Plant and process for producing a fibre from a polymer solution

The invention relates to a plant and a process for producing a spun fibre from a liquid polymer substrate, in particular a fibre as a membrane for fluid separation, in particular for producing membrane hollow fibres for fluid separation.

The prior art discloses production processes of membrane material for fluid separation, wherein such membrane materials based on polyimides are described for example in WO 2014/202324 A1 or WO 2011/009919 A1. Such membrane materials which are integrally asymmetric membranes, so-called "integrally skinned asymmetric membranes" (ISA membrane), comprise a separatory layer of 10 to 200 nm. It is well known that polyimides represent a class of polymer materials which make it possible to achieve gas separation of a fluid mixture at a high permeance of one of the fluids and/or at high selectivity. Polyimides are also characterized by very good mechanical, chemical and thermal resistance in applications for gas separation.

However, polyimides have only a moderate permeability, and so even WO 2011/009919 A1 and US 9,873,093 B2 propose providing a heat treatment step at high temperatures of over 300°C after fixing and drying the polymer. It is further proposed, for attainment of defined, high selectivities, to provide a defined gradient during heating in the context of the heat treatment which according to WO 2011/009919 A1 comprises for example three stages in a recirculating drying cabinet, namely at 70°C (0.5 h), 150°C (2 h) and 250°C (12 h).

For further improvement WO 2014/202324 A1 proposes drying hollow fibre preferably at a temperature in the range from 50°C to 100°C followed by heat treatment at close to the glass transition temperature. The drying is said to remove for example water, isopropanol or hexane, with the result that the total water and/or residual solvent content is in the range from 0% to 5% by weight. This is because an excessively high residual content of water and solvent in the heat treatment of whole membrane bundles leads to the membranes sticking to one another. Excess water can also lead to hydrolysis and thus to chain scission and a mechanically unstable membrane. According to WO 2014/202324 A1 it is advantageous when the maximum content of water before commencement of heat treatment is below 5% by weight, irrespective of the fact that any water content would evaporate during the heat treatment itself.

It is proposed to provide a drying unit and a heat treatment unit, wherein the heat treatment is carried out at a temperature in the preferred range from 140°C to 180°C under vacuum in the range from 0.6 to 0.9 bar and under an inert gas atmosphere, wherein a very long heat treatment time of preferably 10 to 16 hours is required.

It is also known to coat the raw fibre with a functional separatory layer before the final heat treatment step, as described for example in US 2017/166699 A1. This document discloses a

process for producing a thermally rearranged polybenzoxazole, polybenzimidazole or polybenzothiazole as a fibre membrane, wherein a coating may be provided.

In addition to the aforementioned adjustment of the basic porosity and material characteristics of an individual fibre in order to adjust the separation characteristics of the fibre (permeability, permeance and selectivity), it is known that the superordinate fibre geometry, in particular its uniformity and symmetry, accounts for a very large proportion of the functional quality of the hollow fibre and thus of the finished filter module. Even small geometrical deviations of individual hollow fibres in a fibre grouping (fibre bundles) of a filter module with for example 80 to 160 individual fibres or more result, due to local inhomogeneities and the resulting altered (local) permeability and/or local selectivity, in significant disadvantages in the separation performance of the entire filter module, so that required specifications of the entire filter module are not achieved and/or complex aftertreatments are required.

In the present case "filter module" is to be understood as meaning a fully manufactured module for gas separation having a housing in which the total number of hollow fibres is especially introduced as a potted group, also named “potting section”. The filter module generally has at least three conduit connections, such as the feed connection for the raw gas, the permeate connection, also named “outlet 1” and the retentate connection, also named “outlet 2”.

For this reason for quality monitoring of the spun hollow fibre the geometry of the fibre cross section is regularly measured in the laboratory. To this end, samples of the fibre are taken, the fibre is thermally stabilized, also named “frozen” and cut transversely to the fibre longitudinal direction using a suitable cutting apparatus. The resulting cross-sectional area of the fibre is measured in an optical microscope calibrated for spatial measurement.

The disadvantage of these known and generally proven process modes and quality monitoring is that individual fibres are geometrically measured only with a long time delay from production and thus control data of the plant or of the process can be optimized only with a long time delay.

It is accordingly an object of the present invention to provide a plant and a process for a fluid separation membrane which is more readily controllable than known plants and processes while achieving unchanged or increased product quality in terms of permeability and/or selectivity.

According to the invention this object is achieved with a plant for producing an, especially spun, fibre from at least one liquid polymer substrate comprising a control unit, a storage and feed unit for media, a spinning unit for forming the fibre, wherein downstream of the spinning unit for treatment of the fibre at least the following plant units are comprised in the recited sequence and wherein a plurality of guide and drive elements are provided along a transport path of a fibre through the plant:

a. an exchange unit, in particular for solvent exchange, comprising a fixing unit, into which the fibre can be introduced or passed immediately after the spinning unit,
b. at least one aftertreatment unit especially comprising at least one thermal treatment unit, wherein the fibre passes from the fixing unit to the aftertreatment unit in a main conveying direction (A), wherein the fibre is a solid fibre or a hollow fibre, wherein

downstream of the spinning unit at least one contactless and non-destructive detection station with at least one detection unit is provided, by means of which at least one measured value relating to the geometry of the fibre conveyed in a transport direction can be detected in situ, and wherein the detection unit is at least in data communication with the control unit and is configured to effect data processing of the at least one measured value.

The detection unit is advantageously a tomography apparatus. Tomography is a group of imaging techniques that allows the external and internal spatial structure of bodies to be detected and for example represented as cross-sectional representations, for example computed tomography (CT), magnetic resonance imaging (MRI) and more. The tomography apparatus is the respective measuring (transmitting/measuring) apparatus associated with the tomography process.

In the present case the term "measured values relating to geometry" refers especially to the external diameter, internal diameter, wall thicknesses and/or layer thicknesses of the fibre or fibre layers. The terms "measured values relating to geometry", "geometry measured values" and/or "geometry data" are in some cases used synonymously.

A "polymer substrate" may be a molten polymer material produced from a solid, in particular from a solid granulate of the polymer material, for example by heating and/or subjection to pressure. The polymer substrate may alternatively be a liquid polymer solution comprising the polymer material and a suitable solvent.

"Polymer solution" is especially to be understood as meaning liquid and/or liquefied polymers which are present especially in a solvent or solvent mixture. The polymer solutions especially include aromatic polyimides, aromatic polyether imides, polyarylene ethers, aromatic polybenzimidazoles and/or mixtures thereof. Polymer solutions also include polymers having an intrinsic microporosity (PIMs). The polymer solution may further comprise 2D or 3D fillers, which are suitable in terms of size and constitution for spinning using the spinning unit for hollow fibres. These may include for example zeolites or organometallic scaffold and support materials. Also to be included are hollow fibre membranes where the active separatory layer is at least partially formed from an inorganic material such as for example at least one zeolite and/or at least one organometallic compound.

In the case of a fibre spun from a molten polymer material the term "exchange unit" is to be understood as meaning a curing and cooling unit in which a first solidification of the fibre is effected. The curing and cooling unit may be a cooling apparatus or comprise same. In the case of a fibre obtained from a polymer solution the term "exchange unit" is to be understood as meaning a station or unit for solvent exchange which is a fixing unit in which at least partial solidification of the fibre material is effected, wherein the fixing unit is especially arranged such that the fibre may be introduced thereinto or passed therethrough immediately after the spinning unit. Furthermore, the "exchange unit" for at least partial solidification of the polymer material may comprise at least one radiation emitter, for example a UV or IR emitter, to excite at least one radiation-activated, crosslinking component of the polymer material for chemical reaction and thus initiate at least partial solidification of the polymer material.

The individual fibre is primarily a hollow fibre spun from the polymer solution. However, this invention is altogether not restricted in terms of the polymer substrate, provided the latter is penetrable by a tomographic emitter, in particular can be penetrated by a light beam from an OCT unit. The polymer substrate from which the hollow fibre is spun is typically continuously supplied as ring fluid via an annular gap of the spinning nozzle or the spinning head, wherein the hollow, central core is dimensioned (internal diameter) and held open by control via a solvent. This solvent is supplied as core fluid to the spinning nozzle continuously and in parallel with the polymer substrate via a central (core) outlet.

The aftertreatment unit advantageously comprises at least one thermal treatment unit and optionally also the heat treatment station and may further also comprise a washing unit upstream of the at least one thermal treatment unit. The aftertreatment unit may further comprise at least one coating unit, in particular a coating unit in which a polymer substance such as for example polydimethylsiloxane (PDMS) is applied to the fibre as coating composition. Application may be carried out using a bath, for example an immersion bath, dipping device, a coating apparatus, or a spray apparatus.

The thermal treatment unit may thus comprise a thermal treatment station which is configured as a drying station or heat treatment station with a heat treatment furnace for heat treatment of the fibre/the polymer material. The thermal treatment unit may additionally comprise at least one further thermal treatment station, in particular arranged upstream of the heat treatment station. This at least one additional thermal treatment station may especially be a drying station after the exchange station for removing the solvent of the exchange station, wherein downstream thereof after a coating station at least one further drying station may be provided, in particular for removing the solvent present in the coating station/the coating composition employed therein. Even if reference is presently made to “a thermal treatment unit” this is generally not a constructional unit but rather the term is used to bundle all thermal treatment stations or steps.

The washing unit is especially used to wash out and/or to displace non-solvent, especially water, fractions added to the fibre in the fixing step by means of a volatile fluid, for example an alcohol. The washing unit can therefore be considered as a further or second exchange unit.

