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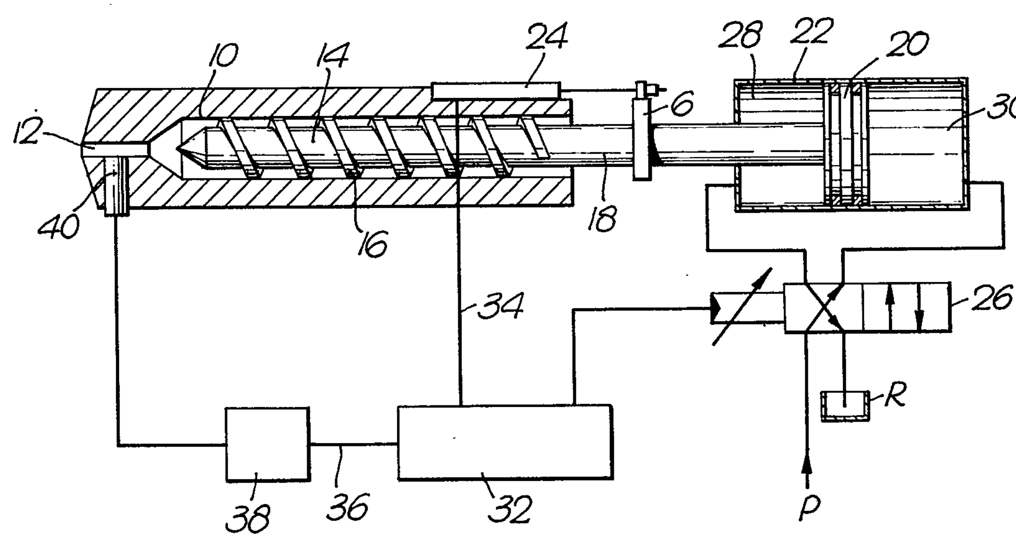
(54) **Moulding or extrusion of synthetic plastics products**

(57) Apparatus is disclosed for use in the moulding or extrusion of synthetic plastics products in which the axial position of a rotatable plasticising screw 14 in a cylinder 10 is controlled, via a hydraulic piston (20) and cylinder (30), through a hydraulic servo-valve 26, by means of a position programmer 32, in accordance with signals received by the position programmer from a displacement transducer 24 and one or more sensors, for example a temperature sensor 40 which, in accordance with a control algorithm (38) determines or jointly determine a set value to be matched, by operation of the servo-system, with the sensed value of the screw displacement, as sensed by transducer 24. It is thus possible to maintain closer control over the plasticising conditions than has previously been possible.



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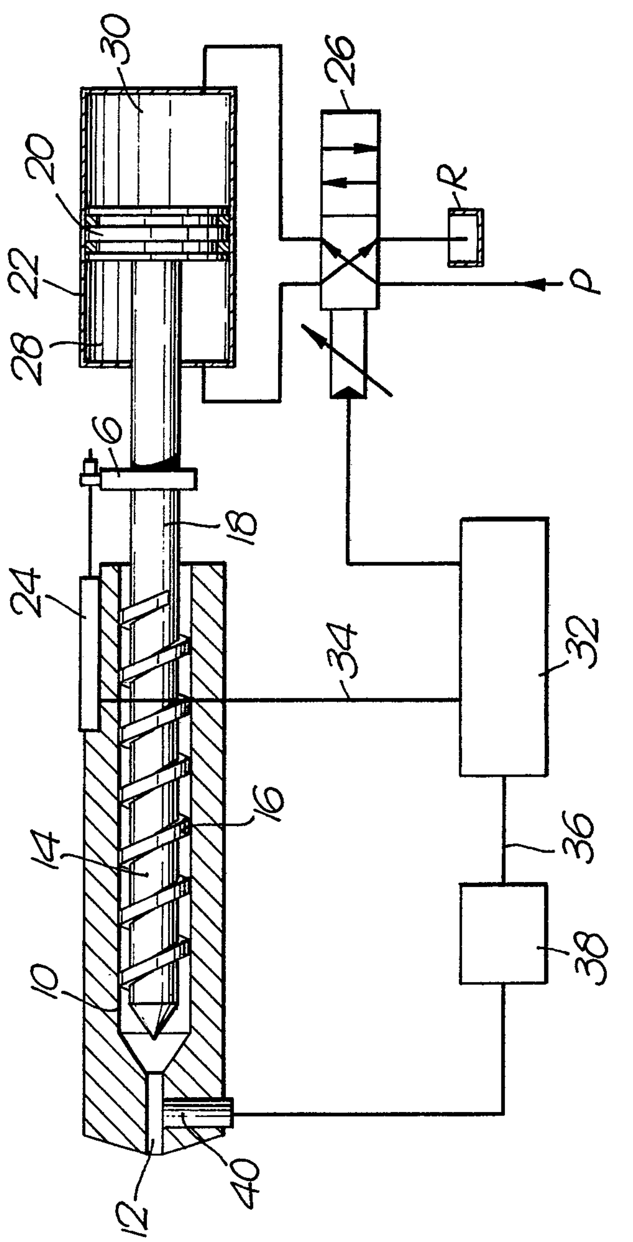

