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CONCRETE COMPONENT HAVING A REINFORCING ELEMENT, METHOD FOR PRODUCING SAME AND METHOD FOR BENDING A REINFORCING BAR OF A REINFORCING ELEMENT

The invention relates to a concrete component having a non-metal reinforcing element which can be shaped for reinforcing the concrete component, to a method for its production, and to a method for bending a reinforcing bar of a reinforcing element. For example, the reinforcing element of a concrete component can be intended to increase the load-bearing capacity of the concrete component.

Strengtheners for plastics are known today and are already used in many ways in plastics construction. Such strengtheners must meet various requirements. In particular, they are intended to increase the mechanical strength of composite parts (tensile strength, tensile stiffness, crack bridging). The strengthening elements must not only impart strength, but rather must also enable shaping of the composite material together with the plastics matrix, for example in the construction of boats, aeroplanes, bicycles, etc. DE 10 2011 087 226 A1 describes a pseudo-thermoplastic, self-crosslinking composite material that can be used for plastics construction and that has a plastics matrix made from a reversibly cross-linked plastics.

Reinforcements for strengthening structures made of mineral binders have different requirements from a composite material for plastics components. They must be resistant to the media used in the mineral concrete component, in particular to alkaline substances. Furthermore, they must be permanently heat-resistant to temperatures up to 80°C Finally, such reinforcements should be simple and economical to produce and it should be simple to handle them on the construction site. Especially at construction sites, it is necessary that persons with little or no specialist knowledge can create a concrete component in a simple way and without defects.

US 6 612 085 B2 describes a reinforcing bar for concrete structures. The reinforcing bar is made from a composite material of a depolymerisable and repolymerisable thermoplastic resin and longitudinally oriented strengthening fibres. This is intended to achieve low viscosity during processing. The structure of the reinforcing bar is intended to allow it to be put into any different shape. During depolymerisation and repolymerisation, the polymer chains are broken up and reassembled, respectively, in the longitudinal direction. This allows the thermoplastic reinforcing bar to be made more shapeable by heating, put into the desired shape and then hardened again by cooling. After the plastics material cools off, it remains a thermoplastic.

US 6 023 903 A describes another reinforcing element. It consists of strengthening fibres that are integrated into a resin. The reinforcing element has a plurality of flanges that project away from a core, producing a shape having a cross-shaped or star-shaped cross section. In the core, a slot is formed at the location where the reinforcing element is supposed to be bent, such that a flange that is supposed to be curved at the bend site is separated from the core. This allows for bending of the reinforcing element, which would otherwise be hindered by the structure with a cross-shaped or star-shaped cross section.

WO 97/19226 A1 describes a reinforcing element and a method for using it in a product. The reinforcing element consists of a grid made of textile fibre strands. The grid can be impregnated with a thermoset resin in the B-state. After being applied to a product, the fibre reinforcement can be completely hardened and then retains its shape due to the thermosetting properties of the plastics matrix.

WO 97/19226 A1 discloses a concrete component comprising a concrete matrix, into which at least one reinforcing element is embedded for reinforcement, the reinforcing element having at least one reinforcing part in the form of a reinforcing bar, the at least one reinforcing bar extending in an extent direction and having at least one strengthening thread, the at least one strengthening thread being arranged in a plastics matrix of the reinforcing bar, which plastics matrix consists of a reversibly cross-linked plastics, at least one of the present reinforcing bars extending rectilinearly in at least one bar portion or over its entire length.

EP 2 666 922 A1 discloses the use of a thermoplastic resin for textile reinforcement of a concrete element. Unlike thermosetting plastics, there are no cross-linkings; instead, the molecule chains are interconnected by means of intermolecular forces.

In the publication Manfred Cobach et al.: "*Textilbeton in Theorie und Praxis*" [The theory and practice of textile-reinforced concrete], in "*Tagungsband zum 6. Kolloquium zu textilbewehrten Tragwerken*" [Conference proceedings of the 6th seminar on textile-reinforced concrete], 19/20.09.2011, there is an article on pages 15-26 by T. Gries et al. entitled "*Textile Verstärkungsstrukturen – Übersicht der Forschungsaktivitäten im Rahmen des SFB32*" [Textile strengthening structures – overview of research under SFB32], in which alkali-resistant glass and carbon rovings for reinforcements are studied.

It is proposed to use epoxy resin, polyurethane or styrene-butadiene rubber (SBR) as the plastics matrix for the reinforcements.

WO 2013/170313 A1 discloses epoxy resins that are intended to have a self-healing effect, for example so as to be able to repair scuffed epoxy resin surfaces.

In practice, the plastics matrices used for such composite material reinforcements are mainly thermosetting resins, for example epoxy resin, vinyl ester resin or polyester resin. Up to now, thermoplastic resins have not been used in practice since the long-term operating temperatures are too low. In addition, thermoplastics have a tendency to creep, and therefore can reduce the strength of the concrete component. On the other hand, high-temperature thermoplastics are expensive, and some must be processed at very high temperatures, which additionally increases the costs. Moreover, the quality of the bond with the embedded fibres is problematic when thermoplastics are used. There are only a few fibre or roving types with a sizing agent, which ensures a sufficiently good bond for the thermoplastic matrix.

Most reinforcements, especially steel reinforcements at construction sites, are prefabricated. This relates above all to shear reinforcements and starter bars. In order to be able to produce completely steel-free concrete components from composite-material reinforcements, it is necessary to provide not only planar, flat reinforcing meshes or straight reinforcing bars, but rather also two-dimensional or three-dimensional bar-shaped or mesh-shaped reinforcing elements that are curved or bent. Today this is accomplished by adapting the composite-material reinforcement elements to the specific use during production, producing them so as to be ready to be installed, and installing them at the construction site, especially by casting a concrete component. Once the composite material has completely hardened, the prefabricated reinforcing element can no longer be reshaped. Adaptation, for example in order to further compensate for manufacturing tolerances on the construction site, is no longer possible with these prefabricated reinforcing elements. Alternatively, in a not yet completely hardened, partly cross-linked state, called "stage B" or prepreg, the reinforcing elements made of composite material are still shapeable but are storable only to a limited extent. The reason is that even when such prepregs are stored in a cooled state, they continue to react and age. Moreover, cooled storage is complex and expensive.

If prepregs are supposed to be reshaped into a three-dimensional curved and/or bent shape, they are laid over a corresponding mould or laid into a mould and hardened. The strengthening fibres are not pretensioned and can form waves, at least in some places, depending on the shape. This can in turn reduce the tensile strength or tensile stiffness of the reinforcing element.

Due to the above-mentioned material-based disadvantages, the sometimes very high material prices and the complicated reshaping, concrete components with non-metal reinforcements have not become widely accepted so far. This is the case even though the problem of corrosion of steel-reinforced concrete components does leads to high maintenance costs and sometimes a short service life, such as in bridge construction, and therefore there is a great need for concrete components with non-metal reinforcements that are reasonably cost-effective.

Therefore, the object of the present invention can be considered to be creating a concrete component having a reinforcing element that solves at least some of the above problems and in particular does so through improved handling with high technical performance.

This object is achieved by a concrete component having the features of claim 1, by a method for its production having the features of claim 10, and by a method for bending having the features of claim 11.

A concrete component is created having a reinforcing element made of a composite material. To reinforce the concrete component, the reinforcing element is integrated into the mineral concrete matrix. The design, size, shape, etc. of the reinforcing element depends on the application. The reinforcing element has at least one reinforcing part in the form of a reinforcing bar. The reinforcing element can be formed by a single reinforcing part in the form of the reinforcing bar. Alternatively, the reinforcing element can also be formed by a plurality of reinforcing bars that are separately produced and then interconnected. The reinforcing element can also have a plurality of reinforcing bars and be designed to be mesh-shaped in the form of a reinforcing mesh, for example. A plurality of reinforcing parts can be interconnected and form e.g. a mesh.

The reinforcing bar can extend in an extent direction. The extent direction is, so to speak, the direction in which the reinforcing bar extends, and need not be rectilinear. At places where the reinforcing bar is curved the extent direction corresponds to a tangent that touches a curved central axis of the reinforcing bar or that touches the curvature of the reinforcing bar.

The reinforcing element or the reinforcing bar has one or more strengthening threads. The at least one strengthening thread extends in the extent direction, at least in the rectilinearly extending portions of the reinforcing bar. The at least one strengthening thread is formed of one or more filaments, and can also be called a strengthening yarn. As filaments it is possible to use plastics fibres and/or natural fibres. Depending on the application, it is possible to use all filaments, even those used up to now, such as glass fibres of different types (e.g. AR glass fibres), carbon fibres or basalt fibres.

The at least one strengthening thread is arranged in a plastics matrix of the reinforcing bar. A plurality of strengthening threads can be arranged to form a reinforcing mesh with the formation of crossing sites, and be embedded into the plastics matrix in this position. Therefore, the strengthening threads can form a textile mesh that can be in the form of a woven fabric and/or a laid scrim and/or a warp knit. To produce the reinforcing element, a textile mesh of this kind in its mesh shape can be embedded into the plastics matrix, for example soaked with plastics in a steeping-bath process, or laid into a mould into which the plastics is then introduced.

The plastics matrix of the composite material of the reinforcing element consists of a reversibly cross-linked plastics. The plastics material has a plurality of components, at least one of which is a polymer. The cross-linkings between the molecular or polymer chains can be broken by supplying energy, especially thermal energy. The ability to break cross-linkings should be understood to mean that, at the place where the energy is supplied, not necessarily all but most of the cross-linkings of the molecular chains are broken by supplying energy. Thus, supplying energy can break at least 50% or at least 70% or at least 90% of the cross-linkings that are produced. In this state, the workability approximately corresponds to that of a thermoplastic.

A plastics matrix of this kind or the plastics used for the plastics matrix can be reshaped, in particular bent, by breaking the cross-linkings by supplying energy. The cross-linkings can be broken locally at the corresponding reshaping or bend site. Breaking the cross-linkings allows the molecular or polymer chains to slide relative to one another, which makes the plastics reshapeable. This allows a reinforcing bar that was produced in a straight line to be bent at one or more places and reshaped into any two- or three-dimensional shape. Furthermore, the local releasing of the cross-linkings also allows a plurality of reinforcing bars to be connected, e.g. like a mesh, and a reinforcing element to be produced, for example in the form of a reinforcing mesh.

During production, the reinforcing element (e.g. reinforcing bar or reinforcing mesh) can be completely hardened at first. The polymer is in a cross-linked state and has the material properties of a thermoset. Storage times are not restricted and there are no additional expenses for cooling to avoid ageing. The fact that the cross-linkings can be reversibly broken and recreated makes it possible to produce standard reinforcing elements and to adapt them, either in the factory or also on site as required, to specific requirements, in particular in conjunction with other reinforcing elements or reinforcing bars or by reshaping them. The previous limitations on storability of prepregs or the lack of shapeability of completely hardened thermoset reinforcing elements are eliminated. Moreover, the plastics offers high temperature stability and a low tendency to creep, properties like those of usual thermosets.

A reinforcing element can be produced in a simple way by preparing one or more strengthening threads. The at least one strengthening thread is introduced into the plastics matrix. For example, the at least one strengthening thread can be soaked in a bath of liquid plastics. Then, the plastics matrix is hardened. To accomplish this, the strengthening thread(s) included in the not yet hardened plastics is/are arranged in a mould, such that the reinforcing element or the reinforcing bar assumes the desired shape. The plastics matrix is hardened in this mould. As an alternative to soaking the at least one strengthening thread before inserting it into the mould, it is also possible to arrange the at least one strengthening thread in the mould, to introduce the liquid plastics of the plastics matrix into the mould, for example to inject it, and then to harden the plastics matrix in the mould.

In both cases it is advantageous if the at least one strengthening thread is pretensioned with a tensile stress before the plastics of the plastics matrix hardens. This ensures that the at least one strengthening thread is arranged completely stretched in the reinforcing bar of the reinforcing element. This ensures that the tensile strength or tensile stiffness of the reinforcing element that is produced is optimal. Preferably, a reinforcing element in the form of a reinforcing bar is produced as a rectilinear bar without a bend site in the mould. The cross-sectional contour of such a bar can be freely chosen. For example, the bar can have a circular cross section.

It is preferred that the plastics of the plastics matrix is cross-linked at room temperature. The plastics can be self-crosslinking with or without the addition of a cross-linker. In the completely hardened state, the plastics forms a plastics material similar to a thermoset or has thermosetting properties. Supplying energy and releasing the cross-linkings in a temperature range clearly above the operating temperature range and above the glass transition temperature range makes the thermosetting plastics become thermoplastic, and allows it to be reshaped. The energy for releasing the cross-linkings can be input by radiation, for example infrared radiation and/or UV radiation and/or another kind of electromagnetic radiation. The energy can additionally or alternatively also be input by thermal convection and/or heat conduction and/or ultrasound.

The plastics of the plastics matrix preferably has a glass transition temperature of at least 50°C or at least 80°C or at least 90°C or at least 100°C. Additionally or alternatively, the glass transition temperature of the plastics of the plastics matrix is, in particular, no more than 130°C or no more than 140°C or no more than 150°C. This can achieve a sufficiently large range in which the plastics matrix can be used. Moreover, it is possible to keep the required supply of energy to release the cross-linkings small.

Preferably, the reversibly cross-linked plastics can be cross-linked by means of a Diels-Alder reaction and the cross-linkings can be broken by means of a retro-Diels-Alder reaction.

The plastics can have a first component having at least two dienophilic double bonds and a second component having at least two diene functionalities. The first component and/or the second component can have more than two functionalities.

Preferably, the first component and/or the second component is a polymer, for example a polyacrylate, a polymethacrylate, a polystyrene, a copolymer of one or more of the previously mentioned polymers, a polyacrylonitrile, a polyether, a polyester, a polyamide, a polyester amide, a polyurethane, a polycarbonate, an amorphous and semicrystalline poly-α-olefin, an ethylene propylene diene monomer rubber (EPDM), an ethylene propylene rubber (EPM), a polybutadiene, acrylonitrile-butadiene-styrene (ABS), styrene-butadiene rubber (SBR), a polysiloxane and/or a block and/or comb and/or star copolymer of one or more of these polymers.

The plastics of the plastics matrix is substantially inert with respect to water and alkaline substances, and therefore not only is it itself insensitive to these substances, but also it is as impervious to diffusion as possible, to protect the embedded fibres from such substances as well as possible.

The first component can be a dienophilic component having two dienophile groups, or an isocyanate or amine having at least two functional groups per molecule. It can be an amine, a diamine, a component having a carbon-sulfur double bond and an electron-acceptor group, a trifunctional dithioester linker, a difunctional polymer from a polymerisation (ATRP), an isocyanurate and preferably an isocyanate. It is further preferable if the isocyanate is a diisocyanate, such as a 2,2,4-trimethyl-1,6-hexamethylene diisocyanate (TMDI) and/or a 3-isocyanatomethyl-3,5,5-trimethylcyclohexyl isocyanate (isophorone diisocyanate, IPDI).

The second component having at least two diene functionalities can be a diene having alcohol or amine functionality, such as polyhydric alcohols and/or polyfunctional polyamines. In particular, it can be sorbic alcohol and/or sorbic acid. Preferably, the dienophile is a dithioester. It is also possible to use, as the second component, polymers that have been obtained by polymerisation (ATRP) and functionalised with conjugated diene groups, such as cyclopentadienyl-terminated poly(methyl methacrylate) (PMMA-Cp_2).

Examples of various plastics that can be used as a plastics matrix are also indicated in DE 10 2010 001 987 A1.

The reinforcing element can have a plurality of interconnected reinforcing bars. At the connection sites, these reinforcing bars are preferably interconnected exclusively by means of the plastics of the plastics matrix. To produce the connection, energy can be supplied to at least one of the reinforcing bars at the connection site, such that the cross-linkings are released, and contact with or pressure against the other reinforcing bar followed by hardening then produces an integral bond. Additional means of connection or adhesives are not required. The energy can be input by heat and/or UV radiation and/or ultrasound excitation at the connection site.

This makes it possible to interconnect two or more reinforcing bars of the reinforcing element. At every connection site it is possible, by energy input (especially heating or melting the plastic), first to release at least some of the cross-linkings, preferably of all reinforcing bars to be connected at the connection site. After the supply of energy ends, cross-linkings reform at the respective connection site, producing covalent bonds in the entire structure at the connection site. The connection site is very stable and has only a small tendency to creep. This small tendency to creep is especially advantageous for the concrete component that contains the reinforcing element, since component deformations due to cracking in the concrete end up being significantly smaller than in the case of other reinforced concrete components.

Energy can be supplied at connection sites selectively, for example even separately. This makes it possible to selectively connect e.g. the reinforcing bars or other reinforcing parts of the reinforcing element at the connection site, for example in a mechanised way by means of a robot, a gripper arm, another manipulator or even manually by a person. Alternatively, energy can also be supplied to the reinforcing bars or other reinforcing parts, which are to be connected, at a plurality of connection sites simultaneously or in a region having one or more connection sites or in the entire reinforcing part. This allows individual reinforcing parts to be connected at a plurality of connection sites very quickly and simply, for example for simple production of a reinforcing mesh or a reinforcing cage. In at least one bar portion or over its entire length, a reinforcing bar of the reinforcing element extends rectilinearly. The strengthening threads along the rectilinearly extending portion or along the entire length of the reinforcing bar are preferably arranged or held in the plastics matrix under tensile stress. This optimises the tensile strength or tensile stiffness of the reinforcing element.

At least one of the reinforcing bars of the reinforcing element can have a bend site. As explained, the strengthening threads are held under tensile stress in the plastics matrix, at least outside this bend site. This tensile stress is also not eliminated by the local release of the cross-linkings to produce the bend site, but rather is preserved.

At the bend site, at least some of the strengthening threads can extend at an angle to the extent direction and, in particular, approach the central axis of the at least one reinforcing bar. At the bend site, a bend inside can have an inner curvature, and a bend outside that is opposite the bend inside with respect to the central axis of the reinforcing bar can have an outer curvature. The magnitude of the inner curvature is greater than the magnitude of the outer curvature. It is especially preferred if as large a proportion as possible of the strengthening threads at the bend site have a curvature magnitude corresponding to the curvature magnitude of the central axis of the reinforcing bar. The strengthening thread has no waviness. At the bend site, the compressed strengthening threads running in the region of the inner curvature are moved away from the bend inside into the interior of the reinforcing bar when the reinforcing bar is bent. This can avoid waviness due to an excessive length of the strengthening threads running in the region of the bend inside and improve the tensile stiffness or the tensile strength of the reinforcing bar.

The reinforcing element can also have a rough or uneven outside surface. This can improve the bond with the concrete matrix of the concrete component or with another cast component having a matrix made of a mineral building material. In the region of the outside surface, it is possible to provide a rib element that projects outwards away from the central axis of the reinforcing bar with respect to the adjacent outside surface. The rib element can be one or more strengthening threads soaked with the plastics of the plastics matrix that are arranged in the region of the outside surface of a reinforcing bar and that form a projection with a, for example, helical shape. This can be done during or after the production of a reinforcing bar.

