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(54) **DEVICE AND METHOD FOR MULTIPLE CHANNEL ANGULAR PRESSING**

(57) The invention relates to a device and method for the simultaneous multiple processing of materials by means of severe plastic channel angular deformation. The invention is based on the use of a spatial arrangement of dies in an angular channel configuration, which are preferably housed in die holders and which are stacked against each other, and a multiple pressing system that can be combined with a feeder that continuously feeds material to the pressing zone, thereby providing highly efficient multiple processing of materials. In relation to other processes developed to date, the invention allows the simultaneous extrusion of multiple parts, thereby significantly reducing the force required to close the dies used.

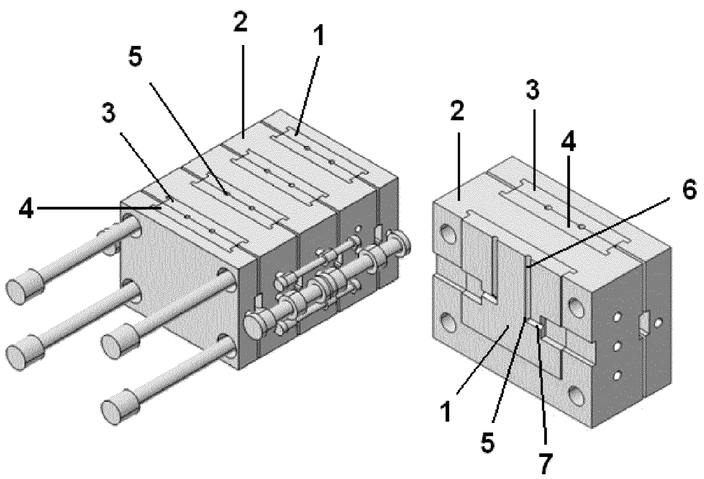

Fig. 1

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Description

FIELD OF THE INVENTION

[0001] The invention mainly relates to the metalworking sector, specifically to the metallic materials processing area by means of severe plastic deformation.

PRIOR STATE OF THE ART

[0002] In recent years there has been a growing interest in the production techniques of materials with submicron and/or nano-micron grain size, as a result of improved mechanical properties which can be obtained with said materials, related to increased hardness, tenacity and strength, amongst others. The abovementioned techniques can also produce materials with superplastic performances at high temperatures and can undergo very large deformations without fracture occurring in the material.

[0003] Among the various techniques for producing materials with submicron and/or nano-micron grain size, the processes of severe plastic deformation (SPD) are characterised in that they cause very high plastic deformations to the processed materials (ε>1, where ε is the equivalent plastic deformation value) without producing significant modifications of the cross-section thereof. This maintenance of the dimensions of the parts makes it possible to process them several times and thus accumulate large plastic deformations in the material, which leads to the appearance of a new microstructure which replaces the initial one. As a result, it is possible to obtain materials with submicron or nano-micron grain size.

[0004] Among the existing processes for producing materials by means of severe plastic deformation, the equal channel angular extrusion or pressing process, or ECAE/ECAP, is highlighted. Equal channel angular extrusion (ECAE) has been applied to a large number of materials and was initially proposed by V.M. Segal et al. (Segal V. M., Russian Metallurgy, Vol. 1, 1981, pp. 99-105, Segal V.M., Materials Science and Engineering A, Vol. 271, 1999, pp. 322-333; Segal, Materials Science and Engineering, Vol.197, 1995, 157-164).

[0005] By means of the ECAE technique, material passes through a die containing two equally sectioned channels (circular, square or polygonal), one channel being an inlet and another an outlet, which intersect forming a vertex or "elbow", with an angle generally of 90°. When a sufficient force is exerted by pressing or "punching" means, and when said puncher arrives at the channel vertex, the processed material (also called "test specimen") moves to the outlet channel behind the elbow, wherefrom it is extracted. The material is, thus, deformed by means of a stress cutting mechanism, upon passing through the angular channel in the presence of high hydrostatic pressure. Once the test specimen has been processed, it can be reinserted into the inlet channel and the process can be repeated, with the subsequent build-up of deformation. Additionally, ECAE-based techniques allow the test specimens to be processed in different ways, depending on the type of materials used and the deformations one wants to apply thereto, and the process can be repeated a specific number of times according to the requirements. It is therefore possible to keep the orientation of the test specimen constant in successive repetitions; to rotate the test specimen 90° with respect to the longitudinal axis of the test specimen in each repetition; or to rotate the test specimen 180° also with respect to the longitudinal axis of the test specimen, amongst other possibilities.

[0006] In spite of the conventional channel angular extrusion process present in the state of the art, a satisfactory manner for a large number of materials is suitable, as said process does not lack certain limitations and drawbacks. Amongst said drawbacks of the conventional process is that the use thereof features low processing speeds per piece produced, said speed decreasing the productive performance of the process with important economic consequences. Additionally, conventional channel angular extrusion techniques require very high closure forces to be applied in order to prevent the extrusion dies from opening, in the event that these dies include several divided sections, in order to be able to suitably mechanize the angular channel.

[0007] In short, although the ECAE process is quite interesting, due to the fact that it allows the production of very high deformations, the industrial application thereof has been limited by both the processing speed and the small size of the test specimens that can be manufactured. By means of the present invention, the two aforementioned drawbacks are resolved, as it provides a multiple compression method (MCM), making it possible to produce several pieces during each processing stage and further permitting the incorporation of a continuous material feeder in the extrusion zone. Furthermore, the closure forces are significantly reduced by means of the spatial configuration proposed by the present invention for the extrusion process, so it is possible to manufacture a much larger number of pieces than those produced to date, which makes the proposed process much more productive.

[0008] Some patents relating to the production of materials by means of channel angular severe plastic deformation have been developed (C. J. Luis, P. A. González, J. Gil, J. Alkorta, ES2224787; M. Jarret, W. Dixon, May 1994, US Patent n° 5309748; V. Segal, R. Goforth, K. Hartwig, Mar 1995, US Patent n° 5400633; V. Segal, L. Segal, Feb 1997, US Patent n° 5600989; V. Segal, May 1996, US Patent n° 5513512; L. Semiatin, D. Delo, May 1999, US Patent n°

5904062 y K. Hartwig, 2005, US Patent n° 6883359). In patent US5600989, V. Segal proposes a system that has a single inlet channel, wherein two test specimens are inserted, and two outlet channels of dimensions equal to half those of the inlet channel, which is different from the system proposed herein. No method that uses the technology proposed herein has been found in the aforementioned patents, as the present invention uses a spatial arrangement of the extrusion dies which allows the process to be performed simultaneously, significantly reducing the forces required to close the dies since the reaction forces that appear offset each other, as a result of the spatial distributions of the dies and die holders proposed herein. That means that they can be stacked (in series, with radial symmetry, etc.) in an unlimited number of dies-die holders, solely limited by the dimensions of the equipment where they are going to be connected, as the closure force required is not increased in relation to what is needed to apply in order to extrude with a single die. Likewise, the invention can be combined with a continuous material feeding system, which shall make greater production speeds possible.

OBJECT OF THE INVENTION

[0009] One object of the present invention is an angular channel pressing device for the multiple extrusion of materials which comprises a plurality of extrusion dies, wherein:

- each one of said extrusion dies comprises one or more angular channels, wherethrough the materials are extruded, said angular channels being equipped with at least one inlet and at least one outlet,
- the plurality of extrusion dies can be stacked in series,
- the materials that pass through the angular channels belonging to the series formed by the extrusion dies can be extruded simultaneously, through the compression of said materials by means of one or more pressing means.

[0010] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the series formed by the extrusion dies is capable, during the pressing of the processed materials through the channels, of maintaining the integrity thereof by means of applying one or more closure means.

[0011] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the series formed by the extrusion dies has a configuration such that the closure force required to maintain the integrity of each individual die within the series is offset by the closure forces required to maintain the integrity of their neighbouring dies in said series.

[0012] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the extrusion dies are housed in die holders.

[0013] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the extrusion dies are housed in a single die holder.

[0014] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the extrusion dies are divided into two symmetrical parts.

[0015] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein one or more angular channels comprised in the extrusion dies are divided in half, each half being housed in each one of the symmetrical parts of the extrusion dies.

[0016] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the plurality of extrusion dies, upon the stacking in series thereof for the multiple processing of materials, forms an array which keeps radial symmetry with respect to a vertical or horizontal axis.

[0017] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the angular channels of the array that form the extrusion dies are angularly and equidistantly spaced.

[0018] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the extrusion dies are configured by joining an upper part which houses an inlet channel and a lower part which houses an outlet channel, where the angular channels wherethrough the materials are processed are formed by joining each inlet channel with each outlet channel, when the upper and lower part of the dies come into contact with each other.

[0019] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the angular channels comprise one or more 90° angles.

[0020] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the angular channels have a circular, oval, square, rectangular or polygonal cross-section.

[0021] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the extrusion dies have a plurality of angular channels of different cross-sections.

[0022] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the inlet and the outlet of the angular channels have the same cross-section.

[0023] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the inlet and the outlet of the angular channels have different cross-sections.

[0024] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the inlet and the outlet of the angular channels have the same length.

[0025] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the inlet and the outlet of the angular channels have different lengths.

[0026] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the fillet radii, defined as the interior and exterior radii of the curvature profiles which make up the angular channels, are equal.

[0027] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the fillet radii are different.

[0028] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials which comprises a plurality of punchers for processing materials.

[0029] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the punchers are comprised in the pressing means.

[0030] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the pressing means and/or closure means comprise one or more hydraulic, mechanical, pneumatic or electromechanical system, said systems being used either individually or in combination.

[0031] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the feeding of the processed materials is carried out either manually, through automatic supply means or by a combination thereof.

[0032] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the extrusion dies comprise connection means for performing a simultaneous opening or closure of the extrusion dies.

