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(54) **Method and apparatus for continuous extrusion of thixo-magnesium into plate or bar shaped extrusion products**

(57) A method for extrusion of magnesium based alloys for obtaining net shapes, or near net shapes in the form of plate or bar shaped extrusion products. The extrusion product of the method has a thixotropic structure and stable shape. The method includes providing magnesium based alloy feed stock and converting at least a portion of the feedstock into a thixotropic slurry. The method further exerts a driving force on the feedstock, upstream of the thixotropic slurry, to advance the feedstock in a downstream direction and subjecting a downstream end of the thixotropic slurry to controlled rapid cooling to obtain a thixotropic structure. The method fur-

ther allows a downstream end of the converted feedstock to escape through a shaping die, so as to obtain bar stock having a predefined cross-sectional shape. An extrusion device for carrying out the method is also provided. The extrusion device includes a supply arrangement for feeding feedstock, a conversion chamber, agitation means, cooling means and a shaping die. The agitation means advantageously includes an inductive heater that electromagnetically agitates any liquid or semi-liquid metal in the conversion chamber.

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Description

[0001] The invention relates to a method and apparatus for extrusion of thixotropic metal structures, in particular using magnesium, or magnesium alloys.

[0002] The extrusion of thixotropic magnesium alloy, in which a billet is used for pressurizing and feeding a thixotropic slurry from a buffer space through a forming die and with cooling at or near the forming die is known. Such an extrusion process can only be used for thixomolding of discrete products of finite length. It is also known to use screw extruders in feeding injection moulds with charges of thixotropic magnesium to obtain discrete products. The use of thixotropic material, by the known processes and apparatus, is thereby limited to relatively small products. Such processes are discontinuous. Larger products such as continuous plate or sheet extrusions and profiled bars cannot be obtained by the known thixomolding processes. For continuous extrusion it is important that the creation of fresh thixotropic material and the increase of pressure takes place simultaneously and continuously.

[0003] Accordingly the present invention envisions continuous extrusion of thixotropic magnesium, or magnesium alloy to enable manufacture of larger products, such as sheet and profiled bars. It is thus an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art. It is also an object of the present invention to provide alternative apparatus and process solutions which are less cumbersome in operation and which moreover can be practiced relatively inexpensively. Alternatively it is an object of the invention to at least provide the public with a useful choice.

[0004] To this end the invention provides a method for extrusion of magnesium based alloys for obtaining net shapes, or near net shapes, having a thixotropic structure, the method including: providing magnesium based alloy feed stock; converting at least a portion of the feedstock into a thixotropic slurry; exerting a driving force on the feedstock, upstream of the thixotropic slurry, to advance the feedstock in a downstream direction; subjecting a downstream end of the thixotropic slurry to controlled rapid cooling to retain a thixotropic structure; and allowing a downstream end of the converted feedstock to escape through a shaping die, to obtain bar stock having a predefined cross-sectional shape. By this arrangement of operational steps the invention provides for continuous extrusion of thixotropic magnesium, or magnesium alloys, in which the primary formation of the non-dendritic, thixotropic structure is incorporated within the extrusion process itself.

[0005] According to a further aspect of the method of the invention the step of conversion includes inductively heating and electromagnetically stirring the slurry in a partly solid and a partly liquid state. Related to this further aspect it may be further advantageous when the electromagnetic stirring is enhanced by an impeller structure

immersed in the thixotropic slurry. At the same time the impeller structure may be set into motion by the electromagnetic action of the inductive heating. The invention thereby includes at least one practical solution for mechanical and/or electromagnetic stirring compatible with the configuration of an extruder accepting billets or bar as feedstock.

[0006] The invention also provides for an extrusion device from which a thixotropic metal composition emanates continuously. Accordingly an extruder device is provided, including: a supply arrangement for feeding feedstock; a conversion chamber; agitation means; cooling means; and a shaping die, wherein the agitation means includes an inductive heater that electromagnetically agitates any liquid or semi-liquid metal in the conversion chamber. One aspect of the extrusion device according to the invention is an agitation zone in a conversion chamber and the use of a pressure differential between the at least partially molten metal and an outlet opening of the conversion chamber to create a continuous flow of metal in a thixotropic state.

[0007] According to a further aspect of the extruder device according to the invention, the conversion chamber may have one or more conduits for connecting to one or more of a source of inert gas and a supply of at least one reaction component or additive. Thereby the invention also enables using the process and extrusion device for obtaining porous thixo-magnesium extrusions. The invention thus includes a process and device for obtaining lightweight porous metal structures and the lightweight metal composites obtained thereby. Magnesium and magnesium-alloy foams are characterized by a high impact energy absorption capacity, low thermal conductivity, good electrical conductivity and high absorptive acoustic properties. Such materials are useful as load-bearing materials and as thermal insulators. Porous thixo-magnesium is also particularly useful for biomedical applications, including biocompatible and biomedical devices, such as implants or scaffolds. In particular porous biomedical implants may also be useful in drug delivery from the pores of the porous structure. The adding, in a controlled manner, of other materials and/or additives during thixomolding production is also envisioned by the invention. The process features the steps of heating a composite of a metal matrix and finely divided solid stabilizer particles above the liquidus temperature of the metal to form a molten metal composite and mixing the molten metal composite and drawing in a gas, or by adding gas forming compounds, into the melt to obtain metal foam. The resulting expanded, viscous molten composite material contains evenly distributed pores. This viscous molten composite material is directly formed into a solidified shaped extrusion product without destroying the integrity of the foam pores. The invention thus also relates to a continuous production of gas foamed thixo-magnesium extrusion product.

[0008] The invention will now be described in reference to the accompanying drawings, in which:

Figure 1 schematically illustrates a first solution according to the invention for obtaining a thixotropic magnesium or magnesium alloy extrusion product; Figure 2 schematically illustrates a variation of the solution of Figure 1;

Figure 3 is an example of a nozzle head suitable for use with the variation of Figure 2;

Figure 4 represents a top plan view of an extruder device for obtaining thixotropic magnesium, or magnesium alloys;

Figure 5 is a longitudinal cross-section according to the line V-V in Figure 4;

Figure 6 is a modified version of the extruder device of Figure 5;

Figure 7 shows a top plan view of yet another embodiment of extruder device;

Figure 8 shows a longitudinal cross-section according to line VIII-VIII in Figure 7;

Figure 9 is a longitudinal cross section of an extruder device somewhat similar to Figures 4 and 5, but using three successive induction coils to obtain a linear travelling magnetic field for stirring, heating and propulsion of magnesium slurry;

Figure 10 is a transverse cross section of an extruder showing an alternative radial arrangement of coils for obtaining a rotating travelling field;

Figure 11 is a perspective view of an extruder device in which the functions of heating and stirring are separated; and

Figure 12 is a perspective view of a heating chamber, partly in cross section, showing an example of a restrictive stator for use as a stirring arrangement.

[0009] In Figure 1 is schematically illustrated a first proposed solution for continuously extruding thixotropic magnesium or thixotropic magnesium alloy. On one end of an extruder 1 a bar of magnesium feedstock 3 is advanced into a heating zone 5. In the heating zone 5 the magnesium material obtains a semi-solid state, while a stirring arrangement 7 changes the semi-solid material into a thixotropic slurry. The thixotropic slurry is advanced from heating zone 5 into a cooling zone 9 by means of a force F exerted on the feedstock 3. In the cooling zone 9 the thixotropic slurry takes the form of magnesium with a thixotropic structure of a temperature still sufficiently elevated to enable extrusion through a die 11. Leaving die 11 is a shaped profile 13 of magnesium alloy, with a thixotropic structure and stable shape. The stirring arrangement 7 is schematically shown as an impeller or mixer, but this may also be stirring by an electromagnetic field. Conventionally stirring may also be accomplished by a single or double extruder screw. It is usually important that cooling in the cooling zone 9 after the formation of the thixotropic slurry in heating zone 5 is accomplished rapidly. After sufficient cooling, the thixotropic structure becomes stable.