In order to bend a rectilinear reinforcing bar, energy is input, preferably locally at the bend site, in order to release the cross-linkings of the plastics of the plastics matrix there. The energy can be input, for example, in the form of heat and/or UV radiation and/or another kind of electromagnetic radiation and/or by ultrasound excitation. Then, the reinforcing bar can be bent and hardened again. During hardening, at least most of the cross-linkings of the plastics of the plastics matrix are recreated. In particular, at least 85% or at least 90% or at least 95% of the released cross-linkings are recreated.

In order to perform the bending process, it is preferable to use a bending device. The bending device has an energy input apparatus to input the energy at the bend site, for example a heating apparatus and/or an ultrasound apparatus. The heat can be input by heat conduction and/or by thermal convection and/or by thermal radiation. The energy input apparatus can be in contact with the reinforcing bar or it can be arranged at a distance from it. The ultrasound apparatus can release at least some of the cross-linkings at the bend site by ultrasound excitation.

The bending device also has a tool arrangement. On the inside of the bend site, a first tool part is arranged, this first tool part being set up and serving to support the reinforcing bar on the bend inside during bending. For this purpose, the first tool part can have a first working surface whose curvature corresponds to the specified inner curvature to be achieved in the reinforcing bar. Starting from the bend site, a first bar portion of the reinforcing bar to be bent projects away in a first direction, and a second bar portion projects away in a second direction. In a rectilinear reinforcing bar that is yet to be bent, the two directions are oriented opposite to one another.

The tool arrangement has a holding apparatus that acts on the first bar portion and supports the reinforcing bar on one side of the bend site. The tool arrangement also has a forming tool that is set up to act on the second bar portion and to execute the bending movement relative to the holding apparatus and relative to the first tool part. The holding apparatus can be stationary when the forming tool executes the bending movement. It is also possible for both the holding apparatus and the forming tool to be movable, such that the bending movement is performed on both the first and the second bar portions.

The support on the first tool part achieves the desired inner curvature on the inside of the bend. Moreover, the first tool part can preferably be set up to press the strengthening threads in the region of the bend inside in the direction towards the central axis, away from the inside of the bend, to prevent waviness of these strengthening threads.

The tool arrangement can optionally have a second tool part that is set up to act on the bend outside of the reinforcing bar at the bend site. The second tool part and the first tool part can exert a force or a pressure on the reinforcing bar at the bend site, at right angles to the bend axis. Preferably, the first and/or second tool part(s) is/are set up to reshape the cross-sectional shape of the reinforcing bar at the bend site with respect to the original cross-sectional shape of the first bar portion or of the second bar portion, and to do so before or during bending. In particular, the cross-sectional dimension parallel to the bend axis becomes larger, while the cross-sectional dimension becomes smaller at right angles to the bend axis and in the direction radial to the curvature. The reinforcing bar is given a lateral shaping, so to speak, at the bend site. This shaping allows the strengthening threads to be moved from the bend inside and/or the bend outside closer to the central axis of the reinforcing bar.

Advantageous embodiments of the invention follow from the dependent claims, the description and the drawings. Preferred example embodiments of the invention are explained in detail below with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of an example embodiment of a device and a method for producing a reinforcing bar;

Fig. 2 is a schematic perspective sectional view of a reinforcing bar;

Fig. 3a is a greatly simplified schematic illustration of a Diels-Alder reaction and a retro-Diels-Alder reaction;

Fig. 3b is a greatly simplified schematic illustration of reversible cross-linking caused by irradiation of a plastics material with light;

Fig. 4-7 are block diagram-like representations of a method and a device for bending a reinforcing bar;

Fig. 8 is a schematic representation of a bent reinforcing bar at the bend site and the adjacent rectilinear bar portions;

Fig. 9 is a cross section through the bend site of the reinforcing bar along the sectional line IX-IX in Fig. 8;

Fig. 10 and 11 are block diagrams of an example embodiment of a method and a device for producing a rib element in the region of the outside surface of a reinforcing bar;

Fig. 12 and 13 are each a block diagram of an example embodiment of a method and a device for introducing particles, for example sand, in the plastics of the plastics matrix of a reinforcing bar;

Fig. 14-16 are block diagrams of an example embodiment of a device and a method for producing a reinforcing element made from a plurality of reinforcing bars;

Fig. 17-19 are schematic illustrations of an example embodiment of a method for reshaping a reinforcing element made from a plurality of reinforcing bars;

Fig. 20 shows a reinforcing element in the form of a reinforcing mesh;

Fig. 21 and 22 are schematic views of an example embodiment of a device and a method for producing the reinforcing mesh shown in Fig. 20;

Fig. 23 and 24 are schematic illustrations of another example embodiment of a method for reshaping a reinforcing bar;

Fig. 25 and 26 are schematic diagrams of another example embodiment of a method for connecting two reinforcing bars;

Fig. 27 is a partly cutaway schematic perspective view of a concrete component; and

Fig. 28-30 are each schematic top views of various example shapes of concrete components.

The invention relates to a concrete component 48 having a mineral concrete matrix 49, into which a reinforcing element 50 is embedded. The concrete matrix 49 can have, for example, cement and aggregate, and optionally it can have concrete admixtures or concrete additives.

The concrete component 48 and the reinforcing element 50 can be implemented in various embodiments. Fig. 27-30 show various example embodiments of the concrete component 48. It can, for example, be cuboidal (Fig. 27 and 28). When viewed in cross section or top view, it can also have one or more bent portions, e.g. its cross section can be circular arc-shaped (Fig. 30). The example embodiment according to Fig. 29 has a bent cross section, and can form a right angle, for example. Any combinations of the embodiments shown can also be present in a single integral concrete component 48, e.g. one or more corners or angled portions and/or one or more bent portions.

It has at least one reinforcing part 29, that extends in an extent direction S. If the reinforcing element 50 has only one rectilinearly extending reinforcing part 29, it is in the form of reinforcing bar 30. The reinforcing element 50 can also be in the form of a reinforcing mesh 80 having a plurality of reinforcing parts 29 bordering openings 85 of the reinforcing mesh 80. A mesh shape or any other shape can also be obtained if a plurality of previously produced reinforcing bars 30 are interconnected to form a reinforcing element 50.

Fig. 1 schematically illustrates an example embodiment for producing a reinforcing bar 30 in a block diagram-like representation. The production device 31 carries out a pultrusion process, for example. It has a creel 32 having a plurality of bobbins 33. The bobbins 33 each have a strengthening thread 34 or strengthening yarn wound on them, which is unwound from the bobbin 33 during the production process. The example method involves passing the strengthening threads 34 through a bath 35 of liquid plastics K and soaking them with the plastics K. The plastics K adheres at least to the outside surface of the strengthening threads 34. After that, the strengthening threads 34 provided with the plastics K are passed into a mould 36, where they are partly or completely hardened in the desired cross-sectional contour. A removal apparatus 37, for example driven reels or rollers, transport the hardened reinforcing bar profile out of the mould 36 and finally a cutting-off tool 38 cuts it to a desired length. This produces straight reinforcing bars 30. In the example embodiment, the reinforcing bars 30 have a circular cross-sectional shape (Fig. 2). Any other cross-sectional contours, for example elliptical, polygonal or also any cross-sectional shapes with curves and/or corners, can also be produced. The mould 36 can define the cross-sectional shape of the reinforcing bar 30.

The reinforcing bar 30 extends in an extent direction S. In the preferred example embodiment, the reinforcing bars 30 are produced as rectilinearly extending reinforcing bars. The strengthening threads 34, which are integrated into a plastics matrix consisting of the plastics K by hardening the plastics K, are preferably held under tensile stress during the hardening of the plastics K, such that in the reinforcing bar 30 they are integrated under tensile stress into the plastics matrix made of the plastics K. This avoids wavy or kinked strengthening threads 34 in the reinforcing bar 30 and increases its tensile strength or tensile stiffness.

The tensile stress or stretching of the at least one strengthening thread 34 can be achieved by using a pultrusion process to produce the reinforcing element 50 and, for example, the reinforcing bar 30, and it is achieved without requiring special additional measures to tension the strengthening threads 34.

In departure from the example embodiment illustrated in Fig. 1, the liquid plastics K can also be applied to the strengthening threads 34 within the mould 36.

The plastics K of the plastics matrix has cross-linked molecular chains, in particular polymer chains. The cross-linkings arise below the corresponding glass transition temperature of e.g. 50°C, 80°C, 100°C, 130°C or 150°C The cross-linkings are produced independently, without the addition of a special cross-linker. Therefore, the plastics K can be designated as self-crosslinking. When the cross-linkings have been made, the properties of the plastics K are substantially those of a thermoset.

Inputting energy into the plastics K of the plastics matrix with the help of an energy input apparatus 43 can release the cross-linkings. This should be understood to mean that at least some of the cross-linkings, in particular at least 50%, can be released to make it possible to reshape the reinforcing bar 30 at the place where the cross-linkings have been released. Preferably at least 80% or at least 90% of the cross-linkings can be released at the place where the energy has been input. According to the example, to release the cross-linkings thermal energy is input, for example by means of an energy input apparatus 43 in the form of a heating apparatus 44. With the help of the heating apparatus 44, heat can be input by applying thermal radiation and/or by thermal convection and/or by heat conduction locally at a reshaping point or bend site 45 (Fig. 1-8). This releases the cross-linkings of the plastics K at the bend site, such that the reinforcing bar 30 can be reshaped, for example bent.

Fig. 23 and 24 schematically illustrate an energy input apparatus 43 in the form of an ultrasound apparatus. The ultrasound apparatus 46 has an excitation unit for ultrasound excitation, which is connected to a sonotrode 46a. At the end opposite the excitation unit, the sonotrode 46a has a forming tool end 46b. The forming tool end 46b can have, for example, a convexly curved forming tool surface corresponding to an inside radius of curvature to be produced on a reinforcing bar 30.

Arranged opposite the forming tool end 46b, there is a counter-holding tool 47 that has, for example, two legs that are mounted on a knee or pivot point such that they can be pivoted towards one another. The bend site of a reinforcing bar 30 to be bent lies on the counter-holding tool 47, between the forming tool end 46b and the counter-holding tool 47. The ultrasound apparatus 46 inputs energy in the form of ultrasonic vibrations into the reinforcing bar 30 at the bend site 45 or in the region of the bend site 45, such that at least some of the cross-linkings are released and a flexibility is achieved. Then, a relative motion between the counter-holding tool 47 and the forming tool end 46a can bend the reinforcing bar 30 at the bend site 45, as schematically shown in Fig. 24. In the process, the two legs of the counter-holding tool 47 fold towards one another according to the desired angle of bend, and bend the reinforcing bar 30 around the forming tool end 46b, so to speak.

The ultrasound apparatus 46 can also, for example, produce a connection between two reinforcing bars 30 at a connection site. At the place where a reinforcing bar 30 is supposed to be connected to another reinforcing bar 30, energy can be input by means of the ultrasound apparatus 46 and at least some of the cross-linkings of the plastics K can be released. This energy input can be performed at one or both of the reinforcing bars to be connected. Then, the reinforcing bars 30 to be connected are put in contact with one another at the connection site and possibly pressed against one another. Then, the plastics K is hardened again at the connection site by cooling it (for example in the air). When this happens, at least some of the cross-linkings are recreated and covalent bonds form in the entire structure at the connection site between the plastics K of the touching reinforcing bars 30. This can achieve a stable connection with very a small tendency to creep.

The small tendency to creep is advantageous for the concrete component 48. If a reinforcing element 50, such as the reinforcing mesh 51 shown in Fig. 25, is produced from a plurality of reinforcing bars 30 or other individual reinforcing elements, smaller crack widths arise in the concrete component 48 due to the small tendency to creep of the reinforcing element 50. The plastics K is insensitive to water and mineral components of the concrete matrix 49 and therefore is especially well suited for the reinforced concrete component 48. The concrete component 48 according to the present invention is substantially lighter than steel-reinforced concrete components. The load on lower walls or wall portions of a structure can be reduced, while achieving very good stability. The shielding of electromagnetic radiation of a concrete component 48 of this kind is less than that of steel-reinforced concrete components; this can be advantageous when creating inner walls, for example if wireless radio connections (e.g. a WLAN connection) are supposed to be produced in a building.

According to the example, the plastics K has a glass transition temperature of at least 80°C to 90°C, preferably over 100°C. Heating the plastics K above the glass transition temperature releases the cross-linkings and gives the plastics K a thermoplastic property at the place with the released cross-linkings, making it deformable. The molecular chains, in particular the polymer chains, can be displaced with respect to one another, achieving deformability.

Recooling causes the plastics K to harden again after the reshaping or bending. At least most of the cross-linkings are recreated, for example at least 90% or 95% of them. The thermoplastic properties are lost, and the plastics K regains the thermosetting properties that it has below the glass transition temperature.

Preferably, the plastics K used is a plastics material that can be cross-linked by means of a Diels-Alder reaction and whose cross-linkings can be broken by means of a retro-Diels-Alder reaction. The Diels-Alder reaction and retro-Diels-Alder reaction are schematically illustrated in Fig. 3. In Fig. 3a, the letter "E" indicates that breaking the cross-linkings requires an energy input (symbol "+E"), while cooling releases energy in the form of heat from the plastics K (symbol "-E") and the cross-linkings are recreated.

Fig. 3b shows another possibility of reversible cross-linking. The plastics K used can be a plastics material K that is reversibly cross-linkable by means of light, e.g. UV radiation. In the initial state (state I in Fig. 3b) at room temperature, the plastics K has thermoplastic properties and can be deformed. In the state II of Fig. 3b, the plastics K has been put into the desired shape and therefore is under tensile and/or compressive stress. In this state, it can be irradiated with light of a first wavelength λ1, causing cross-linking of the cross-linkings that have not been connected up to now (state III in Fig. 3b). This gives the plastics K thermosetting properties and causes it to maintain its shape, even if external forces no longer act on the material (state IV in Fig. 3b). If the reversible cross-linkings are supposed to be released again, the plastics K can be irradiated with light of a second wavelength λ2, causing it to change back into its initial state with thermoplastic properties, since at least some of the cross-linkings are released (transition from state IV back to state I). This process can be repeated multiple times.

Photoreactive plastics that allow reversible cross-linking to contain, for example, coumarin derivatives, cinnamic acid, cinnamates and stilbenes ($C_{14}H_{12}$). For example, a first wavelength λ1 above 260 nm can dimerise the double bond of cinnamic acid with adjacent stannic acid molecules, forming a cyclobutane. The cyclobutane rings formed can be broken by UV light of a second wavelength λ2 of less than 260 nm.

Photoreactive plastics have two components: molecular photochromic groups, which act as switches, and permanent network structures. The photochromic switches produce photo-reversible covalent cross-linkings, which are formed or broken under the influence of light, depending on the wavelengths. The permanent network structures are cross-linked polymers or penetrating polymer networks. Suitable polymers are ethylene glycol-1-acrylate-2-cinnamic acid and four-arm star poly(ethylene glycol) with cinnamylideneacetic acid and copolymers of n-butyl acrylate or butyl acrylate with hydroxyethyl methacrylate.

By means of one or more of the described reinforcing bars 30 it is possible to produce a reinforcing element 50. In the simplest case, the reinforcing element 50 is formed by a single reinforcing bar 30. As illustrated by Fig. 14-19, it is also possible to use a plurality of reinforcing bars 30 that have already been produced to produce a reinforcing element 50 from them. For example, a reinforcing element 50 having a mesh structure made of crossing reinforcing bars is illustrated. It is also possible to produce any other reinforcing elements 50 reinforcing bars 30 that extend rectilinearly and/or have one or more bend sites 45. For example, a reinforcing element 50 can also have a plurality of rectilinearly extending reinforcing bars 30, between which another reinforcing bar is arranged in a zigzag or wave shape. A reinforcing element 50 can extend mainly in one plane and consequently have a substantially two-dimensional shape, as illustrated, for example, on the basis of the mesh structure. A mesh of this kind or another two-dimensional structure can also be put into a three-dimensional shape, an example of which is illustrated by Fig. 17-19.

To produce a reinforcing element 50 (according to the example a reinforcing mesh 51), first a plurality of reinforcing bars 30 are arranged in parallel with one another on a support 52 and heated with the help of a heating apparatus 44, such that the cross-linkings are released (Fig. 14). These reinforcing bars 30 form a first layer 53 of reinforcing bars 30. Another, second layer 54 of reinforcing bars 30 is laid onto this first layer 53 of reinforcing bars 30 (Fig. 15). Then, the two layers 53, 54 are squeezed or pressed against one another. This can be done using a pressing arrangement 55. Pressing the reinforcing bars 30 against one another can also change their cross-sectional contour. The pressing arrangement 55 can also be used to set a desired thickness d of the reinforcing mesh 51 or the reinforcing element 50.

The pressing arrangement 55 can have, for example, two rotating rollers 56, which are arranged at a distance from one another. The two layers 53, 54 can be transported through the gap between the rollers 56, thereby pressing the layers against one another. The distance between the lateral surfaces of the two rollers 56 is adjusted such that after the reinforcing bars 30 are pressed against one another the desired thickness d of the reinforcing element 50 is obtained. Before the two layers 53, 54 of the reinforcing bars 30 are pressed together by means of the pressing arrangement 55, they can be heated again by means of a heating apparatus 44. This also releases the cross-linkings on the reinforcing bars 30 of the second layer 54, improving the connection between the touching reinforcing bars 30 of the two layers 53, 54.

As already explained above, the energy could be input in a way other than heat, for example by ultrasound excitation (Fig. 25). The energy can be input along one region of the reinforcing bars 30, and thus at a plurality of or all connection sites 58 simultaneously (e.g. by the heat of the heating apparatus 44). It is also possible for the energy to be input (e.g. by ultrasound excitation or heat) locally or at certain points, e.g. at one or more connection sites 58, for example with the help of a manipulator or manually.

The reinforcing bars 30 are connected at the crossing or connection sites 58 exclusively by the plastics K of the plastics matrix. Additional adhesives or mechanical connection means are not provided. Upon cooling and recreation of the cross-linkings, the plastics K of the touching reinforcing bars 30 connect and form a stable reinforcing element 50.

Fig. 20 illustrates a reinforcing element 50 in the form of a reinforcing mesh 80. The reinforcing mesh 80 is formed in that a plurality of strengthening threads 34 first form a textile structure 82 having one or more connection sites or crossing sites 81. At the crossing site 81, the crossing strengthening threads 34 can lie loosely on one another or be directly bound together as textiles, or be held or connected indirectly by means of at least one binding thread of a binding system. This textile structure 82 can be in the form of a laid scrim and/or a woven fabric and/or a warp knit and/or a weft knit. It is possible to provide a textile binding only at certain crossing sites 81, while at other crossing sites the strengthening threads loosely touch one another in the form of a laid scrim, a float or the like. If the textile structure 82 is formed by a woven fabric, any weaves can be implemented, such as a linen weave, a body weave, an atlas weave or a cross weave. The weave types can also be combined with one another in any way.

This textile structure 82 as a whole is embedded into a plastics matrix. Thus, in this example embodiment the reinforcing mesh 80 is produced not by first producing reinforcing bars 30 and then connecting them, but rather by first producing the textile structure 82 and then embedding it in a plastics matrix.

