EM97-109

Laser Ply Projection System - S92 Composite Rotor Blade

author

STEVE SUCIC
Senior Manufacturing Engineer
Sikorsky Aircraft Corporation
Stratford, Connecticut

abstract

The objective in helicopter design and manufacturing is to fabricate structural components while minimizing weight. Composite reinforced materials can be tailored to have varying properties based on material type and fiber orientation, thus maximizing load in a given direction. As the benefits of high strength versus weight are gained, composite fabrication becomes costly. Currently, there are a number of automated composite fabrication methods being utilized. As the composite part is tailored to its application so must the part fabrication process. The development of the S92 Composite Anhedral Tip Skins was an ideal candidate for laser ply projection system.

conference

COMPOSITES '97 MANUFACTURING AND TOOLING
January 20-22, 1997
Anaheim, California

terms

Composite Materials
Graphite
Laminates
Lasers

Society of Manufacturing Engineers
One SME Drive · P.O. Box 930 · Dearborn, Ml 48121
Phone (313) 271-1500

SME TECHNICAL PAPERS

This Technical Paper may not be reproduced in whole or in part in any form without the express written permission of the Society of Manufacturing Engineers. By publishing this paper, SME neither endorses any product, service or information discussed herein, nor offers any technical advice. SME specifically disclaims any warranty of reliability or safety of any of the information contained herein.

INTRODUCTION:

The design of the S92 Main Rotor Blade improves lift by taking advantage of composite materials and airfoil geometry. The S92 helicopter incorporates the latest technologies in main and tail rotor composite manufacturing. The S92 Helicopter uses four tail rotor blades and four main rotor blades to produce 26,400 pounds of lift. The tail rotor blade, which provides stability, utilizes the torque tube / flexbeam configuration. The main rotor blade consists of a composite spar, composite cuff, and structural anhedral tip skins with honeycomb core, see Figure 1.

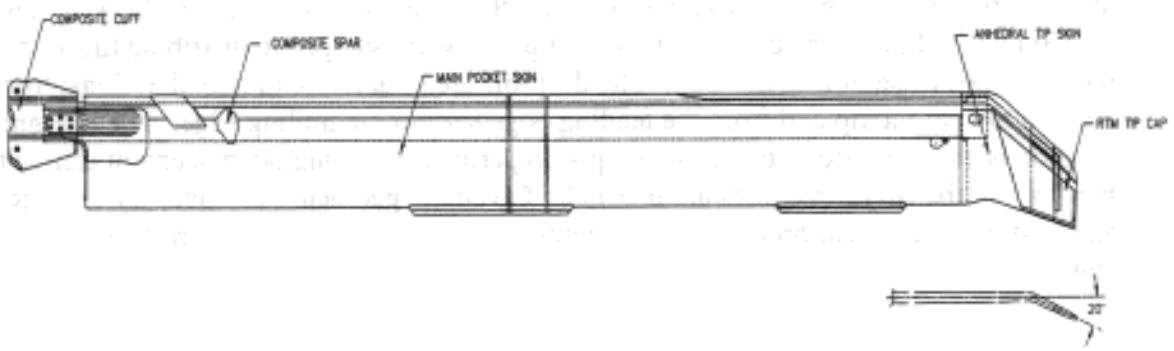


Figure 1 S92 Main Rotor Blade

The main blade includes a 20 degree anhedral kick at the tip, that produce additional lift. In order to minimize the complexity of the blade fabrication, the angled sweep section was fabricated as a separate detail of the blade assembly. This simplified the main skin fabrication and also the subsequent tooling string. Fabricating the anhedral tip skin as separate details also minimized component count. The structural member was incorporated into the tip skin lay-up. The complex lay-up and size of the tip skin were ideal for laser ply projection.

A majority of the tip skin's uni-directional plies drop off within the edge of part (EOP), preventing guides or features (outside of part) to locate ply position. Each ply is unique in shape, size, and location. A large quantity of templates (guides) would have been required if a laser ply projection system was not available. The ply patterns were designed in CATIA (3-D model) and developed using FiberSim.

