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AUTOMATION OF CUTTING AND DRILLING OF COMPOSITE COMPONENTS

Prepared By:	Charles W. Warren
Academic Rank:	Assistant Professor
Institution:	The University of Alabama Department of Mechanical Engineering Tuscaloosa, Alabama
NASA/MSFC:	
Laboratory:	Materials and Processes
Division:	Process Engineering
Branch:	Chemical and Non-Metals Processes
MSFC Colleagues:	Eutiquio Martinez Gail Gordon

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1 Introduction

This report outlines the research that was conducted during the ten weeks of the NASA / ASEE Summer Faculty Fellowship Program. The task was to develop a preliminary plan for an automated system for the cutting and drilling of advanced aerospace composite components. The components under consideration are being hand manufactured by Martin Marietta Manned Space Systems. The immediate goal is to automate the production of these components, but the technology developed can be readily extended to other systems.

Working with the engineers and technicians at NASA and Martin Marietta (MMC), a tentative plan has been developed to automate this process. In the sections below, a description of current methods at MSFC, current methods in industry, and the proposed plan for automation are given.

1.1 Composite Components Description

There is a desire to replace many of the components of the Space Shuttle System with components made from composite materials. The components under consideration here are manufactured by Martin Marietta for use on the External Tank. Three specific parts are considered here, but the technology developed could easily be extended to other components. The components studied are the LO2 Feedline Fairing, the Nosecone, and the Intertank Access Door.

These components are laid by hand using a prepreg material in a mold (tool) and a vacuum bagging process is used to remove voids. The component is placed into a large autoclave for curing while still in the mold. Once the part has been cured, it is removed from the mold and the excess is trimmed and appropriate holes are drilled. The difficulty lies in the fact that the parts are very large. Cutting and drilling to close tolerances (approximately .030 inches) is difficult for components that are odd shaped and almost five feet across. There are also plans to manufacture components that are much larger than the three in this study.

1.2 Current Methods of Processing (MSFC)

There are several methods of processing the components in use at MMC. Once the components have been cured, trim lines are placed on the components that identify the final edge to be achieved. A rough cut is then performed close to the trim line using either a band saw or a hand-held jig saw using a diamond impregnated blade. Conventional wood or metal cutting blades are not well suited for cutting composite materials.

Once the rough cut is made, hand-held diamond impregnated grinders are used to remove most of the remaining trim material and clean the edge. The final operation in the trimming process is to obtain a finished edge. This is done by a large amount of hand sanding.

The next operation is to drill several holes in the components for later use in the assembly process. Bushings are clamped onto the top and bottom of the surface being drilled to prevent the delamination problem and feedrates are carefully control to prevent heat buildup. The drilling process is slow and tedious due to the number of holes to be drilled in each component.

2 Current Methods of Cutting (Literature)

During the ten weeks of the summer program, an extensive literature survey was conducted into current methods of processing composite components. Much of the literature centered around the aerospace industry. These articles described the processing of composite components that are used on military aircraft. The second most described systems are those in the automobile industry. These articles described the automated cutting of plastics, but the technology can be extended to composites.

Most of the literature for cutting composites described water jet cutting systems. There were several papers that compared cutting with water jets, lasers, and routers. These three techniques are the best suited for automation.

3 System Specification

When automating a system such as this, there are many decisions to be made with respect to methods and equipment used. Fortunately, most of the required major equipment items for this project are already available at MSFC. There are three major operations here that should be performed by a robot. They are: locating the part to be cut, positioning the cutter, and positioning the drill. The devices for accomplishing this should be mounted with an automatic tool changer between the device and the robot. Although not entirely necessary, they greatly extend the life of the mounting hardware. Robot end effectors are notorious for being difficult to mount repeatedly.

The entire system should be coordinated by a central computer system that directs the operation. High level commands are sent to the individual device controllers for processing. Each device, (robot, water jet, drill), will have a separate computer controller. The waterjet and drill could share a controller since both operations will not occur simultaneously with this system.

Below is a list of components needed to complete the system. Also, recommendations are given for a specific device that could accomplish the task.

- **Robot** – A gantry type robot is by far the best suited for this task. They typically have a wide range of motion needed to process large parts and the rigid structure. These robots are typically more accurate than other type of robots, which allows tools to be precisely positioned. There is a Cimcorp XR225 robot installed in Building 4707. This is a very accurate robot that is ideal for this task. Several vendors of cutters and drills have used this model of robot to position their tools and highly recommended it.

- **Water Jet Cutter** – Water jet cutting systems are very versatile and work well with composites. There is, however, a large capital investment that must be factored into the decision to purchase such a system. The highest cost item is the 60,000 psi pump. Again, there is a very good system installed in Building 4707. Its pump could easily handle another cutting nozzle. The pump is manufactured by Flow International, but both major vendors of abrasive water jet cutters can use this pump. There is high pressure plumbing already installed on the Cimcorp robot as well, which will reduce development costs significantly.

- **Part Locating Device** – A vision system or the laser range finder would work well for part locating. Although either of these optical systems would work well, my feeling is that the laser system would be more economical. However, a vision system is only slightly more expensive and should identify part locations faster.

- **Drilling Device** – Although a turnkey drilling system is available from EOA Systems, Inc. for approximately $70,000, it would be difficult to justify the large capital expenditure for the part production volume in this study. It is intended for use in an aircraft production environment where thousands of high precision holes are drilled regularly.

  A smaller, less sophisticated device can be developed that would be adequate as an R & D tool. It would be capable of high precision drilling with hardware to prevent delamination.

- **Tool Changer** – Although not absolutely necessary, a tool changer is very useful when tools are to be swapped on the robot. The relatively low cost, ($2,000 to $5,000 depending on capacity and features), is justified easily by the time savings and extended mounting hardware life.

- **Computer Control Hardware** – IBM PC/AT compatible computers are very well suited to this task. Intel 80386 or 80486 based computers are readily available with a tremendous amount of third party hardware peripherals and software available. These systems are well understood and economical to purchase and operate. They could be used as the high level coordinator as well as the controller for the water jet and the drill.

- **Software** – The control and coordination software for this system will need to be developed. A simple-to-operate, menu -driven software package should be developed for each computer. The software for the high level coordinating computer will handle the interface between the human operator and the rest of the systems. Software is also used that handles communication between the various control computers.

- **Communication Links** – There are many standards for communication links to choose from. RS–232 is a well understood standard used in the personal computer business. There is also a great deal of hardware and software available. The speed of this link is also adequate for the tasks in this study.

- **Off-line Programming** – The Deneb Software on the Silicon Graphics hardware is an excellent system for off-line programming. This is in place and needs no modification. Any program or path translation could easily be done by the software to be included on the high level coordinator.

4 Conclusions

There is an excellent opportunity for developing a state-of-the-art, automated system for the cutting and drilling of large composite components at MSFC. Most of the major system components are in place: the robot, the water jet pump, and the off-line programming system. The drilling system and the part locating system are the only major components that need to be developed. Also, another water jet nozzle and a small amount of high pressure plumbing need to be purchased from, and installed by, one of the two major vendors. Once the system components have been obtained, the system needs to be tied together in a coherent manner.

Although there is some startup effort involved, there will be a tremendous amount of potential in the system. The system will be capable of processing existing and many future parts developed.