SYSTEMS AND METHODS FOR FABRICATING JOINT MEMBERS

CROSS-REFERENCE

[0001] This application claims priority to U.S. Provisional Patent Application Serial No. 62/020,084 filed July 2, 2014, which is entirely incorporated herein by reference.

BACKGROUND

[0002] Space frame construction is used in automotive, structural, marine, and many other applications. One example of space frame construction can be a welded tube frame chassis construction, often used in low volume and high performance vehicle design due to the advantages of low tooling costs, design flexibility, and the ability to produce high efficiency structures. These structures require that tubes of the chassis be connected at a wide variety of angles and may require the same connection point to accommodate a variety of tube geometries. Traditional methods fabrication of joint members for connection of such tube frame chassis may incur high equipment and manufacturing costs.

SUMMARY

[0003] A need exists for a fabrication method which may be able to generate joints to connect tubes with a variety of geometric parameters. Provided herein is a method of 3-D printing joints for the connection of tubes, such as carbon fiber tubes. The joints may be printed according to the specification of geometric and physical requirements at each tube intersection point. The method of 3-D printing the joints may reduce manufacturing costs and may be easily scaled.

[0004] The 3-D printing method described in this disclosure may allow for the printing of fine features on the joints that may not be achievable through other fabrication methods. An example of a fine feature described in this disclosure may be centering features to force the center of a connecting tube and the center of an adjoining joint protrusion to be co-axial. The centering features may provide a gap between an outer surface of inner region of a joint and an inner surface of a connecting tube, through which adhesive may be applied. Another example may be that nipples can be printed on the joint which may connect to equipment to introduce adhesive to bind a joint and tube assembly.

[0005] Disclosed is a method of fabricating a joint member for connection of a plurality of connecting tubes forming a space frame, the method comprising: determining a relative tube angle, tube size, and tube shape for each of the plurality of

connecting tubes to be connected by the joint member; determining a stress direction and magnitude to be exerted by the plurality of connecting tubes at the joint member; and 3-D printing the joint member having a configuration that (1) accommodates the relative tube, angle, tube size, and tube shape at each joint member, and (2) supports the stress direction and magnitude exerted by the plurality of connecting tubes.

[0006] In some embodiments, the space frame is configured to at least partially encloses a three-dimensional volume. Each connecting tube of the plurality of connecting tubes may have a longitudinal axis along a different plane. The space frame may be a vehicle chassis frame.

[0007] The method may further comprise 3-D printing centering features on at least a portion of the joint member. The centering features may be printed on a joint protrusion of the joint member configured to be inserted into a connecting tube. The characteristics of the centering features can be determined based on the stress direction and magnitude to be exerted by the plurality of connecting tubes at the joint member. The stress direction and magnitude to be exerted by the plurality of connecting tubes at the joint member may be determined empirically or computationally.

[0008] Disclosed is a vehicle chassis comprising: a plurality of connecting tubes; and a plurality of joint members, each joint member sized and shaped to mate with at least a subset of the plurality of the connecting tubes in the plurality of connecting tubes to form a three-dimensional frame structure, wherein the plurality of joint members are formed by a 3-D printer. In one aspect, there is provided a vehicle chassis comprising: a plurality of connecting tubes; and a plurality of joint members produced by a 3-D printer, each joint member sized and shaped to mate with at least a subset of the plurality of the connecting tubes in the plurality of connecting tubes to form a three-dimensional frame structure, wherein the plurality of joint members comprise 3-D printed mounting features, the mounting features providing panel mounts for mounting of panels on the three-dimensional frame structure.

[0009] In some embodiments, each joint member of the plurality of joint members is sized and shaped such that the joint member contacts an inner surface and an outer surface of a connecting tube when the connecting tube is mated to the joint member. Optionally, at least one joint member of the plurality of joint members comprises internal routing features formed during 3-D printing of the joint member. The internal routing features may provide a network of passageways for transport of fluid through the vehicle chassis when the three-dimensional frame structure is formed. The internal routing features may provide a network of passageways for transport of electricity through electrical components throughout the vehicle chassis when the three-dimensional frame structure is formed.

[0010] The plurality of joint members may comprise mounting features formed during 3-D printing of the joint members. The mounting features may provide panel mounts for mounting of panels on the three-dimensional frame structure.