[0010] Figure 2 shows schematically a variation of the continuous extrusion shown in Figure 1. A schematically

illustrated extruder 101 is again fed with a bar of magnesium alloy feedstock 103. In a heating zone 105 the magnesium material is converted to a semi-solid state in which it is stirred by a stirring arrangement 107 to obtain a thixotropic slurry. In the process according to Figure 2 the thixotropic slurry is advanced directly to the die 111, which is cooled so that a separate cooling zone can be eliminated. While being shaped by the die 111 into a particular cross-sectional shape, the magnesium material is also cooled down sufficiently to ensure that the profile 113 leaving the die 111 has a thixotropic structure and stable shape. Again the magnesium material is advanced through the successive stages of the process according to Figure 2 by a force F exerted on an upstream end of the feedstock bar 103.

[0011] A particular advantage of cooling the thixotropic slurry in the die, is that with feedstock bars 103 of finite length, a new feedstock bar may be inserted without a joint or seam forming in the extruded profile 113. Figure 3 shows an example of a nozzle head 115 suitable for use with the cooled die 111 of the arrangement according to Figure 2. This nozzle head 115 can have several cooling zones which will determine its length. Such a nozzle head provided with successively staged cooling zones may effectively achieve controlled cooling at or near the forming die. Eliminating the joints between successive shots of bar feedstock has the additional advantage that the extruded profiles are homogenous in structure throughout their length. This eliminates the practice of detecting and removing defective portions by sawing and scrapping the defective portions. Moreover eliminating defective joints also has the benefit that the obtained extruded profiles or bars are not limited in length.

[0012] Figure 4 is a top plan view of an extruder for thixotropic magnesium according to the invention and Figure 5 is a longitudinal cross-section according to the line V-V in Figure 4.

[0013] The extruder 201 of Figures 4 and 5 is fed by a magnesium alloy bar 203. This bar 203 is fed into the extruder 201 by a pair of driven rollers 221, 223 by which it is advanced into a heating chamber 205. The heating chamber 205 in its interior is additionally supplied with an inert gas atmosphere through a first conduit 225. An optional second conduit 227 is provided to enable circulation of the inert gas to provide additional temperature control. It is also envisioned to mix the inert gas with a reaction component such as a foaming agent and then the gas atmosphere can be recirculated from the second conduit 227. The gas withdrawn from the second conduit 227 can then be supplanted with the reaction component and be returned to the first conduit 225. Foam-forming gas may be selected from the group consisting of carbon dioxide, inert gases, such as argon (Ar), or the like. It is important for the foaming gas, not to react with the molten magnesium. Also a blowing agent that reacts with the Magnesium melt may be employed. Such blowing agents may include magnesium carbonate (MgCO_3) or magnesium hydride (MgH_2). Similarly zirconium hydride (ZrH_2)

may be added as a gas forming compound to obtain metal foam. The cell size of the foam may be controlled by adjusting the gas flow rate and/or the agitation parameters. The flow direction of the inert gas or the mixture of inert gas and the reaction component can also be reversed from the second conduit 227 to the first conduit 225, if so desired.

[0014] Apart from foaming agents, it is also envisioned to supply other constituents to the molten magnesium, such as agents for alloying, agents for improving corrosion resistance and/or agents for medical purposes. Useful alloying elements that can be commercially used to modify the properties of magnesium include: aluminium (Al), silver (Ag), beryllium (Be), cadmium (Ca), lithium (Li), manganese (Mn), rare earth elements (REE), silicon (Si), zinc (Zn), and zirconium (Zr). Certain alloying elements that can be used to increase corrosion resistance include manganese (Mn) and rare earth elements (REE). Medical agents can notably include hydroxy apatite (HA) $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$, which in orthopedic applications (implants) stimulates bone growth.

[0015] In another possible use of the device of Figures 4 and 5, the inert gas atmosphere may be supplied via the first conduit 225. Preferably the inert gas is supplied to the first conduit at a controlled over pressure so that losses of gas escaping from the heating chamber 205, by gaps around the perimeter of feedstock bar 203 are supplanted through the same first conduit 225. The second conduit 227 will then be available for additives that may have a desired reaction with the thixotropic slurry before it is being cooled. Administering additives through the second conduit 227 may include feeding of further components, for example alloying components when manufacturing alloys, reinforcing components when manufacturing magnesium compound materials or other additional materials for modifying the magnesium materials. Surrounding the heating chamber 205 is an induction coil 229, which includes a helically wound conductor wire 231, for heating and stirring, which is partially represented by its centre line 233. Alternatively a travelling magnetic field may be employed as will be explained herein below. Downstream of the heating chamber 205, is located a die block 235 and a cooling section 237 in a common housing 239. The cooling section 237 is provided with a coolant passage 241, which is helically wound about a central passage 243 of the cooling section 237. The helically extending coolant passage 241 in Figure 5 is partially represented by its centre line 245. The coolant passage 241 has a first entrance or exit 247 and a second entrance or exit 249. The flow of coolant through passage 241 may be either from the first entrance or exit 247 to the second entrance or exit 249 or vice versa. The proper selection of the coolant flow direction depends on whether the largest absorption of heat is desired at an upstream or a downstream end of the cooling section 237. In an advantageous embodiment the flow of coolant may be adjustable for flow rate and flow direction to best meet the rapid cooling required to freeze the thixotropic struc-

ture obtained in the heating chamber 205. In the die block 235 an extrusion product 251 emits in its final cross-sectional shape.

[0016] Figure 6 shows an alternative embodiment 201A of the device of Figure 5. The device 201A is similar in having contoured driving wheels 221A, 223A feeding a feedstock bar 203A into a heating chamber 205A. The heating chamber 205A has again a first conduit 225A for supplying an inert gas atmosphere and a second conduit 227A for recirculating the inert gas or for supplying an additive reaction component to the thixotropic slurry that is formed in the heating chamber 205A. The heating chamber 205A is surrounded by a helically wound induction coil 229A for heating and stirring the feedstock bar 203A in its semi-solid state. A die block 235A is positioned at a distance downstream of the heating chamber 205A, so that the thixotropic slurry formed in heating chamber 205A is air cooled to a solid thixotropic structure, which is still at a sufficiently elevated temperature to be malleable by the die block 235A to obtain the extrusion product 251A.

[0017] Figures 7 and 8 show yet another embodiment of extruder 301 according to the invention. To a large extent this extruder 301, of which Figure 8 shows a cross-section according to line VIII-VIII of Figure 7, is similar to the extruders of Figures 4-6 except for the section where the extrusion is formed. A magnesium alloy bar 303 is again fed by a pair of driven rollers 321, 323 into an upstream end of a heating chamber 305. The first and second rollers 321, 323 are formed as wheels with a circumference contoured in accordance with the outer circumferential contour of the feedstock bar 303 for maximum frictional engagement with the circumference of the bar 303. The heating chamber 305 is surrounded by a helically wound induction coil 329 for heating and stirring the feed stock 303 in its semi-solid/semi-liquid state. The electromagnetic stirring action imposed by the induction coil 329 may be enhanced by a mechanical stirring device (not shown, but conventional) within the heating chamber 305. This additional mechanical stirring device such as an impeller or mixer, may be engaged for rotation by the electromagnetic field of the induction coil 329, or may employ a conventional separate driving means. A useful alternative to heating and stirring may be provided by a travelling magnetic field, as will be further explained herein below. The heating chamber 305 is also provided with a first conduit 325 for supplying an inert gas and a second conduit 327 for supplying a reaction agent or for recirculating the inert gas atmosphere. The induction coil conductor wire 331 is again in part represented by its centre line 333. Downstream of the heating chamber 305 there can be a cooling section 337 contained within a housing 339 and having a helical coolant passage 341. The coolant passage extends from a first entrance or exit 347 to, or from, a second entrance or exit 349.

