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**CORRECTED PUBLICATION**

(54) **SYSTEM AND METHOD FOR DETERMINING CUMULATIVE TOW GAP WIDTH**

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See (60) Related U.S. Application Data.

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**Related U.S. Application Data**

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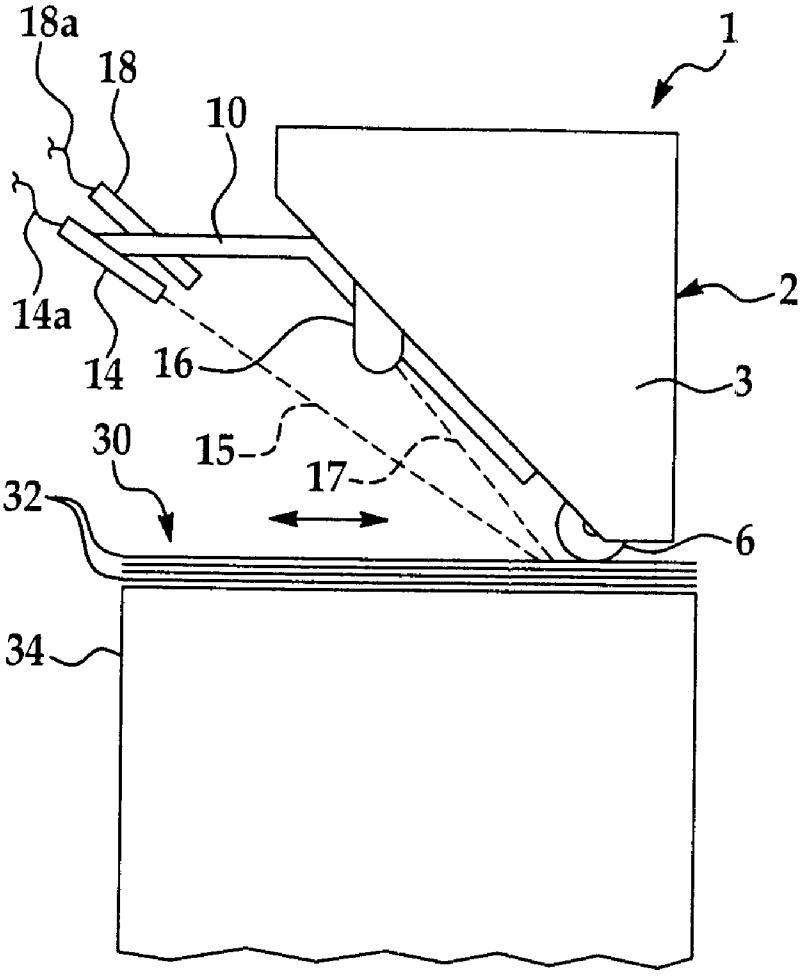
***G06K 9/00*** (2006.01)

(52) **U.S. Cl.** ..... **382/106**

(57) **ABSTRACT**

A system for determining cumulative tow gap width includes an in-process vision system having at least one camera adapted to record images of a composite material and a data analysis computer communicating with and adapted to receive image data from the in-process vision system. The data analysis computer may be adapted to calculate a cumulative gap width of tow gaps in the composite material. A user interface may communicate with and be adapted to receive data analysis results from the data analysis computer. A method for determining cumulative tow width gap of tow gaps in a composite structure is also disclosed.



