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[54] **TEMPERATURE MEASUREMENT AND CONTROL OF ROTATING SURFACES**

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[51] **Int. Cl.** **H05b 5/06;** H05b 3/02

[58] **Field of Search** 219/10.49, 10.61, 10.77, 219/469, 470, 471; 73/351; 338/28, 159

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[57] **ABSTRACT**

Means for transferring heat to a moving filament in a filament processing machine wherein a rotatable roller or endless belt contacting the filament is heated from a stationary heat source. For sensing the temperature of the contacting surface of the roller or belt a temperature sensor extends into a pocket formed in a side edge of the roller or belt, the pocket extending parallel with and adjacent to the contacting surface. The sensor is mounted on an intermediate support which in turn is mounted on the machine frame. There is a high thermal resistance between the intermediate support and the sensor and between the support and the frame. The support is in good thermal contact with the ambient.

7 Claims, 4 Drawing Figures

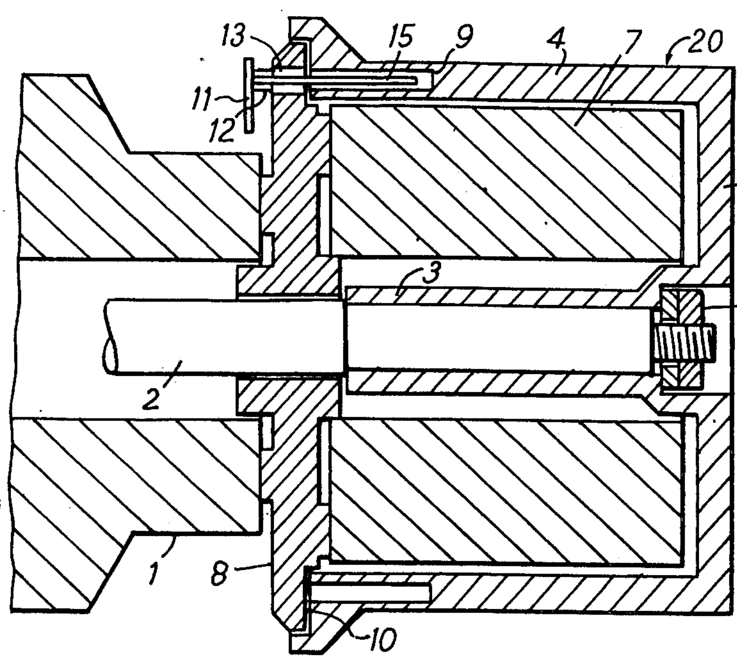


FIG. 1

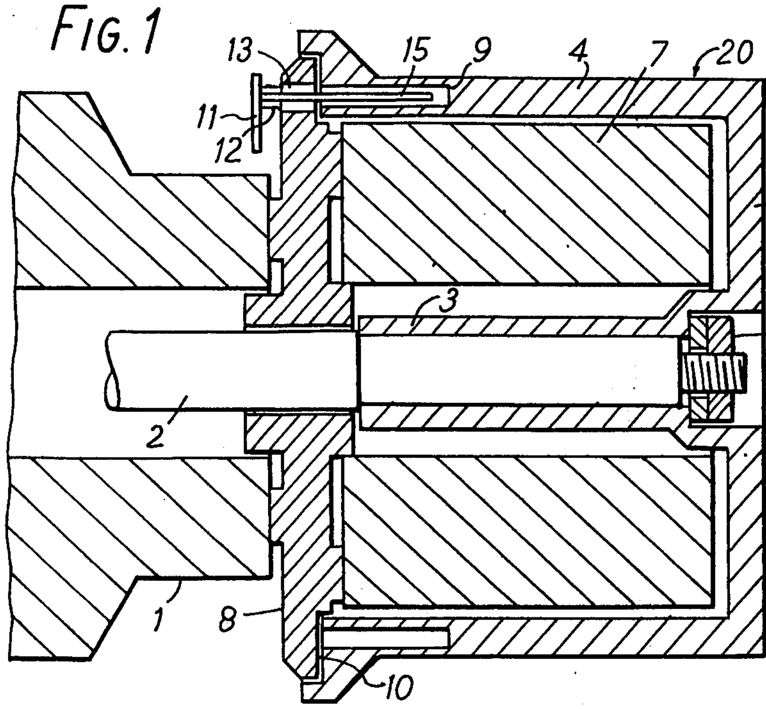


FIG. 2

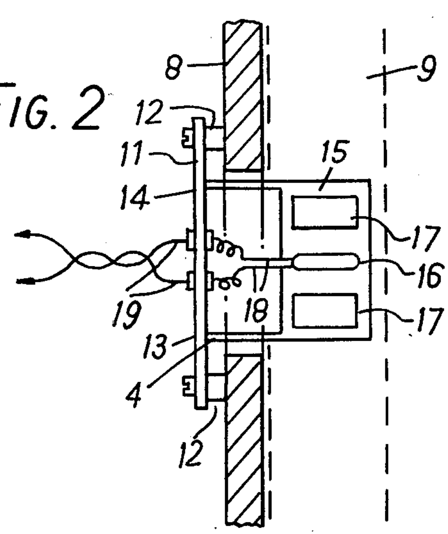
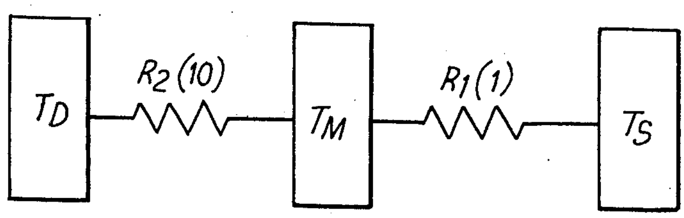


