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(54) METHOD FOR PRODUCING FORGINGS MAINLY MADE OF METALS AND ALLOYS OF TITANIUM GROUP AND A FORGING SYSTEM FOR CARRYING OUT SAID METHOD

(57) The invention relates to metal-forming process. The inventive method for producing forging consists in heating a billet and forging said billet with the aid of a press provided with two manipulators in several passes by four-side reduction in four-headed forging devices associated with macro-shears of metal in a transversal direction with respect to the plane of the billet. Forging is carried out within an acceptable temperature range in two stages i.e. a rough forging is carried out in the first stage, at the second stage, a final forging is carried out by enclosing from 40 to 100 % of the perimeter of the cross-section of the billet by each pair of the working surfaces of the heads for each single reduction. The inventive forging system comprises a forging press provided with top and bottom plates which have locks for arranging and fixing forging tools, a movable tool table for positioning changeable forging tools thereon which are embodied in the form of two or more four-headed forging devices and one or two manipulators.

One or more four-headed forging devices for rough forging and one four-headed forging device for final forging are disposed on the positions of the tool table. The free space between the heads of the final forging device within the cross section thereof, when the heads are in the closed position, is selected such that it is 1.1 - 1.4 times less than the free space between the heads of the rough forging device. The working surface of each head of the rough forging device is embodied in the form of a plane parallel to the reference plane of the head, and two lateral planes adjacent thereto and arranged on two sides thereof at an angle of 135 - 170°.

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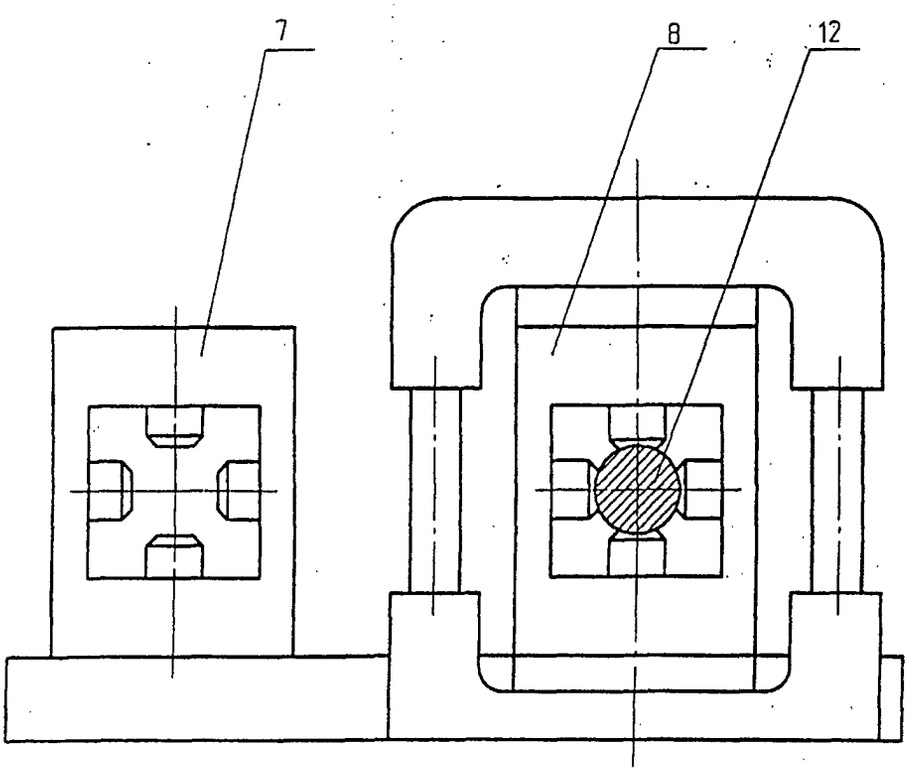


Fig. 3

Description

Field of the Invention

[0001] This invention relates to the field of metals non-cutting shaping, and particularly, to method of production of forged pieces from ingots and preliminary deformed in forging complexes billets; at that, these complexes consist of hydraulic forging presses with one or two manipulators and equipped with four-hammer block forging devices.

[0002] The invention can be used in machine-building and metallurgical industries for producing of forged pieces mainly of metals and alloys from the subgroup of Titanium (Titanium, Zirconium, Hafnium) and also for manufacturing of forged pieces of Niobium, Tantalum and their alloys. All these metals and alloys on their bases are combined by the fact, that they actively absorb'gases and oxidize at high temperatures when preheating before deformation and during hot deformation itself.

[0003] A production process has been proposed for manufacturing of zirconium alloy billets used for producing components for cores of nuclear power reactors - fuel elements claddings and other structural components. (Zaimovsky A.S., Nikulina A.V., Reshetnikov N.G. Zirconium Alloys In Nuclear Power Engineering. Moscow. Energoizdat. 1981. Pp. 51-71). The production process comprises producing of ingot by vacuum-arc (or electron beam) melting, forging of preheated ingot with press or hammer to produce definitely sized rods, hot extrusion of rods and cold rolling with intermediate and final thermal treatments. The most important stage in the production process is the method of manufacturing of forged pieces, comprising preheating of ingot to the β-phase temperature, followed by forging of the latter in press or hammer at the temperature when zirconium alloy is in β and α+β phases. Additional billet preheatings are carried on, if necessary.

[0004] Currently in use technology of forged pieces production by forging in presses and hammers provides high metal quality due to intensive deformation processing of metal cast structure along the whole cross section of ingot.

[0005] But for all this, Zirconium and its alloys oxidize intensively at high temperatures, which results in metal big losses due to scaling. Besides, it is necessary to remove gas-saturated layer from forged pieces's surfaces after descaling. At this, the longer is the preheating of the ingot (billet) followed by forging, the thicker surface gas saturated layer has to be removed to provide that metal quality corresponds to claimed requirements.

[0006] It has previously been proposed the forging technique for Titanium alloy ingots, comprising the preliminary ingot deformation by drawing it in press or hammer at the temperature, which is 150-250°C higher than the temperature of polymorphic transformation of ingot material; then heating and final forging of semiproduct in radial-forging machine (inventor's certificate USSR #1541867, cl.B21J/04, 1988).

[0007] Application of radial forging machine / RFM/ after hammer or press forging allows to improve the surface quality of forged pieces, to obtain geometrically correct and accurate forging cross section.

[0008] It has also been proposed previously the method of forged pieces production, comprising ingot heating, followed by forging in press with two manipulators during several stages by quadrilateral swaging in four-hammer block forging devices with additional macro-shift of metal in billet's transversal plane at every single swaging, feeding and tilting of billet. (Lazorkin V.A., Ckorniakov Yu.N., Tyurin V.A., Zaluzhny Yu.G., Kulikov V.A., Degtiariova T.V. Increasing of efficiency of forging drawing of billets of special steels and alloys in presses. Magazine "Forging-stamping production", 1994, #2, pp.3-5).

[0009] Application of four-hammer block forging devices allows to improve sufficiently process efficiency, accuracy of final forged pieces and metal yield in comparison with traditional manufacturing processes of forged pieces in hammers and presses.

[0010] It is also known the forging complex, consisting of forging press equipped with movable tool table with several positions of forging tool changing, forging tooling, positioned on the tool table and two manipulators, synchronized with press operation (Relis S.I., Lapin V.V., Sobolev Yu.V., Means of efficiency improvement of automatic forging complexes application. Review. Moscow. NIImash. 1983, pp.2-13. Series C-3. Forging-stamping machine building).

