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SIMUL8-PLANNER FOR COMPOSITES MANUFACTURING

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ABSTRACT

SIMUL8-PLANNER is a simulation-based planning and scheduling tool that intelligently sequences product flow across the plant. Combining order planning with production modeling, SIMUL8-PLANNER can generate production schedules that satisfy delivery objectives and capacity limits. This paper examines a case study where the SIMUL8-PLANNER tool was used to answer the complex scheduling problem of sequencing part requirements through a Composites Manufacturing Center. First a production model was used to capture the current workings of plant processes and product flow. Next, a sequencing system was added to the production model in order to provide a powerful, flexible, and adaptive scheduling system for all of the work cells and machines within the facility, complete with links to the company's ERP / shop-floor data systems. SIMUL8-Planner provides a practical approach and powerful platform for developing, testing, and refining production schedules before they are released to the shop-floor in a virtual and risk-free setting. It offers a flexible and open scheduling system that can be used for a wide range of production scheduling applications.

1 INTRODUCTION

SIMUL8-PLANNER sequences product flow across the plant's resources, and generates production schedules that satisfy delivery objectives and finite capacity limits. This tool provides a practical approach and powerful platform for developing, testing, and refining production schedules before they are released to the shop-floor in a virtual and risk-free setting.

Off-the-shelf scheduling tools typically work well for a limited set of manufacturing applications, but are not easily adapted to address specific production problems or resolve complex scheduling issues. SIMUL8-PLANNER offers a flexible and open scheduling system that can be used for a wide-range of production scheduling applications.

Using a comprehensive production model of specific manufacturing processes, the system can quickly generate schedules that consider batching rules, machine loading requirements, resource dependencies and availabilities, multiple product routings, and other constraints such as space or tooling. Sophisticated scheduling heuristics or customer scheduling rules can be applied at all stages of the production process, permitting changes to the order sequence to enhance overall system performance. The resultant schedules are, by definition, feasible since they are developed through a detailed and accurate production model.

The simulation approach has the advantage of providing feedback on the impact of the schedule on operational objectives. What may appear to be a good schedule using less rigorous techniques could, in practice, lead to overtasked machines, frequent product changeovers, overflowing buffers, and product transfer delays due to materials handling constraints. However SIMUL8-PLANNER eliminates this by generating a feasible, finite capacity production schedule that can be assessed on both operational and business performance levels. This may include schedule conformance to customer service levels, machine utilization targets, production lead-times, and work-in-progress levels.

The ability to accurately simulate a production schedule in advance of releasing it to the shop-floor offers significant benefits. The Planner may assess a schedule under specific business and operating conditions to determine if current objectives can be met and what, if any, improvements can be made. This may be done automatically by adjusting the priorities of the applied scheduling rules, or by manually changing order sequences or machine line-ups. The ability to quickly revise and re-test schedules leads to ideas for improving the scheduling process which can then be incorporated into the system as new or adjusted rules.

The SIMUL8-PLANNER approach has been introduced recently to several Composites manufacturing centers as a scheduling system to improve due date conformance and to make better use of operating capacity within these facilities. The complexity of composite manufacturing, with exacting tolerances on product lay-up and precise cure-cycles for part processing through the autoclaves, can be helped by an end-to-end view of the process to meet order due dates. SIMUL8-PLANNER provides this visibility by detailing the process steps and operating rules across each of the manufacturing areas within the composites production facility. The system is then able to generate feasible and efficient shop-floor schedules on a daily basis.

This paper outlines the use of the SIMUL8-PLANNER system for planning and scheduling a composites manufacturing center.

2 COMPOSITES MANUFACTURING

A typical composites manufacturing process flow, shown in Figure 1, consists of:

- Ply Cutting – Cutting composites material per designed geometry.
- Lay Up – Laminate composites layers.
- Cure – Cure laminated part through autoclave.
- Trim – Trim excess material.
- Sub Assembly – Install sub assembly structures.
- Non-Destructive Test.