[0033] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the connection means are, preferably, an arrangement of sliding fastenings on bars, said fastenings being installed in the dies, and where said bars connect each one of the dies to its die or adjacent dies.

[0034] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, which further comprises means for controlling the temperature, said means preferably being heating systems or cooling systems, used individually or in combination.

[0035] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials by means of pressing.

[0036] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the materials extruded are metals or alloys thereof.

[0037] Another object of the present invention is an angular channel pressing device for the multiple extrusion of materials, wherein the materials extruded are polymeric, ceramic or non-metallic compound materials.

[0038] Another object of the present invention is a method for multiple channel angular pressing for the multiple extrusion of materials which comprises:

- the stacking in series of a plurality of extrusion dies, said extrusion dies comprising one or more angular channels, wherethrough the materials are processed.
- the simultaneous extrusion of the materials through the angular channels comprised in the series formed by the dies, by means of the application of one or more pressing forces.

[0039] Another object of the present invention is a method for multiple channel angular pressing for the multiple extrusion of materials, wherein the integrity of the series formed by the extrusion dies is maintained by means of the application of one or more closure forces, so that the closure force required to keep the integrity of each individual die within the series is offset by the individual closure forces required to maintain the integrity of their neighbouring dies in said series.

DESCRIPTION OF THE FIGURES

[0040]

Figure 1	shows a three-dimensional view of a possible configuration of the extrusion dies and die holders according to the invention, wherein the angular channels have a circular cross-section, showing both the individual embodiment (right) of each die-die holder, as well as the stacking thereof for multiple processing (left).
Figure 2	shows an embodiment of the extrusion dies and die holders according to the invention,

wherein the angular channels have a square cross-section.

Figure 3 shows another possible embodiment of the invention for the spatial arrangement of the angular channel dies with circular cross-section, wherein the die and the die holder make up a whole, single piece.

Figure 4 shows another possible embodiment of the invention for the spatial arrangement of the angular channel dies with rectangular cross-section, wherein the die and the die holder make up a whole, single piece.

Figure 5 shows another possible embodiment of the dies for the MCM-SPD process according to the invention, wherein the dies are divided, with radial symmetry, at the midpoint of each channel. In figure 5(a), a section is shown wherein the configuration of the stacked dies according to radial symmetry in the initial stage is observed; in Figure 5(b), an intermediate stage of the MCM-SPD process is shown and, in Figure 5(c), a joint view in the initial stage of the MCM-SPD process is shown. In Figure 5(d), a joint view is shown wherein a configuration with two channels (interior and exterior) for each die is shown; in Figure 5(e), a section that shows detail of the channels observed in Figure 5(d) is shown; and Figure 5(f) shows a joint view in an intermediate stage of the MCM-SPD process.

Figure 6 shows another possible constructive scheme of the dies for channel angular extrusion of rectangular cross-sectioned pieces, wherein the in series stacking distribution of the dies has been substituted by a radial symmetry stacking distribution which places the centres of the extrusion channel cross-sections angularly equidistant from each other. The inlet and outlet angular channels are configured by coupling an upper part with a lower part, as shown in Figure 6(a). Likewise, in Figure 6(b) and in Figure 6(c), the punchers used at the beginning and in an intermediate stage, respectively, are shown. Figures 6(d), 6(e) and 6(f) show another configuration scheme, similar to the previous one, but with the difference that they feature internal and external channels.

Figure 7 shows a cross-section wherein the arrangement of the punchers for applying the MCM-SPD process according to the invention is observed.

Figure 8 shows a graphic representation of the obtained value, by means of simulating with finite elements, of the total force (in kN) for keeping the dies from opening along the y-axis, with the length of the test specimens extruded (in mm) along the x-axis, in the MCM-SPD process according to an embodiment of the invention, considering the constructive scheme shown in Figure 1, wherein the diameter D = 10 mm, the fillet radii R_{ext} =R_{int} = 2 mm, the angle between the extrusion die channels Φ = 90° and the length of the processed test specimens L_{init} = 80 mm, considering the processing of AA5083 at ambient temperature and friction factor of 0.1.

Figure 9 shows a graphic representation of the obtained value, by means of simulating with finite elements, of the processed force per extruded test specimen (in kN) along the y-axis versus the length of the extruded test specimens (in mm) along the x-axis, considering the constructive scheme shown in Figure 1, wherein the diameter D = 10 mm, the fillet radii R_{ext} =R_{int} = 2 mm, the angle between the extrusion die channels O = 90° and the length of the processed test specimens L_{init} = 80 mm, considering the processing of AA5083 at ambient temperature and friction factor of 0.1.

Figure 10 shows a graphic representation of the obtained value, by means of simulating with finite elements, of the total force (in kN) for keeping the dies from opening along the y-axis, with the length of the test specimens extruded (in mm) along the x-axis, considering the constructive scheme shown in Figure 1, wherein the diameter D = 20 mm, the fillet radii R_{ext} =R_{int} = 2 mm, the angle between the extrusion die channels O = 90° and the length of the processed test specimens L_{init} = 200 mm, considering the processing of AA5083 at ambient temperature and friction factor of 0.1.

Figure 11 shows a graphic representation of the obtained value, by means of simulating with finite elements, of the processed force per extruded test specimen (in kN) along the y-axis versus the length of the extruded test specimens (in mm) along the x-axis, considering the constructive scheme shown in Figure 1, wherein the diameter D = 20 mm, the fillet radii R_{ext} =R_{int} = 2 mm, the angle between the extrusion die channels O = 90° and the length of the processed test specimens L_{init} = 200 mm, considering the processing of AA5083 at ambient temperature and friction factor of 0.1.

Figure 12 shows a graphic representation of the obtained value, by means of simulating with finite elements, of the total force (in kN) for keeping the dies from opening along the y-axis, with the length of the test specimens extruded (in mm) along the x-axis, considering the constructive scheme shown in Figure 1, wherein the diameter D = 20 mm, the fillet radii R_{ext} =R_{int} = 4 mm, the angle between the extrusion die channels O = 90° and the length of the processed test specimens L_{init} = 200 mm, considering the processing of AA5083 at ambient temperature and friction factor of 0.1.

Figure 13	shows a graphic representation of the obtained value, by means of simulating with finite elements, of the processed force per extruded test specimen (in kN) along the y-axis versus the length of the extruded test specimens (in mm) along the x-axis, considering the constructive scheme shown in Figure 1, wherein the diameter D = 20 mm, the fillet radii R_{ext} =R_{int} = 4 mm, the angle between the extrusion die channels O = 90° and the length of the processed test specimens L_{init} = 200 mm, considering the processing of AA5083 at ambient temperature and friction factor of 0.1.
Figure 14	shows a three-dimensional view of the final deformation stage according to the invention, using hydraulic actuators.
Figures 15(a) and 15(b)	show, respectively, the initial and final stages of the MCM-SPD process, when hydraulic actuators are used for the pressing and closure of the extrusion dies.
Figure 16	shows a possible configuration of an automatic material feeder for the MCM-SPD process according to the invention.
Figure 17	shows the opening/closing sequence of the dies-die holders used in the MCM-SPD process according to an embodiment of the invention.
Figure 18	shows the opening sequence of the dies (isometric view) used in the MCM-SPD process according to the invention, when the die closure system is connected to the closure means thereof.
Figure 19	shows an isometric view of a die-die holder array according to the invention, wherein the use of heating coils can be observed in the die holder of the dies used in the MCM-SPD process, in order to decrease the elastic limit of the material and facilitate the plastic deformation process.
Figure 20	shows a lateral scheme of the MCM-SPD process according to the invention, using heating coils in the deformation zone.

DESCRIPTION OF THE INVENTION

[0041] The present invention comprises a simultaneous angular and/or polychannel angular deformation method that does not significantly modify the cross-section of the processed material, and is applicable to very diverse cross-sections (square, rectangular, circular, polygonal, etc.). To this end, as shown in figures 1-6, a simultaneous angular or polychannel angular deformation device is used, which comprises an arrangement of extrusion dies (1), preferably situated in die holders (2), said dies (1) preferably being divided into two symmetrical parts (3, 4) each one of them comprising one or more angular channels (5), and said channels (5) comprising an inlet (6) and an outlet (7). The extrusion dies (1) are stacked against each other. Likewise, as shown in Figures 5-7, to compress the test specimens, an array of punchers (8), equal to the number of the angular channels (5) of the aforementioned dies (1), which fit therein are used to exert the compression force required to process multiple materials by means of severe plastic deformation. The spatial arrangement of the extrusion dies (1) according to the present invention permits the extrusion process to be performed simultaneously for all of the dies (1) used, significantly reducing the forces required to close them, as the reaction forces which tend to open the dies (1) and which appear during the channel angular deformation process are offset, as only the application of a single closure force on the array of dies (1) used is needed, applied solely on the first die, thus avoiding the need to apply a closure force on each individual die (1). The fact that the dies (1) are kept together during the extrusion process is of utmost importance, since if these open during said process it can cause the punchers (8) to be broken and/or the flow of material between the dies (1) to the exterior. As can be observed in Figures 8, 10 and 12, which show the closure force (F) of a die (1), in kN, necessary when two test specimens are simultaneously extruded as a function of the extruded length (L) in mm, and in Figures 9, 11 and 13, which show the necessary force (F) in kN for the individual extrusion of each test specimen as a function of the extruded length (L) in mm, the necessary force to keep the dies (1) closed during the channel angular extrusion process is in the order of four or five times the compression force required to extrude each test specimen, a result of the hardening of the material, the geometry of the die (1) and the friction with the channels (5) of the die (1). Additionally, the increase of the closure forces required in each die, as the number of test specimens extruded increases therein, would cause, in practice, the multiple processing of materials by means of a single die with a plurality of channels (5) to become a very demanding method with respect to the closure forces required, limiting, in the end, the number of test specimens that can be processed. With the present invention, the closure force for a succession of dies (1) remains constant and independent of the number of stacked dies (1), so the "Closure force / Compression Force" ratio is much less than that in the event that one would want to simultaneously extrude several pieces with conventional channel angular extrusion processes, using several presses to extrude one piece in each one. Furthermore, the productivity achieved by means of the present invention is much greater than other configurations existing in the state of the art. Said productivity is limited solely by the dimensions of the equipment used to carry out the process, since, as has been mentioned, the limitation does not come from the closure force that must be applied with said equipment.