[0011] Forging complex provides simultaneous operation of press and two manipulators in manual, semiautomatic and automatic modes, which results in high level of process mechanization and automatization, while tooling change is carried on by moving of the tool table in predetermined position by operator order from press control board.

[0012] It is also known the forging complex comprising forging press with upper and low plates with locks for clamping and fixing of forging tooling; movable tool table with several positions of forging tool change; forging tooling, consisting of two or more four-hammer block forging devices, located in positions of tool table; and two manipulators (Lazorkin V.A., Ckorniakov Yu.N., Tyurin V.A., Zaluzhny Yu.G., Kulikov V.A., Degtiariova T.V. Increasing of efficiency of forging drawing of billets of special steels and alloys in presses. Magazine "Forging-stamping production", 1994, #2, pp.3-5).

[0013] This forging complex, which has been chosen as prototype of the present invention, provides considerably higher operative efficiency of the process in comparison with automatic forging complexes equipped with traditionally used tooling - flat and cut out hammer blocks.

[0014] However, with this forging complex it is difficult to provide high accuracy and quality of geometry of round

cross section forged pieces, and to eliminate metal losses as scale, especially when manufacturing forged pieces of Titanium metals and alloys subgroup.

DISCLOSURE OF THE INVENTION

[0015] An object of the invention is to establish the method of producing of forged pieces and forging complex on base of four-hammer block forging devices for this method realization, which provide the increase of operative efficiency, metal yield, accuracy of forged pieces and also high surface quality of round cross section forged pieces, mainly of Titanium metals and alloys subgroup.

[0016] Solution of the problem is attained when the previously proposed forged pieces production method, comprising ingot heating, followed by forging in press with two manipulators during several stages by quadrilateral swaging in four-hammer block forging devices with additional macro-shift of metal in billet's transversal plane at every single swaging, feeding and tilting of billet is supplemented with introduction of the following stages and production parameters: forging is carried on in forging temperatures admissible range, with forging reduction ratio 2.0 : 1 - 32.0 : 1 for one heating of ingot, in two stages, first the rough forging in one or several four-hammer block forging devices for rough forging, and then calibrating forging in one four-hammer block forging device for calibrating forging with forging reduction ratio 1.05 : 1 - 1.8 : 1 and embracing of perimeter of billet cross section at every single swaging by each pair of working sections of the hammer blocks by 40-100%.

[0017] A further solution of the problem is attained also when at initial stage of rough forging, manipulator, which holds the ingot, performs one feed of the ingot into working area of four-hammer block forging device for rough forging, followed by several ingot swaging and tilting stages without feed, till the forged portion of the ingot is clamped by other manipulator.

[0018] A further solution of the problem is attained also when prior to forging in one or several four-hammer block forging device for rough forging the forging of the ingot is carried on by two hammer blocks.

[0019] Besides, a further solution of the problem is attained also when in previously proposed forging complex, comprising upper and low plates with locks for clamping and fixing of forging tooling; movable tool table with several positions of forging tool change; forging tooling, consisting of two or more four-hammer blocks forging devices, located in positions of tool table; and one or two manipulators, the following constructive changes have been carried on: in tool table working sections there were mounted one or several four-hammer block forging devices for rough forging and at least one four-hammer block forging device for calibrating forging with hammer blocks , the working surfaces of which, while closing, repeat the shape of the final forged piece cross section. At the same time, the area of free space between hammer blocks of forging device for calibrating forging with closed hammer blocks is 1.1 - 1.4 times less than the area of free space between hammer blocks of forging device for rough forging, having minimum area of free space between hammer blocks at closed position of hammer blocks, and working surface of every hammer block in four-hammer block forging device for rough forging is made in a form of a plane parallel to hammer block's supporting plane with two adjacent at 135-170° lateral planes.

[0020] And finally, solution of a problem is attained when in four-hammer block forging device for calibrating forging of round cross section forged pieces the hammer blocks of the same pair symmetrically oriented relative to each other, have, each of them, two working sections in the form of projections, separated by made in the body of the hammer block groove, to the inner part of which the working projection of the second pair of hammer block, positioned in mutually perpendicular plane, has been introduced with a gap; at the same time the working surface of each hammer block in its cross section has concave curvilinear shape with variable curvature radius and curvature radius of hammer block working surfaces, having two working sections, is 1.05 - 1.25 times more than curvature radius of working surfaces of the second pair of hammer blocks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The patented production method of forged pieces and forging complex for its realization are explained in the schematic drawings /fig.1-10/.

Fig.1 presents the schematic drawing of forging complex with two manipulators, top view;
Fig.2 - front view of forging press with four-hammer block forging devices;
Fig.3 - front view of forging press in position, at which four-hammer block forging device for calibrating forging is mounted in press working area;
Fig.4 - hammer blocks of four-hammer block forging device for rough forging in closed position;
Fig.5 - hammer blocks of four-hammer block forging device for calibrating forging in closed position;
Fig.6 - hammer blocks of four-hammer block forging device for calibrating forging of round cross section forged pieces with curvilinear working surfaces;

Fig.7 - section A-A in Fig.6;
Fig.8 - section B-B in Fig.6;
Fig.9 - section C-C in Fig.7;
Fig.10 - section D-D in Fig.8.

In Fig. 6, dotted line shows forged piece diameter d after calibration, and in Fig.9, 10 - curvature radii R_1 and R_2 of working sections of hammer blocks, positioned in mutually perpendicular planes.

[0022] Forging complex consists of forging press 1, manipulators 2,3, movable tool table 4 with several /shown 4/ positions of forging tooling change, forging tooling /four-hammer block forging devices 5...8/, control board 9 / Fig.1/. Four-hammer block forging device 5 is attached to upper 10 and low 11 plates of press and tool table by means of special clamps /not shown/ / Fig.2/. A number of four-hammer block forging devices, located in position of tool table prior to forging process, is defined depending on accepted production process. However, it should be at least one four-hammer block forging device for rough forging and one four-hammer block forging device for calibrating of forged pieces 12 / Fig.3/.

[0023] Working surface of every hammer block of forging device for rough forging consists of central face /bc/ and adjacent to it from two sides at an angle α = 135-170° two lateral faces /bk and cf/ /Fig.4/.

[0024] The area of free space between hammer blocks in cross section of forging device for rough forging /F/ with closed position of hammer blocks is designated in Fig.4 by letters *abcd*. The area of free space between hammer blocks in cross section of forging device for calibrating forging /F'/ with closed position of hammer blocks is designated in Fig.5 by letters a'b'c'd'. At the same time, the area of free space between hammer blocks of forging device for calibrating forging with closed hammer blocks is 1.1 - 1.4 times less than the area of free space between hammer blocks of forging device for rough forging, having minimum area of free space between hammer blocks at closed position of hammer blocks, i.e. the ratio F/F1 = 1.1 - 1.4 is maintained.

THE PREFERRED VARIANT OF INVENTION EMBODIMENT

[0025] The claimed production method of forged pieces in described (Fig.1...Fig.10) forging complex is carried on as follows. At first forging complex is prepared for operation. For this purpose, necessary four-hammer block forging devices for rough and calibrating forging with necessary sets of hammer blocks are installed in position of tool table, and just before discharge of the ingot /billet/ preheated to forging temperature from the furnace, forging device 5 for rough forging is supplied into working area of press 1 by means of tool table 4 /Fig.2/. From press control board 9 operator orders to attach the upper movable part of forging device to the upper plate 10 of press movable crossbeam by means of special clamps /not shown in drawing/ /Fig.1,2/. After performing of these steps forging press is ready for operation.