The connection of the detection unit with the control unit is presently to be understood as meaning any data-communicating wired or wireless connection, by means of which at least a portion of the measured values or (digital) data derived therefrom are transmitted, wherein at least temporary storage of measured values or the data derived therefrom is to be included. Furthermore, "data processing" or "processing of measured values or measured data" with regard to the detected measured values of the detection unit is to be understood as meaning any at least partially computer-implemented utilization, filtering, evaluation, linking with other plant and/or process data, representation in any form, storage, etc. of the measured values. The aforementioned data processing may be carried out centrally on a computer or computer unit or at least partially in decentralized processor units, in particular microprocessor units, wherein the detection unit may comprise at least one processor unit. Data utilization in the plant may consist in that

- in the simplest case values or value ranges are displayed to an operator on an (operator) monitor or a printout, said operator deriving control requirements for the system,
- specific control requirements of the plant are suggested on an (operator) monitor and/or
- at least partially automated control commands are sent to at least one plant component, unit or station.

The present hollow fibres for gas separation may especially be of two basic types:

i) ISA membrane
These comprise a support structure and a thin outer layer as the separatory layer, wherein the support structure and the outer separatory layer are produced monolithically from the same material in the spinning process and specific high separation characteristics are formed in the heat treatment step by heating to a temperature slightly below the glass transition temperature. A first separatory layer is formed during exchange or displacement of the solvent in the fixing station of the exchange unit since displacement of the solvent results in formation of a compressed layer like a skin on the outside of the membrane. The thickness of this separatory layer is adjustable for example via the distance of the spinning nozzle from the fixing bath. In a further advantageous embodiment it may be provided that the separatory layer/the fibre comprising the recited separatory layer are coated with at least one polymer material distinct therefrom (coating step), especially with the polymer material polydimethylsiloxane (PDMS).

ii) Asymmetric composite membrane (AC membrane) comprising a base fibre as a basic or support structure and an applied outer separatory layer, wherein at least one further

coating layer may be included.
To this end a porous base fibre which, in contrast to the ISA membrane, does not yet comprise an outer separatory layer is spun in a spinning apparatus and the subsequent exchange steps. This base fibre is then coated with at least one polymer material distinct from the base fibre as the outer separatory layer in an application station (application step). This separation layer may
i) comprise or substantially consist of a polymer material corresponding to one of the polymer solutions described herein, for example aromatic polyimides, aromatic polyether imides, polyarylene ethers, polybenzoxazoles, aromatic polybenzimidazoles and/or mixtures thereof, wherein optionally one or more 2D or 3D fillers may be included, for example zeolites or organometallic scaffold and support materials or
ii) be substantially formed from an inorganic material, for example at least one zeolite and/or at least one organometallic compound, wherein suitable binders may be provided.

The base fibre and/or the separatory layer of an AC membrane according to i) or ii) may be provided with a coating, in particular polydimethylsiloxane (PDMS), analogously to the ISA membrane.

In one variant of the plant and the process at least one application station or an application step for applying a separatory layer to a base fibre may therefore be provided to produce an AC membrane. It is further possible to provide at least one coating station as specified hereinabove, wherein the detection unit is configured to detect the thickness of the coating layer or the functional separatory layer of a base fibre (AC membrane).

The recited hollow fibres for gas separation, the recited polymers and/or substance mixtures thereof and the two recited fundamental types are particularly suitable for in-situ detection using an OCT unit. Without wishing to be bound to a particular interpretation, one reason for this may be that these polymers and/or substance mixture exhibit an adequate translucency and adequately good homogeneous light scattering. This applies equally to both fundamental types.

In an advantageous embodiment of the plant it may be provided that the detection unit is an optical coherence tomography unit (OCT unit), wherein the OCT unit especially comprises a measuring head having a beam axis dependent on its construction.

The detection unit in the form of an OCT unit may especially comprise at least one base unit and a measuring head. The base unit may comprise a central processor unit, at least one light emitter for light beam or measurement beam generation, wherein the light emitter is advantageously controlled by the processor unit. The base unit further comprises a detector for the reflected beam. The measuring head of the detection unit is essentially used for guiding and focusing the

measurement beam and the reflected beam and so the measuring head determines the position and orientation of the beam axis. The measuring head can form an assembly with the light emitter or be connected to the base unit, in particular the light emitter, in particular via light-conducting cables. The basic construction of a local, immovable OCT unit and its components is known and so the above elucidation should not be understood to be limiting.

In an advantageous embodiment the measuring head comprises a mirror unit having at least one motor-drivable, i.e. adjustable, mirror or reflector which may especially be secured to at least one synchronously drivable mirror carrier. The situation, inclination and/or position of the at least one mirror is altered via a control signal sent for example by the processor unit to the motor-drive of the mirror/the mirror carrier. This is done for example via a control cable, wherein the type of data transmission is in principle unlimited and may especially be effected as an electronic, acoustic or optical signal and via corresponding active or passive transmission means. The at least one mirror altered in its situation, inclination and/or position alters the beam axis of the light beam in parallel for example and is therefore scanned over the sample surface/scans the sample surface. Synchronization with the optical detector which at least partially receives the reflected beam may be necessary here.

The particular advantage of the OCT unit is that it is particularly economic and is very small in construction compared to other tomographic devices. It is also unnecessary to take safety measures against for example magnetic or radiological effects, such as are necessary in MRI or CT for example.

The measuring head of the OCT unit is advantageously arranged above the fibre(s), so that contamination on the lens is avoided. It may further be advantageous when the beam axis of the measuring head

- is inclined relative to the z-axis and rotated about at least one of the two other axes (x-axis, y-axis), advantageously by 10° to 60°, ideally by 20° to 50° and in particular by 45°. The fibre longitudinal axis is oriented identically or substantially identically to the x-axis, with the result that the z-axis is perpendicular to the fibre longitudinal axis of the fibre, wherein the fibre longitudinal axis is oriented in transport direction.

In an advantageous embodiment the beam axis/the measuring head may be aligned perpendicularly to the fibre longitudinal axis which substantially corresponds to the x-axis and/or the transport direction of the fibre at the detection site and be rotated by 45° from the perpendicular, generally the vertical, about the fibre longitudinal axis. This has the advantage that the measured value and data evaluation and for example the derivation of control data may be carried out in an altogether Cartesian system.

In the present case the plant comprises a main conveying direction which is substantially defined by the sequences of the treatment units and stations. The main conveying direction is a superordinate conveying direction of the plant or the process. The actual transport direction of the fibre or the fibre bundle along a (sub)section may diverge therefrom.

Thus, not only a single, superordinate Cartesian system is used, but rather a described plant site, in particular the detection region of the detection unit/the detection station, and the local orientation of the fibre is in each case described anew in relation to a local Cartesian system. In this case, the "respective" x-axis is oriented substantially identically to the local fibre longitudinal axis F_A or the local transport direction of the fibre. Furthermore, the indication that an individual fibre or fibre group is oriented “parallel or identically to the x-axis in the transport direction" is not to be understood in the mathematical sense but is used essentially for simplified linguistic description. Relatively small directional deviations of the individual fibres in the direction of the y-axis and/or the z-axis are thus also to be included. In particular a group of “parallel” individual fibres and/or individual fibres that are “parallel to the x-axis” may have different spacings in the direction of the y-axis in the detection region of the detection unit and/or the spacing in the y-direction and optionally also in the z-direction to adjacent individual fibres may vary on a transport section.

It may advantageously be provided that the one detection station comprises two or more detection units, each having a measuring head, wherein the at least two measuring heads are differently inclined with respect to the z-axis relative to the transport path of a fibre to be measured (i.e rotation about the y-axis) and/or are differently rotated about the fibre longitudinal axis (x-axis) from the vertical.

As an advantageous alternative or supplementary embodiment it may be provided that at least one measuring head is mounted and motor-drivable in such a way that it is rotatable in its inclination relative to the z-axis and/or about the fibre longitudinal axis (x-axis). For description of the inclination, tilt and/or the accompanying motion of the measuring head these elucidations shall be understood analogously for the beam axis of the measuring head.

The particular advantage of this different and/or alterable orientation of the beam axes is that a possibly only one-sided deformation of the fibre is also detected. By comparing the resulting geometries from at least two different beam axes a very valid assessment of the symmetry in the plane of the fibre dissected by the measurement beam may be made compared to only one measurement beam which transilluminates the fibre in only one orientation of the beam axis.

It may analogously be advantageous to identify plant-dependent influences when two detection stations are arranged along the main conveying direction in the plant at different sites and separately from one another, wherein the evaluation of the measured values may at least partially

be carried out in a common processor unit, in particular in one of the detection units and/or the control unit. The respective measuring heads of the at least two detection stations may be oriented or tilted identically or differently relative to the transport path of the individual fibre analogously to the above elucidations.

A measuring head is in each case part of a detection unit and for example connected to the base unit.

In a further advantageous embodiment of the plant it may be provided that the detection unit is configured alone or in conjunction with the control unit to detect and/or to determine through evaluation of measured values at least one of the following measured values of the fibre:

c. - external diameter (D),
   - cross-sectional area and/or
d. in the case of a fibre in the form of a hollow fibre
   - wall thickness (wA, wB) and/or
   - internal diameter (d)
e. inclusions and structural defects, for example bubbles.

The plant is advantageously configured such that during measurement using the measurement beam the fibre is conveyed, especially continuously, in the transport direction, the main conveying direction and/or actual transport direction of the fibre or the fibre bundle.

Upon passage of the measurement beam through the fibre especially the boundaries along the beam axis are identified as particularly high-contrast and thus light-coloured sites (peak regions). In the detection unit and/or the control unit after suitable measured value processing and/or digitalization the relative positions of these peak regions to one another may be measured to derive the local geometry or the geometry profile of the fibres, such as in particular the external diameter, the internal diameter and/or the local wall thickness. Also derivable from this is a calculation of the external cross-sectional area, the annular area and/or the internal cross-sectional area and these values may be utilized for a manual and/or at least partially automatic subsequent control of the plant.

In addition to boundary detection and the derivation of the recited geometries a further advantage is that foreign body inclusions and gas inclusions in the fibre, in particular in the wall of the fibre, are detected with the result that the detection station itself and/or the connected control unit can send suitable warning and error messages.

