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Tomorrow's aerospace composites factory is here today

Industry 4.0 technologies drive manufacturing engineering innovation

Siemens Digital Industries Software

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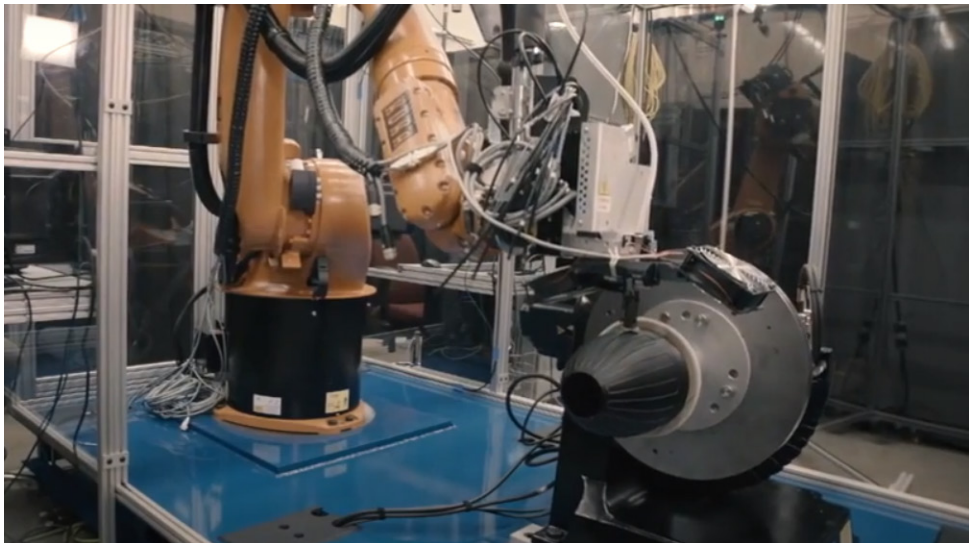
The use of composite materials in the aerospace and defense (A&D) industry has been accelerating since the first use of composites in the F-14 in the 1970s. As materials and manufacturing technologies have developed, the percentage by structural weight of composites used in aircraft manufacturing has quickly and significantly increased – from two percent in the F-15 to around 50 percent in the V-22 tilt-rotor aircraft and the 787 Dreamliner.

At the same time, the traditional aerospace factory with conservative concepts, repetitive tasks and labor-rich processes is transforming into the factory of the future – using Industry 4.0 technologies in smart, connected, transparent and automated processes that are adaptable to product changes and demand fluctuations. Nations across the globe are forming public-private partnerships and investing heavily in engineering and manufacturing digitalization to directly impact gross domestic product through the manufacturing sector.

Many A&D companies believe they are too busy coping with day-to-day challenges in their production operations, to implement Industry 4.0 concepts and technologies. This article discusses some key factory-of-the future concepts including advanced robotics, production simulation, additive manufacturing, augmented and virtual reality (AR/VR) and the industrial Internet of things (IIoT), and describes how these technologies can be leveraged to transform A&D composites manufacturing.

Robotics and additive manufacturing for composites

Siemens and Stratasys, a leading manufacturer of 3D printers and 3D production



Breakthrough technology: Stratasys composite material extruder attached to a KUKA robot, programmed using Siemens multi-axis software.

systems, are collaborating to break through the layer-by-layer approach of conventional additive technologies and the limiting processes of conventional composites production. One of the results of this cooperation is the Robotic Composite 3D Demonstrator, which uses a Stratasys composite material extruder as an end-effector mounted on a KUKA robot that is simulated and programmed by advanced multi-axis software from Siemens. One of the unique capabilities this brings to industry is the 8-axis kinematics of the robot and the tables, which enable precise material placement for maximized part strength and build speed. The technology can eliminate the need for support material and reduces post-processing labor and lead time.