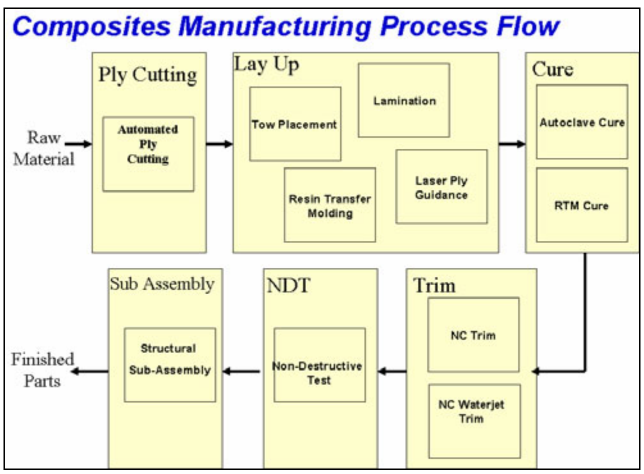

Figure 1: Composites Manufacturing Process Flow

3 INTRODUCTION TO THE PROBLEM

Composites manufacturing centers are usually responsible for producing specialized high-carbon parts for various final assembly programs. Composites materials are being used increasingly in aerospace and automotive assemblies where strength and lightness are key requirements of the finished vehicle. This increased demand has created challenges for manufacturers to keep pace, given the lengthy and complex production process. The manufacturing of these composite materials involves part routings through various lay-up, trim, drill, and cutting processes, as well as parts batching through Autoclaves (ovens) that apply heat and pressure to form the composite parts.

Composite manufacturers have approached the task of scheduling production by concentrating on level-loading the lay-up area. This is the department responsible for the initial layout and lamination of the cut composite material shapes. By ensuring that this department is fully loaded over the planning horizon, it is generally believed that production throughput is maximized. However, due to the complex cure-cycles and load restrictions of the autoclaves, and sequencing requirements of other downstream processes, this approach often creates high work-in-progress and inefficient product batches for these machines.

In addition, the task of manually creating schedules for the lay-up department is time-consuming; it lacks flexibility and the capability to adapt to the constantly changing environment within the plant. Therefore changes to staffing levels, machine outages, or new and revised orders are not always taken into account. This creates further inefficiencies in production schedules.

To overcome these problems, a faster, more automated approach to production scheduling was recommended. The proposed system was designed to not only generate production plans for the lay-up area but also to synchronize composite production across the all of the plant processes quickly and efficiently. The SIMUL8-PLANNER system captures all of the detailed operations and handles disparate batch operations, operational constraints such as resources and tooling, and complex routings.

4 SIMUL8-PLANNER SCHEDULING SYSTEM

The Composites scheduling system was developed using SIMUL8-PLANNER, which provides a fast and flexible modeling environment that captures the key manufacturing processes within a production model. This dynamic model can define all aspects of the manufacturing process including: the cycle or process times for individual parts at each machining center; resource requirements (either special tooling or skilled workers); the availability of equipment and resources; work-in-progress inventory levels; and all material handling constraints.

The system can be linked to existing MRP or ERP systems to download current orders, product routings, bills of materials, product stock levels of raw materials, work-in-progress and finished goods. The system can also capture the manufacturing rules and constraints that govern how products can be processed or assembled at each step of the way.

Once complete, the production model can be used to simulate the flow of planned production based on an existing schedule. The application of this simulation approach to scheduling in the Composites Manufacturing Center offers a practical and feasible solution which cannot be guaranteed using algorithm-based optimization packages. It provides the opportunity to look at each area of the facility and apply global and local sequencing rules to deal with the interdependencies of the different operations.

By capturing all of the processes within the plant, as shown in Figure 2, the production model provides visibility to the entire product work flow and helps to identify the key constraints. Through the use of "what-if" analysis, the tool is capable of applying different sequencing rules. These can be as simple as "maximize due date conformance" or a blend or rules that may include equipment utilization or work-in-process. These can generate alternative schedules which can then be evaluated against current production objectives and performance targets.

