

The invention relates to a hydraulic arrangement for the injection-moulding unit of a plastics material injection-moulding machine including a variable delivery pump, which feeds the hydraulics consumer apparatus of the injection moulding unit with pressure oil via at least one supply line, and including a control unit, which is disposed in the supply line and comprises a proportional pressure/quantity valve and a pressure sensor for the pressure-dependent control (pressure-programme control), said control unit having associated therewith a control feedback line, which connects the control member of the variable delivery pump to the supply line upstream of the proportional pressure/quantity valve in order to maintain a constant operational pressure gradient.

The term "operational pressure gradient" in this concept is understood to mean a pressure gradient which is just about sufficient as a basis for the operation and the control of the variable delivery pump, i.e. at a lower limit.

By comparison to previous hydraulic systems on the basis of a single proportional pressure/quantity valve in one supply line for several consumers, a known hydraulics arrangement of this type (DE-PS 31 19 095) offers many varied possibilities to adapt to different operational requirements whilst maintaining a minimal drive output.

Based thereon, it is the object of the invention to further develop a hydraulics arrangement of the initially mentioned type in such a manner that in particular the running of the injection process can be speeded up and adapted to a further improved degree to

at times extremely varying operating requirements due to changing the object of production.

This object is achieved in that the first control unit is followed by a second control unit relative to its control behaviour in that the control speed of the second control unit is determined by the magnitude of the operational pressure gradient of the first control unit, which second control unit is a proportional pressure/quantity valve, including a pressure sensor for pressure-dependent control as well as a displacement-to-voltage converter for the travel-dependent control (quantity-programme control).

The functional co-acting of the first and the second control unit in the hydraulic system creates the basic preconditions for speeding up the injection of the plastics material into the injection mould and, if appropriate, the setting down of the injection-moulding unit onto the injection mould and picking it up therefrom by simple additional measures.

This is done in the most simple case by programming the operational pressure gradient via the first pressure sensor of the first control unit. The operational pressure gradient, originally concipated for energy savings, then becomes an auxiliary means for an increase in switch speed of the proportional pressure/quantity valve of the second control unit, as the conveying speed, which has been increased by a higher operational pressure gradient, permits smaller flow-through cross-sections in the proportional pressure/quantity valve of the second control unit, which results in shorter switch feed paths. An increased reactionary speed of the proportional pressure/quality valve of the second control unit is of particular significance in a differentiated running of the injection process with several speed- or pressure

stages. Consequently, the second control unit is not hydraulically arranged after the first control unit but relative to its control behaviour, as the control speed of the second control unit is determined by the magnitude of the operational-pressure gradient of the first control unit.

A further extremely effective way of speeding up the injection of plastics material is contained in patent claim 2 and 3. Accordingly, the storage unit can be recharged during the injection and during the post-pressure phase with an operating pressure gradient which has been optimised via the first control unit.

A further extremely simple way of speeding up the injection of plastics material, which additionally permits a more precise control of the dynamic pressure during pre-plastification, is contained in patent claim 4. A differentially switched hydraulic system is the result of connecting the cylinder spaces and the injection cylinders and the return cylinders. In this system, the effectively loaded surface is considerably reduced. In the case of injection, this means speeding up the injection stroke of the conveyor screw. In the case of dynamic-pressure control, increased dynamic pressure is created in the proportional pressure/quantity valve which controls the dynamic pressure. This is of the same significance as the possibility of a significant increase in the pressure-control scale of the dynamic pressure.

Further possibilities of adaptation to different operational requirements are contained in patent claims 4 to 7.

In the following, the invention will be explained by way of two examples of embodiment, based on the drawing.

Shown are, in

Fig. 1: the hydraulic system of the hydraulic arrangement; and

Fig. 2: the system as in Fig. 1 with hydraulic accumulator.

Apart from setting the injection mould unit down onto injection mould or removing it therefrom, the hydraulic arrangement also controls the pre-plastification and the injection of the plastics material into the injection mould and the retracting drive of the conveyor screw in the plastification cylinder. The latter serves to reduce the pressure in the plastification cylinder prior to setting down the injection-moulding unit from the injection mould. However, it is often also necessary to drive the conveyor screw back for its removal or cleaning or the like. Hydraulic consumers of the injection-moulding unit are supplied with hydraulics oil via supply lines by a control pump 2 of relatively large output or a control pump of lesser output (pressure-maintenance pump 12). A supply pipe 3 with pressure-relief valve 6 leads from control pump 2, which draws the hydraulic oil via a suction filter 1 from tank 42, to a first control unit E1, which includes a proportional pressure/quantity valve 4 and a pressure sensor 5 for pressure-dependent control (pressure-programme control). This first control unit E1 is provided with a feedback line 43, which connects control member 2a of control pump 2 to consumer line 3 downstream of the proportional pressure/quantity valve 4 for the purpose of maintaining a constant operating-pressure gradient.

