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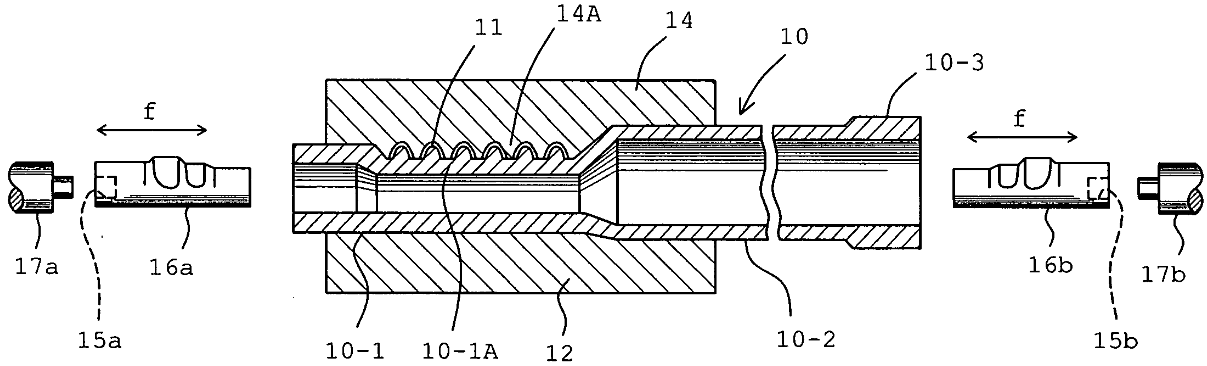
(54) Method and apparatus for plastic working of hollow rack bar and hollow rack bar

(57) A preparatory working device by which a work piece (10) to be fed to a rack bar forging device is obtained. The device is provided with a die sets (22,37,48) for obtaining a diameter reduction at a location of a blank pipe, which becomes a toothed part of a rack bar, while the wall thickness being substantially unchanged or slightly increased. The device is further provided with a die set (32,44) for reducing a wall thickness at a location of the blank pipe, which becomes a connection part of the rack bar. The wall thickness reduction is one half of the initial thickness, which causes the length of the work piece (10) to be elongated. Then a rack bar forging by a die set (12,14) is done.

Fig.2



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Description

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The present invention relates to a production of rack bar in a steering mechanism of a vehicle from a pipe shaped blank by plastic working, and, more particularly, to its improvement, by which an increased reduction in the weight of the product is obtained in comparison with the prior art.

2. Description of Related Art

[0002] A rack bar is a main part of a steering system of a vehicle and has conventionally been produced by machining from a solid bar of a rounded cross-sectional shape by using originally a hobbing machine and recently a broaching machine. However, such a machining from a solid bar of rounded cross-sectional shape makes the product to be heavy. Therefore, a solution has been proposed, wherein the machined product is subjected to a subsequent boring by using a gun drill to obtain a hollow structure, thereby reducing the weight. However, this solution makes the production cost to be increased on one hand and, on the other hand, makes the resource consumption efficiency to be reduced.

[0003] Thus, the applicants of this application et al have proposed an improvement, wherein a plastic working (forging) of a pipe shaped blank is done for obtaining a rack bar of a reduced weight while keeping a reduced resource consumption as well as an increased vehicle performance. In this rack forging technology, a pipe shaped blank is held by a die set having toothed portions at a side facing the blank and a mandrel is inserted into the hollow space of the blank, so that toothed portions corresponding to those of the die set are copied to the blank. See specifications of Japanese Patent No. 3547378, Japanese Patent No. 3607204 and Japanese Patent No. 3607205 and Japanese Un-Examined Patent Publication (Kokai) No. 2006-026703.

[0004] In the prior art disclosed in above patents, pipe shaped blanks just supplied by manufacturers of predetermined fixed wall thickness of a value of about 4mm are used. This predetermined wall thickness of the blank pipe is decided by the tooth height desired for the particular rack bar. In order to obtain an increased tooth height of a rack bare, a blank pipe of in increased wall thickness is needed at locations where the toothed portions are created. In the prior art, a blank pipe of a uniform value of wall thickness was used, resulting in an excessive wall thickness at the locations other than the toothed portions. Thus, the prior art is defective in an increased product weight and reduced material consumption efficiency. Thus, a long felt need has been existed as far as a reduced production cost, increased material consumption efficiency and increased performance are concerned.

SUMMARY OF THE INVENTION

[0005] The present invention aims to overcome the above difficulties in the prior art and, in particular, to provide a technology, by which an effective use of the material along the entire length of the blank is realized, a desired performance as a rack bar is obtained and increased degrees of a weight reduction, a cost performance, a resource saving and a vehicle performance is realized.

[0006] According to the present invention, a method for forging a of a rack bar of radially outwardly copied type is provided, wherein a pipe shaped work piece is held by a die set, the material of the work piece is plastically flown to the die set located diametrically outward from the work piece in a manner that a toothed shape of the die set is copied to the work piece. The present invention features that an adjustment of the cross sectional area of the work piece is preliminary done by a local increase or decrease of wall thickness of the work piece prior to the execution of the rack forging process of radial expanded copied type. Namely, upon the execution of the preliminary adjustment of the cross-sectional area, a work piece is subjected to plastic workings for desirably increasing or decreasing the wall thickness at the respective axial positions of the work piece along the length thereof. As a result, desired values of cross-sectional area corresponding to desired functions at the respective portions of the work piece along its length are obtained.

[0007] The above mentioned adjustment of the wall thickness of work piece at the respective portions along its length is carried out by so-called swaging or ironing process under a single stage or a plurality of divided stages.

[0008] An adjustment of the cross-sectional area according to the present invention is carried out by an apparatus, which is constructed by a combined die set having an elongated mandrel and a plurality of dies and a vertical or horizontal hydraulic cylinder mechanism, which is cooperated with the die set in a manner that a desired local increase or decrease of the wall thickness of the blank pipe is obtained at respective positions of the blank pipe along its length. In place of the hydraulic cylinder mechanism, any suitable reciprocating mechanism, such as a ball screw type, where a rotating movement is converted to a linear movement, may be employed.

[0009] In a power steering mechanism of an electric operated type, a rack bar of VGR (variable gear ratio) type is usually used. In this type of mechanism, it is needed that values of the pitch as well as the inclination angle of toothed portions are varied along the length. Such a construction of the VGR rack bar makes it difficult that it is machined from a solid work piece. Therefore, a forging from a pipe shaped blank is usually employed. Furthermore, unlike the hydraulic operated type, the electric operated type requires an increased bending strength of toothed portion, i.e., an increased size of tooth part as well as an increased thickness.

[0010] The present invention can achieve this goal, while obtaining the maximum reduction of the weight of a rack bar. Namely, according to the present invention, a forging of toothed portions is done by a radially outwardly directed plastic flow of metal of a pipe shaped blank while preventing fibrous metals from being broken. Under such principle of rack formation, an adjustment of the cross sectional area of the blank pipe is essential and has been done by a grinding. In contrast, according to the present invention, a plastic working is done for obtaining a desired increase or decrease in the wall thickness at locations along the length of the work piece, so as to obtain desired values of cross-sectional area, corresponding to the desired functions required at the respective locations. In more detail, at the location where a toothed form is to be formed, a wall thickness corresponding to the wall thickness of the blank pipe is basically maintained, so that a desired toothed shape is obtained under the plastic flow, although a wall thickness increase by a diameter reduction can be taken when it is necessary.