[0042] Therefore, the present invention avoids the drawbacks related to the force required to keep the dies (1) closed by increasing the number of test specimens extruded during each stage of the process. This makes it possible to stack, in a parallel succession (Figures 1-4), with a radial symmetry (Figure 5) or by means of other arrangements, a number of dies-die holders limited solely by the dimensions of the equipment where they are going to be coupled, as the necessary closure force remains invariable, with relation to what would be required for extrusion with a single die (1).

[0043] The angular channels (5) comprised in the dies (1) wherethrough the material is processed include one or several angles of any value effective for producing a stress cutting effect on the material. A preferred value for said angular channel (5) angles is 90°. However, the process is also effective using angular channels with angles of other values. Likewise, the fillet radii, defined as the interior and exterior radii of the curvature profiles which make up the channels (5) for performing the deformation of the materials, are preferably equal, although they can have different values.

[0044] Figure 1 shows a three-dimensional view of a possible configuration of the spatial arrangement used for the channel angular extrusion dies (1), which, as observed, are divided into two symmetrical parts (3, 4), each one of which has two angular channels (5) with a circular cross-section, situated in die holders (2), which are stacked in series, one after the other, in order for it to be possible to simultaneously process eight test specimens with circular cross-sections, although said number can vary by stacking a greater or lesser number of consecutively arranged die-die holder arrays. By means of this configuration of dies (1), the closure forces required are offset two by two, solely having to apply the force necessary to keep one die (1) closed during the extrusion process.

[0045] Figure 2 shows a similar scheme to that of Figure 1, with the difference that in the present case dies with square cross-sections are used.

[0046] In other embodiments of the invention (Figures 3 and 4), the dies (1) and the die holders (2) make up a single, whole piece.

[0047] In another embodiment of the invention, the die-die holder arrays are stacked with a radial symmetry in the shape of circular sections, as shown in Figure 5. Figure 5(a) shows a section wherein the configuration of the dies (1) stacked according to radial symmetry in the initial stage of the processing is observed. Figure 5(b) shows an intermediate stage and Figure 5(c) shows a joint view during the initial stage of the process. Figure 5(d) shows a joint view wherein a configuration with two channels (5) (interior and exterior) for each die is observed. Figure 5(e) shows a section with the detail of the channels observed in Figure 5(d), and Figure 5(f) shows a joint view during an intermediate stage of the processing of the materials.

[0048] Another possible embodiment of the extrusion dies (1) according to the present invention is that proposed in figure 6. In this spatial arrangement of the dies (1), the distribution of the horizontal stacking in series has been substituted by a vertical stacking distribution, which places the centres of the cross-sections of the channels (5) angularly equidistant from each other. Likewise, in this configuration, the dies (1) are not divided symmetrically, but rather the inlet (6) and the outlet (7) of the angular channels (1) are configured by an upper part (9) of the die (1) on a lower part (10) of said die (1) (see Figure 6(a)). Figure 6(b) and Figure 6(c) show the punchers (8) used during an initial processing stage of the materials and during an intermediate stage, respectively, and Figure 6(d), Figure 6(e) and Figure 6(f) show another configuration scheme, similar to the previous one, but with the difference of featuring internal (11) and external (12) channels. In these embodiments, the forces required to close the dies are offset by a different geometry to the embodiments in Figures 1-5. Nevertheless, in all of them there is a decrease in the forces required to keep the dies (1) closed, it only being necessary to offset the vertical force which appears when the material is deformed at the outlet (7). In the same manner as in other embodiments of the invention, it is possible to simultaneously process several pieces with lesser closure forces than in the traditional channel angular extrusion configurations, there being a diametral offset of the closure forces which are produced between each pair of channels (5) present in the extrusion die (1). In this embodiment of the invention, the extrusion dies (1) can be stacked in pairs, their respective lower parts (10) opposing each pair of dies (1), and the use of two sets of punchers (8) being necessary to press the processed test specimens, each set of punchers (8) being applied on each one of the upper parts (9).

[0049] In order to exert the compression force and the closure force required to process the material in the different embodiments of the invention, hydraulic actuators (13) can be used, for example, such as those shown in Figures 14-15. It should be highlighted that it is possible to use any other compression and closure system, for example, mechanical, pneumatic, electromechanical, or a combination thereof. As can be observed in the hydraulic system shown in the aforementioned Figures 14-15, one or more pressing means (14) exert the compression force required for the multi-extrusion of material, said pressing means (14) comprising a plurality of punchers (8) which exert the compression force on the test specimens situated in the channels (5) of the dies (1), said punchers (8) being able to have different cross-sections depending on the design of the extrusion dies (1) used. On the other hand, one or more closure means (15) exert the compression force required to keep the entire array of dies (1) closed during the extrusion process. Once the process is complete, the array can return to the starting position in order to proceed to the extraction of the deformed material.

[0050] Once each stage of the MCM-SPD (actuation of the pressing means (14) on the inlet (6) of the channels (5), channel angular deformation of the test specimens and withdrawal of said pressing means (14) to the starting position) has finished, it is possible to extract the extruded material. However, it must be pointed out that the present invention permits multiple test specimens to be continuously processed without extracting the material, since, after each test specimen is processed, it is found in the outlet (7) of the channels (5). This allows, by means of the processing of subsequent dies (1), the new test specimens that pass through the inlet (6) of the channels (5) to push the test specimens in the outlet (7) in each process, so that the latter leave said channels (5) without having to perform an individualised extraction.

[0051] Likewise, the extrusion device according to the present invention can comprise both a manual supply of the extruded materials, or automatic and continuous feeding means (16) of said materials (see Figure 16), the latter providing greater production speeds. The present invention also makes it possible to reprocess a single test specimen, reinserting it into the inlet (6) of the angular channels (5) and repeating the extrusion process as many times as one wishes, depending on the specific characteristics of the process performed or of the materials processed. Preferably, the extrusion process is applied at least twice on each test specimen, and rotations can be applied around the longitudinal axis thereof with respect to its original orientation, during each processing subsequent to the first.

[0052] For a more simple and efficient embodiment of the opening of the dies (1), the present invention comprises, optionally, connection means (17) for connecting the extrusion dies (1). As shown in Figure 17, said means (17) allow, simultaneously and in connected fashion, both the opening and closing of the dies (1) to be performed. The aforementioned connection means (17) are preferably an arrangement of sliding fastenings (18) on bars (19), where said bars (19) join each one of the dies (1) to its die or adjacent dies. This option is of interest for simultaneously and efficiently lubricating the inlet (6) and the outlet (7) of the channels (5) of the dies (1). It is also possible, in an embodiment of the present invention (Figure 18), to couple the aforementioned connection means (17) to the closure means (15), so that the opening or closing of the dies (1) is performed in a single stage, combining it simultaneously with the withdrawal or the application, respectively, of said closure means (15), thus optimising the processing times of the extruded materials.

[0053] The method and device object of the present invention are applicable to starting materials with very diverse cross-sections, both solid and hollow. For example: square or rectangular sectioned pellets, circular or oval sectioned pellets, or polygonally sectioned pellets. Such materials can feature starting shapes with diverse cross-sections, such as bars, plates, sheets, tubes, hollow profiles, etc.

[0054] The materials which can be processed by means of the present invention are, preferably, metals and alloys thereof. Nevertheless, it is also possible, by means of other embodiments of the invention, to use other types of materials, such as polymers, ceramic materials, or other types of non-metallic compounds. Said materials can be submitted, before or after their processing, to surface treatments, thermal, or of other types, depending on the requirements of said processing.

[0055] For any of the possible embodiments of the invention, the extrusion process can be performed at ambient temperature or at controlled temperature, using, in the second case, dies (1) which can be heated or cooled, through temperature control means (20). Heat transfer through the extruded materials can be performed by using different heating or cooling methods, depending on the needs of the processing. Figure 19 shows an isometric view of a die-die holder set where the temperature control means (20) are heat coils installed in the die holders (2) of the dies (1) used in the MCM-SPD process. Figure 20 shows a constructive lateral scheme of the extrusion dies (1), using said heating coils in the deformation zone.

EMBODIMENTS OF THE INVENTION

<u>Example 1: Simultaneous processing of 16 pieces with circular cross-section (80 mm in length and 10 mm in diameter) of the aluminium alloy AA6060 using the MCM-SPD process.</u>

[0056] You start with aluminium alloy AA6060 pellets 80 mm long and 10 mm in diameter. Said alloy is processed by means of MCM-SPD at ambient temperature, using eight dies (1), divided into two symmetrical parts (3, 4) and housed in die holders (2), according to the arrangement shown in Figure 1, wherein the diameter (D) of the channels (5) of the die (1) is 10 mm, each of the fillet radii inside and outside the channel (Rext and Rint) have a value of 2 mm, the angle between the channels (5) of the extrusion (O) dies (1) has a value of 90° and the length of the processed test specimens is of 80 mm. The compression speed used is 140 mm/min and two hydraulic cylinders and a vertical cylinder are used to generate the required pressure. The latter exerts the compression force and is capable of producing 1200 kN, and the horizontal cylinder, which prevents the opening of the dies (1), is capable of producing a compression force of 1200 kN. A molybdenum disulphate spray is used as a lubricant. The lubricant is applied before placing the material on the dies (1), wherefore dies (1) divided by their central planes are used and whereto a closing pressure is applied by the previously mentioned hydraulic system. The dies are at ambient temperature. With the proposed configuration and a single downstroke, it is possible to produce sixteen test specimens of the aluminium alloy, considered highly deformed and without significant modifications of the cross-section thereof. Likewise, it is possible to perform the mechanical closure of the entire array without doing anything other than applying the force required to keep a single die (1) closed, as a result of the spatial distribution characteristic of the MCM-SPD process. An automated warehouse that performs the function of automatically supplying the material and conducting the test specimens to the inlet channel of the dies is used for feeding the material to the angular channel dies (1). Subsequently, the material obtained is re-inserted in the inlet (6) of the angular channels (5), rotating said material 180° with respect to its longitudinal axis, and the extrusion process is repeated.