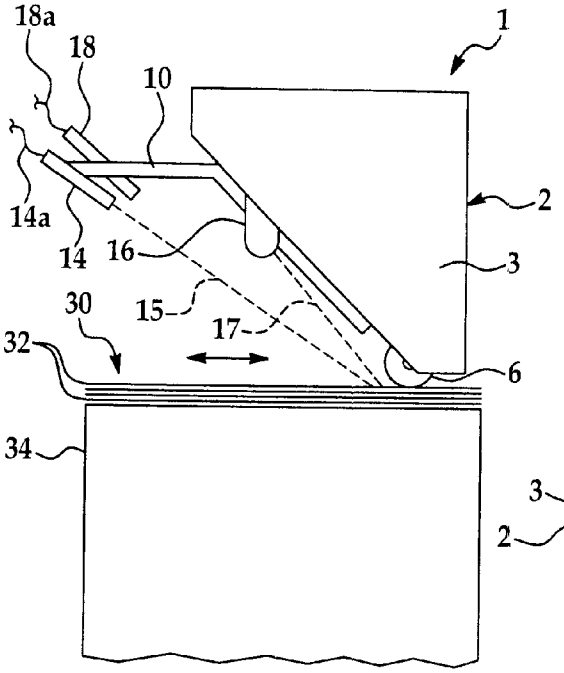



FIG. 1

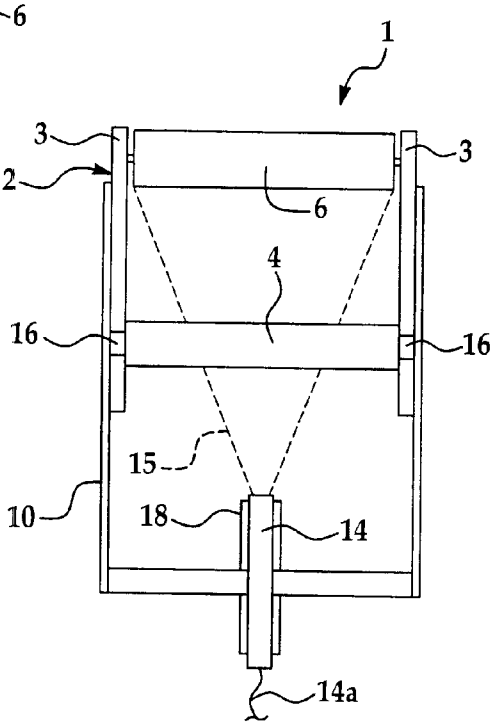



FIG. 2

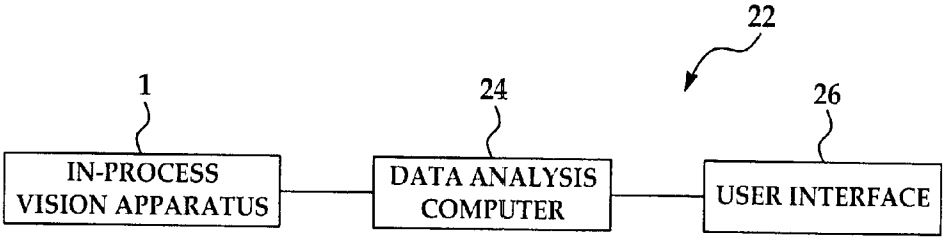



FIG. 3

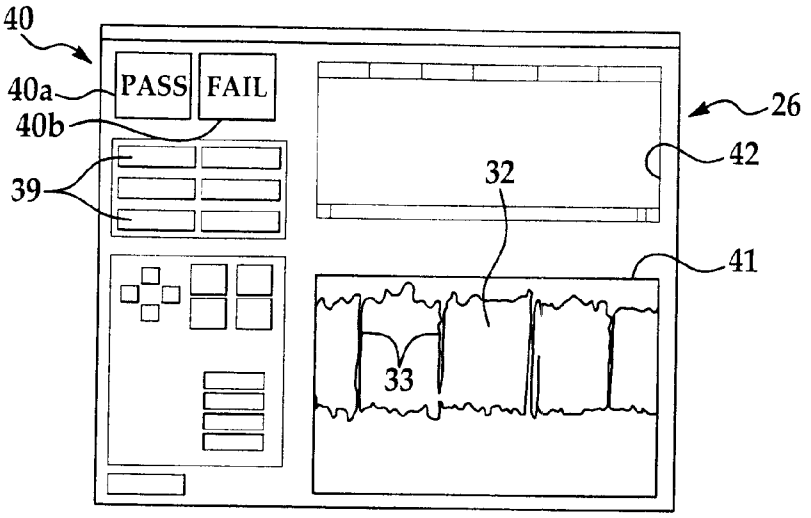



FIG. 4

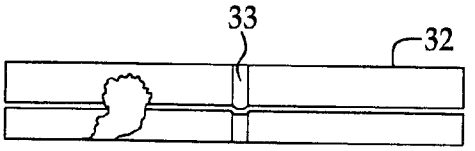



FIG. 5

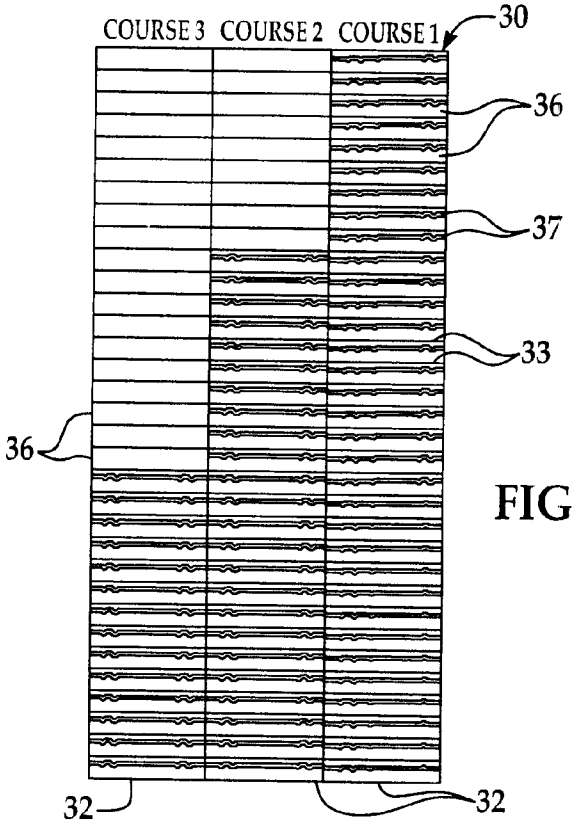



FIG. 6

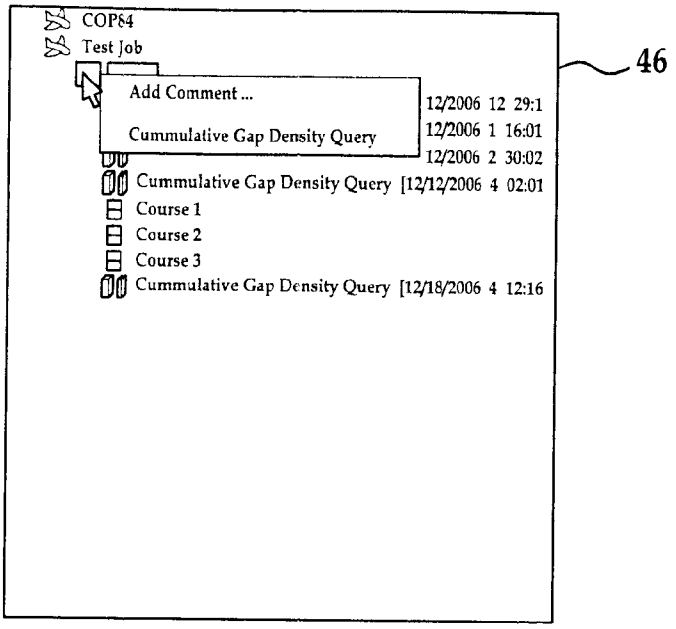

COP84
Test Job
Add Comment ...
Cummulative Gap Density Query
12/2006 12 29:1
12/2006 1 16:01
12/2006 2 30:02
Cummulative Gap Density Query [12/12/2006 4 02:01
Course 1
Course 2
Course 3
Cummulative Gap Density Query [12/18/2006 4 12:16
46