FIG. 3A



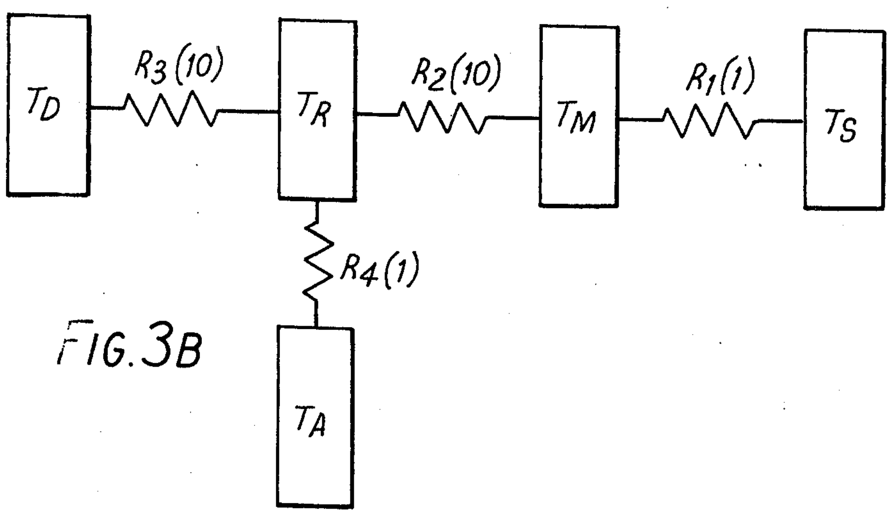


FIG. 3B

TEMPERATURE MEASUREMENT AND CONTROL OF ROTATING SURFACES

This invention relates to heat transferring means.

In many technological processes it is required to transfer heat to a rapidly moving filament and to be able to control the heat take-up of the filament to within narrow limits. Examples are the drawing and texturising of synthetic natural-fibre substitutes or alternatives. It is often convenient to transfer the heat at a rotating roller which also imparts the transport energy by having the filament wound round a cylindrical surface concentric with the axis of rotation. The critical processing parameter is the temperature of the filament, which due to its intimate contact with the rotating cylindrical surface is at a temperature substantially equal to the temperature of that surface.

Supplying heat energy to the rotating roller by means normally used for stationary members leads to considerable maintenance problems due to the sliding surfaces involved. Methods of overcoming this problem are known, one being to induce electrical currents into the roller, thereby transferring energy through the stationary medium through which the roller rotates without mechanical friction.