[0026] Preheated to forging temperature ingot of Titanium subgroup metals and alloys / Titanium, Zirconium, Hafnium/ or Niobium, Tantalum or their alloys are discharged from the heating furnace and by means of manipulator 2 are fed to press working area 1, where it is forged in four-hammer block forging device 5 for rough forging /Fig.1/. In process of plastic deformation after every single swaging by manipulator 2 there is performed the feed of the ingot, or after every single swaging there is performed the feed and the tilting of the ingot around its longitudinal axis , depending on accepted forging process. When the specified level of ingot extension is attained, manipulator 3 grips the ingot by the forged portion and simultaneously with manipulator 2 performs feed or feed with tilting of the ingot /Fig.1/. Forging is carried on in permissible forging temperatures range with forging reduction ratio 2 : 1 - 32.0 : 1 for one heating of the ingot /without additional heating/. Forging is carried on in two stages, starting with rough forging in one or several four-hammer block forging devices for rough forging, and then calibrating forging in four-hammer block forging device for calibrating forging with forging reduction ratio 1.05 : 1 - 1.8 : 1 and embracing of perimeter of billet cross section at every single swaging by each pair of working sections of the hammer blocks by 40-100%.

[0027] When forging of ingots with large cross-sections, it is possible to carry on the initial forging with two hammer blocks with following forging of obtained intermediate ingot in four-hammer block forging device for rough forging. This is done because four-hammer block forging device for forging of ingots with large cross-sections sometimes can't be located inside press working zone.

[0028] Calibrating of forged pieces with square and rectangular cross sections is carried on by hammer blocks with flat working surfaces, and calibrating of forged pieces with round cross sections is carried on by hammer blocks with concave curvilinear surfaces.

[0029] When forging with high forging reduction ratio / Y> 8:1/, drawing of the ingot is carried on in several four-hammer block forging devices for rough forging. After completing of ingot forging in four-hammer block forging device for rough forging 5, billet is withdrawn from press working zone, the movable part of forging device 5 is disconnected from press upper plate 1 and this device is withdrawn from press working zone /Fig.1/. Then four-hammer block forging device for rough forging 6 is introduced into press working zone and is attached by its upper movable portion to the

plate of press 1. After this, forging of billet in forging device 6 is continued. If necessary, the same operation step is carried on after mounting one more four-hammer block forging device 7 for rough forging. The last, the final step - calibration of forged piece 12, is carried on in four-hammer block forging device 8 for calibrating forging, after it is installed into press working zone /Fig.3/.

[0030] Availability in the claimed forging complex construction of preliminary prepared and installed in positions of tool table four-hammer block forging devices for rough and calibrating forgings and their consequent application during forging process provides the possibility of obtaining of high extensions / forging reduction ratio up to 32 : 1/ with one heating of ingot in forging temperatures range. During forging intensive deformation heating of billet takes place. At the same time some quantity of billet heat, which is lost when cooling in the air, is compensated by the intensive heating of billet during its swaging in four-hammer block forging devices.

[0031] To carry on forging with forging reduction ratio less than 2.0 : 1 is not rational, because manufacturing of products of Titanium subgroup metals and alloys is not provided with necessary quality of forged pieces.

[0032] Implementation of ingot forging with forging reduction ratio more than 32.0 : 1 is not possible, because in this case the billet is cooled to the temperature that is less than permissible forging temperature, and the heat produced as the result of deformation heating is not enough to compensate heat losses during billet cooling. When calibrating with forging reduction ratio less than 1.05 : 1 it is not possible to provide forged pieces surface high quality and accuracy, and calibration with forging reduction ratio 1.8 : 1 sufficiently decreases process operative efficiency and results in possible collar marks in billet surface. When embracing of perimeter of billet cross section at every single swaging by each pair of working sections of the hammer blocks by less than 40%, it is not possible to provide forged pieces surface high quality and accuracy, and embracing of perimeter of billet cross section by more than 100%, is not possible with hammer blocks of such design.

[0033] In those cases, when it is necessary to carry on forging with high forging reduction ratio /Y>15 : 1/, ingot /billet/ shall be as short as possible , so that the length of the final forged piece should not exceed the maximum permissible length provided in this equipment. Then, in the initial stage of rough forging, manipulator, which holds the short ingot, performs its single feed into working zone of the four-hammer block forging device for rough forging, followed by several swaging and tilting of ingot without feeding, till the forged portion of the ingot is gripped by other manipulator. Then forging is carried on with two manipulators.

[0034] The ratio $F/F^{/}$ = 1.10 - 1.4 provides high quality of forged piece at transition stage from forging in four-hammer block forging device for rough forging to calibrating forging in four-hammer block forging device for calibrating forging. Where F, F' - are the space areas between hammer blocks in cross-section of four-hammer block forging device for rough and calibrating forging, consequently.

[0035] At $F/F^{/} < 1.10$ it is not possible to provide high quality of forged pieces surface quality after calibration.

[0036] At F/F' > 1.4 the operative efficiency of the process is decreased, collar marks may occur on the surface of forged piece.

[0037] In four-hammer block forging device for rough forging each hammer block has working surface, which is produced by three faces /Fig.4/. Two lateral faces are adjacent to the central face at an angle α = 135-170°. At α < 135° collar marks may occur on the surface of forged piece, and at α > 170° it is not possible to provide high forging reduction ratio in one four-hammer block forging device for rough forging.

[0038] To produce round cross-section forged pieces with diameter d /In Fig.6 shown with dotted line/ with high surface quality and high dimension accuracy, in four-hammer block forging device for calibrating forging of round cross section forged pieces, the hammer blocks of the same pair symmetrically oriented relative to each other, have, each of them, two working sections in the form of projections 13 and 14, separated by made in the body of the hammer block groove with width L, to the inner part of which (L) the working projection 15 of second pair of hammer blocks, positioned in mutually perpendicular plane, has been introduced with a gap, necessary for operation, symmetrically to the latter /Fig.6-8/. At the same time the working surface of each hammer block in its cross section has concave curvilinear shape with variable curvature radius / Fig.9,10/. And curvature radius R1 of hammer block working surfaces, separated by the groove (L) is 1.05 - 1.25 times more than curvature radius of working surfaces of the second pair of hammer blocks / Fig.9,10/, thus the ratio : R1 = (1.05-1.25)R2 is maintained.

[0039] This design of hammer blocks for calibration allows to compensate small / but existing/ widening of the billet during its final calibration.

[0040] At R1< 1.5 R2 - significant increase of accuracy and surface quality of forged piece is not attained.

[0041] At R1 > 1.25 R2 - surface quality gets worse and forged pieces accuracy decreases.

INDUSTRIAL APPLICATION

[0042] Example of industrial application of the invention. Ingot with diameter 450 mm of zirconium alloy E110 was cut into three equal pieces, each 1165 mm long (L=1165mm), then these pieces were preheated in electric batch-type furnace to the temperature 950°C and forged in automatic forging complex comprising two four-hammer block forging

devices for rough forging and one four-hammer block forging device for calibrating forging; hydraulic forging press with effort 1250 t; and two forging manipulators, operating synchronically with each other and press.