FIG. 7

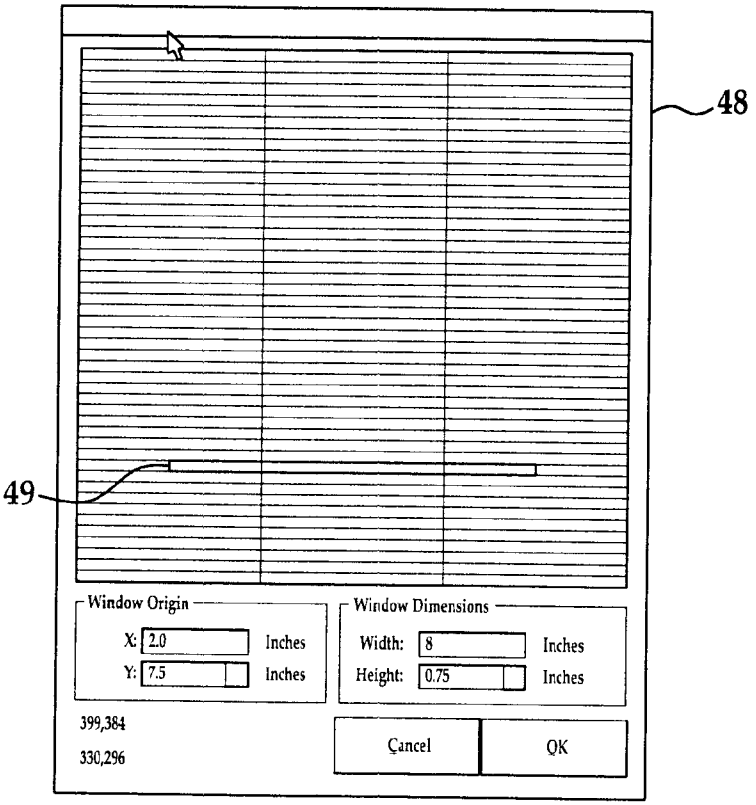

48
49
Window Origin
X: 2.0 Inches
Y: 7.5 Inches
Window Dimensions
Width: 8 Inches
Height: 0.75 Inches
399,384
330,296
Cancel
OK