The measured value processing is advantageously carried out within the detection unit which forwards subsequently processed data to a control unit of the plant. In the simplest case this is also to be understood as meaning a visual representation for a plant operator via a monitor, an acoustic

signal, etc. The visual representation may advantageously be the display of a measured value, a target value deviation and/or a specific suggestion for operating the plants which is visible to an operator via a monitor. This representation can be effected in any way on the basis of text, signs, colors, graphics or any other basis.

The measured value processing, data transmission, storage and use of the data of the detection station shall not be understood to be limiting altogether and may especially be effected at least partially in decentralized fashion using different (microelectronic) components.

In a further advantageous embodiment of the plant it may be provided that the detection station comprises a drive unit, in particular a linearly displaceable drive unit, by means of which at least one detection unit is displaceable and/or tiltable transversely to the transport direction (y-direction) in order to detect, using the detection unit, geometry data of at least two individual fibres moved in the transport direction (x-direction). Compared to tiltable systems the linear drive unit is advantageous because an identical or largely identical distance to the individual fibre to be measured is maintained with the result that (almost) no new focusing due to the distance of the optics from the fibre surface in the direction of the beam axis is necessary.

It has surprisingly been found that sequential detection of the geometry data of the individual fibres is sufficient because the influencing parameters on fibre geometry generally do not suddenly change at least in settled production operation. It is thus economically very advantageous when a drive unit, such as a linear drive, may be used to displace one or more detection units with their respective associated measuring head transversely to the local transport direction of the fibres/the fibre longitudinal axes thereof.

In a further advantageous embodiment of the plant it may be provided that the at least one detection station is arranged at one of the following plant sites:
- between the spinning unit and the exchange unit;
- between the fixing bath and washing unit;
- in the region of the washing unit or after the washing unit, especially in the transition between two washing stations or washing baths;
- between the fixing unit and the aftertreatment unit;
- within or after the aftertreatment unit, in particular after the thermal treatment unit, primarily after a thermal treatment station of the thermal treatment unit.

An advantageous plant site of the detection station is in particular after the fixing and/or washing station, also exchange station, because at this plant site a still rather easily deformable raw fibre is transported and the influence of the spinning unit is still immediately apparent, as may be the case only to a reduced extent, if at all, after a thermal treatment unit. The control requirements for the upstream spinning unit can thus also be derived more directly. It has nevertheless proven

advantageous for the individual fibres at the plant site of the detection unit to be largely externally dry due to otherwise adverse signal noise in the case for example of adherent liquid droplets or inherently unstable liquid films.

In a further advantageous embodiment of the plant it may be provided that the detection unit is configured for
- detecting the presence and/or position of an individual fibre and/or
- motor-driven geometric alignment of an individual fibre for optimal detection of an individual fibre by the detection unit.

The detection unit is advantageously configured, upon approaching of the drive unit with the measuring heads to an individual fibre, to identify the peak region as optimal and to send corresponding control commands to the drive unit in order to stop the measuring head at least temporarily in this optimal position relative to the individual fibre and to especially undertake the individual measurements in this optimal position.

In a further advantageous embodiment of the plant it may be provided that at least one detection station comprises a further position sensor, by means of which the transverse arrangement (perpendicular) to the conveying direction of the fibres is detectable, wherein the at least one additional position sensor is for example one of the following sensors: laser scanner, for example a (3D) laser scanner, a thermal sensor, a camera, a sound sensor (ultrasound, sonar).

This separate position sensor may be, for example, a 3D laser sensor, a CCD camera or any other suitable sensor, in particular a contactless sensor, whose objective is merely that of position detection of the individual fibre. The position sensor is configured and/or in data communication with the control unit in such a way that this position information can always be made available for controlling the drive unit for at least one next individual fibre. In this way the measuring head can immediately assume the optimal measuring position relative to the next individual fibre to be measured. It is advantageous when the measuring head/the detection unit still independently controls small final optimization movements.

For effective resolution of quality defects detected by the detection station it may be advantageous when individual off-specification fibres are cut off from the strand and individually discharged. This makes it possible for example to undertake more complex rearrangements or further analyses of the plant and plant elements, such as especially the spinning unit, without having to interrupt production completely. It may therefore be advantageous when a cutting and discharging station comprising a cutting apparatus for cutting and discharging at least one individual fibre is arranged downstream of the detection station. The cutting apparatus may comprise a motor-driven knife or pair of knives, in particular a rotating, percussive or scissor-like knife or pair of knives. The motor-

driven knife may especially perform the cutting operation under automatic control, at least controlled taking into account and/or on the basis of the measured values from the detection unit.

A particular speed advantage is provided by such an additional positioning sensor if a problematic individual fibre or a group of problematic individual fibres must be measured more often than the rest of the individual fibres, for example because in the case of a problematic individual fibre an adverse trend away from the (target) specification is observed. The additional position sensor then enables very rapid, immediate positioning of the drive unit from any preceding measurement position and the corresponding return thereof.

In a further advantageous embodiment of the plant, it may be provided that the control unit is configured for receiving measured values from the detection unit and, based on the measured values, transmitting control data to the plants and/or to individual plant components for altered control, especially for automatic control/automatic adaption of control.

It may be advantageous when the plant or a corresponding control unit is configured such that the altered control can concern at least the following: the spinning unit, the residence time of the fibre and/or another manipulated variable and wherein

a. in terms of the spinning unit this may concern the following:
   - the volume flow of at least one individual nozzle,
     wherein it may be advantageous to distinguish between control of core and/or ring fluid and the associated apparatuses in the case of hollow fibre production and to control these independently,
   - the temperature of the at least one volume flow in/to an individual nozzle,
   - the volume flow of at least one inert gas in at least one down channel of an individual nozzle and/or

   the temperature of the at least one inert gas in the down channel of the individual nozzle;

b. in terms of the residence time of the fibre this may concern the residence time in at least one of the following units, such as in:
   - the exchange unit, especially the fixing unit and/or the washing unit,
   - a section of the fixing unit and/or of the washing unit and/or
   - the thermal treatment unit, wherein
   - the residence time in the respective units is especially adjustable via path length alteration for example using deflection elements displaceable in their distance to one another, in particular motor-displaceable deflection elements;

c. in terms of any other manipulated or controlled variable this may especially concern the following:

- the tensile force on the fibre in the transport direction (x-direction),
- the function of a separation and discharging unit for at least one individual fibre or a group of individual fibres,
- the pressure or temperature of at least one process medium,
- the pressure or temperature of the fibrous material, such as the polymer substrate,
- the elevation and/or the distance of the spinning unit and/or individual spinning heads from the exchange station, i.e. the distance to the liquid surface of the exchange station from the outlet of the spinning head which the newly formed fibre must overcome in free fall.

The term "concern", "concerns" and analogous terms in connection with control are to be understood as meaning that the respective parameter, the respective manipulated variable, the actuator, the actuator position etc. may be altered, especially made larger, smaller, switched on or off or adjusted to a fixed value, especially may be controlled according to a sensor value/measured value.

The “elevation” and/or “distance” of the spinning unit and/or individual spinning heads from the exchange station is to be understood as meaning the distance to the liquid surface of the exchange station from the outlet of the individual spinning head or a group of spinning heads of the spinning unit which a newly formed fibre must overcome in free fall. The term "free fall" is to be understood as meaning the motion of the fibre without external mechanical guidance, wherein a very small internal tension over the fibre material itself may be present. This very small internal tension in the direction of the longitudinal axis of the fibre may be introduced into the fibre via downstream transport and guiding apparatuses.

In this context it may be advantageous for easier adapted control of the spinning unit according to a. to exercise control over the storage and feed unit in order to undertake a control of the process which precedes or runs simultaneously with that of the spinning unit. This may concern pure process parameters, such as the pressure or temperature of the fluids and media of the storage and feed unit, it also being possible for example to adapt the qualities and/or concentrations for example of the fibre material and/or of a coating material.

The above points for control of the spinning unit may be controlled for an individual nozzle or for a group of two or more individual nozzles, wherein it may be advantageous to undertake, especially automatically undertake, simultaneous (parallel) control of a group of two or more individual nozzles and/or the supplying conveying and/or control elements, for example pumps, valves, actuators, heat exchangers, mixers etc.

To adjust and control the residence time the plant may advantageously comprise an accumulator, also named belt or strip accumulator, in the respective transport section, the plant part or the apparatus or device, such as a drying unit, for example in a furnace, a fluid bath, for example at

least partially immersed, in the form of a dynamic, driven accumulator. Such an accumulator comprises two or more guide and deflection units which move relative to one another and/or are adjustable in their distance to one another. The individual fibres are guided by the guide and deflection units in such a way that changing the position of at least one guide and deflection unit brings about a change in the path length within the accumulator, thus making it possible to control the residence time in the respective plant part, apparatus or device. The accumulator may especially be an integrated component of the respective plant part, apparatus or device. In an advantageous embodiment of the accumulator at least one deflection means may further comprise a deflection body, in particular a deflection roller, which is drivable about its own longitudinal axis by a motor and can thus introduce a force into the individual fibres in the conveying direction. Primarily, a plurality of such deflection bodies is provided.

In the present context the term "plant component" shall not be understood as limiting and shall include any constructional or functional units, actuating means or actuators for directly or indirectly effecting a desired controlled variable. Accordingly, "control of the spinning unit" is also to be understood as meaning adapting manipulated and/or controlled variables in supplying apparatuses, such as valves, throttles, heat exchangers, pump speeds/outputs etc.

In a further advantageous embodiment of the plant it may be provided that
the control unit is configured for receiving measured values from the at least one detection unit and, based on the received measured values, transmitting altered and/or new manipulated variables and/or controlled variables to the plants to control downstream plant elements, for example
- the thermal treatment unit,
- an electrical discharge unit, especially for siliconization,
- a heat treatment station.