The first control unit E1 co-acts with a second control unit E2 or E2" respectively, corresponding to the first control unit 1, which is associated with a

displacement-to-voltage converter 22 for travel-dependent control. A hydraulic accumulator 29 with pressure sensor 28 can be added, if required by way of a directional valve 27, between the first control unit E1 and the second control unit E2 for the purpose of injecting the plastic material. The cylinder spaces 37 and 38 of the piston-cylinder units (injection cylinder 24 and retracting cylinder 25), which effect the forward movement (injection of the plastic material) and the retracting movement of the conveyor screw, are interconnectable by means of a directional valve 33. Control unit E1 is provided downstream with the second control unit E2 or E2" respectively, both in the supply line 35 to the piston-cylinder unit (drive cylinder 23) for setting down and lifting the injection mould unit and in the supply line 34 which leads to injection cylinder 24, and control-technically with a directional valve 15 in supply line 36 which leads to the drive cylinder 25. In supply line 39, which leads to rotary oil motor 19 for conveyor screw 40, control unit E1 is provided downstream with a directional valve 16. Drive cylinder 23 is charged by pressure-maintenance pump 12 via a switching valve 8 and via the first control unit E1.

The hydraulic accumulator 29 can be recharged during the injection of the plastic material and during the following post-pressing phase for pressing the plastic material into the injection mould, selectively by control pump 2 via control unit E1 and directional valve 27 or by pressure-maintenance pump 12 via pressure inlet valve 32 and directional valve 27 or simultaneously by control pump 2 and pressure-maintenance pump 12.

All speeds and pressures of the hydraulic system can be driven in the closed control circuit with a minimum of energy input and minimum use of hydraulic components.

In the following, the construction of the control arrangement will be described in detail, based on the course of an injection cycle.

1: First example of embodiment of a control in the phase of setting down the injection moulding unit onto the injection mould or picking it up therefrom

The control unit E2' with proportional pressure/quantity valve 9 and pressure sensor 10 operates as a switching valve. Speed and pressure are determined by control unit E1 with proportional pressure/quantity valve 4 and pressure sensor 5.

Due to feedback line 43, a constant operating pressure gradient is maintained by this control unit E1. When controlling the speed, feedback takes place via the displacement-to-voltage converter 21 acting as displacement transducer. The speed can selectively also be controlled in that the proportional pressure/quantity valve 4 of control unit 1 is controlled up to a predetermined geometrical value. The displacement path of the valve piston is then detected by a displacement transducer and returned as an actual value to the nominal value. A changeover to a pressure control takes place when reaching a pressure value, which is preset in the programme, during the drive movement. The actual pressure value is detected by pressure transducer 5 and fed to the electric amplifier. When both the programme-determined nozzle-engagement position is reached with the aid of displacement-to-voltage converter 21, and simultaneously the programme-determined nozzle-engagement pressure with the aid of pressure sensors 5

and 10 (controlling), then the following takes place: a directional valve 8, which is arranged in front of control unit E2', which here operates as a switching valve, is switched to 'engage nozzle'. This causes control pump 2 to be set at Zero by control unit E1. At the same time, the proportional pressure/quantity valve 9 of control unit E2' operates as a pressure-control valve. The actual pressure value is detected by pressure transducer 10 and fed back to the electrical amplifier. The latter is able to perform a nominal/actual comparison. Thus, both the speed return and displacement position are by way of travel sensor 21.

2: Second example of embodiment of a control in the phase of setting down the injection moulding unit or picking it up

Speed control, pressure control and positioning are effected by way of proportional pressure/quantity valve 9 of control unit E2'. Thereby, both control pump 2 and pressure-maintenance pump 12 can be used for supplying hydraulic oil. For this reason, the operation of a control pump allows parallel functions with the other control pump. The actual values are fed back to the nominal values by means of the displacement-voltage converter 21 in order to control the speed and the positioning of the nozzle. The actual pressure value is detected by pressure sensor 10 and fed back for the purpose of pressure control. The control piston of the proportional pressure/quantity valve 9 is arranged so that positioning or 'stay' of the nozzle are possible without controlling the position, whereby the proportional pressure/quantity valve 9 shuts. A pressure-relief valve 7 is included in the pressure pipe 47 which leads from pressure-maintenance pump 12 to control unit E2'.

