SCARF REPAIR APPARATUS, SYSTEM, AND METHOD

FIELD

This disclosure relates generally to repairing parts with abnormalities, and more particularly to repairing laminated parts using a scarf repair apparatus, system, and process.

BACKGROUND

Many structures are made of fiber-reinforced polymers because of their high strength and low weight. However, repairing damage to fiber-reinforced polymer parts can be complicated, time-intensive, and expensive. Although some techniques, such as scarf repair techniques, have been designed specifically to repair fiber-reinforced polymer parts, such techniques still suffer from several shortcomings. For example, conventional void forming techniques do not accurately estimate the size (e.g., depth and shape) of abnormalities and thus are unable to accurately determine the size of a void in the part that accommodates the removal of the abnormality. Accordingly, in some conventional scarf repair techniques, the size of the void is estimated and manually formed to be larger (e.g., wider and deeper) to ensure the abnormality is sufficiently removed, which may lead to an unnecessary waste of the laminated material of the part and a reduction in the structural integrity of the part. In addition, manually scarfing plies using conventional methods introduces variation and can negatively affect the appearance of the overall repair.

SUMMARY

The subject matter of the present application has been developed in response to the present state of the art, and in particular, in response to the shortcomings of conventional scarf repair techniques that have not yet been fully solved by currently available techniques. Accordingly, the subject matter of the present application has been developed to provide an apparatus, system, and method that may overcome at least some of the above-discussed shortcomings of prior art techniques. For example, the apparatus, system, and method described herein may promote accuracy, a reduction in material and labor losses, and a reduction in the variation

inherent in conventional manual scarfing processes by providing a significant improvement in the appearance of the repair area.

The following is a non-exhaustive list of examples, which may or may not be claimed, of the subject matter, disclosed herein.

Disclosed herein is a duplicator assembly for forming a first void in a laminated material of a part that matches a second void in a scarf repair guide. The scarf repair guide comprises a physical guide based on a digital scarf repair model. The duplicator assembly comprises an arm, comprising a first end portion and a second end portion. The first end portion is spaced apart from the second end portion. The duplication assembly also comprises a probe that is fixed to the first end portion of the arm and configured to trace the second void in the scarf repair guide. The duplication assembly further comprises a milling tool, fixed to the second end portion of the arm such that the milling tool is co-movably coupled with the probe via the arm. The preceding subject matter of this paragraph characterizes example 1 of the present disclosure.

The duplicator assembly further comprises a handle fixed to the first end portion. The handle is co-movably coupled with the probe. The preceding subject matter of this paragraph characterizes example 2 of the present disclosure, wherein example 2 also includes the subject matter according to example 1, above.

The probe is movable relative to the arm in response to a contour change of the second void in the scarf repair guide. The milling tool is pivotably coupled with the second end portion. The milling tool pivots relative to the arm in response to the probe moving relative to the arm. The preceding subject matter of this paragraph characterizes example 3 of the present disclosure, wherein example 3 also includes the subject matter according to any one of examples 1-2, above.

The duplicator assembly further comprises an articulatable arm coupled to the arm. The articulatable arm is manually movable relative to the part and the scarf repair guide to manually move the arm relative to the part and the scarf repair guide. The preceding subject matter of this paragraph characterizes example 4 of the present disclosure, wherein example 4 also includes the subject matter according to any one of examples 1-3, above.

The articulatable arm is manually movable about at least three axes of rotation such that the probe and the milling tool are manually movable about the at least three axes of rotation. The

preceding subject matter of this paragraph characterizes example 5 of the present disclosure, wherein example 5 also includes the subject matter according to example 4, above.

The arm, the probe, and the milling tool form an arm assembly. The arm assembly is selectively releasably coupled to the articulatable arm. The preceding subject matter of this paragraph characterizes example 6 of the present disclosure, wherein example 6 also includes the subject matter according to any one of examples 4-5, above.

Further disclosed herein is a system for forming a first void in a laminated material of a part to repair the part. The system comprises a scarf repair guide, comprising a physical guide based on a digital scarf repair model, that is non-movably fixed relative to the part and comprises a second void. The first void matches the second void. The system also comprises an arm assembly. The arm assembly comprises an arm that comprises a first end portion and a second end portion. The first end portion is spaced apart from the second end portion. The arm assembly also comprises a probe that is fixed to the first end portion of the arm and configured to trace the second void in the scarf repair guide. The arm assembly further comprises a milling tool that is fixed to the second end portion of the arm such that the milling tool is co-movably coupled with the probe via the arm. The milling tool is configured to form the first void in the part to match the second void in the scarf repair guide as the probe traces the second void in the scarf repair guide. The preceding subject matter of this paragraph characterizes example 7 of the present disclosure.