[0011] In comparison, at locations other than the location for the formation of the toothed portions, a desired strength is obtained, even when the wall thickness is smaller than the wall thickness of the blank pipe. Therefore, according to the present invention, a wall thickness reduction is done so long as a desired strength within a permissible range is obtained. A wall thickness reduction may be done by ironing, which causes the work piece to be axially elongated. Namely, in the present invention, the length of the product must be decided while an axial elongation as generated by the reduction of the wall thickness of the blank pipe is taken into the consideration. In other words, in the present invention, a blank pipe of a reduced axial length for a value corresponding the axial elongation can be used, resulting in a corresponding reduction of the weight of product. Namely, in the prior art as in '378, '204, '205 or '703 patent, the weight of a product is almost equal to that of the blank pipe and is about 1,236kg when the blank of wall thickness of 4mm and of a diameter of 25mm has a length of 615mm. In contrast, in the present invention, the value of wall thickness at toothed portions is maintained to that of the blank pipe, i.e., 4mm and the wall thickness of the portion other than the toothed portion is reduced to 2mm by an ironing process, while keeping the desired strength of the product. Thus, according to the present invention, it is possible to use a blank pipe of a reduced length for a value corresponding to the lengthwise elongation as generated by the ironing. The inventor has found that a desired performance is obtained even when the length of a blank pipe is reduced so that the weight of a blank pipe, i.e., the weight of a product is reduced to 920g, although the weight reduction depends on a length of toothed portions having a value of a wall thickness, corresponding to that of the blank pipe. In this example, a weight reduction of the present invention is 25.6% over the prior art as in '378, '204, '205 or '703 patent and is, even, better than 60% over the prior art where a solid blank rather than the pipe shaped blank is used. Irrespective of such an additional process like a swaging or ironing for obtaining a cross sectional area control, a substantial reduction of the cost is obtained. Assuming that a material cost is 170 yen/kg, a resultant reduction of the material cost would be (1.236-0.920)×170=53.7yen per one product. In addition, the redemption cost of the die set would be, at the most, 10yen per one product. It will thus be understood that a material cost reduction of about 48yen per one product is possible. Furthermore, as a result of a reduction of a weight of a product, i.e., a rack bar, a resultant reduction in the weight of a vehicle is obtained, which assists in an improvement of a drive ability of the vehicle, on one hand, and, on the other hand, in a reduction in a fuel consumption efficiency. The reduction in the fuel consumption efficiency per one car would be minimal but is significant in view of a huge automobile market, which might be amount to 70,000,000 cars in worldwide.

[0012] Furthermore, as a result of the ironing after the swaging, a highly improved surface roughness is obtained not only at the inner surface but also at the outer surface, which allows a dimension to be controlled within a tolerance of microns, thereby allowing a increased product quality and precision to be easily obtained.

BRIEF EXPLANATION OF ATTACHED DRAWINGS

[0013]

Figs. 1a to 1e are schematic views of a series of stages for producing a rack bar according to the present invention.

Fig. 2 is a schematic view of a process for forging a rack bar from a pipe shaped blank by using a shuttle type rack bar forging system.

Figs. 3a to 3c are schematic views of a series of stages for carrying out a diameter reduction of a blank pipe.

Figs. 4a to 4g are schematic views of a series of stages for carrying out a wall thickness reduction of a blank after subjected to the diameter reduction process.

Figs. 5a to 5d are schematic views of a series of stages for obtaining, from an initial blank, under one shot principle, a worked blank suitably for a supply to a subsequent rack bar forging process.

BEST MODE FOR PRACTICING THE INVENTION

[0014] Figs. 1a to 1e illustrates a series of steps or stages for forming a rack bar according to the present invention. In Fig. 1a, a reference numeral 10 denotes a blank pipe (intermediate part) or a work piece supplied from a maker after subjected to a phosphate coating process. In Fig. 1a, the wall thickness of a blank is designated by to and its length by L_0, respectively. In this particular embodiment, the wall thickness to has a value of 4mm, the material at a portion (tooth profile forming portion) of the blank pipe of this value of wall thickness is subjected to radially outwardly directed plastic flow, resulting in a formation of toothed portions of desired values of height and strength.

[0015] At a second step as shown in Fig. 1b, a first stage diameter reduction is done only at the tooth profile forming portion. Namely, at the location 10' of the blank pipe of a predetermined length from its left-hand end is subjected to a diameter reduction, so that the wall thickness t_1 is obtained, which is equal to or slightly increased over the wall thickness to of the blank pipe. Such a diameter reduction is done by a swaging process as will be explained later. The length of the reduced diameter part 10' corresponds to that of a toothed part 11 (Fig. 1e) of a rack bar. The remaining portion, which was not subjected to the diameter reduction, is designated by 10".

[0016] At a third step as shown in Fig. 1c, a wall thickness reduction is done at a part of a rack bar, which becomes a connection part (axially extended part from the toothed part). As illustrated above, a wall thickness to of 4mm of a blank pipe is suitable for the toothed part to obtain desired values of tooth height and strength needed for a rack bar product after the completion of a forging process. However, such a value of wall thickness of 4mm is excessive for the connection part in view of its designated function, since the connection part is less stressed when compared with the toothed part. Thus, a portion of a blank pipe, which becomes a connection part of a rack bar as a forged product, is subjected to a plastic working so that a wall thickness reduction is done from to of a blank pipe to t_2, which is, for example, about 1/2 of to, i.e., $t_2 \approx 0.5 \times t_0$ (=2mm) . For obtaining such a wall thickness reduction, an ironing process may be employed, which accompanies with an elongation of the blank pipe from a length of L_0 to L_1. In short, in a blank pipe, as an axial extension of a reduced diameter portion 10-1 of a wall thickness of t_1 corresponding to the portion 10' in Fig. 1b, a wall thickness reduced portion 10-2 of a wall thickness of t_2 is formed as shown in Fig. 1c. The length L_1 corresponds to a length of a rack bar as a final product. In the prior art, a blank pipe of a length corresponding to that of a product is needed. Contrary to this, the length L_1 corresponding to that a product is obtained by a wall thickness reduction accompanied with the corresponding axial elongation. Thus, an initial blank pipe of a reduced length can be employed for a value corresponding to an axial elongation as obtained during a wall thickness reduction process. In short, in comparison with the prior art, a blank pipe length can be reduced from a value of L_1 to a value of L_0. Thus, a corresponding material consumption as well as weight reduction are obtained, thereby obtaining a material cost reduction as well as a running cost reduction.

[0017] In the third step shown in Fig. 1c, a relatively short length portion 10-3 is left, which has a value of thickness to corresponding to that of the initial blank pipe. This value of wall thickness at the portion 10-3 is suitable for machining screw threads for an engagement with a part of a steering mechanism. Preferably, prior to such a machining, a process for a diameter reduction is done so that a desired reduced value of inner diameter is obtained, which is suitable for the machining.

[0018] Also in the third step in Fig. 1c, the reduced diameter portion 10-1 is obtained by additionally reduce the diameter of the portion 10' obtained at the second step in Fig. 2b.

[0019] At a fourth step shown in Fig. 1d, in the blank pipe as obtained at the third step, a flattening is done at a location of the blank pipe where toothed portions are to be formed. Namely, the reduced diameter portion 10-1 of the blank is, at its upper surface 10-1A, flattened, resulting in a semi-circular cross-sectional shape of the blank at the portion 10-1.

