A Review on Band Heaters for Heating Performance Enhancement

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Abstract: Band heaters are available with elements of different diameters and heights, designed to heat and maintain the temperature of cylindrical parts. Heat transfer is usually achieved by conduction or radiation for high power heaters. They are suitable for solid heating, liquids or gases heating. Applications for band heaters are various they can be fitted to nozzles or extruder barrels, process plastics or today’s materials such as resins that requires high temperature or for heating conducts. They can also be used in plastic injection moulding as process of materials requires high heating power and high temperatures.

Key words: Injection Moulding, Band/Barrel Heater, Watt Density.

I. INTRODUCTION

To bring the injection moulding machine (IMM) or extruder machine to a functioning temperature, heat is required; this heat brings the machine to a proper temperature for startup and for maintaining the desired temperature under normal operations. There are three methods of heating the extruder: electric heating, fluid heating, and steam heating. The electric heating is the most common method of heating the extruders or injection moulding machine.

Electric resistance heaters which are widely use in extruder/IM machines are called band/barrel heaters since they are in the form of a circular band, which fits over the screw barrel of the machine. The heat generated by the extruder heaters is made possible by passing a certain amount of current through a conductor of certain resistance, as the resistance creates barrier to the flow of electrons, heat is generated. The amount of heat generated is given by the equation below:

\[ Q_c = I^2R = VI = V^2/R \]

Where \( I \) is the current, \( R \) is the resistance, and \( V \) is the voltage. This equation is valid for direct current (DC) as well as single phase alternating current (AC), provided the current and voltage are expressed as root mean square (rms) values and the circuit being purely resistive (phase difference zero). With three phase circuit the heat generation is:

\[ Q_c = 3VI \quad ......... \quad [1] \]

II. BAND HEATER

In IMM machine, the raw material, called resin, is usually in the form of granules. These granules is stored in a feed hopper, a bottom opened bottle which feeds the press with resin, shown in Figure. The granules need to be molten to enable an injection into the tool cavity chamber, i.e. a cavity that reflects the final shape of the plastic product, the IMM machine is therefore equipped with a plasticizing unit in order to melt the resin. Initially in the plasticizing unit a screw, which rotates with help of a motor, melts the granules. Most of the heat is created by friction in the screws rotation but
heating bands are often added to supplement the heat generating. When the granules are melted the screw inject the polymer into the cavity chamber with an axial movement.

In band heaters the heating element is sandwiched between an insulating material which is a good conductor of heat and bad conductor of electricity. The band heaters used now a day are classified according to the insulators used in them, as below;

1) Mica band heater
2) Ceramic band heater
3) Mineral insulated band heater

III. MICA BAND HEATER

Mica strip are usually used to insulate resistance band heaters. These heaters are low cost but not quite durable and are not very reliable. They can withstand temperatures of up to 500°C and have a loading capacity of about 50 kW/m². Recent types of mica heaters can handle power densities up to 165 kW/m². The durability of a heater depends on the usage and the contact between the barrel and the surface of the heaters. Inadequate surface contact will cause overheating and the outcome will reduced heater life or even premature burnout of the heater element. Commercially, are available special paste to improve the heat transfer between the heater and the barrel. A mica core produces a thin, efficient heater. Heat from the precisely wound resistance element is quickly transferred to the working surface for fast heat-up and response. Mica provides excellent dielectric strength and heat transfer capability for long heater life. The mica core is encased in a continuous corrosion resistant sheath and formed.

All full mica band heaters are designed with closed ends to protect against contamination. Maximum sheath temperature is 800°F.

A. Construction

Figure No.3 Construction of Mica Band Heaters

1. Mica insulation.
2. Element ribbon.
3. Rust resistant steel sheath.
4. Radial lock-up tabs.
5. Post terminals.

B. Features

- The Standard Band Heaters are manufactured in one or two piece constructions with maximum inside diameters of 111/2”and 221/2” respectively. Three or more sections are employed when heaters of larger diameters are needed (as for blown film extrusion dies).
- Holes and cutouts are available. Maximum wattage may be reduced with the addition of holes and cutouts. Drawing required for specific location.

C. Sizes

Construction of units with inside diameters over 111/2” must be manufactured in accordance with the following table.