In order to be able to control the amount of heat supplied to give the correct processing temperature it is necessary to be able to measure the temperature of the moving filament or some other body whose temperature has an unvarying relationship with the filament temperature. Due to the last qualification the alternatives to the filament temperature will be bodies that are rotating in intimate contact with the filament while it is receiving heat from the rotating roller, and this implies that the heat controlling equipment must either rotate with the roller or that the temperature sensing signal must bridge the gap between the rotating roller and some non-rotating location.

Methods are known which use the radiant energy from either the filament surface or some alternative surface that is well coupled thermally to the filament surface. Radiation occurs across a non-mechanical medium so that there is again no friction and no maintenance to keep a constant mechanical condition is required. Equipment to measure the temperature of the source of these radiations based on optical methods of collection and focussing and spectral analysis are expensive and not appropriate for multiple industrial use. Methods which sum the radiant energy over a solid angle and convert it to another form of energy which is amenable to measurement are subject to loss errors which may be variable.

It is an object of this invention to reduce the variable heat equilibrium of a simple radiant heat collector that is adaptable for use with a rotating heated surface.

According to the present invention, there is provided means for transferring heat to a rapidly moving filament comprising a roller, endless belt or the like conveying element, means for mounting the conveying element on a frame of a filament processing machine, a heating source adapted for mounting on the machine frame for supplying heat to a surface of the conveying element which, in use, contacts the filament, a recess formed in a side edge of the conveying element which, in use, is adjacent to the frame, the recess extending adjacent to and parallel with the filament contacting sur-

face of the element, and a temperature sensor for extending into the recess without contacting the side walls thereof, wherein the temperature sensor is mounted in good thermal contact with a structure having a substantial area extending into radiation from the side walls of the recess, the structure is supported from an intermediate support which is in good thermal contact with the ambient atmosphere, there being a high thermal resistance between the intermediate support and the structure, and supports of high thermal resistance are provided for mounting the intermediate support on the frame of the machine.

The intermediate support may also carry electrically insulated connections for any electrical connections between the temperature sensor and frame related measuring and/or control equipment.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is an axial section of heat transferring means according to the invention;

FIG. 2 is a detail of the mounting of a temperature sensor in the heat transferring means of FIG. 1; and

FIGS. 3A and 3B show schematically temperature and thermal resistance parameters in a known heat transferring means and in the heat transferring means of FIGS. 1 and 2, respectively.

Referring now to FIG. 1 of the drawings, a roller **20** is supported from a main frame **1** of a filament processing machine by means of a rotatable shaft **2.** The roller **20** includes an inner hollow cylinder **3** and a coaxial outer cylinder **4** secured together by means of an annular outer face **5.** Inner cylinder **3** is securely and concentrically locked to the rotatable shaft **2** by a nut and washer **6.**

For supplying heat to the outer cylinder of the roller **20** a heat source **7** is supported on the main frame **1** by an intermediate stationary disc **8** and extends into the space between cylinders **3** and **4.** Heat source **7** may be an electrical induction winding or a radiant heater which, when energised by alternating current, induces electrical current in the equivalent of a short circuited single turn formed by the outer cylinder **4.**

At the end of the roller **20** which is adjacent to the frame **1** and disc **8,** an annular slot **9** is formed in the cylinder **4.** This slot extends axially along the outer cylinder **4** to a location in close proximity to a section of the outer surface of the cylinder whose temperature is typical of the heat transferring surface. A gap **10** which allows for rotation of cylinder **4** relative to disc **8** is made as small as possible so as to minimise the amount of air change in slot **9.** This allows the surface of the slot **9** to reach the same or nearly the same temperature as the outer surface of cylinder **4.**