The basic method sequence for producing a reinforcing mesh 80 having a textile structure 82 is illustrated by way of example in Fig. 21 and 22 on the basis of an example embodiment, e.g. with the textile being soaked by means of a steeping-bath process. The strengthening threads 34 are fed in a textile machine 83, for example a loom or a knitting machine, where they are connected into the desired textile structure 82, for example a mesh structure. This textile structure 82 can be wound onto a storage roll 84, for example for interim storage. When needed, the textile structure 82 can be removed from the storage roll 84 and embedded into the plastics matrix. This can be done by soaking the textile structure 82 with liquid plastics K in the bath 35, analogously to the example embodiments according to Fig. 1, 10, 11 and 12. The soaked textile structure 82 is then partly or completely hardened in a furnace, in a mould 36 or open. Finally, the reinforcing mesh 80 thus produced can be cut to the desired length by a cutting-off tool 38.

The parts of the process shown separately in Fig. 21 and 22 can also be combined with one another. The textile structure 82 produced in the textile machine 83 can also be fed directly to the bath 35. Interim storage is not required.

The number of thread layers or groups of the textile structure 82 can vary. The textile structure 82 has at least two groups of strengthening threads, the strengthening threads 34 within a group running substantially in parallel with one another. In the example embodiment according to Fig. 20, two groups of strengthening threads are provided, which are oriented approximately at right angles to one another. The strengthening threads 34 of a common group form into approximately parallel strands, each having one or more strengthening threads arranged at a distance from one another. It is also possible to arrange, for example, three or more such groups of strengthening threads 34. The angle at which the strengthening threads of the groups intersect depends on the number and the orientation of the groups, and can be selected depending on the application.

In all cases, the textile structure 82 has sufficiently large stitches or openings 85 to be able to produce the bond with the concrete matrix 49.

The textile structure 82 can also have a reinforcing system having stretched strengthening threads 34, which are held by means of a binding system having at least one connecting thread or are connected at the crossing sites 81. In the case of knitting, this can be done by a knitting thread. In the case of weaving, this can be done, for example, by a crossing thread. However, in the case of cross-weaving it is also possible for the strengthening threads 34 to be directly interconnected. Here many possible embodiments and variations are conceivable.

Fig. 17-19 schematically illustrate how a reinforcing element 50 and, according to the example, the reinforcing mesh 51, can be reshaped from its substantially two-dimensional shape into a three-dimensional shape. For example, it can be heated locally at one or more bend sites 45, such that the cross-linkings there are released again. Then, it can be put into the desired shape with the help of a forming tool 57. Alternatively to the highly schematic illustration in Fig. 18 and 19, the forming tool 57 can also have two forming tool parts 57, between which the reinforcing element 50 to be reshaped is enclosed or clamped, to put it into the desired shape.

Fig. 4-7 schematically illustrate a method and a bending device 60 for bending a reinforcing bar 30. According to the example, the reinforcing bar 30 originally extends rectilinearly. According to the example, the bending device 60 comprises the energy input apparatus 43 or the heating apparatus 44, and a tool arrangement 61. The tool arrangement 61 also has a holding apparatus 62, a forming tool 63 and, at the bend site 45, a first tool part 64 and optionally a second tool part 65. Starting from the bend site 45, a first bar portion 30a of the reinforcing bar 30 extends in a first direction, and a second bar portion 30b extends in another direction, according to the example in the opposite direction. The holding apparatus 62 is set up to act on the first bar portion 30a and to support the reinforcing bar 30 during the bending process. The forming tool 63 is set up to act on the second bar portion 30b. The holding apparatus 62 and the forming tool 63 are movable relative to one another, to bend the reinforcing bar 30 about a bend axis A. In the example embodiment, the forming tool 63 is movable, while the holding apparatus 62 can be stationary with respect to a machine base of the bending device 60. Alternatively or additionally, the holding apparatus 62 could also be movable with respect to the machine base.

According to the example, the bend axis A is defined by the first tool part 64. The first tool part 64 is set up to support the reinforcing bar 30 at the bend site 64 on the bend inside BI. The bend inside BI of the reinforcing bar 30 is located on the side of the reinforcing bar 30 facing the bend axis A. Diametrically opposite the bend inside BI or opposite the bend inside BI with respect to a central axis M (Fig. 8) of the reinforcing bar 30, there is, at the bend site 45, a bend outside BA. The magnitude of the curvature to be produced at the bend site 45 is greater on the bend inside BI than on the bend outside BA.

In the example illustrated here, a bend is produced at the bend site 45 having a substantially constant radius on the bend inside BI and on the bend outside BA or on the concentric planes of bending between them. The magnitude of the inner curvature is greatest on the bend inside BI, or the bend radius is smallest on the bend inside BI. The magnitude of the outer curvature is smallest on the bend outside BA, or the bend radius is greatest on the bend outside BA (see especially Fig. 8). To produce the defined curvature, the first tool 64 has a working surface, whose curvature-producing inner curvature corresponds to the bend inside BI. In the example embodiment the first tool 64 and preferably also the second tool 65 is/are each formed by a reel or roller. At the point of contact with the bend inside BI, the roller for the first tool 64 has a radius that corresponds to the radius to be produced on the bend inside BI.

As is schematically illustrated in Fig. 4-7, before the reinforcing bar 30 is bent it is locally heated at the bend site 45 by means of the heating apparatus 44. Local heating has the advantage that outside the bend site 45, the strengthening threads 34 do not lose the tensile stress with which they are embedded into the plastics matrix.

After the local heating to release the cross-linkings, the reinforcing bar 30 can be reshaped at the bend site 45. On the first bar portion 30a, the reinforcing bar is supported by the holding apparatus 62. The forming tool 63 acts on the other side of the bend site 45 and executes a bending movement in the direction indicated by arrow P (Fig. 6 and 7) on an arc about the bend axis A and/or a linear movement at a distance from the bend axis A. The forming tool 63 can be moved or slide in its extent direction relative to the second bar portion 30b. It is also possible to clamp the second bar portion 30b rigidly in the forming tool 63 if, for example, the first bar portion 30a is movable in its extent direction relative to the holding apparatus 62.

While the bending movement in the direction indicated by arrow P is being performed, the reinforcing bar 30 is supported on the first tool part 64 and is given a defined bend.

In the preferred example embodiment described here, after the cross-linkings are released at the bend site 45 the cross-sectional contour of the reinforcing bar 30 is reshaped at the bend site 45. To accomplish this, the two tool parts 64, 65 are moved relative to one another in a transverse direction Q and press against the reinforcing bar 30 from opposite sides to reshape its cross-sectional contour (Fig. 6). This reduces the dimension of the reinforcing bar 30 in the transverse direction Q at the bend site 45 and increases its dimension at right angles to the transverse direction Q and in parallel with the bend axis A (Fig. 9). Fig. 9 schematically illustrates how the originally circular cross section (illustrated by the dashed line) is reshaped at the bend site 45 and given a substantially oval or elliptical contour, the dimension of the cross section in the transverse direction Q being smaller than the dimension at a right angle to it.

This reshaping or shaping by means of the two tool parts 64, 65 causes the strengthening threads running next to the bend inside BI to stretch, so to speak, in the region of the bend site 45, and to be shifted away from the bend inside BI. This prevents the strengthening threads 34 forming waves in the region of the bend inside BI and thus weakening the tensile strength of the reinforcing bar 30 or of a reinforcing element 50 produced from it. On the opposite bend outside BA, the strengthening threads 34 are shifted away from the bend outside BA due to the growing path. The value of the cross-sectional surface area of the reinforcing bar 30 remains substantially constant at the bend site 45. Only the dimensions in the transverse direction Q and at a right angle to it change.

This reshaping of the cross-sectional shape of the reinforcing bar 30 at the bend site 45 can be performed before the bending movement is performed (cf. Fig. 6 and 7). It is also possible also to carry out the bending movement in the direction indicated by arrow P simultaneously with the deformation of the cross-sectional contour (Fig. 6), at least in phases (Fig. 7).

In the example embodiment described up to now, the reinforcing bar 30 has a substantially planar outside surface. This outside surface should be understood to mean a surface whose unevenness is defined by the plastics K that is used. In a variant example embodiment, this outside surface can also have projections and/or depressions, producing an uneven or rough outside surface, the unevenness and/or roughness being greater than the unevenness or roughness produced by the plastics K itself.

A first possible way of doing this is to put a rib element 70 on the reinforcing bar 30 while it is being produced or after it has been produced. The rib element 70 can be formed, for example, by a line-like element that is applied in the region of the outside surface of the reinforcing bar in a screw-like or helical manner. The rib element 70 can be produced from a reversibly cross-linkable resin system or a thermoset resin such as an epoxy resin or vinyl ester resin, and strengthening threads 34, e.g. in a pultrusion process (Fig. 10) that can be carried out analogously to the production of the reinforcing bar 30. Only the number of the strengthening fibres 34 used is smaller, forming a rib element 70 whose cross section is thinner. The rib element 70 produced can be wound onto the outside surface during the production process of the reinforcing bar 30 before hardening or complete hardening of the plastics K, and it then connects to the reinforcing bar 30 while the plastics K hardens.

The production method of the reinforcing bar 30 can proceed analogously to the method illustrated by Fig. 1. Following the mould 36, a winding unit 71 then winds the rib element 70 helically around the reinforcing bar 30, which has not yet hardened. For example, the winding unit 71 can revolve around the reinforcing bar 30, while the latter is moved in its extent direction S by the removal apparatus. Finally, the reinforcing bar 30 is cut to the desired length, according to the example by means of the cutting-off tool 38. This process can be called "hard into wet", since the already hardened rib element 70 is introduced into the not yet hardened plastics matrix of the reinforcing bar 30.

As an alternative to this, it is also possible to perform a "wet into wet" process. This involves putting the rib element 70 onto the reinforcing bar 30 while the rib element is in the not yet hardened state but is also in the heated state with released cross-linkings. This can be done either by reheating the prefabricated rib element 70 to release the cross-linkings, or by producing the rib element 70 simultaneously with the reinforcing bar 30 and feeding the not yet hardened rib element 70 to the production device 31 for producing the reinforcing bar 30 and then winding it onto the not yet hardened reinforcing bar 30 (analogously to the above "hard into wet" process).

Ribbing the reinforcing bar 30 can improve the bond of the reinforcing bar 30 or reinforcing element 50 with a concrete component 48. The advantage of using a reversibly cross-linkable resin is that after the cooling and re-cross-linking of the resin the ribbing has higher strength and a smaller tendency to creep, since the connection is made by means of the cross-linked polymer and thus covalent bonds.

Alternatively or additionally, the bond between the reinforcement and the concrete can also be improved by putting particles 72, such as grains of sand, into the plastics matrix of the reinforcing bar 30. This makes it possible to give the outside surface of the reinforcing bar an uneven or rough structure having elevations and depressions whose particle size is greater than the unevenness or roughness of the plastics K of the plastics matrix.

A first possibility for introducing particles 72 into the plastics matrix of the plastics K is illustrated in Fig. 12. In this figure, the production device 31 for producing the reinforcing bar 30 has a particle introduction apparatus 73 following the mould 36. Before the plastics K hardens, in the particle introduction apparatus 73 the particles 72 are put onto the not yet hardened surface or outside surface of the plastics K, for example by a flow of gas carrying the particles 72 that is directed onto the outside surface of the plastics K. The kinetic energy or energy of impact and/or the application of additional pressure in the particle introduction apparatus 73 causes the particles 72 to go at least partially into the plastics matrix and thus to penetrate the surface of the thermoplastic phase of the plastics K. This achieves a rough or uneven outside surface. The hardening of the plastics matrix causes the particles 72 to connect to the plastics K. The rest of the process is analogous to the production method using the production device 31 shown in Fig. 1.

Alternatively to the method according to Fig. 12 the particles 72 can also be applied following the production of the reinforcing bars 30, according to the method shown in Fig. 1 and described above. To accomplish this, the reinforcing bar 30 can be heated by a heating apparatus 44, such that the plastics K changes back into its thermoplastic phase. Then, the particle introduction apparatus 73 can introduce the particles 72 into the plastics matrix in the region of the outside surface, analogously to the method according to Fig. 12. This also makes it possible to provide the reinforcing bars with sand or with particles 72 only in those parts where it is technically necessary.

It is also possible to apply both a rib element 70 and particles 72. The combination can also be spatially limited.

The invention relates to a concrete component 48 according to claim 1, having a concrete matrix 49 in which at least one reinforcing element 50 is arranged, the reinforcing element 50 having at least one reinforcing part 29, to a method for producing said concrete component and to a method for bending a reinforcing element 50. It is essential to the invention that the at least one reinforcing part has one or more strengthening threads 34 or strengthening yarns arranged in a plastics matrix made of a plastics material K. The plastics material K is designed as a reversibly cross-linked plastics. It has molecular chains, in particular polymer chains, which contain cross-linkings that can be reversibly produced. Most of the cross-linkings, at least 50%, can be released by inputting energy, especially heat, into the plastics K, and recreated by recooling. This makes it possible to produce and store a reinforcing element 50 in completely hardened form as a standard element, such as a reinforcing bar having a single reinforcing part, or as a reinforcing mesh having reinforcing parts that are interconnected obliquely or at right angles. Depending on the particular application, the produced reinforcing element 50 can be reshaped into the desired shape by releasing the cross-linkings in one or more locations through the input of energy, reshaping the reinforcing element and then hardening the reinforcing element again by recreating the cross-linkings. This process can be repeated multiple times, such that it is also possible, for example, to adapt the reinforcing element at the construction site.

LIST OF REFERENCE NUMERALS

30	Reinforcing bar
30a	First bar portion
30b	Second bar portion
31	Production device
32	Creel
33	Bobbin
34	Strengthening thread
35	Bath
36	Mould
37	Removal apparatus
38	Cutting-off tool
43	Energy input apparatus
44	Heating apparatus
45	Bend site
46	Ultrasound apparatus
46a	Sonotrode
46b	Forming tool end
47	Counter-holding tool
48	Concrete component
49	Concrete matrix
50	Reinforcing element
51	Reinforcing mesh
52	Support
53	First layer
54	Second layer
55	Pressing arrangement
56	Roller
57	Forming tool
58	Connection site
60	Bending device

61	Tool arrangement
62	Holding apparatus
63	Forming tool
64	First tool part
65	Second tool part
70	Rib element
71	Winding unit
72	Particles
73	Particle introduction apparatus
80	Reinforcing mesh
81	Crossing site
82	Textile structure
83	Textile machine
84	Storage roll
85	Opening
A	Axis of bend
BA	Bend outside
BI	Bend inside
d	Thickness of reinforcing element
K	Plastics
M	Central axis
Q	Transverse direction
S	Extent direction

Patentkrav

1. Betonkomponent (48) med en betonmatrix (49), i hvilken mindst et armerings-element (50) er indlejret til armering, hvor armeringselementet (50) har mindst en armeringsdel (29) i form af en armeringsstang (30),
hvor den mindst ene armeringsstang (30) strækker sig i en udstrækningsretning (S) og har mindst en forstærkningstråd (34),
og hvor den mindst ene forstærkningstråd (34) er indrettet i en kunststofmatrix af armeringsstangen (30), som består af et reversibelt tværbundet kunststof (K), hvis tværbindinger kan adskilles og gendannes reversibelt flere gange, og derved kan adskilles på en sådan måde, at armeringsstangen (30) er bøjelig,
hvor mindst en af de tilstedeværende armeringsstænger (30) strækker sig i en lige linje i mindst et stangafsnit (30a, 30b) eller over hele dens længde, og hvor den mindst ene forstærkningstråd (34) er indrettet under en trækspænding i kunststofmatrixen langs det mindst ene stangafsnit (30a, 30b), strækkende sig i en lige linje, eller over hele dens længde.

2. Betonkomponent ifølge krav 1,
kendetegnet ved, at armeringselementet (50) omfatter flere indbyrdes forbundne armeringsstænger (30).

3. Betonkomponent ifølge krav 1 eller 2,
kendetegnet ved, at mindst en af de tilstedeværende armeringsstænger (30) har mindst et bøjningspunkt (45).

4. Betonkomponent ifølge krav 3,
kendetegnet ved, at mindst nogle af armeringsstængerne (34) strækker sig på skrå i forhold til udstrækningsretningen (S) ved bøjningspunktet (45), og hvor deres afstand fra en midterakse (M) af den mindst ene armeringstang (30) er reduceret.

5. Betonkomponent ifølge krav 3 eller 4,
kendetegnet ved, at bøjningspunktet (45) har en bøjningsinderside (BI), med en indvendig krumning, og en bøjningsyderside (BA), med en udvendig krumning, placeret over for bøjningsinderside (BA) i forhold til en midterakse (M) af den

mindst ene armeringsstang (30), hvor den indvendige krumning af armeringsstangen er større end den udvendige krumning, og hvor ingen af forstærkningstrådene (34) ved bøjningspunktet (45) har en krumning, som er større end den indvendige krumning.

6. Betonkomponent ifølge et af de foregående krav,
kendetegnet ved, at hver armeringsstang (30) har flere forstærkningstråde, som danner en tekstilstruktur (82) med krydsningspunkter (81) og/eller tekstilbindingspunkter, og at tekstilstrukturen (82) er indlejret i kunststof-matrixen.

7. Betonkomponent ifølge et af de foregående krav,
kendetegnet ved, at kunststoffet (K) i kunststofmatrixen har en glasovergangs-temperatur på mindst 50°C eller 80°C eller 90°C eller 100°C.

8. Betonkomponent ifølge et af de foregående krav,
kendetegnet ved, at det reversibelt tværbundne kunststof (K) kan tværbindes ved hjælp af en Diels-Alder-reaktion og kan adskilles ved hjælp af en retro-Diels-Alder-reaktion.

9. Betonkomponent ifølge et af kravene 1 til 7, **kendetegnet ved, at** mindst nogle af tværbindingerne af det reversibelt tværbundne kunststof (K) kan adskilles ved hjælp af elektromagnetisk stråling og/eller ved hjælp af ultralydsexcitering, og/eller at mindst nogle af tværbindingerne af det reversibelt tværbundne kunststof (K) kan tværbindes ved hjælp af elektromagnetisk stråling.

10. Fremgangsmåde til fremstilling af en betonkomponent (48) med en betonmatrix (49) og mindst et armeringselement (50), som har mindst en armeringsdel (29) i form af en armeringsstang (30), med følgende trin:

- tilvejebringelse af flere forstærkningstråde (34),
- indsættelse af forstærkningstrådene (34) i en kunststofmatrix i et reversibelt tværbundet kunststof (K), hvis tværbindinger kan adskilles og gendannes reversibelt flere gange, og derved kan adskilles på en sådan måde, at armeringsstangen (30) er bøjelig,

- hærdning af kunststofmatrixen til fremstilling af den mindst ene armeringsstang (30) af armeringselementet (50), hvor mindst en af de tilstedeværende armeringsstænger (30) strækker sig i en lige linje i mindst et stangafsnit (30a, 30b) eller over hele dens længde, og hvor den mindst ene forstærkningstråd (34) er indrettet under en trækspænding i kunststofmatrixen langs det mindst ene stangafsnit (30a, 30b), strækkende sig i en lige linje eller over hele dens længde,
- indlejring af den mindst ene armeringsstang (30) af armeringselementet (50) i betonmatrixen (49),
- hærdning af betonmatrixen (49).