<u>Example 2: Simultaneous processing of 8 pieces with circular cross-section (200 mm in length and 20 mm in diameter) of the aluminium alloy AA5083 using the MCM-SPD process at a 150° temperature.</u>

[0057] You start with aluminium alloy AA5083 pellets 200 mm in length and 20 mm in diameter. Said alloy is processed by means of MCM-SPD at a temperature of 150 °C, using four dies (1), divided into two symmetrical parts (3, 4) and housed in die holders (2), according to the arrangement shown in Figure 1. The diameter (D) of the channels (5) of the die (1) is 20 mm, each of the fillet radii inside and outside the channel (Rext and Rint) have a value of 4 mm, the angle between the channels (5) of the extrusion (O) dies (1) has a value of 90° and the length of the processed test specimens is of 200 mm. The compression speed used is 120 mm/min and two hydraulic cylinders are used to generate the required pressure. The vertical one, which exerts the compression force, is capable of producing 3000 kN and the horizontal cylinder, which prevents the opening of the dies (1), is capable of producing a compression force of 5000 kN. A synthetic oil resistant to the temperature process is used as a lubricant, before placing the material on the dies (1) and proceeding to the heating, for which dies (1) divided by their central plane are used and whereto a closing pressure is applied by the previously mentioned hydraulic system. The dies (1) are at a temperature of 150 °C, using, for this, heating coils situated near the deformation zone. Upon the placement of the material, the dies shall begin to heat up until reaching the fixed reference temperature (150 °C), the material being situated inside the dies (1). Once the temperature has been measured by the use of thermocouples situated at different points of the dies (1), the MCM-SPD is initiated. With the proposed configuration and a single downstroke, it is possible to produce eight test specimens of the aluminium alloy, considered highly deformed and without significant modifications of the cross-section thereof.

<u>Example 3: Simultaneous processing of 4 pieces with square cross-section (100 mm in length and 9 mm on the side) of low-content carbon steel using the MCM-SPD process.</u>

[0058] You start with low-content carbon steel pellets 100 mm long and 9 mm wide. Said steel is processed by means of MCM-SPD at ambient temperature, using two dies (1), divided into two symmetrical parts (3, 4) and housed in die holders (2), according to the arrangement shown in Figure 2, wherein the channels (5) of the die (1) feature a cross-section that is 9 mm on the side, the fillet radii outside and inside the channel (Rext and Rint) have a value of 1.25 and 2.0 mm, respectively, the angle between the channels (5) of the extrusion (O) dies (1) has a value of 90 °C and the length of the processed test specimens is 100 mm. The compression speed used is 80 mm/min and two hydraulic cylinders are used to generate the required pressure. The vertical one, which exerts the compression force, is capable of producing 2000 kN and the horizontal cylinder, which prevents the opening of the dies (1), is capable of producing a compression force of 2500 kN. A molybdenum disulphate spray is used as a lubricant before placing the material on the dies (1), which are divided by their central plane and whereto a closing pressure is applied by a hydraulic system. The dies (1) are at ambient temperature. With the proposed configuration and a single downstroke, it is possible to produce four highly deformed pieces of steel and without significant modifications of the cross-section thereof. An automated warehouse that performs the function of automatically supplying the material and conducting the test specimens to the inlet channels (5) of the dies (1) is used for feeding the material into the angular channel dies (1). Subsequently, the material obtained is re-inserted in the inlet (6) of the angular channels (5), rotating said material 180° with respect to its longitudinal axis and the extrusion process is repeated.

<u>Example 4: Simultaneous processing of four pieces with rectangular cross-section of 100 x 20 mm x 150 mm of stainless steel A309 by means of MCM-SPD, at a temperature of 525 °C</u>

[0059] You start with four blocks of stainless steel A309, (100 mm x 20 mm x 150 mm) (length x width x height). Said steel blocks are processed by means of MCM-SPD at a temperature of 525 °C and using two channel angular extrusion dies (1), divided in two symmetrical parts (3, 4) and housed in die holders (2), which feature a 95° angle between the inlet channel and the outlet channel, and fillet radii of 3.0 mm between the inlet channels and outlet channels. The spatial configuration of the dies (1) places the geometric centres of the extrusion punchers in a special arrangement such that their geometric centres are on the vertices of a 300 x 300 mm rectangle. The simultaneous extrusions are performed at 50 mm/min and a hydraulic cylinder with a vertical press of 4000 kN is used to generate the necessary pressure. In order to decrease the friction in the extrusion channels (5), a graphite lubricant is applied on the dies (1) before placing the material thereon and starting the heating. Dies (1) are used which are divided at their central plane and whereto a closure pressure is applied by means of a hydraulic system capable of providing a closure force of 4000 kN. The dies (1) are at a temperature of 525 °C, wherefore heating coils are used which, through conduction, provide the required heat to the deformation zone, wherein thermocouples are housed to regulate the processing temperature. With the proposed configuration and a single downstroke, it is possible to produce four highly deformed blocks of steel and without significant modifications of the cross-section thereof. At the end of the process, a stress-relieving thermal treatment is performed on the processed pieces. An automated manipulator is used for both the feeding and the extraction of the material once is has been deformed.

Claims

1. Channel angular pressing device for the multiple extrusion of materials which comprises a plurality of extrusion dies (1), wherein:

   - each one of said extrusion dies (1) comprises one or more angular channels (5), wherethrough the materials are extruded, said angular channels (5) being equipped with, at least, one inlet (6) and, at least, one outlet (7),
   - the plurality of extrusion dies (1) can be stacked in series,
   - the materials that pass through the angular channels (5) belonging to the series formed by the dies (1) are extruded simultaneously, through the compression of said materials by means of one or more pressing means (14).

2. Device according to claim 1, wherein the series formed by the extrusion dies (1) is capable, during the pressing of the processed materials through the channels (5), of maintaining the integrity thereof by means of the application of one or more closure means (15).

3. Device according to either of claims 1-2, wherein the series formed by the extrusion dies (3) has a configuration such that the closure force required to maintain the integrity of each individual die (1) within the series is offset by the closure forces required to maintain the integrity of their neighbouring dies (1) in said series.

4. Device according to any of claims 1-3, wherein the extrusion dies (1) are housed in die holders (2).

5. Device according to any of claims 1-4, wherein the extrusion dies (1) are housed in a single die holder (2).

6. Device according to any of claims 1-5, wherein the extrusion dies (1) are divided into two symmetrical parts (3, 4).

7. Device according to claim 6, wherein one or more angular channels (5) comprised in the extrusion dies (1) are divided in half, each half being housed in each one of the symmetrical parts (3, 4) of the extrusion dies (1).

8. Device according to any of claims 1-7, wherein the plurality of extrusion dies (1), upon the stacking in series thereof for the multiple processing of materials, forms an array which keeps a radial symmetry with respect to a vertical or horizontal axis.

9. Device according to claim 8, wherein the angular channels (5) of the array that form the extrusion dies (1) are angularly and equidistantly spaced.

10. Device according to any of claims 1-3, wherein the extrusion dies (1) are configured by means of joining an upper part (9) which houses an inlet channel (6) and a lower part (10) which houses an outlet channel (7), where the angular channels (5) wherethrough the materials are processed are formed by joining each inlet channel (6) with each outlet channel (7), when the upper (9) and lower (15) parts of the dies (1) come into contact with each other.

11. Device according to any of claims 1-10, wherein the angular channels (5) comprise one or more 90° angles.

12. Device according to any of claims 1-11, wherein the angular channels (5) have a circular, oval, square, rectangular or polygonal cross-section.

13. Device according to any of claims 1-12, wherein the extrusion dies (1) have a plurality of angular channels (5) of different cross-sections.

14. Device according to any of claims 1-13, wherein the inlet (6) and the outlet (7) of the angular channels (5) have the same cross-section.

15. Device according to any of claims 1-13, wherein the inlet (6) and the outlet (7) of the angular channels (5) have different cross-sections.

16. Device according to any of claims 1-15, wherein the inlet (6) and the outlet (7) of the angular channels (5) have the same length.

17. Device according to any of claims 1-15, wherein the inlet (6) and the outlet (7) of the angular channels (5) have different lengths.

18. Device according to any of claims 1-17, wherein the interior and exterior fillet radii of the angular channels (5) are equal.

19. Device according to any of claims 1-17, wherein the interior and exterior fillet radii of the angular channels (5) are different.

20. Device according to any of claims 1-19, which comprises a plurality of punchers (8) for processing materials.

21. Device according to claim 20, wherein the punchers (8) are comprised in the pressing means (14).

22. Device according to any of claims 1-21, wherein the pressing means (14) and/or closure means (15) comprise one or more hydraulic, mechanical, pneumatic or electromechanical systems, said systems being used either individually or in combination.

23. Device according to any of claims 1-22, wherein the feeding of the processed materials is carried out either manually, through automatic supply means (16) or by a combination thereof.

24. Device according to any of claims 1-23, wherein the extrusion dies (1) comprise connection means (17) for making an opening or a simultaneous closure of said extrusion dies (1).