[0043] Weight of cast billet was 1205 kg. According to the present invention the area of free space between hammer blocks of forging device for calibrating forging with closed hammer blocks was 1.2 times less than the area of free space between hammer blocks of the second four-hammer block forging device for rough forging, i.e. forging device for rough forging with minimum area of free space between hammer blocks of two similar devices at closed position of hammer blocks. Working surfaces of each hammer block in four-hammer block forging device for rough forging consisted of central face, located parallel to supporting face of hammer block and two lateral faces, adjacent to the central face from both sides at an angle 135°. As it was necessary to produce round forged pieces with diameter 113 mm, for their calibration it was used four-hammer block forging device, the hammer blocks of one pair of which had two working sections separated by the groove, and the hammer blocks of the second pair, positioned in mutually perpendicular plane - one working section. At the same time, curvature radii of concave curvilinear surfaces of the first pair of the hammer blocks were 1.15 times more than curvature radii of concave curvilinear surfaces of the second pair of the hammer blocks, i.e. there was maintained the ratio R1 = 1.15R2.

[0044] Cast billet with diameter 450 mm was forged according to the following scheme: ingot ∅ 450 mm → 360 x 360 mm → 290 x 290 mm → 220 x 220 mm → 160 x 160 mm → 120 x 120 mm →∅113 mm.

[0045] Forging was carried on in two stages: first rough forging in two four-hammer block forging devices for rough forging, then calibrating forging in four-hammer block forging device for calibrating forging. Total forging reduction ratio was 15.9 : 1. Forging of the billet with cross section dimension up to 220 x 220 mm (forging reduction ratio 3.28 : 1) was carried on in the first forging device for rough forging, and with cross section dimension up to 120 x 120 mm - in the second four-hammer block forging device for rough forging. During the second stage, square billet with cross section 120 x 120 mm was forged in four-hammer block forging device for calibrating forging into forged pieces with diameter 113 mm (forging reduction ratio 1.44 : 1). During calibration process, embracing of perimeter of billet cross section at every single swaging by each pair of working sections of the hammer blocks by 80-90% was carried on.

[0046] After forging, billets with diameter $109^{-0.5}$ with hole diameter $28.5_{0.5}$ mm and 190 mm long were produced from obtained forged pieces with diameter 113 mm by mechanical treatment.

[0047] Operative efficiency of forging process was 4681 kg/h, diameter tolerance did not exceed ± 1 mm, product yield was 84.6%.

[0048] Then the above mentioned billets were used for producing of tubes 9.13 x 7.72 mm with quality meeting the requirements of TU 95.2594-96.

[0049] To compare, as the base subject was accepted the technological process for producing of forged pieces of the alloy E110, valid in JSC "Chepetsky Mechanical Plant". Under this technological process the preheated ingot is first forged with hammer with dropping parts mass 5t, into forged pieces with square cross section 110 x 110 mm with preheating (or secondary heating) of the second portion of the ingot. Then these billets were preheated and forged with hammer with dropping parts mass 3t by flat hammer blocks to diameter 117^{+10} mm. After forging, billets with diameter $109^{-0.5}$ with hole diameter $28.5_{0.5}$ mm and 190 mm long were produced from obtained forged pieces by mechanical treatment. Operative efficiency of forging process was 2036 kg/h, diameter tolerance ± 5 mm, product yield was 69.4%. Thus, the operative efficiency of forging process in comparison with the base technological process increased 2.3 times, tolerance of dimension of forged piece cross section decreased 5 times, and metal yield increased by 15.2%.

[0050] Tables 1 and 2 illustrate experimental data conforming effectiveness of the claimed inventions (production method and forging complex).

Table 1.

Experiment #	Total forging reduction ratio YΣ	Forging reduction ratio at calibration, YK	Embracement of billet cross section perimeter at calibration, %	Operative efficiency, kg/h	Product yield, %	Diameter tolerance, ±mm	Remarks
1	15.9 : 1	1.44 : 1	80-90	4681	84.6	1	
2	15.9 : 1	1.8 : 1	80-90	4170	84.1	1	

Table 1. (continued)

Experiment #	Total forging reduction ratio YΣ	Forging reduction ratio at calibration, YK	Embracement of billet cross section perimeter at calibration, %	Operative efficiency, kg/h	Product yield, %	Diameter tolerance, ±mm	Remarks
3	15.9 : 1	1.9 : 1	60-90	-	-	-	Foreign inclusion s on forged piece surface, reject
4	15.9 : 1	1.05 : 1	80-90	4695	84.3	1	
5	15.9 : 1	1.03 : 1	80-90	-	-	-	Ridges on forged piece surface, reject
6	1.8 : 1	1.12 : 1	80-90	-	-	-	Metal poor quality because of insufficient cast structure processing
7	33 : 1	1.4 : 1	80-90	-	-	-	Billet was cooled to the temperature less than permissible. Forging is stopped.
8	15.9 : 1	1.4 : 1	30	3900	83.1	2	Forged piece surface has hammer blocks imprints.
9	25.2 : 1	1.6 : 1	60-80	4190	84.5	1	Prior to forging in four-hammer blocks forging devices ingot

Table 1. (continued)

Experiment #	Total forging reduction ratio YΣ	Forging reduction ratio at calibration, YK	Embracement of billet cross section perimeter at calibration, %	Operative efficiency, kg/h	Product yield, %	Diameter tolerance, ±mm	Remarks
							forging was carried on by two hammer blocks.
10 basic subject	15.9	-	-	2036	69.4	5	Forged piece surface has coarse marks of hammer blocks
11 prototype	15.9 : 1	-	-	3350	80.1	2-3	Hammer block imprints on forged piece surface

Table 2

Experiment #	F/F', units	α, degrees	R1/R2, units	Operative efficiency, kg/h	Diameter tolerance, ±mm	Remarks
1	1.2	135	1.15	4681	1	
2	1.2	125	1.15	-	-	Foreign inclusions on forged piece surface , reject
3	1.2	170	1.15	4675	1	
4	1.2	180	1.15	-	-	Forged piece is not forged to required size
5	1.1	135	1.15	4610	1	
6	1.4	155	1.15	4320	1	
7	1.5	155	1.15	3800	1	Foreign inclusions on forged piece surface

Table 2 (continued)

Experime nt #	F/F', units	α, degrees	R1/R2, units	Operative efficiency, kg/h	Diameter tolerance, ±mm	Remarks
8	1.2	135	1.04	4600	2	Hammer block imprints on forged - piece surface
9	1.2	135	1.3	4680	2	Forged piece surface quality is unsatis factory
10 basic subject	-	-	-	2036	5	Hammer block coarse imprints are left on forged piece surface
11 prototype	-	-	-	3350	2-3	Hammer block imprints on forged piece surface

[0051] Compared to the prototype and the basic subject the claimed production method of forged pieces mainly of Titanium subgroup metals and alloys and forging complex for this method realization provide increase of operative efficiency 1.4 - 2.3 times, metal yield by 2 - 15.2%, decrease of tolerances of forged pieces cross section dimension 2-5 times, and also improvement of forged pieces surface quality.

Claims

1. A method of production of forged pieces mainly of metals and alloys from the subgroup of Titanium, comprising ingot heating, followed by forging in press with two manipulators during several stages by quadrilateral swaging in four-hammer block forging devices with additional macro-shift of metal in billet's transversal plane at every single swaging, feeding and tilting of billet, wherein forging is carried on in forging temperatures admissible range, with forging reduction ratio 2.0 : 1 - 32.0 : 1 for one heating of ingot, in two stages, first the rough forging in one or several four-hammer block forging devices for rough forging, and then calibrating forging in one four-hammer block forging device for calibrating forging with forging reduction ratio 1.05 : 1 - 1.8 : 1 and embracing of perimeter of billet cross section at every single swaging by each pair of working sections of the hammer blocks by 40-100%.