11. Fremgangsmåde til bøjning af en armeringsstang (30), som strækker sig i en udstrækningsretning (S) og har mindst en forstærkningstråd (34), hvor den mindst ene forstærkningstråd (34) er indrettet i en kunststofmatrix af armeringsstangen (30), som består af et reversibelt tværbundet kunststof (K), hvis tværbindinger kan adskilles og gendannes reversibelt flere gange, og kan adskilles på en sådan måde, at armeringsstangen (30) er omformbar,
hvor mindst en af de tilstedeværende armeringsstænger (30) strækker sig i en lige linje i mindst et stangafsnit (30a, 30b) eller over hele dens længde, og hvor den mindst ene forstærkningstråd (34) er indrettet under en trækspænding i kunststofmatrixen langs det mindst ene stangafsnit (30a, 30b), strækkende sig i en lige linje eller over hele dens længde, med følgende trin:
- indførsel af energi ved et bøjningspunkt (45) til opløsning af tværbindingen af kunststoffet (K) af kunststofmatrixen,
- bøjning af armeringsstangen (30) ved bøjningspunktet (45),
- hærdning af armeringsstangen (30) ved bøjningspunktet (45).

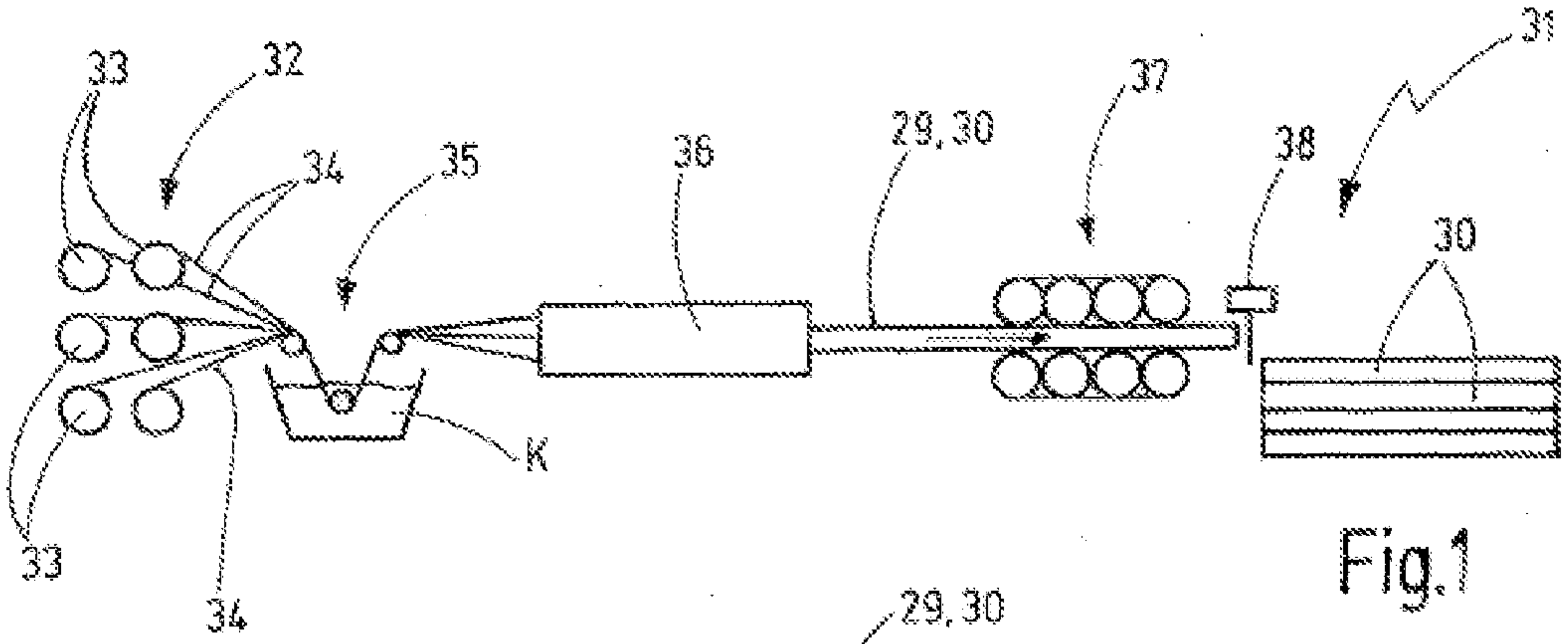

Fig.1

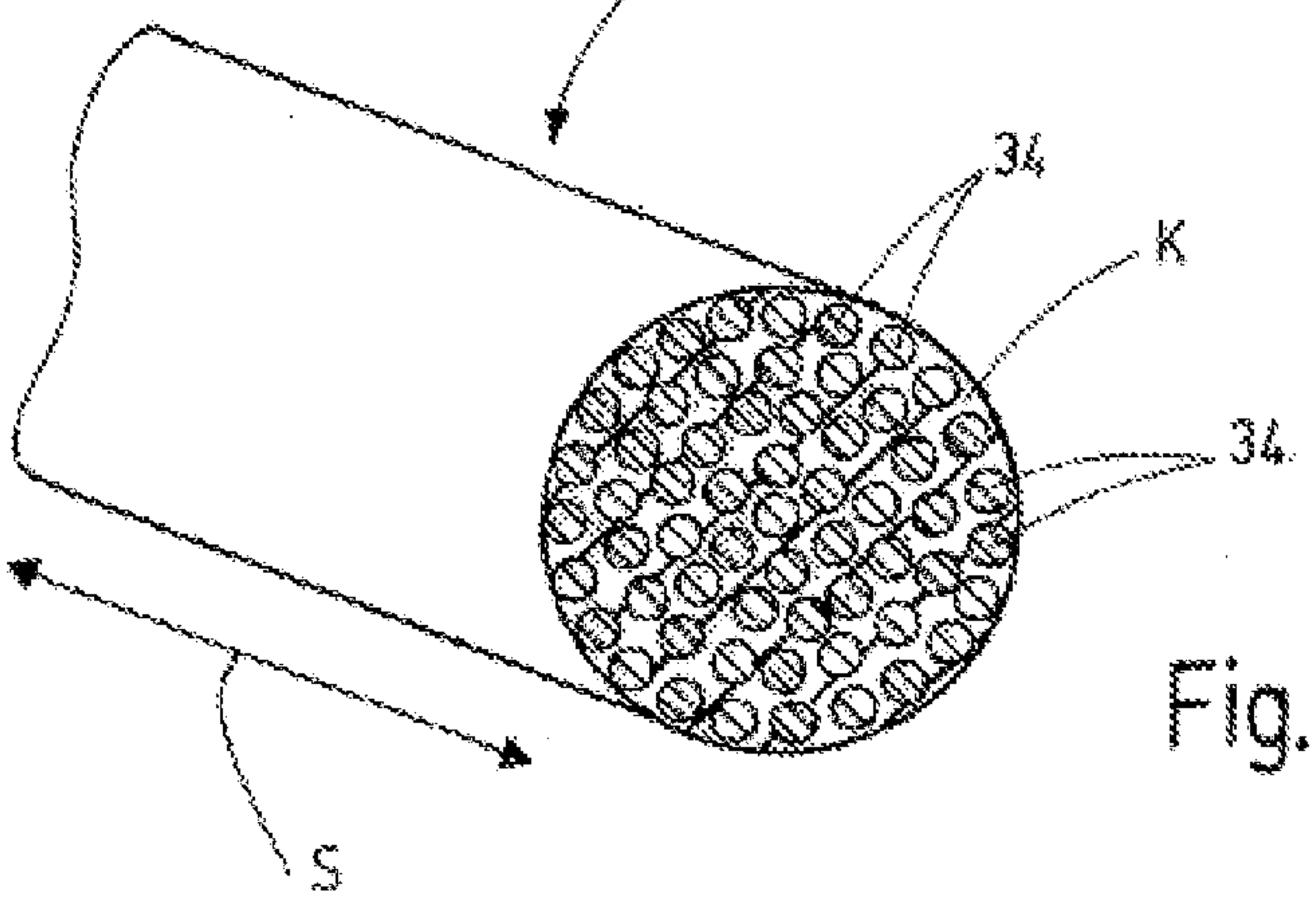

Fig.2

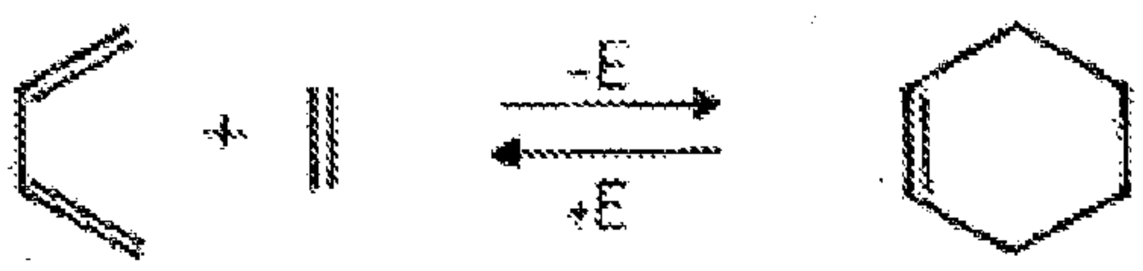

Fig.3a

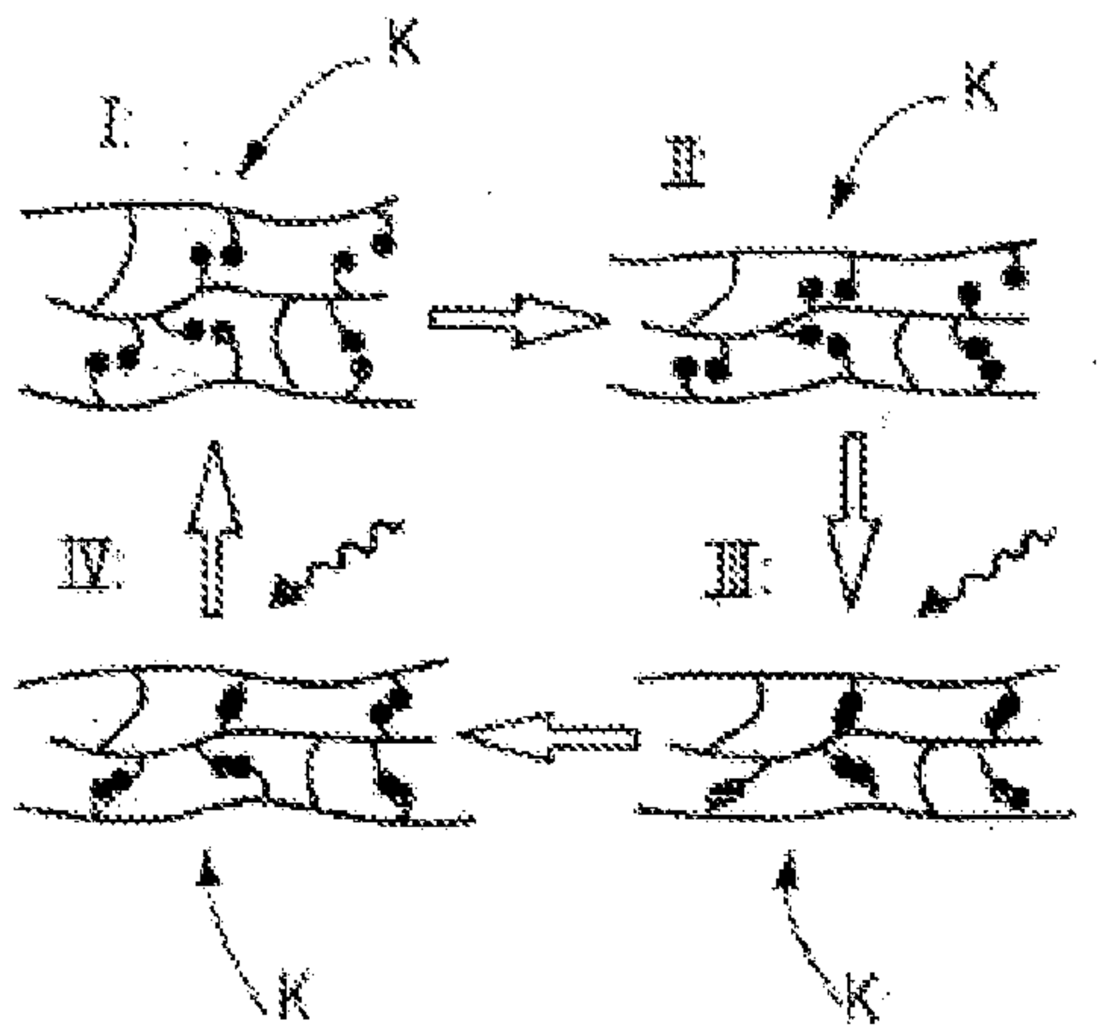

Fig.3b

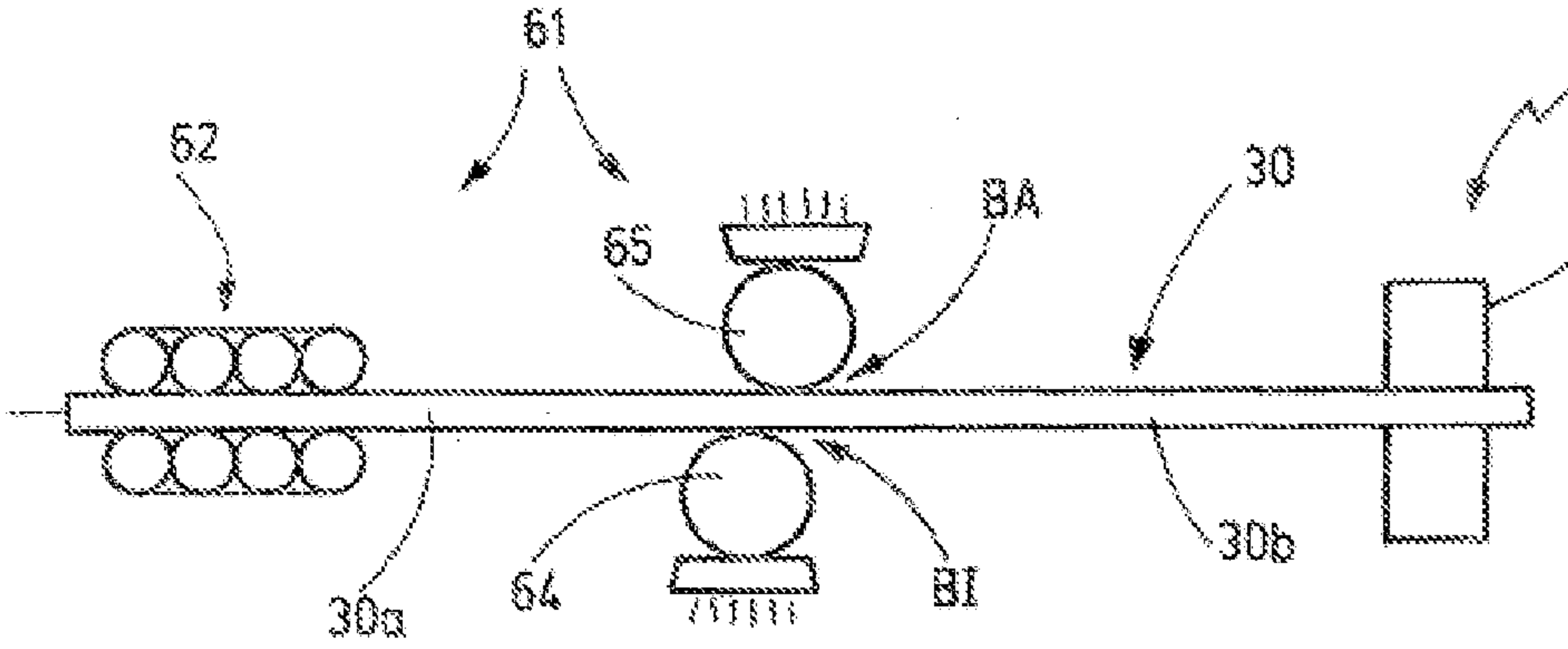

Fig.4

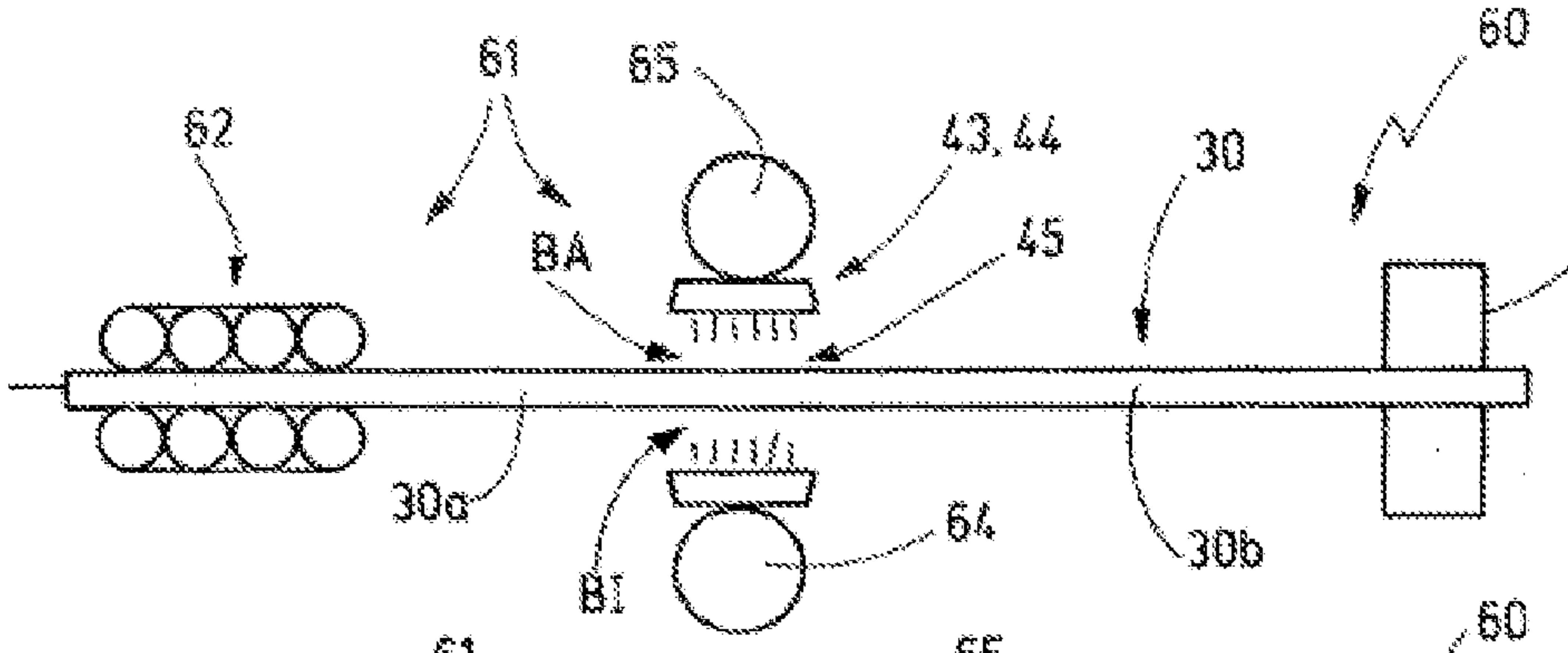

Fig.5

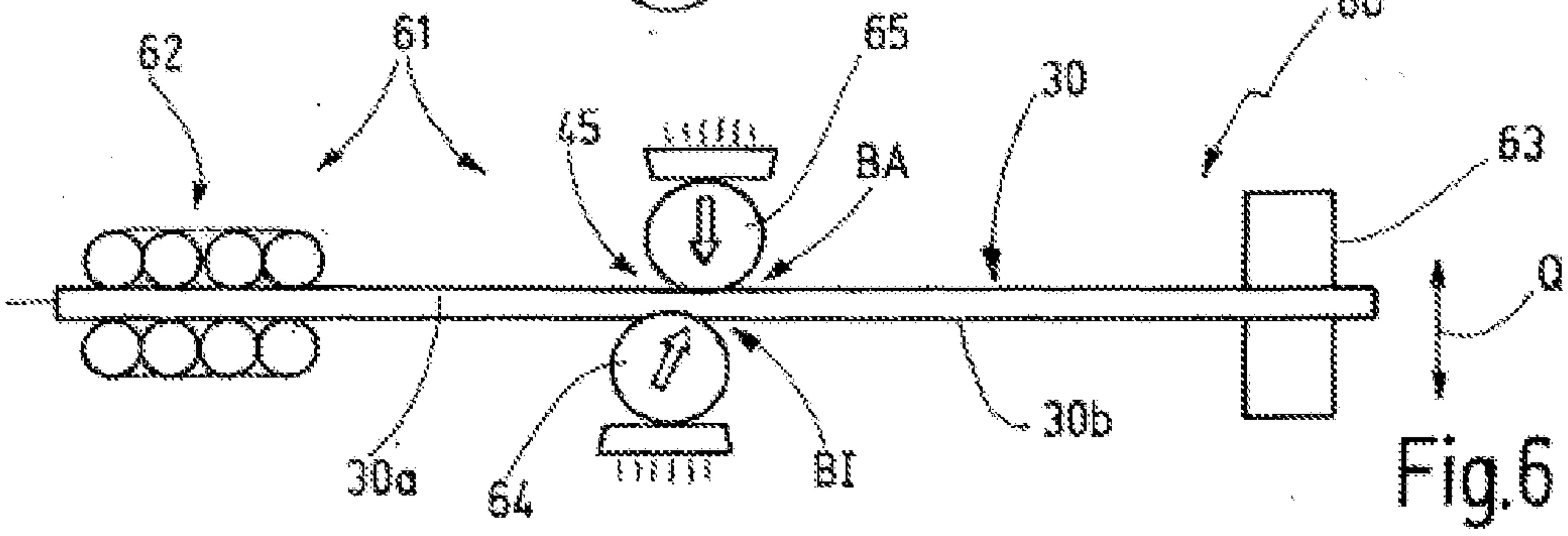

Fig.6

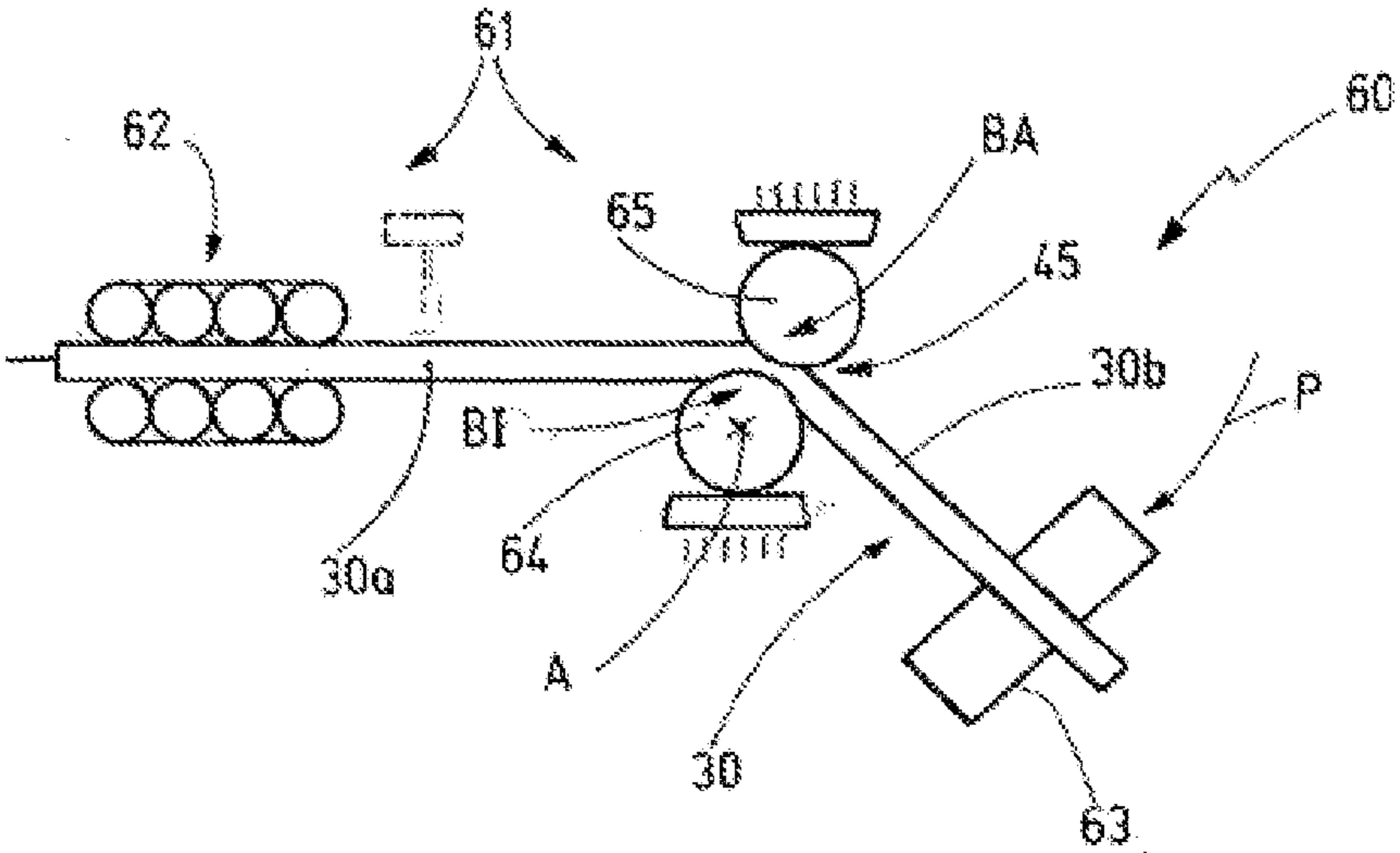

Fig.7

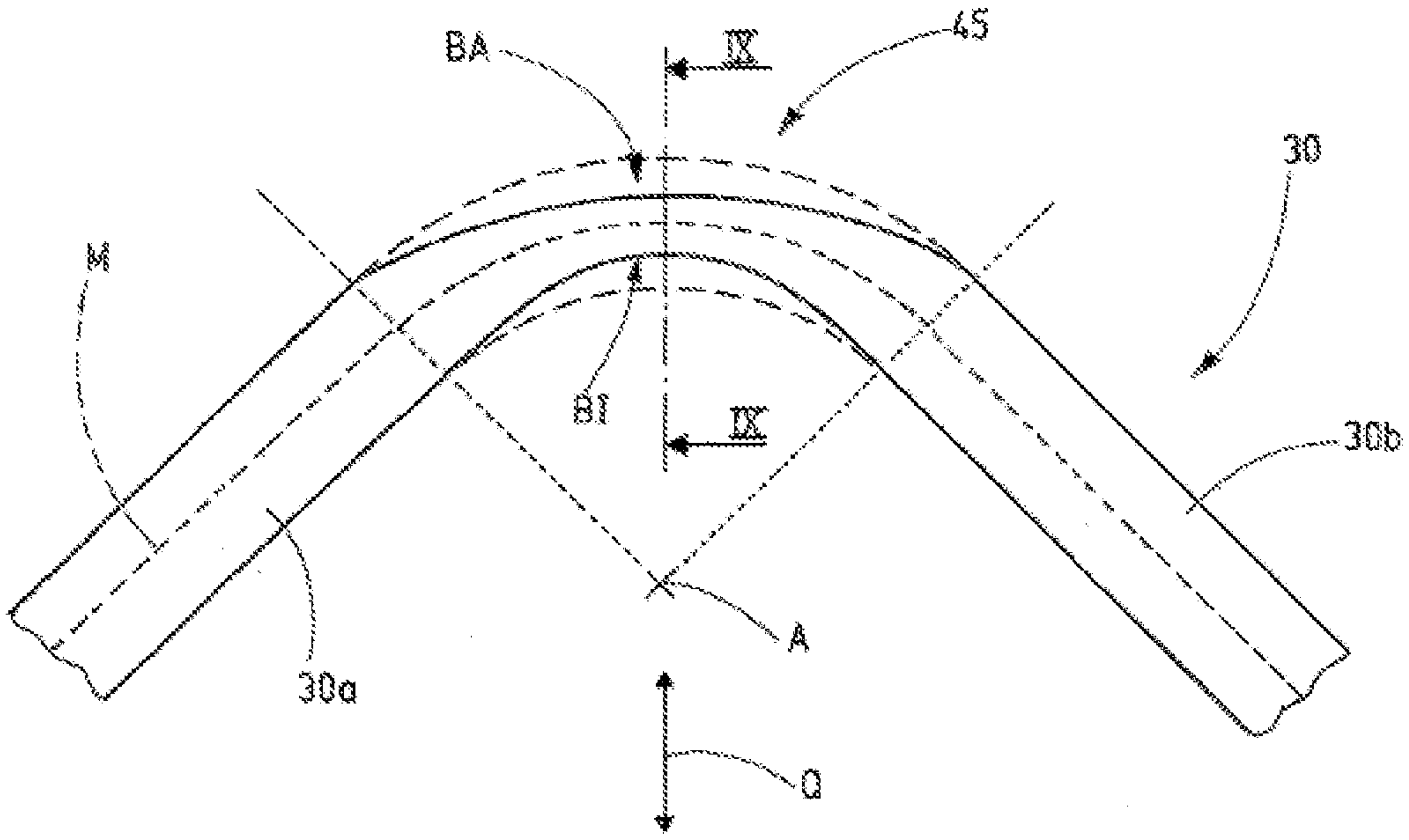

Fig.8

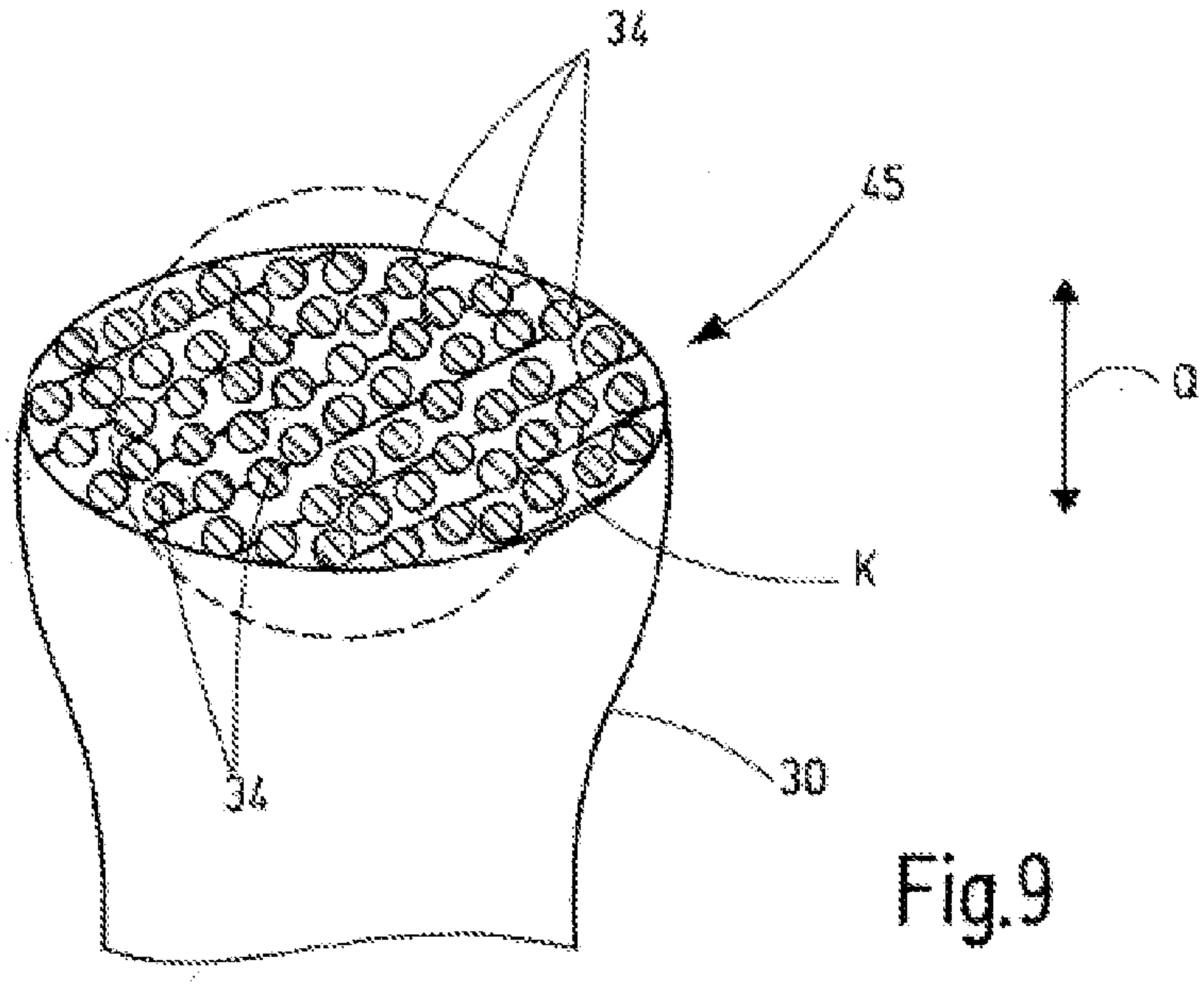

Fig.9

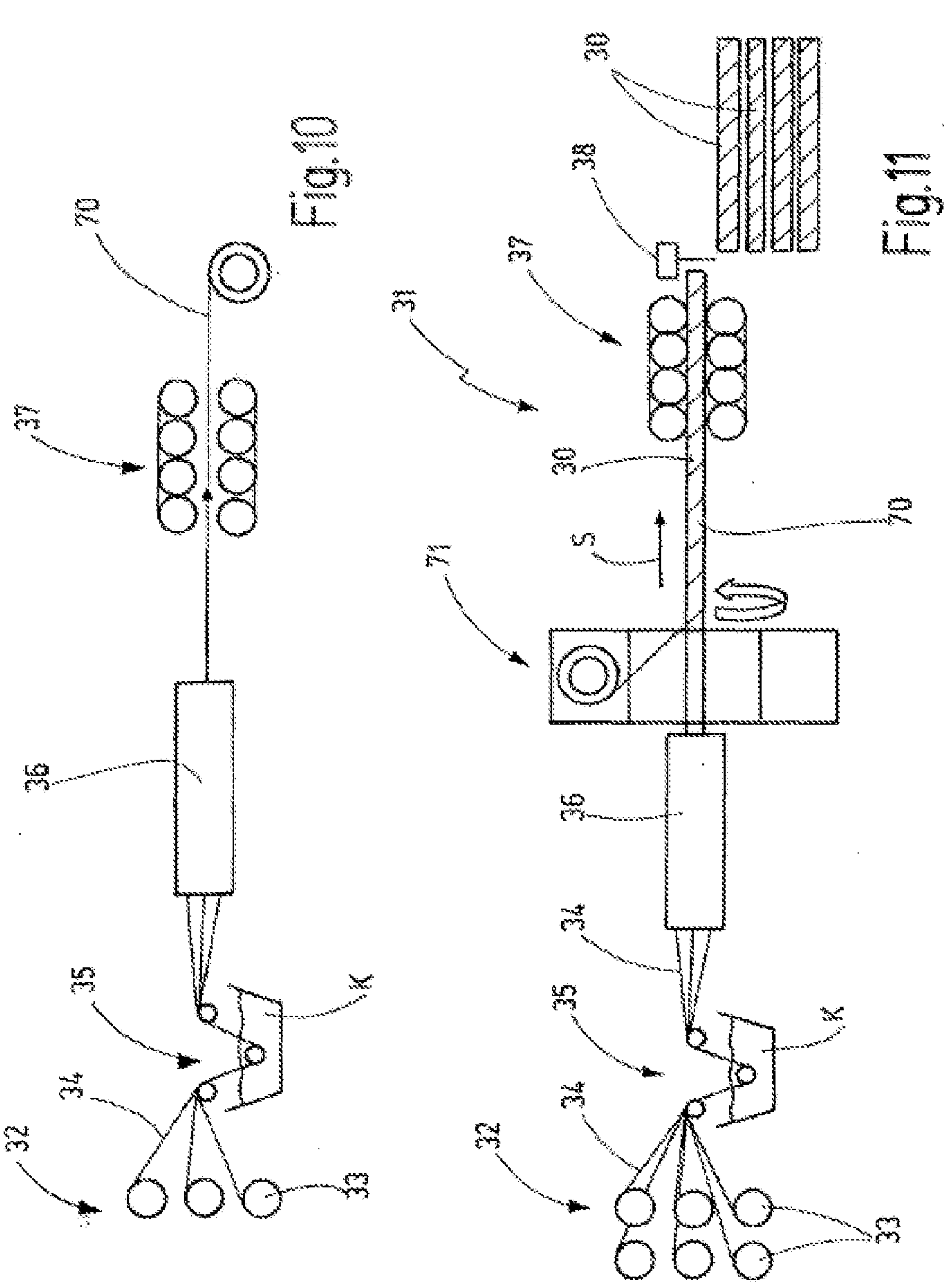
Fig.10
Fig.11
30
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S