FIG. 8

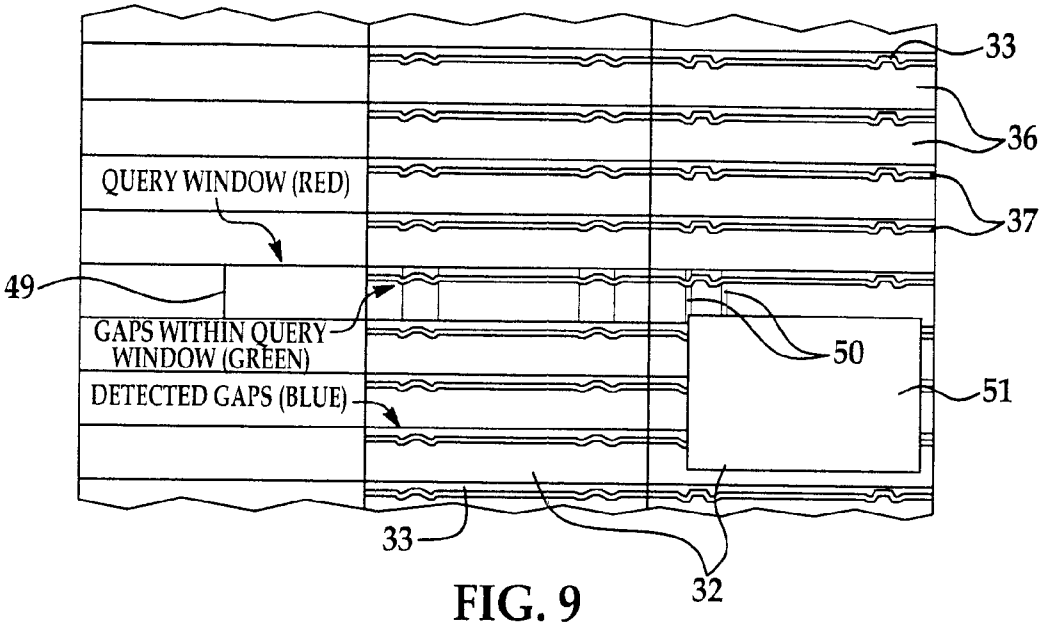

33
36
37
QUERY WINDOW (RED)
49
GAPS WITHIN QUERY WINDOW (GREEN)
DETECTED GAPS (BLUE)
50
51
33
32

FIG. 9

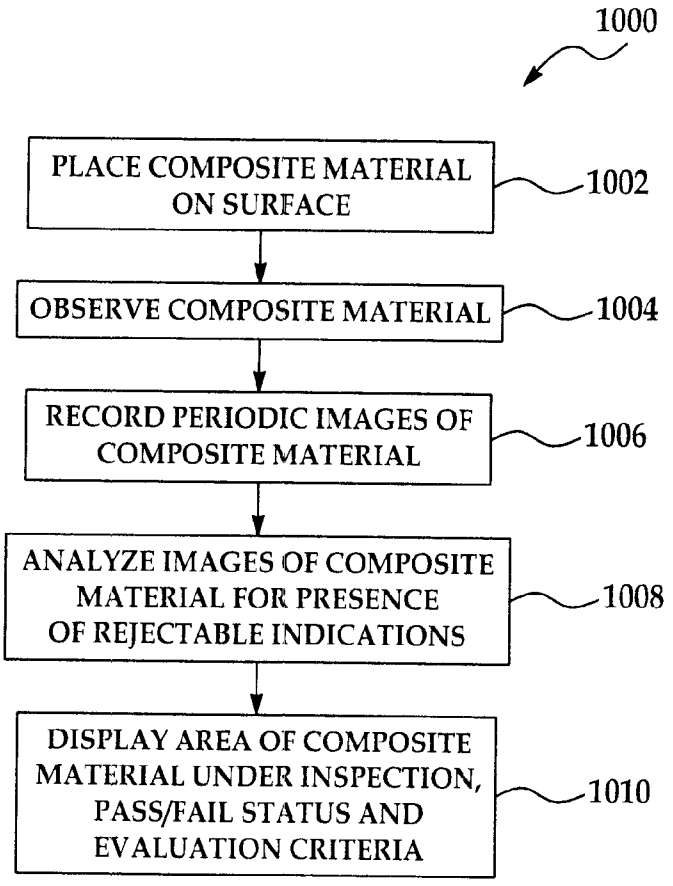

1000
PLACE COMPOSITE MATERIAL ON SURFACE
1002
OBSERVE COMPOSITE MATERIAL
1004
RECORD PERIODIC IMAGES OF COMPOSITE MATERIAL
1006
ANALYZE IMAGES OF COMPOSITE MATERIAL FOR PRESENCE OF REJECTABLE INDICATIONS
1008
DISPLAY AREA OF COMPOSITE MATERIAL UNDER INSPECTION, PASS/FAIL STATUS AND EVALUATION CRITERIA
1010

FIG. 10

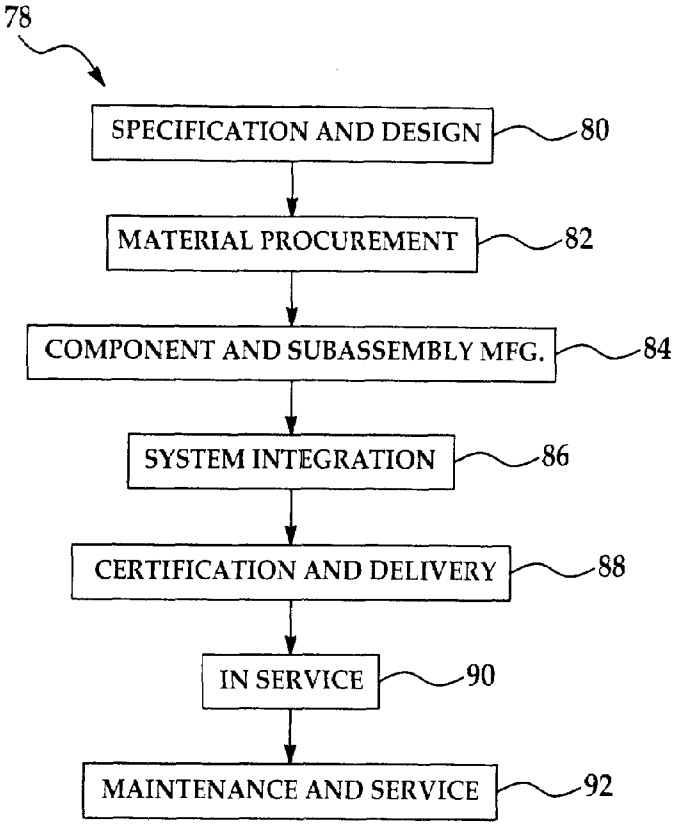

78
SPECIFICATION AND DESIGN
80
MATERIAL PROCUREMENT
82
COMPONENT AND SUBASSEMBLY MFG.
84
SYSTEM INTEGRATION
86
CERTIFICATION AND DELIVERY
88
IN SERVICE
90
MAINTENANCE AND SERVICE
92

FIG. 11

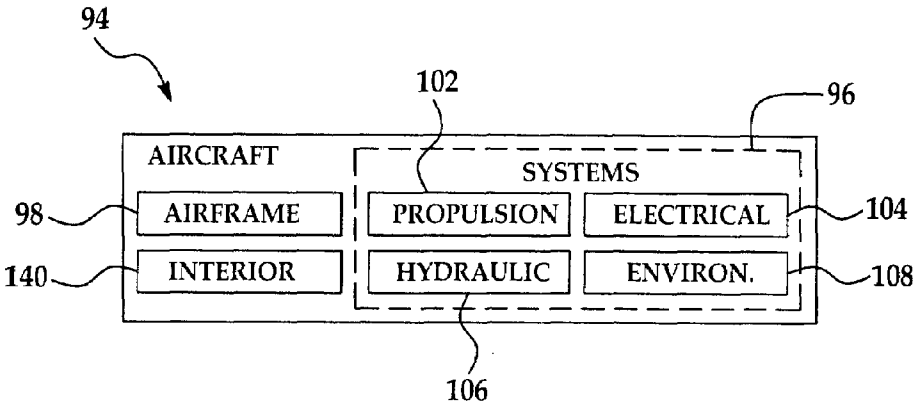

94
102
96
AIRCRAFT
SYSTEMS
98
AIRFRAME
PROPULSION
ELECTRICAL
104
140
INTERIOR
HYDRAULIC
ENVIRON.
108
106

FIG. 12

# SYSTEM AND METHOD FOR DETERMINING CUMULATIVE TOW GAP WIDTH

## TECHNICAL FIELD

**[0001]** The disclosure relates to fabrication of composite structures. More particularly, the disclosure relates to a system and method for determining cumulative tow gap width in fabricated composite structures.