[0018] It will be apparent from Figures 7 and 8 that the extrusion device 301 does not have a die block associ-

ated with the cooling section 337. Similar to the embodiment 201A of Figure 6, the cooling section 337 is also optional in the embodiment of Figures 7 and 8 and may be deleted in favour of air cooling. A separate description of such an alternative execution of the embodiment of Figures 7 and 8 is deemed redundant. Whatever the means of cooling employed, the feed stock bar 303 downstream of the heating chamber 305 emerges as a converted bar 353 of frozen thixotropic structure towards a grooved rotatable wheel 355 of a stationary shoe 357 extrusion device. The grooved wheel 355 is rotatable about shaft 359 and has a counter roller 361, rotatable about shaft 363 to bring the bar 353 of converted thixotropic magnesium alloy in frictional engagement with the groove 365 of wheel 355. The stationary shoe 357 is provided with an abutment 367 extending into the groove 365 of wheel 355. An extrusion die 369 with an exit opening 371 that extends radially away from the wheel 355 is formed in the vicinity of the abutment 367. The converted bar 353 engaged in groove 365 is advanced by friction of the wheel 355. Extrusion pressure is then generated by the abutment 367 as the shoe 357 covers the groove 365 in a stationary manner. As a result, the bar material 353 starts to flow through the extrusion die 369 to emit as an extrusion product 351 from the exit opening 371. Because of the frictional heat generated by shear within the material by this process, the material remains sufficiently malleable without additional heating and without destroying the thixotropic structure thereof. The use of the wheel and shoe type extrusion device of Figures 7 and 8 is commonly referred to as "conform extrusion" and is a variation on prior art devices, as represented by US 3765216 to Derek Green and by US 4794777 to John East et al..

[0019] In the above described embodiments similar components have been indicated by reference numerals differing a full integer of 100 (hundred) between the successively described embodiments. It is thus intended that the descriptions of similar components are interchangeable from one embodiment to the other.

[0020] The invention thus provides for a method for the extrusion of magnesium based alloys for obtaining net shapes, or near net shapes in the form of plate or bar shaped extrusion products. The extrusion product of the method has a thixotropic structure and stable shape. The method of the invention includes providing magnesium based alloy feed stock and converting at least a portion of the feedstock into thixotropic slurry. The method further exerts a driving force on the feedstock, upstream of the thixotropic slurry, to advance the feedstock in a downstream direction and subjecting a downstream end of the thixotropic slurry to controlled rapid cooling to obtain a thixotropic structure. The method of the invention further allows a downstream end of the converted feedstock to escape through a shaping die, so as to obtain bar stock having a predefined cross-sectional shape. An extrusion device for carrying out the method is also provided by the invention as described above. The extrusion devices

as described herein above each include a supply arrangement for feeding feedstock, a conversion chamber, agitation means, cooling means and a shaping die. The agitation means advantageously includes an inductive heater that electromagnetically agitates any liquid or semi-liquid metal in the conversion chamber.

[0021] The following is a description of a number of embodiments using a travelling magnetic field for stirring, heating and propelling the magnesium slurry, which will each be explained briefly. In the previously described embodiments heating and stirring by induction technique has already been explained. However the use of travelling magnetic fields additionally allows to exert a propelling force on the magnesium slurry. This may either replace, or supplement traditional advancing means, such as a pair of driving rollers. The so-called travelling Magnetic field may be excited by several configurations of induction coils and/or permanent magnets. Such magnetic induction fields offer particular possibilities for stirring, propulsion and to a certain extent also to control or optimize heating. In Figures 4 and 5 of the present disclosure an example of stirring and heating by a single induction coil 229 is given. As shown in Figure 9 several successive induction coils 429A, 429B and 429C may be arranged about heating chamber 405. A linear travelling field can be obtained by feeding the coils with an alternating current and shifting phases between the current flowing through the individual coils 429A, 429B, 429C. Figure 9, in which reference numerals differ a full "200" with those used in Figures 4 and 5, thus shows continuous thixo-extrusion with three induction coils to obtain a travelling magnetic field for stirring heating and propulsion of magnesium slurry. In Figure 9 the first and second drive roller 421, 423 are optional in regard of the transport of the feedstock bar 403 during extrusion, but can be a useful addition to assist in the initial supply of magnesium feedstock when starting the extrusion process. The number of windings and the number of coils indicated in Figure 9 is merely a schematic indication and can be varied in accordance with the skilled person's knowledge.

[0022] Figure 10 is a transverse cross section of yet another form of extruder showing an alternative radial arrangement of coils for obtaining a rotating travelling field. By feeding the spools L1, L2, L3, L4, L5 and L6 with phase-shifted current a stirring action is obtained.

[0023] In Figure 11 an extrusion device 501 is shown that uses a combination of an induction coil, or other form of heating element 529, and radially arranged coils 571, 572, 573 for exciting a rotating travelling field. Induction coil 529 ensures the heating of the magnesium slurry, while stirring is accomplished by the rotating travelling field of the radial coils 571-573. Optional active or passive cooling can be accomplished after the aforementioned steps. The stirring action of a rotating travelling magnetic field can be further enhanced by adding one or more further sets of radially disposed coils, which excite rotation in opposite directions. To improve the stirring action of the extruder devices described so far, the heating

chamber 5, 105, 205, 205A, 305, 405 or, by way of example, 505 can also be provided with a stationary stirring arrangement, in the form of a stator 507, as shown in Figure 12.

[0024] The magnesium based alloy extrusion products with a thixotropic structure, obtained by the invention, are particularly suitable for load bearing and shock absorbing applications such as found in the automotive industry. Advantageous features of the structures obtainable by the invention additionally include its biodegradable character, which makes it particularly suitable for medical and biomedical structures, such as implants for various purposes.

[0025] It is thus believed that the operation and construction of the present invention will be apparent from the foregoing description. The invention is not limited to any embodiment herein described and, within the purview of the skilled person; modifications are possible which should be considered within the scope of the appended claims. Equally all kinematic inversions are considered inherently disclosed and to be within the scope of the present invention. Wherever reference is made in the above to magnesium, it is to be understood that this includes reference to magnesium alloys and in particular to such alloys that allow thixotropic structures. The term comprising when used in this description or the appended claims should not be construed in an exclusive or exhaustive sense but rather in an inclusive sense. Expressions such as: "means for ..." should be read as: "component configured for ..." or "member constructed to ..." and should be construed to include equivalents for the structures disclosed. The use of expressions like: "critical", "preferred", "especially preferred" etc. is not intended to limit the invention. Features which are not specifically or explicitly described or claimed may be additionally included in the structure according to the present invention without deviating from its scope.

