CLAIMS

1. A process 100 for preparing a composite structure, comprising:

(a) projecting 106 a first image 50 onto a surface of a composite structure, wherein the first image 50 indicates a repair area where composite material should be removed;

(b) adjusting 110 a location and a size of the projected first image 50 so that the first image 50 overlies and is registered with the repair area on the surface;

(c) removing 120 composite material in the repair area;

(d) measuring 114 a baseline three-dimensional profile of the repair area of the surface before any composite material is removed in operation (c);

(e) measuring 122 an updated three-dimensional profile of the repair area of the surface after composite material has been removed in operation (c);

(f) determining depths 126 in respective regions of the repair area following operation (c) based on differences between the baseline and updated three-dimensional profiles;

(g) identifying 120 a region of the repair area where additional composite material should be removed based in part on the depths determined in operation (f); and

(h) projecting 126 a second image onto the repair area of the surface, wherein the second image indicates the region identified in operation (g).

2. A process 100 for preparing a composite structure, comprising:

(a) projecting 106 a first image 50 onto a surface of a composite structure, wherein the first image 50 indicates a repair area where composite material should be removed;

(b) adjusting 110 a location and a size of the projected first image 50 so that the first image 50 overlies and is registered with the repair area on the surface;

(c) removing 120 composite material in the repair area;

(d) measuring 114 a baseline three-dimensional profile of the repair area of the surface before any composite material is removed in operation (c);

(e) measuring 122 an updated three-dimensional profile of the repair area of the surface after composite material has been removed in operation (c);

(f) determining depths 126 in respective regions of the repair area following operation (c) based on differences between the baseline and updated three-dimensional profiles;

(g) identifying a region 56a, 56b of the repair area where no additional composite material should be removed based in part on the depths determined in operation (f); and

(h) projecting a second image 52 onto the repair area of the surface, wherein the second image 52 indicates the region identified in operation (g).

3. A process 100 for preparing a composite structure, comprising:

(a) projecting 106 a first image 50 onto a surface of a composite structure, wherein the first image 50 indicates a repair area where composite material should be removed;

(b) adjusting 110 a location and a size of the projected first image 50 so that the first image 50 overlies and is registered with the repair area on the surface;

(c) removing 120 composite material in the repair area;

(d) measuring 114 a baseline three-dimensional profile of the repair area of the surface before any composite material is removed in operation (c);

(e) measuring 122 an updated three-dimensional profile of the repair area of the surface after composite material has been removed in operation (c);

(f) determining depths 126 in respective regions of the repair area following operation (c) based on differences between the baseline and updated three-dimensional profiles;

(g) identifying a region 56c of the repair area where too much composite material was removed in operation (c) based in part on the depths determined in operation (f); and

(h) projecting a second image 52 onto the repair area of the surface, wherein the second image 52 indicates the region identified in operation (g).

4. The process 100 as recited in claim 1, 2 or 3, further comprising:

retrieving 104 the first image 50 from an image database or constructing the first image 50 based on information about the composite structure 10 retrieved from a database using a first computer system 22 at a remote location;

sending 104 the first image 50 from the first computer system 22 to a second computer system 20 located in proximity to the composite structure 10 via a network 28; and

sending 104 the first image 50 from the second computer system 20 to a projector 34 which is aimed at the composite structure 10.

5. The process 100 as recited in claim 1, 2 or 3, wherein the first image 50 further indicates respective regions 50a, 50b, 50c, 50d in the repair area where material should be removed to respective depths which are different.

6. The process 100 as recited in claim 5, wherein the regions 50a, 50b, 50c, 50d indicated in the first image 50 have outlines corresponding to respective plies of different sizes.

7. The process 100 as recited in claim 1, 2 or 3, wherein the removing 120 operation comprises sanding to a maximum depth that removes a defect in the repair area.

8. The process 100 as recited in claim 7, wherein the removing 120 operation further comprises sanding composite material to form a taper that extends from the maximum depth to a second area on the surface that surrounds the repair area.

9. The process 100 as recited in claim 1, 2 or 3, further comprising projecting the second image 52 onto a second area of the surface, wherein the second image comprises a specification of instructions for a procedure for removing composite material from the repair area of the surface.

