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BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for monitoring, documenting and/or controlling an injection molding machine according to the preamble of claim 1, as well as an injection molding machine for carrying out this this method.

PRIOR ART

[0002] To keep a check on the consistency of plastic material, pasty compositions, emulsions and liquids, the viscosity is determined in dependence on the shear rate. The viscosity describes dynamic shear stresses caused by internal friction in moving liquids or in pasty compositions. The definition of viscosity is based on Newton's theory, which states that the shear stress is proportional to the shear rate. The proportionality factor is in this case referred to as viscosity (shear viscosity). The two terms shear stress and shear rate can be explained by the example of a liquid film of a thickness d which rests on one bounding surface and is moved on the other at a velocity v on account of the shear force acting on it. The shear stress corresponds to the shear force per unit area and the shear rate corresponds to the quotient v/b, and consequently the change in the velocity of displacement of one bounding surface in relation to the other divided by the distance between the two bounding surfaces.

[0003] In order to determine a relationship between the shear rate and the shear stress or the viscosity, viscosity measurements must be carried out for various shear rates. The viscosity can be determined by the Hagen/Poiseuille method by means of a capillary through which the liquid or composition to be investigated flows on account of a charging pressure. The shear stress and the shear rate, and consequently the viscosity, can be determined from the rate of flow, the charging pressure, the change in pressure along the capillary and the cross section of the capillary. Because the shear rate depends both on the charging pressure and on the cross section of the capillary, measurements for various shear rates can be carried out by changing these variables.

[0004] U.S. registered design 3,438,158 discloses, for example, determining the flow stress and the viscosity of a non-Newtonian fluid. This involves pumping the fluid through a pipe of known diameter at a known flow rate. By repeated measurement of the pressure differences or the pressure drop along a given length of pipe under different conditions in each case, the aforementioned rheological parameters can be determined.

[0005] DE 10 2005 032 367 A1 already discloses a method for monitoring and/or controlling the filling with melt of at least one cavity of an injection molding machine. According to this document, material or viscosity fluctuations can be indirectly ascertained, monitored and controlled, to be precise by analyzing the differences in the time for filling with the melt from cycle to cycle. Although such a method allows differences in viscosity to be detected, and possibly corrected, it cannot be used to ascertain a genuine viscosity profile in the physical unit of pascals per second (Pa s). But to be able to quantify a change in viscosity, it must be known in the genuine physical unit.

[0006] In classical rheometry, the viscosity is ascertained as a quotient of shear stress and shear rate, usually for material determination in the laboratory. Serving for this purpose are so-called rheometers, which have a die and an exactly defined melt channel for ascertaining the viscosity, with a contrast here in comparison with an injection molding process in that isothermal conditions prevail. That is to say that both the metal die and the plastics melt are at the same temperature. Serving for measurement in a rheometer are two melt pressure sensors (no mold internal pressure sensors), which are arranged a certain distance apart and measure the pressure drop over this distance. The shear stress can then be calculated on the basis of the geometry of the melt channel, which may be designed for example as a bore or as a rectangular channel, and on the basis of the pressure drop. In this case, the melt discharge through the die is forced out (extruded) at different rates or under different pressures, with the result that different pressure gradients (Δp) are obtained. Each individual pressure gradient produces a shear stress of its own, and consequently a value in the profile of a viscosity curve.

[0007] At the same time, the corresponding shear rate is calculated once again on the basis of the geometry of the melt channel and on the basis of the time that elapses while the melt passes from the first melt pressure sensor to the second melt pressure sensor.

[0008] Finally, there is also a more simple method than that for determining viscosities, one in which only one melt pressure sensor is used. It measures the pressure drop from the sensor to atmospheric pressure of 1 bar. In the case of this method, however, a computational correction must be made—the so-called “Bagley correction”—in order to compensate for run-out pressure losses. These run-out pressure losses occur when the melt leaves the channel into the open and expands. Otherwise, the further procedure corresponds to the method of a rheometer.

[0009] A further method for monitoring injection molding processes is shown by U.S. Pat. No. 4,833,910. For this purpose, two pressure sensors are positioned in the cavity at a known distance in the direction of flow of the melt. The viscosity is determined by way of the pressure difference ascertained in this way, the time difference, the radius of the channel and the distance between the two sensors.

OBJECT OF THE INVENTION

[0010] The object of the present invention is to monitor, and possibly control, an injection molding process under practical conditions.