25. Device according to claim 24, wherein the connection means (17) are, preferably, an arrangement of sliding fastenings (18) on bars (19), said fastenings (18) being installed in the dies (1), and where said bars (19) connect each one of the dies (1) to its die or adjacent dies.

26. Device according to any of claims 1-25, which further comprises means for controlling the temperature (20), said means preferably being heating systems or cooling systems, used individually or in combination.

27. Use of a device according to any of claims 1-26 for the multiple extrusion of materials by means of pressing.

28. Use according to claim 27, wherein the materials extruded are metals or alloys thereof.

29. Use according to claim 27, wherein the materials extruded are polymeric, ceramic or non-metallic compound materials.

30. Channel angular pressing method for the multiple extrusion of materials which comprises:

- the stacking in series of a plurality of extrusion dies (1), said extrusion dies (1) comprising one or more angular channels (5), wherethrough the materials are processed.
- the simultaneous extrusion of the materials through the angular channels (5) comprised in the series formed by the dies (1), by means of the application of one or more pressing forces.

31. Method according to claim 30, wherein the integrity of the series formed by the extrusion dies (1) is maintained by means of the application of one or more closure forces, so that the closure force required to keep the integrity of each individual die (1) within the series is offset by the individual closure forces required to maintain the integrity of their neighbouring dies (1) in said series.