The system further comprises a scarf repair modeling module that is configured to generate a digital scarf repair model based at least partially on data corresponding with an abnormality in the part. The system also comprises a scarf repair guide forming tool that is configured to make the scarf repair guide based on the digital scarf repair model. The preceding subject matter of this paragraph characterizes example 8 of the present disclosure, wherein example 8 also includes the subject matter according to example 7, above.

The scarf repair guide forming tool comprises an additive manufacturing machine. The preceding subject matter of this paragraph characterizes example 9 of the present disclosure, wherein example 9 also includes the subject matter according to example 8, above.

The system further comprises a defect modeling module that is configured to generate a computer-aided design (CAD) model of at least the abnormality in the part based on the data corresponding with the abnormality in the part. The scarf repair modeling module is further configured to generate the digital scarf repair model based at least partially on the CAD model. The preceding subject matter of this paragraph characterizes example 10 of the present disclosure, wherein example 10 also includes the subject matter according to any one of examples 8-9, above.

The scarf repair modeling module is further configured to generate the digital scarf repair model according to scarf repair parameters defined prior to generating the CAD model of at least the abnormality in the part. The preceding subject matter of this paragraph characterizes example 11 of the present disclosure, wherein example 11 also includes the subject matter according to example 10, above.

The system further comprises a scanning tool that is configured to scan the part to generate the data corresponding with the abnormality in the part. The preceding subject matter of this paragraph characterizes example 12 of the present disclosure, wherein example 12 also includes the subject matter according to any one of examples 10-11, above.

The arm assembly is further configured to form the first void in a surface of the part and the scarf repair guide is non-movably attached to the surface of the part. The preceding subject matter of this paragraph characterizes example 13 of the present disclosure, wherein example 13 also includes the subject matter according to any one of examples 7-12, above.

Additionally disclosed herein is a method of making a scarf repair guide for repairing a laminated material of a part. The method comprises scanning at least a portion of the part containing an abnormality. The method also comprises generating data corresponding with the abnormality in response to scanning at least the portion of the part containing the abnormality. The method further comprises generating a digital scarf repair model based at least partially on the data corresponding with the abnormality. The method additionally comprises making the scarf repair guide, comprising a physical guide, based on the digital scarf repair model. The preceding subject matter of this paragraph characterizes example 14 of the present disclosure.

The method further comprises generating a computer-aided design (CAD) model of at least the abnormality in the part based on the data corresponding with the abnormality. The digital scarf repair model is generated based on the CAD model. The preceding subject matter of this paragraph characterizes example 15 of the present disclosure, wherein example 15 also includes the subject matter according to example 14, above.

The data corresponding with the abnormality comprises an orientation of the part, a location of the abnormality on the part, and a shape of the abnormality. The preceding subject matter of this paragraph characterizes example 16 of the present disclosure, wherein example 16 also includes the subject matter according to any one of examples 14-15, above.

Also disclosed herein is a method of repairing a laminated material of a part. The method comprises tracing a second void, of a scarf repair guide non-movably fixed relative to the part, with a probe. The scarf repair guide is based on a digital scarf repair model generated by a scarf repair modeling module configured to generate the digital scarf repair model based at least partially on data corresponding with an abnormality in the part. The method also comprises co-moving a milling tool with the probe as the probe traces the second void. The method further comprises removing the laminated material of the part with the milling tool as the milling tool co-moves with the probe to form a first void in the laminated material of the part that matches the second void in the scarf repair guide. The preceding subject matter of this paragraph characterizes example 17 of the present disclosure.

The step of tracing the second void with the probe comprises moving the probe according to any one of at least three degrees of freedom. The step of co-moving the milling tool comprises movement of the milling tool according to any one of the at least three degrees of freedom. The preceding subject matter of this paragraph characterizes example 18 of the present disclosure, wherein example 18 also includes the subject matter according to example 17, above.

The step of tracing the second void with the probe comprises pivoting the probe in response to a contour change of the second void in the scarf repair guide. The step of co-moving the milling tool comprises co-pivoting the milling tool with the probe. The preceding subject matter of this paragraph characterizes example 19 of the present disclosure, wherein example 19 also includes the subject matter according to any one of examples 17-18, above.

The step of tracing the second void with the probe comprises manually moving the probe along the second void. The preceding subject matter of this paragraph characterizes example 20

CLAIMS

1. A duplicator assembly for forming a first void in a laminated material of a part that matches a second void in a scarf repair guide, where the scarf repair guide comprises a physical guide based on a digital scarf repair model, the duplicator assembly comprising:

an arm, comprising a first end portion and a second end portion, wherein the first end portion is spaced apart from the second end portion;

a probe, fixed to the first end portion of the arm and configured to trace the second void in the scarf repair guide; and

a milling tool, fixed to the second end portion of the arm such that the milling tool is co-movably coupled with the probe via the arm.