[0020] A fifth step is shown in Fig. 1e, where a forging of toothed portions is done at the flattened portion 10-1A of the blank pipe. Namely, the blank pipe is held by a die set and mandrels are inserted to the blank pipe alternately between left-handed and right-handed directions. As a result, a rack bar forging is done in a manner that toothed portions on the die set are copied to the blank pipe, so that toothed portions 11 are formed as shown in Fig. 1e. The rack bar fording may be done by a system as describe in any of ’378, ’204, ’205 and ’703 patents. Namely, any of elongated type mandrel as in ’378, ’204 or ’205 patent or a shuttle type mandrel as in ’703 patent may be desirably used. In the embodiment, the latter shuttle type mandrel as shown in Fig. 2 is used. Namely, Fig. 2 shows a combined type die set for a rack bar forging, which includes a bottom die 12 and a top die 14, between which the blank pipe 10 is held. As explained in detail in ’703 patent, short sized mandrels (shuttles) 16a and 16b are arranged on the left-handed and the right-handed sides of the die set. Outwardly from the shuttles 16a and 16b, pusher rods 17a and 17b are respectively arranged in a manner that the pusher rods 17a and 17 engage, at respective ends, with recesses 15a and 15b at the ends of the shuttles 16a and 16b. The reduced diameter portion 10-1 of the blank pipe is arranged between the upper and lower dies 12 and 14. Under a closed condition between the dies, the upper wall 10-1A of the reduced diameter portion 10-1 of the blank pipe is pressed by toothed portion 14A of the upper die 14 and is substantially flattened, thereby completing the flattening process as explained with reference to Fig. 1d and allowing the rack forging process to be instantly commenced. Namely, a reciprocating movement of the shuttle shaped mandrels 16a and 16b by the pusher rods 17a and 17b is obtained in a manner that the mandrels 16a and 16b are alternately inserted to the blank pipe 10 held between the dies 12 and 14. As a result, the metal of the blank pipe at the diametric reduced portion 10-1 is plastically flown radially outwardly toward the toothed portions 14A of the upper die 14, so that a forging of toothed portions on the flattened surface 10-1A of the diametric reduced portion 10-1 of the blank pipe is done in a manner that the toothed shape 11 of the die is copied to the blank pipe 10.

[0021] After the completion of the forging of the rack bar, conventional processes for finishing to a product are done, which includes a correction of a curving, additional swaging at both ends, a working of grooves, a working of width-across-flat portion, an inner diameter tapping, a quench-and-temper process, an outer diameter machining, a test of meshed condition and anti-corrosive treatment, et al. The thus obtained final product is wrapped and shipped. Any more detailed explanation of these processes are omitted, since they are not directly related with the essence of the present invention.

[0022] Now, a diameter reduction process as schematically illustrated in Fig. 1b and a wall thickness reducing process at a connection portion as schematically illustrated in Fig. 1c, as preliminary steps for a cross-sectional area adjustment process prior to a rack bar forging process will be explained in more detail. First, the diameter reduction process in Fig. 1b will be explained in more detail with reference to Figs. 3a to 3c. A die set for practicing this step includes a die holder20, a die set constructed by a guide 22, a drawing die 23 and a squeezing die 24, which are, in series, inserted to the holder 20, and a mandrel 26 of a three stepped shape. The mandrel 26 is connected to a hydraulic cylinder mechanism (not shown) . The mandrel 26 is formed with a front portion 26-1 of reduced diameter and having a length corresponding to that of the toothed portion 11 (Fig. 1e) of a rack bar as a final product. Furthermore, the mandrel 26 is, at its rear end, formed with a rear portion 26-2 of an increased diameter.

[0023] A diameter reduction process as practiced by the device shown in Figs. 3a to 3c will be explained. Namely, at the first stage as shown in Fig. 3a, a blank pipe 10 after the completion of a phosphate coating process is mounted to the mandrel 8. As explained in Fig. 1a, the blank pipe 10 has a length of L_0 and a wall thickness of t_0, which is uniform along the entire length. The mandrel 26 is moved forward as shown by an arrow a in Fig. 3a, which causes the blank pipe 10 to be pushed as shown by arrows a' in Fig. 3b due to the fact that the diameter expanded portion 26-2 of the mandrel 26 contacts, at its end surface (shoulder), with the blank 10. As a result, the blank 10 is, first, inserted into the die holder 20 and then into the guide 22 under a guide action of a tapered portion 22A at the inlet end of the guide 22. During the movement in the guide 22, the blank 10 is substantially not subjected to any plastic deformation, thereby keeping the outer diameter of the blank pipe to be unchanged. In other words, a small clearance exists between the inner diameter of the blank pipe 10 and the front portion 26-1 of the mandrel 26.

[0024] A further forward movement of the blank 10 causes the latter to be introduced into the drawing die 23 via its tapered inlet portion 23A, so that the blank 10 is subjected to a diameter reduction in a manner that a clearance with respect to the front portion 26-1 of the mandrel 26 is diminished. In Fig. 3b, a portion of the blank 10 thus subjected to diameter reduction is designated by a reference numeral 10' and a portion of the blank 10 of the original diameter not subjected to diameter reduction is designated by a reference numeral 10". The reduced diameter portion 10' has a length, which corresponds to that of a toothed portion of a rack as the final product. In short, a worked blank (intermediate product), which corresponds to the work piece shown in Fig. 1b, is thus obtained.

[0025] In this embodiment, the mandrel 26 is finally and additionally moved in the forward direction as shown in Fig. 3c, so that the reduced diameter portion 10' is, at its tip end, squeezed by a die 24 and the squeezed portion of the work piece is designated by a reference numeral 10"'. Although such a squeezed portion 10"' is not shown in the corresponding Fig. 1b, it is used for an engagement with a mandrel during a subsequent wall thickness reduction process and is cut and removed after the completion of the use.

[0026] Figs. 4a to 4g illustrates the detail of a wall thickness reduction process and a diameter reduction process at the connecting portion of the rack bar as explained schematically in Fig. 1c. A plastic working device for a wall thickness reduction is provided, which includes a long stroke hydraulic cylinder device (not shown), a mandrel 30 connected to the hydraulic cylinder device so that the mandrel 30 is axially reciprocated, a die 32 cooperating with the mandrel 30 for a diameter reduction, and a striker 34 for a diameter expansion at an axial end and which is shown in Fig. 4a at its position radially outwardly retracted as illustrated by arrows b'. The mandrel 30 forms a stepped member constructed by an inlet or front part 30-1, an intermediate part 30-2 of an increased diameter connected to the part 30-1 and a rear part 30-3 of a reduced diameter to that of the inlet part 30-1 for a connection with a hydraulic mechanism (not shown). The inlet part 30-1 and the increased diameter part 30-2 have values of length, which correspond, respectively, to those of a toothed part and a connection part (shaft) of a rack bar as a final product.

[0027] Fig. 4a illustrates a condition of the plastic working device, whereat a blank pipe 10 after subjected to the preliminary diameter reduction process by the device in Fig. 3 is held by the mandrel 30. As shown in Fig. 4a, the mandrel 30 has an outer profile, which corresponds to an inner profile of the blank at an area from the portion 10' to 10". The inlet part 30-1 of the mandrel 30 is, at its leading end, contacted with the squeezed part 10"' as obtained at the process as shown in Fig. 3c. Then, a hydraulic pressure is introduced into the hydraulic cylinder mechanism, causing its piston rod (not shown) to be extended, so that the mandrel 30 in connection with the piston is moved forwardly as shown by an arrow a. Due to the fact that the leading end of the inlet part 30-1 of the mandrel is in contact with the squeezed part 10"' of the mandrel 10, the blank 10 is entrained by the movement of the mandrel 30 toward the die 32 as shown by the arrow a. As a result, the blank 10 is introduced into the die 32 from the squeezed part 10"' . The portion 10' of the blank after the squeezed part 10"' in the direction of its movement as shown by the arrow a has a value of an outer diameter, which is slightly larger than that of the inner diameter of the die 32. However, the difference in these values substantially corresponds to a clearance of the portion 10' with respect to the inlet part 30-1. Therefore, the portion 10' is subjected to a slight diameter reduction and the work piece is not substantially subjected to any wall thickness reduction or is subjected only to a very slight wall thickness reduction. Namely, it is shown in Fig. 4b that no wall thickness change occurs in the portions 10"' and 10' even after the passage of the die 32.

