Proceedings of the 2015 Winter Simulation Conference
L. Yilmaz, W. K. V. Chan, I. Moon, T. M. K. Roeder, C. Macal, and M. D. Rossetti, eds.

AGENT-BASED SIMULATION FOR COMPOSITE MANUFACTURING TECHNOLOGY EVALUATION

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ABSTRACT

With increasing demand for lightweight composite airplanes, advanced composite manufacturing techniques are being developed to deliver more airplanes quickly, with increased quality and decreased costs. These advanced techniques require production readiness evaluations as part of airplane development programs. Manufacturing techniques must be evaluated for cost, rate capability, and quality, among other considerations. This study considers a composite layup technique called AFP (Automated Fiber Placement) as applied to large airplane structures. The study's goals were to determine critical performance variables for further technology development, to determine rate and quality capability, and to define baseline performance requirements. An agent-based approach was used to allow for parameter experimentation across a large number of variables and variable values. The result was a validated set of performance parameters with baseline values to meet program requirements.

1 MOTIVATION AND SYSTEM DESCRIPTION

Boeing Commercial Airplanes estimates in its 2015 competitive market outlook that there is a demand for nearly 9,000 wide-body airplanes in the next 20 years. Much of that demand will be fulfilled by current and next generation airplanes that have a large number of composite parts and structures. In order to meet this demand aerospace manufacturers are investing significant efforts into developing new technologies for composite materials and manufacturing techniques. These materials and techniques must of course be validated, tested, and qualified prior to production use. Manufacturing techniques are difficult to test in the development phase, especially for production performance metrics such as rate capability and utilization due to the interconnected and complex nature of a live production system. Hence a simulation approach is an ideal method for estimating production performance parameters.

Advanced Fiber Placement (AFP) is a technique of applying multiple "tows" of thin resin-impregnated fibers to a contoured tool. This technique is well suited to aerospace applications where high accuracy over large, contoured parts is required. There are currently several vendors who supply AFP systems, and they continue to develop machine and control technologies to meet the increasing requirements of end users. An AFP system consists of one or more robots, and each robot has a number of heads that each lay down a tow. There is a spool for each head that feeds the fiber material to the head. The robots move back and forth over a tool (or the tool rotates under the robot head) to lay down the material.

2 PROBLEM STATEMENT

This study was requested by manufacturing technology groups within Boeing to evaluate the feasibility and capability of AFP for use on a specific part for an airplane program in development. The requestors were interested in estimating how the current state of the art would perform on a given part in a proposed production system. Furthermore, they were interested in developing a set of parameters and minimum allowable values for use in a Request for Proposal (RFP) document. The customer provided a set of decision variables, KPIs, and system properties as detailed in Table 1. They also provided high-level part geometry and production rate requirements.

Table 1. Problem characteristics

Decision variables: Number of robots, number of heads per robot
KPIs: Layup speed (pounds per hour) for specified part, system non-recurring cost
Downtime parameters: Head change time, Spool capacity, Percent failed courses, Downtime per failure, Quality check time
Performance parameters: Acceleration/Deceleration, Max Linear speed, Max rotational speed, Cut time, Min distance between robots

3 SIMULATION APPROACH

Due to the nature of the input data available, an agent-based approach was used. The robots and robot heads were modeled as agents with properties such as speed and acceleration, and the part was modeled as a set of agents representing one tow width of material to be laid down (called a "course"). These course agents were populated with part geometry data. In this way, we could experiment with the number of robots and the number of heads per robot, as well as robot performance parameters.

4 RESULTS

The results of this study determined the efficient frontier of robots/robot heads and non-recurring cost. The minimum required configuration for production rate requirements was also identified. Several of these solutions were then selected for detailed sensitivity analysis for robot performance and downtime parameters (Figure 1). A linear regression on these detailed results highlighted two key critical parameters that were most responsible for driving laydown performance.

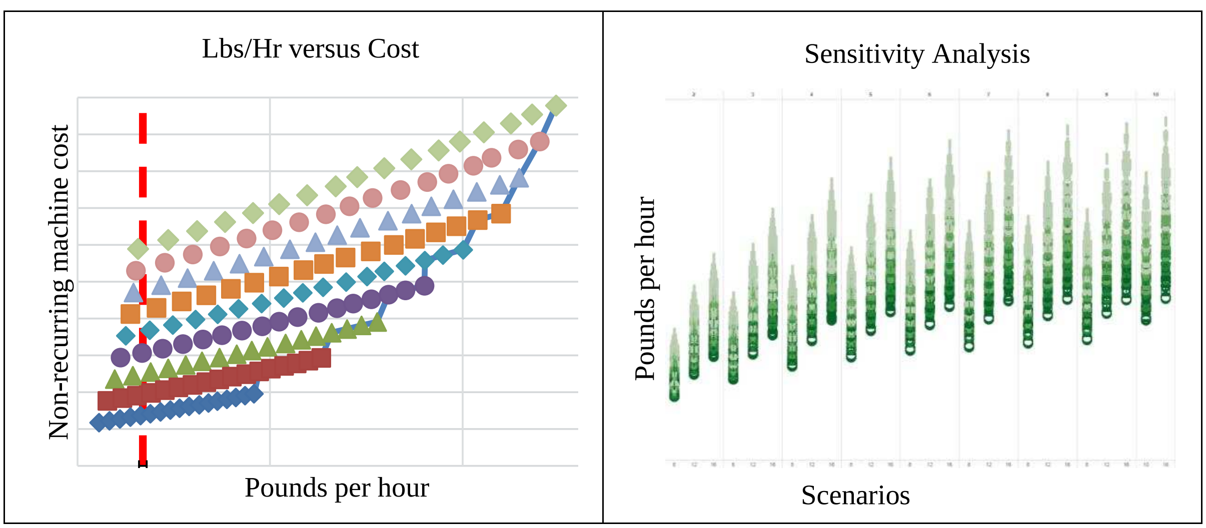

Figure 1. Optimal frontier and detailed sensitivity analysis for selected scenarios

5 IMPACT AND CONCLUSION

This study was critical for informing decision makers about a specific technology's production performance long before the actual part or system could be tested. We verified that this technology could meet rate requirements, and what the minimum non-recurring cost of doing so would be. The sensitivity analysis provided input into minimum performance requirements for vendors who were developing this technology.