SPECIFICATION

Moulding or extrusion of synthetic plastics products

This invention relates to the moulding or extrusion of synthetic plastics products.

Apparatus is known for use in the moulding of synthetic plastics products, comprising a cylinder fitted at one end with a nozzle, a screw disposed axially within the cylinder and having its screws crests cooperating closely with the bore of the cylinder and the screw being connected at its end remote from the nozzle with a part coaxial with the screw and extending sealingly through an axial passage at the end of the cylinder remote from the nozzle, to driving means for rotating the screw, the screw being mounted for rotation and axial movement within the cylinder, the apparatus including an inlet passage, for the supply of plastics material to the cylinder, which passage enters the cylinder adjacent the rear end of the screw, the apparatus including means operable to ensure that plastics material can be delivered through the cylinder out of said nozzle at least principally by rotation of the screw, the apparatus including control means for controlling the axial position of the screw in the cylinder during rotation thereof, the nozzle having an internal passage which tapers towards the tip of the nozzle and wherein the screw, at its end nearer the nozzle, is provided with a tapering tip shaped to conform closely with the internal passage through the nozzle, control means being provided for controlling the axial position of the screw, said control means further including sensing means for sensing the axial position of said screw in said cylinder, the control means being arranged to move the screw axially in accordance with a sensed deviation of the actual position of the screw from its desired position in such a way as to tend to maintain correspondence between the actual position of the screw and its desired position.

Apparatus of a kind set forth in the preceding paragraph is herein referred to as being of "the kind specified". In apparatus of the kind specified at least a substantial amount of the heating of the plastics material required to bring it into the plasticized and flowable condition necessary for injection moulding or extrusion is provided by the mechanical work done on the material by the screw during rotation of the screw, before the plasticised plastics material passes from the cylinder. In such apparatus, the screw is normally position only slightly rearwardly of its forwardmost position, so that a significant amount of the heat added to the plastics material by work done by rotation of the screw is added during passage of the plastics material through the narrow annular passage defined between the tip of the screw and the opposing internal surface of the nozzle. As the cross section of this passage is variable with the axial position of the screw, so also is the heating of the plastics material during passage through this passage, and therefore the final temperature of the plastics material, and therefore the viscosity of the material, being temperature dependent, is also variable with the axial position of the screw. Other factors, such as the pressure of the plastics material at a particular point in the apparatus, (dependent for example on the viscosity), are also dependent directly or indirectly on the screw position.

Appropriate control of the axial position of the screw to within fine limits is therefore highly desirable.

Our British Patent Specification No. 1,572,514 discloses apparatus of the kind specified in which the axial position of the screw is sensed by sensing means in the form of switches controlling the application of a forward biasing force to the screw, the switches being associated with timing means in such a way that each said switch is effective to control the position of the screw during a respective part of the operating or mould filling cycle of the machine, the arrangement being such that, in operation, the screw oscillates or "hunts" slightly about a mean position determined by the switch for the time being rendered effective by the timing means, so that the axial position of the screw varies in a desired manner during the machine operating cycle. A need exists, however, for an apparatus which is more versatile and adaptable than that disclosed in our Patent Specification No. 1,572,514.