This makes it possible for example to adapt the drying time and/or temperature to the thickness of the hollow fibres
In the present case "receiving" data is also to be understood as meaning intermediate storage and optionally evaluation, such as averaging, converting, filtering, extrapolating/interpolating or other mathematical processing of the data in order to make these useful for the purpose of providing or adapting manipulated and/or controlled variables.

The invention further provides a process for producing a fibre, including a solid fibre or a hollow fibre, from a polymer substrate, wherein the fibre is produced in a plant configured according to at least one of the preceding variants or embodiments and wherein

i) in-situ measured values relating to the geometry of the fibre conveyed in the transport direction are detected and/or determined, namely at least
a diameter, a wall thickness and/or a cross-sectional area, and

ii) in a subsequent control step at least one plant part/element is controlled, especially controlled multiple times, on the basis of the at least one measured value.

The step recited under i) is thus especially an in-line monitoring of a new control parameter, namely of the recited fibre geometry.

The in-situ measured values are received at least in part by decentralized processor units (CPU) and/or a central control unit, optionally temporarily stored and/or suitably filtered, processed and transmitted to an executing plant element, such as an actuator, and/or used therein to generate the subsequent control step for at least one plant part/element.

In the present case all aspects and advantages elucidated in respect of the plant shall identically or analogously also apply to the process and vice versa, provided these are not technically precluded/impossible.

The same detection unit and process may moreover also be used to measure a coating layer on a fibre. It is especially possible to detect a coating layer if said layer has a thickness of not less than 2 µm, especially of not less than 3 µm. Every tomographic technique and apparatus has specific resolution limits that affect the resolution of measurement especially in the lower threshold range. The aforementioned limits are defined by the wavelength of the employed light source and the optics, especially the opening width (aperture) of the objective lens, of a corresponding tomography apparatus and the resolution resulting therefrom. This then gives rise to a further two boundaries along a beam axis S, wherein in the geometry evaluation of the individual fibre a distinction may be made between the “harder” boundaries of the fibre material and the “softer” boundary of the possibly still liquid or pasty coating material and for example the thickness of the separatory layer of an AC membrane. This makes it possible to monitor the homogeneity of a coating layer and a separatory layer and thus the performance or application quality of an associated (application) apparatus with the same at least one detection unit.

In the present case “in-situ” measurements or measured values are to be understood as meaning that these are undertaken and/or detected during the ongoing, uninterrupted production process of the individual fibre(s). It is advantageous when an individual measurement on an individual fibre consists of a plurality of identical measurements according to the same measurement principle. In this case “transported” fibre is to be understood as meaning a fibre moved in the transport direction at a speed $v > 0$ m/s or an uncut fibre temporarily stopped at $v = 0$.

In the case of an individual fibre which is in the form of a hollow fibre, especially the internal and external diameter and/or the wall thickness of the hollow fibre are determined. A detection unit, such as an OCT unit, is used to determine especially in one step, especially the first step, the

external boundaries and internal boundaries for a hollow fibre, from whose distance to one another the diameter and thus the wall thickness may be determined.

These measured values are advantageously used to generate and/or adapt at least one manipulated variable and/or a controlled variable for a plant part/element, in particular effect repeated control operations. As mentioned above this is to be understood as also including simple displays, printouts and subsequent manual plant control by a plant operator.

In an advantageous embodiment of the process a first detection step which is a position detection step may be used to determine the transverse position of the conveyed individual fibre to be detected (sample fibre), wherein detection of the transverse position of this individual fibre is effected using
- the detection unit itself and/or
- another (additional) position sensor.

A "sample fibre" is to be understood as meaning an individual fibre
- which is directly measured by the detection unit or
- whose current position in the y-direction is determined specifically because this individual fibre is or shall be approached by the detection unit as the next individual fibre to be measured.

As mentioned above in this embodiment of the process the position sensor detects the position data of individual fibres, in particular in the y-direction, in a step preceding that of displacing the detection unit/the measuring head. These position data are then provided in a subsequent step for controlling the displacement path of the OCT unit/the drive unit thereof in the y-direction, thus allowing fastest possible individual fibre detection. The drive unit thus completes at least a subsection of its motion “transverse” to the transport direction of the individual fibres based on the position data provided directly or indirectly by the position sensor.

In a further advantageous embodiment of the process
- a further detection step which is a boundary detection step or
- a first boundary detection step
comprises detecting the individual fibre (sample fibre) using the detection unit in a first orientation of the detection unit, wherein

i) the external boundaries along a conveying section of the individual fibre are detected, especially repeatedly detected along a conveying section of the individual fibre, and wherein the diameter (D) and/or the cross-sectional area of the individual fibre is determined from at least one pair of external boundaries, and

ii) optionally (additionally) in the case of an individual fibre (sample fibre) in the form of a hollow fibre the internal and external boundaries of the individual fibre are detected, especially repeatedly detected along a conveying section of the individual fibre and wherein the external diameter (D), the wall thickness (w_A, w_B) and/or the cross-sectional area of the individual fibre are detected from at least one pair of internal and external boundaries.

In an advantageous embodiment of the process 5 to 20 individual measurement points are set in a single measurement while the fibre is conveyed in the transport direction. An individual measurement from such a group of measurement points has a duration of about 0.5 to 2.5 s.

These measurement points may be used to derive an average value in respect of the desired control value, for example the internal diameter. Alternatively or in addition for safety reasons the most unfavourable measured value from the group of measurement points of the individual measurement may be considered as guiding, with required control commands being derived therefrom. The process is in principle not limited in terms of the selection and/or combination of the measured values of an individual measurement and/or of an overall measurement.

It may further be advantageous when only the measured value or the (sub)group of measured having the highest intrinsic quality are selected and evaluated, wherein the intrinsic quality value is a quality criterion inherent to the measured value, such as freedom from noise, sharpness, contrast strength, uniqueness etc.

In the present case “overall measurement” is to be understood as meaning a defined sequence of individual measurements on different individual fibres, especially a repeating sequence of individual measurements on different individual fibres, predominantly on all individual fibres of the plant. In the simplest case an overall measurement comprises approaching and measuring all individual fibres 1 to n in the y-direction consecutively as sample fibres. A new overall measurement can commence when individual fibre 1 is approached again as the sample fibre or when in the opposite y-direction the nth individual fibre is approached and measured as the first sample fibre.

Since the individual fibres on the transport in the detection region of the measuring head of the detection unit are guided in the y-direction only to a limited extent, if at all, an adjustment of the position of the measuring head relative to the sample fibre may also be carried out using the drive unit during the individual measurement. This is done using the sensor data of the detection means itself and/or of a position sensor in analogous fashion.

In a further advantageous embodiment of the process in the further detection step which is a boundary detection step the individual fibre may be detected in a second orientation of the detection unit/the measuring head thereof using a further detection unit, wherein

a. the further detection unit is arranged in the same detection station and/or

b. the further detection unit is comprised by a further detection station which is arranged downstream of the first detection unit.

A particular advantage of this at least double arrangement and different orientation of the measuring heads/the beam axes thereof is that in the circumferential direction of for example a hollow fibre the external and internal diameter may be determined in two places and the wall thickness may be determined in four places. This makes it possible to achieve very high quality information about the geometry of the hollow fibre, in particular about the uniformity and symmetry of the wall profile in the circumferential direction of the individual fibre and/or also about flattenings or ovalities of the outer fibre surface which ideally has a symmetrically round, annular shape.

In a further advantageous embodiment of the process the further detection step may be followed by a control step in which on the basis of received measured values from the detection unit the control unit transmits control data/commands to at least one plant part/element for altered control, especially automatic altered control.

It may be advantageous for the process when the altered control concerns at least the following: the spinning unit, the residence time of the fibre and/or another manipulated variable, and wherein

a. in terms of the spinning unit this concerns the following:
   - the volume flow of at least one individual nozzle,
   - the temperature of the at least one volume flow in/to an individual nozzle,
   - the volume flow of at least one inert gas in at least one down channel of an individual nozzle and/or
   - the temperature of the at least one inert gas in the down channel of an individual nozzle and

b. in terms of the residence time of the fibre this concerns the residence time in at least one of the following units, such as in:
   - the exchange unit, especially the fixing unit and/or the washing unit,
   - a section of the fixing unit and/or of the washing unit and/or
   - the thermal treatment unit, wherein
   - the residence time in the respective units is especially adjustable via path length alteration for example using deflection elements displaceable in their distance to one another, in particular motor-displaceable deflection elements;

c. in terms of any other manipulated or controlled variable this especially concerns the following:
   - the tensile force on the fibre in the transport direction (x-direction),

- the function of a separation and discharging unit for at least one individual fibre or a group of individual fibres,
- the pressure or temperature of at least one process medium,
- the pressure or temperature of the fibrous material, such as the polymer substrate,
- the height and/or the distance of the spinning unit and/or individual spinning heads from the exchange station.

In this context it may be advantageous for the process for easier adapted control of the spinning unit according to a. to exercise control over the storage and feed unit in order to undertake a control of the process which precedes or runs simultaneously with that of the spinning unit. This may concern pure process parameters, such as the pressure or temperature of the fluids and media of the storage and feed unit, it also being possible for example to adapt the qualities and/or concentrations for example of the fibre material and/or of a coating material.

The above process features for control of the spinning unit may be controlled for an individual nozzle or for a group of two or more individual nozzles, wherein it may be advantageous to undertake, especially automatically undertake, simultaneous (parallel) control of a group of two or more individual nozzles and/or the supplying conveying and/or control elements, for example pumps, valves, actuators, heat exchangers, mixers etc.

For optimized production of a highly uniform internal and external diameter of the hollow fibre it may be particularly advantageous according to one variant of the process to distinguish between control of core and/or ring fluid and the associated apparatuses and to control these independently of one another. The independent control especially concerns the magnitude of the respective volume flow and/or the temperature of the respective volume flow in/to an individual nozzle for the core fluid or the ring fluid.