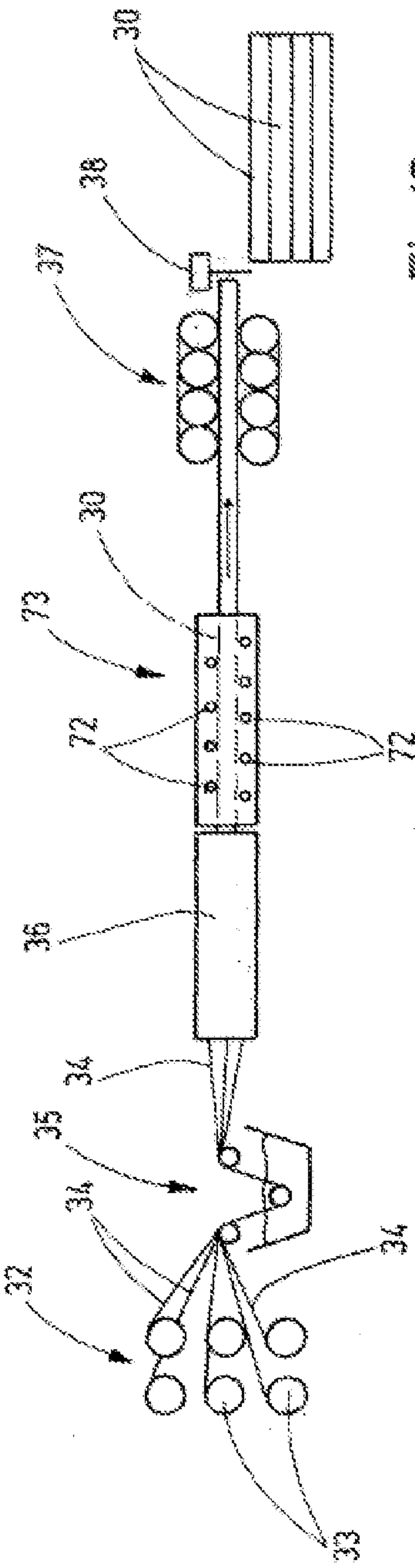

Fig.12

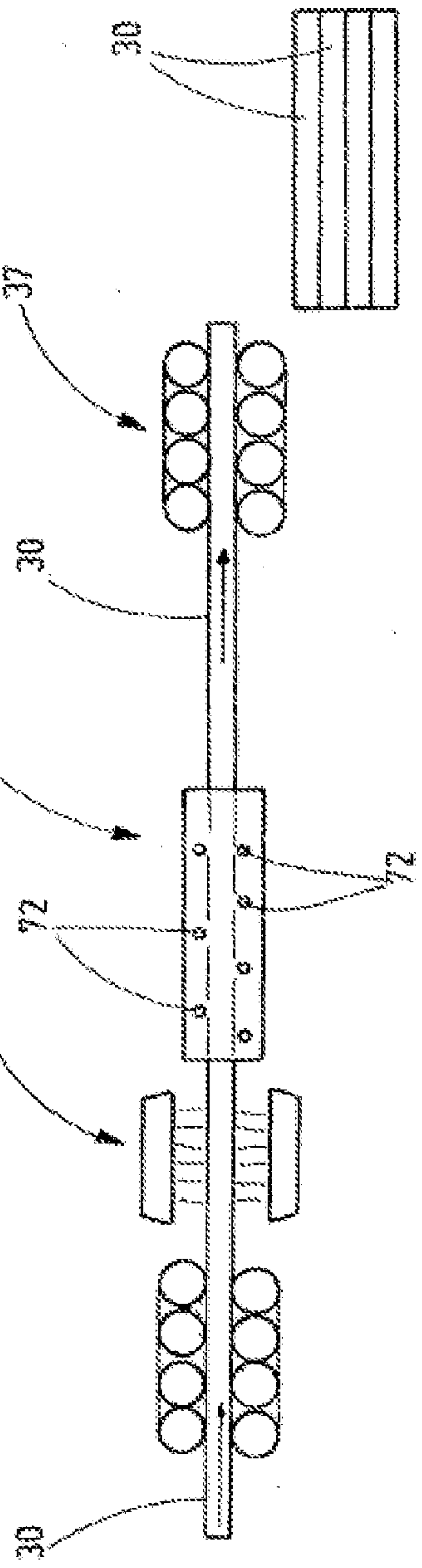

Fig.13

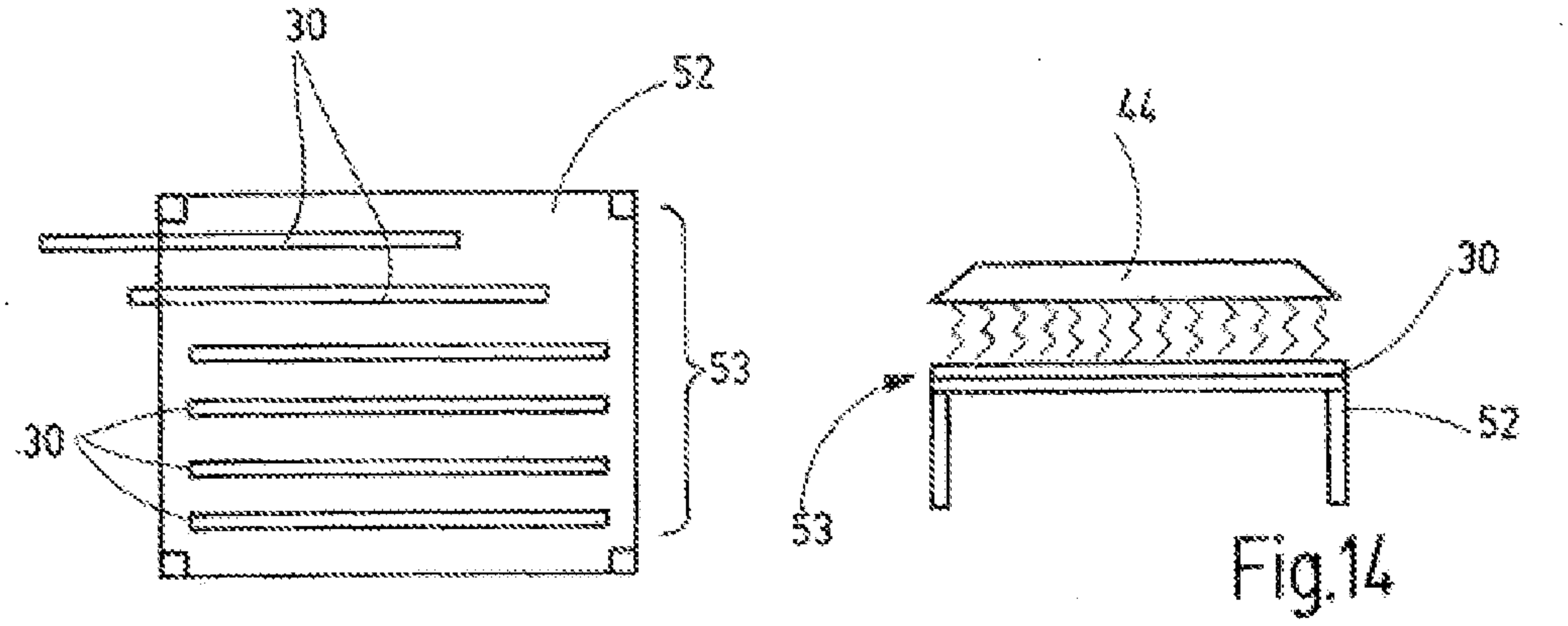

Fig.14

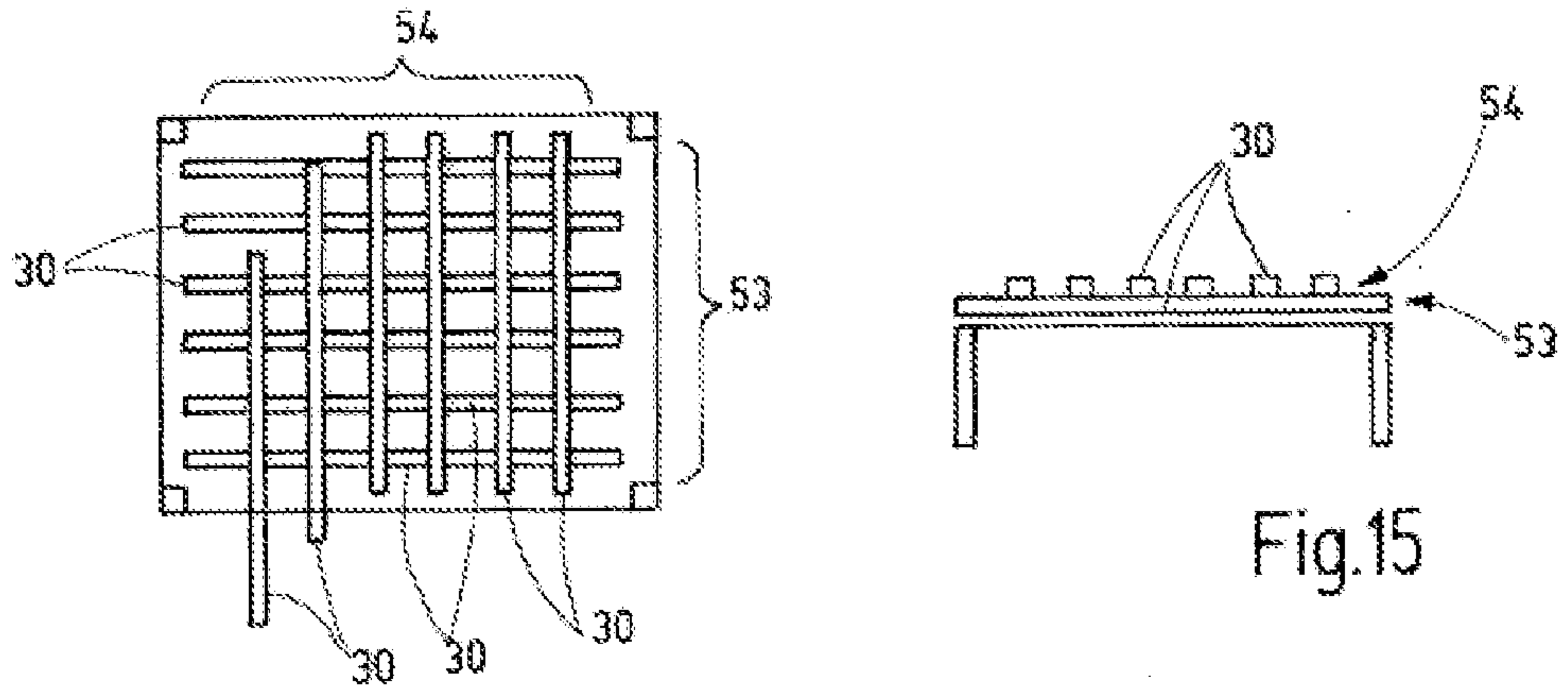

Fig.15

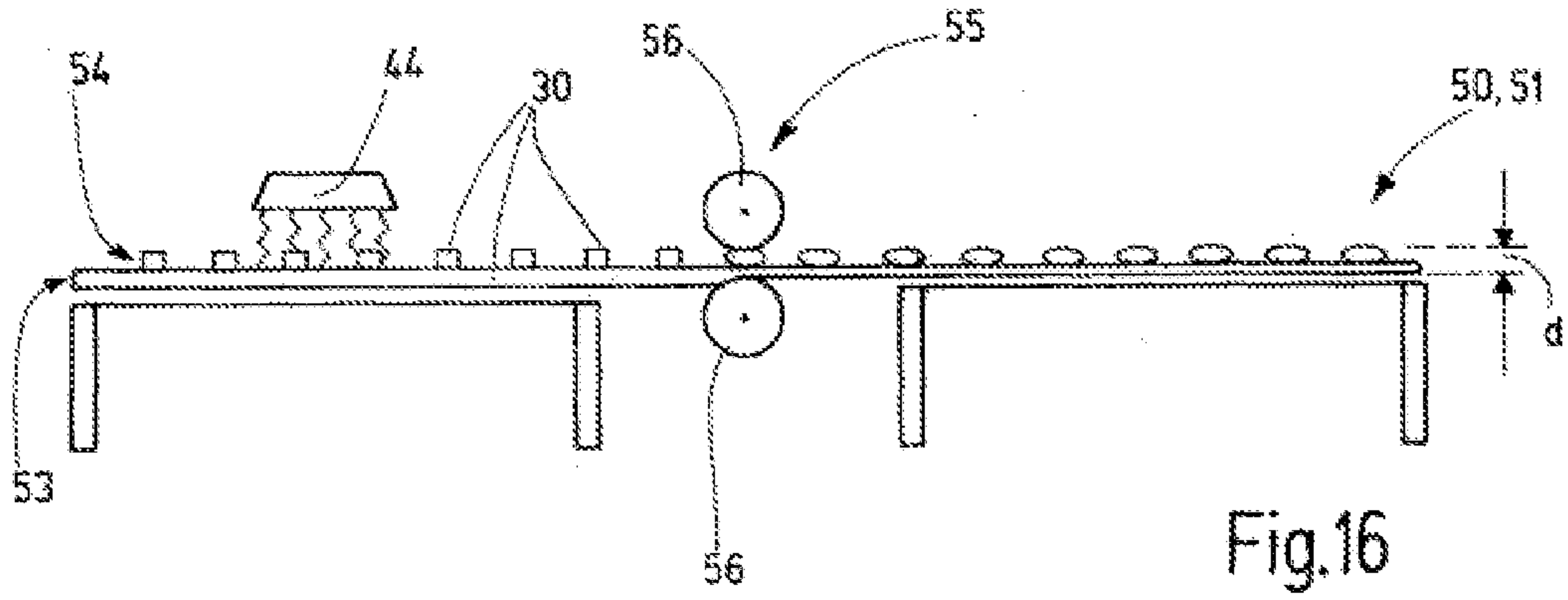

Fig.16

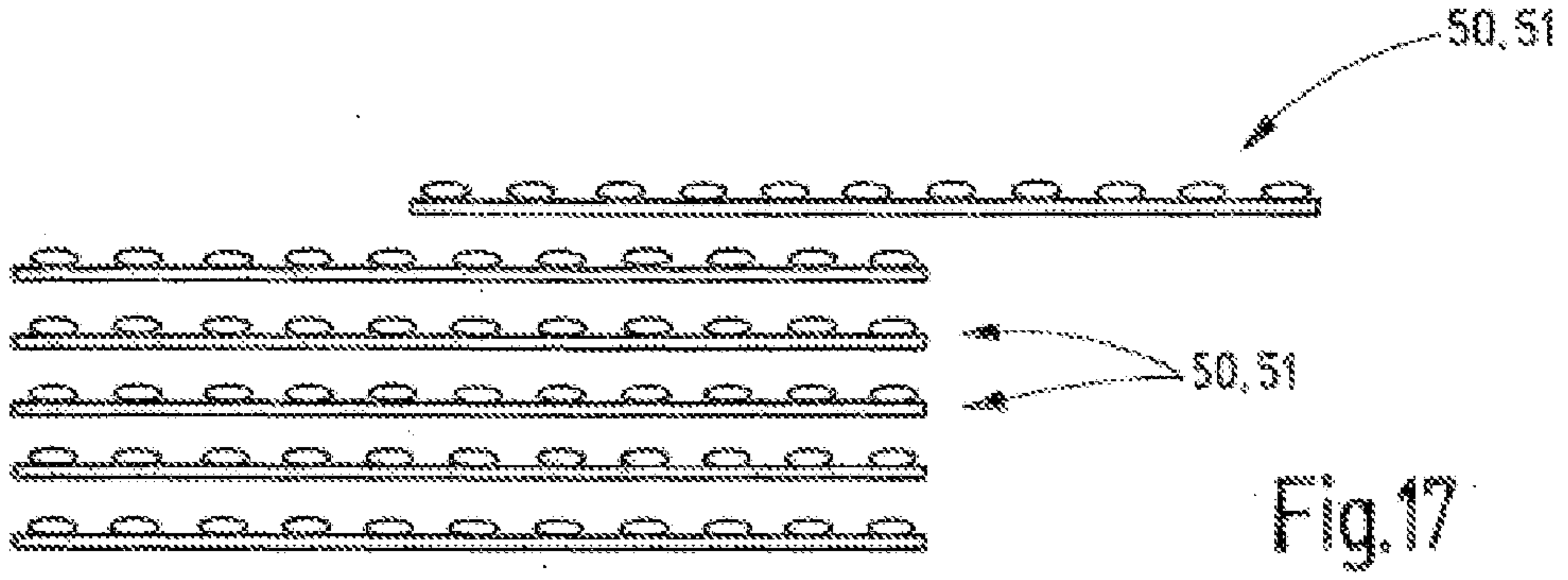

Fig.17