Accordingly, it is one object of the present invention to provide an improved machine of the kind specified.

According to the invention there is provided apparatus of the kind specified wherein said control means includes first means for controlling the axial position of the screw in accordance with a deviation of the position of the screw, sensed by said sensing means, from a desired position represented by a signal applied to an input of said first means so as to tend to maintain correspondence between said sensed and desired positions, and means for supplying such a signal to said input of said first means.

An embodiment of the invention is described below by way of example with reference to the accompanying schematic drawing.

The apparatus, in this embodiment of the invention, comprises a cylinder 10 fitted at one end with a nozzle 12, a screw 14 being disposed axially within the cylinder 10 and having its screw crests 16 cooperating closely with the bore of the cylinder. The screw 14 is connected at its end remote from the nozzle 12 with a part, indicated schematically at 18, coaxial with the screw and extending sealingly through an axial passage (not shown) at the end of the cylinder remote from the nozzle 12, to driving means (not shown) for rotating the screw. The screw 14 is mounted for rotation and axial movement within the cylinder, the axial position of the screw in the cylinder being controlled by means of a double acting hydraulic piston 20 disposed in a hydraulic cylinder 22. The piston 20 divides the cylinder 22 into two chambers, 28 and 30 respectively. The screw 14 is coupled directly or indirectly to piston 20 via part

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

18. The apparatus includes a linear displacement transducer 24 which cooperates with an element 6 fixed with respect to the screw 14, preferably fixed to the portion of the part 18 which is outside the cylinder 10, the displacement transducer 24 providing an electrical output signal indicative of the axial position of the screw.

The apparatus also includes an inlet passage (not shown) for the supply of plastics material to the cylinder, which passage enters the cylinder adjacent the rear end of the screw 14. In mechanical and structural respects, the apparatus is very similar to that disclosed in our Patent Specification No. 1,572,514, to which reference may be had.

It will be appreciated that whilst the tip of the screw 14 is shown in the drawing as being withdrawn substantially from the nozzle end of the cylinder 10, during the intrusion phase, e.g. during a mould filling operation, the screw tip is spaced from the nozzle end of the cylinder 10 to an extent which is small in relation to the distance from said nozzle end to the inlet passage through which plastics material is introduced into the cylinder 3. Thus, during the intrusion phase only a narrow annular passage is defined between the tapering tip of the screw and the opposing internal surface of the nozzle, and plastics material is delivered through the cylinder out of the nozzle 12 principally by rotation of the screw, a substantial portion of the heat supplied to the plastics material to render it flowable being provided by the mechanical work done, in rotation of the screw 14, by the means (not shown) provided for rotating the screw about its axis.

The apparatus includes a source P of hydraulic fluid under pressure and a fluid reservoir R at low pressure. A four-way hydraulic servo valve 26, in one position thereof, connects the chamber 28 on one side of the piston 20 with the fluid pressure source P and connects the other chamber 30 with the reservoir R, while in its other position, the valve 26 connects the chamber 30 with the fluid pressure source P and the chamber 28 with the reservoir R. The valve 26 may have an intermediate position in which both chambers 28 and 30 are isolated from the source P and the reservoir R. The position of the servo valve 26 is controlled by electro-mechanical means, not shown, which in turn is controlled by a position programmer 32, so that by appropriate operation of the position programmer 32, and consequently of the servo-valve 26, the piston 20, and thus the screw 14, can be advanced or retracted at will.

The position programmer 32 receives, on an input 34 thereof, the position signal from the displacement transducer 24, indicative of the actual position of the screw, and receives, on an input 36 thereof, a set position signal, indicative of the desired position, provided by a computer 38. The position programmer 32 controls the position of the servo valve 26 continuously in such a way as to tend to position the screw 14 in such a way as to make the actual position of the screw, as sensed by the displacement transducer 24 correspond with the desired or set value of the screw position as determined by the computer 38. Thus the position programmer 32, servo valve 26, piston 20 and displacement transducer 24 together constitute a closed control loop.

