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TENSION CONTROL OF RUNNING THERMOPLASTIC FILAMENTS

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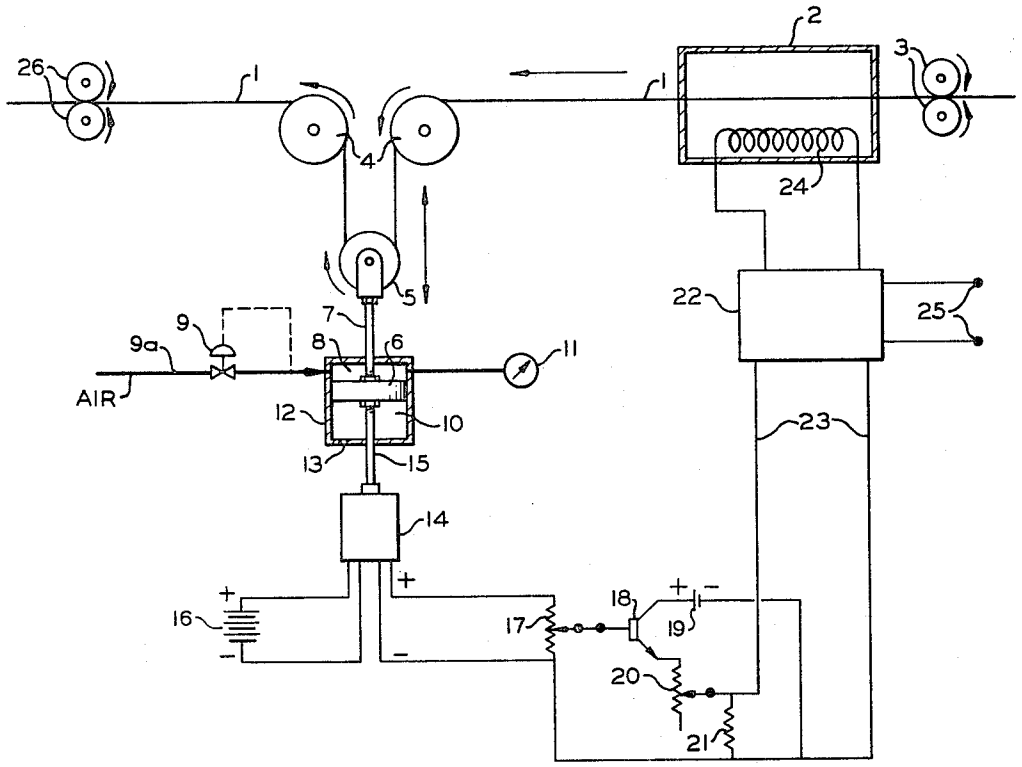