[0028] During the further forward movement of the mandrel 30, its diameter expanded portion 30-2 is faced with the wall thickness reduction die 32 via the portion 10" of values of the wall thickness and the outer diameter, which are substantially unchanged with respect to those of the initial blank pipe. The portion 10" has a value of an outer diameter, which is properly larger than that of an inner diameter of the die 32 for a wall thickness of the work piece. The difference of these values is, for example, about one half of the wall thickness of the work piece. As a result, the portion 10" (Fig. 4a) of the blank is subjected to an ironing operation by the die 32 during the forward movement of the blank as shown by the arrow a, so that a wall thickness reduction as well as an axial elongation are occurred in the portion 10" of the blank. This thin walled portion obtained from the portion 10" on the increased diameter portion 30-2 in Fig. 4a, which is passed through the die 32A and is subjected to a wall thickness reduction, is illustrated by 10-2 in Fig. 4b. In accordance with the progress of this ironing process, the length portion 10" of the work piece located rearward from the die 32 and of the same wall thickness as that of the initial blank pipe is gradually reduced, while moved toward the connection portion 30-3 on the increased diameter portion 30-2 of the mandrel 30. Finally, a relatively short length of the portion 10" of the same wall thickness as that of the initial blank pipe is left on the connection portion 30-3 of the mandrel under a condition that the portion 10" is passed through the die 32 as shown in Fig. 4b. At the extremity position in the forward stroke of the mandrel as shown by the arrow a as shown in Fig. 4b, the work piece is completely passed through the die 32 and the rearward end surface of the blank 10 exceeds slightly from the front end surface of the striker 34, which is under in its retracted position.

[0029] At the next step as shown in Fig. 4c, the striker 34 is, from the radially retracted position, moved radially inwardly as shown by arrows b toward a position, whereat the front end of the striker 34 is contacted with the connection part 30-3 of the mandrel.

[0030] Then, a switching of the introduction of the hydraulic cylinder mechanism is done in a manner that the mandrel 30 is retracted in the right-handed direction as shown by an arrow c. Due to the fact that the rear end portion 10" of the blank 10 is contacted with a shoulder portion 30-4 of the mandrel located between the diameter expanded part 30-2 and the inner diameter setting part 30-3, the blank 30 is entrained by the movement of the mandrel 30 until the part 10" is made contacted with the striker 34. However, when the rearward movement of the mandrel 30 in the direction as shown by the arrow c is done until the portion 10" is made contact with the striker 34, the entrained movement of the blank 10 is ceased due to the fact that the blank is engaged with the striker 34, on one hand and, on the other hand, the rearward movement of the mandrel 30 in the direction as shown by the arrow c is continued. During such a rearward movement of the mandrel 30 in the direction as shown by the arrow c, the large diameter part 30-2 is engaged with the part 10" of the work piece, so that the latter is radially outwardly displaced. Thus, at the rear end of the work piece, a part 10-3 is formed as shown in Fig. 4d, which part has a value of wall thickness nearly equal to that of an initial blank pipe and which is radially outwardly expanded with respect to the wall thickness reduced part 10-2. At the later stage, the part 10-3 may be subjected to a diameter reduction process, so as to obtain an increased wall thickness, which is suitable for a subsequent tapping operation. In Fig. 4d, a fully retracted position of the mandrel 30 is illustrated.

[0031] At the following stage, the work piece in Fig. 4d after subjected to the wall thickness reduction and the axial elongation is subjected to the processes as shown in Figs. 4e to 4g for obtaining a diameter reduction (second stage diameter reduction) of the work piece at location, which corresponds to a toothed part of a rack bar as a product. Thus, a device for diameter reduction is provided, which comprises a mandrel 36 and a die 37. The mandrel 36 is formed with a front part 36-1 of reduced diameter, a taper part 36-2 and a base part 36-3, which is in connection with a hydraulic cylinder (not shown). At the first step in Fig. 4e, to the mandrel 36, the work piece as obtained at the step in Fig. 4d is inserted.

[0032] An introduction of a hydraulic pressure to the hydraulic cylinder causes the mandrel 36 to be moved forward, so that the work piece on the mandrel 36 is introduced into the die 37. As a result of the introduction of the mandrel into the die 37, the portions 10"' and 10' of the work are subjected to a diameter reduction for a value corresponding to a difference between the inner diameter of die 37 and the outer diameter of the work.

[0033] Fig. 4f illustrates the most forwardly moved position of the mandrel 36 with respect to the die 37, whereat the shoulder portion 36-2 of the mandrel 36 is faced with the die at its inlet end. The part 10' (Fig. 4e) of the work is, at its entire length, subjected to a diameter reduction while keeping the wall thickness being unchanged, thereby obtaining a reduced diameter portion 10-1 as shown in Fig. 4f having a tip end as illustrated by 10-1'. From this extreme position, the mandrel 36 is retracted in the rearward or reverse direction as shown by an arrow c in

Fig. 4g. The part 10-1 of a reduced diameter as also illustrated in Fig. 1c is thus obtained. Then, the tip end portion 10-1' needed only for the engagement with the mandrel 36 during the execution of the diameter reduction is now unnecessary and thus cut off. The part 10-1 of a reduced diameter as also illustrated in Fig. 1c is thus obtained. The worked blank pipe as illustrated in Fig. 1c is thus obtained. The worked blank in Fig. 1c is then subjected to the processes of a rack forging as already explained with reference to Figs. 1d and 1e.

[0034] Figs. 5a to 5d illustrate a second embodiment of the present invention, wherein preliminary plastic working processes for obtaining a work piece, i.e., a diameter reduction at a location becoming a toothed part of a rack bar and a wall thickness reduction as a location becoming a connection part (shaft part) of the rack bar as illustrated in Figs. 1b and 1c, respectively are done under one shot principle from a blank pipe after subjected to the phosphate coating process followed only by a squeezing at its tip end. In this embodiment, a plastic working device is provided, which is constructed by a die set 38 and a mandrel 39. The die set is constructed by an outer cylindrical body (die holder) 40 and an end-to-end connected structure of a series of members, which includes a first guide cylinder 42, a squeeze die 44, a second guide cylinder 46 and a diameter reduction die 48. The outer cylindrical body 40 is, at its front end, formed with an inward projected portion 40-1, with which the diameter reducing die 48 located at the front end of the end-to-end connected combined die structure is engaged, while a retainer member 49 is screwed to the rear end of the outer cylindrical body 40 in manner that the member 49 is engaged with the first guide cylinder 42 located at the rear end of the end-to-end connected structure, so that the structure is fixed to the outer cylindrical body 40. The first guide cylinder 42 has a front end 42A outwardly tapered for a smooth introduction of the blank by the mandrel 39, which is followed by a remained part of a uniformed inner diameter. The squeeze die 44 is formed with an inner stepped part 44A, which is cooperated with the mandrel for obtaining a wall thickness reduction of blank. The squeeze die 44 is connected, via the second guide cylinder 46 of an uniform inner diameter, to diameter reducing die 48, which has a tapered par 48A, which functions purely for diameter reduction of the tip end of the blank while keeping its wall thickness. In short, the combined die structure is cooperated with the mandrel 50 for carrying out the designated working.

[0035] The mandrel 39 is formed with a rear large diameter part 50, a middle diameter part 52 and a front small diameter part 52-2. The mandrel 39 is connected with a hydraulic cylinder mechanism (not shown) for obtaining a reciprocated movement of the mandrel 39. The middle diameter part 52 is formed with a tapered part 52-1, from which the small diameter part 52-2 is axially forwardly projected. Finally, the plastic working device is further provided with a blank knockout pin 54 for removing a product after completion of the designated processes.

[0036] An operation of the second embodiment of the present invention will now be explained. As illustrated with reference to Fig. 1a, the work piece 10 is an original blank pipe supplied from a maker, to which a phosphate coating process has been completed. In addition, the work piece has been subjected a squeezing process only at its leading end, while the remaining part is left at a straight shape with a uniform wall thickness. The work piece (blank pipe) 10 is introduced into the plastic working device by means of the mandrel 39 moving in the left-handed direction as shown by an arrow a in Fig. 5a. Namely, the mandrel receives the work piece 10 without substantial clearance at the middle diameter part 52 and engages with the squeezed tip end 10a of the work piece at the front small diameter part 52-2. As a result, the work piece 10 is entrained by the forward movement of the mandrel 39 as shown by the arrow a. However, any substantial working is not obtained, i.e., the diameter as well as the wall thickness of the work piece are unchanged, until a condition is obtained, where the front end of the work piece 10 is made contact with the stepped part 44A of the squeezing die 44 as shown in Fig. 5a.