3: Pre-plastification (Metering)

In this phase, the rotating conveyor screw 40 retracts under the dynamic pressure of the plastic material collecting in front of it. The conveyor screw 40 is driven by oil motor 19, which is supplied via supply pipe 39. This is done with the aid of control unit E1 via directional valve 16. The required revolutions of conveyor screw 40 can be selectively controlled or set via proportional pressure/quantity valve 4 of control unit E1. When controlling the revolutions, then the pulse is fed back from the inductive proximity switch 20 to the amplifier as actual value. Controlling the revolutions is by way of adjusting the proportional pressure/quantity valve 4 to a geometrical value relative to the through-flow. The displacement path of the valve piston is then detected by displacement transducer 4a and fed back to the electronic amplifier as an actual value. When arriving at a preset permissible maximum torque of conveyor screw 40, which is measured by pressure sensor 5 as a pressure value, then the actual pressure value is fed back. The rotation of the conveyor screw 40 is then pressure-controlled. Tank pipe 39a of oil motor 19 extends via oil cooler 14 and feedback filter 13. The dynamic pressure in the material collecting in front of the screw conveyor is controlled via the proportional pressure/quantity valve 18 of control unit E2. The actual pressure value is then detected by pressure sensor 17 and fed back. Cylinder spaces 38 of retracting cylinders 25 are connected to tank 42 via directional valve 15, switch position A to T, so that hydraulics oil can be drawn from tank 42 into cylinder spaces 38. Cylinder space 37 is emptied via tank pipe 41.

The dynamic-pressure control can selectively also be performed in a different manner if an extremely different or precise control is required. In this case, the dynamic pressure is also controlled via the proportional pressure/quantity valve 18, and the actual pressure value is detected by pressure sensor 17 and fed back. However, in contrast to the aforescribed dynamic-pressure control, cylinder space 37 of injection cylinder 25 is connected via pipes 44, 45 by means of directional valve 33 to cylinder spaces 38 of retracting cylinders 25. Directional valve 15 is in the closed position, as no hydraulics oil is to be additionally drawn into cylinder spaces 38 during plastification in this switch arrangement.

By connecting cylinder spaces 38 to cylinder space 37, a different switch arrangement is arrived at with the result that the effectively loaded surface area in the system is considerably smaller. Consequently, an increased pressure occurs at proportional pressure/quantity valve 8. It is thus possible to control the dynamic pressure over a considerably increased pressure-control scale, i.e. to control with more accuracy.

4: Injection of the plastics material into the injection mould

Injection speed and injection pressure are controlled by proportional pressure/quantity valve 18 of control unit E2.

The actual speed value as well as the actual position value of conveyor screw 40 is fed back via displacement-to-voltage converter 22, which serves a displacement transducer. The actual pressure value is fed back by pressure sensor 17. The operational pressure gradient, i.e. the pressure gradient from

control pump 2 to pressure sensor 17, is freely selectable. The proportional pressure/quantity valve 4 of control unit E1 is then opened to such an extent that it is possible to control the operational pressure gradient via control feedback line 43. In this respect, control unit E1 serves the control of an optimised operational pressure gradient during the injection process and during the post-pressure phase.

Only one proportional pressure/quantity valve 18 operates between injection cylinder 24 and control pump 2 to control the injection, thus ensuring optimum use of energy.

Control unit E2 is arranged directly adjacent to the plastification cylinder of the injection-moulding unit, thus establishing extremely short supply lines, which increases the control accuracy. During the injection process, cylinder spaces 38 of retracting cylinder 25 are connected via directional valve 15 to tank 42.

If an extremely high injection speed is required, then injection can be performed by yet another method:

Inside spaces 38 of retracting cylinders 25 are connected by pipes 45, 44 to cylinder space 37 of injection cylinder 25 by means of directional valve 33. Directional valve 15 is then in the closed position. This makes it possible to achieve an increased injection speed at the same pump output.

5: Retraction of the conveyor screw or reduction of dynamic pressure in the plastification cylinder

Retraction of conveyor screw 40 is initiated by operating directional valve 15, which is positioned in supply pipe 35, switch position P to A. Thereby, proportional pressure/quantity valve 18 of control unit E2 is in position A to T. Speed and pressure are

determined by proportional pressure/quantity valve 4 of control unit .4

Here again, the speed can be selectively controlled or driven. The pressure is controlled when arriving at a preset pressure value, which is measured by pressure sensor 5.

6: Injection of pre-plastified plastics material by way of the hydraulic accumulator..