The closed loop hydraulic servo system adopted ensures more precise axial positioning of the plasticizing screw in the cylinder 10. By arranging the elements as shown in the figure, or as described in respect of the variants mentioned below, the axial position of the plasticising screw can be continuously and precisely controlled throughout the intrusion phase of a moulding process.

In the arrangement illustrated, the computer 38 receives an input signal from a transducer 40, (which may be a temperature transducer disposed at the outlet of the cylinder 10), and sets the desired position of the screw, in terms of the signal applied to the input 36, in accordance with the signal received from the transducer 40. The transducer 40 may be a temperature transducer preferably inserted into the plastics flow channel at the outlet of the cylinder 10, or elsewhere in the plastics flow path to the mould. Because there exists a certain relationship between the axial position of the screw and the melt temperature sensed by the transducer 40, a control algorithm may be applied to the temperature signal provided by the transducer 40 to derive a suitable set position signal to be applied to the input 36. By this means, closed loop melt intrusion temperatue control is effected.

This arrangement might be utilised in moulding articles in PVC. In such an application, the melt intrusion temperature could be programmed to give a good degree of control of the extent of gellation in the plastisized polymer.

In a variant, the transducer 40 may be a pressure transducer supplying to the computer 38 a signal corresponding to the polymer melt pressure at the mould entry. The computer 38 may then be arranged to provide, at the input 36, a varying set-position signal which is determined not only by the pressure sensed by transducer 40, but also by the time elapsed since a mould filling operation commenced, the control algorithm of computer 38 being in this case devised to provide a desired pressure profile, (i.e. pressure versus time relationship), arrived at previously, in order to secure optimum properties in the finished moulded article. The pressure profile referred to may be derived by measuring the degree of gellation, and/or degradation and/or some other material parameter in different parts of the moulding under various control conditions, as will be apparent to those skilled in the art. In this way closed loop melt intrusion pressure control is effected.

In a further, somewhat more sophisticated embodiment, a combination of the two previously mentioned variants may effectively be obtained by adaptive updating of the optimum temperature (or pressure) profile. This can be achieved by entering current information into a computer model representing moulded part quality, and providing a computer algorithm which converts the latest quality data into suitable signals for automatically correcting the temperature (or pressure) profile.

It will be appreciated that, in a similar manner, a temperature profile (temperature versus time relationship) may be derived such as to give optimum moulded part properties, and the computer 38 arranged to vary the set position provided at input 36 accordingly in much the same way as described in relation to control to afford a desired pressure profile.

Similarly, it would be possible to provide the computer 38 with signals from a number of transducers, for example from a plurality of temperature transducers disposed at different parts of the apparatus or from various transducers for pressure, temperature, viscosity etc, and for the computer to be arranged to derive from any combination of signals from these transducers, a respective optimum set position signal to be applied to the input 36 of the position programmer.

Since it is possible to rotate the screw continuously, it will be appreciated that the apparatus described may also be used for continuous extrusion of plastics products, as well as for moulding etc.

As discussed in our Patent Specification No. 1,572,514, a problem which has been encountered with injection moulding and the like apparatus of the kind incorporating a screw which is disposed axially in a cylinder and is rotated continuously to convey plasticised plastics material along the cylinder is that the continual rotation of the screw, by virtue of the heat generated by friction between the plastics material and the screw and cylinder, may overheat the plastics. This gives rise to a problem since the time during which the screw rotates during a particular mould filling operation cannot generally be varied in accordance with the desired temperature, and yet uncontrolled variations in the temperature of the plastics material between successive mould filling operations, as well as during a single mould filling operation, will lead to defects and lack of uniformity in the moulded products.

While some control of the temperature of the plastics material may be obtained by variation of the axial position of the screw in embodiments of the present invention described above, adequate control of temperature may not be made available by this means, particularly if some other variable is also to be controlled by variation of the screw position. To minimise difficulties arising in this way it is preferred, in embodiments of the present invention, to make additional provision for the regulation of the temperature of the cylinder and/or the screw.