Projecting into the slot **9** without contacting the cylinder **4** is a temperature sensor **16** which is supported in the manner shown in more detail in FIG. **2** of the drawings. Referring to FIG. **2,** a platform **11** which serves as an intermediate support for sensor **16** has a good temperature radiating surface so that it remains at substantially ambient temperature. To further assist in achieving this object the platform **11** is supported on the disc **8** by pillars **12** of high thermal resistance. Between the pillars **12** a slot **13** is cut in the disc **8** and from the platform **11** two supports **14** extend via the slot **13** to a radiant energy pick-up surface **15** which is located within the annular slot **9.**

Mounted on the pick-up surface **15** is the temperature sensor **16.** The surface **15** is modified by slots **17** to give optimum selection between minimum radiation resistance between the surfaces of annular slot **9** and the pick-up surface **15** and maximum conduction resistance to supports **14.** Electrical connection between the sensor **16** and insulated connectors **19** on the platform **11** is via electrical connectors **18,** which are kept small in diameter and spiralled to increase their length, thereby reducing thermal shunting.

In the above embodiment the ratio between the temperature drop from the inner surface of slot **9** to temperature sensor **16** and the temperature drop from the sensor **16** to the platform **11,** which serves as a heat sink, is minimised. Further, the mounting of platform **11** is such that it remains near to ambient temperature notwithstanding that the machine frame **1** on which it is mounted may rise tens of degrees Celcius from start up to sustained running.

The effect of including platform **11** in the heat transferring means of FIGS. **1** and **2** is now described with reference to FIGS. **3A** and **3B** of the drawings. FIG. **3B** shows schematically the temperatures and thermal resistances at various locations in the heat transferring means of FIGS. **1** and **2,** whilst FIG. **3A** shows these two parameters at locations in a heat transferring means corresponding to that in FIGS. **1** and **2** except that there is no platform **11,** the temperature sensor **16** being supported directly on the machine frame **1.**

Referring first to FIG. **3A**, T_S represents the temperature of the inner surface of slot **9,** which is substantially equal to the temperature of the outer surface of cylinder **4,** and hence the surface temperature of a filament as it leaves the roller **20.** T_M is the temperature of the sensor **16,** T_D is the temperature of the machine frame **1,** R_1 is the thermal resistance between the inner surface of slot **9** and the sensor **16** and R_2 is the thermal resistance between sensor **16** and the frame **1.**

The relationship between the three temperatures is then given by:

$$T_S - T_M/R_1 = T_M - T_D/R_2 \qquad 1.$$

$$T_M = \theta\, T_S + (1 - \theta)\, T_D \qquad 2$$

where

$$\theta = R_2/R_1 + R_2$$

In practice, it is difficult to make R_2 much greater than **10** × R_1, this relationship being indicated in FIG. 3A. Substituting $R_2 = \mathbf{10} \times R_1$ in equation (2) gives,

$$T_M = (\mathbf{10/11} \times T_S) + (\mathbf{1/11} \times T_D) = \mathbf{0.090}\ T_S + \mathbf{0.0909}\ T_D \qquad 3$$

The constant factor **10/11** × T_S can be allowed for in calibrating the device but there remain errors in the reading of T_M due to the term **1/11** × T_D. In a case where the mahine warms up through 30°C. there is an error in the reading of T_M of 1/11 × 30°C = 2.73°C.

Referring now to FIG. 3B, T_R represents the temperature of the platform **11,** which is interposed between the sensor **6** and the machine frame **1,** and T_A is the ambient temperature. R_3 is the thermal resistance between the platform **11** and the frame **1** and R_4 is the thermal resistance between the platform and the surrounding air due to radiation and contact. Since the heat supplied to the heat sink, platform **11,** from the inner surface of slot **9** and from the machine frame **1** equals the heat lost from the platform to the ambient air,

$$T_S - T_R/R_1 + R_2 + T_D - T_R/R_3 = T_R - T_A/R_4$$

$$T_R = T_S R_3 R_4 + T_D(R_1R_4 + R_2R_4) + T_A(R_1R_3 + R_2R_3/R_3R_4 + R_1R_4 + R_2R_4 + R_1R_3 + R_2R_3 \qquad 4.$$

Also,

$$T_M = R_2/R_1 + R_2\ T_S + R_1/R_1 + R_2\ T_R \qquad 5.$$

(as in equation (2), above)