SOLUTION OF THE OBJECT

[0011] The solution to this object is provided by the characteristic features of claim 1.

[0012] In accordance with the present invention, the method according to the invention can be realized in a simple manner, as provided by a first preferred exemplary embodiment, by the viscosity being ascertained on the basis of at least one mold internal pressure sensor and at least one mold wall temperature sensor. On the one hand, the pressure of the melt as it arrives at the mold internal pressure sensor is ascertained and on the other hand the pressure of the melt as it arrives at the mold wall temperature sensor is ascertained. The pressure loss corresponds here exactly to the pressure value that prevails at the time of a rise in temperature, with the result that a second pressure value is not required since the pressure difference between the atmospheric pressure and this value is assumed. To ascertain the shear stress, the time that the melt needs to pass between the two sensors is used.

[0013] It is expedient here if the mold internal pressure sensor is provided in the vicinity of the entry of the melt into the cavity and the mold wall temperature sensor is provided in the following course of the flow path or in the vicinity of the end of the flow path of the melt. If, for example, the mold wall temperature sensor is situated in the vicinity of the end of the flow path, it is also possible at the same time to switch over automatically to the so-called follow-up pressure, while however the method according to the invention likewise functions very well if the mold wall temperatures sensor is positioned anywhere in the course of the melt flow.

[0014] If in the present invention mention is made of the mold wall temperature sensor or the mold internal pressure sensor, this means that both sensors are preferably arranged in the inner wall or near the surface of the cavity, i.e. in the first case they come into contact with the melt directly, in the second case they are only separated from the melt by a thin web.

[0015] It should once again be expressly pointed out that the present invention does not replace the rheometer. By contrast to determination of the viscosity with the rheometer, according to the present invention a permanent monitoring of the injection molding process takes place. A viscosity value is monitored only if it changes; that is if there is a response in the course of the process that resumes this viscosity value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Further details and advantages of the invention emerge from the following description and on the basis of the drawing, in which:

FIG. 1 shows a schematic side view of an injection molding machine according to the invention,

FIG. 2 shows as a first exemplary embodiment a basic construction of a cavity of an injection mold provided with measuring sensors, to be precise with a mold internal pressure sensor and a mold wall temperature sensor,

FIG. 2a shows a schematic representation of various arrangements of pressure and temperature sensors in a cavity with associated diagrams of the pressure and temperature profiles over time;

FIG. 3 shows a diagram of the pressure and temperature profile over time produced on the basis of the measurement data ascertained with the first exemplary embodiment as shown in FIG. 2,

FIG. 4 shows as a second exemplary embodiment a schematic representation of a cavity of an injection mold with only one wall temperature sensor, which is not the subject of the invention.

[0017] Schematically represented in FIG. 1 is an injection molding machine P, which in a known way comprises an injection mold 1 with a cavity 1. 1 and a nozzle 2 , through which a melt of plastics material is introduced into the cavity 1. 1. The nozzle 2 is in turn connected to an extruder 3 , to which a feed hopper 4 for plastics pellets or granules is assigned.

[0018] An arrow 5 indicates a measuring point for measuring the mold wall temperature - to be precise the inner wall temperature of the cavity, whereas an arrow 6 indicates that point where the melt pressure is measured in the region of the injection nozzle. Furthermore, an arrow 7 indicates that point where the hydraulic pressure is decisive as a measured variable.

[0019] The basic construction of a cavity 9 represented in FIG. 2 as an exemplary embodiment, with a rectangular cross section and the dimensions of height H and width W for determining the respective geometry is only given by way of example. A mold internal pressure sensor 10 is provided near a sprue 19 and a mold wall temperature sensor 11 is provided at a distance S (9) therefrom; a mold wall indicated by 12 is “cold” and the interior of the cavity 9 during filling with the melt is “warm”.

[0020] The diagram shown in FIG. 3 was produced on the basis of measurement data ascertained with the arrangement of sensors in the cavity 9 as shown in FIG. 2. In this diagram, the time ts in seconds is indicated on the y axis and the pressure p is indicated on the x axis on the left and the temperature (abstract) is indicated on the x axis on the right, with a curve 13 reproducing the mold internal pressure profile and a curve 14 reproducing the mold wall temperature profile. At a point of intersection of the two curves, the pressure value at the point in time of the rise in temperature is indicated by an arrow 15 , i.e. an automatic calculation of a shear stress takes place on the basis of Δp. The automatic calculation of a shear rate takes place on the basis of Δt.