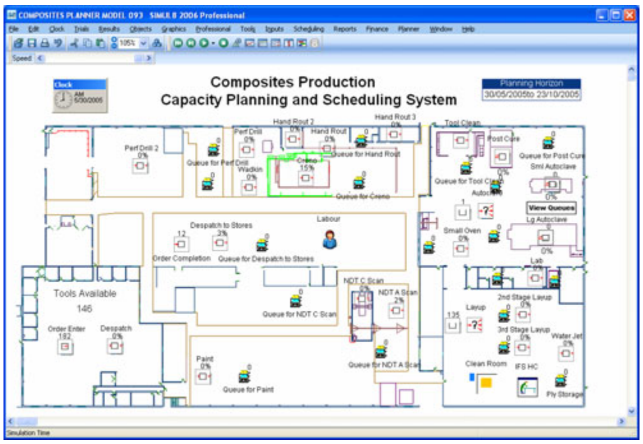

Figure 2: Plant Layout as in the Production Model

Through experimentation with the available scheduling rules, the system is capable of generating efficient production schedules that not only satisfy manufacturing constraints but also maximize the objectives of the Composites Manufacturing Center management. These objectives can be a blend of weighted factors such as on-time delivery, reduced work-in-progress, reduced manufacturing lead-times and minimum direct costs.

By efficiently scheduling key bottleneck processes, the system effectively applies a pull production system and ensures that these processes are supplied with work at all times. This addresses both the requirements of a scheduling system and tackles the high-level operational objective of creating a lean environment.

5 PRODUCTION MODEL – CAPTURING THE WORK FLOW

The first step in the application of SIMUL8-PLANNER is to capture the current workings of plant processes and product flow within a production model. This model includes equipment, machine buffers, skilled labor, product routings and process times; it is used to execute a production plan which is then refined to become a detailed production schedule through global and local scheduling rules. The local and global scheduling rules are used to refine the high-level production plan. For example, if a machine with large set-up times has a local scheduling rule to minimize set-ups then small sequencing modifications could be made at this piece of equipment to ensure that its local rule is optimized. In this particular case, the facility was already sectioned into Cost Centers, but the model required operational detail for the machines and processes within these areas, where the different job operations were completed.

The second step in creating the production model is to define the process flow for individual products. The Composites Manufacturing Center had already captured the detailed product routings within an internal database that mapped individual jobs to a particular work center code. All routings data was imported into the system and these work center codes were then mapped to individual capacity areas, or work cells, defined within the model. This provided the ability to specify production flow for each product through these work cell areas, complete with the corresponding processing, set-up, and wait times, as well as any special tooling or labor requirements as shown in Figure 3 with a sample parts routing sheet.

Product Routings Sheet

Product Number	Product Code	Product Description	Job Number	Process	Operation Time	Setup Time
158	56473-292728	Composites Part	1	Layup	2.2	0
			2	Autoclave	5.5	0
			3	Lab	0.667	0
			4	2nd Stage Layup	4	0
			5	Autoclave	5	0
			6	Post Cure	6.75	0
			7	Lab	1.67	0
			8	Creno	0.35	0
			9	NDT A Scan	0.8	0
			10	Paint	3	0
			11	Despatch to Stores	0.033	0

Figure 3: Sample Product Routing with Process Times

Having defined production flow, the model is required to simulate the system constraints. Within the Composites Manufacturing Center production, the main constraints are the tools which carry the composite parts. The majority of parts are loaded onto specific tools at lay-up and remain there until the autoclave process is completed. Parts cannot be launched into the lay-up area at the start of production without their associated tool type being available. Therefore, the production model looks for the availability of these tool types before releasing work orders. The same applies for tool requirements within the trim and drill department, and the part racking system at the autoclaves.

Resources are slightly more complex than the tooling constraint, since there can be different skill sets, shift patterns, holidays and availabilities. Each defined capacity area, or work cell, is assigned a particular resource skill set. These skill sets employ specific shift patterns to define their availability over time. This may include statutory holidays and plant shutdown days to ensure that the work cells can only be operational while the skilled teams are available within the plant.

6 DEVELOPING ORDER SEQUENCING RULES

To begin experimentation with order sequencing, order information was imported into SIMUL8-PLANNER through a series of defined CSV, Excel, and database order extracts. A fully customizable import was created so the end-user could easily run different programs and organize separate program imports for "what-if" analysis purposes. An extract of the input dialog screen is shown in Figure 4. This feature was helpful during the validation phase of system implementation, since it provided the opportunity to run all assigned work orders, thus identifying any capacity issues.

Order Import Options

Program	Description	Import	File Name
1	Area 1	Yes	Area 1 040306.csv
1	Area 2	Yes	Area 2 040306.csv
2	Area 3	Yes	Area 3 040306.csv
1	Area 4	Yes	Area 4 040306.csv
3	Area 5	Yes	Area 5 040306.csv
1	Area 6	No	Area 6 040306.csv

Figure 4: Custom Order Download Interface

During development of the scheduling rules the production model provided an excellent platform to test different product sequences and scheduling options for the imported orders. This allowed the team to consider fixed operating rules, as well as adaptive scheduling functions, and investigate their impact upon due date conformance and the utilization of production capacity.