FIG. 1

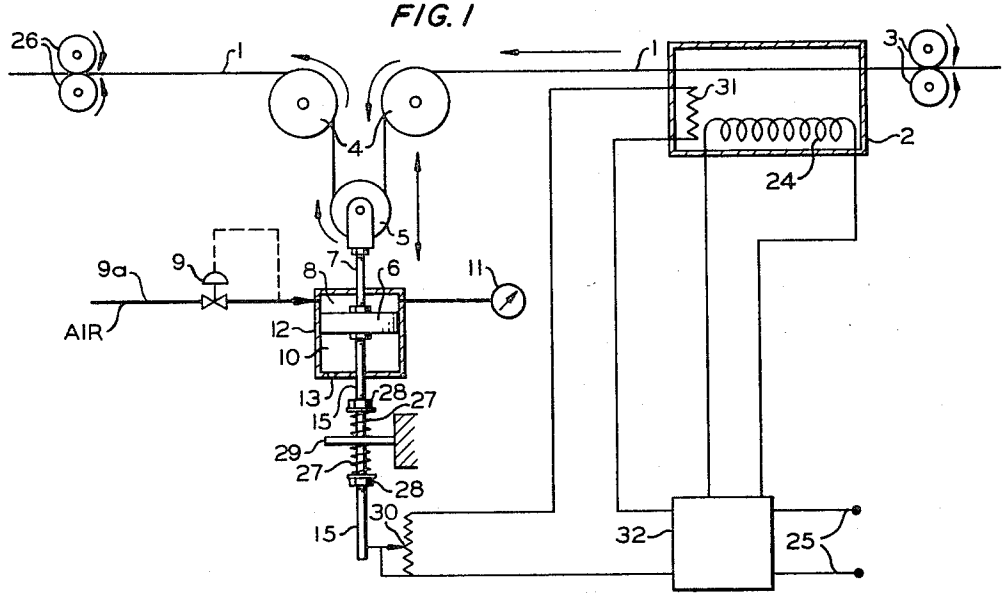


FIG. 2

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TENSION CONTROL OF RUNNING THERMOPLASTIC FILAMENTS

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ABSTRACT OF THE DISCLOSURE

The tension in a running filament is controlled by passing said filament over a movable member, sensing any movement in said member, and passing a signal proportional to said sensed movement to control apparatus that controls the conditions effecting the tension in said running filament.

This invention relates to the control of tension in running filaments. In one of its aspects this invention relates to the control of the temperature for heating and drawing thermoplastic filaments.

In the manufacture of thermoplastic filaments and artificial threads it is sometimes desired to subject a traveling filament to a treatment involving heating the filament under tension. Examples of such treatment are drying processes and the stretching and shrinking of thermoplastic filaments. When carrying out such treatments, the tension of the heated filament is dependent to a very large extent on its temperature and slight variations in temperature usually cause marked variations in tension. In stretching thermoplastic filaments, the tension at which they are stretched determines the physical properties of the stretched filament. The tensile strength, the smoothness, and the elasticity of the stretched filament are very closely related to the tension at which it is stretched. Since increase in tension is a result of low temperature of the filament and a decrease in tension is a result of high temperature of the filament it is highly desirable to maintain a substantially uniform temperature of the filament during the heating and stretching operations. Conventional control methods do not allow uniform control of tension in running filaments. Control systems now in use for tension control do not offer a critical control of tension that is necessary for obtaining the uniformity in the output product.

It is an object of this invention to provide an improved apparatus for the control of conditions that affect the tension of a running filament. Another object of this invention is to provide an improved method for the control of conditions that affect the tension of a running filament. Still another object of this invention is to provide an improved apparatus for controlling the draw temperature of a running thermoplastic filament. Still another object is to provide an improved method for the control of the draw temperature of a thermoplastic filament.

Other aspects, objects and advantages of this invention will be apparent to those skilled in the art upon examination of the specification, drawing and claims.

We have invented an apparatus and method for controlling the conditions that affect the tension of a running filament. According to the present invention, a running filament under tension is passed over a movable element that is connected to a piston mechanism. The tension of the running filament exerts a force on the movable piston. A second force is applied to the piston to oppose the force exerted by the tension in the filament. The second force is constant and is proportional to the desired tension of the filament. Thus any difference between the actual tension and the desired tension will cause the piston to move.

By sensing the movement of the piston and generating a signal that is proportional to the movement, and passing this signal to a control mechanism, it is possible to very closely control the conditions that affect the tension of the running filament.

