper and quicker to enact. Motion analysis allows the designer to learn more about the machinery in the concept phase and perform dynamic interference detection prior to building engineering models.

- Thermal analysis is critically important in machine design. Managing temperature, whether it's of printed circuit boards, mechanical devices, or of fluidic systems can be an important design challenge that an engineer must overcome. SolidWorks Simulation analysis software can perform steady-state or transient thermal analysis on parts or assemblies. After meshing the design, the designer sets any relevant constraints, then sets power or heat flux conditions associated with a geometrical feature of the model. Because component material properties include thermal conductivity, coefficient of thermal expansion, and heat capacity, the designer gets a realistic prediction of temperature distributions under prescribed loads and operating conditions.
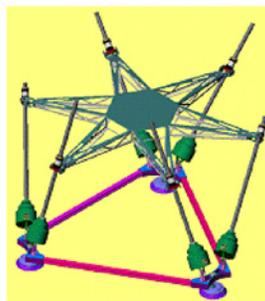

FIGURE 6:
END-OF-ARM AUTOMATION TOOLING DESIGNED BY PUSHCORP, INC.

- Vibration analysis is valuable in many types of machinery products. Many have motors, pumps, and other vibration sources that can adversely affect performance of surrounding electronic and mechanical devices. Optimal performance, with a minimal amount of adverse effects on these components, requires an understanding of the natural frequencies at which a component or assembly will vibrate and the impact of any stresses or deflections that

may occur. Using SolidWorks Simulation analysis software, an engineer can simulate the natural frequencies of a part or assembly and use this information to modify the design or materials used to avoid resonance and deflection in certain areas or improve performance. Random vibration analysis can also help engineers stiffen electrical systems that are designed to survive earthquakes and represent a more cost-effective approach than conducting physical shake tests. Analysis can be used to minimize frequency and vibration to minimize the perturbations' effects on the system performance.
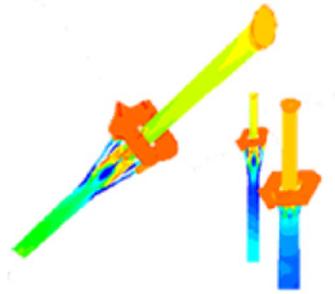

FIGURE 7:
NEUMAG IMPROVES NOZZLE DESIGN WITH SOLIDWORKS FLOW SIMULATION.

- Fluid-flow analysis has a number of applications in the machine design domain. Fluid-flow properties play a large role in heat transfer analysis. Large machinery generally has large heat sources such as power supplies and motors that require active cooling. Convective and conjugative heat transfer are dependent on fluid-flow properties. Fluidic systems such as hydraulics can also be modeled and their designs evaluated. Third, this analysis can be used in the design process of fluidic components such as nozzles, valvings, pump systems, and lubrication systems. Whatever a manufacturer's analytical needs, SolidWorks Flow Simulation offers high-powered computational flow dynamics (CFD) analysis for understanding the impact of fluid flow on temperature in electrical systems.

- Nonlinear analysis gives electronics and electrical product designers the ability to evaluate product performance within a complex, 3D-simulated environment, giving them a far more accurate determination of the different factors that may cause a device to fail. Nonlinear analysis tools are effective for analyzing static and dynamic problems with geometric and material nonlinearity, hyperelasticity, creep, thermo-plasticity, and viscoelasticity. SolidWorks Simulation Premium nonlinear analysis software can also analyze nonlinear contact problems involving surface interactions of models with or without friction.
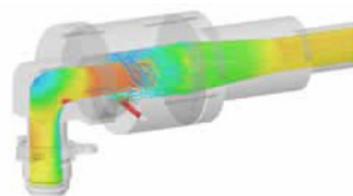

FIGURE 8:
CYCLONIC INERTIAL SEPARATOR BY DAVID RACHELS AND HIS ENGINEERING TEAM

Large machinery generally has large heat sources such as power supplies and motors that require active cooling.