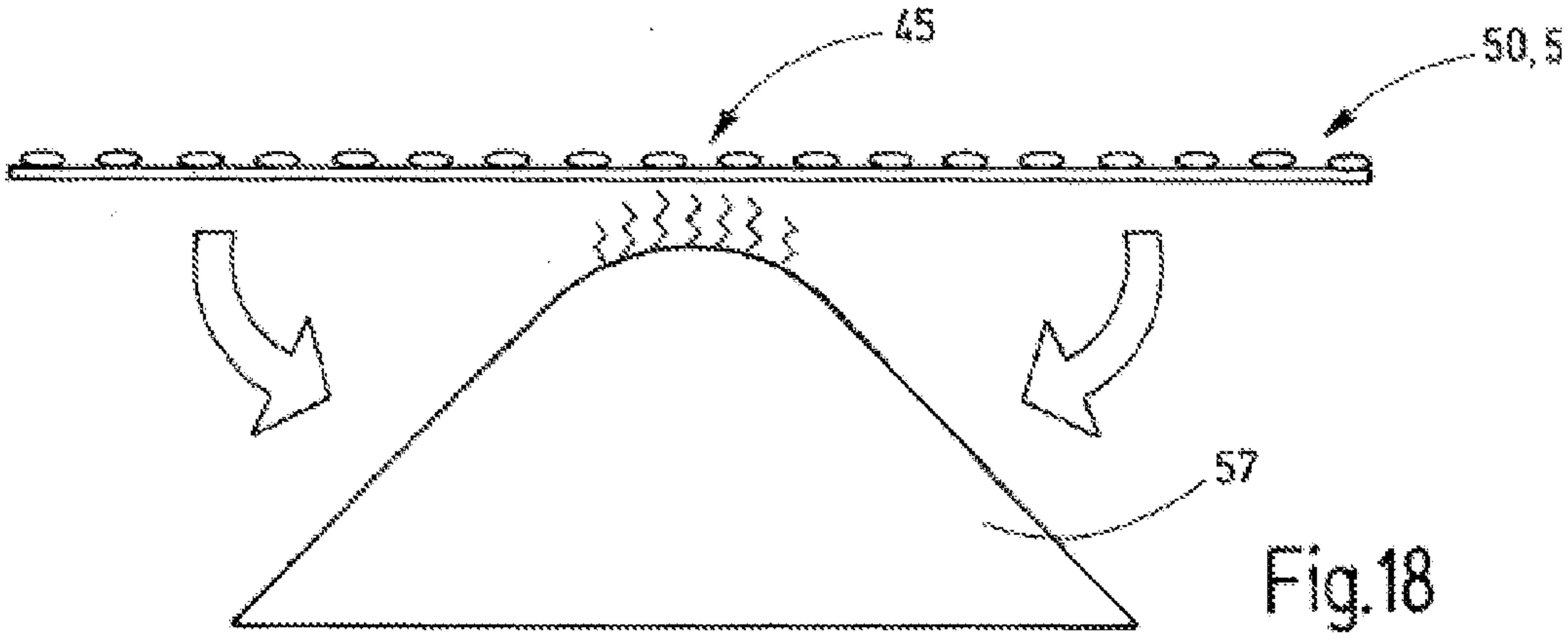

Fig.18

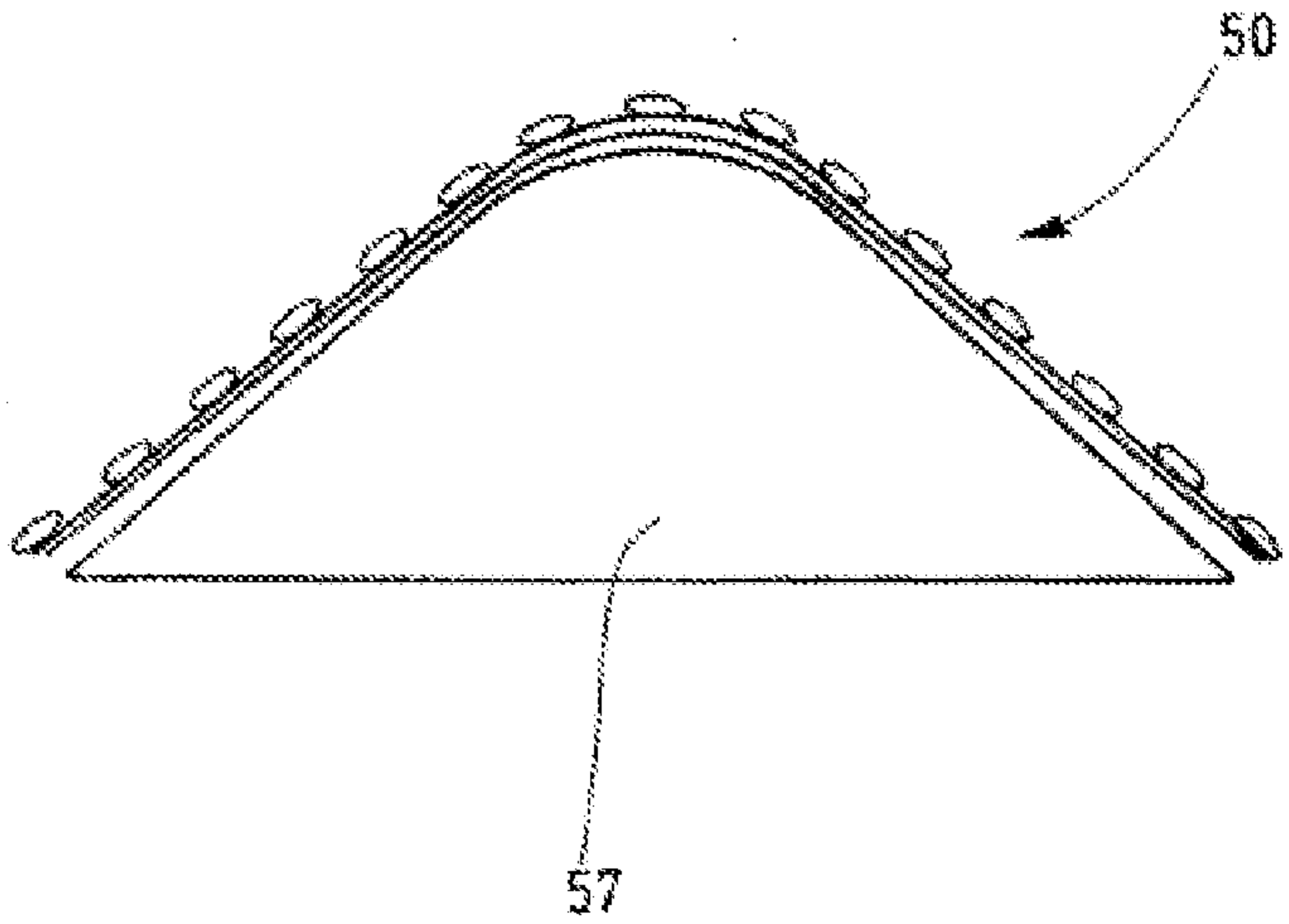

Fig.19

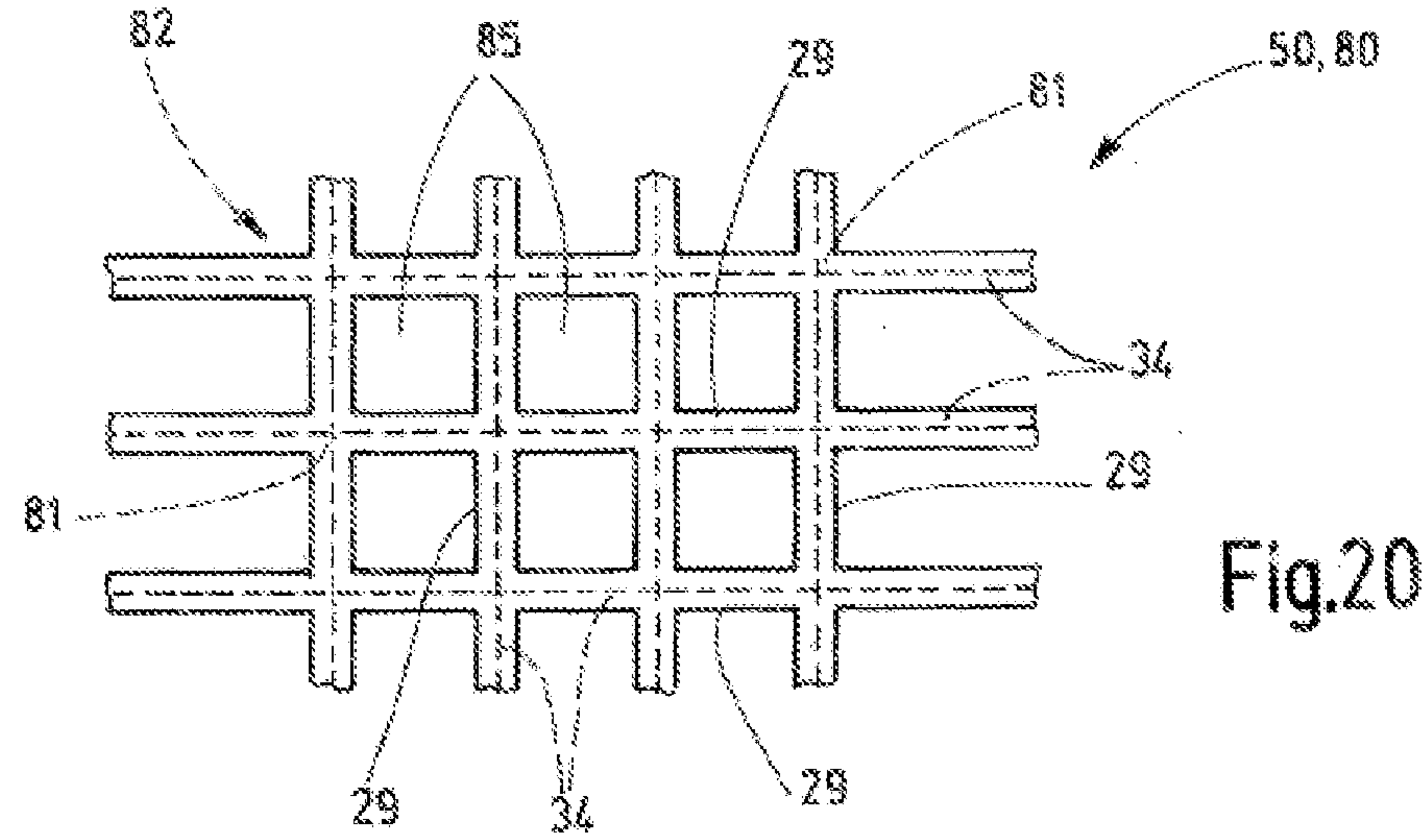

Fig.20

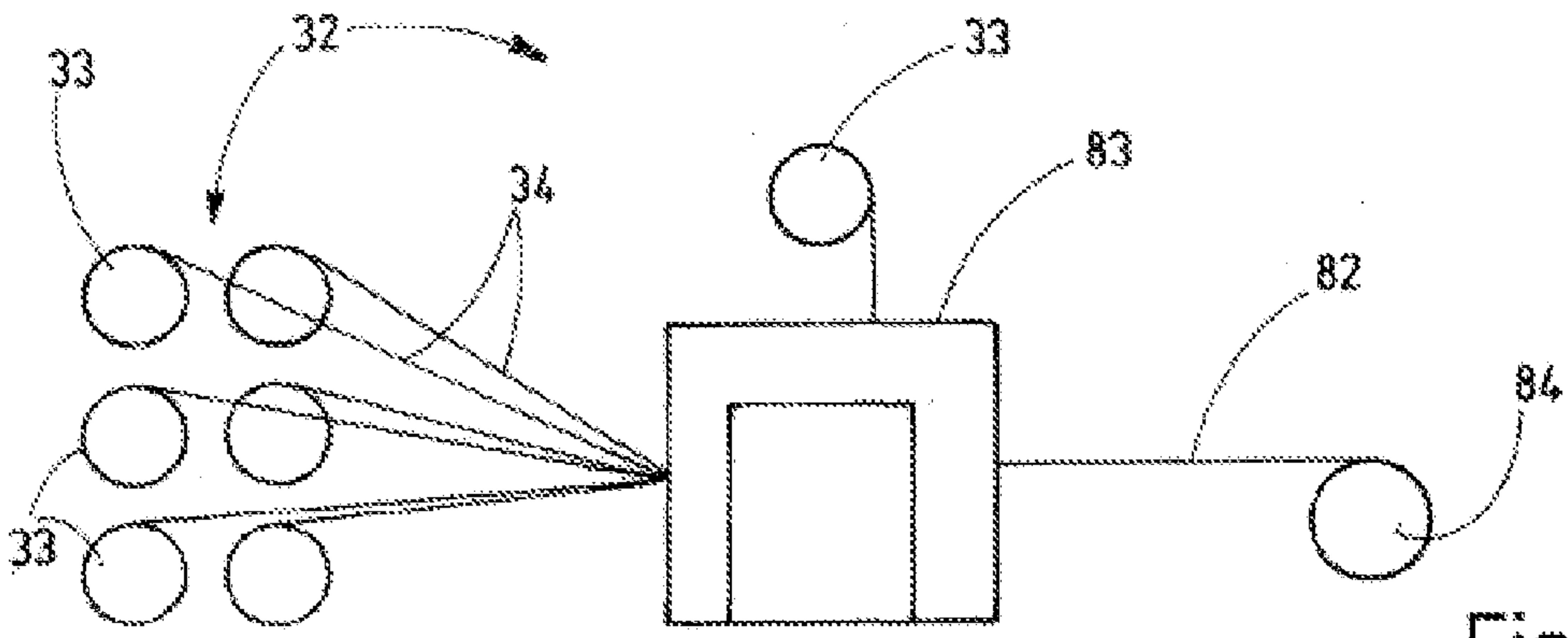

Fig.21

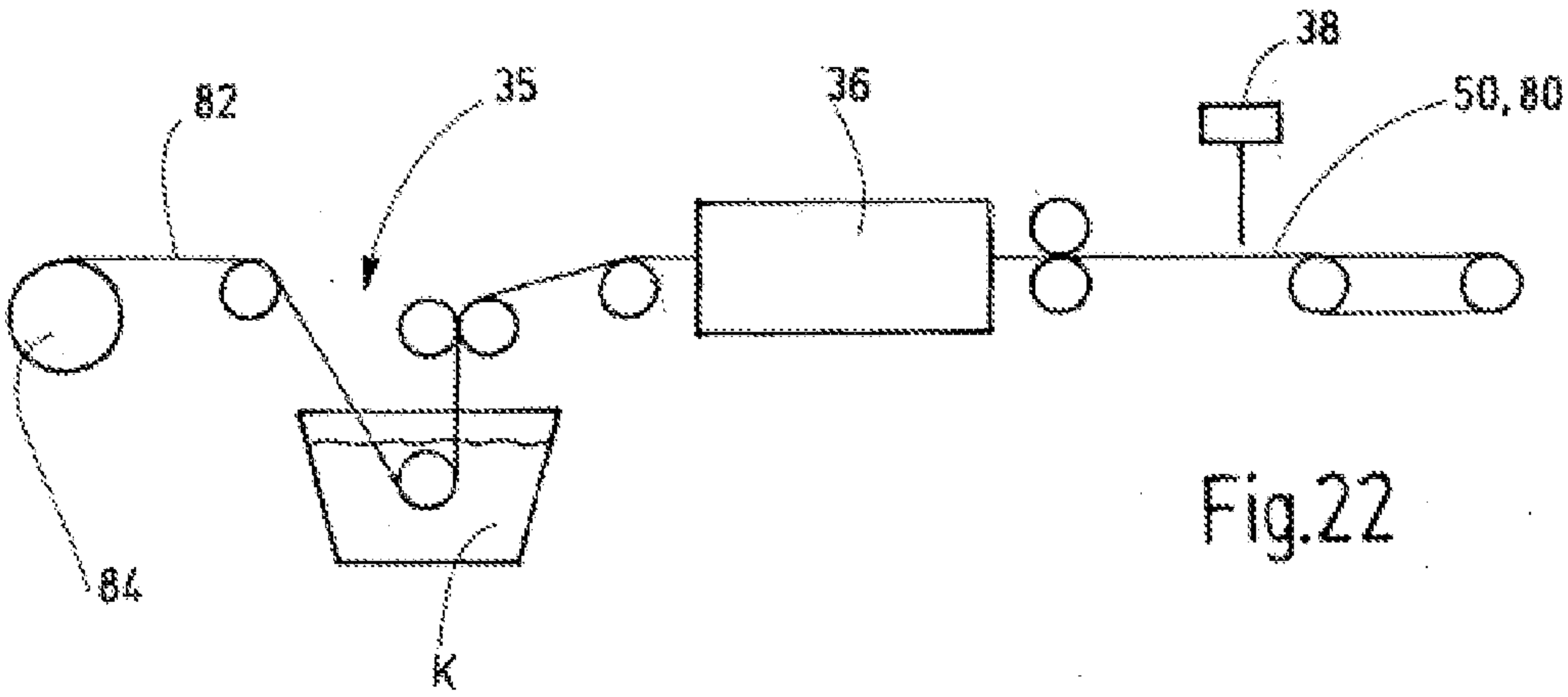

Fig.22

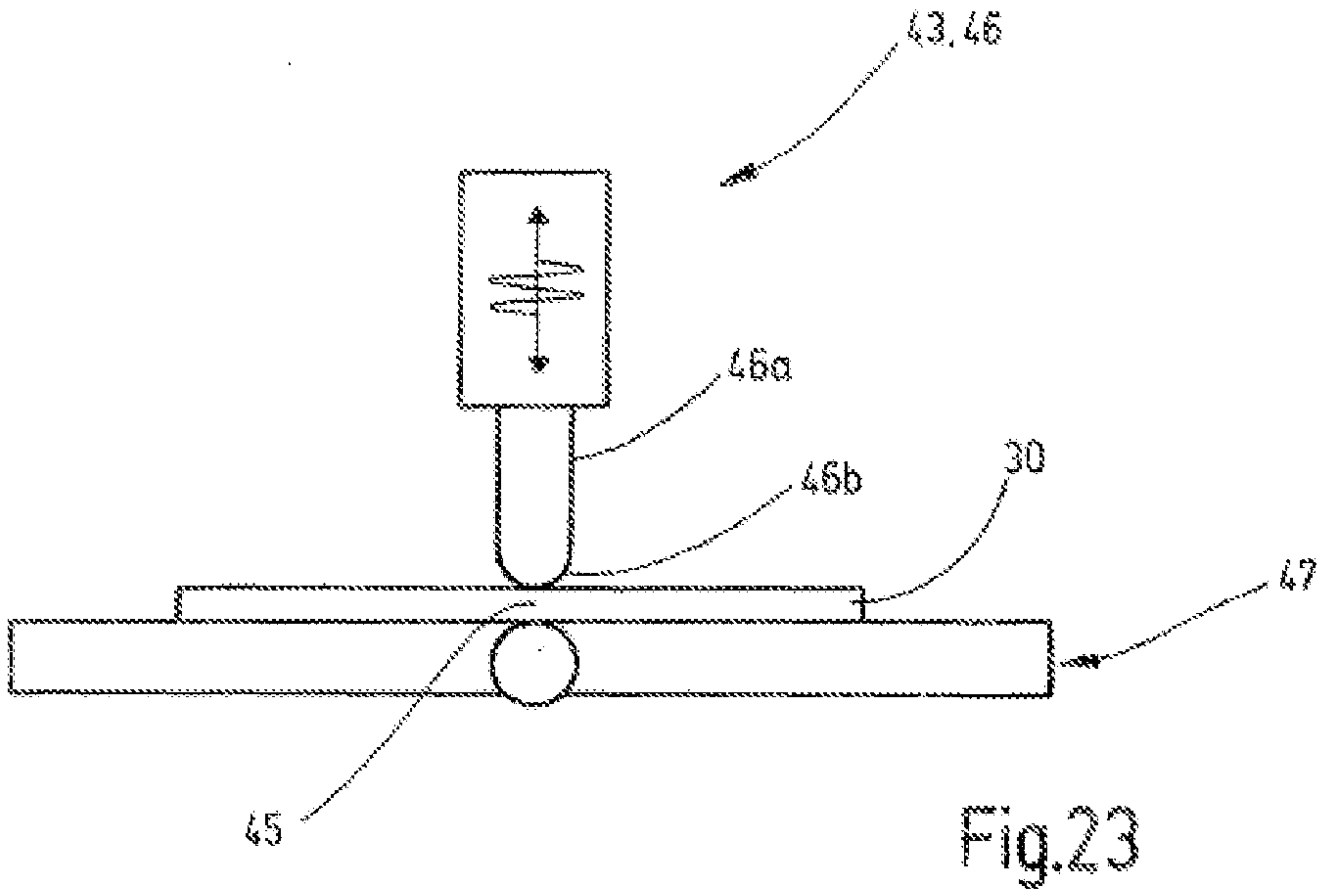

Fig.23

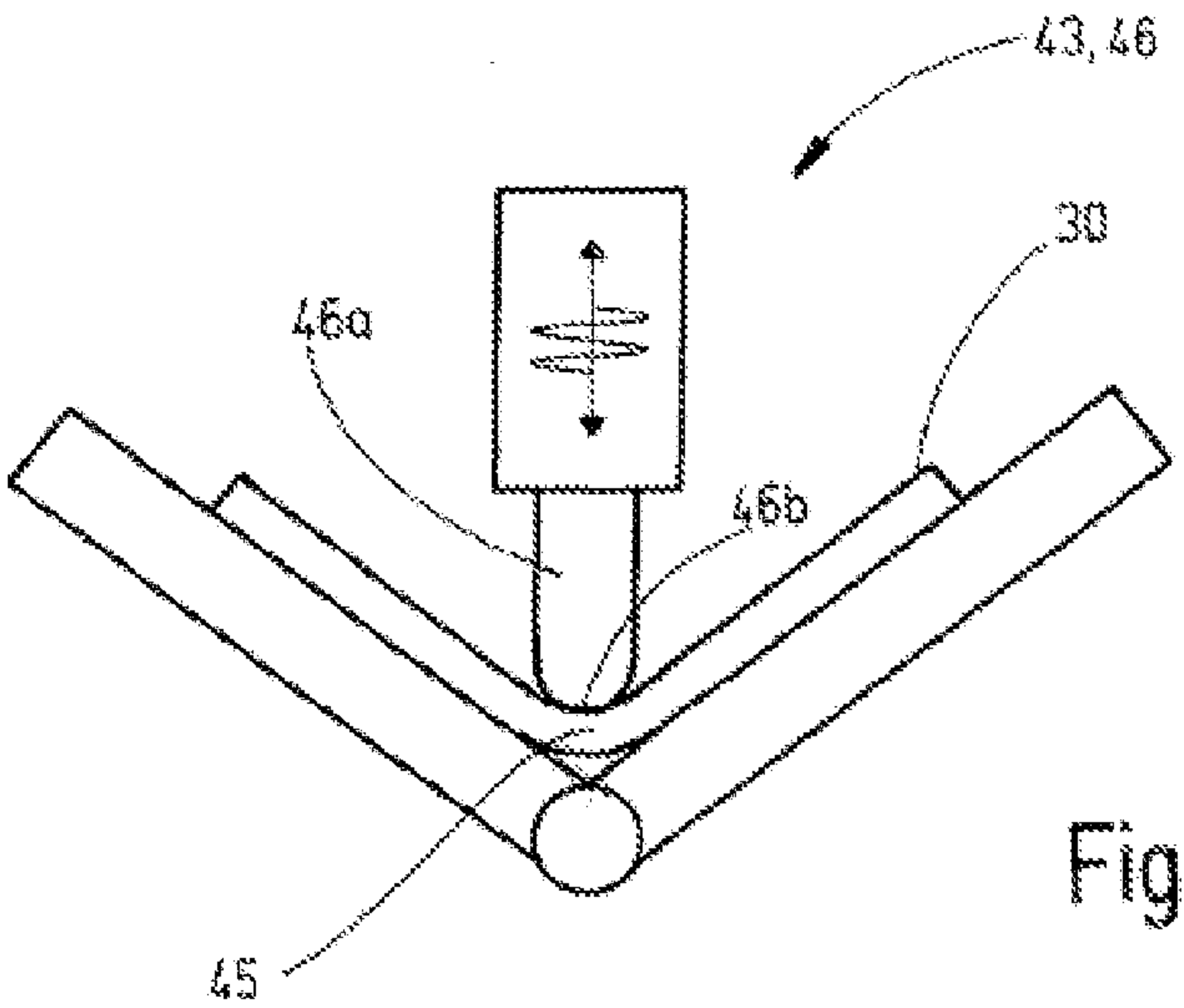