Substituting the values for R_1, R_2, R_3 and R_4 given in FIG. 3B gives

$$T_M = \mathbf{0.914}\ T_S + \mathbf{0.00764}\ T_D + \mathbf{0.0764}\ T_A \qquad 6$$

With the known transferring means of FIG. 3A it is clear from equation (**3**) that under conditions where the controlled temperature T_S is 200°C, the ambient temperature starts at 20°C. and rises to 25°C and the temperature of the machine frame **1** rises by 30°C, the temperature of the sensor T_M starts at 183.6°C, rises to 186.3°C. on warm up of the machine, and further increases to 186.80° C with the 5°C rise in ambient temperature.

For the heat transferring means of FIG. **3B**, equation (6) shows that the corresponding temperatures recorded by the sensor **16** are 184.5°, 184.7°and 185.1°C.

In practice, a calibration is effected to remove errors under normal conditions, say at T_A = 25°C and a rise in T_D of 30°C to 55°C. In the case of the known device of FIG. **3A** this gives rise to a total error of 3.2°C when the machine is started up at an ambient temperature of 20°C. The error reduces to 2.7°C when ambient temperature of 25°C is reached. In the device of FIG. **3B** the total error is 0.6°C at start up, reducing to only 0.2°C at an ambient temperature of 25°C.

In the heat transferring means of FIGS. **1** and **2** the platform **11** and pick-up surface **15** are made of a high conductivity metal, blackened to enhance its heat radiation properties. The supports **14** are made of metal with a low cross-sectional area, to increase their thermal resistance, or of ceramic material. The pillars **12** are made of ceramic material and are hollow to allow for fixing by screws to the disc **8.**

It will be appreciated that heat transferring means according to the invention may have an endless band or belt in place of the roller **20** of FIGS. **1** and **2.** In this case a slot corresponding to slot **9** may be formed along one lateral edge of the belt to receive a temperature sensor. Preferably, the sensor extends into the slot at a location where the belt contacts a driving roller therefor.

For supplying heat to the roller surface or endless band or belt a source of heat radiation may replace the winding **7.** Alternatively, slip rings may be employed to supply heating current to the roller, band or belt.

I claim:

1. An apparatus for transferring heat to a rapidly moving filament comprising:
   a conveying element having an endless conveying surface;
   means for mounting said element on a frame of a filament processing machine;
   a heating source mounted on said frame for supplying heat to a surface of said conveying element which, while in use, contacts said filament;
   a recess formed in a side edge of said conveying element, adjacent to said frame, said recess extending adjacent and parallel to the surface of said conveying element;
   a radiant energy pick-up surface disposed within said recess, said surface having substantial area and being exposed to radiation from the side walls of said recess;
   a temperature sensor mounted in good thermal contact with said pick-up surface and extending into said recess without contacting the sidewalls thereof;
   intermediate support in good thermal contact with the ambient atmosphere for support of said pick-up surface, said support having a high thermal conductivity and there being a high thermal resistance between said intermediate support and said pick-up surface; and
   support means of high resistance for mounting said intermediate support on the frame of the machine.

2. Heat transferring means as claimed in claim 1, wherein the conveying element is a hollow, rotatable roller, and the recess is an annular cylindrical recess formed in a cylindrical side wall of the roller.

3. Heat transferring means as claimed in claim 2, wherein the heating source extends into the interior of the hollow roller.

4. Heat transferring means as claimed in claim 2, wherein the intermediate support is a platform, the high thermal resistance supports are pillars, and the thermal resistance between the intermediate support and the structure is increased by slots formed in the structure.

5. Heat transferring means as claimed in claim 1, wherein the intermediate support is a platform, the high thermal resistance supports are pillars, and the thermal resistance between the intermediate support and the said pick-up surface is increased by slots formed in the said pick-up surfaces.

6. Heat transferring means as claimed in claim 1, wherein the heating source comprises an electrical winding for inducing heating currents in the conveying element.

7. Heat transferring means as claimed in claim 1, wherein the heating source comprises a heating element for supplying radiant heat to the conveying element.

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