## BACKGROUND

**[0002]** Methods of fabricating composite structures include the fiber placement or automated collation process. In such a process, one or more ribbons of composite material or tows may be laid down on a substrate which may be a tool, mandrel or one or more underlying and compacted layers of composite material. Conventional fiber placement processes may utilize a heat source to assist in compaction of the plies of composite material at a localized nip point. The ribbon or tow of composite material and the underlying substrate may be heated at the nip point to increase the tack of the resin of the plies while being subjected to compressive forces to ensure adhesion to the substrate. To complete the part, additional strips of composite material may be applied in a side-by-side manner to form layers and may be subjected to localized heat and pressure during the consolidation process.

**[0003]** A complex and detailed inspection guideline may be necessary for the inspection of composite structures that are fabricated using the fiber and tape placement processes. The guideline may establish acceptance criteria for discrete inconsistencies such as tow gaps, tow overlaps, twists, dropped tows and foreign objects. In-process vision technology may be capable of detecting and making accept/reject decisions on these inconsistencies during the manufacturing process. The guideline may also establish a requirement for maximum allowable cumulative, or total, tow gap width within any 12-inch area perpendicular to the direction of material placement or lay-down.

**[0004]** The existing solution to meeting the requirements of the inspection guidelines may include manual visual inspection by the human eye. An operator may select at random a number of regions of the correct size according to the inspection guideline. The operator may then apply a manual template that will define the area in which the inspection is to be made. The operator may utilize a means of determining and documenting the location of the region with respect to the entire surface area of the ply. Within each area, the operator may be required to visually identify tow gaps and measure each one manually using a tool such as a six-inch scale or a dial caliper. The widths of all identified gaps may be documented, the sum of the gap widths may be calculated and the sum for the specific area may be determined. The approach may be carried out on each ply of each part which is manufactured.

**[0005]** The existing solution to meeting the requirements of the inspection guidelines may require extensive cycle time and touch labor and may carry a high risk of inaccurate measurement. This approach may be viable for small parts but unmanageable for large surface areas. The approach may also be labor-intensive and prone to a high probability of error in measurement. Reduction of fatigue and risk of error may require multiple inspectors which may increase the touch labor required to complete the inspection.

**[0006]** The disclosure is generally directed to a system for determining cumulative tow gap width. An illustrative embodiment of the system includes an in-process vision system having at least one camera adapted to record images of a composite material and a data analysis computer communicating with and adapted to receive image data from the in-process vision system. The data analysis computer may be adapted to calculate a cumulative gap width of tow gaps in the composite material. A user interface may communicate with and be adapted to receive data analysis results from the data analysis computer.

**[0007]** The disclosure is further generally directed to a method for determining cumulative tow gap width of tow gaps in a composite structure. An illustrative embodiment of the method includes providing a composite material, recording periodic images of the composite material, analyzing the images of the composite material for presence of rejectable indications in the composite material and formulating a pass/fail status of the composite material based on the rejectable indications.

## BRIEF DESCRIPTION OF THE ILLUSTRATIONS

**[0008]** FIG. **1** is a partially schematic side view of an in-process vision system of an illustrative embodiment of the system for determining cumulative tow gap width.

**[0009]** FIG. **2** is a top view of the in-process vision system shown in FIG. **1**.

**[0010]** FIG. **3** is a block diagram of an illustrative embodiment of the system for determining cumulative tow gap width.

**[0011]** FIG. **4** is a screenshot of a vision system user interface.

**[0012]** FIG. **5** is a sectional view of a pair of laminated composite tape strips, with a tow gap in the tape strips.

**[0013]** FIG. **6** is a simulated multi-course laminate utilized for laboratory validation.

**[0014]** FIG. **7** illustrates a menu for selection of a cumulative gap query.

**[0015]** FIG. **8** is a front view of a selection of cumulative gap query interface.

**[0016]** FIG. **9** is a window which illustrates cumulative gap analysis.

**[0017]** FIG. **10** is a flow diagram of an illustrative method for determining cumulative tow gap width.

**[0018]** FIG. **11** is a flow diagram of an aircraft production and service methodology.

**[0019]** FIG. **12** is a block diagram of an aircraft.

## DETAILED DESCRIPTION

**[0020]** The disclosure is generally directed to a system and method for determining tow gap width within any designated area of any ply or tow on the surface of a part or structure produced by automated material placement. The system and method may utilize archived in-process vision data for any automatically placed tow, query selected surface area regions on the tow and sum the detected tow gap widths within each surface area region of the tow. Accordingly, the system and method may extensively reduce inspection cycle times and enhance accuracy of tow gap width measurements in fabrication of composite materials.

**[0021]** Referring to the drawings, an illustrative embodiment of the system for determining cumulative tow gap width, hereinafter system, is generally indicated by reference

numeral **22** in the schematic block diagram of FIG. **3**. The system **22** may include an in-process vision apparatus **1** which is shown in FIGS. **1** and **2** and will be hereinafter described. The in-process vision apparatus **1** may be adapted to illuminate and view composite tape strips or tows **32** (FIG. **1**), including tow gaps **33** (FIG. **5**) which form in the tows **32** during consolidation of a composite structure **30** (FIG. **3**). The in-process vision apparatus **1** may operate in conjunction with an automated fiber or material placement machine (not shown) which is known to those skilled in the art.