Assembly analysis

Large-scale assembly analysis is absolutely critical for machinery designers. Industrial machinery by its nature contains many complex subassemblies of many parts. As such, analysis on machine designs requires a wide range of attachment, interconnection, and encapsulation methods. Designers require that analysis run on their parts, subassemblies, and full assemblies. These assemblies can be affected by heat, pressure, vibration, impacts, and electromagnetic fields at all levels of the design.
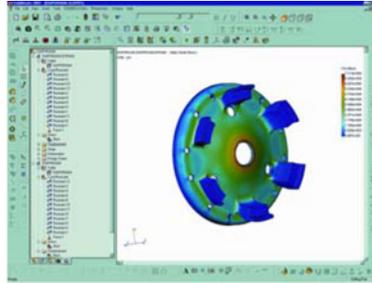

FIGURE 9:
CHUCK DESIGNED BY SPEEDGRIP CHUCK INC.

SolidWorks Simulation analysis software enables engineers to simulate all of these behaviors by allowing for the analysis of small or large CAD assemblies. The software allows engineers to assign different materials to different parts of the assembly and specify how the components will interact with each other. SolidWorks Simulation assembly gap/contact analysis allows you to simulate various real-life conditions for large machines.

Many of what in the past have been physical tests on large machines can now be moved to computer simulations. Drop tests, to ensure that shipping does not damage the machinery, can be performed during the design phase and easier, less costly changes can be made prior to physical prototyping and manufacturing. Thermal analysis can ensure that no components within the system become overheated and can aid in designing appropriate heating and cooling systems within the machinery. Sources of vibration within a system can be modeled and their effects on surrounding components studied. This allows for effective isolation systems to be developed early in the design cycle.

3D Visualization

SolidWorks Simulation analysis tools enable analysis of machinery and large-scale industrial products at the component, assembly, and system levels.

▪ 3D visualization provides a designer with a first check of design intent, proper operation, and aesthetics as the project develops.

▪ 3D CAD enables the designer to view a product design from all angles and examine the internal parts of the product throughout the design process. This gives designers a clear and accurate review of parts and assemblies early in the design cycle.

SolidWorks Simulation assembly gap/contact analysis allows you to simulate various real-life conditions for large machines.

- 3D visualization reduces communication and fabrication errors, saving development time by more effectively conveying design information so that designers can find problems early in the design cycle.

- Designers can view the product from all sides and look inside by hiding the outer enclosure or other parts.

- 3D animations of simulations allow you to see how the machinery functions in the real world.

- Section plots allow you to see simulation results inside the part and not just on the surface.

Collaboration tools offer new ways for product designers to work more effectively with other members of the development team.

FIGURE 10:

THE JOHNSON CORPORATION DESIGNS SYSTEMS FOR PROCESS INDUSTRIES.

Design communication and collaboration tools

- Design collaboration has become an increasingly important part of the product development process, enabling designers to share designs easily with anyone, anywhere.

- Collaboration tools offer new ways for product designers to work more effectively with other members of the development team. The ability to share design resources over the Internet benefits all product designers, from independent consultants to engineers in large multinational corporations.

- SolidWorks Simulation analysis tools allow designers to share analysis results in various formats such as:

  - HTML reports of analysis results
  - VRML files
  - AVI files
  - SolidWorks Simulation allows users to publish SolidWorks eDrawings® files for analysis results.

Conclusion

Machinery manufacturers face relentless demands by customers and the market to create systems that are cheaper, more reliable, and more productive. Companies that wish to remain successful utilize all the tools available to them. With analysis and simulation tools, the developer can evaluate designs early in the design cycle, determine causes of premature failures in the field, quickly explore designs changes aimed at reducing cost and weight, and determine the product's factor of safety. Analysis tools are particularly valuable to machine designers due to the size and complexity of the systems they are developing. SolidWorks simulation and analysis tools reduce product development costs, ensure products reach the market promptly, and allow engineers to experiment with materials and designs that can result in products of minimal weight and cost.