In the process according to the invention the fibres and/or the at least one (fibre) bundle are preferably conveyed at a conveying speed $v_F > 0$ in the transport direction in the range from 0.2 m/s to 1.4 m/s, ideally in the range from 0.5 m/s to 1.0 m/s. This conveying speed v_F of the fibre is advantageously unchanged during detection using the detection unit.

As mentioned above in respect of the plant for measured value determination the control operation shall analogously also include an optical representation being effected for a plant operator via a monitor or a local signal (optical or acoustic) in case of exceedance of a threshold value and the plant operator initiating manual control commands and/or otherwise adapting relevant parameters for fibre geometry formation. In a simple case a spinning head which is operating out of specification can be deactivated or the fibre produced by the spinning head can be at least temporarily discharged and disposed of until possibly subsequent maintenance operations and/or constructional adaptations may be undertaken at the spinning head.

In an improved process, derived control commands are sent to the relevant plant components in at least partially automated fashion, for example to a valve or conveying unit arranged upstream of the spinning unit. It is especially advantageous to control the supply pressures and/or volume streams of the polymer substrate (annular gap) and the process medium for cavity formation by means of a core liquid via a central tube of the spinning nozzle independently and separately for each individual nozzle, especially on the basis of the geometry data determined by the detection unit.

The solution according to the invention will now be described in detail with reference to exemplary embodiments. The figure shows:

Fig. 1 shows the plant in a first variant,
Fig. 2 shows the plant in a second variant,
Fig. 3 shows the plant in a third variant,
Fig. 4 shows three detail and partial views I.-III. of the detection station in a first embodiment
Fig. 5 shows two detail and partial views I.-II. of the detection station in a further embodiment and
Fig. 6 shows the experimental result using a plant after commencement of detection using a displaceable detection unit.

The plant 100 as shown in figure 1 has a main conveying direction A shown from left to right. The plant 100 comprises a control unit 130, a storage and feed unit 140, a spinning unit 106, an exchange unit 240 and an aftertreatment unit 170. The exchange unit 240 comprises in the exemplary plant shown a fixing unit 150 and a washing unit 160, wherein the aftertreatment unit 170 comprises a thermal treatment unit 200 with a drying station 210. Connected downstream of the aftertreatment unit 180 in the forwarding direction B is a heat treatment station 250. The fibre 110 is transported through the plant 100 in the main conveying direction A and repeatedly diverted and/or deflected laterally or vertically in subsections. Descriptions such as "vertical", "transverse", "perpendicular" or "parallel" are not to be understood in the mathematical sense but rather as "substantially so", i.e. as self-evident descriptions to aid understanding.

The control unit 130 is connected to the plant 100 and many plant components via data conduits 132, as shown by way of example by a dashed line. Other elements for energy and data transmission and automation of the plant are basically known to those skilled in the art and not further illustrated here. The storage and feed unit 140 is likewise only outlined and comprises two tanks 142 or tank farms for media, in particular a tank (farm) 142 for the product or fibre media 102, such as for example the polymer substrate, especially the polymer solution and/or the starting materials thereof, and a tank (farm) 142 for process media 104. Also included are a pump and/or valve unit 146 and an (inert) gas storage means 144. A heat exchanger 148 is also arranged in the

conduit path of the inert gas. Further known apparatuses for filling, treating, conditioning and/or conveying media are customary in the art and not presently represented.

These plant components feed unit 140 are especially in media communication with the spinning unit 106. The fibre 110 is formed in the spinning unit 106 in a manner which is not further described here, wherein details for fibre production and the construction of these elements may be found for example in WO 2014/202324 A1. Process media employed downstream of the spinning unit 106 may further be stored in and provided from the feed unit 140.

The freshly formed fibre 110 is introduced into the fixing medium of the fixing unit 150 in free fall from height H, the distance of the spinning unit 106 from the liquid surface of the fixing medium of the fixing unit 150 and discharged from the bath of the fixing unit 150 via guide rollers 108. The individual fibres 110 are oriented at a defined spacing to one another transverse to the transport direction using lane guides 109 which have a comb-like or multi-fingered configuration. The washing unit 160 comprises a plurality of guide rollers 108 which are arranged below the fluid level of the washing liquid and by means of which the fibres 110 are held in the washing liquid, in particular in an alcoholic washing liquid, for a defined cycle time to remove the water content and solvent residues from the fibre 110. The washing unit 160 may also be composed of a plurality of serially arranged baths (not shown).
For the hollow fibre 110 formed from a polymer solution 102 the fixing station 150 dissolves out the solvent content and subsequently the washing unit 160 washes out water contents with a volatile medium, such as an alcohol.

Connected downstream of the washing unit 160 is a drying station 210, wherein in a grouping station 260 at the entrance to the drying station 210 the fibres 110 are combined into a (fibre) bundle 112 and passed as a strand via deflection rollers 108 through the drying stations. The drying station 210 especially serves to condition the fibres 110 for the subsequent heat treatment to prevent adhesion of fibres 1110 to one another and/or membrane damage through excessively fast vapour formation. The drying station 210 is connected to a gas feed conduit 212 and a gas discharge conduit 214, wherein the gas feed conduit 212 has arranged in it a heat exchanger 216 for heating the gas supplied via the feed conduit C. This gas supplied via the feed conduit C is especially dehumidified air. In the drying station 210 the bundle 112 in the form of a strand is repeatedly deflected by deflection rollers 108 while it is surrounded and dried by the heated gas. The deflection rollers 108 are typically static bodies over which the conveyed fibre 110 or the bundle 112 is drawn, wherein in certain variants (not shown) it may be advantageous to drive at least individual deflection rollers 108 such that these rotate about their own longitudinal axis and in the direction of the fibre longitudinal axis and thus uniformize and/or reduce the stress within the fibre 110/the bundle 110.

A detection station 120 with a detection unit 122 is arranged in the transition between the exchange unit 240 and the drying station 210. In this region the individual fibres 110 are advantageously passed through lane guides 109 spaced apart from one another, especially substantially parallel to one another. As shown in detail in particular in figures 5 and 6 the detection unit 122 with its associated measuring head 124 itself is arranged on a drive unit 125 and may thus be displaced transversely to the transport direction floating above the fibres. The fibres 110 themselves are for example floatingly conducted in the detection area of the detection unit 122, wherein a lower shielding plate may be provided (not shown) in order to keep ascending vapours away from the measuring head 124 and also to provide a defined contrast between the fibre material and the background in order that disruptive scattered light, gas movements and any other inhomogeneities adjacent to the fibre 110 are avoided. The Cartesian system illustrated relates to the location of the detection station 120, wherein the individual fibres 110 are oriented substantially parallel to the x-axis. The measuring head 124 and its beam axis (not shown) is perpendicular to the sample fibre and is inclined by 45° relative to the z-axis and rotated about the x-axis, wherein the z-axis represents the 0° position of the inclination. The measuring head 124 is not rotated about the y-axis.

The measured values received by the detection unit 120 via the measuring head 124 (reflected beam) are optionally at least partially processed in a base unit with an internal processor unit and at least temporarily intermediately stored if required. The partially or completely processed and measured values from the control unit 130 are subsequently provided for control of at least one plant component. The data conduit 132 shown as a dashed line may be any data network or any communication technology, in particular an Ethernet or a data bus system or else a PoDL system (Power over Data Line System).
Plant 100 shown in figure 2 differs from plant 100 according to figure 1 especially in that the detection station 120 comprises a position sensor 136 in addition to the displaceable detection unit 122. Also arranged downstream of the detection station 120 and at the entrance to the aftertreatment unit 170 is a cutting and discharging station 114. The discharging of a defective fibre 110 into a container arranged therebelow is shown in very schematic form.

The detection unit 122 with its associated measuring head 124 is held against or on the drive unit 125 and is displaced transversely to the transport direction of the fibres 110. The measuring head 124 and the associated beam axis is aligned relative to the sample fibre 110 and the transport path of an individual fibre analogously to the plant according to figure 1. The position sensor 136 is designed as a 3D laser scanner or CCD camera which continuously detects the respective orientations of the individual fibres 110 and the fibre longitudinal axes F_A thereof and provides the drive unit 125 and/or the control unit 130 especially with the y-coordinates of the individual fibres 110 and the orientations of the fibre longitudinal axes F_A. The position sensor 136 is locally mounted in the detection station 120 and as a consequence of its construction can detect all individual fibres 110 from a single position. This allows the measuring head 124 to be immediately

displaced into the optimal position relative to the (next) sample fibre 110 on the basis of the provided y-coordinates in a very rapid motion. The detection unit 122 itself can then carry out the last adjustments in the direction of the y axis, for example on the basis of the detected contrasts and/or boundaries.

A dehumidification station 220 is arranged upstream of the detection station 120 and on the discharging upward conveying section out of the washing unit 160. This detaches by means of a slot nozzle, shown in cross section as a triangle, or a group of individual nozzles the liquid film or liquid droplets adhering to the individual fibres 110 and forces this free liquid content (process medium 104) back into the bath of the washing unit 160. The dehumidification station 220 is fed especially with conditioned air via the gas conduit 222.

In contrast to the two preceding exemplary embodiments the embodiment according to figure 3 comprises two detection stations 120, wherein the first detection station 120 is arranged upstream of the thermal treatment unit 200 and the second detection station 120 is arranged downstream of the thermal treatment unit 200. In the example shown the beam axes of the two measuring heads 124 are arranged in a single plane which is oriented parallel to a plane defined by the z- and the y-axis, wherein the two measuring heads 124 and their beam axes S are each inclined by 45° from the vertical in opposite directions relative to the z-axis and rotated about the x-axis in opposite directions. The angle α to the vertical for example is plus 45° and the angle β to the vertical minus 45°, so that the angle between the two beam axes is 90°.