To this end, the cylinder 10 may be provided with temperature regulating means, comprising heating means and cooling means, which may be substantially the same as described in our Patent Specification No. 1,572,514, including, inter alia, respective heating and cooling means for separate axially spaced zones of the cylinder, and the screw 14 may likewise be provided with separate cooling means for the screw tips and the body of the screw, which again may be substantially of the form described in our Specification No. 1,572,514.

Furthermore, as also disclosed in our Specification No. 1,572,514, the cooling means for the screw and the screw tip and the temperature regulating means for the various zones of the cylinder may be controlled by timing means arranged to initiate cooling of the screw and the screw tip and the various zones of the cylinder at a predetermined time or times before rotation of the screw commences, so as to avoid an overshoot of the temperature of the plastics material, above the value desired, due to the delay between the initiation of cooling and the full effect of the cooling on the plastics material taking effect.

CLAIMS

1. Apparatus of the kind specified wherein said control means includes first means for controlling the axial position of the screw in accordance with a deviation of the position of the screw, sensed by said sensing means, from a desired position represented by a signal applied to an input of said first means so as to tend to maintain correspondence between said sensed and desired positions, and means for supplying such a signal to said input of said first means.

2. Apparatus according to claim 1 wherein said means for supplying such a signal to said input of said first means comprises a transducer arranged to sense the axial position of the screw or the value of some quantity dependant on the axial position of the screw, said means for supplying a signal to said input being arranged to vary said signal in accordance with variations in the axial portion of the screw as sensed by said transducer, or in the value of the respective quantity sensed by said transducer.

3. Apparatus according to claim 2 wherein said transducer is a temperature transducer arranged to sense the temperature of the plastics material at a predetermined position in the apparatus.

4. Apparatus according to claim 2 wherein said transducer is a pressure transducer arranged to sense the pressure of the plastics material at a predetermined position in the apparatus.

5. Apparatus according to claim 1 wherein said means for supplying such a signal to said first means includes a computer arranged to vary said signal in accordance with a control algorithm, dependant on one or more variables.

6. Apparatus according to claim 5 wherein said computer is arranged to vary said signal, in accordance with a control algorithm which is such as to afford a predetermined variation with time of a predetermined quantity.

7. Apparatus according to claim 5 of claim 6 wherein one such variable is an output signal from a transducer associated with the apparatus.

8. Aparatus according to any preceding claim wherein the axial position of the screw is controlled by a double acting piston and cylinder arrangement disposed outwith the screw cylinder, and the apparatus includes a control valve which in one position connects the chamber on one side of said piston with a source of hydraulic fluid under pressure and the chamber on the other side of said piston with a low pressure reservoir and which control valve in another position thereof reverses such connections, and wherein said first means includes means for moving the valve between said positions thereof.

9. Apparatus according to any preceding claim wherein said sensing means comprises a linear displacement transducer.

10. Apparatus according to any preceding claim, wherein means is provided for regulating the temperature of the cylinder and/or the screw.

11. Apparatus according to claim 10, wherein

means is provided for cooling the screw tip, separate means is provided for cooling the body of the screw, and wherein respective axially spaced zones of the cylinder have respective separate temperature regulating means.

12. Apparatus according to claim 11, including timing means controlling the cooling means for the screw tip and the temperature regulating means for the various zones of the cylinder, said timing means being arranged to initiate cooling of the screw and screw tip and of the various zones of the cylinder at a predetermined time or times before rotation of the screw commences.

13. Apparatus according to claim 1 and substantially as hereinbefore described with reference to, and as shown in the accompanying drawings.

14. A method of forming synthetic plastics products by extrusion or moulding, utilising apparatus according to any of claims 1 to 13.

15. A method according to claim 14 and substantially as hereinbefore described with reference to the accompanying drawings.

16. A synthetic plastics product produced using the apparatus of any of claims 1 to 13 or using the method of claim 14 of claim 15.

17. Any novel feature or combination of features as described herein.

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