2. The method of claim 1, wherein at initial stage of rough forging, manipulator, which holds the ingot, performs one feed of the ingot into working area of four-hammer block forging device for rough forging, followed by several ingot swaging and tilting stages without feed, till the forged portion of the ingot is clamped by other manipulator

3. The method of claims 1 or 2 , wherein prior to forging in one or several four-hammer block forging devices for rough forging, the ingot forging with two hammer blocks is carried on.

4. Forging complex comprising upper and low plates with locks for clamping and fixing of forging tooling; movable tool table with several positions of forging tool change; forging tooling, consisting of two or more four-hammer block forging devices, located in positions of tool table; and one or two manipulators, wherein in tool table working sections there were mounted one or several four-hammer block forging devices for rough forging and at least one four-hammer block forging device for calibrating forging with hammer blocks , the working surfaces of which while closing repeat the shape of the final forged piece cross section; at the same time the area of free space between hammer blocks of forging device for calibrating forging with closed hammer blocks is 1.1 - 1.4 times less than the area of free space between hammer blocks of forging device for rough forging, having minimum area of free space between hammer blocks at closed position of hammer blocks, and working surface of every hammer block in four-hammer block forging device for rough forging is made in a form of a plane parallel to hammer block's supporting plane with two adjacent at 135-170° lateral planes.

5. The forging complex of claim 4, wherein in four-hammer block forging device for calibrating forging of round cross section forged pieces the hammer blocks of the same pair symmetrically oriented relative to each other, have, each of them, two working sections in the form of projections, separated by made in the body of the hammer block groove, to the inner part of which the working projection of second pair of hammer block, positioned in mutually perpendicular plane, has been introduced with a gap; at the same time the working surface of each hammer block in its cross section has concave curvilinear shape with variable curvature radius and curvature radius of hammer block working surfaces, having two working sections, is 1.05 - 1.25 times more than curvature radius of working surfaces of the second pair of hammer blocks.