Claims

1. Method for extrusion of magnesium based alloys for obtaining net shapes, or near net shapes, having a thixotropic structure, the method including:
 - providing magnesium based alloy feed stock;
 - converting at least a portion of the feedstock into a thixotropic slurry;
 - exerting a driving force on the feedstock, upstream of the thixotropic slurry, to advance the feedstock in a downstream direction;
 - subjecting a downstream end of the thixotropic slurry to controlled rapid cooling to obtain a thixotropic structure; and
 - allowing a downstream end of the converted feedstock to escape through a shaping die, to obtain bar stock having a predefined cross-sectional shape.
2. Method according to claim 1, wherein the step of conversion includes heating of the feedstock to a temperature between its liquidus and its solidus temperature.
3. Method according to claim 2, wherein the step of conversion includes inductively heating and thereby electromagnetically stirring the slurry in a partly solid and a partly liquid state.
4. Method according to claim 3, wherein the electromagnetic stirring is enhanced by an impeller structure immersed in the thixotropic slurry.
5. Method according to claim 4, wherein the impeller structure is set into agitating motion by the electromagnetic action of the inductive heating.
6. Method according to any one of claims 1 to 3, wherein the step of conversion includes using a travelling magnetic field.
7. Method according to claim 6, wherein the travelling magnetic field is a rotating field.
8. Method according to any one of claims 1 to 5, wherein the method is continuous.
9. Method according to any one of claims 1 to 8, wherein the feedstock is a quasi continuous bar of magnesium alloy feedstock.
10. Method according to any one of claims 1 to 9, wherein the step of cooling is carried out simultaneously with the step of allowing the converted feedstock to exit through the shaping die.
11. Method according to any one of claims 1 to 10, wherein the step of conversion is carried out in an inert gas atmosphere.
12. Method according to any one of claims 1 to 11, wherein a reaction component or additive is administered to the thixotropic slurry.
13. Method according to claim 12, wherein the reaction component or additive includes a foaming agent.
14. Method according to claim 13, wherein the foaming agent is a gas.
15. Method according to claim 12, wherein the reaction component or additive includes an alloying component.
16. Method according to claim 12, wherein the reaction component or additive includes a reinforcing component.

17. Extruder device (1; 101; 201; 201A; 301) including:

a supply arrangement for feeding feedstock (F; 221, 223; 221A, 223A; 321, 323);
a conversion chamber (105; 205; 205A; 305); 5
agitation means (7; 107; 229; 229A; 329);
cooling means (9; 115; 237; 337); and
a shaping die (11; 111; 235; 235A; 369), wherein
the agitation means includes an inductive heater
that electromagnetically agitates any liquid or 10
semi-liquid metal in the conversion chamber.

18. Extruder according to claim 17, wherein the conversion chamber has a first conduit for connecting to a source of inert gas. 15

19. Extruder according to claim 17 or 18, wherein the conversion chamber has a second conduit adapted to connect to a supply of at least one reaction component or additive. 20

20. Extruder according to any one of claims 17 to 19, wherein the cooling means includes a coolant passage, extending helically about a central passage for converted feedstock. 25

21. Extruder according to any one of claims 17 to 20, wherein the shaping die includes a rotatable wheel, a stationary shoe and an extrusion die incorporated in the stationary shoe. 30

22. Extruder according to claim 21, wherein the rotatable wheel has a circumferential groove and the stationary shoe has an abutment extending into the groove. 35

23. Article of manufacture obtained by the method of any one of claims 1 to 16.

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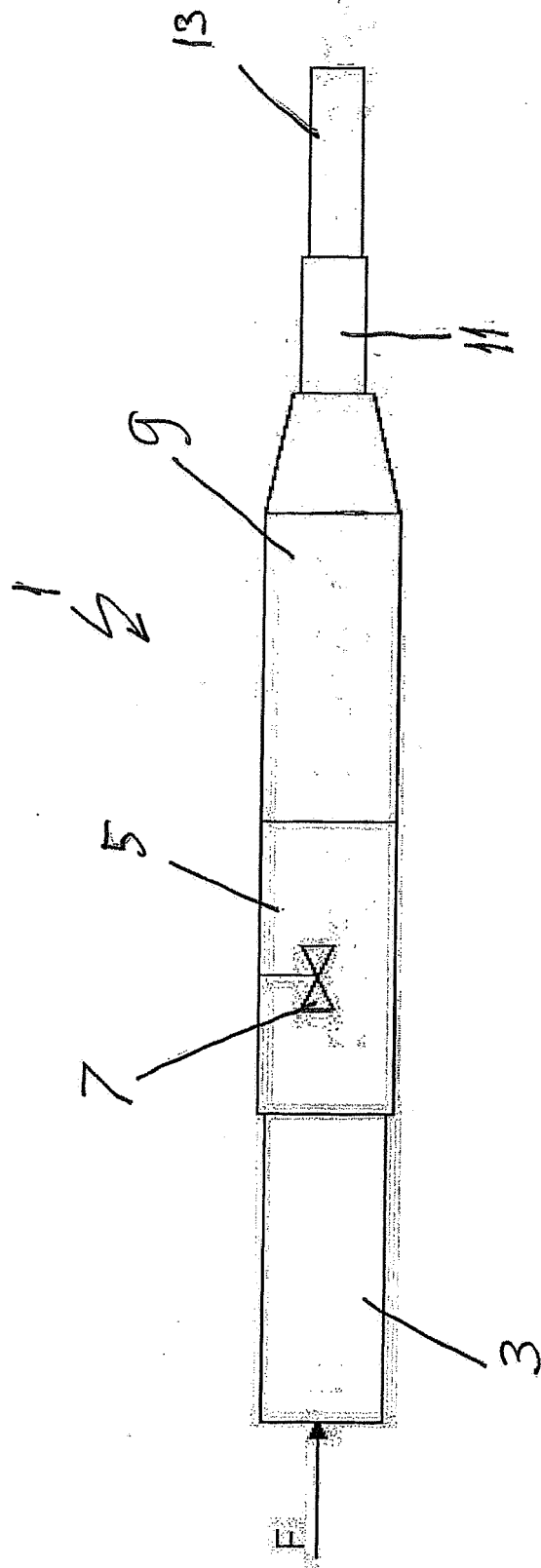