**[0022]** As shown in FIG. **3**, a data analysis computer **24**, having a user interface **26**, may communicate with the in-process vision apparatus **1**. The data analysis computer **24** may be adapted to receive and store images of selected queried surface regions on the tows **32** which are viewed by the in-process vision apparatus **1**. Based on these images, the data analysis computer **24** may also be adapted to detect and calculate the cumulative gap width of the tow gaps **33** within the queried surface region or regions of the tows **32** (such as a 12-inch area, for example and without limitation) which may be perpendicular to the direction of material placement or lay-down of the tows **32**. The data analysis computer **24** may further be adapted to compare the calculated cumulative tow gap width to maximum allowable cumulative tow gap width criteria. The data analysis computer **24** may be programmed to accept (pass) the tows **32** for continued fabrication of the composite structure **30** in the event that the calculated cumulative tow gap width meets the maximum allowable cumulative tow gap width criteria and reject (fail) the tows **32** for fabrication in the event that the calculated cumulative tow gap width does not meet the maximum allowable cumulative tow gap width criteria.

**[0023]** A screenshot of a suitable exemplary user interface **26** for the data analysis computer **24** is shown in FIG. **4**. The user interface **26** may include, for example and without limitation, various control inputs **39**; a pass/fail indicator **40**; an inspection window **41** which presents a real-time image frame of the region on the tow or tows **32** which is being viewed by the in-process vision apparatus **1**; and a defects window **42**. The control inputs **39** of the user interface **26** may facilitate the entering and changing of parameters such as acceptance (pass/fail) criteria and image frame size of the image presented in the inspection window **41**, for example and without limitation. In the example shown in FIG. **4**, a sample of a tow **32** with tow gaps **33** of several different widths is shown in the inspection window **41**. The defects window **42** of the of the user interface **26** may indicate the breadth, angle, length and/or other parameters of the tow gaps **33** in the tows **32**.

**[0024]** The pass/fail indicator **40** of the user interface **26** may include a pass button **40***a* and a fail button **40***b*. The data analysis computer **24** may be adapted to illuminate the pass button **40***a* in the event that the calculated cumulative tow gap width meets the maximum allowable cumulative tow gap width criteria and may be adapted to illuminate the fail button **40***b* in the event that the calculated cumulative tow gap width does not meet the maximum allowable cumulative tow gap width criteria. The pass button **40***a* may be a highly-visible color such as red and the fail button **40***b* may be a different color such as green, for example and without limitation.

**[0025]** An exemplary structure for the in-process vision apparatus **1** is shown in FIGS. **1** and **2**. Generally, the in-process vision apparatus **1** may include a frame **2** which may include a pair of spaced-apart frame plates **3**, as shown in FIG. **2**. Each of the frame plates **3** may have a generally triangular shape, as shown in FIG. **1**. At least one frame plate connector **4** (FIG. **2**) may extend between the frame plates **3**. A compaction roller **6** may extend between the frame plates **3**.

**[0026]** A laser mount bracket **10** may extend from the frame plates **3** of the frame **2**. At least one laser **14** having laser wiring **14***a* may be provided on the laser mount bracket **10**. The laser **14** may be adapted to emit a laser beam **15** generally toward the compaction roller **6**. At least one digital camera **18** having camera wiring **18***a* may also be provided on the laser mount bracket **10**. At least one area light **16** may be provided on the laser mount bracket **10**, or on one or both of the frame plates **3** of the frame **2**, generally between the camera **18** and the compaction roller **6**. As shown in FIG. **2**, in some embodiments, an area light **16** may be provided on each frame plate **3** of the frame **2**. Each area light **16** may be adapted to emit a light beam **17** (FIG. **1**) generally toward the compaction roller **6**.

**[0027]** As further shown in FIG. **1**, in typical application of the system **22**, the in-process vision apparatus **1** may be positioned over a composite structure **30** which may include multiple adjacent strips or tows **32** of composite tape. The in-process vision apparatus **1** may be supported over the composite structure **30** using any suitable support structure (not shown). The tows **32** may include multiple fibers embedded in a resin or other material which becomes tacky or flowable upon the application of heat. The tows **32** may be arranged on a work surface **34** such as a table or mandrel, for example and without limitation, and may be compacted to form the composite structure **30** according to an automated collation technique which is known to those skilled in the art. For example, an article entitled "Material Selection/Fabrication Issues for Thermoplastic Fiber Placement" by Richard Sharp et al. published in the "Journal of Thermoplastic Composite Materials" (January 1995) discusses one conventional fiber placement process and is incorporated herein by reference.

**[0028]** The automated collation process may include guiding the tows **32** from material creels (not shown) to the automated collation or fiber placement machine (not shown) with which the in-process vision apparatus **1** works in conjunction. In particular, the tows **32** may be sequentially and automatically guided onto the work surface **34** beneath the in-process vision apparatus **1** and fed under the compaction roller **6**. Focused heat energy may then be applied to the incoming tow **32** and the underlying previously-compacted tows **32** that were previously laid on the work surface **34**. With the combination of heat and pressure applied by the compaction roller **6**, the tow **32** is consolidated into the previous layer of compacted tows **32**, thus forming an additional layer of the composite structure **30**. As shown in FIG. **6**, multiple tows **32** may be laid side-by-side on the work surface **34** to form multiple adjacent courses of the composite structure **30**. During the consolidation process, the compaction roller **6** may be moved along the tows **32** as indicated by the double-headed arrow in FIG. **1**.