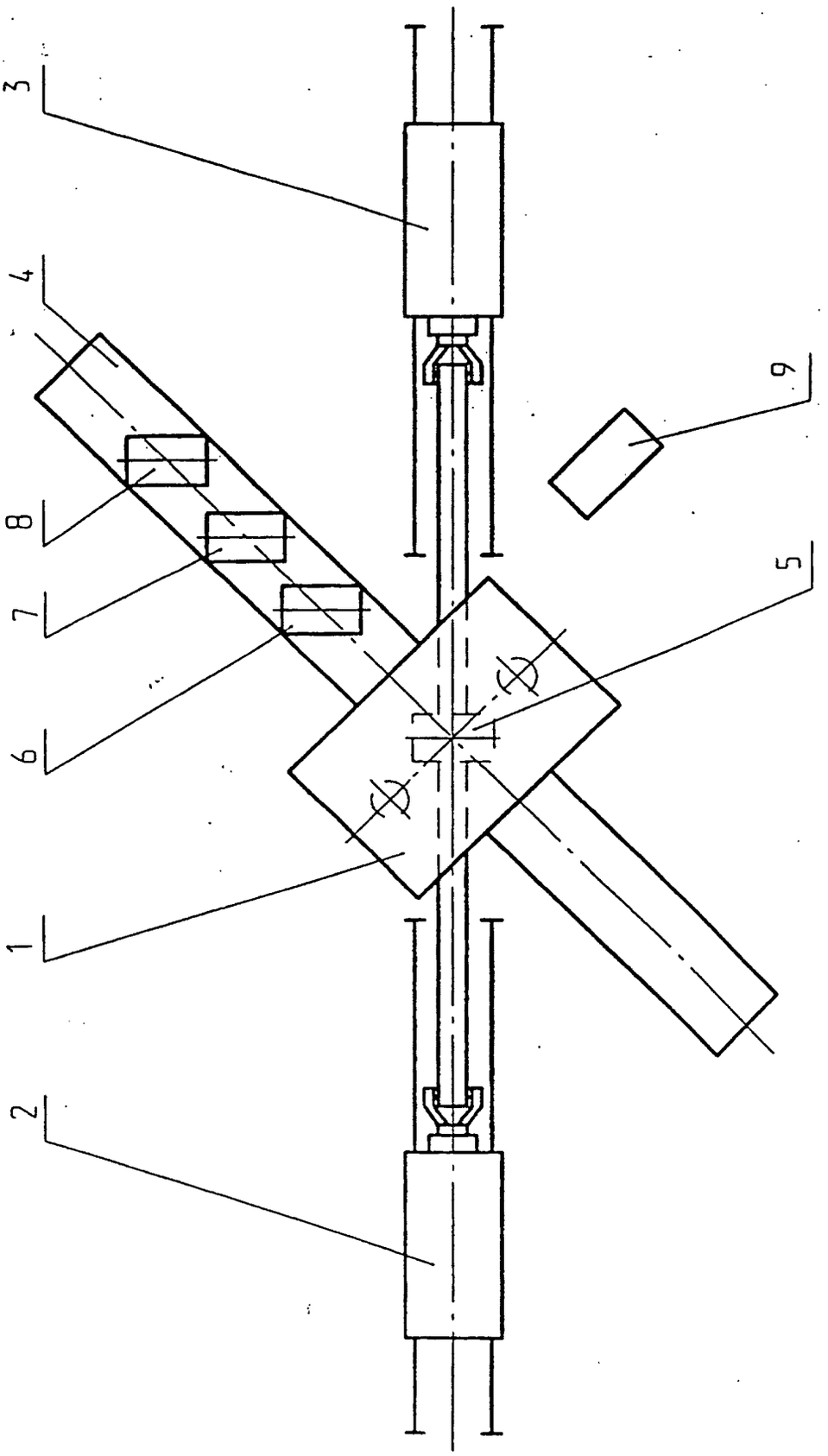


Fig. 1

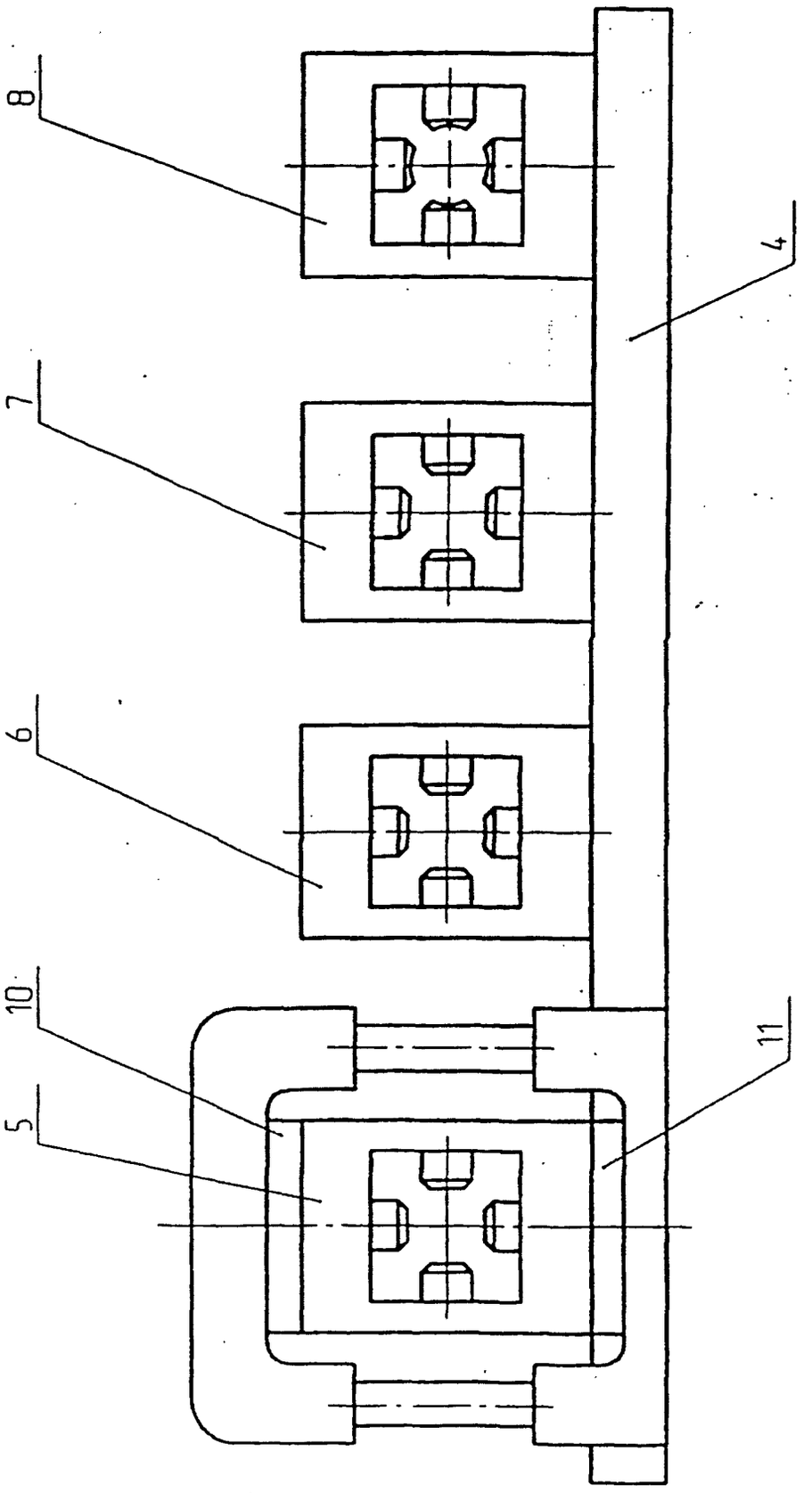


Fig. 2

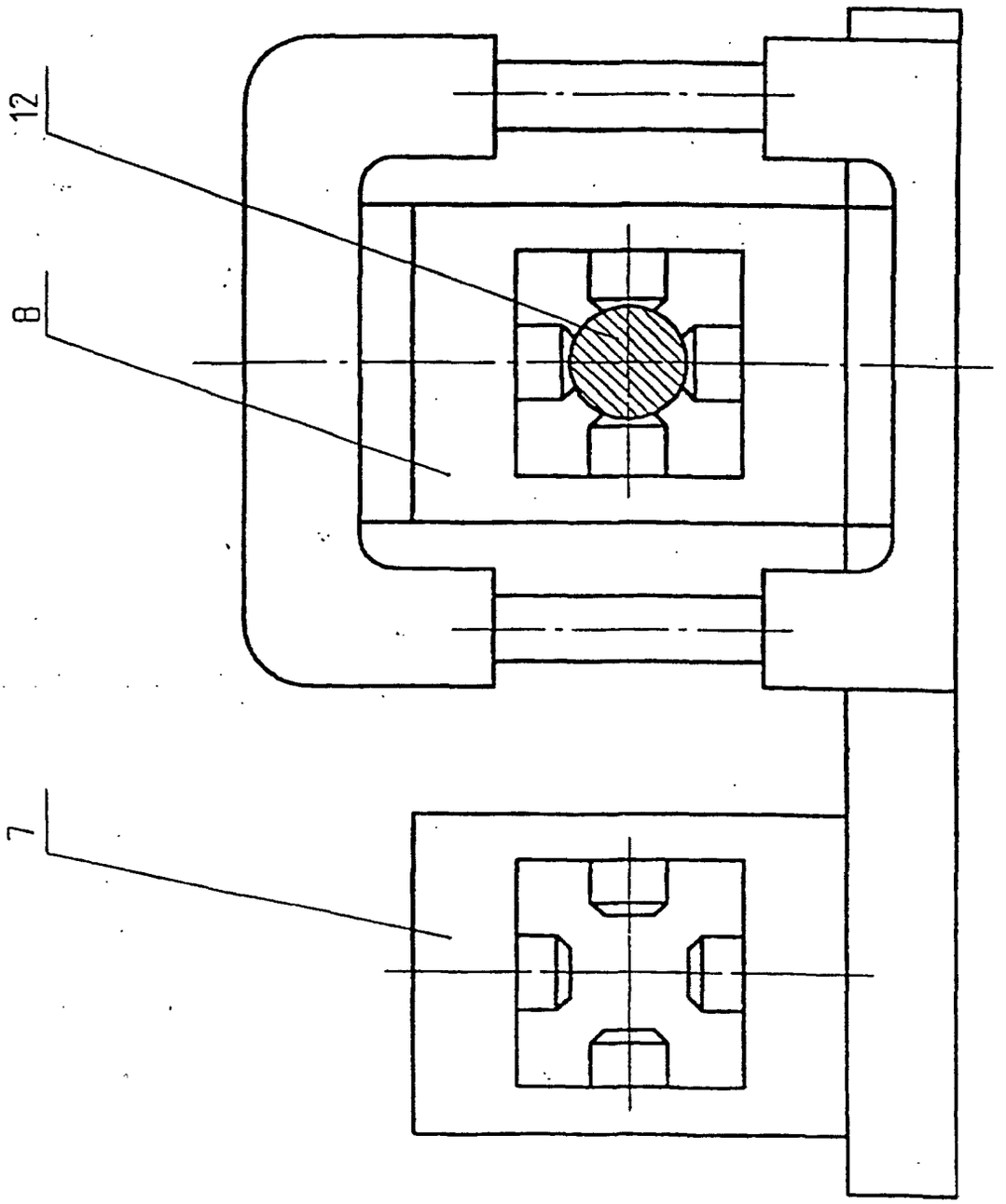


Fig. 3

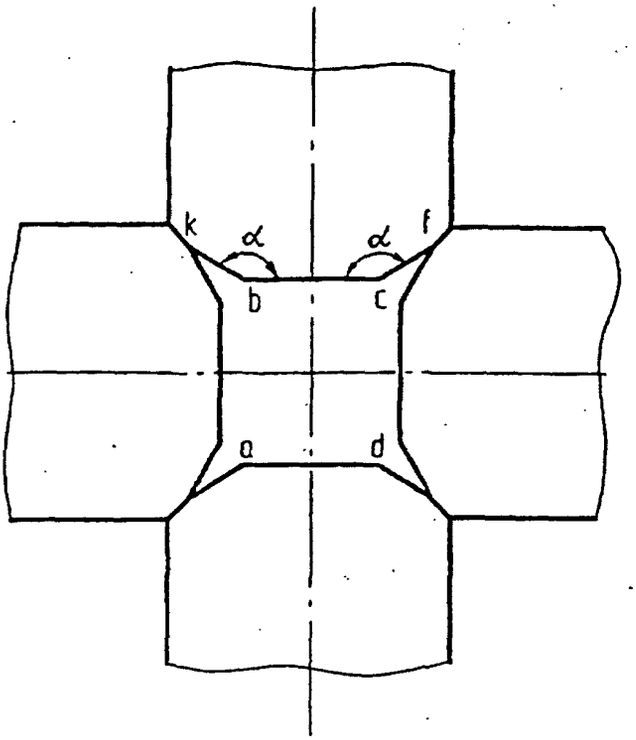


Fig. 4

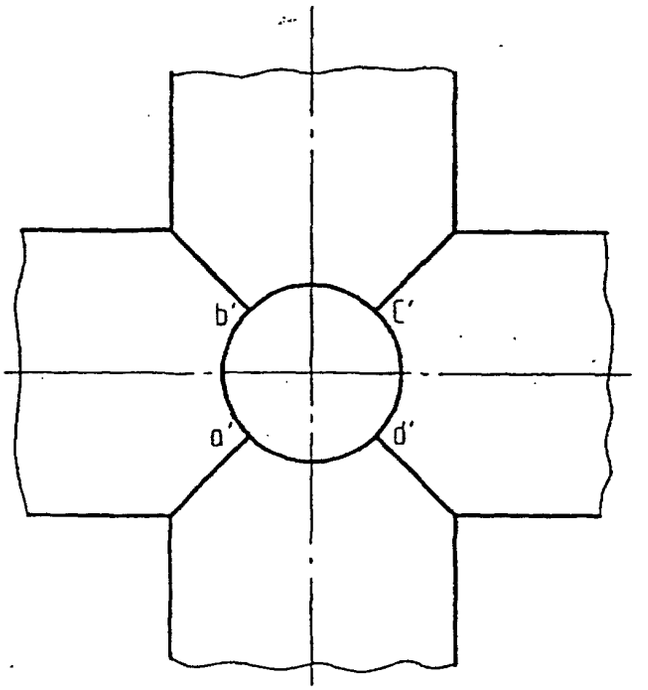


Fig. 5

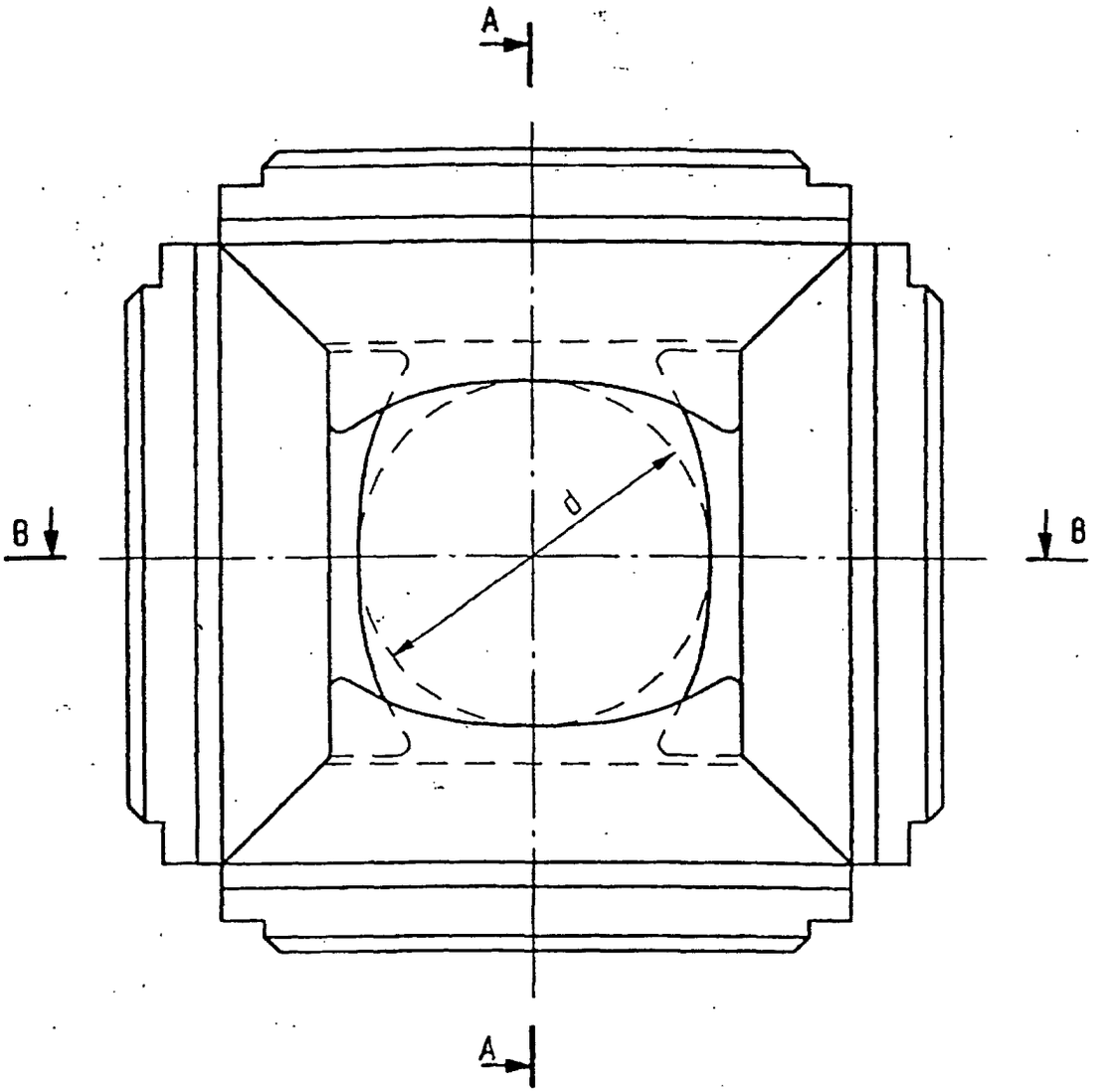


Fig. 6

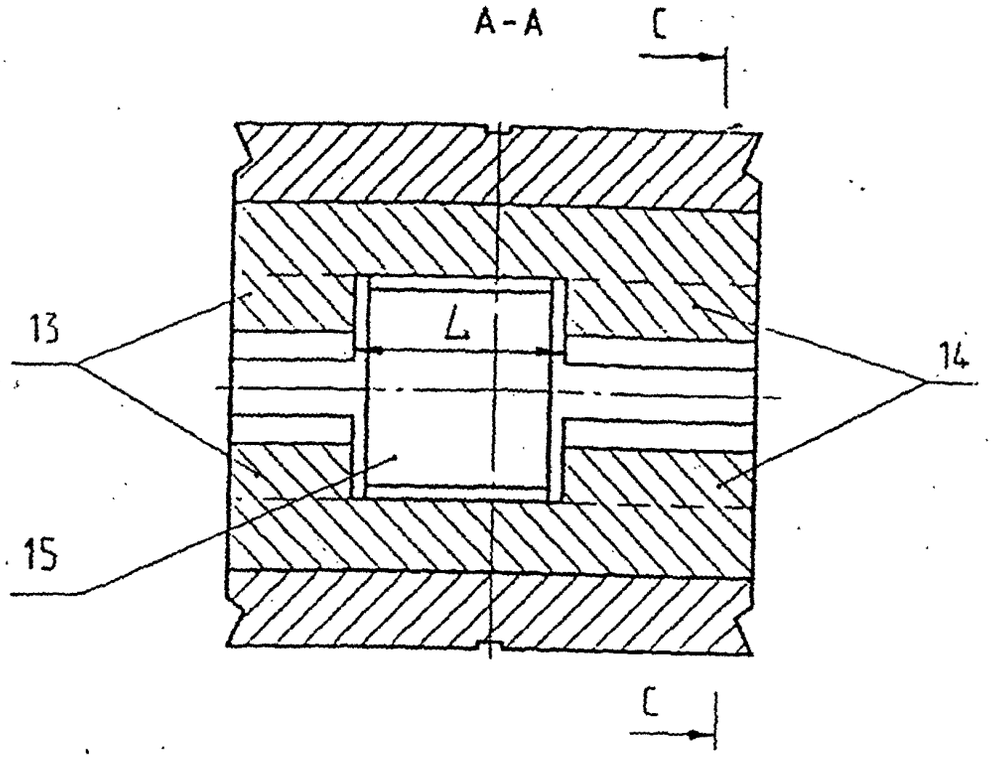


Fig. 7

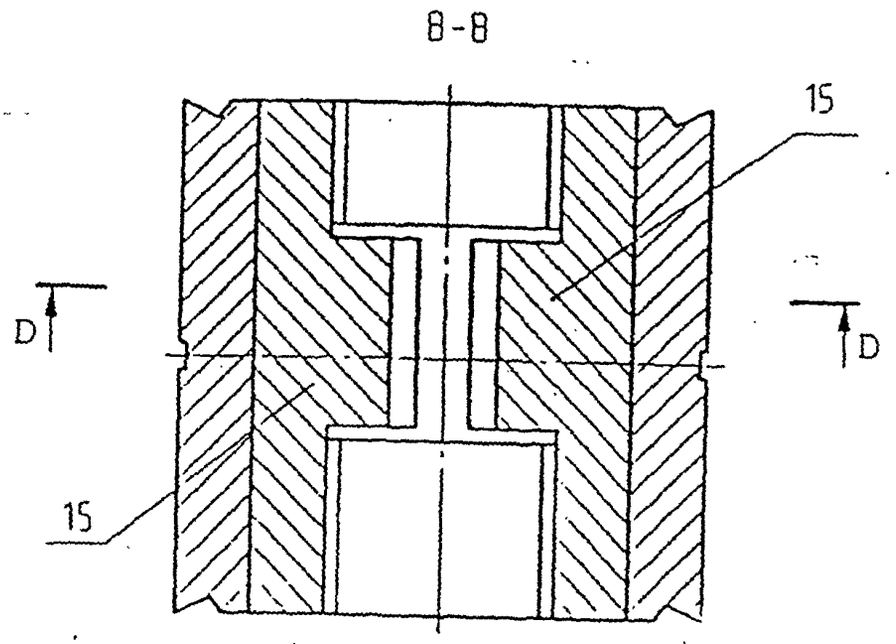


Fig. 8

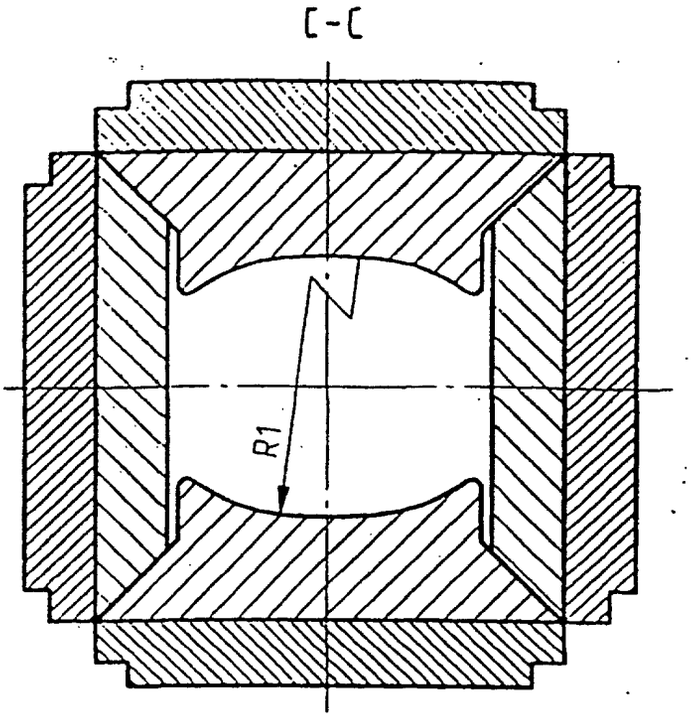


Fig. 9

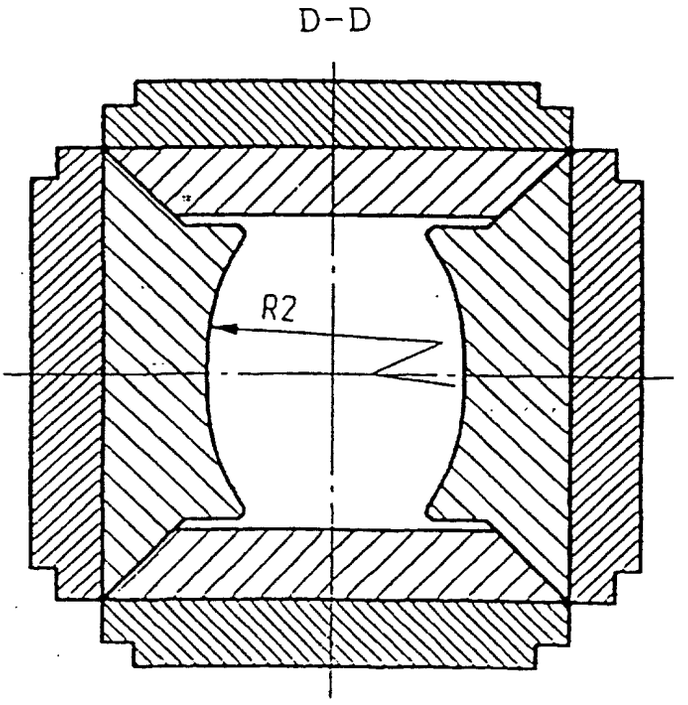


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 02/00389

A. CLASSIFICATION OF SUBJECT MATTER

B21J 1/04,5/00,13/02

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)

B21J 1/00,1/02,1/04,5/00,5/02,5/06,9/00,9/02,13/00,13/02

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SU 1402400 A1 (UKRAINSKY NAUCHNO-ISSLEDOVATELSKY INSTITUT SPETSIALNYKH STALEI, SPLAVOV I FERRO-SPLAVOV) 15.06.1988	1-5
A	SU 810353 (ORLOVSKY FILIAL ZAOCHNOGO MASHINOSTROITELNOGO INSTITUTA) 07.03.1981, the claims, figure 1	4-5
A	RU 2003417 C1 (VSEROSSYSKY INSTITUT LEGKIKH SPLAVOV) 30.11.1993, the abstract	1-3
A	WO 93/24255 A1 (TJURIN VALERY ALEXANDROVICH) 09 December 1993 (09.12.1993), the claims, the drawings.	1-5
A	GB 1376952 (LANGENSTEIN & SCHEMANN AKTIENGESELL-SCHAFT) 11 Dec. 1974, the claims, figures 1,3	4-5

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

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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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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 such 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
04 December 2002 (04.12.2002)	10 December 2002 (10.12.2002)
Name and mailing address of the ISA/ RU	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)