The advantage of a detection station 120 divided in this way is that a first detection of the still very easily mechanically deformable fibre 110 is effected, as also described above. The physical and mechanical influence of the thermal treatment unit 200 may further be detected and estimated via the second detection unit 122 in addition to the further geometric data by the different angle of inclination of the measuring head relative to the fibre 110. Through observing the transport speed and a targeted, time-delayed approaching of the sample fibres 110 before and after the thermal treatment unit 200, it is possible to target largely identical fibre sections of the same individual fibre 110, with the result that the measured values from the second detection station 120 may be evaluated complementarily and simultaneously to those from the first detection station 120.

In the embodiment of figure 3 the individual fibres 110 are transported through the drying station 210 in parallel and spaced apart from one another and formed into a (fibre) strand 112 using the grouping station 260 downstream of the second detection station 120. The schematically illustrated conveying means 280 convey the (fibre) strand 112 in the forwarding direction B.

Although the detection station 210 is shown substantially in a horizontal orientation in the figures, wherein the transport direction of the fibre is parallel to the main conveying direction A, it is apparent to those skilled in the art that the orientation of the detection station 210 and/or the

transport direction of the fibre in the detection region of the at least one measuring head is not limited and may occupy any spatial orientation and/or inclination.

Figure 4 shows the detection station 120 in three partial views I., II. and III.
Partial view I is a top view of the detection station 120 which is at least in data communication with the control unit 130 via data conduits 132. Altogether eleven individual fibres 110 are arranged parallel to one another, wherein their fibre longitudinal axes F_A are in a common plane E defined by the x- and the y-axis. The group of individual fibres 110 floats in the detection region of the detection station 120 above a shielding plate 118 configured as a bottom sheet or bottom element (fig. 5). The (local) transport direction of the individual fibres 110 corresponds to the fibre longitudinal axes F_A and is substantially parallel to the x-axis. Arranged above the individual fibres 110 is the drive unit 125 whose mounting is inside the detection station 120 and is likewise not shown. The drive unit comprises a displaceable mover 126, which is held and guided on a linear guide element 128, a kind of rail, wherein the directions of motion are indicated by the double arrow. The drive unit 125 and the detection unit 122 are in data communication with the control unit 130 via the connections 132.

The mover 126 itself is moved for example via a spindle drive that engages with a suitable transmission on the mover 126 (not shown). Alternatively, the mover 126 itself may be motorized and mesh for example with a driven ring gear for example on a static gear rack of the guide element 128. In principle a multiplicity of drive types are known and conceivable for displacing a mover 126 with a positioning precision of 2 to 10 µm.

The mover 126 itself serves as a carrier and drive element for the detection unit 122 with its associated measuring head 124. The detection unit 122 and the measuring head 124 form one assembly in the example shown.

The partial images II. and III. especially serve to elucidate the beam paths and to illustrate the detected geometries of the hollow fibre 110.

The partial image II. shows the drive unit 125 in a front view and six individual fibres 110 which were cut vertically. The light beam transmitted by the detection means 122, also known as the impulse beam, parallel to the beam axis S is shown as a solid arrow and is incident on the fourth individual fibre 110 (sample fibre) from above and to the left. The measured beam reflected by the fibre 110 (also known as the reflected beam), is shown as a dashed arrow and runs in the direction of the measuring head 124. The measuring head 124 or its beam axis S is oriented vertically, i.e. parallel to the z-axis. From the light source of the detection unit 122 a light beam is transmitted parallel to the beam axis S in the direction of the sample fibre 110, shown as a solid arrow pointing downwards. This light beam is at least partially reflected back into the measuring head 124 and the detection unit 122 as a reflected beam, shown as a dashed arrow.

Partial view III. shows an enlarged representation of the sample fibre 110 from partial image II. in a vertical cross section.

The light beam is incident on the first outer surface of the fibre 110, the first boundary G_1, and this generates a first very strong reflection and thus a first reflected beam. After passage of the light beam through the wall of the individual fibre 110, which is shown as hatched, a second comparable reflected beam is transmitted back in the direction of the measuring head 124 at the second boundary G_2, the transition from the solid into the inner cavity. Analogous reflected beams are generated at the third boundary G_3 and the outer, fourth boundary G_4. In a sheetlike 2D representation the four boundaries G_1-G_4 are shown as light patches or short strips and their distance from one another may be measured. This makes it possible to determine the following geometry data: External diameter D, internal diameter d, (upper) wall thickness w_A and (lower) wall thickness w_B.

These may be used in simple fashion to identify for example the size of the cross sectional area, differences in the two wall thicknesses w_A, w_B, to determine the internal (free) flow cross section or cross-sectional area and also altogether to derive information about the symmetry of the individual fibre 110.

Analogously to figure 4, figure 5 comprises a drive unit 125 with a mover 126, wherein the displaceable mover 126 has two detection units 122 arranged on it. The beam axes S_1, S_2 of the two measuring heads 124 are oriented at right angles onto the same (middle) sample fibre 110, i.e. there is a right angle between the fibre longitudinal axis F_A and the two beam axes S_1, S_2. Furthermore, the two beam axes S_1 and S_2 are rotated about their x-axis in opposite directions, so that these transilluminate the individual fibre 110 at different angles and sites of incidence in the circumferential direction as shown in partial image II. Partial image I. or figure 5 shows two embodiments of detection units 122. In the left-hand detection unit 122 the base unit 123 is connected to the measuring head 124 via light-conducting cables and further conductor tracks and only the measuring head 124 is rotated or inclined according to the desired position of the beam axis S_1. In the right-hand embodiment of the detection unit 122 this is a closed assembly having an integrated measuring head 124, wherein the entire detection unit 122 is inclined or rotated according to the desired position of the beam axis S_2.

Analogously to the partial image III. of figure 4 the partial image II. of figure 5 shows the individual fibre 110 in a magnified view as a vertical cross-sectional representation, wherein the fibre wall is shown as hatched. The fact that the beam axes are rotated in opposite directions results in 2 x 4 boundaries at the respective phase transitions (not shown for clarity). This arrangement on the circumference of the hollow fibre accordingly results in the determination of two external diameters D1, D2, two internal diameters d1, d2 and four wall thicknesses w_{A1}, w_{A2}, w_{B1}, w_{B2}.

These eight geometry data from the measured values of the OCT unit allow a very differentiated interpretation of the total fibre geometry, from which corresponding control data for the plant/individual plant components may be derived.

Figure 6 shows results from the quality monitoring of the plant/the finished filter modules before and after implementation of the detection station and is subsequently discussed in connection with the experiments.

In all depicted exemplary embodiments of the plant and the process it is possible according to one variant (not shown) for at least one deflection roll 108, especially two or more deflection rolls 108, to be part of a dynamic, driven accumulator which is integrated for example in the exchange unit 240, the drying station 210 etc. and by means of which the respective residence time of the fibre 110 may be adjusted.

Experiments and experimental results

Experimental setup

The experimental setup of the detection station 120 for measuring a group of 40 individual hollow fibres 110 from a production plant 100 in which continuous and substantially parallel fibres were moved in the direction of the fibre longitudinal axis FA (x-axis) corresponded substantially to the plant and OCT system shown and described in figure 1 and figure 4.

The individual fibres, herein hollow fibres, were conveyed parallel to one another on an industrial production plant and had an average distance to one another of about 1.5 cm. The respective pairs of two individual fibres each had spacings of 0.2 to 2.0 cm, wherein these pairwise distances were not static but rather changed regularly as a result of the rather loose fibre transport in the transverse direction.

The fibres were conveyed at an identical or largely identical conveying speed v_F which was varied in the range from 0.5 m/s to 1.0 m/s. The conveying speed v_F in the recited experiments was in each case 0.67 m/s.

The detection unit and measuring head employed was the OCT system from Thorlabs Telesto TEL321C1/M.

The detection station 120 was arranged in the region of and above the washing unit 160 at the transition of two individual baths and shielded from the vapours from the washing unit 160 with a shielding element in the form of a stainless steel sheet. The detection unit 122 with the OCT

measuring head 124 was arranged on a linear drive unit 125 whose linear guide element 128 was in the form of a rail. This was arranged perpendicular to the transport direction (x-axis) and above the moving fibres 110. The detection unit 122 and the measuring head 124 were secured to the motor-driven mover 126 and the detection unit 122 and the measuring head 124 were connected to one another via glass fibre cables and control cables. The processing of the measured values detected as reflections by the measuring head was carried out substantially in the base unit 123 of the detection unit 122.

The beam axis S of the measuring head 124 was rotated by 45° about the x-axis and was perpendicular to this axis and the fibre longitudinal axis F_A.

The mover 124 comprised an electric drive unit which was engaged via a coupling unit with a stationary gear rack of the linear guide element and was electrically drivable thereby. The control of the movement path of the mover 124 was carried out according to measured values from the measuring head 124/the detection unit 122 and/or on the basis of control commands from the control unit 130 of the plant.

Experimental procedure

In each experiment the conveying speed v_F of the group of individual fibres in the direction of the fibre longitudinal axis F_A was kept largely constant at 0.67 m/s. The 40 individual fibres 110 were successively approached and measured in simple sequence and recurrently.

In an individual measurement the following steps were performed, wherein the position coordinates at least in the y-direction are constantly stored and evaluated along with the (accompanying) transmitted radiation and/or reflected radiation/measured values:

- Scanning step: The measuring head approached in the positive y-direction while transmitting a light beam (pulse). ("positive" means a first direction).

- Position detection 1a (coarse): The measuring head detects an individual fibre 110 by an elevated reflection which is generated by the presence of the first outer surface of an individual fibre 110.

- Position detection 1b (coarse): The measuring head is displaced further in the positive y-direction and detects from the same individual fibre 110 a further elevated reflection which is generated by the presence of the second outer surface of an individual fibre 110.

