CoTexx® Knitted Heating Fabric – Working Instruction

Basic Information
CoTexx Knitted Heating Fabric is a fabric made of high frequency litz wire for heating surfaces electrically. The Knitted Heating fabric has a width between 25 and 120 mm and is offered in rolls of up to 20 m.

CoTexx Knitted Heating Fabric can be easily cut to length with scissors. Please note that cutting between the connection points or drilling a whole will destroy the wires and thus the heating.

The resistance of one segment of heating fabric depends on the material of the wires (copper or resistance alloy), its width, and is directly proportional increasing with the length.

Above pictures show soldering spots at both ends of each segment. They are needed to connect the segment of Knitted Heating Fabric with an appropriate power supply. Characteristic of high frequency litz wire is that every strand is insulated against each other by a thin
layer of lacquer. To remove this lacquer at the connection spots, a solder temperature of at least 390 °C is required.

**Lay Out Design**
A heating area usually consists of several segments of Knitted Heating Fabric placed side by side to form a heating element. Cooler temperatures at the edges of the heated area can be prevented by choosing an all-round overlap of at least 20 mm.

Example: The blue area needs to be heated. It is covered by five segments.

![Diagram of heating area covered by five segments](image)

Information of each segment is listed in the table below. By comparing the calculational resistance values with the measured ones, soldering errors can be detected.

<table>
<thead>
<tr>
<th>Segment Number</th>
<th>Length</th>
<th>Width</th>
<th>Area</th>
<th>Resistance (488 Ω/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,00 m</td>
<td>0,09 m</td>
<td>0,27 m²</td>
<td>131,76 Ω</td>
</tr>
<tr>
<td>2</td>
<td>3,00 m</td>
<td>0,09 m</td>
<td>0,27 m²</td>
<td>131,76 Ω</td>
</tr>
<tr>
<td>3</td>
<td>2,50 m</td>
<td>0,09 m</td>
<td>0,23 m²</td>
<td>109,80 Ω</td>
</tr>
<tr>
<td>4</td>
<td>2,00 m</td>
<td>0,09 m</td>
<td>0,18 m²</td>
<td>87,84 Ω</td>
</tr>
<tr>
<td>5</td>
<td>1,50 m</td>
<td>0,09 m</td>
<td>0,14 m²</td>
<td>65,88 Ω</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12,00 m</td>
<td>1,08 m²</td>
<td>527,04 Ω</td>
<td></td>
</tr>
</tbody>
</table>

If all five segments of the example are switched in series, a total resistance of 527,04 Ω would result. When the length of all segments has been determined and thus the total resistance is known, the power of the heating can be calculated according to Ohm’s Law as follows:

\[ P = \frac{U^2}{R} ; [W] = \frac{[V^2]}{[Ω]} \]

With an exemplary voltage of 230 V this would mean a heating power of

\[ P = \frac{230 V^2}{527 Ω} = 100,4 W = 93 \frac{W}{m^2} \]

This power is too less for heating up the area / the mould with e.g. 2 °C/min. and holding 80 °C at room temperature. Therefore, the total length is divided into several segments with all the same length. These segments are switched in parallel. The total resistance can be calculated according to the formula (n is the number of segments switched in parallel):

\[ R = \frac{R_{\text{serial connection}}}{n^2} \]
Please note: the segments need to have the same resistance, otherwise the temperature is not homogeneous! The calculated power values represent the maximal power of the heating. This power is reduced by connecting controllers, which stop the electrical current flow when reaching a selected temperature.

A heating power of 1487 W/m² is enough for the example. Therefore the overall length is divided into 4 segments of 3.0 m length, which are switched in parallel.

<table>
<thead>
<tr>
<th>Number of Segments Switched in Parallel</th>
<th>Length of Each Segment</th>
<th>Factor of the Resulting Resistance</th>
<th>Total Resistance of the Example</th>
<th>Heating Power of the Example (230 V, 1.08 m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12,00 m</td>
<td>1,000</td>
<td>527,04 Ω</td>
<td>100 W</td>
</tr>
<tr>
<td>2</td>
<td>6,00 m</td>
<td>0,250</td>
<td>131,76 Ω</td>
<td>401 W</td>
</tr>
<tr>
<td>3</td>
<td>4,00 m</td>
<td>0,111</td>
<td>58,56 Ω</td>
<td>903 W</td>
</tr>
<tr>
<td>4</td>
<td>3,00 m</td>
<td>0,063</td>
<td>32,94 Ω</td>
<td>1606 W</td>
</tr>
<tr>
<td>5</td>
<td>2,40 m</td>
<td>0,040</td>
<td>21,08 Ω</td>
<td>2509 W</td>
</tr>
</tbody>
</table>

The following picture shows the circuit, the position of the soldering spots and the connection studs / bushings, to plug in the power supply.