Table No.1 Inside Diameters

<table>
<thead>
<tr>
<th>Construction</th>
<th>Inside Diameter Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Piece</td>
<td>Over 111/2” to 221/2”</td>
</tr>
<tr>
<td>Three Piece</td>
<td>Over 221/2” to 36”</td>
</tr>
<tr>
<td>Four Piece</td>
<td>Over 36” to 48”</td>
</tr>
</tbody>
</table>

The above is based on a watt density of 30 watts per square inch of surface.

D. Wattage
The watt density may be varied, depending on operating temperature in accordance with the following table.

### Table No.2 Watt density

<table>
<thead>
<tr>
<th>Operating Temperature (°F)</th>
<th>°C</th>
<th>Watts Per Square Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>300°F</td>
<td>149°C</td>
<td>40</td>
</tr>
<tr>
<td>400°F</td>
<td>204°C</td>
<td>30</td>
</tr>
<tr>
<td>500°F</td>
<td>260°C</td>
<td>21</td>
</tr>
<tr>
<td>600°F</td>
<td>316°C</td>
<td>12</td>
</tr>
<tr>
<td>700°F, 900°F Max.</td>
<td>371°C to 482°C</td>
<td>10</td>
</tr>
</tbody>
</table>

The following information will help to understand watt density in order to select the proper wattage for our application.

Wattage will affect the durability and performance of band heater. To prevent heater failure, do not exceed the maximum recommended watt density for a specific heater size.

\[
\text{Watt density (W/\text{In}^2) = \frac{\text{WATTAGE}}{(3.14 \times \text{Inner Diameter} \times \text{Width}) - (\text{Cold Section})}}
\]

### Table No.3 Length of Cold Section

<table>
<thead>
<tr>
<th>Model</th>
<th>Cold Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-Piece</td>
<td>1” X Width</td>
</tr>
<tr>
<td>Two-Piece</td>
<td>2” X Width</td>
</tr>
<tr>
<td>Holes And Cutouts</td>
<td>(Size + 1/2”) X Width</td>
</tr>
</tbody>
</table>

Factors to be considered while selecting watt density.

- Select narrower heaters for superior heat transfer (1” – 2.5” wide).
- Select watt density according to the operating temperature.
- Select the corresponding wattage for your application in order to prevent short cycling and inefficient operation.
- Consider the safe heating pattern of the heated material, the thermal conductivity, and coefficient of expansion of the cylinder when determining puissance.

### E. Operation

When heating a material for the first time, the material temperature should be monitored with a temperature indicating device and the final drum heater control setting recorded for future reference. The material should be mixed to get an accurate temperature since the material near the outside of the drum will heat faster than the material near the center. This initial set-up should be done with the three heat switch set on high. If the material you are heating exhibits excellent heat receptivity you may maintain your desired temperature with the three heat switch set on medium or low, thus reducing power consumption.

- Use on all metal drums only.
- For use indoors only.
- Do not use to heat flammable materials.
- Do not use in hazardous areas.
- Vent container to prevent pressure build-up.

**Time vs. Temperature:**
Achieved at maximum setting, Covered 55 gallon drum filled with water at 70°F.

### F. Applications

Mica band heaters are used in Cylinders, Dies, Drums, Holding Tanks, Injections and Blow Molding Machines, and Plastic Extruders.[2]

### IV. CERAMIC INSULATED BAND HEATERS

Ceramic Insulated Band Heaters are specifically designed and engineered to meet the ever increasing demand for energy conservation and to improve operation efficiency. The ceramic band heaters are capable of generating the higher temperatures essential to process today’s high temperature resins. Electrical energy savings are achieved by using a 6 mm (1⁄4”) thick ceramic fiber insulating blanket, reducing power consumption by 25 to 30%. Because of the low thermal conductivity of the ceramic fiber insulation, the external surface temperature of the ceramic band heater is approximately 204°C (400°F) while running the inside surface temperature at 649°C (1200°F). Ceramic band heaters transmit heat through both conduction and radiation. The element winding is designed to run at maximum temperature and heat the ceramic blocks to the point at which they radiate energy into the barrel as well as conduct energy by being in contact with the barrel. Therefore, the fit is not as critical as in other types of bands. Ceramic band heaters have become extremely popular among Original Equipment Manufacturers as the standard heaters for the barrels of plastic injection molding machines, extruders, and blow molding equipment.
A. Construction

**Standard:** The basic ceramic band heater design consists of a helically wound resistance coil made from nickel-chrome wire, evenly stretched and precisely strung through specially designed ceramic insulating bricks, forming a flexible heating mat. The ceramic heating mat along with 1/4" thick ceramic fiber insulation is installed in a stainless steel housing made with serrated edges, providing maximum flexibility for ease of installation. This allows the use of wider band heaters, eliminating the need for numerous narrow width and two-piece band heaters.