**[0029]** During compaction of the tows **32** into the composite structure **30**, inconsistencies such as the tow gaps **33** shown in FIG. **5** may form between laminated tows **32**. Therefore, the system **22** may be operated to view and record surface regions on the composite structure **30**, and the tow gaps **33** which have formed in the tows **32** in each surface region, during consolidation for the purpose of calculating a cumulative tow gap width of the tow gaps **33**. By comparing

the calculated cumulative tow gap width of the tow gaps **33** to maximum allowable cumulative tow gap width criteria for the tow gaps **33**, the data analysis computer **24** of the system **22** may determine whether to accept (pass) or reject (fail) the tows **32** for fabrication of the composite structure **30**. Accordingly, the laser **14** (FIGS. **1** and **2**) of the in-process vision apparatus **1** may be operated to emit the laser beam **15** against the surface of the tows **32** at a selected surface region which is generally adjacent or proximate to the compaction roller **6**. The area light or lights **16** may also be operated to emit the light beam or beams **17** against the surface of the tows **32** to illuminate the region. The camera **18** may be operated to view the illuminated region on the surface of the tows **32**.

**[0030]** The images which are sighted by the camera **18** of the in-process vision apparatus **1** may be transmitted to and stored in the memory of the data analysis computer **24** (FIG. **3**) of the system **22**. At that point, the data analysis computer **24** may calculate the cumulative tow gap width of the tow gaps **33** in the tows **32** corresponding to the selected surface area on the composite structure **30** and compare the calculated cumulative tow gap width to maximum allowable cumulative tow gap width criteria which may have been previously pre-stored in the memory of the data analysis computer **24**. In the event that the calculated cumulative tow gap width meets the maximum allowable cumulative tow gap width criteria, the data analysis computer **24** of the system **22** may accept or pass the tows **32** for further fabrication of the composite structure **30**. In that case, the data analysis computer **24** may illuminate the pass button **40***a* of the pass/fail indicator **40** on the user interface **26** shown in FIG. **4**. On the other hand, in the event that the calculated cumulative tow gap width does not meet the maximum allowable cumulative tow gap width criteria, the data analysis computer **24** may reject the tows **32** for further fabrication of the composite structure **30**. In that case, the data analysis computer **24** may illuminate the fail button **40***b* of the pass/fail indicator **40** on the user interface **26**.

**[0031]** The data analysis computer **24** may display each image frame which is sighted by the camera **18** in real time in the inspection window **41** (FIG. **4**) of the user interface **26**. The size of the image frame may be selectively adjusted by operation of the control inputs **39** (FIG. **4**) of the user interface **26**.

**[0032]** FIG. **6** illustrates multiple image frames **36** of a simulated multi-course laminate utilized for laboratory validation. The laminate or composite structure **30** includes three courses of the tows **32** labeled "Course **1**", "Course **2**" and "Course **3**", respectively, from right to left. The multiple individual image frames **36** which are viewed sequentially by the camera **18** of the in-process vision apparatus **1** (FIGS. **1-3**) throughout the course of consolidation are shown on each tow **32**. A laser line **37** which is formed by impingement of the laser beam **15** (FIG. **1**) of the laser **14** on the surface of the tows **32** is shown in each image frame **36**. Each laser line **37** is distorted to reveal a tow gap **33** between stacked or laminated tows **32** in each course. Since the composite structure **30** may include multiple side-by-side courses of the tows **32**, as in FIG. **6**, each image frame **36** of the camera **18** may cover more than one course in some applications.

**[0033]** The image frames **36** on the multiple courses of tows **32** shown in FIG. **6** may be displayed on the data analysis computer **24** by, for example, calling up the menu **46** shown in FIG. **7** and selecting "Test Job" and clicking on "Ply **1**" on the menu **46**. The process of determining the cumulative gap width of the tow gaps **33** may then be initiated by right-clicking on "Ply **1**" and selecting "Cumulative Gap Density Query" on the menu **46**. The menu **46** may be designed to include a complete list of parts or composite structures **30**; under each may be available the cumulative gap determination result by ply number.

**[0034]** The cumulative gap density query interface **48** shown in FIG. **8** may facilitate selection of the dimensions of the query window or immediate region within which the cumulative gap is being calculated. In the cumulative gap density query interface **48**, the length of the query window **49** corresponds to the width of two of the three material courses. The query window **49** may be any selected dimensions; as it is "stepped" sequentially across the ply, the gaps are totaled within each region covered.

**[0035]** When the size of the query window **49** has been selected, clicking "OK" on the cumulative gap density query interface **48** may generate an image such as the one shown in FIG. **9**. Tow gaps **33** are indicated in the solid lines on the image. Highlighting a particular tow gap **33** may provide the ply course and image frame in which the gap was detected; it may also provide the width of the tow gap **33** and its x coordinate location. Gap indicator lines **50** in the query window **49** may indicate the gaps that are being totaled inside the query window **49**. Positioning of the cursor in the query window **49** may display the result of the query in a query result box **51**. The total cumulative gap width may be the sum of the gaps found inside the query window **49**, divided by the height of the query window **49** in image frames **36**. In the example shown in FIG. **9**, the height of the query window **49** equals the height of one image frame **36**. The cumulative gap density may be the total cumulative gap divided by the query window **49**.

**[0036]** Referring next to FIG. **10**, a flow diagram **1000** of an illustrative method for determining cumulative tow width gap is shown. In block **1002**, composite material may be placed on a surface. In block **1004**, the composite material may be observed. In block **1006**, periodic images of the composite material may be recorded. In block **1008**, images of the composite material may be analyzed for the presence of rejectable indications. In block **1010**, the area; the pass/fail status; and evaluation criteria of the composite material under inspection may be displayed.