[0037] An introduction of the hydraulic pressure into the hydraulic cylinder device for operating the mandrel is continued from the condition as shown in Fig. 5a, so that the mandrel is moved forwardly to a condition as shown in Fig. 5b, where the tapered part 52-1 of the mandrel 39 is faced with the tapered part 44A of the squeezing die 44. The mandrel 39 is further forwardly moved from the condition as shown in Fig. 5b, which causes the blank 10 to be also forwardly moved, while the contact of the blank with the squeezed part 10a. During the forward movement, the blank 10 is passed through the die 44, so that the blank 10 is subjected to a diameter reduction process. After the completion of the diameter reduction process, the portion 10"" of reduced diameter of the is made substantial contact with the front small diameter part 52-2 of the mandrel. However, the value of wall thickness of the portion 10"" is slightly increased or substantially unchanged with respect to the value of wall thickness of the initial blank. However, the portion 10""' of the blank, which is located on the middle diameter part 52 of the mandrel and which is engaged with the squeezing die 44, is subjected to a wall thickness reduction. The remaining portion 10-3 of the blank located rearward from the die 44 is not subjected to diameter reduction, i.e., the outer diameter is maintained. However, this portion 10-3 of the unchanged outer diameter of the blank is pushed back on the middle diameter part 52 of the mandrel 39 in the rearward direction in accordance with the progress of the wall thickness reduction by the squeezing die 44. In short, a rearward push-back type wall thickness reduction is done.

[0038] When the mandrel 39 is further moved in the forward direction from the condition as shown in Figs. 5b to 5c, a cooperation of the middle diameter portion 52 of the mandrel with the taper portion 44A of the die 44 is obtained, which causes the blank pipe to be subjected to a wall thickness reduction, so that the wall thickness reduced portion 10"'" is created, while the portion 10-3 of the unchanged wall thickness is pushed back in the rearward direction as shown by arrows b. As a result, an elongation of the axial length of the work, which corresponds to the degree of the wall thickness reduction, is obtained. The further forward movement finally causes the blank to be engaged with the die 48 and to be subjected to a diameter reduction, so that a reduced diameter portion 10-1 of a substantially unchanged wall thickness is projected out of the die 48 as shown in Fig. 5d. As a result, a worked blank member of substantially the same as that explained with reference to Fig. 1c, is created, which is constructed by a diameter reduced part 10-1 of a value of wall thickness unchanged with respect to that of the initial blank pipe (a part becoming a toothed part of a rack bar as a final product), a wall thickness reduced part 10-2 of a value of the thickness reduced, for example, to one half of that of the blank pipe (a part becoming a connection part of the rack bar as a final product) and an end part 10-3 having a cross sectional area allowing an additional tapping working (a part for forming a screw portion for connection with an adjacent part).

[0039] In short, this second embodiment is advantageous in that a worked blank for forging a rack bar is obtained under one shot process from a straight blank pipe while preparatory works are eliminated except for a squeezing process at the tip end, resulting in a high efficiency of the process.

[0040] In the embodiments as explained, the hydraulic cylinder device for operating a mandrel is illustrated as horizontal type. However, a hydraulic cylinder device of vertical type may also be used. In addition, in place of such a hydraulic cylinder device, a mechanism such as an elongated ball screw operated by a servomotor of a variable velocity may also be used.

Claims

1. Method for producing a rack bar comprising the steps of:

> providing a work piece of pipe shape;
> subjecting the pipe shaped work piece to plastic workings for adjusting wall thickness of the work piece to desired values at the respective positions along the length of the work piece corresponding to functions as required, and;
> forging linearly spaced toothed portions on the work piece after subjected to said wall thickness adjustment, thereby obtaining a rack bar.

2. Method according to claim 1, wherein the adjustment of the wall thickness values is done by a single integrated step.

3. Method according to claim 1, wherein the adjustment of the wall thickness values is done by a plurality of divided steps.

4. Method for producing a rack bar comprising the steps of:

> providing a work piece of pipe shape;
> subjecting the pipe shaped work piece to plastic workings for reducing the wall thickness of the work piece except at a location where the rack is to be formed, while freeing the corresponding plastic extension of the work piece along the length of the work piece, and;
> forging linearly spaced toothed portions on the portion of the work piece of unchanged wall thickness or slightly increased wall thickness after subjected to said local wall thickness adjustment, thereby obtaining a rack bar.

5. Method according to claim 4, wherein the adjustment of the wall thickness values is done by a single integrated step.

6. Method according to claim 4, wherein the adjustment of the wall thickness values is done by a plurality of divided steps.

7. In an apparatus for producing a rack bar from a pipe shaped work piece, wherein the work piece is held by a die set having linearly spaced toothed portions, and a mandrel is inserted to the work piece so that toothed portion corresponding to the toothed portions on the die set are forged to the pipe shaped work piece, the improvement comprising a device for effecting an adjustment of the wall thickness of the work piece to desired values at the respective positions along the length of the work piece corresponding to functions as required, prior to the execution of the forging of the rack bar.

8. An apparatus according to claim 7, wherein said device comprising:

> a die set including an elongated mandrel and a plurality of dies, and;
> a driving means for moving the work piece to the first die set for effecting the desired adjusting wall thickness of the work piece.

9. A hollow rack bar used as a steering part of a vehicle, which is forged from a pipe shaped blank, including a first portion of a wall thickness, which substantially the same as or slightly increased from the wall thickness of the blank pipe and a second portion of a wall thickness, which is highly reduced from the wall thickness of the blank pipe and which is elongated for a length corresponding to the reduction of the wall thickness, the rack portion being formed on the first portion of the blank pipe.

Fig.1a

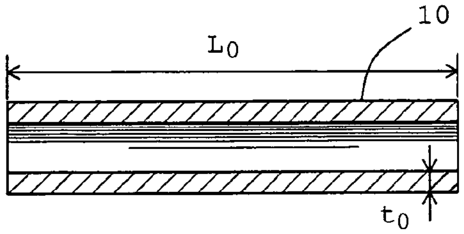


Fig.1b

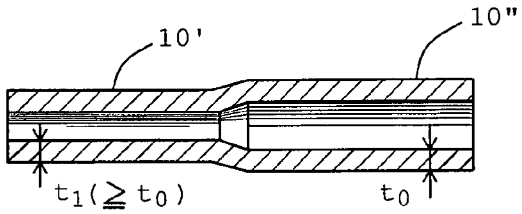


Fig.1c

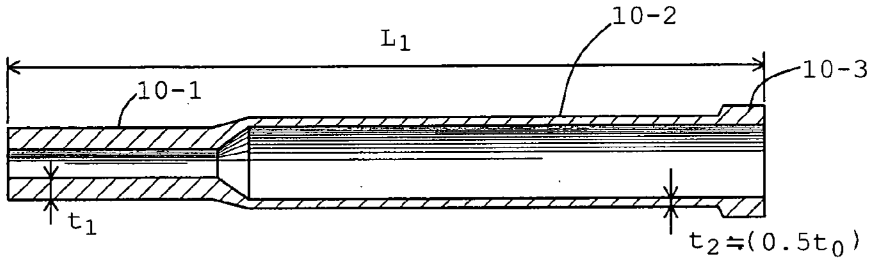


Fig.1d

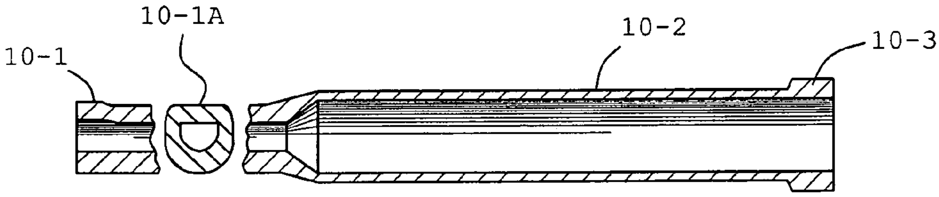
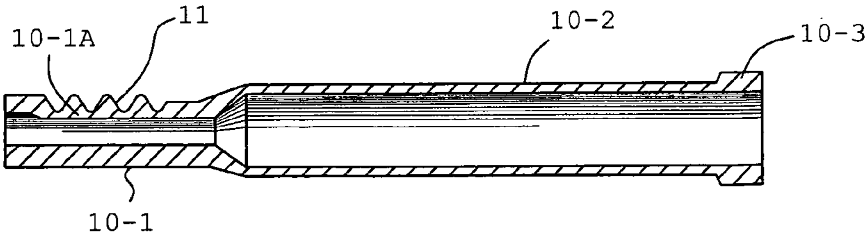