FiberSim, the translator between machine language and CATIA, serves dual functions in laser ply projection. One is to unwrap a CATIA ply surface onto a 2-D ply pattern for Gerber nesting and cutting. The Gerber nests and cuts the composite reinforced materials while maintaining fiber orientation. The other function of FiberSim is to define the 3-D perimeter of the ply for laser projection. The laser guide projects the perimeter as defined by FiberSim onto a contoured mold surface. The perimeter projected onto the contoured mold matches the 2-D pattern cut by the Gerber (after 2-D ply is formed to mold surface). The outline is displayed for each ply pattern in the proper sequence by the laser guide.

PRODUCIBILITY:

The requirements of the blade for strength and lift were optimized by the design of the Upper and Lower Anhedral Tip Skins. The design of a typical composite blade skin is flexible and requires a structural member. The flexible skin is bonded to a spar which acts as the load carrying member. This is the configuration of the main pocket skins, aft of the composite spar. The anhedral tip skin design integrates both flexibility and stiffness. The leading edge section carries the load and therefor has a thicker ply build-up, as shown in Figure 2. These plies transfer the required loads from the Tip Cap into the Composite Spar. The plies in the build-up area were stepped to distribute the load into the flexible section of the skin. The drop-off area flared out in two directions; from the root toward the tip and from the leading edge toward the trailing edge. The size and location of the plies are internal to the tip skin perimeter making ply placement difficult. Forty six of the fifty three plies are internal. Given the geometry, ply size, ply type, cost and lead-time, different processes or methods to fabricate (lay-up) the part were considered.

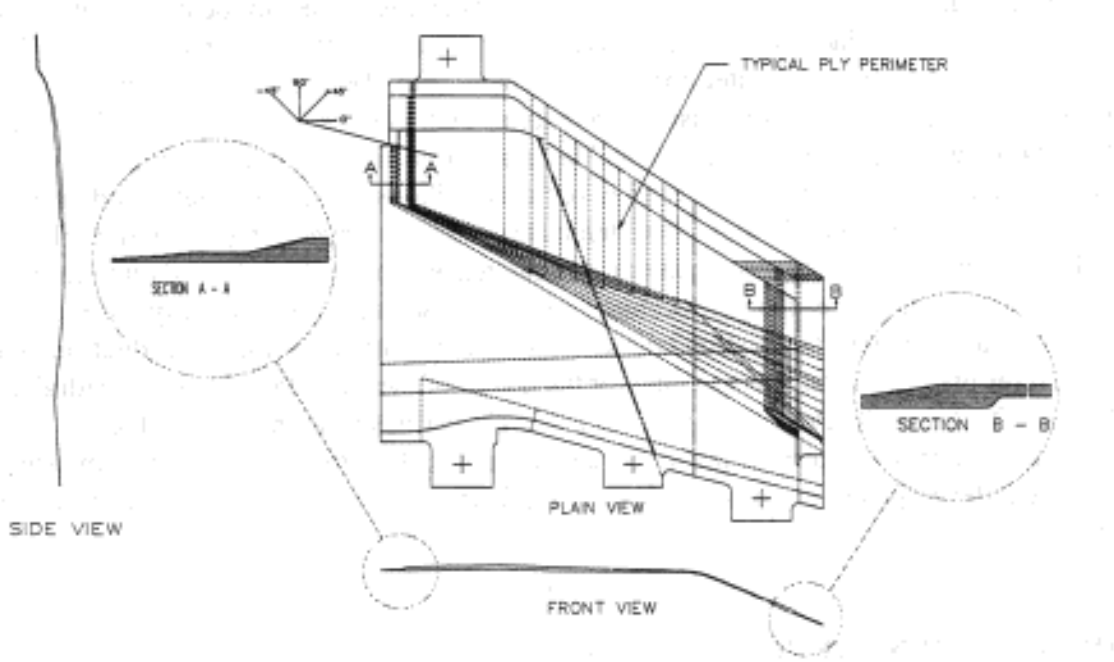


Figure 2 Upper Anhedral Tip Skin

METHOD OF FABRICATION:

A number of different methods were explored to aid or automate the lay-up: fiber placement, tape lay-up, pick-e-place, templates and laser ply projection. In the process of selecting a lay-up method, the following constraints were adhered to: cost, time to production and flexibility. Fiber Placement is an automated system that numerically places a series of single tows on to a contoured surface. As the tows are placed onto the surface, a trailing roller consolidates each tow onto the previous one. A potential issue with this method is jagged edges are created as the tows drop off. A smooth cut is the optimum end to a ply. As the number of jagged edges increases so does stress. A Tape Lay-up Machine is similar to Fiber Placement. They both place material onto a contour and consolidate it with a roller that follows. The Tape Lay-up system differs in the type of material it uses. The tape lay-up places uni-directional tape onto a contoured surface. Tape consists of a varying number of rows of uni-directional tows. Types of materials used are limited with each of these systems. In order to change material type, the machine is stopped and the material rolls changed. This increases down time. The anhedral tip skins require four different types of prepreg materials to meet design requirements. These include uni-directional graphite, uni-directional fiberglass, woven graphite and wire mesh. Fiber Placement and Tape Lay-up systems are mature technologies but require high volume and large part size to be cost effective. These two methods are best suited for large composite fixed wing assemblies such as: wing sections, bulkheads, vertical and horizontal stabilizers. The next alternative, Pick-n-Place, is an emerging technology which utilizes n/c cut plies and places them onto a contoured surface. This system is constrained to smaller parts and is limited to the degree of surface curvature. Pick-n-Place is not material type

sensitive as with the other two systems. Plies are assembled using a computer controlled vacuum head. With the use of robotic movements, this system is expensive and requires high volume to be cost effective. The final two methods, manual templates and laser ply projection, share a common feature: cost. The first three methods are expensive (cost millions) while templates and laser projection are considerably less. Both templates and laser projection require digital definition of ply location, mold contour, and reference coordinates. The advantages of laser ply projection over the ply locating template are accuracy, repeatability, easy of modification, and part fabrication cost savings. Due to part size, time to production, and cost, laser ply projection was selected for the lay-up of the S92 Main Blade Anhedral Tip Skins. The Laser Ply Projection requires a 3-D ply perimeter definition and tool coordinate points. To project plies onto a contoured surface the following systems are required: development of plies in 3-D model, 3-D translation, n/c ply kit, laser projection system.

DEVELOPMENT OF PLIES IN CATIA:

The definition of each ply in a 3-D model is required for both n/c ply cutting and laser projection, as shown in Figure 3. Definition of each ply perimeter is made in CATIA (3-D surface model). Plies that extend to the edge of part (EOP) are extrapolated out to an oversized configuration. Enlarging the outer plies allows for final EOP machining. The contour was balanced by rotating it out of aircraft position. In the definition of ply perimeters in the model, each ply is on its own layer. Fiber direction is defined by an attribute that is parallel to the fiber. The ply perimeter is then concatenated, creating a closed boundary. After the plies were defined on the balanced contour, a model of the contour was made for 5-axis n/c machining of the steel OML mold. The machined contoured mold included the contour surface, bagging area, reference lines, and six laser coordinate system points. All of these features were inspected via coordinate measurement machine (CMM) and verified back to the CATIA model.

3-D TRANSLATION:

The master model is used to create 2-D flat patterns and laser projection data using FiberSim. The two different FiberSim software packages run in a CATIA environment. The 2-D flat pattern software unwraps a 3-D closed, concatenated curve, defined by a boundary. Each 3-D ply boundary resides on a layer with a vector attribute. The attribute indicates the fiber orientation which is critical in optimizing material strength. The attribute also contains alphanumeric data on the ply material specification and sequence of lay-up. Once the plies are in 2-D, a model is created. The 2-D model is then downloaded to the Gerber ply nesting system.

The other FiberSim software creates ASCII data that is used to define the path of the laser ply projections. Again, the 3-D master model is used to define each of the ply perimeters in space. In addition to the plies, location to the mold is defined here. The mold will have six coordinate targets defined relative to the plies. The targets are

physically located outside the part boundary on the mold surface. Targets serve to align the projector relative to the mold.