FIG. 1

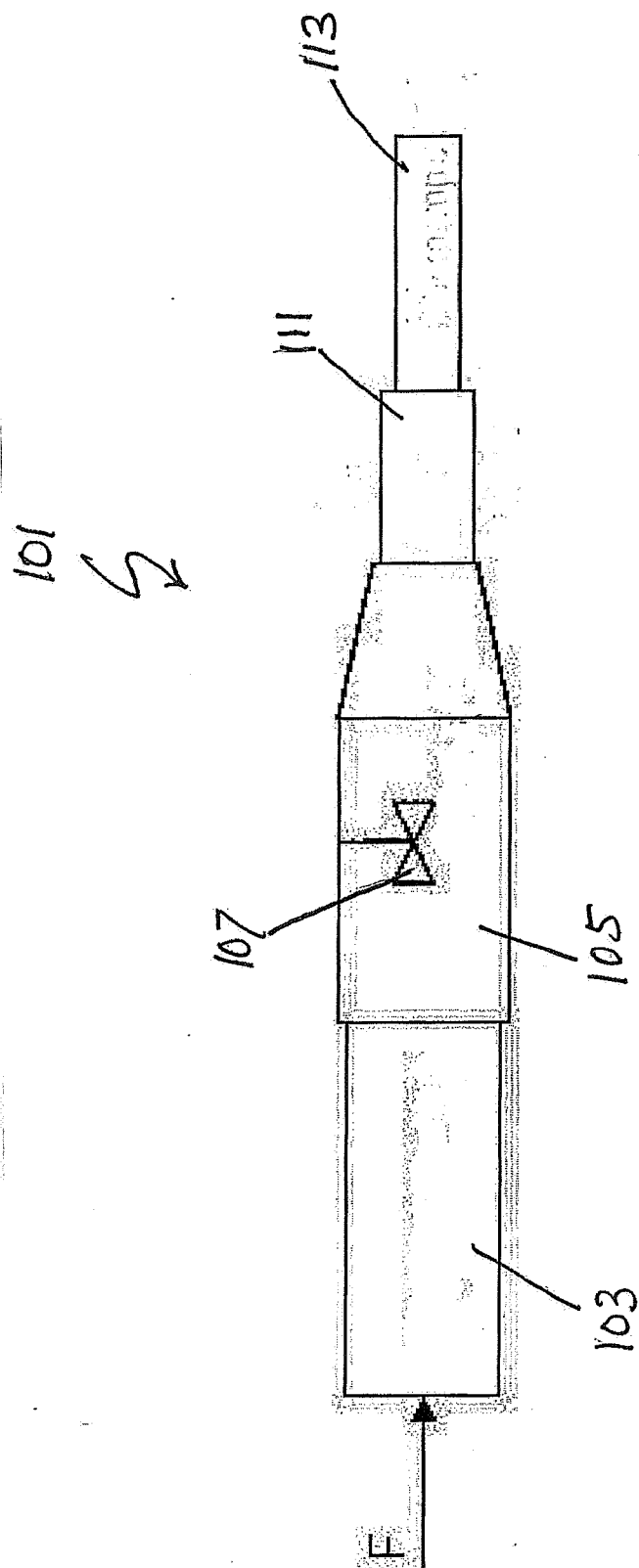


FIG. 2

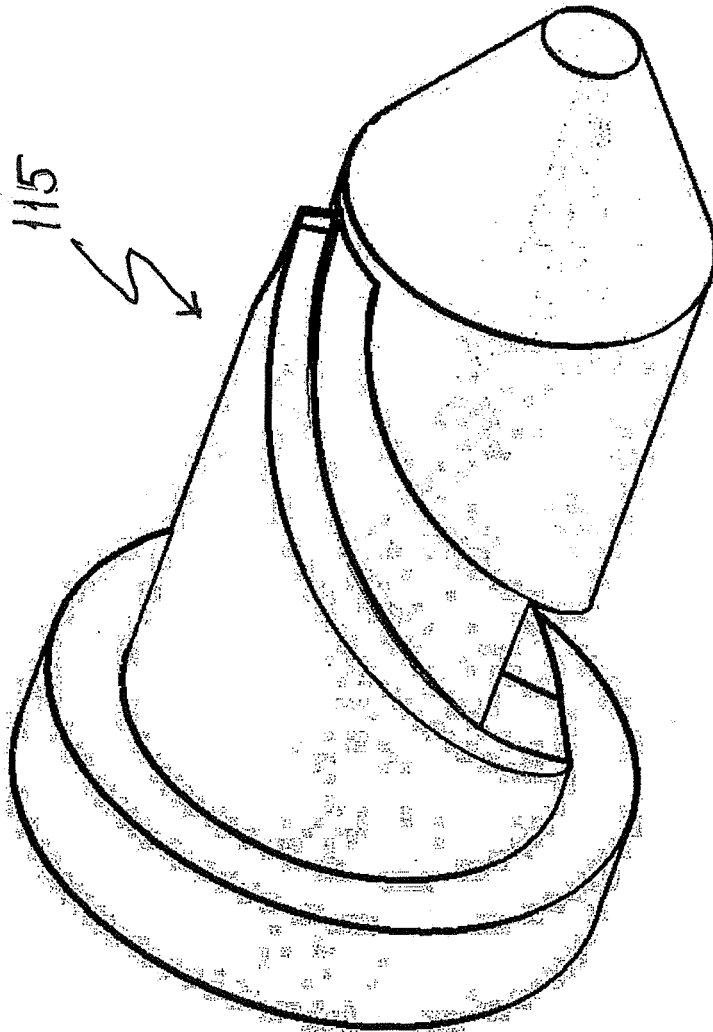
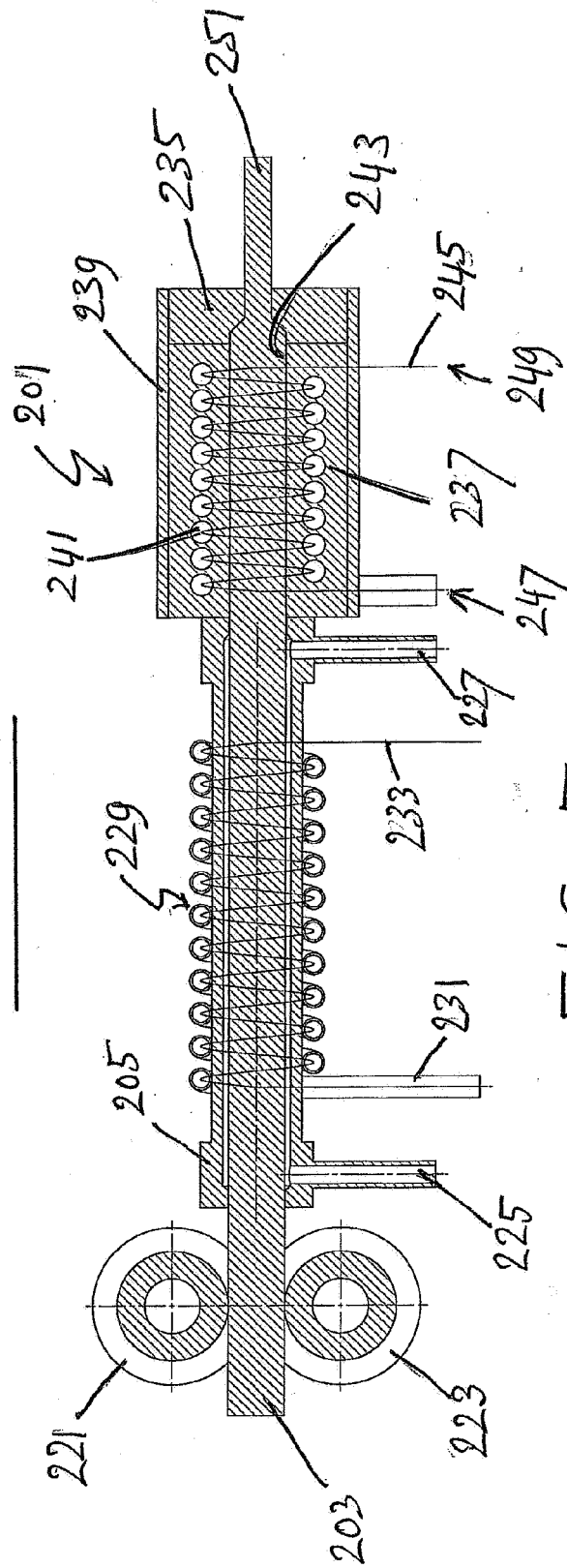
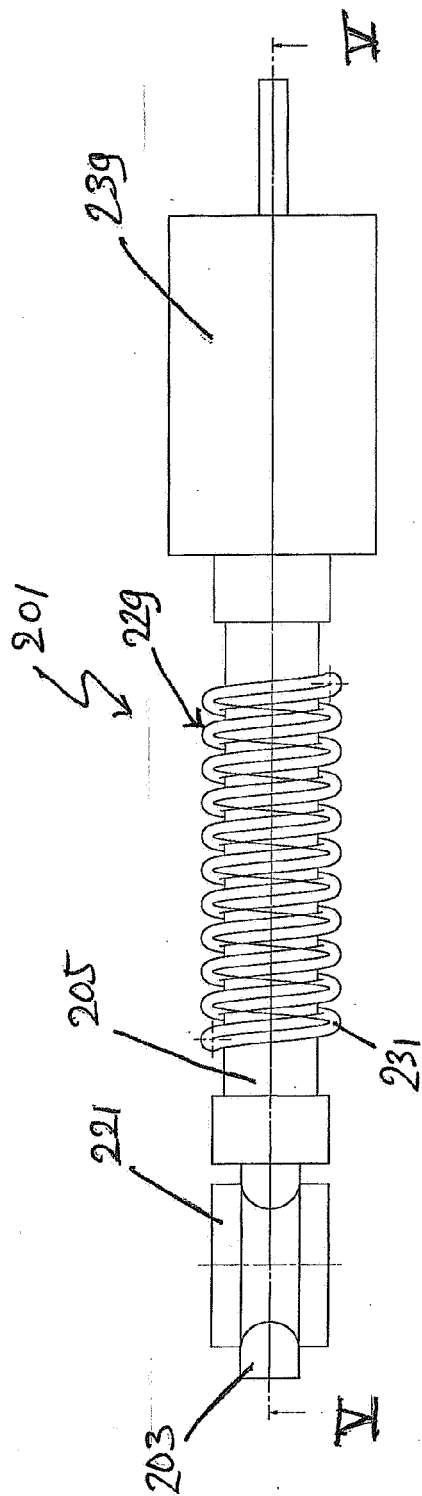