Fig.1e



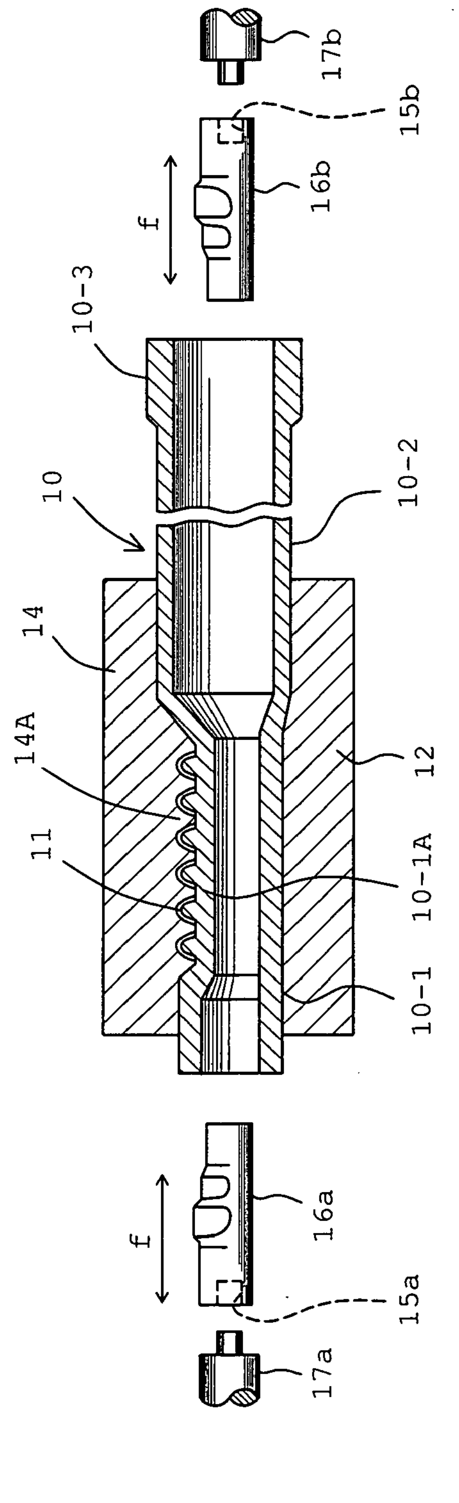


Fig.2

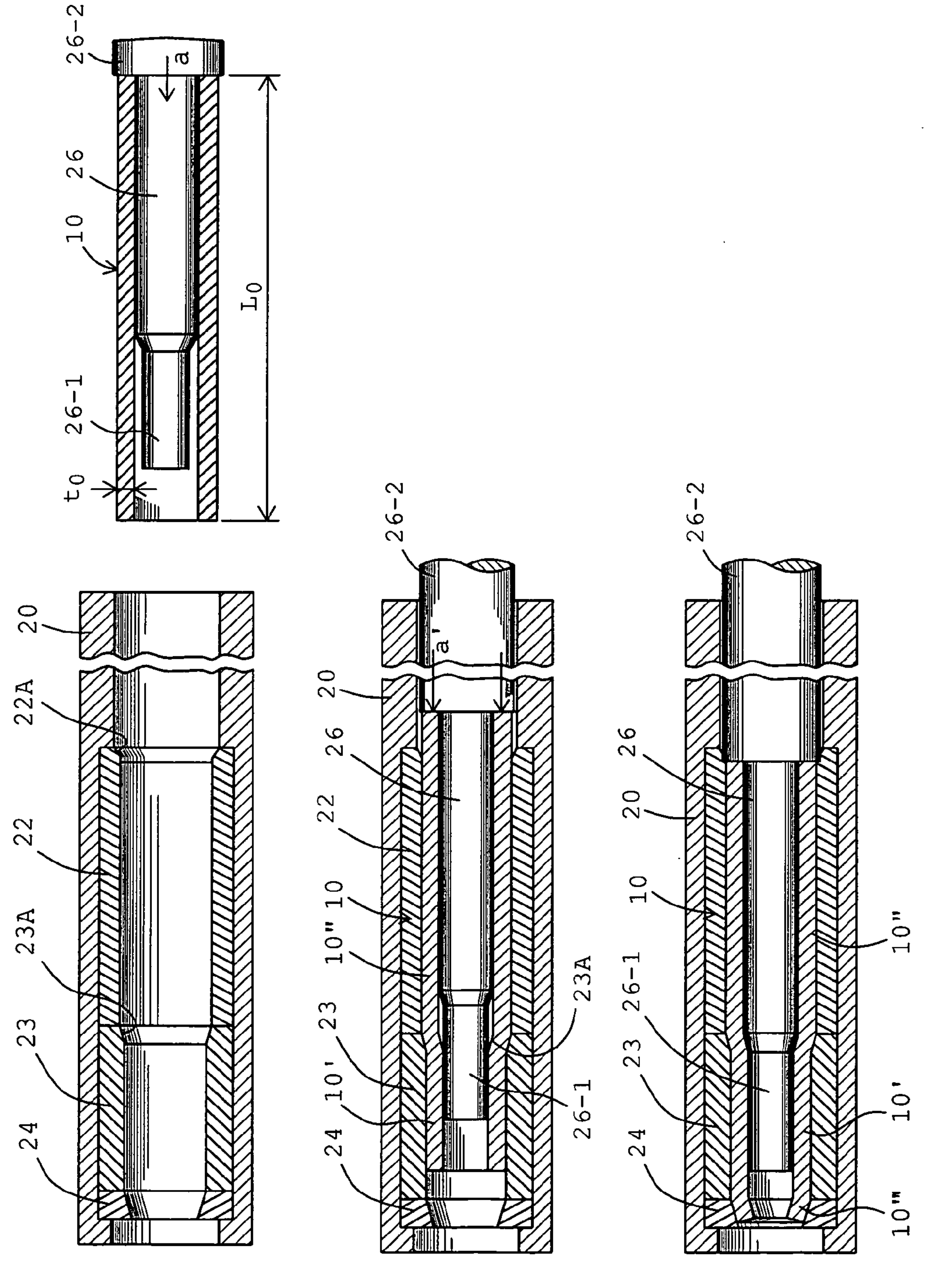
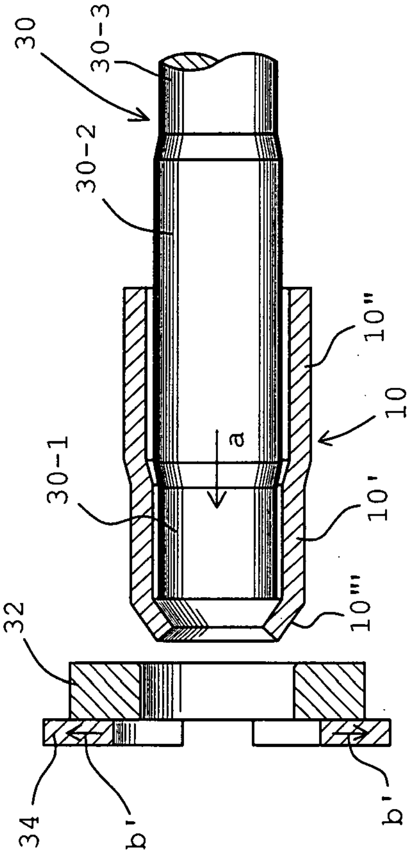