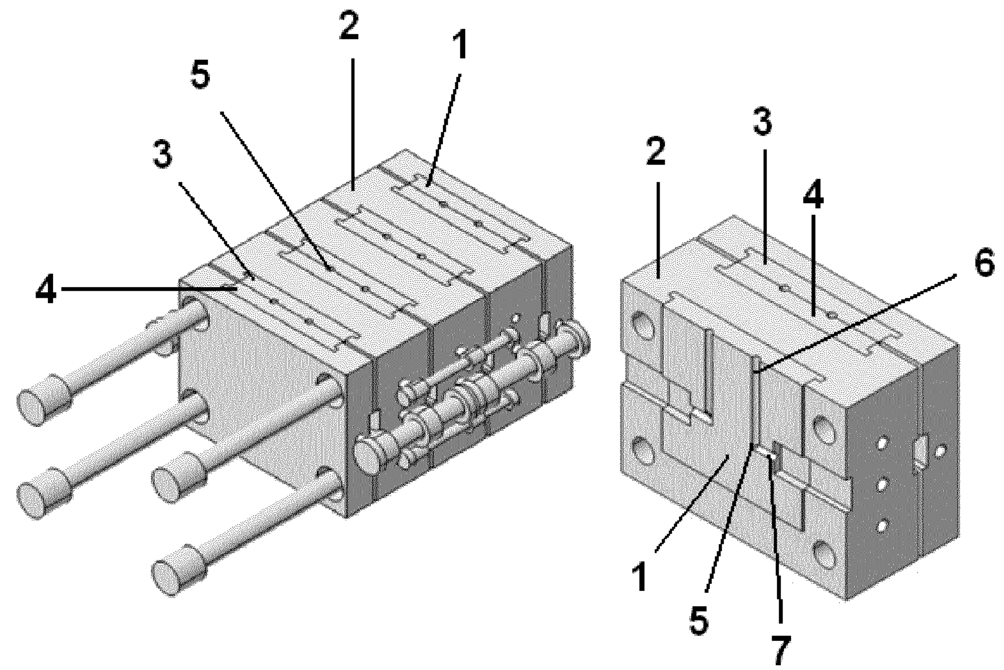

Fig. 1

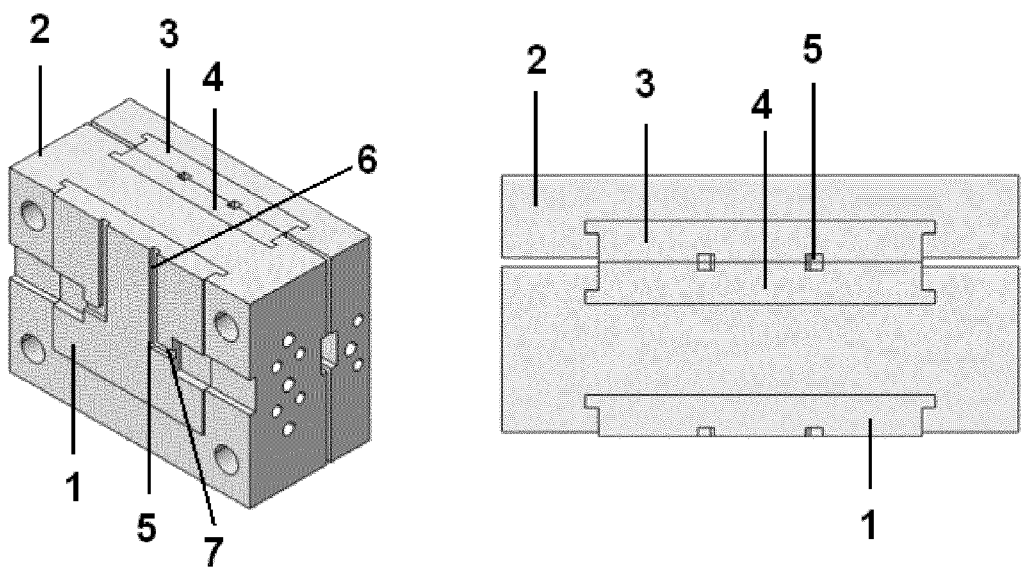

Fig. 2

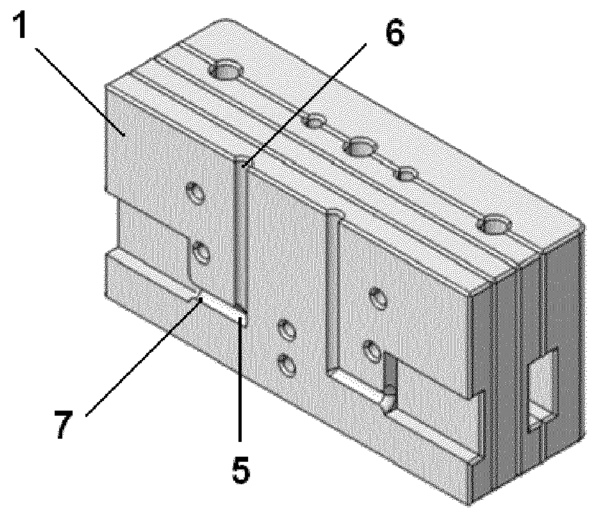

Fig. 3

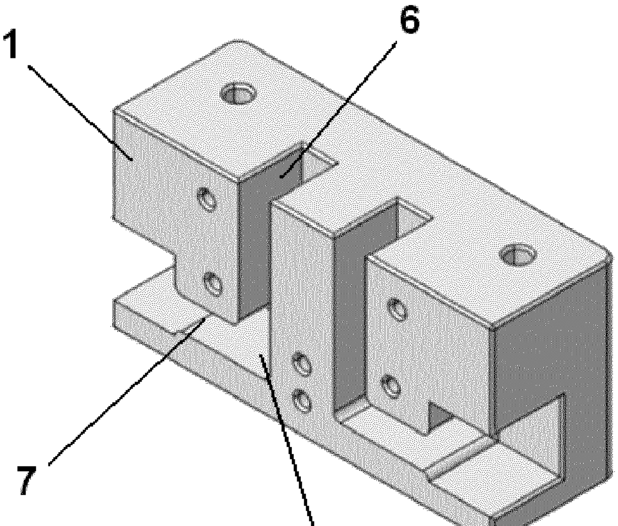

Fig. 4

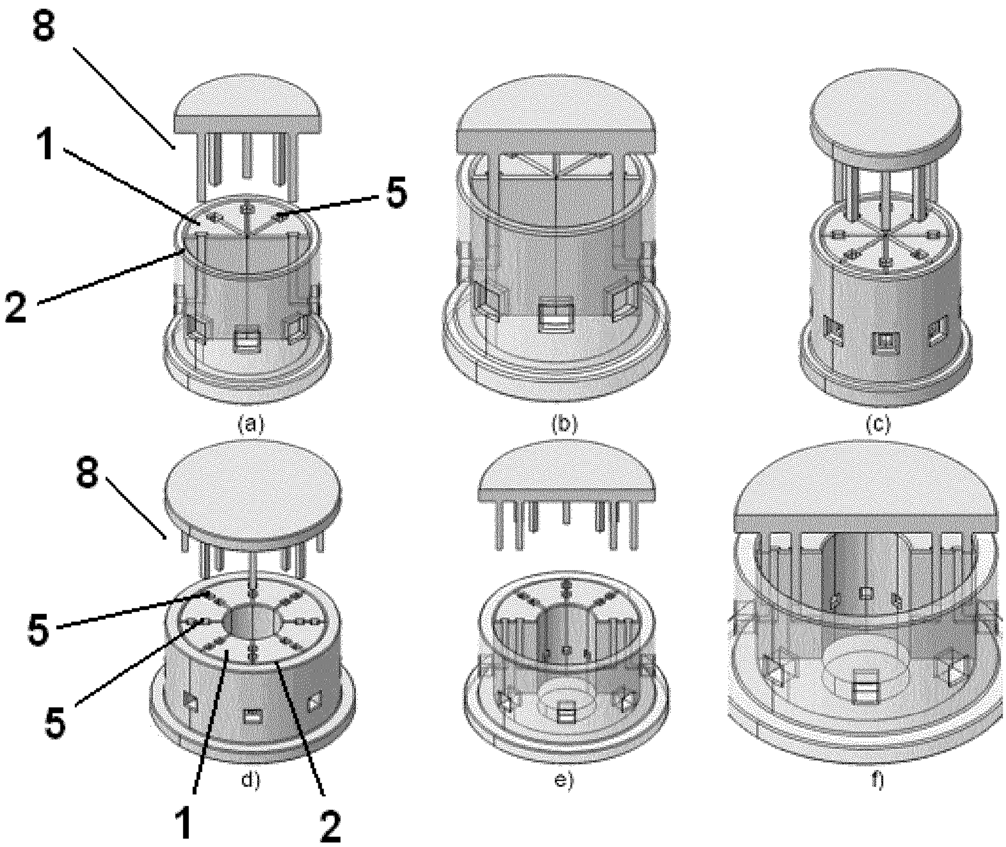

Fig. 5

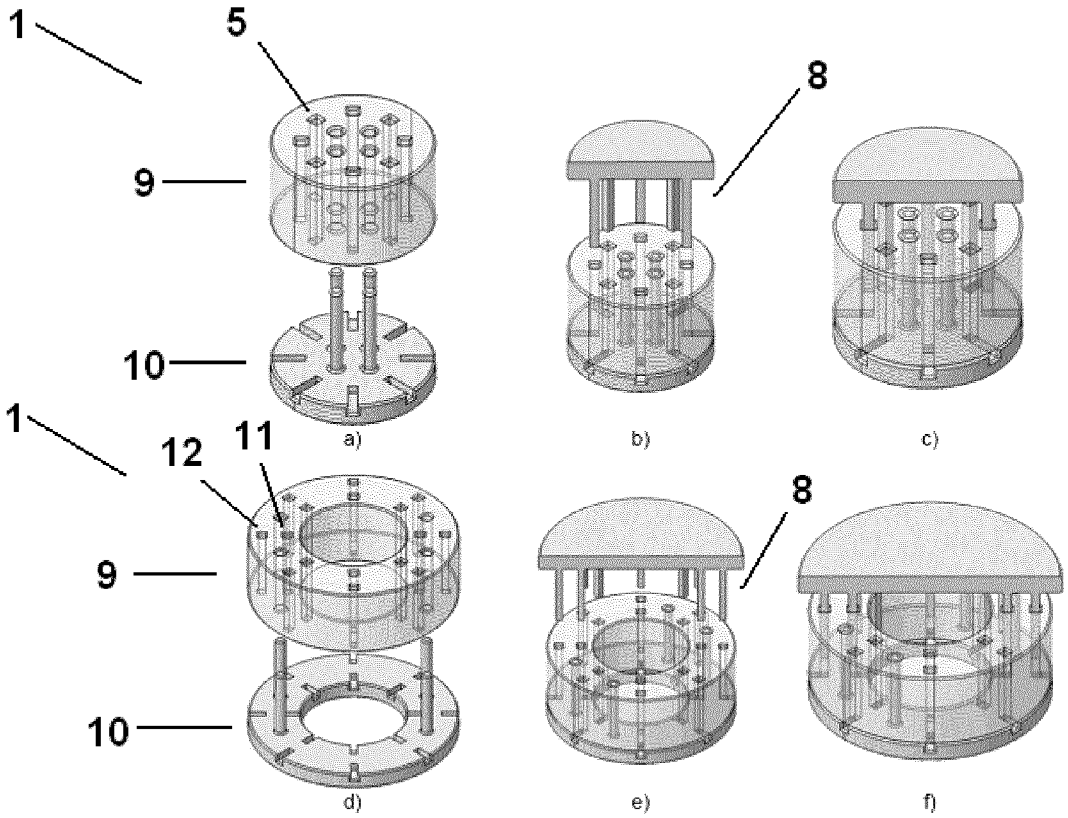

Fig. 6

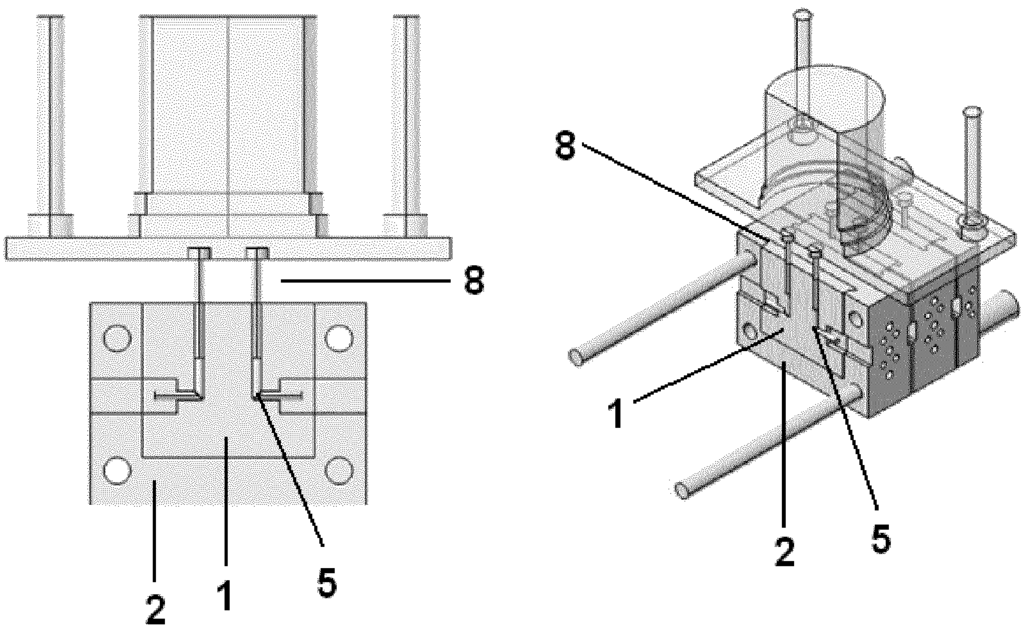

Fig. 7

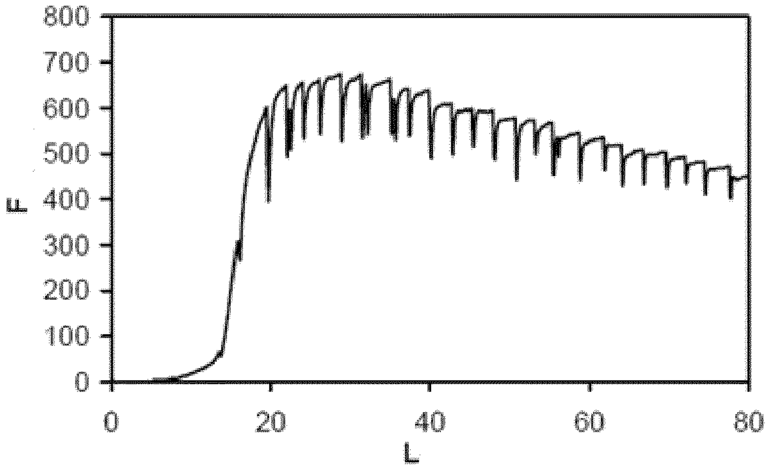

Fig. 8

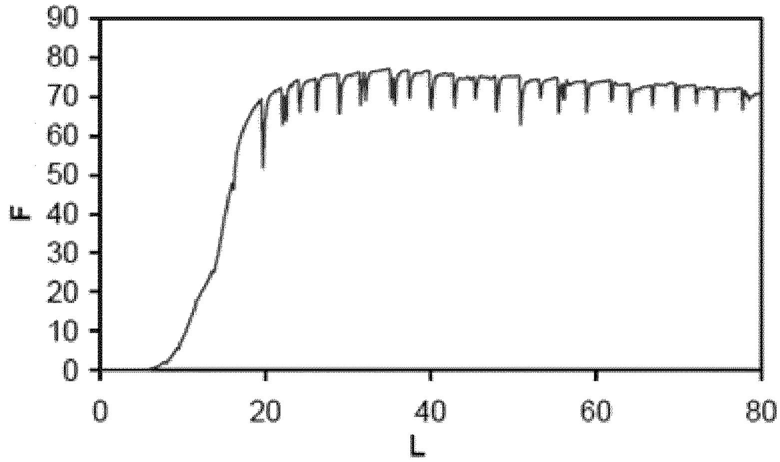
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Fig. 9

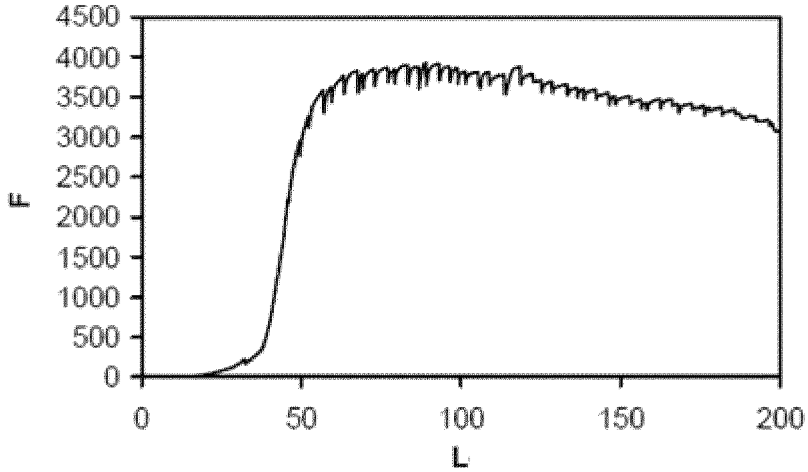
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Fig. 10

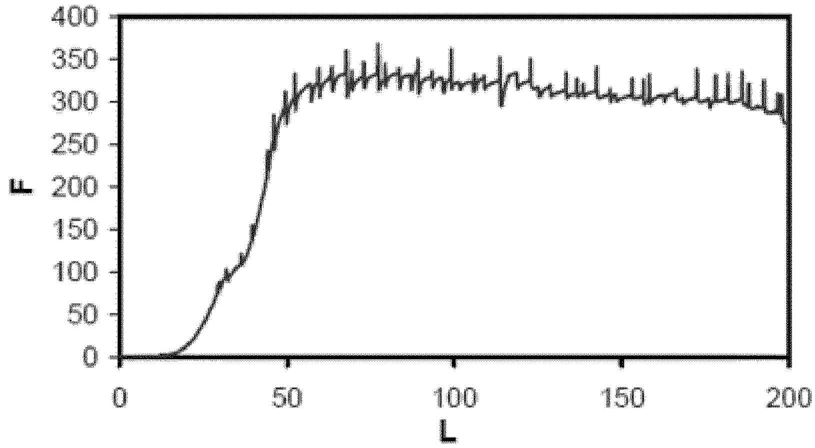
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Fig. 11

