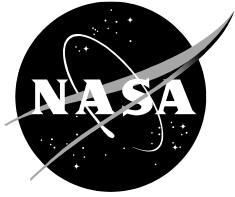


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TransHab Tapered Diamond Stitch Methods Crewed Inflatable Softgoods Structures

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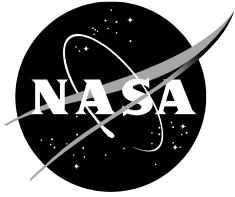
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National Aeronautics and
Space Administration

Johnson Space Center
Houston, TX 77058

August 2022

Background

The NASA TransHab project was a flight development program of a crewed inflatable habitat designed for in-space use. Through the course of the development, several novel technologies were developed and patented by NASA. One of these patents included information regarding a custom seam stitch that was used in the TransHab restraint layer design. The patent in question, US 6,547,189 was filed on April 2, 2001. It is a continuation-in-part of patent US 6,231,010, filed on January 25, 1999. The '189 patent in question and any associated license agreements expired on May 26, 2021. As the patent protection has ended, the details of the custom seam stitch are being disclosed.

Seam Details

The seam stitch developed during the TransHab program is known as the 'tapered diamond stitch' and includes both a 'single' and 'double' tapered diamond pattern for 'end termination' and 'continuous' webbing components respectively. It was designed for 1-in wide Kevlar webbings with load ratings of 6,000 lbf and 12,500 lbf. The stitch pattern was designed to gradually transfer load along the length of the seam using a tapered diamond geometry. The single diamond pattern, shown in Figure 1, is used when load is carried in a single direction, like at a looped end termination. In this pattern, the loop is on the right side of the pattern with the smaller diamonds. The double diamond pattern, shown in Figure 2, is used when load is transferred continuously across two webbing sections, like a lap seam between two strap ends. In this pattern, the stitch is a mirrored copy of the single diamond pattern with the larger diamonds on the outside and the smaller diamonds on the inside. The diamond stitch has been shown in tensile testing to provide greater than 85% load strength efficiency, compared to the pristine webbing.



Figure 1 – Single Tapered Diamond Stitch Pattern



Figure 2 – Double Tapered Diamond Stitch Pattern

Manufacturing Procedure 1 – Looped End Termination Seam (Single Tapered Diamond Pattern)

The following procedure was developed and revised based on lessons learned to repeatably create the diamond stitch seams. This procedure was used to construct an end termination loop with a single webbing looped and stitched back on itself, commonly used to wrap around a pin or clevis, as shown in Figure 3.



Figure 3 – Cross-section View of Loop Seam

Materials

1. Permanent Marker [Extra-Fine Tip]
2. Double Stick Tape [1/2"-3/4" Width, ≤ 0.004 " Thick, Clear Polyester Film, Acrylic Adhesive]
3. Vectran Thread [Tex 120, Bonded, Natural, Per A-A-55220]
4. Vectran Thread [Tex 210, Bonded, Natural, Per A-A-55220]

1. Strap Marking

- 1.1 Use a Permanent Marker (Item 1) to mark the strap to be seamed by labeling the start point and end point of the seam, using two lines spaced 8.0" apart as shown in Figure 4. Lines should be drawn on both the top and bottom strap sections to be stitched.

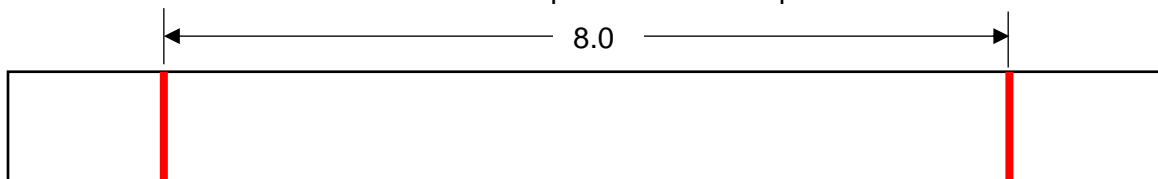


Figure 4 – Loop Seam Marking Dimensions

2. Strap Positioning

- 2.1 On the bottom strap section, apply a 8.0" strip of Double Stick Tape (Item 2) between the red lines, centering the tape in the middle of the strap as shown in Figure 5.