If extremely fast injection of the plastics material is required, then the hydraulic accumulator 29, which is added in the supply pipe between control units E1 and E2', is used. Oil is then drawn exclusively by hydraulic accumulator 29, which is connected via pressure pipes 34", 44 by way of proportional pressure/quantity valve 18' to injection cylinder 24. This already permits charging of accumulator 29 during the injection process as well as during the post-pressure phase. Charging the hydraulic accumulator 29 can be via non-return valve 26 and directional valve 27 by control pump 2, but selectively also by maintenance pump 12 via directional valve 8' and via pressure-inlet valve 32. In the case of charging via control pump 2, the pressure gradient towards accumulator 29 is freely selectable via pressure sensor 5. The charging pressure of accumulator 29, which is measured by pressure sensor 28, can also be matched to the concrete consumption. In any case, only the amount of hydraulics oil required for the next injection process is then charged into accumulator 29. A preset proportional pressure/quantity valve 19a is provided in control unit E2" in order to control the required large quantities of oil. Pilot valve 19a is provided with a directional sensor 18b. Spring 18c ensures that the piston in proportional pressure/quantity valve 18 does not "err". Spring 18c displaces the piston to the right so as to establish

the required hydraulic control pressure. Accumulator 29 is protected by pressure-relief valve 31 and relieved by directional valve 30. In any case, pressure pipe 34" of accumulator 29 is ducted via directional valve 27.

The term "proportional pressure/quantity valve" is to be understood in the widest possible sense and also includes servo valves.

Claims

- 1: Hydraulic arrangement for the injection moulding unit of a plastics material injection moulding machine, including a variable delivery pump (2), which feeds the hydraulic consumer apparatus (24, 23) of the injection moulding unit with pressure oil via at least one supply line (34; 35), and including a control unit (E1), which is disposed in the supply line (34; 35) and comprises a proportional pressure/quantity valve (4) and a pressure sensor (5) for the pressure-dependent control (pressure-programme control), said control unit having associated therewith a control feedback line (43), which connects the control member (2a) of the variable delivery pump (2) to the supply line upstream of the proportional pressure/quantity valve (4) in order to maintain a constant operational pressure gradient, characterised in that a second control unit (E2, E2'') is connected to the output end of the first control unit (E1) in respect of its control behaviour, while the control speed of the second control unit (E2, E2'') is determined by the magnitude of the operational pressure gradient of the first control unit (E1), which second control unit (E2, E2'') includes a proportional pressure/quantity valve (18, 18'), a pressure sensor (17) for pressure-dependent control (pressure-programme control) and a displacement-to-voltage converter (22) for the travel-dependent control (quantity-programme control).



- 2: Arrangement according to claim 1, characterised in that a hydraulic accumulator (29) with pressure sensor (28) is insertable between the first control unit (E1), which is connected to the variable delivery pump (2) via the control feedback line (43), and the second control unit (E2) by means of a directional valve (27), if necessary.
- 3: Arrangement according to one of claims 1 or 2, characterised in that the cylinder chambers (37, 38) of the piston-and-cylinder units (injection cylinder 24; retracting travel cylinder 25), which effect the forward movement (injection of the plastics material) and the return movement of the conveyor screw (40), are interconnectable by means of a directional valve (33).
- 4: Arrangement according to one of the preceding claims, characterised in that a second control unit (E2', E2, E'') is connected to the output end of the control unit (E1) both in the supply line (35) leading to the piston-and-cylinder unit (travel cylinder 23) and in the supply line (34) leading to the injection cylinder (24), and a directional valve (15) is connected to the output end thereof in the supply line (36) leading to the return travel cylinder (25).
- 5: Arrangement according to one of the preceding claims, characterised in that a directional valve (16) is connected to the output end of the control unit (E1) in the supply line (39), which leads to the hydraulic motor (19) for the conveyor screw (40).
- 6: Control device according to one of the preceding claims, characterised in that an additional variable delivery pump with a low delivery output (pressure-



maintenance pump (12) is provided, by means of which the travel cylinder (23) is feedable via a reversing valve (8) and the second control unit (E2').

7: Arrangement according to one of the preceding claims, characterised in that the mounting and lowering of the injection moulding unit is selectively controllable by the first control unit (E1) or the second control unit (E2'), and in that, in the case where the control is effected by the second control unit (E2'), the travel cylinder (23) is selectively feedable by the variable delivery pump (2) or the pressure-maintenance pump (12).

8: Arrangement according to one of the preceding claims, characterised in that the hydraulic accumulator (29) is selectively rechargeable during the injection-moulding of the plastic material and during the subsequent re-pressing phase for subsequently pressing the plastic material into the injection mould assembly by the variable delivery pump (2) via the first control unit (E1) and the directional valve (27) or by a pressure maintenance pump (12) via a pressure inlet valve (32) or simultaneously by the variable delivery pump (2) and the pressure-maintenance pump (12).