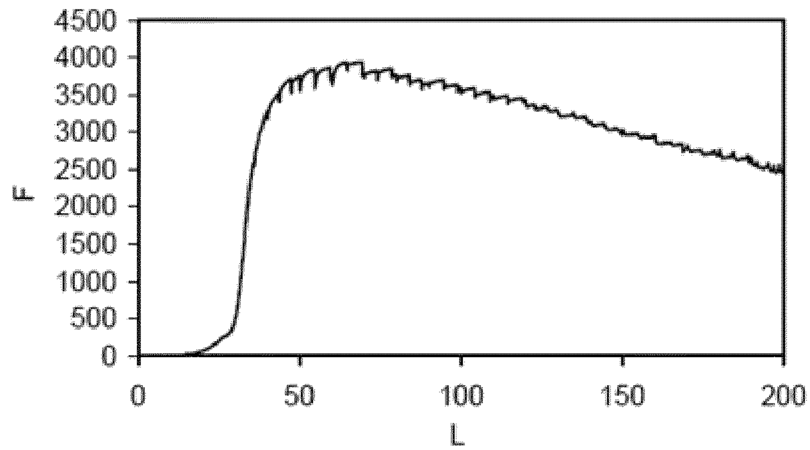
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Fig. 12

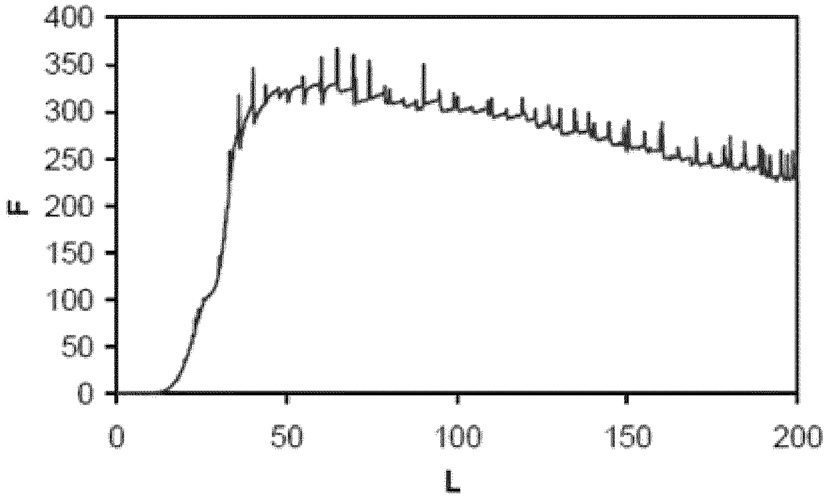

Fig. 13

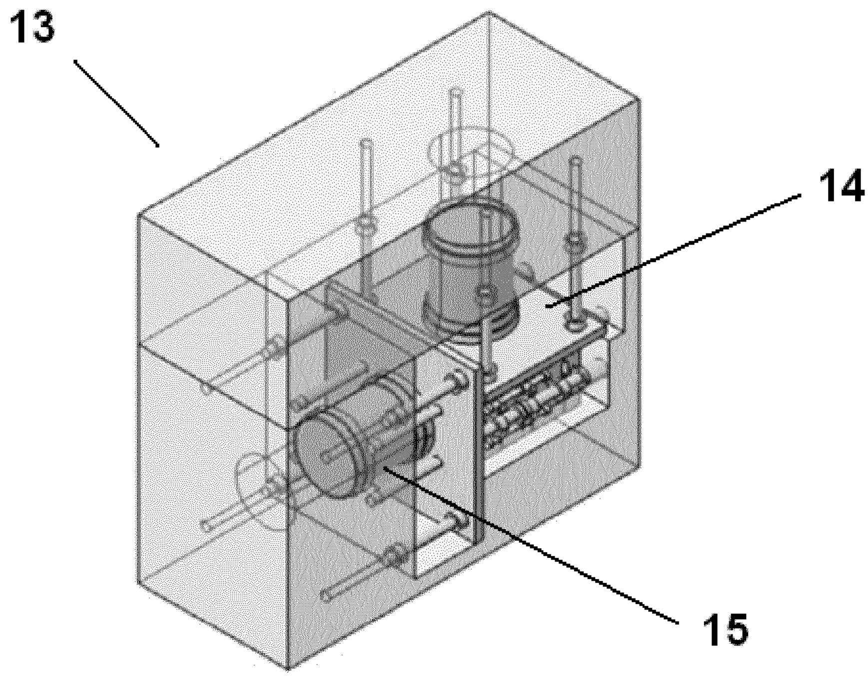

Fig. 14

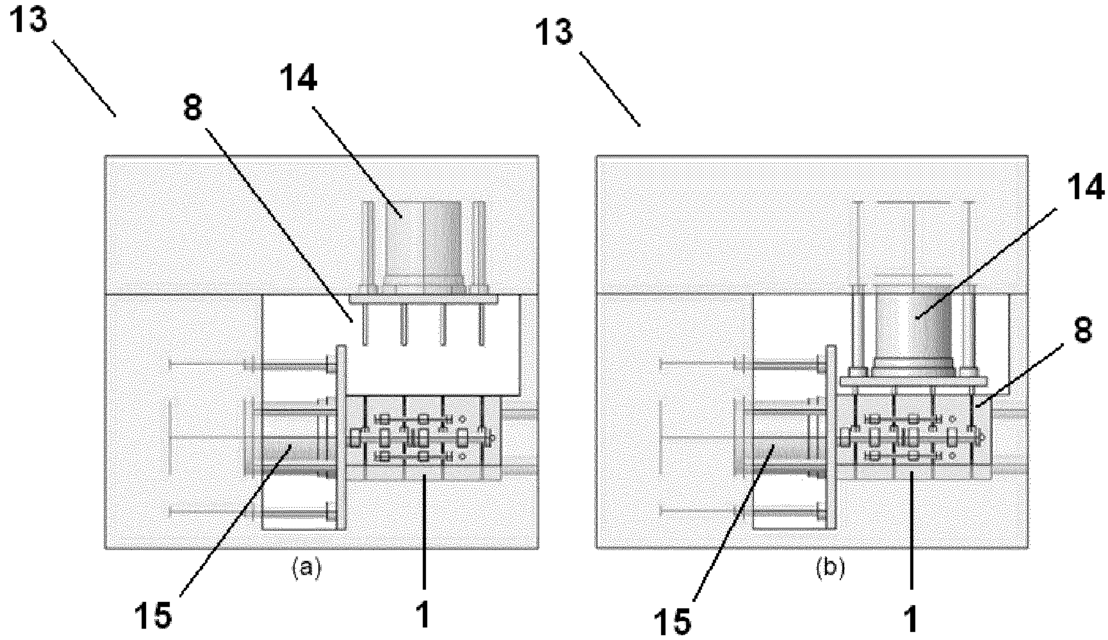

Fig. 15

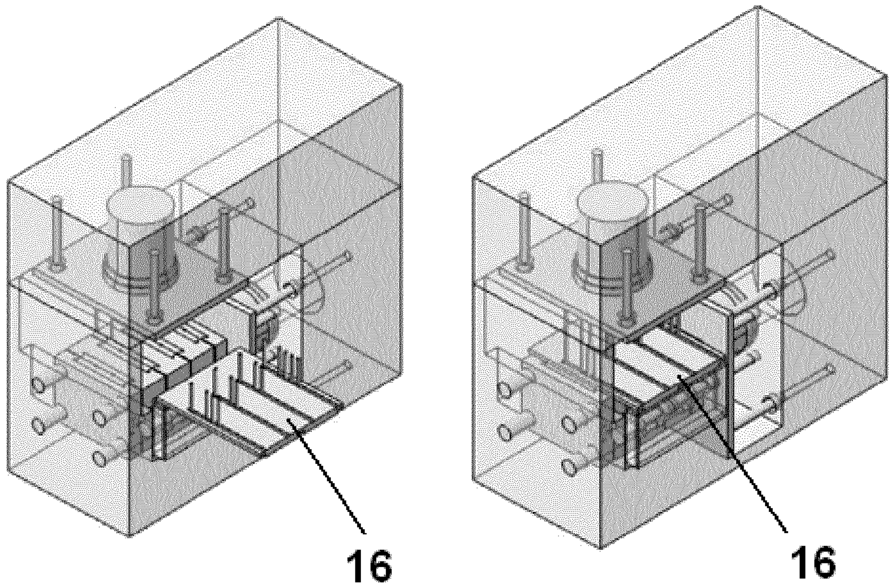

Fig. 16

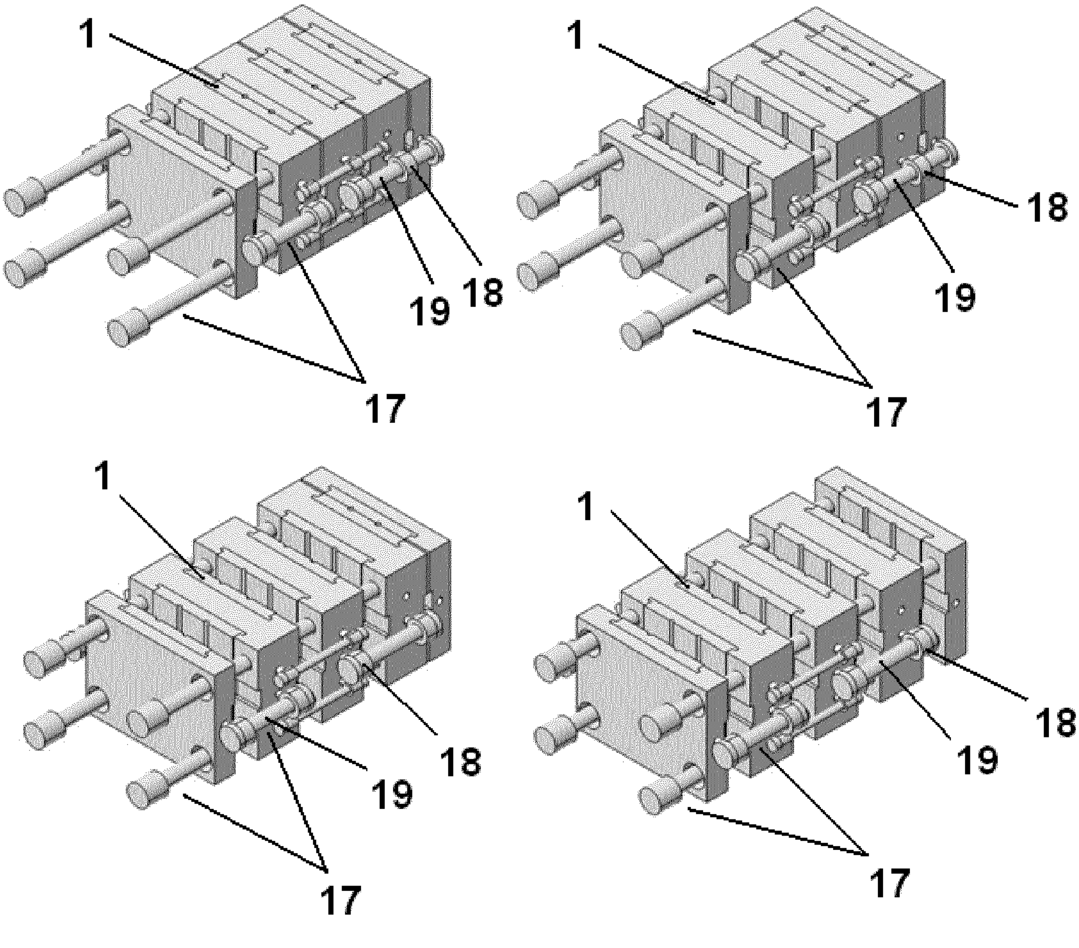

Fig. 17

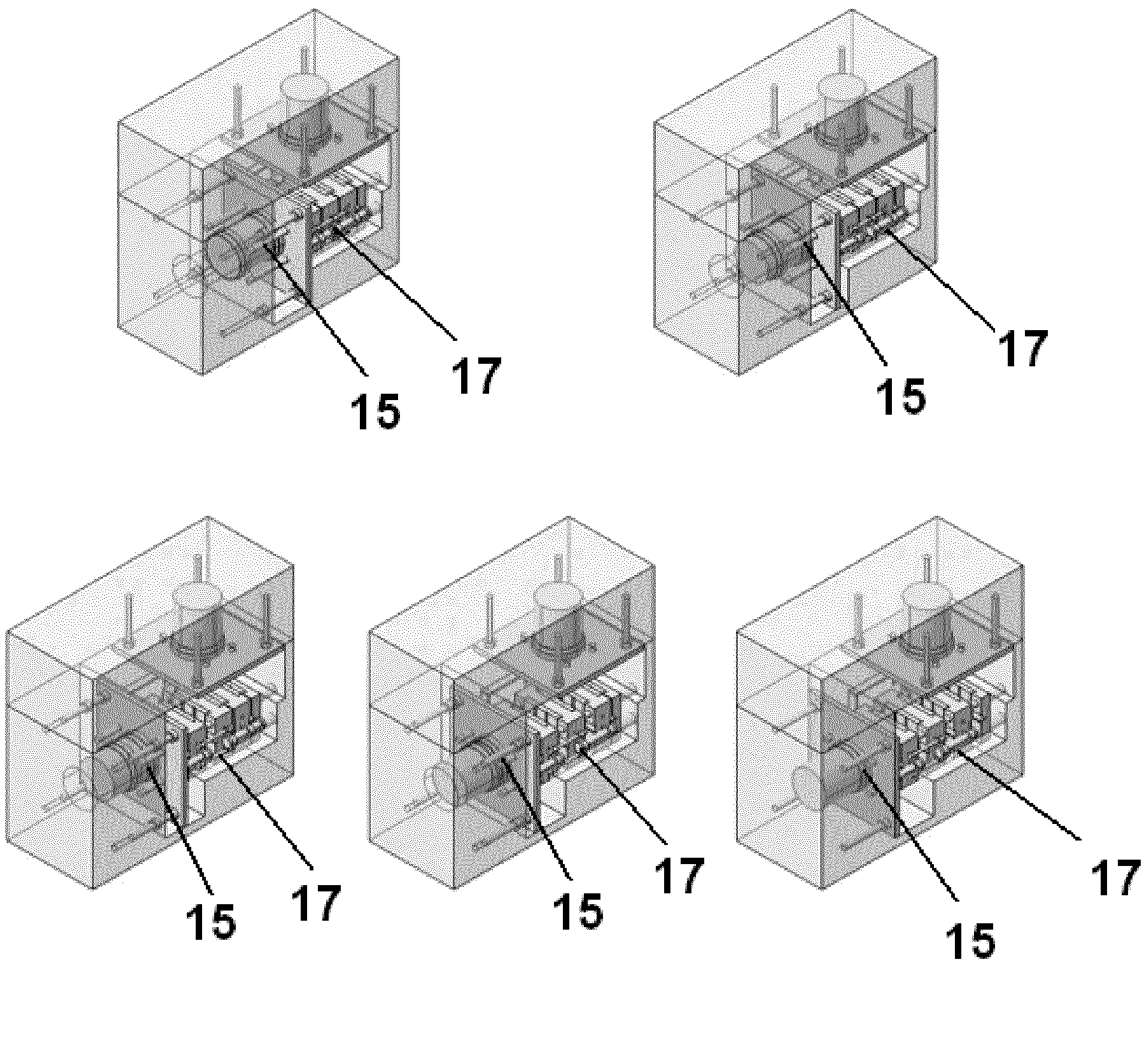

Fig. 18

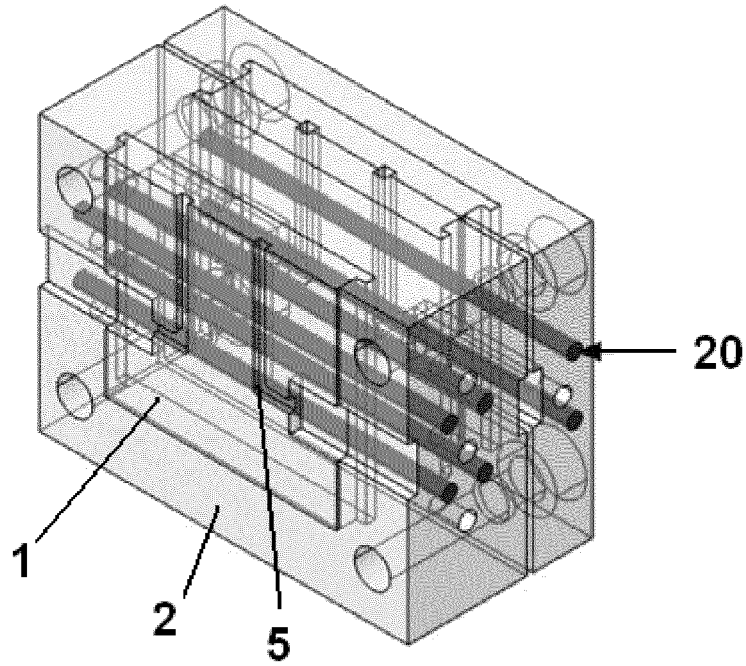

Fig. 19

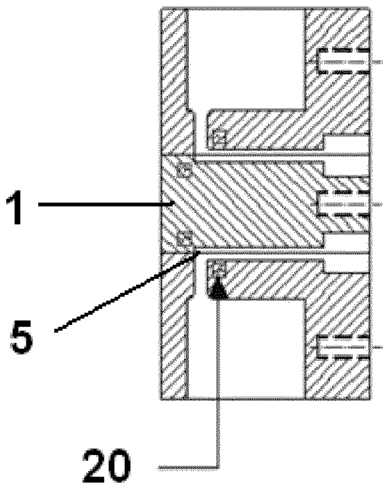

Fig. 20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/ES2011/070194

A. CLASSIFICATION OF SUBJECT MATTER

B21C23/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, INVENES

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5600989 A (SEGAL VLADIMIR ET AL.) 11/02/1997, column 6, line 8 - column 7, line 3; figures 1,11 - 14.	1-31
Y	US 6386009 B1 (NI CHI-MOU ET AL.) 14/05/2002, column 1, line 26 - column 4, line 10; figures 1 - 7.	1-31
A	US 6170309 B1 (MARANDO RICHARD A) 09/01/2001, the whole document.	1-31
A	US 2004255630 A1 (RAGER CHRISTOPHER A) 23/12/2004, the whole document.	1-31
A	US 6895795 B1 (CHAUDHURY PRABIR K ET AL.) 24/05/2005, the whole document.	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure use, exhibition, or other means.

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other documents , such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18/07/2011	**(04/08/2011)**
Name and mailing address of the ISA/ OFICINA ESPAÑOLA DE PATENTES Y MARCAS Paseo de la Castellana, 75 - 28071 Madrid (España) Facsimile No.: 91 349 53 04	Authorized officer A. Andreu Cordero Telephone No. 91 3493055

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/ES2011/070194

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Form PCT/ISA/210 (patent family annex) (July 2009)

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