Production simulation for composite production cells

Aerospace composite manufacturers can accelerate time-to-production and automate manufacturing processes using robotic workcell design, simulation and offline programming for automated composites layup and inspection. Some of the most complex examples are workcells for ultrasonic quality inspection of composite components. Engineering and optimizing such an inspection station requires definition of robotic paths to include a pattern of inspection points; a programmable logic controller to synchronize the devices and control safety interlocks; and definition of the control logic for inter-device signals.

Process Simulate Robotics software in the Tecnomatix® portfolio provides tools for building digital twins of such complex workcells that precisely simulate the operation to validate the process. Manufacturing engineers can author, re-use, validate and optimize manufacturing process sequences in an interactive visual environment with realistic behavior using fully kinematic 3D models. These solutions support a variety of robotic and automation processes, allowing for early validation of automation concepts virtually and the simulation, offline programming and commissioning of complete production systems.

Human simulation refines aerospace production tasks and work environments

Advanced human modeling, visualization and simulation technologies coupled with classic ergonomics and human factors assessment techniques can help aerospace manufacturers optimize production processes, evaluate human factors and validate

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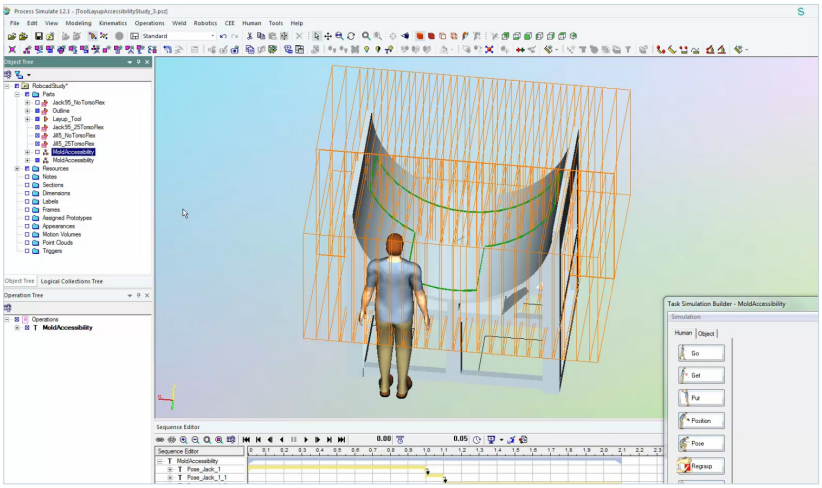

Siemens human modeling and simulation software helps verify human factors such as reachability for composite layup molds.

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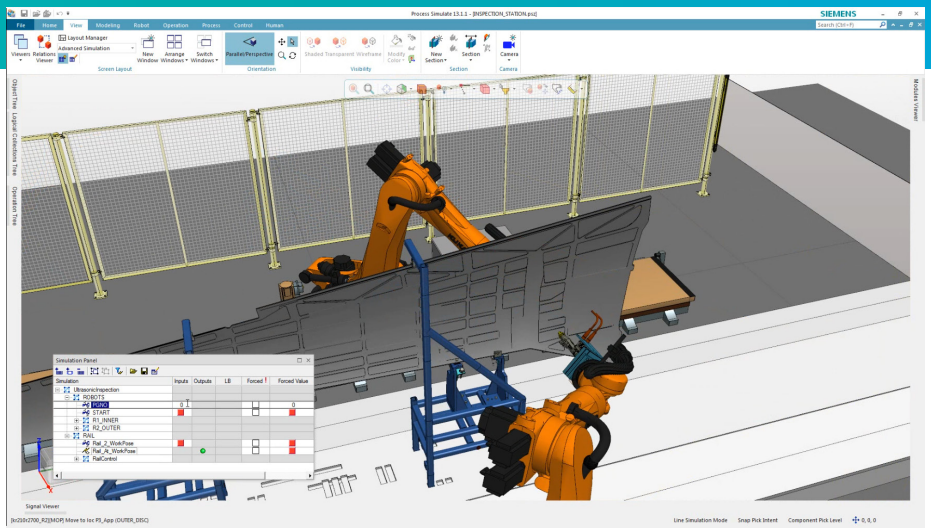
tooling for composites manufacturing, such as manual layup molds. Siemens Process Simulate Human software provides human-centered design tools for performing ergonomic analysis of virtual production environments. The human models can be sized to match worker populations and help assess manufacturing process and tooling designs for multiple factors including reachability, injury risk, user comfort, line of sight, energy expenditure, fatigue limits and other human parameters.