[0021] Schematically represented in FIG. 4 as a second exemplary embodiment is a cavity 17 , which only has one mold wall temperature sensor 18 , which is arranged at a distance S (17) from the entry of the melt (sprue 19).

[0022] The method according to the invention for ascertaining the viscosity profile of a melt in a cavity of an injection mold of an injection molding machine for monitoring, documenting and/or controlling the latter proceeds as follows:

On the basis of the first exemplary embodiment as shown in FIG. 2, during the injection phase of the melt flowing into the cavity 9 by way of the nozzle 2 of the injection molding machine P, the viscosity of said melt is determined by ascertaining the individual quotients for this from the respective shear stresses and shear rates on the basis of the pressure differences occurring in the cavity 9 and the geometry (H×W×total length of the cavity 9). With reference to the exemplary embodiment shown in FIG. 2, this means that the mold internal pressure sensor 10 in the vicinity of the entry of the melt measures the pressure as the melt enters. As soon as the melt reaches the mold wall temperature sensor 11 , a pressure measurement again takes place and the measured pressure difference corresponds exactly to the pressure value that prevails at the point in time of the rise in temperature shown in FIG. 3. A second pressure value is not necessary here, since the pressure difference between the atmospheric pressure (1 bar) and this value is assumed. The advantage of this method is also that the temperature sensor 11 can be used at the same time for automatically switching over to follow-up pressure. Moreover, however, the temperature sensor 11 can be situated anywhere in the course of the melt flow. This is illustrated in particular by FIG. 2a , in which a different arrangement of the pressure sensor 10 and the temperature sensor 11 is shown in three exemplary embodiments. Alongside are the corresponding diagrams analogous to FIG. 3. Irrespective of where the pressure sensor 10 or the temperature sensor 11 is situated, the shear stress Δp and the shear rate Δt are ascertained when the temperature sensor 11 is reached, and the viscosity value is calculated from this will. If this value lies at or near a predetermined value, nothing needs to be changed for the injection molding process. If, however, this value changes, the injection molding process can be changed, for example with respect to the temperature of the melt and/or the pressure or similar parameters, until the desired viscosity value is again ascertained.

[0023] The viscosity profile is finally obtained from the various individual shear stresses and shear rates.

[0024] The first exemplary embodiment has particularly proven to be successful in practice. Here, as specified, the viscosity is ascertained and monitored in a known manner, it being possible for the viscosity profile ascertained in this way also at the same time to be documented and controlled.

[0025] In principle, different viscosities are undesired, since they lead to different properties of the parts. Causes of different viscosities are either different process conditions or different material properties (batch fluctuations). It is therefore also possible to use the method and the device according to the invention for carrying out checks on incoming material.

Patentkrav

1. Fremgangsmåde til overvågning, dokumentering og/eller styring af en sprøjtestøbemaskine (P) med et sprøjtestøbeværktøj (1), i hvilket en smelte indføres, hvori en viskositet af smelten i sprøjtestøbeværktøjet (1) fastslås direkte ved kvotienter af henholdsvis forskydningsspænding og forskydningshastighed ved hjælp af trykforskelle (Δp), hulrummets (1.1; 9; 17; 20) geometri og smeltens flydehastighed (Δt), **kendetegnet ved, at** viskositeten fastslås med mindst en hulrumstrykføler (10) og mindst en værktøjsvægtemperaturføler (11), hvor trykforskellen (Δp) af trykkene, som fastslås med hulrumstrykføleren (10) ved smeltens indløb ved den og ved smeltens ankomst ved værktøjsvægtemperaturføleren (11), anvendes til forskydningshastigheden, og hvor den tid (Δt), som smelten kræver fra hulrumstrykføleren (10) til værktøjsvægtemperaturføleren (11), anvendes til at fastslå flydehastigheden.

2. Sprøjtestøbemaskine (P), som har styremidler arrangeret til udførelse af fremgangsmåden ifølge krav 1, med et sprøjtestøbeværktøj (1) i hvilket en smelte indføres, hvori en viskositet af smelten i sprøjtestøbeværktøjet (1) bestemmes direkte af kvotienter af henholdsvis forskydningsspænding og forskydningshastighed ved hjælp af trykforskelle (Δp), hulrummets (1.1; 9; 17; 20) geometri og smeltens flydehastighed (Δt), hvori der findes mindst en hulrumstrykføler og en værktøjsvægtemperaturføler (10, 11, 18, 21, 22), ved hvilke de under en indsprøjtningsfase af smelten i hulrummet (1.1, 9, 17, 20) registrerbare trykforskelle og ved hulrummets (1.1, 9, 17, 20) geometri de pågældende kvotienter for viskositeten kan bestemmes af forskydningsspændingerne og forskydningshastighederne.