[0011] A system for forming a structure may be provided in accordance with an additional embodiment of the disclosure. The system may comprise: a computer system that receives input data that describes a relative tube angle, tube size, and tube shape for each of a plurality of connecting tubes to be connected by a plurality of joint members to form a frame of the structure, wherein the computer system is programmed to determine a stress direction and magnitude to be exerted by the plurality of connecting tubes at the plurality of joint members: and a 3-D printer in communication with the computer system configured to generate the plurality of joint members having a size and shape that (1) accommodates the relative tube, angle, tube size, and tube shape at each joint member, and (2) supports the stress direction and magnitude exerted by the plurality of connecting tubes.

[0012] In some cases, the frame of the structure at least partially encloses a three-dimensional volume. The plurality of joint members may further comprise centering features on at least a portion of the joint member formed by the 3-D printer. The centering features may be printed on a joint protrusion of the joint member configured to be inserted into a connecting tube. The characteristics of the centering features may be determined based on the stress direction and magnitude to be exerted by the plurality of connecting tubes at each joint member.

[0013] Additional aspects and advantages of the present disclosure will become readily apparent to those skilled in this art from the following detailed description, wherein only illustrative embodiments of the present disclosure are shown and described. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

INCORPORATION BY REFERENCE

[0014] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be

CLAIMS

WHAT IS CLAIMED IS:

1. A vehicle chassis comprising:

a plurality of connecting tubes; and

a plurality of joint members produced by a 3-D printer, each joint member sized and shaped to mate with at least a subset of the plurality of the connecting tubes in the plurality of connecting tubes to form a three-dimensional frame structure,

wherein the plurality of joint members comprise 3-D printed mounting features, the mounting features providing panel mounts for mounting of panels on the three-dimensional frame structure.

2. The vehicle chassis of claim 1, wherein each joint member of the plurality of joint members is sized and shaped such that the joint member contacts an inner surface and an outer surface of a connecting tube when the connecting tube is mated to the joint member.

3. The vehicle chassis of claim 1, wherein at least one joint member of the plurality of joint members comprises internal routing features formed during 3-D printing of the joint member.

4. The vehicle chassis of claim 3, wherein the internal routing features provide a network of passageways for transport of fluid through the vehicle chassis when the three-dimensional frame structure is formed.

5. The vehicle chassis of claim 3, wherein the internal routing features provide a network of passageways for transport of electricity through electrical components throughout the vehicle chassis when the three-dimensional frame structure is formed.

6. The vehicle chassis of claim 1, wherein the plurality of joint members comprises mounting features formed during 3-D printing of the joint members.

7. The vehicle chassis of claim 1, wherein at least one of the plurality of joint members comprises one or more 3-D printed nipples.

8. The vehicle chassis of claim 7, wherein the one or more 3-D printed nipples comprise a pathway for adhesive injection or vacuum infusion.

9. The vehicle chassis of claim 8, wherein the at least one of the plurality of joint members comprises nipples positioned on opposite sides of the joint member.

10. The vehicle chassis of claim 8, wherein the at least one of the plurality of joint members comprises a protrusion for mating with a corresponding connecting tube.

11. The vehicle chassis of claim 10, wherein the one or more 3-D printed nipples are configured to connect with injection equipment to distribute adhesive into a space between the protrusion and the corresponding connecting tube.

12. The vehicle chassis of claim 10, wherein the at least one of the plurality of joint members further comprises a lip configured to fit over an outer diameter of the corresponding connecting tube wherein the protrusion is configured to fit inside the corresponding connecting tube.

13. The vehicle chassis of claim 12 wherein an annular region is formed between a surface of the protrusion and an inner diameter of the lip.

14. The vehicle chassis of claim 13, wherein the one or more 3-D printed nipples are configured to allow injection of adhesive or creation of vacuum in the annular region.

15. The vehicle chassis of claim 10, wherein a surface of the protrusion comprises a plurality of centering features disposed thereon.

16. The vehicle chassis of claim 15, wherein the plurality of centering features are configured to create fluid pathways to spread adhesive injected via one of the 3-D printed nipples.

17. The vehicle chassis of claim 1, wherein at least one of the plurality of joint members comprises mounting features for shear panels or body panels.

18. The vehicle chassis of claim 1, wherein the mounting features comprise a flange.