Examples of apparatus constructed in accordance with the present invention are illustrated in the accompanying drawings. FIGURE 1 is a side view of an apparatus for heating and stretching a monofilament showing the control mechanism for regulating the heat supplied to the heating zone. FIGURE 2 is also a side view of an apparatus for heating and stretching a monofilament showing another preferred control mechanism for regulating the heat supplied to the heating zone. In FIGURE 1, thermoplastic filament **1** is passed through heating chamber **2**. Filament **1** is supplied by a pair of feed rollers **3** and passes through heating chamber **2**, over fixed rollers **4** and over movable roller **5**. Filament **1** is then passed over stretching rollers **26** which are driven with a peripheral speed greater than that of the feed rollers **3** so as to effect the stretching of filament **1** in heating chamber **2**. As filament **1** passes over roller **5** an upward force is exerted on roller **5** that is proportional to the actual tension in filament **1**. Movable roller **5** is connected to piston **6** by means of connecting arm **7**. The upward force exerted on roller **5** is thus exerted on piston **6**. A downward force on piston **6**, proportional to the desired tension in filament **1**, is exerted by air pressure in space **8** above piston **6**. The air pressure in space **8** is maintained at a constant level by means of pressure regulator **9** that regulates air pressure from air supply conduit **9A**. Gauge **11** indicates the pressure in space **8** above piston **6**. Gauge **11** can be calibrated to show the filament tension directly. Piston **6** is disposed in cylinder **12** in such a way that air from space **8** seeps past the walls of piston **6** and into the lower space **10**. By using this "floating piston" arrangement practically all friction is eliminated from the system and no piston rings or seals are required. Air bleed hole **13** is located in the base of cylinder **12** to prevent a pressure buildup on the underside of piston **6**. As filament **1** is pulled over movable wheel **5**, a force is exerted upward on piston **6** that is proportional to the tension of filament **1**. The force exerted upward on wheel **5** in the drawing will be twice the actual tension of filament **1**. The opposing downward force on piston **6** is proportional to the desired tension in filament **1** as regulated by air pressure regulator **9**. The opposing force for an apparatus shown in the drawing will be twice the desired tension of filament **1**. If the actual tension in filament **1** is equal to the desired tension, piston **6** will be stationary. If the filament coming through the heating chamber **2** is not hot enough for the existing drawn-down ratio (a constant in any given case) the tension would tend to increase, causing piston **6** to move upward against the constant pressure maintained above it by air in space **8**. Conversely, if the filament **1** coming through heating chamber **2** is too hot the tension will tend to decrease, causing piston **6** to move downward. Any movement by piston **6** is immediately detected in sensing mechanism **14** which is connected to piston **6** by means of connecting rod **15**. Sensing mechanism **14** can be any suitable mechanism known in the art that will sense a displacement and generate a signal proportional to such displacement. An example of such a mechanism that is commercially available is the Sanborn linear differential transducer No. 7DCDT–100. Such a transducer will sense a physical displacement of its movable core and produce an output signal that is proportional to such displacement. As shown in the drawing, sensing mechanism **14** has an external power source **16**. The output signal from sensing mechanism **14** is passed to a simple electrical circuit wherein it is amplified. An example of such a circuit is shown in the drawing wherein

the output signal of sensing mechanism **14** is passed to a span adjust resistor **17** which allows the circuit to be adjusted for the particular signal strength from sensing mechanism **14**. The base of a NPN transistor **18** is connected to span adjust resistor **17**. Transistor **18** can be any suitable transistor such as transistor No. TI–495 manufactured by the Texas Instrument Company. A small power source **19** furnishes the necessary electrical power for the electrical circuit. The emitter of transistor **18** is attached to current adjust resistor **20** that is means for adjusting the output signal of the electrical circuit. Resistor **21** serves as a damping resistor for the electrical circuit. The output signal from the circuit is then passed to temperature controller **22** by means of electrical leads **23**. The output signal is a linear function of the movement of piston **6**. Temperature controller **22** can be any suitable temperature controller that will regulate the flow of the current through heating coil **24** inside heating chamber **2**. Preferably the heating coil **24** operates on an alternating current that is supplied by a main supply **25** through temperature controller **22**. An example of a suitable temperature controller **22** is the Capacitol temperature controller manufactured by the Wheelco Instrument Division of Barber-Colman Company, Rockford, Ill. As the filament moves over movable wheel **5** any difference in the actual tension in filament **1** and the desired tension as regulated by the air pressure above piston **6** causes piston **6** to move either up or down. This movement causes a similar movement by the movable core of transducer core **14** changing the transducer output. This output is passed to the electrical circuit wherein it is amplified and then passed to the temperature controller **22**. If the tension in filament **1** decreases below the desired level, piston **6** moves downward causing transducer **14** to produce a signal that is passed through the amplifier system to temperature controller **22** that calls for less heat to be applied to heating chamber **2**. Thus temperature controller **22** decreases the amount of electrical current passing through heating coils **24**. If the tension in filament **1** increases above the desired level, movable wheel **5** moves upward and piston **6** moves upward causing the movable core in transducer **14** to move upward. An output signal from transducer **14** is then passed through the amplifying system and then to temperature controller **22** that calls for more heat to be applied to heating zone **2**. Thus temperature controller **22** causes more electrical current to flow through heating coil **24** in heating chamber **2**. It is obvious to those skilled in the art that this type of control system allows a smooth and uniform method of controlling the temperature in heating zone **2**. By using this type of control system, very critical limits can be maintained in the system.