**Double Insulated:** For situations requiring additional insulation for lower external temperatures and increased electrical energy savings, offers double insulated ceramic bands with full 13 mm (1/2") thick ceramic fiber insulation. This will decrease power consumption by 35 to 37% when compared to uninsulated band heaters.

B. Specification

**Performance Ratings:**
- Maximum Temperature: -760°C (1400°F)
- Nominal Watt Density: -3 to 7 Watt/cm² (20 to 45 Watt/in²)
- Maximum Watt Density: -45 Watt/cm² (45 Watt/in²)

**Electrical Ratings:**
- Maximum Voltage: -480 Vac per termination
- Dual Voltage: -Available depending on heater configuration
- Maximum Amperage per Circuit: -
- Lead Wire Termination: -10 A
- Screw Terminations: -25 A

Resistance Tolerance: -10%, −5%
Wattage Tolerance: -5%, −10%

C. Features

- Built-In Thermal Insulation
- Conserves Electrical Energy
- Minimum Heat Loss
- Fully Flexible For Easy Installation
- Good Temperature Uniformity
- Longer Heater Life
- Various Constructions and Terminations
- Heats Through Conduction and Radiation
- Designed to Specifications
- Reduce Heat Loss
- Conserve Energy
- Maximize Operator Comfort
- Reduce Overall Operation Cost

D. Features for Power Saver Construction

1. **Chrome Nickel Steel sheathing.** Chrome Nickel Steel housing with serrated edges provides maximum flexibility for ease of installation.

2. **Thermal insulation.** Built-In heat saving Thermal Insulation standard (4mm) on all Ceramic Bands “Premium Heat” will reduce power consumption. Further reduction can be obtained with higher thickness insulation which prevents heat loss, thereby lowering energy costs.

3. **High Grade Ceramic Insulators.** Interlocking Steatite bricks designed for best combination of physical & dielectric strength, good thermal conductivity to heat cylindrical parts, good for sheath temperature up to 500 Deg C. provides flexibility for ease of installation on the barrel.
4. **Ni-chrome Heating coil.** Helically wound superior quality (60/16, 80/20) Nickel Chrome resistance wire designed for maximum current carrying capacity is strung through specially designed ceramic insulating bricks providing even heat distribution, thus eliminating hot spotting that can cause premature heater failure.

**E. Technical data**

**Sheath material:** Chrome Nickel Steel

**Insulators:** High Grade Steatite Ceramic Insulators (High Temperature)

**Heat Saving Thermal Insulation:** Ceramic Fiber (std.)

**Heating Elements (coil):** NiCr 60:16, NiCr 80:20

**Connection:** Fiber Glass Insulated- Metal Braided Flexible Cable (std. 500mm long) mounted on rigid screw post terminals

**Voltage Range:** 110V - 440V

**Power Rating:** Depending upon application

**Power Tolerance:** ± 10%

**Insulation Resistance (Cold):** < 20 M Ohms

**Sheath Temperature:** Up to 500°C maximum (Chrome Nickel Steel sheath)

**Inner Diameter:** Minimum 60mm in case of Premium 75mm in case of Power saver & 100mm for Power Saver PLUS

**F. Temperature vs. Heat Loss**

From above graph we can see that, the heat loss goes on increasing with increase in surface temperature of the barrel for non insulated band
heaters, as compared with the insulated band heaters [3], [4]

V. MINERAL INSULATED BAND HEATER

A. Features and Benefits
- Maximum watt densities; far in excess of any other type of band.
- Highest application temperatures available.
- Best possible clamping and the resulting improved efficiency.
- Longest life available for any application and reduction of equipment downtime.
- High heat transfer rates and the resulting fast response.
- Rapid heat-up capabilities and no fear of heater failure.
- Reduced number and physical size of heaters required per application.
- Cost-effective performance.
- Choose a Mineral Insulated Band when the temperature of the heater will exceed 650º F (343º C).
- Expandable or two-piece construction.