Virtual commissioning for composites manufacturing

One of the most advanced applications of production simulation is virtual commissioning (VC). Simulation of robotics and automation has traditionally focused on the mechanical aspects of their operation – motion in space, cycle times, collisions and conflicts. Virtual commissioning interlinks mechanical engineering with automation engineering. When designing smart workcells with jigs, automation, sensors, kinematics and inter-device communication, mechanical and automation engineers can work side-by-side, in the same environment, using collaborative tools.

Working with comprehensive, high-fidelity digital twins of complex robotics workcells, engineers can develop, validate, debug and optimize robotic paths and controls logic in a virtual environment, completely offline, before downloading it to the real workcell equipment. Using Tecnomatix VC solutions, companies can use hardware-in-the-loop (HiL) and software-in-the-loop (SiL) simulations to confirm that complex workcells will perform as expected, significantly reducing system installation costs, errors and ramp-up time.



Virtual commissioning of an ultrasonic composite wing quality inspection workcell using Siemens software.

Plant simulation helps optimize production facilities

Advanced simulation technologies enable companies to model, simulate, explore and optimize production facilities well in advance of production execution. Tecnomatix Plant Simulation software includes tools for modeling, simulation, exploring and optimizing poduction and logistics processes. The plant models enable analysis of material flow, resource utilization and labor requirements. Discrete-event simulation and statistical analysis help increase manufacturing accuracy and efficiency, improve throughput and overall system performance and make fast, reliable manufacturing decisions.

One of the most advanced applications of production simulation is virtual commissioning (VC).

Throughput optimization of composites cutting and kitting, using Plant Simulation software.

Augmented reality technology has the potential to completely transform the paradigm of shop floor work instructions.

Virtual reality for production design reviews

Another Industry 4.0 technology that can benefit aerospace composites manufacturers is virtual reality (VR). The technology, established and matured in the video game industry, has developed into a cost-effective and versatile tool for manufacturing engineering of factories. VR use cases and applications include engineering and process reviews, customer proposal reviews, preproduction training, safety zone evaluation, ergonomic analysis, quality inspections, service technician training, service documentation and remote service.

Virtual reality exploits production digital twins created with Process Simulate software to provide a realistic and immersive experience that enables manufacturing engineering teams to virtually tour all aspects of production lines in operation – assembly, drilling, riveting, ultrasonic inspection, painting and others. VR can digitally represent all elements of factory production, including human models to evaluate reachability and ergonomics, and even human-machine interfaces for specific space interaction analysis. Tools for issue management enable production review teams to identify, capture, find, manage and verify issues, and to efficiently resolve them with production modifications – all this in a virtual environment, before the production line has been commissioned.

The Process Simulate VR solution offers many benefits in addition to improved understanding of the factory floor through realistic 3D immersion. VR is safe, because users can go anywhere in the factory without risks or injury, and VR can yield timely insights to inform decision-making. With multi-user and multi-site collaboration tools, companies can perform frequent and continuous analysis of manufacturing processes and reduce travel costs. High-performance visualization running on inexpensive hardware without requiring data conversion helps reduce IT and infrastructure expenses.

Augmented reality transforms work instructions

Augmented reality (AR) technology has the potential to completely transform the paradigm of shop floor work instructions. Traditionally, A&D companies have used blueprints and other hardcopy work instructions to guide shop floor personnel. Unfortunately, it is an endless struggle to keep hardcopy instructions updated, introducing manufacturing mistakes.

With the production digital twin, up-to-date information in the form of electronic work instructions can flow seamlessly to the shop floor. AR technology enables the work instructions to include 3D digital data, projected on physical components, to guide operators step by step through assembly operations. Taking AR solutions to the next level can save the endless chase to update work instructions, as what you see (as a documentation engineer) is what you get on the shop floor for the technicians.