In FIGURE 2, components **1** through **13**, **15**, and **24** through **26** are identical to and function the same as described above in FIGURE 1. Connecting rod **15** is equipped with coil springs **27** and adjusting nuts **28**. Stationary plate **29** has a hole oriented in such a manner as to allow connecting rod **15** to pass through it. One end of each of the springs contacts plate **29** in a manner to exert opposing forces on connecting rod **15**. Coil springs **27** are adjusted by use of adjusting nuts **28**, to a point where the compression force of each is equal at the set point of piston **6** and movable wheel **5**. When the tension of flament **1** changes causing the position of connecting rod **15** to change, springs **27** provide additional driving force toward the set point or null point. This feature gives a more smooth and uniform method of controlling the system. Connecting rod **15** is coupled with sensing mechanism **30** that detects any change of position of piston **6** and movable wheel **5**. It has been discovered that a variable resistor, wherein resistance is varied by movement of connecting rod **15**, gives an accurate indication of movement of the connecting rod. In some cases, a variable resistor will be preferred over other sensing mechanisms because of its sensitivity and reliability. An example of such a variable resistor is the model TP R.2KL.5 Helipot potentiometer, manufactured by the Helipot Corporation of South Pasadena, Calif. Sensing mechanism **30** is connected in series with thermistor sensor **31** which is disposed inside heating chamber **2**. Any change of temperature inside heating chamber **2** will cause the electrical resistance of thermistor sensor **31** to change. The electrical circuit containing sensing mechanism **30** and thermistor sensor **31** is coupled with a suitable temperature controller **32** such as the Model 301 Aeromag controller manufactured by the Aeromag Corporation of Southfield, Mich. As described in FIGURE 1, any change in tension of filament **1** causes a movement of piston **6** and connecting rod **15** that is sensed by sensing mechanism **30**. An electrical signal proportional to the movement of connecting rod **15** and temperature inside heating chamber **2** is sent to a suitable temperature controller that regulates the electrical current flow to heating element **24** inside heating chamber **2**.

It will be obvious to those skilled in the art that the electrical circuits shown in FIGURES 1 and 2 can be modified easily. For example, the electrical circuit can be a conventional Wheatstone type bridge circuit where the temperature sensing element and variable resistor are located in the proper legs of the circuit. When the bridge is unbalanced by a change of tension in the monofilament, the temperature in the heating zone is raised or lowered until the thermistor resistance rebalances the bridge.

Examples of some of the thermoplastic filaments that could be stretched using a device such as this include polyethylene with a draw temperature of about 208° F. and polypropylene with a draw temperature of about 300° F. When a polypropylene filament is drawn, the heating chamber will be heated within a range of from about 500° to 900° F. and the tension applied to the filament will be about 1 gram per denier of the drawn filament.

Various modifications and changes in the above described apparatus may be made by those skilled in the art. For example, the heating zone may be any type heating zone known in the art such as a steam chest or a gas-fired heating zone. Various modifications may be made in the electrical amplifying system and in the sensing mechanism to detect movement in the piston mechanism. This invention can be used for controlling various conditions which affect the tension in a running filament. It can be used in drying processes, in stretching processes and in shrinking processes.

The method of operation in the following example illustrates one preferred embodiment of our invention. The operating conditions of the example should not be interpreted as limiting the scope of the invention.

