**DRAFT**

Description

REAL-TIME VISUAL ROLLER PROCESS ERROR DETECTION

Technical Field

1. This invention relates generally to automatic fiber replacement (AFP) machines.

Background of the Invention

1. Automatic fiber replacement (AFP) machines currently have two primary mechanical configurations. One is the integral head or end effector design (IEE) and the other is the modular head or end effector design (MEE). Both designs use carbon fiber tow wound onto a bobbin or spool. In general operation, the fiber on the spools is unwound by a motor with a tensioning assembly and is directed to a placement tool which lays or places the fiber on a part, such as an aircraft part. Heating is often combined with compaction force to help the carbon fiber tow to stick to the part.
2. The compaction roller, which is usually made from a flexible rubber material, when heated substantially can cause process errors if the carbon fiber adheres too strongly to the roller instead of the tool or part surface. This can cause the carbon wrapping around the roller continuously until a jam is sufficiently large to completely stop the process or until someone notices the error.
3. In another case, the roller adheres to previously placed carbon fiber which can cause substantial damage to the part.
4. In the former scenario, jamming creates down time since the operator must clean the system to continue operation. In the latter scenario, jamming occurs and multiple layers are sometimes stripped from the part, causing large amounts of damage and rework to be done.

Summary of the Invention

1. The invention presented is a real-time automated vision system that detects unusual the presence of carbon fiber on the compaction roller. The camera in combination with an on board computer, lens and lighting solution comprises the main components of the system. The vision system operates independently from the main onboard computer and sends digital IO as the primary communication to the PLC in order to halt the process. The PLC receives the commands and then communicates that a feed-hold is required from the CNC which promptly stops the machine.

Brief Description of the Drawings

1. Figure 1 is a functional diagram of the system of the present invention.
2. Figure 2 is a visual representation of the process error detection algorithm
3. Figure 3 is an example of the process
4. Figure 4 is a picture of the process error at the tool point
5. Figure 5 is a representation of the camera and amplifier system
6. Figure 6 is a figure representing the lighting solution provided

Best Mode for Carrying Out the Invention

1. Automated visual inspection systems using camera sensors are notoriously difficult to reliably tune in the presence of significant variation in lighting during operation. In order to combat the effect of shadows, and general lighting variation, a set of focused LED lights are directed at the compaction roller to reduce relative lighting noise. It is important that the light is focused well on the roller as reflections from the tool can also result in significant brightness variation.
2. There are numerous architectures that can possibly be used to perform the automatic image analysis. In the current implementation, the camera sensor amplifier also has an onboard computer that can quickly evaluate the criterion to trigger an error signal. The amplifier has the specific advantage of being efficient in both data transfer and data processing. This is a significant advantage over sending the images over the network to be processed by a PC transferring the data over to the PLC for data processing as the process can be done in parallel. The feed-hold signal from the amplifier can be used via the PLC in order to trigger the CNC but also can be communicated directly through the CNC network.
3. Figure 1 is a simplified functional diagram of the tensioning system portion of the modular head assembly of the present invention, showing the progress of the tow from the spool to the tool which lays the fabric on a part, such as an aircraft wing. The system, as shown generally at 10 includes a servo motor and gear box assembly 12 which is controlled via inputs from a diameter sensor 14 which senses the diameter of a carbon fabric spool 16 and an input from a linear sensor 16 which senses the position of a dancer element 18 which controls the tension on the fabric. A PLC computer 19, in one embodiment is located on the modular head assembly for high level control of the individual servo motors.
4. In operation, the fabric backing is unwound from the carbon spool 16 under the control of the servo motor assembly 12. The fabric proceeds to a backing spool 17, which removes a backing film from the fabric which then proceeds to the dancer tensioning assembly 18 and from there to one or more redirects 22 and the clamp/add/cutportions of the system. While the backing spool 17 will typically be present in the system, it is not necessary, as the backing film may be removed by other elements or not present for some material types.
5. Figures 2 and 3 illustrate a carbon fiber modular head assembly. A typical modular head assembly will include a plurality of identical carbon fiber placement assemblies arranged in a circular fashion. The modular head assembly is attached to a fiber placement machine which is controlled by a CNC processor, typically located remotely from the modular head itself.
6. Figures 2-5 show various views of a modular head assembly, including a plurality of individual servo motor controlled carbon spool assemblies. Figure 2 shows a back plate 26 on which are mounted a plurality of spool assemblies including a spool containing the carbon fiber material. Each spool assembly, for example 30, comprises a servo motor/controller which rotates a spindle to let the carbon fiber plus backing film off the spool portion of the spool assembly. The diameter of the spool as it is rotated is sensed by an ultrasonic sensor 32 which continuously measures the diameter of the spool for a proper speed command for the servo motor. Each spool assembly also includes a dancer assembly 34 which is used to control the tension of the carbon during the payout thereof. The dancer assembly includes a sliding assembly on which the dancer linearly moves. A linear displacement sensor, such as a linear encoder, 34 provides dancer position information back to the servo motor/controller.