**[0037]** Referring next to FIGS. **11** and **12**, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method **78** as shown in FIG. **11** and an aircraft **94** as shown in FIG. **12**. During pre-production, exemplary method **78** may include specification and design **80** of the aircraft **94** and material procurement **82**. During production, component and subassembly manufacturing **84** and system integration **86** of the aircraft **94** takes place. Thereafter, the aircraft **94** may go through certification and delivery **88** in order to be placed in service **90**. While in service by a customer, the aircraft **94** may be scheduled for routine maintenance and service **92** (which may also include modification, reconfiguration, refurbishment, and so on).

**[0038]** Each of the processes of method **78** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

**[0039]** As shown in FIG. **12**, the aircraft **94** produced by exemplary method **78** may include an airframe **98** with a plurality of systems **96** and an interior **100**. Examples of high-level systems **96** include one or more of a propulsion system **102**, an electrical system **104**, a hydraulic system **106**,

and an environmental system **108**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the invention may be applied to other industries, such as the automotive industry.

**[0040]** The apparatus embodied herein may be employed during any one or more of the stages of the production and service method **78**. For example, components or subassemblies corresponding to production process **84** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **94** is in service. Also, one or more apparatus embodiments may be utilized during the production stages **84** and **86**, for example, by substantially expediting assembly of or reducing the cost of an aircraft **94**. Similarly, one or more apparatus embodiments may be utilized while the aircraft **94** is in service, for example and without limitation, to maintenance and service **92**.

**[0041]** Although the embodiments of this disclosure have been described with respect to certain exemplary embodiments, it is to be understood that the specific embodiments are for purposes of illustration and not limitation, as other variations will occur to those of skill in the art.

What is claimed is:

**1**. A system for determining cumulative tow gap width, comprising:
- an in-process vision system having at least one camera adapted to record images of a composite material;
- a data analysis computer communicating with and adapted to receive image data from said in-process vision system;
- said data analysis computer is adapted to calculate a cumulative gap width of tow gaps in the composite material; and
- a user interface communicating with and adapted to receive data analysis results from said data analysis computer.

**2**. The system of claim **1** wherein said in-process vision system comprises a frame and at least one laser carried by said frame.

**3**. The system of claim **2** further comprising at least one area light carried by said frame.

**4**. The system of claim **1** wherein said data analysis computer is adapted to compare said cumulative gap width of tow gaps in the composite material to maximum allowable cumulative tow gap width criteria.

**5**. The system of claim **4** wherein said data analysis computer is adapted to indicate a pass status of the composite material when said cumulative gap width of tow gaps in the composite material meets said maximum allowable cumulative tow gap width criteria.

**6**. The system of claim **5** wherein said data analysis computer is adapted to indicate a fail status of the composite material when said cumulative gap width of tow gaps in the composite material does not meet said maximum allowable cumulative tow gap width criteria.

**7**. The system of claim **6** wherein said user interface comprises a pass/fail indicator having a pass button and a fail button and said data analysis computer is adapted to illuminate said pass button when said data analysis computer indicates said pass status and said data analysis computer is adapted to illuminate said fail button when said data analysis computer indicates said fail status.

**8**. The system of claim **1** wherein said data analysis computer is adapted to display said image data.

**9**. A system for determining cumulative tow gap width, comprising:
- an in-process vision system and at least one camera carried by said frame plates and adapted to record images of a composite material;
- a data analysis computer communicating with and adapted to receive and store image data from said in-process vision system;
- said data analysis computer is adapted to query selected regions on the composite material and calculate a cumulative gap width of tow gaps in the selected regions; and
- a user interface communicating with and adapted to receive data analysis results from said data analysis computer.

**10**. The system of claim **9** wherein said in-process vision system comprises a frame and at least one laser carried by said frame.

**11**. The system of claim **10** further comprising at least one area light carried by said frame.

**12**. The system of claim **9** wherein said data analysis computer is adapted to compare said cumulative gap width of tow gaps in the composite material to maximum allowable cumulative tow gap width criteria.

**13**. The system of claim **12** wherein said data analysis computer is adapted to indicate a pass status of the composite material when said cumulative gap width of tow gaps in the composite material meets said maximum allowable cumulative tow gap width criteria.

**14**. The system of claim **13** wherein said data analysis computer is adapted to indicate a fail status of the composite material when said cumulative gap width of tow gaps in the composite material does not meet said maximum allowable cumulative tow gap width criteria.

**15**. The system of claim **14** wherein said user interface comprises a pass/fail indicator having a pass button and a fail button and said data analysis computer is adapted to illuminate said pass button when said data analysis computer indicates said pass status and said data analysis computer is adapted to illuminate said fail button when said data analysis computer indicates said fail status.

**16**. The system of claim **9** wherein said data analysis computer is adapted to display said image data.

**17**. A method for determining cumulative tow width gap of tow gaps in a composite structure, comprising:
- providing a composite material;
- recording periodic images of said composite material;
- analyzing said images of said composite material for presence of rejectable indications in said composite material; and
- formulating a pass/fail status of said composite material based on said rejectable indications.

**18**. The method of claim **17** wherein said analyzing said images of said composite material for presence of rejectable indications in said composite material comprises analyzing said images of said composite material for cumulative width of tow gaps in said composite material.

**19**. The method of claim **18** wherein said formulating a pass/fail status of said composite material based on said rejectable indications comprises establishing a maximum allowable cumulative tow gap width criteria, comparing said cumulative width of tow gaps in said composite material with said maximum allowable cumulative tow gap width criteria, passing said composite material when said cumulative width of tow gaps in said composite material meets said maximum allowable cumulative tow gap width criteria and failing said composite material when said cumulative width of tow gaps in said composite material does not meet said maximum allowable cumulative tow gap with criteria.

**20**. The method of claim **17** further comprising displaying said periodic images of said composite material.

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