Fig.24

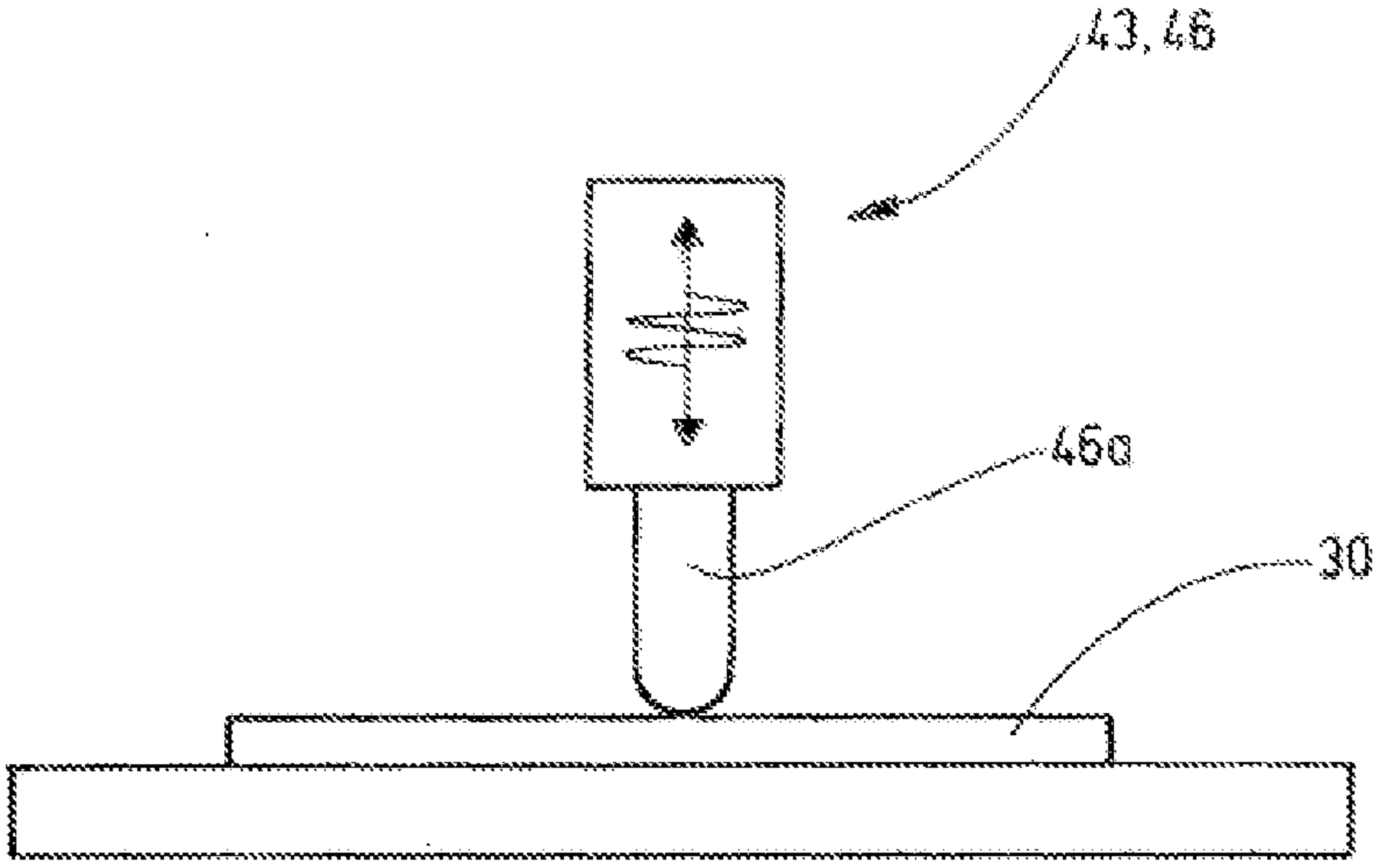

Fig.25

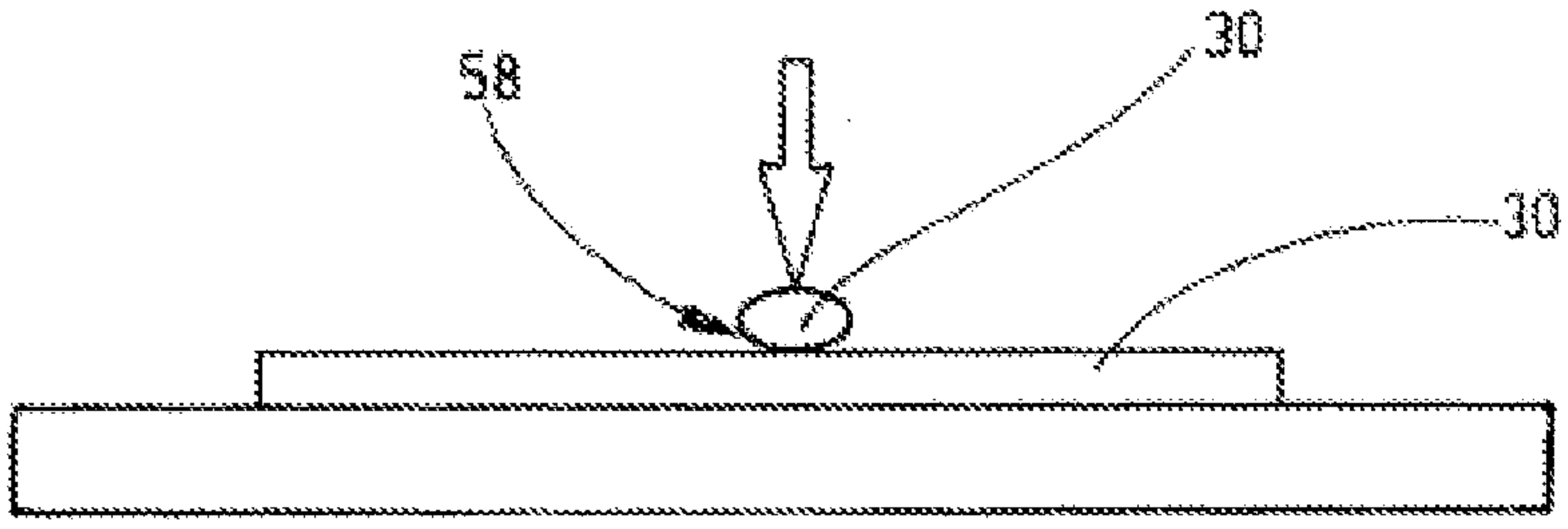

Fig.26

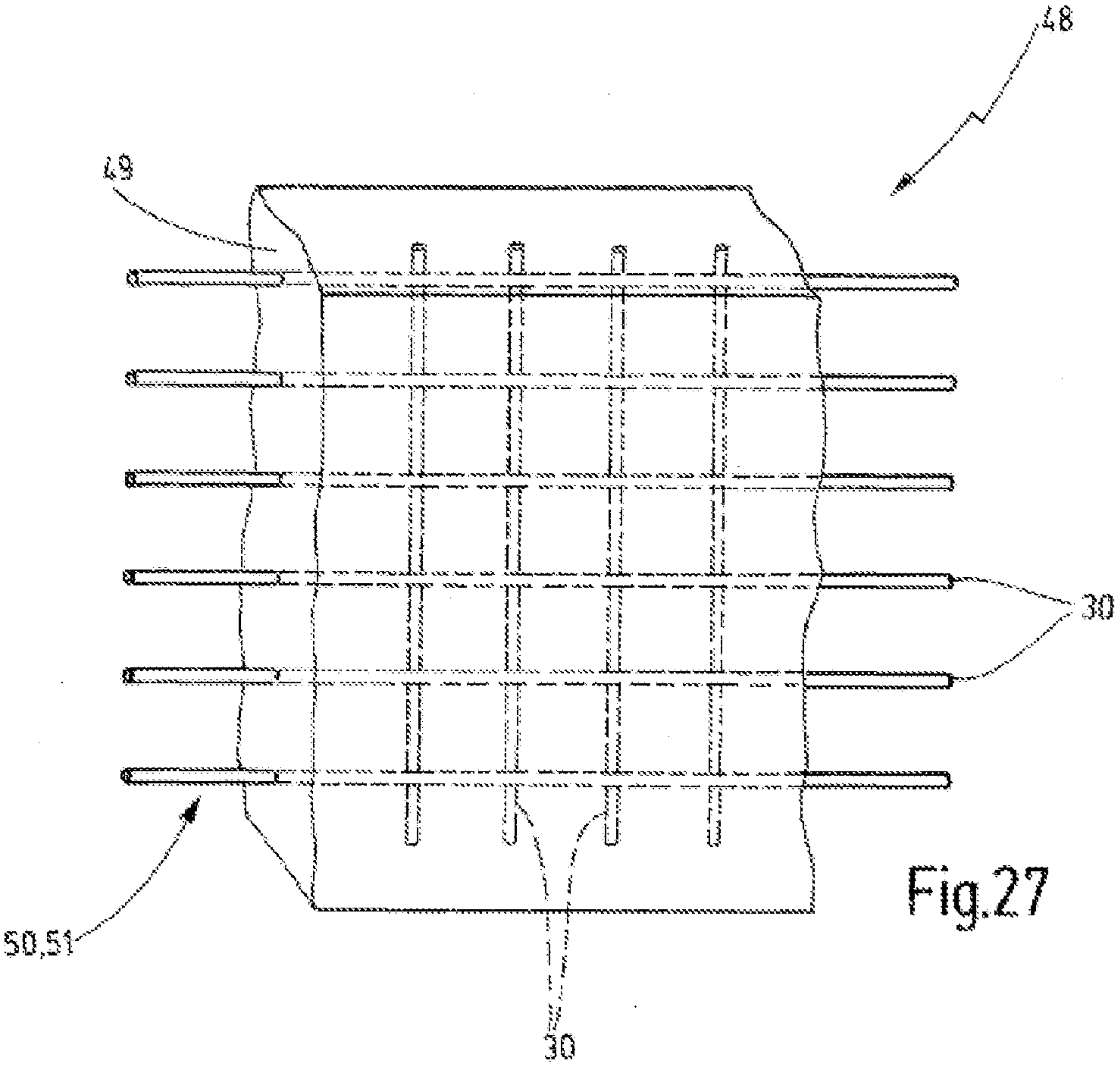

Fig.27

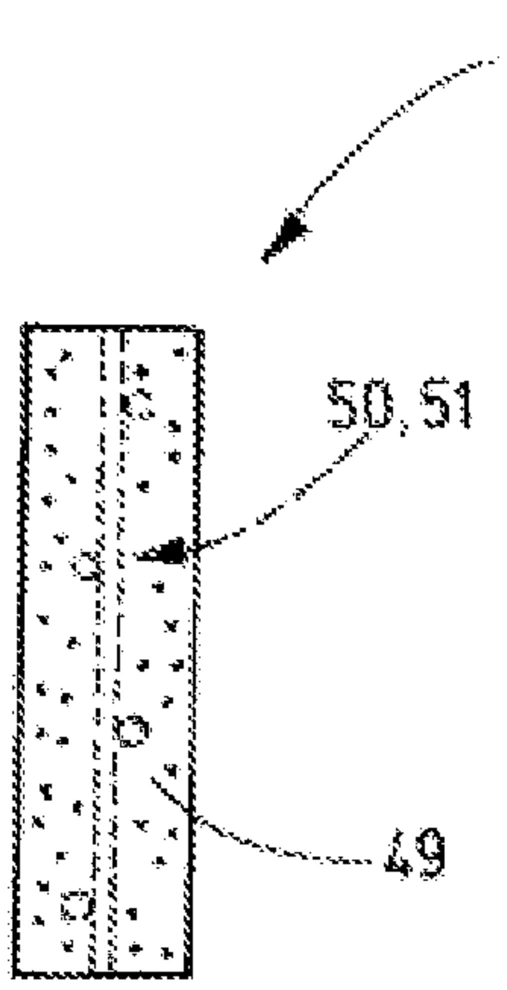

Fig.28

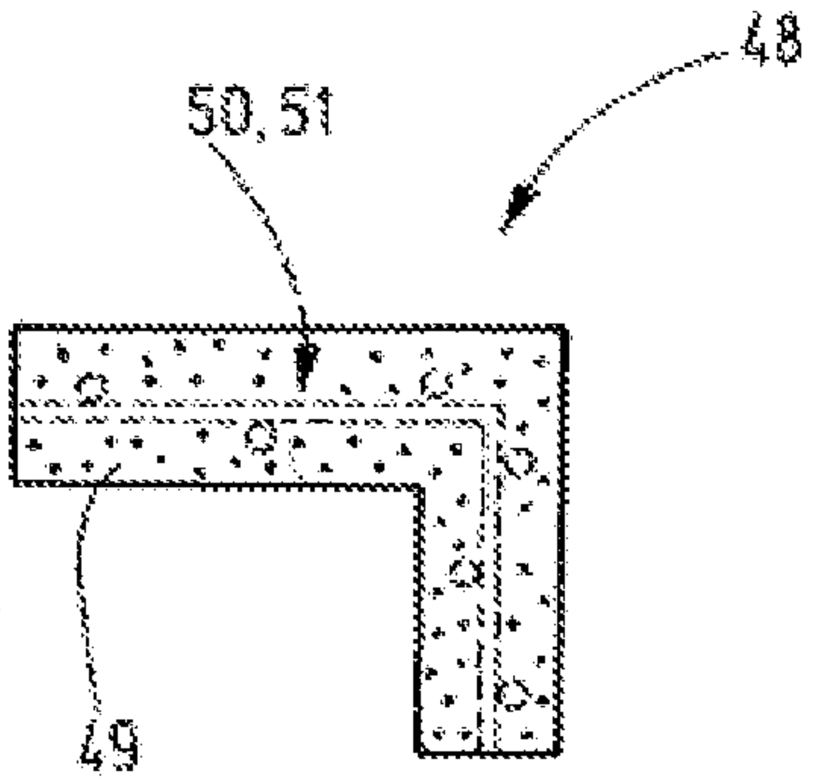

Fig.29

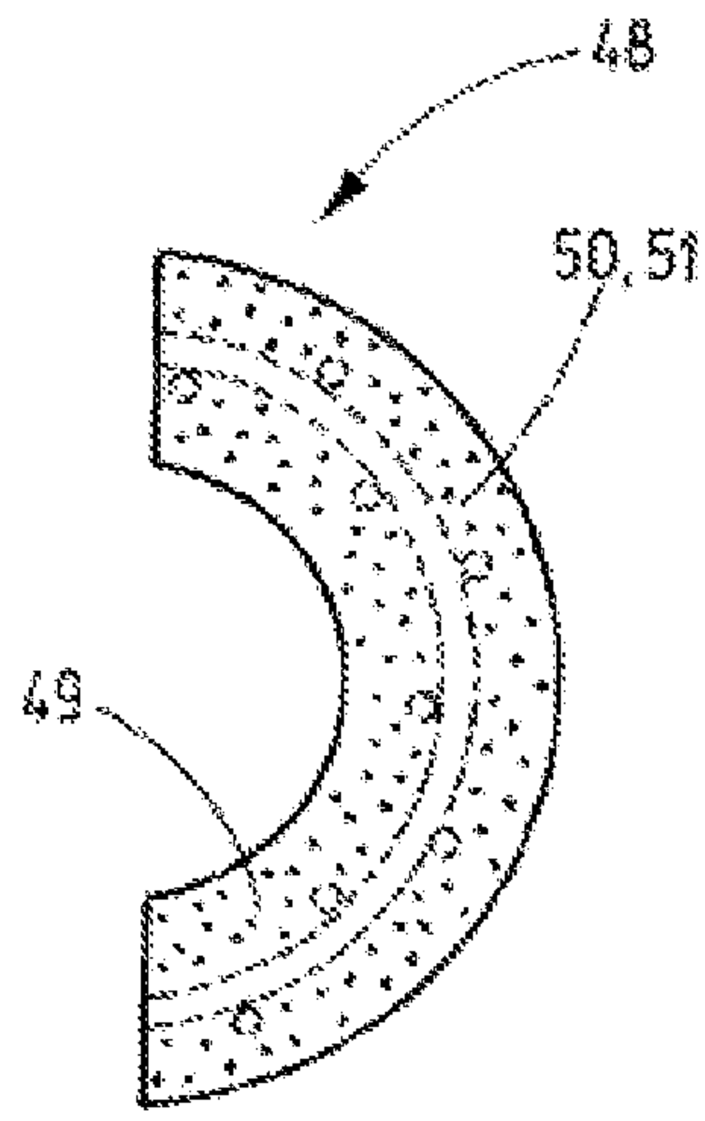

Fig.30