FIG. 3



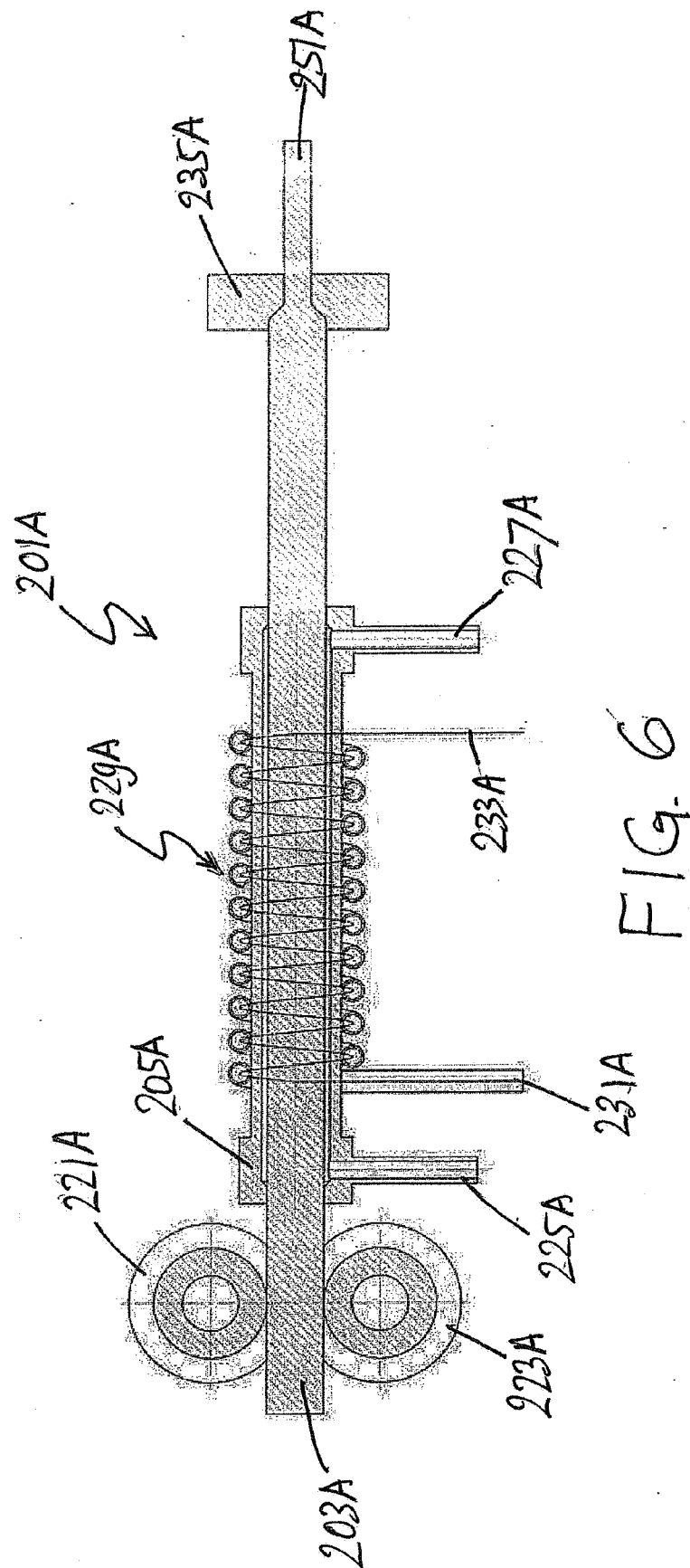
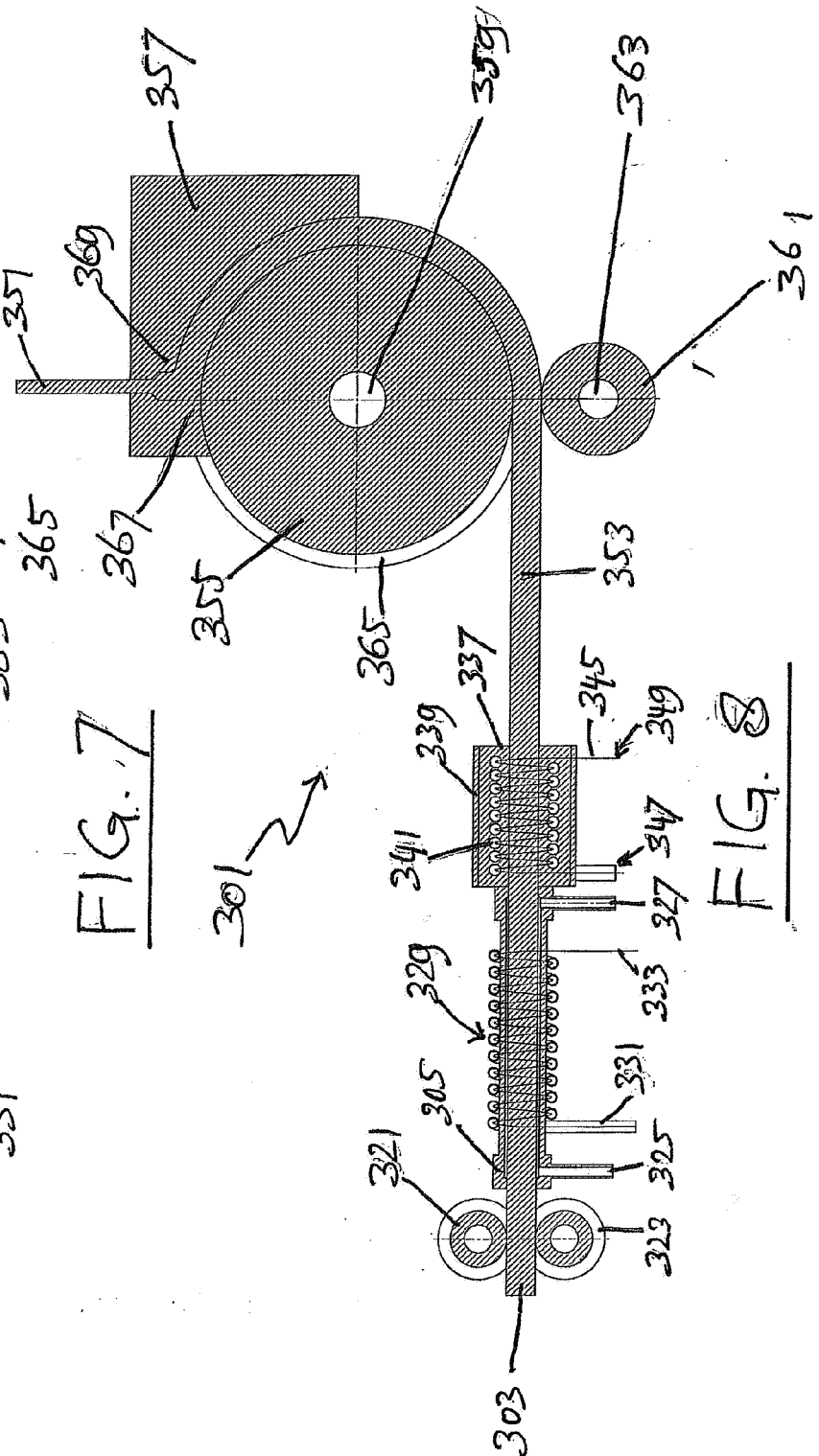
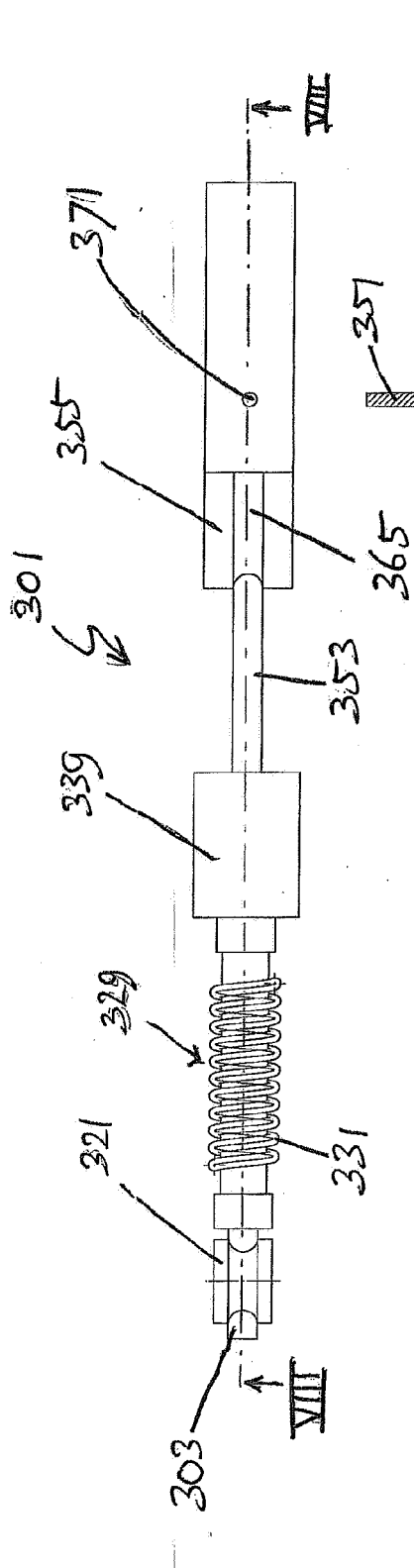