PLY PATTERNS:

The 2-D ply patterns are downloaded to the Gerber nesting system from FiberSim. To maximize material usage and reduce regulated waste, plies are nested. Two principals followed here are ply orientation and size. Plies are nested by material specification and material orientation. After the plies have been nested, the data is reviewed and coordinated to the original 2-D model for verification. With the proper perimeter, material type, and orientation, the ply files are promoted to a resident data base. When a composite part is to be built, a work order is sent to the Gerber N/C Cutter for cutting using the resident data base for that particular part. The plies are cut to the data on a vacuum bed by a reciprocating blade that is n/c controlled. Once the plies are cut, a labeling device adheres a bar code sticker identifying: part number, ply number, sequence and material specification. Since the plies are nested to optimize material usage, sequence is random. After the plies have been cut and labeled, a laser device points to the ply that indicates its lay-up sequence. This eliminates ply sorting at the laminating level. The next process is to utilize the laser ply projection system.

LASER PLY PROJECTION:

To optimize the lay-up of complex contoured composite parts, laser ply projection is used. The laser ply projection consists of two devices: a computer / operator interface, and laser projector. The laser projector is mounted on a structure above the work area. The computer / operator interface provides the data and drive mechanism to define the ply perimeter which is displayed by the projector. The projector displays the ply perimeter onto an n/c machined mold located within the projector working area. Prior to the ply being displayed, the laser projector registers the mold. The mold, which requires high temperature and pressure for laminate cure, will be moved daily from the lay-up area into an autoclave. Therefore, a permanent fixed mold was not practical. The mold is placed under the laser projector. The proper laser file is loaded. Prior to the first ply being displayed onto the contoured mold, the laser verifies the location of the mold using six reflector register points. The laser is able to correct for a two square inch misalignment. Next, the first ply in the lay-up sequence is projected on the mold. A one millimeter (.039") wide red light is displayed on to the mold representing the ply perimeter. With the ply perimeter displayed on the mold, the matching flat pattern ply is placed within the outline. After the ply is accurately located, the remote control is activated to display the next ply. The projector displays the ply perimeter in the order they exist in the original 3D model, eliminating ply sequence variation. During each ply sequence, the laser corrects for any movement between the mold and the projector. The vector scanning laser light maintains accuracy within +/- .015" in a 120" x 120" work area. This was crucial in meeting the requirements for the ply drop-offs at the root end of the tip skin as shown in Figure 2, Section A-A. The ply drop-offs create a precise joggle. The joggle shape is critical since it overlaps and bonds to the structural spar.

During the initial startup, ply geometry and ply sequencing were changed to increase part performance. Ply geometry was changed via the CATLA model and then downloaded through FiberSim into the Gerber Nesting and then cut. In addition, ply sequence was changed on Catia and downloaded through FiberSim to the laser ply projection. This change demonstrated efficiency of the process. All changes were electronically incorporated thus eliminating requirements for machining the templates. Past processes would have required physical rework of templates. In addition, time to incorporate changes was simplified.

Operator (laminator) location is important during the lay-up. At certain locations, depending on the angle, the laser light was not visible. The optimum location is looking down and standing perpendicular to the light. In viewing the light on the four different materials, uni-directional graphite was the most difficult. The light would disperse perpendicular to the fiber direction, creating a slight shadow. Despite the shadowing affect the one millimeter wide band was visible. To minimize shadowing, the overhead lights were dimmed. The best contrast was on white polyester peel ply material.

CONCLUSION:

The laser ply projection system increases accuracy, repeatability, speed of modification and efficiency by electronically displaying the ply location onto a surface. Replacing the operator movements of locating a template onto the mold, tracing the ply perimeter and removing the template with a simple push of a button has increased accuracy and repeatability. As processes and designs are continuously improving, changes in ply perimeters or sequence are performed in minutes verses hours for template rework. The laser ply projection system reduced the lay-up production time by 80 percent over conventional methods. The initial lay-up was conducted using the mechanical features to locate plies. In addition to saving time during lay-up, verification of the flat pattern perimeter and sequence was performed during the lay-up, reducing two inspection operations.