3. Sprøjtestøbemaskine ifølge krav 2, hvori hulrumstrykføleren (10) er tilvejebragt i nærheden af smelteindløbet (19) indgang i hulrummet (9), og værktøjsvægtemperaturføleren (11) er tilvejebragt i det efterfølgende forløb af smeltens flydevej (S9).

4. Sprøjtestøbemaskine ifølge krav 2 eller 3, hvori værktøjsvægtemperaturføleren (11) er tilvejebragt i nærheden af enden af smeltens flydevej.

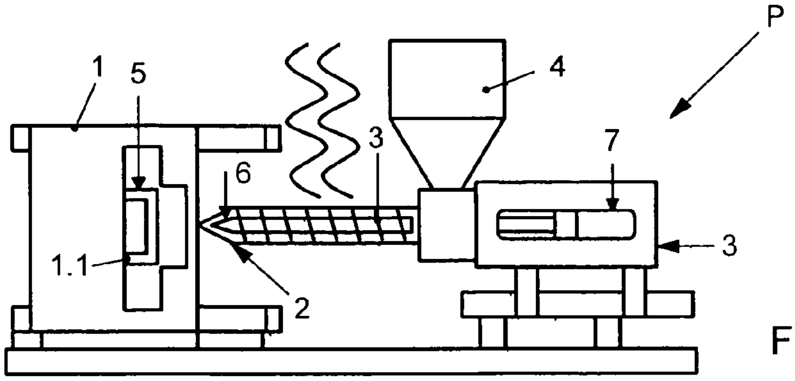


Fig. 1

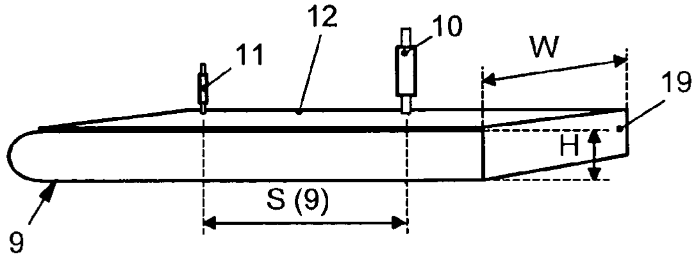


Fig. 2

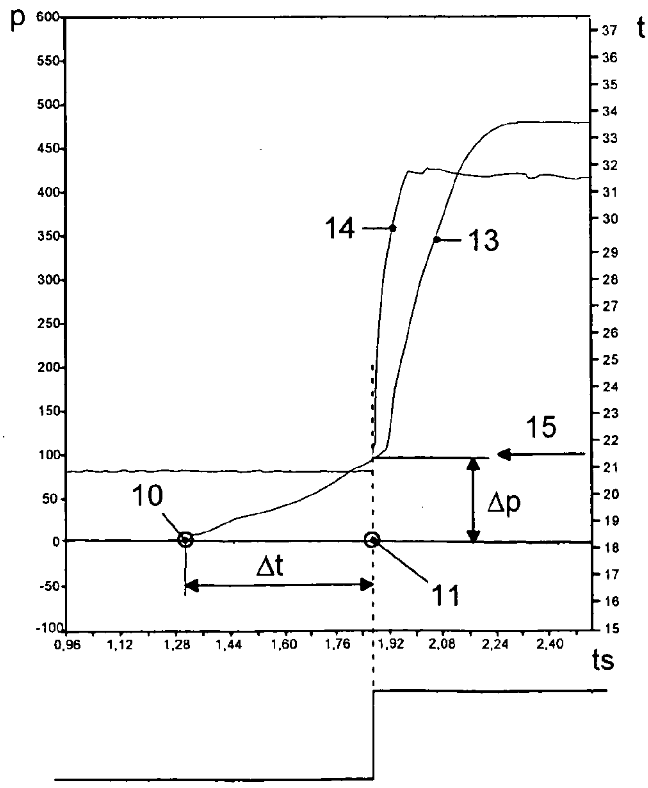


Fig. 3

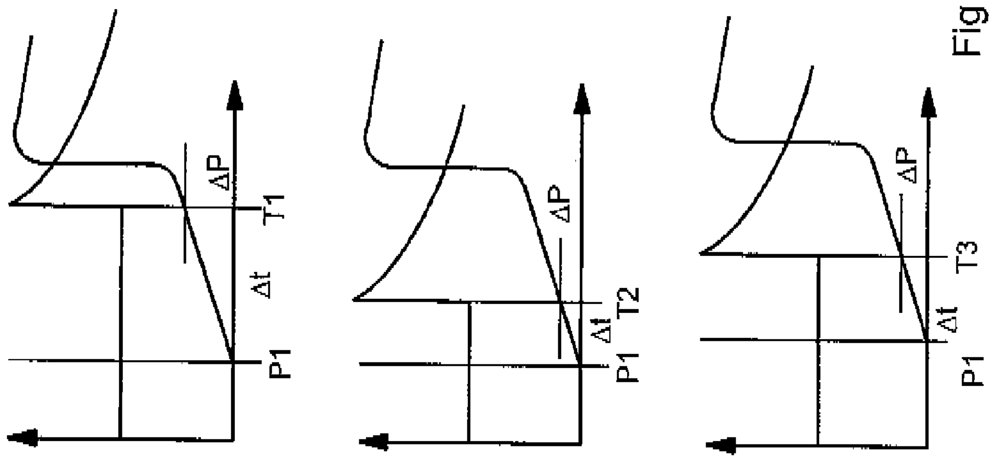
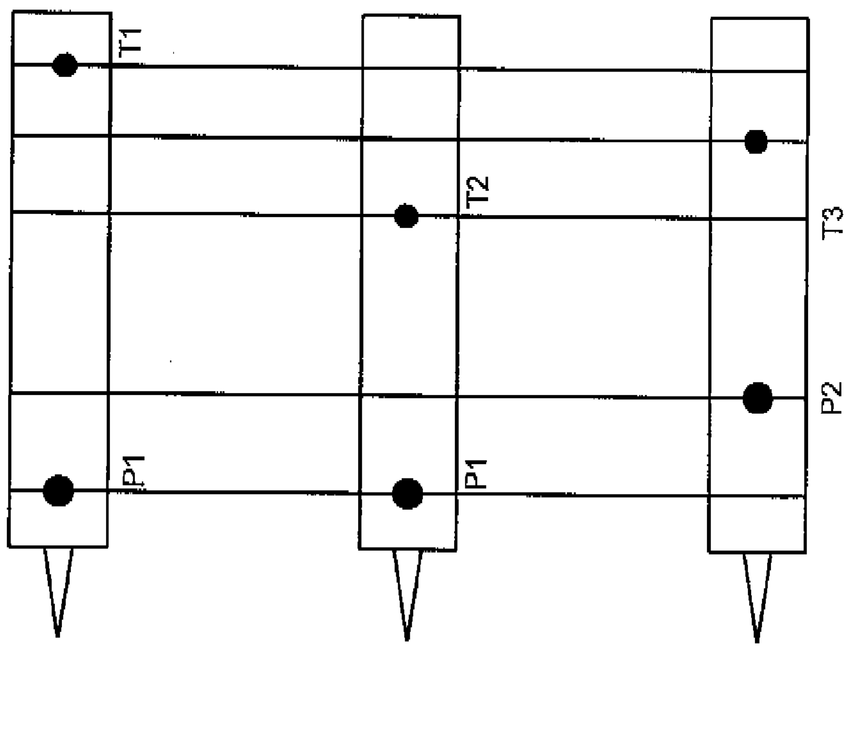


Fig 2a



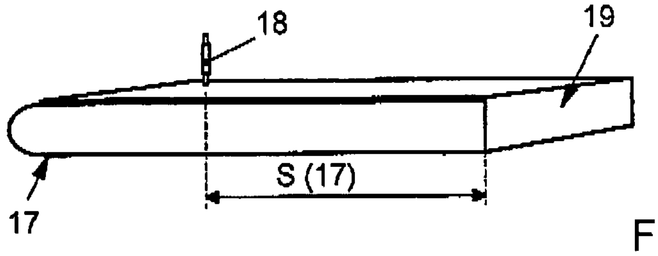


Fig. 4