FIG. 6



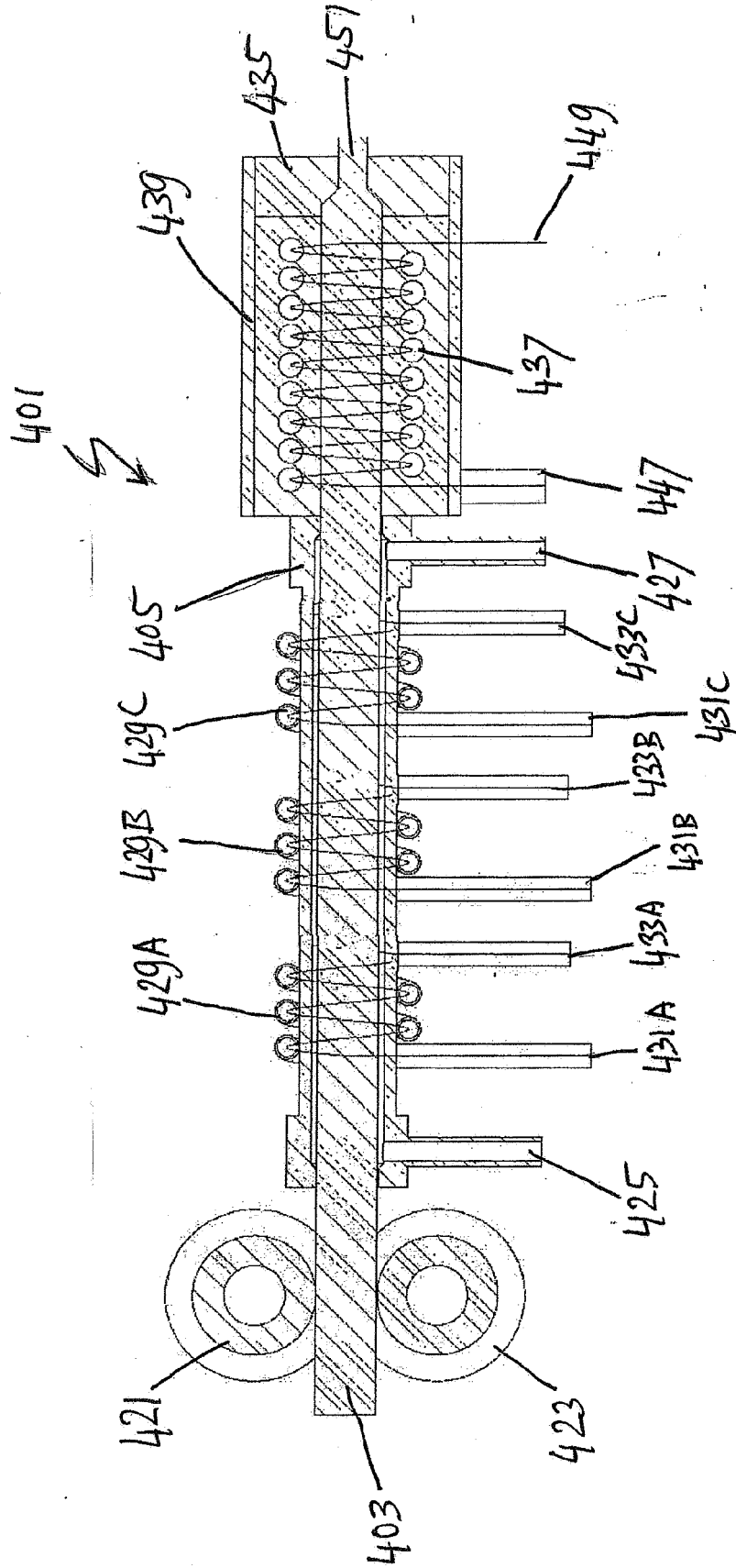


FIG. 9

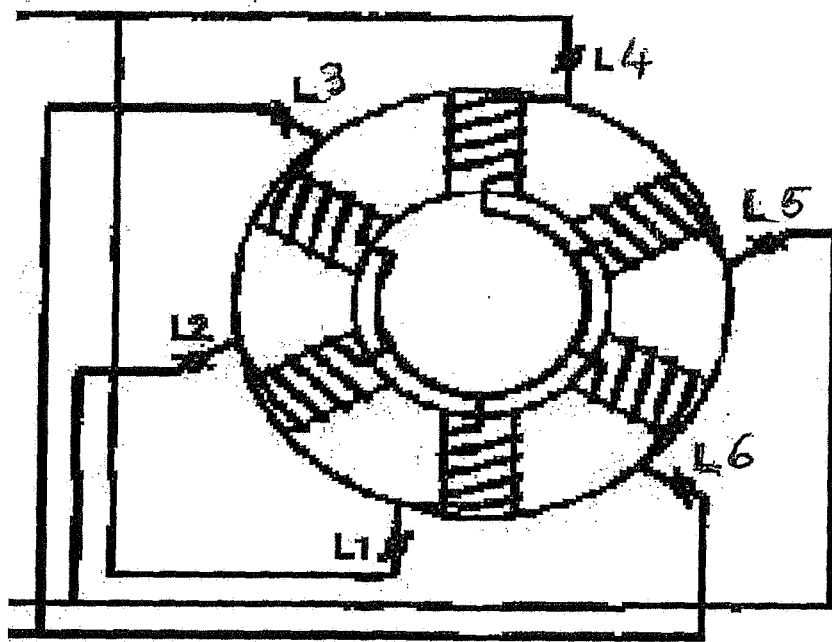
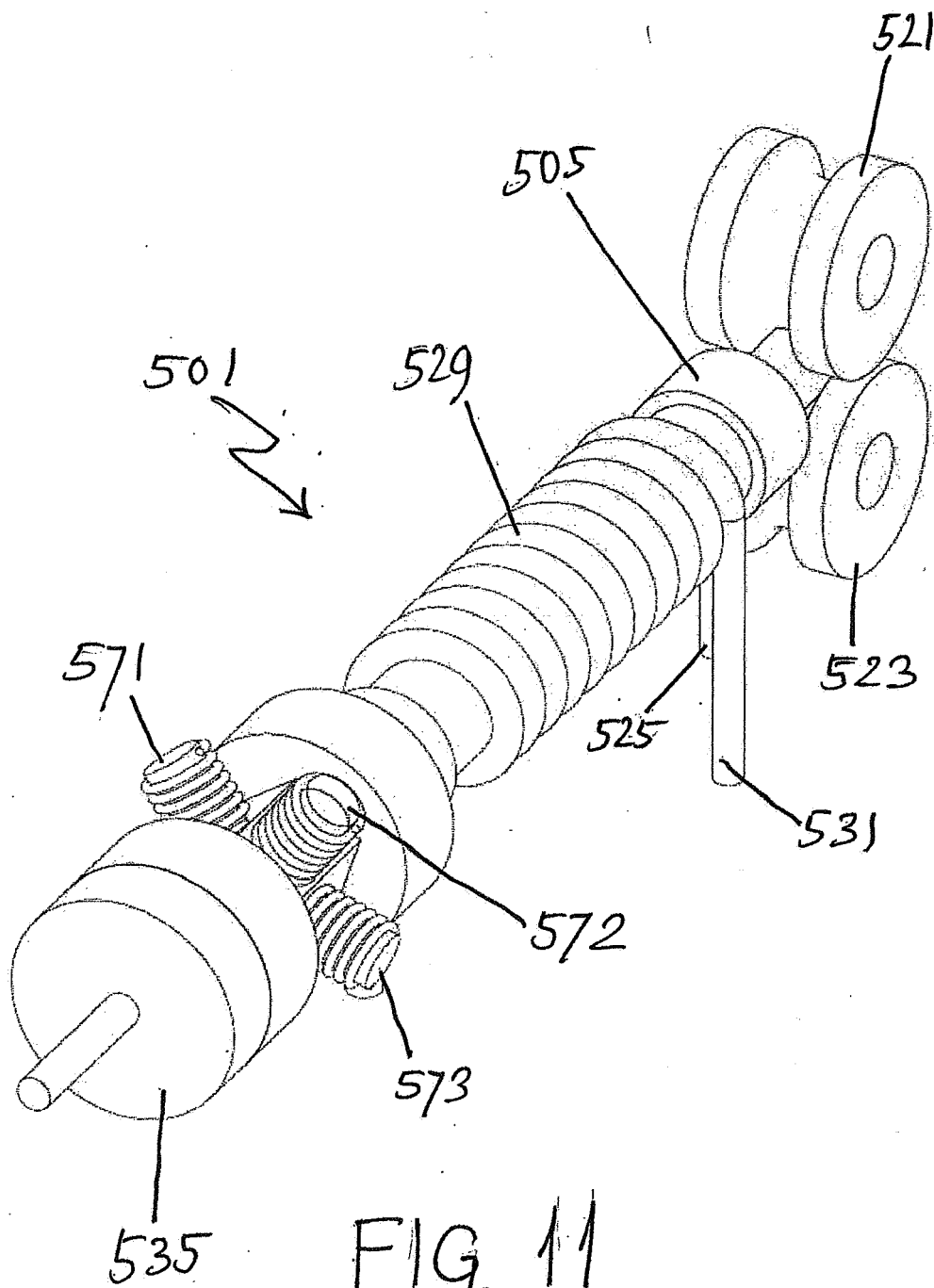


FIG 10



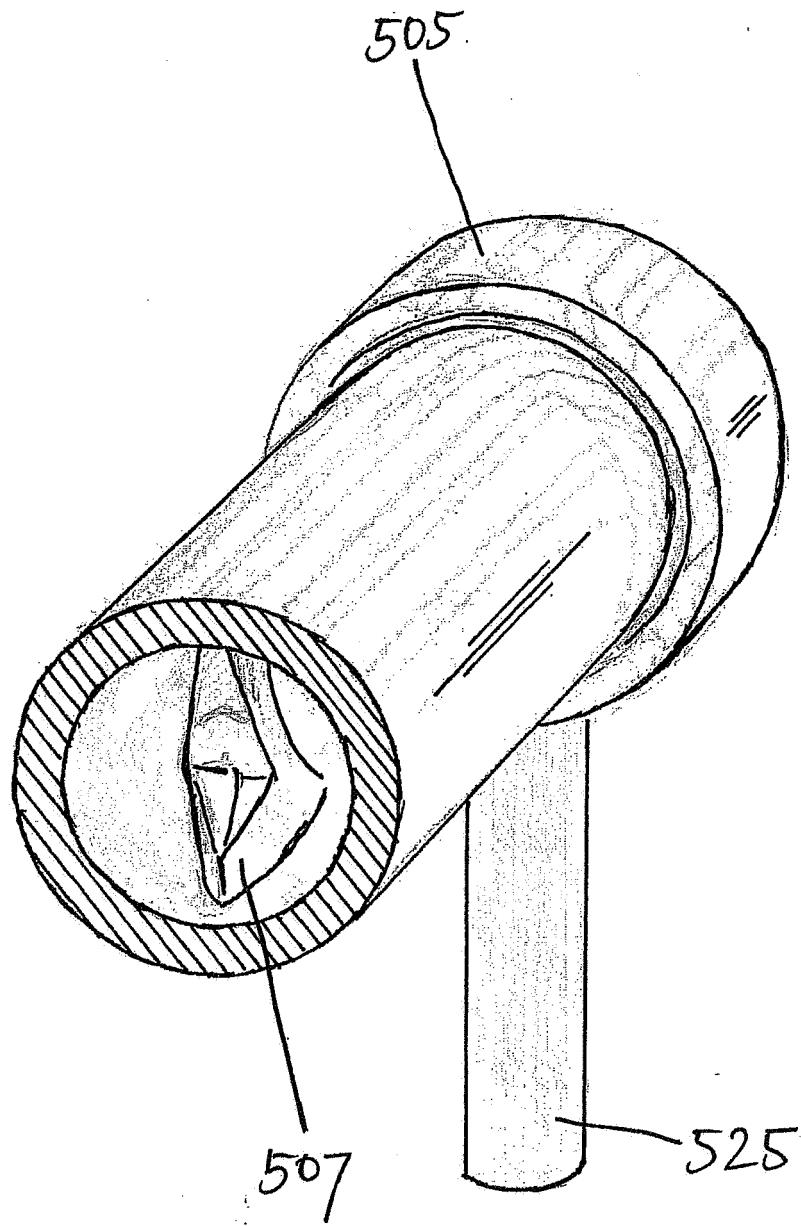


FIG. 12



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 15 9939

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 839 589 A (ALUSUISSE LONZA SERVICES AG [CH]) 6 May 1998 (1998-05-06) * the whole document *	1-23	INV. B21C23/00 C22C23/00
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