Fig.3a

Fig.3b

Fig.3c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10'
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b'
b'

Fig.4a

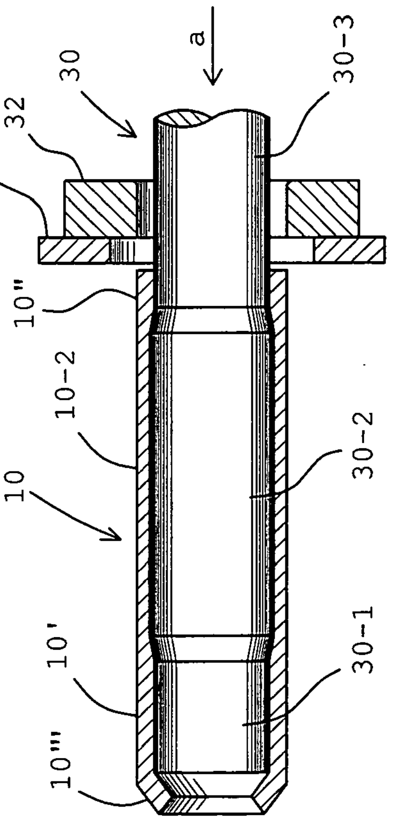
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Fig.4b

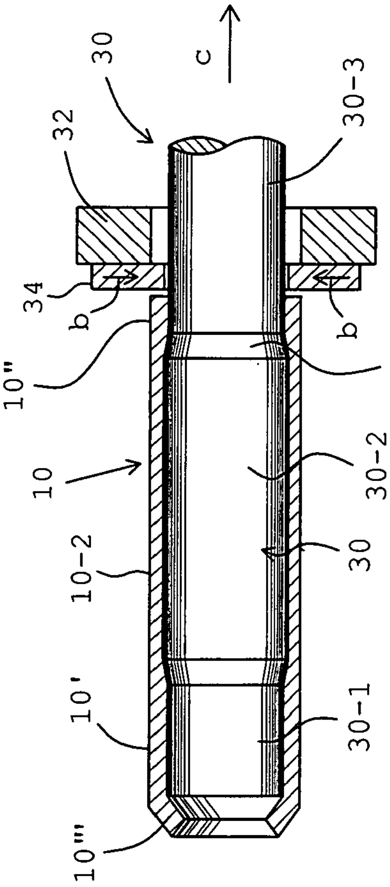
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Fig.4c

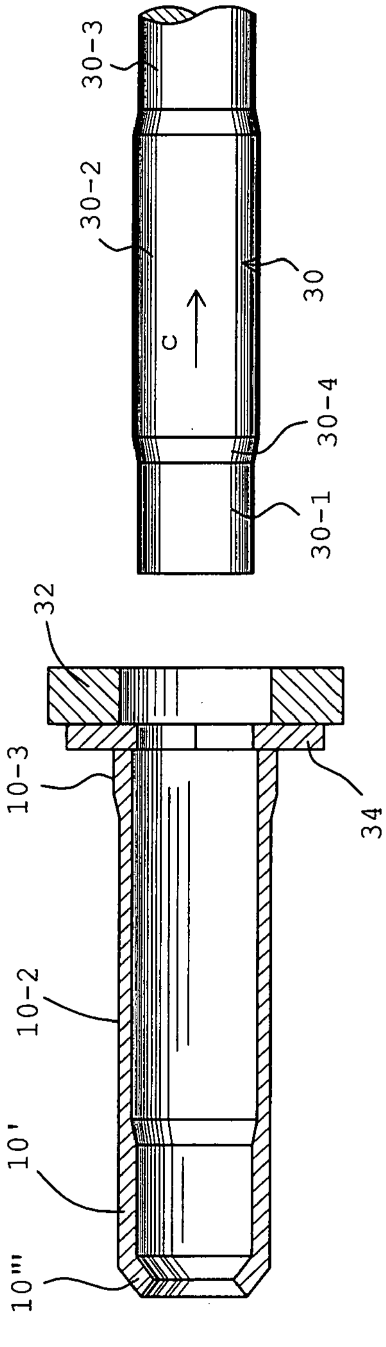
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Fig.4d