What is claimed is:

# Claims

1.  A modular head assembly or end effector for a fiber placement machine having a machine controller, comprising:

a support back plate;

a plurality of carbon fiber spool assemblies, each including a spindle for a carbon fiber spool, servo motor and gear box combination and a dancer assembly for tensioning the carbon fiber as it moves from the spool to a tool assembly which applies the carbon fiber to a part, wherein the spool assemblies include a linear displacement sensor for the dancer assembly and a sensor for determining the diameter of the carbon spool; and

wherein the servo motor combination controls the movement of the spool so that the carbon fiber is payed out in a controlled rate.

4.  The assembly of claim 1, including a tool charger connecting the modular head assembly to the machine controller.

5.  The assembly of claim 1, including a PLC controller mounted on the head assembly with connections extending between the servo motor combinations and the PLC for control of the individual servo motor combinations.

6.  The assembly of claim 4, wherein the spool diameter information is provided to the PLC and the linear displacement information is provided to the servo motor combinations.

7.  The assembly of claim 2, wherein the spool assemblies, the dancer assemblies and the backing member assemblies are all connected to the back plate.

8.  The assembly of claim 1, wherein the spool assemblies are mounted to and removable from the back plate assembly for replacement thereof.

9.  The assembly of claim 1, wherein each of the spool assemblies are individually connected to the PLC computer and wherein the plurality of spool assemblies are connected to each other in series.

10.  The assembly of claim 1, wherein the dancer assembly is mounted on a rail and positioned therealong by a spring assembly such that the dancer moves along the rail to maintain correct tension on the fabric as the fabric proceeds from the spool.

11.  The assembly of claim 1, wherein the spring assembly moves over a length of approximately 1-3 inches.

12.  The assembly of claim 1, wherein the servo motor combinations moves the spindle in both directions, forward and reverse.

13.  The assembly of claim 1, including control/drive connections for the servo motor combinations through the slip ring back to the CNC machine controller.

14.  In a modular head assembly or end effector for a fiber placement machine having a machine controller, wherein the modular head assembly or end effector includes a support back plate, a plurality of one or more carbon fiber spool assemblies, each spool assembly including a spindle for a carbon fiber spool and a dancer assembly for tensioning the carbon fiber as it moves from the spool to a tool assembly which applies the carbon fiber to a part, wherein each spool assembly includes a linear displacement sensor for the dancer assembly and a sensor for determining diameter of the carbon spool, the improvement comprising:

a servo motor and gearbox combination associated with each carbon fiber spool assembly for controlling the movement of the spool so that the carbon fiber is payed out at a controlled rate.

15.  The improvement of claim 14 wherein the servo motor and gearbox combination operates directly in response to the information from the dancer assembly and the diameter of the carbon spool.

16.  The improvement of claim 14, wherein the servo motor and gearbox combination is responsive to control information from a PLC computer located on the modular head assembly.