- Position detection (fine): The measuring head moves over a second reflection maximum detected in the positive y-direction, stops and returns in the negative y-direction to the

position of the detected second reflection maximum. Repeated fine position detection if required.

- Measurement step (individual measurement):

10-fold and/or 10-times detection of the sites of maximum reflection and/or measurement of the fibre geometry, wherein the fibre is conveyed in the x-direction. If necessary (fine) position adjustment in the y-direction with/by alteration of the position of the individual fibre 110 in the y-direction.

The individual duration ID of an individual measurement on an individual fibre (sample fibre) was about 1 to 1.5 seconds, during which the 10 detections (images) which were also evaluated separately were undertaken. A total measurement comprised 40 individual measurements according to the number of individual fibres plus the approach time for optimal positioning of the measuring head relative to the respective sample fibre. The displacing and positioning time VZ of the measuring head from a first fibre to a subsequent fibre was about 1.5 to 2 seconds. The duration Z for a total measurement of n individual fibres was therefore

Z = n x ID + (n-1) VZ which was in the range from about 100 s to 140 s for 40 individual fibres to effect geometric measurement of all fibres in production.

The x-fold detection of the sites of maximum reflection and/or measurement of the fibre geometry may be combined to an averaged individual value for a fibre (geometry) at a detection site and time of the fibre or evaluated as an x-times detection of a single value in each case, so that through the parallel transfer of the fibres during detection a limited profile of the fibre geometry is derivable and analysable from the individual values.

The movement directions of the mover are in principle equivalent in a total measurement so that the starting position may be arranged on either side of the group of individual fibres and a preceding return motion is unnecessary.

The hollow fibres produced according to the invention are especially suitable for gas separation of CO_2, O_2, CH_4 and N_2, especially for gas separation of air or biogases.

The suitability of the fibre for gas separation is evaluated especially with regard to permeance and selectivity. The permeance is the ratio of the permeability to the thickness of the fibre wall or membrane wall and represents a measure of the gas flow through the fibre wall or membrane and is thus an indicator of the structure and permeability of the hollow fibre or of the fibre bundle.

Permeability as the gas permeability and selectivity as the separation sharpness in respect of the desired gases were subsequently tested in the laboratory in the context of quality control of the

finished filter module composed of hollow fibres. Compressed air (~78% by volume N_2, 20.95% by volume O_2 and ~1% by volume other gases) at a pressure of 10 bar (abs.) was supplied at 20°C to the feed side of the filter module and the gas streams and gas concentration were measured at the permeate outlet (conduit) and at the retentate outlet (conduit) after attainment of a steady state for a defined time of 180 seconds.

The specification was deemed as complied with when this corresponded to that of a conventional plant known from the prior art, i.e. when a selectivity of at least 6.1 in respect of O_2 and an O_2 permeance of 10 GPU were achieved. Details are still described in connection with the figures.

In this quality control only one gas measurement and analysis for oxygen was undertaken. The O_2 concentration was measured downstream of the filter module using paramagnetic sensors in the discharge conduits and the total volume flow of the respective conduit was measured in parallel with customary volume flow sensors for gases. The other values especially for the N_2 gas content were calculated.

Permeability and permeance

Gas permeabilities are reported in barrer (10^{-10} $cm^3 \cdot cm^{-2}$ cm s^{-1} $cmHg^{-1}$). The permeances of the hollow fibre membranes for gases are reported in GPU (gas permeation units, 10^{-6} $cm^3 \cdot cm^{-2}.s^{-1}.cmHg^{-1}$) or derived units. The permeance is the ratio of permeability to substrate thickness (membrane thickness) for corresponding units, for example the unit l m^{-2} h^{-1} bar^{-1}.

Permeability

Permeabilities for gases may still be measured by the pressure rise method. A flat film of between 10 and 70 µm in thickness has a gas or gas mixture applied to it on one side. On the other side, the permeate side, a vacuum (about 10 - 2 mbar) prevails at commencement of the experiment. The pressure rise on the permeate side over time is then recorded.

The permeability of the polymer (substrate) may be calculated according to the following formula:

$$P = \frac{V_{dead} . MW_{gas} . l}{\rho . R . T . A . \Delta p} . \frac{dp}{dt} . 10^{10}$$

P	Permeability in barrer (10^{-10} cm^3(STP) cm) / (cm^2 s cmHg)
	[barrer] = 1.333*1017 * [Nm^3*m/(m^2*s*Pa)]
	STP (Standard Temperature and Pressure) is 0°C, 101325 Pa
V_{dead}	volume of permeate side in cm^3
MW_{gas}	molar mass of gas in g mol^{-1}
l	thickness of film in cm

ρ	density of gas in g cm^{-3}
R	gas constant in cm^3 cmHg K^{-1} mol^{-1}
T	temperature in kelvin
A	area of foil in cm^2
Δ p	pressure difference between feed and permeate side in cmHg
dp/dt	Pressure rise per unit time on permeate side in cmHg s^{-1}

If the permeance of hollow fibres is measured a volume rise method may also be used. The permeance P/l (since the thickness of the separating layer is unknown) may be calculated according to the following formula:

$$P/l = \frac{Q(STP)}{R.T.A.\Delta p}.10^6$$

P/l	permeance in GPU (gas permeation units. 10^{-6} $cm^3 \cdot cm^{-2}$ s^{-1} $cmHg^{-1}$)
Q	Gas flow of permeate side in cm^3 (STP)/s
R	Gas constant in cm^3 cmHg K^{-1} mol^{-1}
T	temperature in kelvin
A	external surface area of hollow fibre in cm^2
Δ p	pressure difference between feed and permeate side in cmHg
dp/dt	Pressure rise per unit time on permeate side in cmHg s^{-1}

The selectivities of various gas pairs are pure-gas selectivities. The selectivity between two gases may especially be calculated from the ratio of permeabilities:

$$S = P_1 / P_2$$

S	ideal gas selectivity
P_1	permeability or permeance of gas 1
P_2	permeability or permeance of gas 2

Experimental results

The setup made it possible for the first time to effect in-situ detection and provision of the geometry of the hollow fibres, in particular the non-heat-treated fibre, and to take into account geometry data as further controlled variable(s) in the plant and the process management. The provision of the measured values and geometry data is effected during performance of the experiments by display

on a monitor for interpretation by the plant operator who subsequently initiates the required manual control commands.

In the context of the performed experiments the resulting plant control consisted of manual cutting and discharging of the individual fibres identified as out of specification.

Figure 6 shows in the upper image section an operator view of a control monitor or a (protocol) printout with the individual fibres 1 to 40 (x-axis)/the associated spinning heads 106 of the plant 100 which were produced in parallel on the plant 100 (x-axis). The average internal diameter of all fibres normalized to "1" (one) is plotted on the y-axis, wherein the average internal diameter, normalized to one, is represented by the line at y = 1. The relative size of the internal diameters of the respective individual fibres is plotted as a ratio to the average internal diameter for each individual fibre from a spinning head with its own symbol (small circle, small cross). In addition, two specification ranges I and II are identified at the top and bottom, delimited by the respective horizontally dashed lines. Specification range I and the associated internal diameter is the preferred range, wherein the internal diameters in specification range II are still tolerable. All measured values measured and shown as a small circle represent the median of the internal diameters of the respective individual fibre 110 from a respective defined spinning head which are within the specification range I or II determined via a multiplicity of individual measurements over a defined period of 4 h.
The measured values shown as a small cross represent the median of the internal diameters of the respective individual fibre 110 from a defined spinning head which are outside the specification ranges I and II determined via a multiplicity of individual measurements over a defined period of 4 h.

The 40 spinning nozzles no. 1 to no. 40 are supplied with polymer solution in a fixed assignment of four pump blocks P1 – P4 (1-10, 11-20, 21-30, 31-40), as indicated by the braces which each represent one pump block. The measured geometry data, especially the internal diameters, are not identical to the internal diameters of the finished fibres which are subject to a defined shrinkage due to subsequent drying and/or heat treatment. However, it has been found that the formation of an average value over a longer period of at least one hour or up to a production shift of about 6 hours to 8 hours is sufficient for quality control as a relative measure of relevant geometries of all individual fibres. Here, "relevant geometries" is especially to be understood as meaning the internal diameter, the external diameter and/or the wall thickness at at least one fibre wall passage.

The lower image section shows a graph that shows the result of the quality test for finished filter modules 110 over time (x-axis). The quality check was undertaken in respect of permeance and selectivity, wherein in the present case only the selectivity is shown as a y-axis in the lower image section. The horizontal specification line at 100% (y-axis section) represents the defined target specification for selectivity. For each filter module produced the selectivity was measured in the

laboratory. Every filter module that was in specification is represented with the relative value as a small circle. Analogously, a filter module that was out of specification, here less than 100%, is identified as a small cross. Times or time units t1 to t5 are plotted on the x-axis. The distance from t1 to t2 represents a fixed time unit with a fixed (standard) duration of two or more hours, wherein the time units from t2 to t3 and from t3 to t4 have an identical duration. The time unit from t4 to t5 is shortened and has a duration of about a factor of 0.6 compared to the (standard) duration of for example t1 to t2.

Before bringing online the OCT detection unit at time t_2 in the duration t_1 to t_2 altogether 26 filter modules were produced and their specifications in respect of selectivity tested. 8 specification (~ 31%) of the 26 tested specifications were not achieved, symbolized by the small cross. These filter modules required manual aftertreatment. Bringing the detection station with the OCT detection unit online revealed that precisely three spinning nozzles, no. 3, no. 4 and no. 16, or three defined individual fibres, were deficient in respect of internal diameter, with the result that ~ 31% of the finished filter modules were out of specification for selectivity.

As shown in the upper graph the three measured values which were out of specification for the spinning strands (individual fibres) no. 3, no. 4 and no. 16 are shown as a small cross, which in the upper graph also symbolizes shutdown of the respective spinning heads and rejection and disposal of the respective individual fibres. These fibres were therefore cut manually and continuously discharged without interrupting continuous production in the test phase.