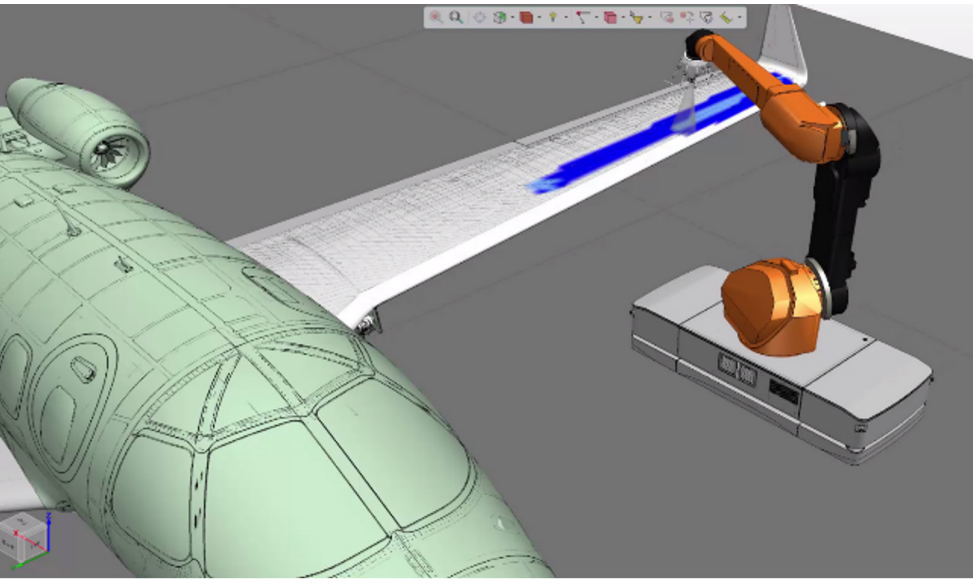
Aerospace manufacturers are moving away from large, inflexible production machines to flexible robotic workcells.

Process simulation and offline programming for more flexible production lines

Traditionally, aerospace companies have manufactured products like airplanes by moving the product to the machines and the tooling. For large aerospace products, moving the product can naturally introduce significant production challenges. In the future aerospace factory, much of the tooling – automated machines and robots – will be mobilized with the help of automated guided vehicles (AGVs). This change in the production paradigm enables aerospace manufacturers to rethink their factories for greater flexibility and efficiency.

Aerospace manufacturers are moving away from large, inflexible production tooling to flexible robotic workcells. One example of this trend is Electroimpact, a world leader in the design and manufacturing of aerospace tooling and automation. Traditionally a provider of large manufacturing equipment like composite layup workcells and C-frame drilling and riveting machines, Electroimpact is transforming into a supplier of flexible robotic workcells and production lines. Electroimpact is partnering with Siemens to develop technology for planning, validation and optimization of these advanced manufacturing systems.