10. A process 100 for laying up plies of composite material in a depression in a composite structure 10 at a repair site, comprising:

(a) projecting 106 a first image 50 onto a surface 8 of a composite structure 10 having a depression, wherein the first image 50 comprises a first plurality of outlines 50a, 50b, 50c, 50d of different sizes and an indication of orientation for a smallest one of the outlines of the first plurality;

(b) adjusting 110 a location and a size of the projected first image 50 so that the first image 50 overlies and is registered with the depression;

(c) placing 138 a first ply of composite material in the depression at a location of the projected first image 50 of the smallest one of the outlines of the first plurality with an orientation such that fibers of the first ply of composite material are parallel to the indication of orientation for the smallest one of the outlines of the first plurality;

(d) projecting a second image 52 onto the surface of the composite structure 10 having the depression, wherein the second image 52 comprises a second plurality of outlines of different sizes and an indication of orientation for a smallest one of the outlines of the second plurality, wherein the second plurality includes all of the outlines of the first plurality except for smallest one of the outlines of the first plurality;

(e) adjusting a location and a size of the projected second image so that the second image overlies and is registered with the depression; and

(f) placing a second ply of composite material in the depression at a location of the projected second image of the smallest one of the outlines of the second plurality with an orientation such that fibers of the second ply of composite material are parallel to the indication of orientation for the smallest one of the outlines of the second plurality.

11. The process 100 as recited in claim 10, further comprising placing 136 a ply of adhesive in the depression before the first ply of composite material is placed in the depression.

12. The process 100 as recited in claim 10, further comprising:

retrieving 104 the first image 50 from an image database or constructing the first image 50 based on information about the composite structure retrieved from a database using a first computer system 22 at a remote location;

sending 104 the first image 50 from the first computer system 22 to a second computer system 20 located at the repair site via a network 28; and

sending 104 the first image 50 from the second computer system 20 to a projector 34 which is aimed at the composite structure 10.

13. A process 100 for laying up plies of composite material in a depression in a composite structure 10 at a repair site, comprising:

(a) projecting 106 a first image 50 onto a surface 8 of a composite structure 10 having a depression, wherein the first image 50 comprises a first plurality of outlines 50a, 50b, 50c, 50d of different sizes and an indication of orientation for a smallest one of the outlines of the first plurality;

(b) adjusting 110 a location and a size of the projected first image 50 so that the first image 50 overlies and is registered with the depression;

(c) placing 138 a first ply of composite material in the depression at a location of the projected first image 50 of the smallest one of the outlines of the first plurality with an orientation such that fibers of the first ply of composite material are parallel to the indication of orientation for the smallest one of the outlines of the first plurality;

(d) illuminating the depression on the surface of the composite structure;

(e) capturing a camera image of the illuminated depression using a camera having a field-of-view that encompasses the depression;

(f) sending the camera image to a computer system at a remote location;

(g) verifying cleanliness and roughness of a surface of the depression based on the camera image received at the remote location; and

(h) sending an approval from the remote location to the repair site to start a repair procedure when the cleanliness and roughness of the surface of the depression have been verified,

wherein operations (d) through (h) are performed before operations (a) through (c).

14. A process 100 for forming a depression in a composite structure located at a repair site, comprising:

(a) removing composite material in an area of a surface of a composite structure;

(b) measuring a three-dimensional profile of the area after composite material has been removed;

(c) determining current depths in respective regions of the area where composite material has been removed;

(d) identifying regions in which the respective current depth is less than a respective target depth;

(e) generating an image that indicates the regions identified in operation (d);

(f) projecting the image onto the surface of the composite structure;

(g) adjusting a location and a size of the projected image so that the regions identified in operation (d) overlie and are registered with respective regions of the area on the surface; and

(h) removing additional composite material from the respective regions in the area of the surface of a composite structure on which the regions identified in operation (d) were projected in operation (g),

wherein operations (a), (b), (g), and (h) are preformed at the repair site and operation (c) through (e) are performed at a remote location.

15. The process as recited in claim 14, wherein operations (b) through (h) are iterated until no regions are identified in operation (d).

REMOTE ADVANCED REPAIR GUIDANCE

ABSTRACT

Systems and processes for enabling an off-site expert to interact with an on-site technician during repair of composite structure. The off-site expert can provide real-time guidance to an on-site technician before and during the performance of repair procedures to avoid errors. The off-site expert is also able to monitor the repair procedures in real time to verify that correct procedures are being employed. In particular, the systems and processes disclosed herein can provide direct visual guidance, feedback, and out-of-plan warnings for manual or automated scarfing and other operations during repair of composite structure. In some embodiments, the repair process combines optical three-dimensional surface measurement, illumination by at least one of visible, ultraviolet and infrared light, and digital light processing projection to provide step-by-step monitoring of the repair.

FIG. 3