The laser ply projection system was instrumental in achieving the design to cost targets of the S92 Composite Anhedral Tip Skins.

1. FiberSim - Flat Pattern 1.3 CATIA Version 3 Interface, Composite Design Technologies, Inc., Wellesley, MA, 1994.

2. FiberSim - Laser Projection Plus CATIA, Composite Design Technologies, Inc., Wellesley, MA, 1995.

3. LASERGUIDE 2-11F Operation Manual, Assembly Guidance Systems, Inc. Chelmsford,MA 01824, 1995.

4. Blake, Scott and Young, Victor, Direct Application of CAD Data in Hand Laid Composites Production: Methods and Benefits, 36th International SAMPE Symposium and Exhibition, April 15-18, 1991.

5. Blake, Scott. Application of Profile Data Directly onto a Tool: No Templates. The Cost Effective Way Forward, Composite Tooling II, Elsevier Science Publishers Ltd., 1992.

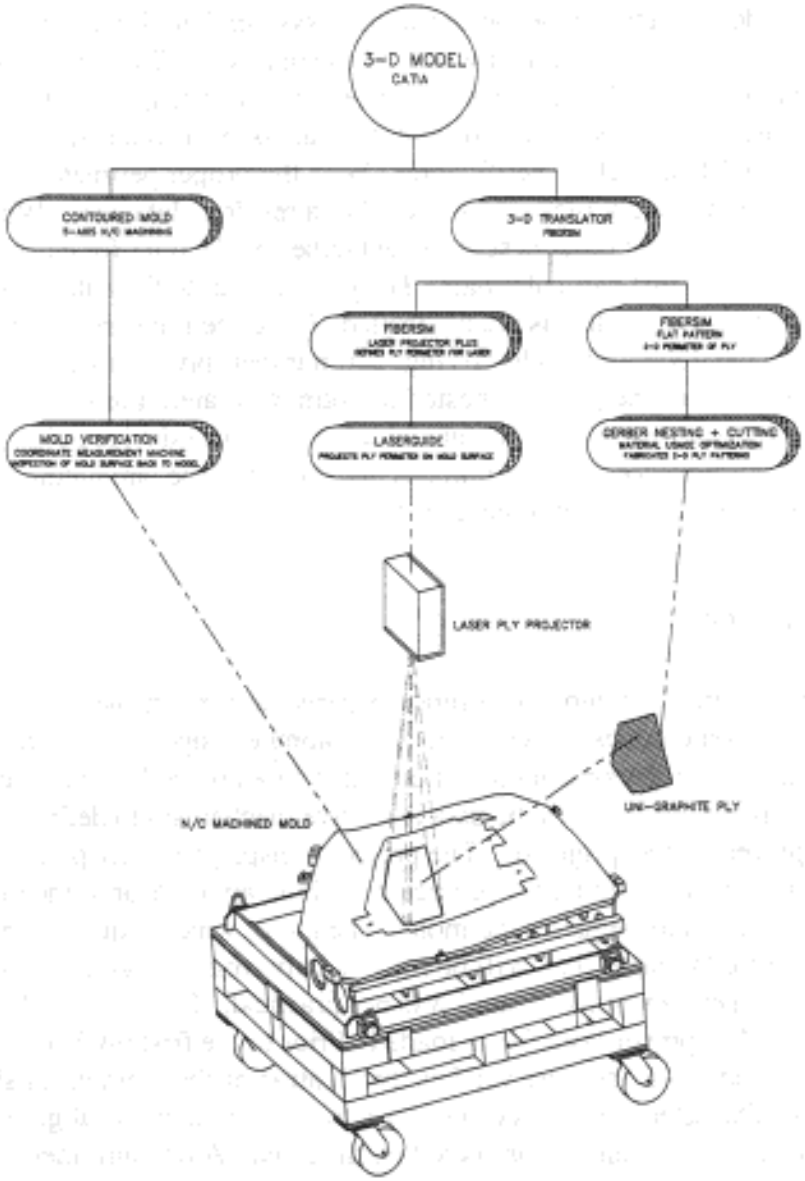


Figure 3 Flow Diagram