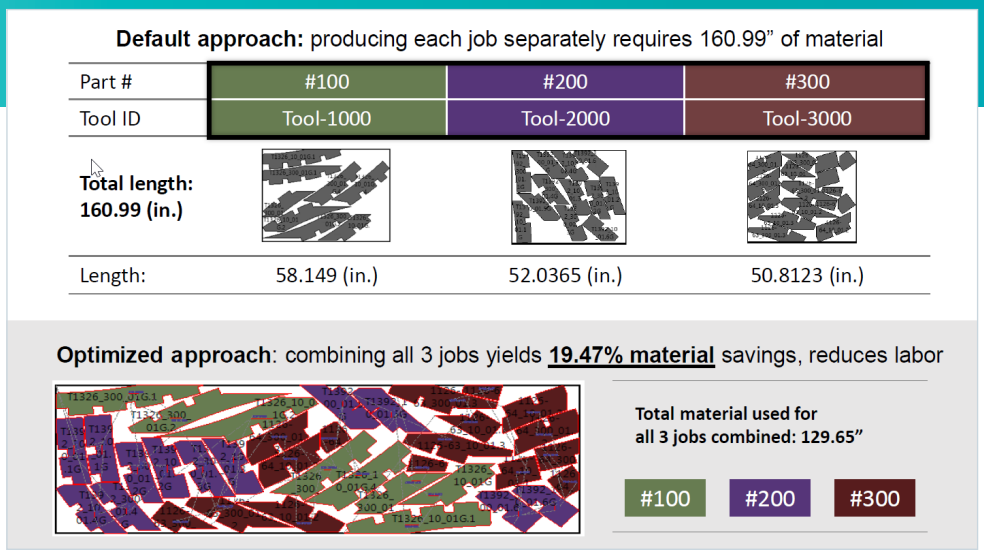
One of the tools Electroimpact provides to its customers is SIMpact PS, a lightweight, simulation-based offline programming system for the company's robots and machines. Built on the Siemens Process Simulate software infrastructure, SIMpact PS incorporates native device building, kinematics, program specification, simulation, collision detection and offline programming (OLP) capabilities. Each application of the software is developed in parallel with the automation components of the project and the requirements of the customer, ensuring maximum capability and accuracy. With SIMpact PS, customers have advanced machine customization capabilities that greatly reduce the amount of custom machine code and minimize change time to the OLP software when changes are made to the machine. The superior simulation performance of Process Simulate reduces the processing time and speed of simulation.



AGVs can mobilize tooling like this painting robot.

Advanced technologies for composites manufacturing

Plataine is another Siemens partner that is focused on optimizing composites manufacturing, using factory-of-the-future technologies such as artificial intelligence (AI) and the Internet of Things (IoT). Plataine's software solutions include capabilities for material and asset tracking, material shelf life management, work in process (WIP) optimization, and composite fabric cutting and kitting. The collaboration with Siemens includes integration of Manufacturing Process Planner software in the Teamcenter® portfolio with Plataine's cutting and kitting application, which optimizes nesting to reduce waste of expensive composite materials.



Integration of Siemens manufacturing planning tools with Plataine cutting and kitting tools enables customers to optimize composites nesting and minimize material waste.

The partnership also integrates Plataine solutions with the Siemens Opcenter™ software manufacturing execution system (MES) to manage composite material on the shop floor.

Leveraging IIoT technology to optimize service maintenance

The Industrial Internet of Things (IIoT) is already revolutionizing aerospace manufacturing. By connecting physical manufacturing assets, IIoT enables the acquisition of data from factory operations to build the digital twin of production performance. With the accessibility of greater amounts of data, at far greater speeds, and with the application of analytics, companies can gain insights to optimize production performance and better manage the maintenance and service lifecycles of their manufacturing assets.

MindSphere®, the cloud-based, open IoT operating system from Siemens, removes many of the barriers that have prevented companies from realizing the promise of IIoT technologies. By enabling fast data integration and evaluation without expensive IT investments, MindSphere helps customers to implement condition-based maintenance strategies that use sensor devices to collect real-time measurements (for example, pressure, temperature or vibration) on production equipment. The data enables companies to perform maintenance at the exact moment it is needed, prior to failure, to minimize production downtime.

Siemens has a vision for a digitalized and connected maintenance process and provides service lifecycle management (SLM) solutions that focus on making complex products easier and less costly to maintain, and increasing asset utilization and productivity with faster and more reliable service. These solutions can monitor and analyze in-service performance data, automatically trigger maintenance events based on conditions, and automate creation of service and maintenance work instructions using Teamcenter SLM software

Where manufacturing meets tomorrow

Tomorrow's factory for aerospace manufacturing is here today. As a trusted leader in the A&D industry, Siemens Digital Industries Software offers proven technologies and digital solutions that solve customers' complex manufacturing challenges. With Xcelerator, a comprehensive and integrated portfolio of software and services, Siemens is bringing Industry 4.0 into the present, where today meets tomorrow.

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