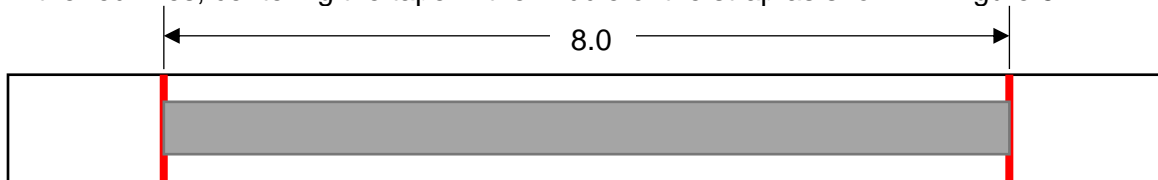


Figure 5 – Loop Seam Tape Placement

- 2.2 Peel back protective cover of Double Stick Tape and place the top strap section over the bottom strap section by aligning the red marks and centering the two straps sections. Apply pressure by hand along the tape length to secure the two strap sections together.

3. Strap Stitching

- 3.1 Stitch the straps together using the tapered diamond pattern (according to Figure 7) using Vectran Thread (Item 3 or 4), Type 301 Stitch per ASTM D 6193, 6-9 Stitches per inch. The stitch pattern should start and end at the red marks on the top strap section. Do not back stitch in any location.

Note: Use Tex 120 Vectran Thread (Item 3) for 6,000 lbf rated webbing and use Tex 210 Vectran Thread (Item 4) for 12,500 lbf rated webbing.

Note: NASA uses a Brother programmable sewing machine (Model # BAS-326G) to sew the tapered diamond seams. Setting the proper thread tension is critical to sewing an efficient seam. The goal of setting the tensions in the machine and bobbin are to get a balanced stitch, i.e. the cross-over point of each stitch should cross at mid-thickness and not be visible from the surface. Achieving this tension balance will require an iterative test process, specific to each machine. It was found that to a certain point, lower thread tensions produce better results.

- 3.2 Tie each of the free ends of the stitch with a surgeons knot. Cut off the free ends approximately 0.5" from each knot as shown in Figure 6.

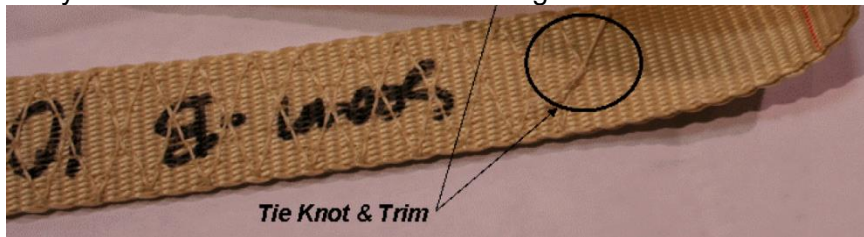


Figure 6 – Loop Seam Tie Knot and Trim

Manufacturing procedure 2 – Continuous Overlap Seam (Double Tapered Diamond Pattern)

The following procedure was developed and revised based on lessons learned to repeatably create the diamond stitch seams. This procedure was used to construct a lap seam with two overlapping webbing sections, as shown in Figure 8, with a double tapered stitch pattern.

Figure 8 - Cross-section View of Overlap Seam

Materials

1. Permanent Marker [Extra-Fine Tip]
2. Double Stick Tape [1/2"-3/4" Width, ≤ 0.004" Thick, Clear Polyester Film, Acrylic Adhesive]
3. Vectran Thread [Tex 120, Bonded, Natural, Per A-A-55220]
4. Vectran Thread [Tex 210, Bonded, Natural, Per A-A-55220]

1. Strap Marking

- 1.1 Use a Permanent Marker (Item 1) to mark the end of each strap to be seamed by labeling the start point and end point of the seam, using two lines spaced 16.0" apart as shown Figure 9. Lines should be drawn on both the top and bottom strap sections to be stitched.
- 1.2 Make a crosshair mark with a Permanent Marker (Item 1) in the center of the top strap section to indicate the starting point of the stitch, as shown Figure 9. The mark shall be located 8.0" from the red line and centered within the strap width.

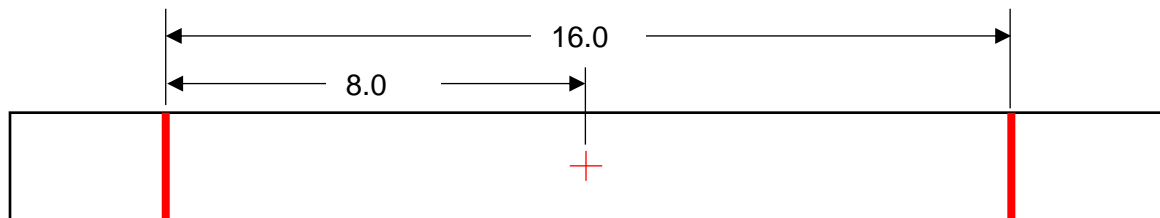


Figure 9 – Lap Seam Marking Dimensions

2. Strap Positioning

- 2.1 On the bottom strap section, apply a 16.0" strip of Double Stick Tape (Item 2) between the red lines, centering the tape in the middle of the strap as shown in Figure 10.