In the period from t2 to t5 altogether 90 filter modules were produced and subjected to quality testing, wherein the respective selectivity was also determined. Immediately after this discharging measure of these three out-of-specification individual fibres beginning at time t2 altogether only one filter module did not attain the (target) specifications for selectivity directly through the production process within the subsequent time units from t2 to t5.

The same advantage was demonstrated also for the permeability of the filter module after discharging of the defective individual fibre nos. 3, 4 and 16 (not shown), wherein the advantageous effect is most pronounced in respect of selectivity.

In addition, the location of the OCT detection unit has proven particularly advantageous because downstream of the fixing unit (150) and/or the washing unit (160) the (hollow) fibre is filled with a known fluid and thus the boundaries between the inner surface and the fluid are very contrast-rich and very readily detectable so that physical dimensions of the geometry data are derivable with very high quality and reliability. Here, "known" fluid also means that the refractive indices and other influences on the radiation required for calculation are known and usable.

Thus, in the five time units after introduction of the OCT unit according to the invention only one module did not achieve both specifications, with the result that attainment of the specifications for all filter modules per unit time was improved from about 70% to over 98%.

List of reference numerals

100 Plant
102 Polymer solution
104 Process medium
106 Spinning unit
108 Guide roller
109 Lane guide (y-direction)

110 Fibre
112 Fibre bundle, partial fibre bundle
114 Cutting and discharging station

118 Shielding plate
120 Detection station
122 Detection unit
123 Base unit
124 Measuring head
125 Drive unit
126 Mover, slide
128 Guide element, rail

130 Control unit
132 Data conduit

136 Position sensor

140 Storage and feed unit, also supply unit
142 Tank
144 Inert gas reservoir
146 Pump (unit)
148 Heat exchanger

150 Fixing unit
160 Washing unit
170 Aftertreatment unit

180 Finishing unit
188 Transport element, transport belt

200 Thermal treatment unit

210 Drying station
212 Gas feed conduit
214 Gas discharge conduit
216 Heat exchanger

220 Dehumidification station

240 Exchange unit

250 Heat treatment station
260 Grouping station
280 Conveying means

α angle
β angle

A Main conveying direction
B Forwarding direction
C Feed conduit
D External diameter; also D1, D2
d Internal diameter; also d1, d2
w_A, w_B Wall thickness (ring thickness, for hollow fibre); also w_{A1}, w_{A2}, w_{B1}, w_{B2}

E Plane
F_A Fibre axis
G Boundary, G_1, G_2, G_3, G_4
H Fall height
P1, P2, P3, P4 Pump block
S Beam axis, also S_1, S_2

Claims

1. Plant for producing a spun fibre (110) from at least one liquid polymer substrate (102) comprising a control unit (130), a storage and feed unit for media (140), a spinning unit (106) for forming the fibre (110), wherein downstream of the spinning unit (106) for treatment of the fibre (110) at least the following plant units are included in the recited sequence and wherein a plurality of guide and drive elements are provided along a transport path of a fibre (110) through the plant:
   a. an exchange unit (240), in particular for solvent exchange, comprising a fixing unit (150), into which the fibre (110) can be introduced or passed immediately after the spinning unit (106),
   b. at least one aftertreatment unit (170) especially comprising at least one thermal treatment unit (200), wherein the fibre (110) passes from the fixing unit (150) to the aftertreatment unit (170) in a main conveying direction (A), wherein the fibre (110) is a solid fibre or a hollow fibre,

   characterized in that

   downstream of the spinning unit (106) at least one contactless and non-destructive detection station (120) with at least one detection unit (122) is provided, by means of which at least one measured value relating to the geometry of the fibre (110) conveyed in a transport direction can be detected in situ, and wherein the detection unit (122) is at least in data communication with the control unit (130) and is configured to effect data processing of the at least one measured value.

2. Plant according to Claim 1, characterized in that the detection unit (122) is an OCT unit (optical coherence tomography unit).

3. Plant according to Claim 1 or 2, characterized in that the detection unit (122) is configured alone or in conjunction with the control unit (130) to detect and/or to determine through evaluation of measured values at least one of the following measured values of the fibre (110):
   a. - external diameter (D),
      - cross-sectional area and/or
   b. in the case of a fibre (110) in the form of a hollow fibre
      - wall thickness (w_A, w_B) and/or
      - internal diameter (d)
   c. inclusions and structural defects.

4. Plant according to any of the preceding apparatus claims, characterized in that the detection station (120) comprises a drive unit (125) by means of which at least one detection unit (122) is displaceable and/or tiltable transversely to the transport direction in

order to detect using the detection unit (122) geometry data of at least two individual fibres (110) moving in the transport direction.

5. Plant according to any of the preceding apparatus claims, characterized in that at least one detection station (120) is arranged at one of the plant sites:
- between the spinning unit (106) and the exchange unit (240);
- between the fixing bath and washing unit (160);
- in the region of the washing unit (160) or after the washing unit (160), especially in the transition between two washing stations or washing baths;
- between the fixing unit (150) and the aftertreatment unit (170);
- within or after the aftertreatment unit (170), in particular after the thermal treatment unit (200), primarily after a thermal treatment station of the thermal treatment unit (200).

6. Plant according to any of the preceding apparatus claims, characterized in that the detection unit (122) is configured for
- detecting the presence and/or position of an individual fibre (110) and/or
- motor-driven geometric alignment of an individual fibre (110) for optimal detection of an individual fibre (110) by the detection unit (122).

7. Plant according to any of the preceding apparatus claims, characterized in that at least one detection station (120) comprises a further position sensor (136), by means of which the transverse arrangement (perpendicular) to the conveying direction of the fibres (110) is detectable, wherein the (additional) position sensor (136) is for example one of the following sensors: (3D) laser scanner, a thermal sensor, a camera, a sound sensor (ultrasound, sonar).

8. Plant according to any of the preceding apparatus claims, characterized in that the control unit (130) is configured for receiving measured values of the detection unit (120) and, based on the measured values, transmitting control data to the plants for altered control and wherein the altered control concerns at least the following: the spinning unit (106), the residence time of the fibre (110) and/or another manipulated variable.

9. Plant according to any of the preceding apparatus claims, characterized in that
the control unit is configured for receiving measured values from the at least one detection unit and, based on the received measured values, transmitting control data to the plants to control downstream plant elements, for example
- the at least one thermal treatment unit,
- an electrical discharge unit and/or
- a heat treatment station.

10. Process for producing a fibre (100), which may be a solid fibre or a hollow fibre, from a polymer solution,
characterized in that
the fibre (100) is produced on a plant which is configured according to at least one of the preceding claims and wherein
i) in-situ measured values relating to the geometry of the fibre (110) conveyed in the transport direction are detected and/or determined, namely at least a diameter, a wall thickness and/or a cross-sectional area, and
ii) in a subsequent control step at least one plant part/element is controlled, especially controlled multiple times, on the basis of the at least one measured value.

11. Process according to Claim 10, characterized in that a first detection step which is a position detection step is used to determine the transverse position of the conveyed individual fibre (110) to be detected, wherein detection of the transverse position of this individual fibre (110) is effected using
- the detection unit (122) itself and/or
- another position sensor (136).

12. Process according to any of the preceding process claims, characterized in that
- a further detection step which is a boundary detection step or
- a first boundary detection step
comprises detecting the individual fibre (sample fibre) using the detection unit (122) in a first orientation of the detection unit (122), wherein

i) the external boundaries along a conveying section of the individual fibre (110) are detected, especially repeatedly detected along a conveying section of the individual fibre (110), and wherein the diameter (D) and/or the cross-sectional area of the individual fibre (110) are determined from at least one pair of external boundaries, and

ii) optionally (additionally) in the case of an individual fibre (110) (sample fibre) in the form of a hollow fibre the internal and external boundaries of the individual fibre (110) are detected, especially repeatedly detected along a conveying section of the individual fibre (110) and wherein the external diameter (D), the wall thickness (wA, wB) and/or the cross-sectional area of the individual fibre (110) are detected from at least one pair of internal and external boundaries.

13. Process according to Claim 12, characterized in that
in the further detection step which is a boundary detection step the individual fibre (110) is detected in a second orientation of the detection unit (122) using a further detection unit (122), wherein the further detection unit (122)

a. is arranged in the same detection station (120) and/or
b. is comprised by a further detection station (120) which is arranged downstream of the first detection unit (120).

14. Process according to any of the preceding process claims, characterized in that the further detection step is followed by a control step in which on the basis of received measured values from the detection unit (120) the control unit (130) transmits control data to at least one plant part/element for altered control, especially for automatically altered control.

15. Process according to Claim 14, characterized in that the altered control concerns at least the following: the spinning unit (106), the residence time of the fibre (110) and/or another manipulated variable, and wherein

a. in terms of the spinning unit (106) this concerns the following:
    i. the volume flow in an individual nozzle, in particular of core and/or ring fluid in the case of a fibre (110) which is in the form of a hollow fibre,
    ii. the temperature in an individual nozzle, in particular of core and/or ring fluid in the case of a fibre (110) which is in the form of a hollow fibre,
    iii. the volume flow of (process) gas (inert gas) in the down channel at an individual nozzle and/or
    iv. the temperature of the (process) gas (inert gas) in the down channel at an individual nozzle;

b. in terms of the residence time of the fibre (110) this concerns the residence time in at least one of the following units:
    i. the fixing unit,
    ii. the washing unit (160) or a section of the washing unit (160) and/or
    iii. the thermal treatment unit;

c. in terms of any other manipulated variable this especially concerns the following:
    i. the tensile force on the fibre (110) in the transport direction,
    ii. the function of a separation and discharging unit for at least one individual fibre (110),
    iii. the elevation of the spinning unit (106) and/or of individual spinning heads outside/above the fixing unit.