Both global and local scheduling rules are used to sequence orders into the plant and across each work area or operating cell. This provides the ability to satisfy local machine operating efficiencies as well as global scheduling objectives, including:

- Maximization of bottleneck machine usage.
- Minimization of equipment set-up and changeovers.
- Minimization of work-in-progress across the plant.
- Maximization of batch sizes at the Autoclaves.
- Order due date conformance.

The two main areas of complexity in the scheduling process are at the Lay-up and Autoclave processes. These define the capacity constraint for the entire plant and potential production output.

Lay-up is a labor intensive process which requires scheduling based on resource availability, skilled personnel, specialized tooling or jigs, and required due date conformance. As lay-up is the first main process within the facility, parts arrive within this area according to their due date requirements. Orders are released into the system on a weekly basis according to their planned launch dates.

There are several areas within lay-up that are responsible for specific parts, such as simple and complex skins. Available orders are routed to the appropriate lay-up department and assigned to their designated tool based upon tooling availability. Once the operational constraints are satisfied, products are then sequenced in priority to work cell areas based on order slack time and due date. The orders with the least slack time are given the highest priority.

Sequencing orders based solely on due date is not appropriate, since the amount of time required to produce parts varies significantly by part type.

The autoclaves are large batch-processing machines that are dependant upon cure cycles, racking, and part availability. As the cure times for batches are extensive, the autoclaves operate on a bus schedule to ensure that resources are available for the load and unload process at either end of the cure cycle. Parts that arrive at the autoclave area cannot be loaded directly into the process. They must wait until an appropriate bus schedule for that part's cure cycle is ready, and there is space available on a rack for that cure cycle. Therefore, efficient part sequencing at the autoclave area is particularly concerned with maximizing the batch for each cycle within the bus schedule.

SIMUL8-PLANNER arranges the line-up of parts outside the appropriate autoclave for the required cure cycle. At the time the autoclave is ready to accept a batch, the available parts are searched in an attempt to produce a full load. If several batches are eligible, preference may be given to the batch with the least aggregate part slack time. If full load part batches are not available then the choice may be given to the largest available load or the load with the least slack time, so as not to miss an autoclave cure-cycle. This combination of operational and scheduling preference, weighted by the end-user, ensures the best use of the autoclaves, taking consideration overall business objectives with current plant and product demand conditions.

Once detailed schedules have been created for each production process they can be analyzed and modified by viewing the details in tabular or Gantt chart format. Figure 5 provides some of the output formats from the SIMUL8-PLANNER system.

7 SYSTEM STRUCTURE

The resultant system has a combination of import and export functions designed to provide ease-of-use and schedule visibility to a variety of end-users. The flow diagram, in Figure 6 provides an overview of the system structure within existing data systems.

Automated order downloads provide a fast transfer of the current order requirements for all departments. Orders for parts with missing information will trigger required downloads from the Excel workbook containing routings and tools information. SIMUL8-PLANNER will then export all generated schedules on a required basis to ERP / shop-floor systems. This provides maximum visibility to the required production plan.