B. Material and Construction
- Precision engineered with computer selected wound resistor element.
- Efficient low expansion clamping systems or welded-to-the-sheath clamping ears.
- Optional lead and screw termination styles.
- High temperature patented mineral insulation heat transfer media.
- High temperature oxidation-resistant sheath material commensurate with maximum operating temperature.
- Stainless steel screw terminals welded to an internal stainless steel pad effecting a positive and secure electrical connection. The surrounding area is insulated with a high temperature refractory cement and ceramic insert.
- When lead wires are specified, they are also welded to a stainless steel pad. The high temperature mica tape lead wire, 842º F (450º C), is ideally suited for most applications.

C. Specifications
Optional features include a sealed low profile cap and tube termination system for low clearance applications. The tube may be lengthened to accommodate radius bends to clear a nozzle hex or other obstructions. Braid and armor lead wire protection is available. A 10” (25.4 cm) length is standard. Flexible leads are 10” (25.4 cm) standard. Other leads are available upon request. Diameters from 3/4” (19 mm) up to 36” (91.4 cm) typical widths from 3/4” (19 mm) up to 6” (152.4 mm) maximum.

D. Applications
The Mineral Insulated Band will consistently outperform other bands in virtually any application. Its ability to withstand extremely high heat makes it the best choice for the plastics industry, especially when processing engineering-grade resins. Additional uses include heating pipes, chemical processing and drum heating. In addition, Mineral Insulated Band can be modified to meet the demands of virtually any special application. Our engineers can utilize a variety of alternative features and options to customize the heater to our specific needs.[5][6][7]

VI. BAND HEATER SELECTION
Prior to selecting a band heater style for an application, there are a number of items that must be taken into consideration. These include type of application, operational temperature, controls and heat required to continually satisfy the application. All band heaters have their own physical and operational characteristics and limitations which should be reviewed prior to making a selection. Once the total wattage requirement has been established, the number of heaters needed can be determined as below.

\[
\text{number of heaters} = \frac{\text{totalWATTAGE}}{\text{Watt density of heater} \times \text{heater width}}
\]

- Knowing the maximum watts per square inch of the heater is essential when making your selection and can be calculated by:
(HeaterID*3.14) – 1 / W²
W/sq. °C = Wattage of Heater

VII. COMPARISON OF MICA, CERAMIC AND MINERAL INSULATED BAND HEATERS

Table No. 4 Comparison of Mica, Ceramic and Mineral Insulated Band Heaters

<table>
<thead>
<tr>
<th>Electric Insulation</th>
<th>MICA</th>
<th>CERAMIC</th>
<th>MINERAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Insulation</td>
<td>No</td>
<td>Ceramic Fiber</td>
<td>Minerals</td>
</tr>
<tr>
<td>Wattage (W/in²)</td>
<td>10 To 40</td>
<td>20 To 45</td>
<td>45 To 100</td>
</tr>
<tr>
<td>Temperature Range (°C)</td>
<td>150-450</td>
<td>150-650</td>
<td>340-760</td>
</tr>
<tr>
<td>Cost</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Durability</td>
<td>less</td>
<td>good</td>
<td>better</td>
</tr>
</tbody>
</table>

From the graph given below we can see that, the ceramic insulated band heaters and mica insulated band heaters gives maximum watt density up to 45 to 50 W/in², where as the mineral insulated band heaters has maximum watt density up to 100 W/in².

VIII. CONCLUSION

After studying in details about three types of band heaters it is seen that, band heaters without thermal insulation causes heat loss to the atmosphere through convection, which increases the cost of energy. Comparative results shows that the mineral insulated band heater gives better watt densities (up to 100 W/in²) and lesser heat loss. Thus mineral insulated band heaters are better band heaters.

IX. REFERENCES

[2] OMEGA HEATER CO. INC. 2059 Ninth Ave,Ronkonkoma, NY 11779-6254
[3] THERMAL CORPORATION 1264 Slaughter Road, Madison, Alabama, USA 35758
[4] PHP 11/12, Tankiwala Industrial Estate, Steel Made Compound, MarolMaroshi Road, Andheri(E), Mumbai 400 059, INDIA.
[5] IDEAL HEATERS, No. 694/A, GuruwarPeth, Opposite SBI TMPune - 411042, Maharashtra, India
[8] TEMPCO electric heater corporation