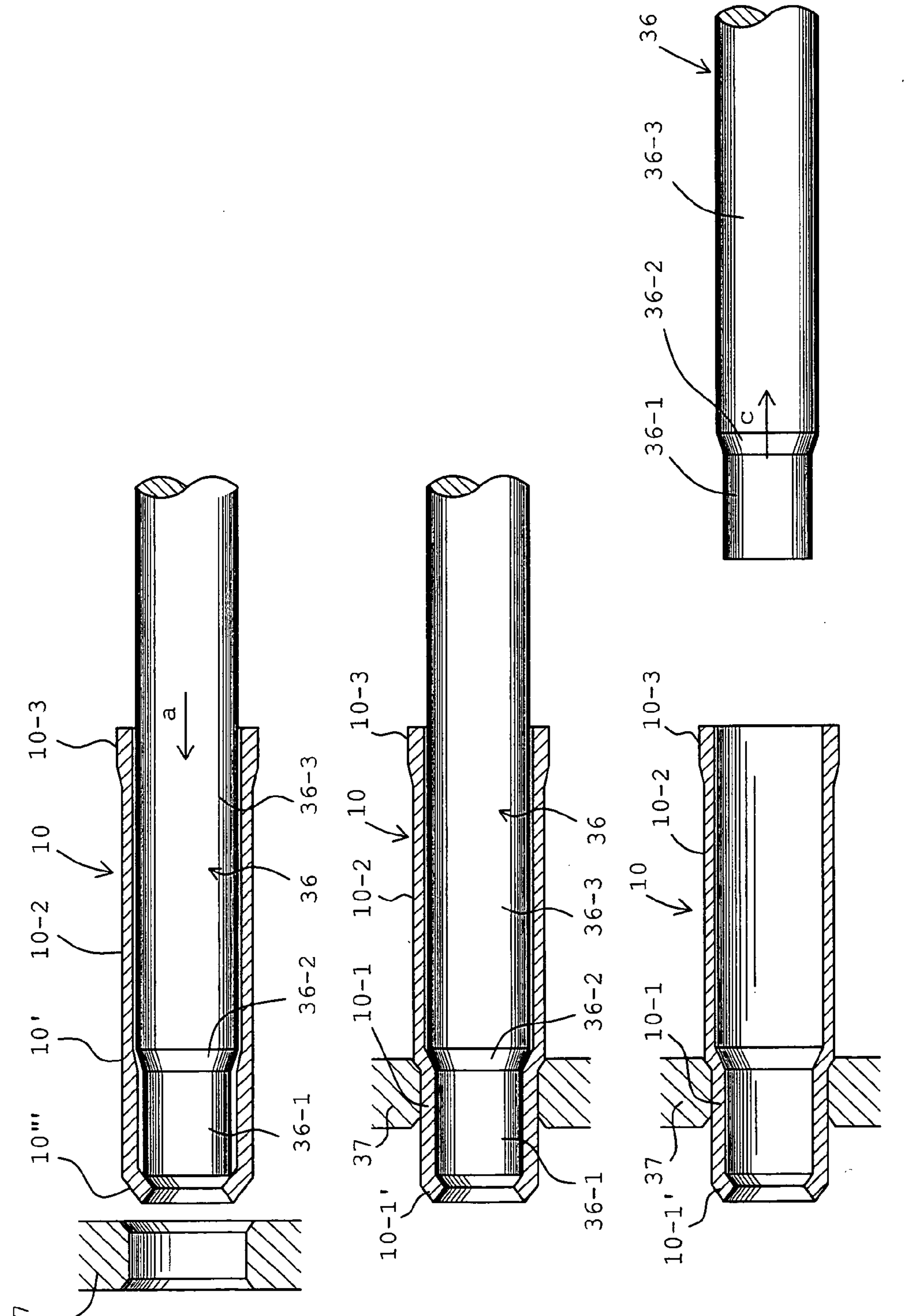

Fig.4e

Fig.4f

Fig.4g

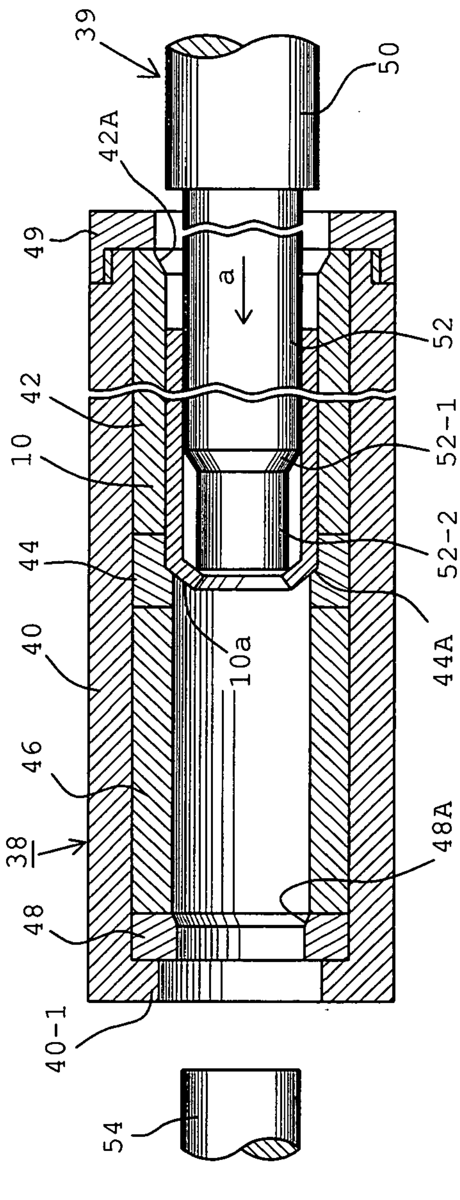
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Fig.5a

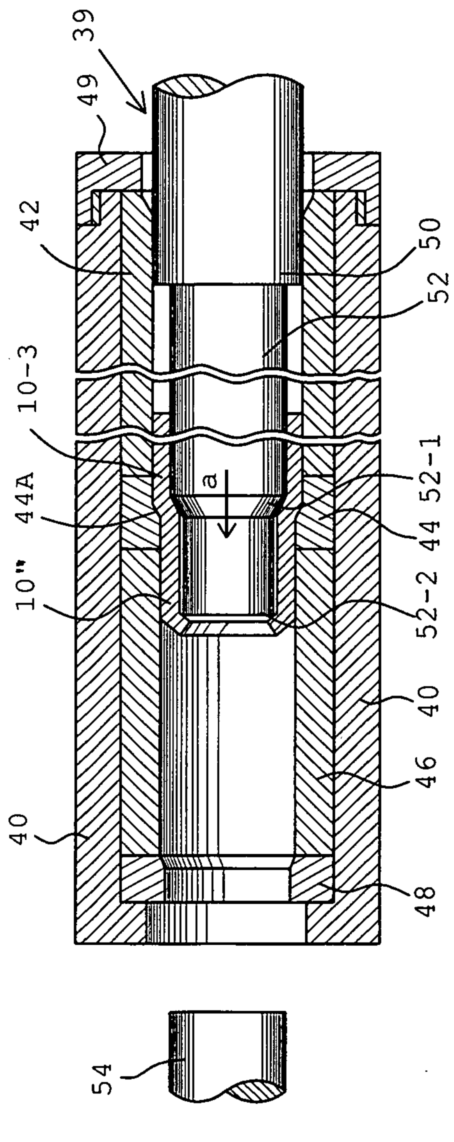
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Fig.5b

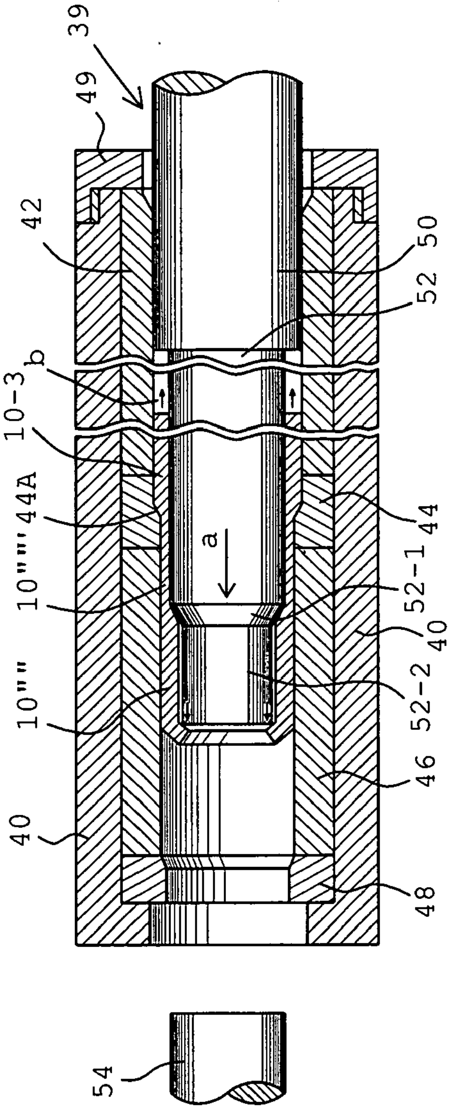
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Fig.5c

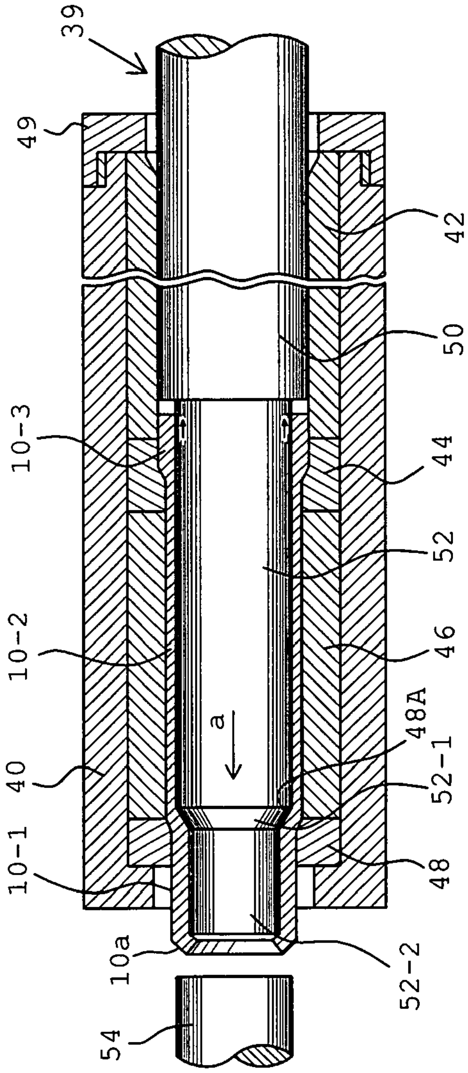
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Fig.5d

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
Munich	7 May 2007	Augé, Marc

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