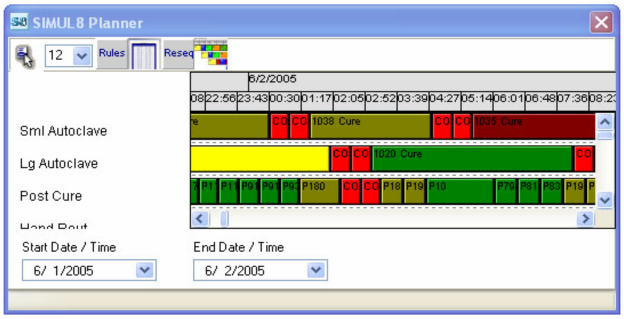

Figure 5: Sample Gantt Chart from SIMUL8-PLANNER

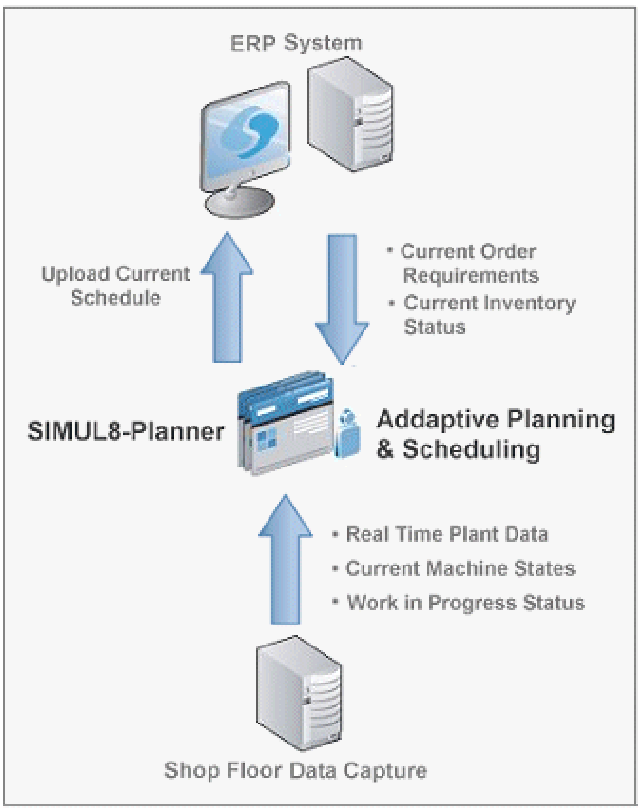

Figure 6: System Architecture

8 SYSTEM FEATURES AND BENEFITS

This approach provides a pragmatic solution to the complex scheduling problem of sequencing part requirements through the Composites Manufacturing Center production. By using a detailed production model of the processes and operations in this area, the system can produce accurate and feasible work schedules by machine.

Providing detailed schedules for each capacity area of the plant yields significant benefits over the previous "push" planning method which only scheduled the initial lay-up process. Previously, parts were released into the lay-up process and the rest of the operating areas had to react to the flow of parts arriving in their area. As a result, supervisors identified and expedited additional work coming down the pipeline to fill batch process requirements.

SIMUL8-PLANNER automatically ensures that batch operations are maximized. This frees up supervisor time for more important tasks. The resultant schedules provide a visibility of the entire production process, showing part locations over time, as well as ensuring feasibility of the schedule at the shop-floor level.

Through the automation of this scheduling process across all departments within the Composites Manufacturing Center, from initial lay-up to pre-delivery inspection, the Planning department can now respond quickly to changing order requirements or interruptions within the production process.

Previous schedules were developed for each lay-up department and left unchanged for periods of two weeks to a month, due to the large amount of work required to generate a new schedule. Because of this, the Planners were unable to react to rush orders, absenteeism, and equipment failures, resulting in obsolete production plans and a large amount of schedule non-conformance.

Through efficient downloads of the current situation, from MRP system and the fast scheduling capability that SIMUL8-PLANNER provides, the Center is now capable of responding to new circumstances and creating optimal schedules for various scenarios.

The system also allows the creation of custom reports that are specific to the requirements of each capacity area, as well as each cost center. For example, the Autoclave schedules require detailed information on the parts contained within each batch, but the cure cycle and schedule start and end times also correspond with the bus schedule requirements.

The system is now capable of producing schedules and providing "what-if" capability to allow the Planners to respond quickly to changes in order requirements, capacity, and resource availability.

9 CONCLUSION

The SIMUL8-PLANNER system was adapted to address the needs of Composites manufacturing scheduling requirements. However, SIMUL8-PLANNER is not limited to this specific application and has proven to be a very flexible and practical tool for a wide range of scheduling problems.

From detailed batch scheduling at the Autoclaves to customized reporting at the process level, and from "what-if" analysis to the speed of execution, this tool provided the flexibility required for responsive end-to-end scheduling for the entire facility.

Automating the scheduling process within these Composite Manufacturing Centers has allowed them to plan production across the entire plant in a synchronized and balanced workflow manner. The system takes into account all order due dates, commonality of operations, resource availability and complex product batching constraints.

This end-to-end visibility of the production process has allowed plant schedulers to be more proactive in an environment of changing operating conditions and requirements. They can now react to new conditions by quickly re-scheduling all of the processes within the plant to ensure the timely and efficient production of composite parts.

AUTHOR BIOGRAPHIES

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