### Installation

In short, two essential steps need to be done when installing the heating: electrical connection and embedding the heating between GFRP or silicone. GFRP has the following tasks:

- Fixing the position of the heating segments, cables between the segments and fixing the connection studs / bushings
- Defining the shape and stability of the mould
- Ensuring an unhindered heat flow from the heating to the mould surface
• Protecting the heating from short cuts due to fluids, carbon fibres, …
• Protecting you as an operator from getting an electric shock (if using voltages of >25 Volt AC or >60 Volt DC)

For usual applications we recommend using on both sides at least two layers of glass fabric 280 g/m² and epoxy resin with a high \( T_g \) for high operation temperatures. Best results are yielded embedding the Heating Fabric by resin infusion processes because of low void content.

First installation step is to cut the Knitted Heating Fabric to length (in the example the segments 1 to 5). Please note: There is no cut between 3b / 4a, just a soldering spot! Furthermore, be careful of not destroying the high frequency litz wire of the Knitted Heating Fabric during handling, because this would have an influence on the temperature distribution.

Extract the litz wires at both ends of each segment to fine-tune the length. Twist and solder both ends together. Measure the resistance of the segment and compare it with the calculated value.

Next is to lay down the segments on the back side of the master mould, either on dry glass fabric (if infusion in one shot) or precured GFRP (infusion or hand laminating with vacuum compacting afterwards possible). Apply hot melting thermoplastic binder or spray adhesive to fix the position of the segments. Please note: the segments of Knitted Heating Fabric should lay next to each other without overlapping (would double the heating power in the overlap, the risk of overheating) or large gaps (would cause unheated stripes).

Now it is time for interconnecting the segments (switching them in series or in parallel) according to the layout design. Four different exemplary soldering techniques are marked in the following picture.
I. Parallel connection of two segments at the segments’ ends

Better than just soldering the two strands of the Knitted Heating Fabric and the braid-ede flat strand together (picture in the middle), is a crimped connection with a wire termination followed by soldering (right picture).

II. Serial connection of two segments with a silicone insulated cable

III. Soldering spot in one segment of Knitted Heating Fabric, to switch segments in parallel

IV. Installing the connection stud / bushing (Recommendation: place them next to the Knitted Heating Fabric, not directly above)
After the connections are completed, it is possible to check the function by applying an extra-low voltage (<25 Volt AC or <60 Volt DC) and measuring the temperature until 40 °C is reached. Alternatively, compare the measured resistance between the two connection studs / bushings with the calculated value.

Please note: Do not connect the heating to voltages of e.g. 110 VAC or 230 VAC before having embedded the heating between GFRP! If the heating is operated with >25 Volt AC or >60 Volt DC it must be assured that all current-carrying components have an electric shock protection. Furthermore, all current-carrying component must have no connection with conductive carbon fibers (risk of short circuit). The connection studs / bushings must be insulated, e.g. with an additional silicone cover, if using an electrical voltage higher than extra low voltage (see paragraph below: Final Steps). In this case the system has to be approved by an electrical technician before initial operation.

Install the Temperature Sensors
CoTexx standard PT 100 temperature sensors come with two or optionally three sensor wires (to eliminate the wires’ resistances). We recommend covering the Knitted Heating Fabric with one layer of glass fabric (at least 80 g/m²) in the area of the sensor to the connection studs / bushings at the edge of the heating area. The sensor, as well as the wires can be fixed with stripes of glass fabric and spray adhesive or hot melting thermoplastic non-woven. Place the sensor in the area of the highest expected temperature (usually the centre of the heating area). Then solder on each lead one connection stud / bushing.

Check the resistance between the connections at room temperature. Depending on the number of wires the resistance should be ca:
- 108 Ω (two wires)
- 2 x 108 Ω, 1 x 0,1-0,5 Ω (three wires)

Fixing the connection studs / bushings and the internal cables
A well-proven method is, to cover each connection stud / bushing with a patch of glass fabric that was cut in the middle. Spray adhesive or hot melting thermoplastic non-woven will fix the position. Analogical, the internal cables and soldering spots can be fixed and covered.
Continuing with the layup

If the heating will be embedded by vacuum infusion, the heating element is covered by at least two layers of dry glass fabric (e.g. 280 g/m²) and further glass or carbon textiles for stiffening the mould. Like usual the infusion is prepared by laying down peel ply, perforated release foil, flow media and a vacuum bag. It makes sense, to let the bushings break through the layup. To prevent the thread of filling with resin, seal it with tacky tape.

If you do not have the possibility of making an infusion, you can impregnate the Knitted Heating Fabric with epoxy resin with a long pot-life. Then cover it with glass fabric, release ply and non-woven. Afterwards put the layup in a vacuum bag and let the epoxy resin cure.

Please note: the temperature stability of the mould cannot exceed the temperature stability of the resin. Please use only resins with high Tg.
Final Steps

After the resin has been hardened, the connection studs / bushings can be laid open. Measure the resistance and compare it with the calculated value. Then install an electric shock protection at those connectors, which will be connected with voltages >25 Volt AC or >60 Volt DC. The following pictures show a protection consisting of a GFRP tube, which is bonded to the surface with silicone or epoxy resin, and a silicone cap.

Plug in the power cables and the cables from the temperature sensor to the controller and slowly increase the temperature until reaching the working temperature.

The heating is now ready for operation.