2. The duplicator assembly according to claim 1, further comprising a handle fixed to the first end portion, wherein the handle is co-movably coupled with the probe.

3. The duplicator assembly according to any of claims 1-2, wherein:

the probe is movable relative to the arm in response to a contour change of the second void in the scarf repair guide;

the milling tool is pivotably coupled with the second end portion; and

the milling tool pivots relative to the arm in response to the probe moving relative to the arm.

4. The duplicator assembly according to any of claims 1-3, further comprising an articulatable arm coupled to the arm, wherein the articulatable arm is manually movable relative to the part and the scarf repair guide to manually move the arm relative to the part and the scarf repair guide.

5. The duplicator assembly according to claim 4, wherein the articulatable arm is

manually movable about at least three axes of rotation such that the probe and the milling tool are manually movable about the at least three axes of rotation.

6. The duplicator assembly according to any of claims 4-5, wherein:

the arm, the probe, and the milling tool form an arm assembly; and

the arm assembly is selectively releasably coupled to the articulatable arm.

7. A system for forming a first void in a laminated material of a part to repair the part, the system comprising:

a scarf repair guide, comprising a physical guide based on a digital scarf repair model, non-movably fixed relative to the part and comprising a second void, wherein the first void matches the second void; and

an arm assembly, comprising:

an arm, comprising a first end portion and a second end portion, wherein the first end portion is spaced apart from the second end portion;

a probe, fixed to the first end portion of the arm and configured to trace the second void in the scarf repair guide; and

a milling tool, fixed to the second end portion of the arm such that the milling tool is co-movably coupled with the probe via the arm, wherein the milling tool is configured to form the first void in the part to match the second void in the scarf repair guide as the probe traces the second void in the scarf repair guide.

8. The system according to claim 7, further comprising:

a scarf repair modeling module, configured to generate a digital scarf repair model based at least partially on data corresponding with an abnormality in the part; and

a scarf repair guide forming tool, configured to make the scarf repair guide based on the digital scarf repair model.

9. The system according to claim 8, wherein the scarf repair guide forming tool comprises an additive manufacturing machine.

10. The system according to any of claims 8-9, further comprising a defect modeling module, configured to generate a computer-aided design (CAD) model of at least the abnormality in the part based on the data corresponding with the abnormality in the part, wherein the scarf repair modeling module is further configured to generate the digital scarf repair model based at least partially on the CAD model.

11. The system according to claim 10, wherein the scarf repair modeling module is further configured to generate the digital scarf repair model according to scarf repair parameters defined prior to generating the CAD model of at least the abnormality in the part.

12. The system according to any of claims 10-11, further comprising a scanning tool, configured to scan the part to generate the data corresponding with the abnormality in the part.

13. The system according to any of claims 7-12, wherein:

the arm assembly is further configured to form the first void in a surface of the part; and

the scarf repair guide is non-movably attached to the surface of the part.

14. A method of making a scarf repair guide for repairing a laminated material of a part, the method comprising:

scanning at least a portion of the part containing an abnormality;

generating data corresponding with the abnormality in response to scanning at least the portion of the part containing the abnormality;

generating a digital scarf repair model based at least partially on the data corresponding with the abnormality; and

making the scarf repair guide, comprising a physical guide, based on the digital scarf repair model.

15. The method according to claim 14, further comprising generating a computer-aided design (CAD) model of at least the abnormality in the part based on the data corresponding with the abnormality, and wherein the digital scarf repair model is generated based on the CAD model.

16. The method according to any of claims 14-15, wherein the data corresponding with the abnormality comprises an orientation of the part, a location of the abnormality on the part, and a shape of the abnormality.

17. A method of repairing a laminated material of a part, the method comprising:

tracing a second void, of a scarf repair guide non-movably fixed relative to the part, with a probe, wherein the scarf repair guide is based on a digital scarf repair model generated by a scarf repair modeling module configured to generate the digital scarf repair model based at least partially on data corresponding with an abnormality in the part;

co-moving a milling tool with the probe as the probe traces the second void; and

removing the laminated material of the part with the milling tool as the milling tool co-moves with the probe to form a first void in the laminated material of the part that matches the second void in the scarf repair guide.

18. The method according to claim 17, wherein:

the step of tracing the second void with the probe comprises moving the probe according to any one of at least three degrees of freedom; and

the step of co-moving the milling tool comprises movement of the milling tool according to any one of the at least three degrees of freedom.

19. The method according to any of claims 17-18, wherein:

the step of tracing the second void with the probe comprises pivoting the probe in response to a contour change of the second void in the scarf repair guide; and

the step of co-moving the milling tool comprises co-pivoting the milling tool with the probe.

20. The method according to any of claims 17-19, wherein the step of tracing the second void with the probe comprises manually moving the probe along the second void.