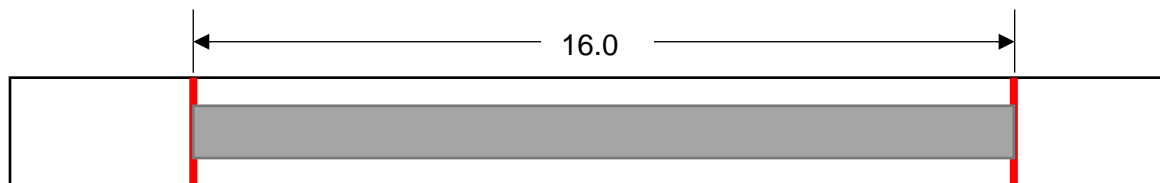


Figure 10 – Lap Seam Tape Placement

- 2.2 Peel back protective cover of Double Stick Tape and place the top strap section over the bottom strap section by aligning the red marks and centering the two straps sections. Apply pressure by hand along the tape length to secure the two strap sections together.

3. *Strap Stitching*

3.1 Beginning at the Seam Starting Point, stitch one half of the double tapered diamond pattern (according to Figure 11) using Vectran Thread (Item 3 or 4), Type 301 Stitch per ASTM D 6193, 6-9 Stitches per inch. The stitch pattern should start and end at the red marks on the top strap section. Do not back stitch in any location.

Note: Use Tex 120 Vectran Thread (Item 3) for 6,000 lbf rated webbing and use Tex 210 Vectran Thread (Item 4) for 12,500 lbf rated webbing.

Note: NASA uses a Brother programmable sewing machine (Model # BAS-326G) to sew the tapered diamond seams. Setting the proper thread tension is critical to sewing an efficient seam. The goal of setting the tensions in the machine and bobbin are to get a balanced stitch, i.e. the cross-over point of each stitch should cross at mid-thickness and not be visible from the surface. Achieving this tension balance will require an iterative test process, specific to each machine. It was found that to a certain point, lower thread tensions produce better results.

3.2 Tie each of the free ends of the stitch with a surgeons knot. Cut off the free ends approximately 0.5" from each knot as shown in Figure 6.

3.3 Repeat steps 3.1 – 0 for the other half of the double tapered diamond stitch pattern. The double pattern is a mirror of the single diamond pattern shown in Figure 7.

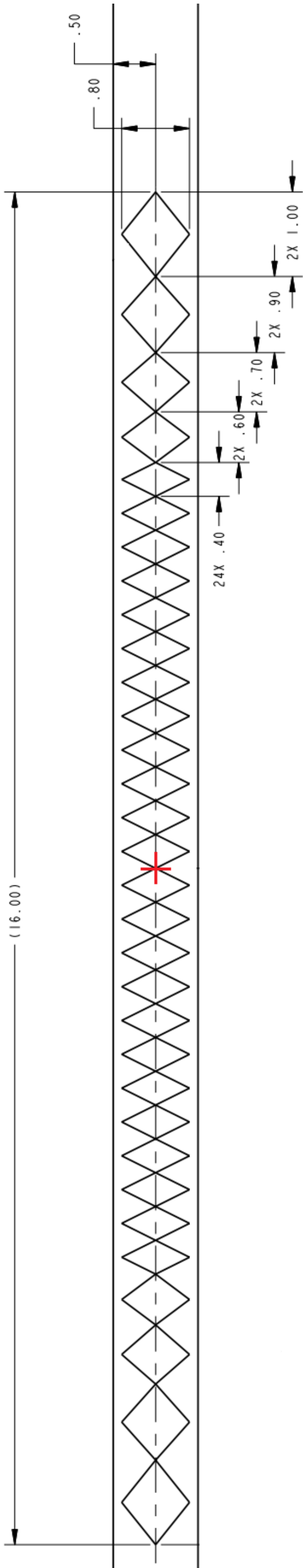


Figure 11 – Double Tapered Diamond Stitch Dimensions