EXAMPLE

Polypropylene having a density of 0.91 gram/cc. and a melt flow of approximately 3 (as determined by ASTM D1238–57T) was extruded by a Hartig screw extruder having a 1¼ inch diameter barrel and a length/diameter ratio of 20/1. The polypropylene was extruded through a filament die having 10 holes, each 42 mils in diameter, into a water bath. From the water bath the filaments were run around a standard set of godet rolls and then through a 9 foot long radiant heating oven having electrical heating elements disposed therein. One of the monofilaments was then passed through the tension control device illustrated and described above as FIGURE 2. All 10 of the filaments were then run around a second set of godet rolls and then to wind-up spools. The two sets of godet rolls were set for a draw ratio of 10:1. The tension controller was set to maintain a tension of 400 grams on the filament. The extrusion rate and the surface speed of the godet rolls were set so as to produce 400 denier filaments at the rate of 300 feet per minute. The tension controller was connected to the radiant heating oven, as illustrated in FIGURE 2, so as

to control the temperature of the filament in the heated draw zone to maintain the preset drawing tension. The draw operation proceeded smoothly with excellent control of tension in all 10 filaments. The draw ratio between the first and second set of godet rolls was then changed from 10:1 to 10.5:1. The tension increased rapidly causing the tension controller to increase the temperature of the filaments in the heated draw zone. As the temperature in the heated draw zone increased, the filament tension decreased until it again reached the original set point value of 400 grams. The readjustment of tension took about one minute. The draw operation then proceeded smoothly with excellent tension control of the 10 filaments.

Since many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is understood that it is not to be unduly limited by the foregoing specific embodiment.

We claim:

1. A method for controlling the tension in a running filament comprising passing said filament over a movable member, said movable member being connected to a movable piston mechanism such that the actual tension exerts a force on said movable piston mechanism, maintaining an opposing force on said piston mechanism proportional to the desired tension of said filament, sensing any movement of said movable piston mechanism, passing a signal proportional to any sensed movement of said movable piston mechanism to a control mechanism and controlling the conditions affecting said tension in said running filament in response to said signal.

2. A method for the control of tension in a running filament while said filament is subjected to conditions which affect the tension in said filament which comprises passing a drawn filament over a series of three wheels arranged in a triangular relationship, one of said wheels being movable and attached to a movable piston mechanism by means of a connecting rod, said connecting rod exerting a force on said piston proportional to the actual tension in said drawn filament, maintaining a constant force on said piston which is proportional to the desired filament tension and which opposes the force exerted by said actual tension, detecting any movement in said piston, generating a signal proportional to said movement, passing said signal to a control mechanism and controlling the conditions which affect the tension in said filament in response to said signal.

3. A method for controlling the draw temperature of a running thermoplastic filament inside a heating zone which comprises passing a drawn filament over a series of three wheels arranged in a triangular relationship, one of said wheels being movable and attached to a movable piston mechanism by means of a first connecting rod such that a force proportional to the actual tension of said filament is exerted on said piston, maintaining a constant opposing force on said piston with air, said opposing force being proportional to the desired tension of said filament, detecting any movement of said piston by means of a linear transducer which is attached to said piston by means of a second connecting rod, generating a signal that is proportional to said movement of said piston, passing said signal to a signal amplifier, and passing the amplified signal to a temperature controller and controlling the temperature inside said heating zone in response to said signal.

4. A method for controlling the draw temperature of a running thermoplastic filament inside a heating zone which comprises passing a drawn filament over a series of three wheels arranged in a triangular relationship, one of said wheels being movable and attached to a movable piston mechanism by means of a first connecting rod such that a force proportional to the actual tension of said filament is exerted on said piston, maintaining a constant opposing force on said piston with air, said opposing force being proportional to the desired tension of said filament, detecting any movement of said piston by means of a change in electrical resistance in a variable electrical resistor which is attached to said piston by means of a second connecting rod, said change in electrical resistance being proportional to said movement of said piston, changing the electrical resistance of a circuit connected in series with said resistor proportional to the temperature inside said heating zone, passing a signal proportional to the total change in resistance in said circuit to a temperature controller and controlling the temperature inside said heating zone in response to said signal.

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