(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 072 337 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
31.01.2001 Bulletin 2001/05

(51) Int Cl.[7]: **B21H 5/02**, B21H 3/06, B21B 31/04, B21H 1/18

(21) Application number: **99114437.9**

(22) Date of filing: **22.07.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: **N.H.K. BUILDER CO., LTD.**
Nukata-gun Aichi-ken (JP)

(72) Inventor: **Hanada, Hideto,**
c/o N.H.K. Builder Co., Ltd.
Nukata-gun, Aichi-ken (JP)

(74) Representative:
Pellmann, Hans-Bernd, Dipl.-Ing. et al
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4-6
80336 München (DE)

(54) Flat-die type rolling machine having device for fastening together die-support frame members and method of fastening the same

(57) Flat-die type rolling machine having a pair of parallel flat dies (28) movable relative to each other for rolling a workpiece (W) therebetween, and a pair of parallel elongate frame member (14) spaced apart from each other, connected at their opposite longitudinal end portions and disposed so as to receive rolling reaction forces transferred from the workpiece to the flat dies in opposite directions away from each other, the machine including a fastening device having at least one spacer member (18, 20) interposed between intermediate portions of the frame members, and at least one tightening rod member (48) each having a longitudinal hole for accommodating a heater and adapted to apply a tightening force to the frame members such that the frame members are forced against the at least one spacer member in opposite directions toward each other, wherein the tightening force is generated as a result of elongation of the at least one tightening rod member by heating thereof by the heater and subsequent contraction of the same by cooling thereof.

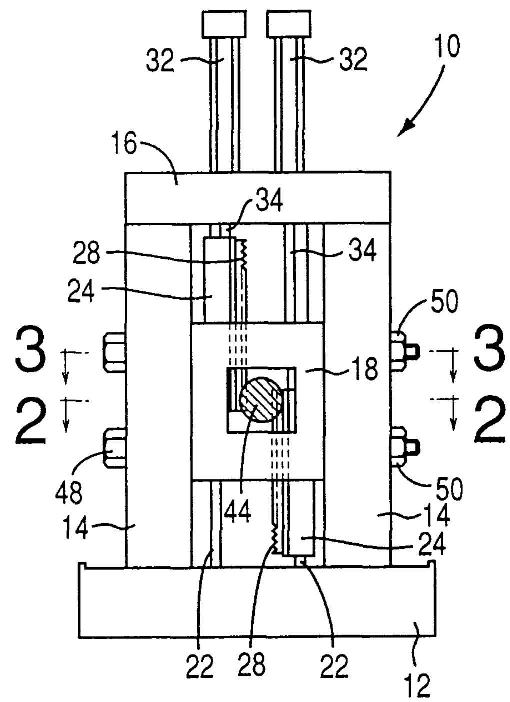


FIG. 1

EP 1 072 337 A1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a flat-die type rolling machine having a pair of flat dies for squeezing and rotating a workpiece therebetween for shaping an outer circumferential surface of the workpiece, and more particularly to techniques for applying a tightening force to a pair of elongate frame members which receive from the flat dies respective components of a rolling reaction force, for improving accuracy of rolled products. This invention is also concerned with a method of fastening together such a pair of elongate frame members and a spacer member interposed therebetween so as to applying a sufficiently large tightening force for resisting the rolling reaction force.

Discussion of the Prior Art

[0002] Generally, a flat-die type rolling machine has a pair of opposed flat dies which are disposed on diametrically opposite sides of a cylindrical workpiece such that at least one of the flat dies is linearly movable relative to the other, so that the workpiece is squeezed and rolled by the opposed flat dies, to thereby shape an outer circumferential surface of the workpiece. During a rolling operation, components of a rolling reaction force are transferred from the workpiece to the flat dies in opposite directions away from each other in a direction in which the flat dies are spaced apart from each other. Usually, the flat dies are supported by a pair of elongate frame members which are spaced apart from each other in the above-indicated direction, so that the frame members receive the respective components of the rolling reaction force from the flat dies interposed therebetween, in the rolling operation. An example of such a flat-die type rolling machine is disclosed in JP-Y1-50-99243.

[0003] Conventionally, the pair of elongate frame members in such a flat-die type rolling machine are connected to each other at their longitudinally intermediate portions by a tie bar device, in order to reduce an amount of deflection of the intermediate portions of the frame members away from each other. In the presence of such a tie bar, however, the conventional rolling machine inevitably suffers from a significant amount of outward deflection of the frame members due to the rolling reaction force generated in the rolling process, leading to considerable deterioration of the dimensional accuracy of rolled products.

[0004] On the other hand, it is considered possible to apply a pre-load to the pair of frame members so that the pre-load acts on the frame member in opposite directions toward each other, namely, toward the pair of flat dies and the workpiece. However, an excessive amount of the pre-load on the frame members causes an accordingly large amount of inward deflection of the intermediate portions of the frame members. Therefore, this solution has a limit in the amount of the pre-load that can be applied to the frame members.

[0005] Thus, it has been difficult to obtain rolled products having a sufficiently high degree of dimensional accuracy, on the order of several microns, in particular.

SUMMARY OF THE INVENTION

[0006] It is therefore a first object of the present invention to provide a flat-die type rolling machine which is effective to solve the problem described above.

[0007] A second object of the invention is to provide a method suitable for fastening together the pair of elongate frame members and at least one space member interposed therebetween in such a flat-die type rolling machine, for minimizing the amount of deflection of the frame member due to a rolling reaction force generated in a rolling process.

[0008] The first object indicated above may be achieved according to a first aspect of this invention, which provides a flat-die type rolling machine comprising a pair of flat dies movable relative and parallel to each other for squeezing and rolling a workpiece therebetween to shape an outer circumferential surface of the workpiece, and a pair of elongate frame members extending parallel to each other in a first direction and spaced apart from each other in a second direction perpendicular to the first direction such that the pair of flat dies are interposed between the pair of elongate frame members in the second direction, the pair of elongate frame members being connected to each other at opposite longitudinal ends portions thereof and disposed so as to receive from the pair of flat dies, respectively, respective components of a rolling reaction force which are transferred from the workpiece to the pair of flat dies in opposite directions away from each other in the second direction, the flat-die type rolling machine being characterized by further comprising a fastening device including at least one spacer member interposed between mutually corresponding longitudinally intermediate portions of the pair of elongate frame members, and at least one tightening rod member each of which has a longitudinally extending hole for accommodating a heater and applies a tightening force to the pair of elongate frame members such that the elongate frame members are forced against the at least one spacer member in opposite directions toward each other in the above-indicated second direction. The tightening force is generated as a result of elongation of the at least one tightening rod member by heating thereof by the heater and subsequent contraction of the at least one tightening member by cooling thereof.

[0009] In the flat-die type rolling machine constructed according to the first aspect of the present invention, a considerably large tightening force is applied to the longitudinally intermediate portions of the elongate frame members, by so-called "shrinkage tightening" of the at least one tightening rod member. Namely, the sufficiently large tightening force is generated as a result of elongation of the at least one tightening rod member by heating thereof by activation of the heater and subsequent contraction of the at least one tightening member by cooling thereof by turning off the heater. Since the tightening force received by the at least one spacer member interposed between the frame members, the amount of deflection of the elongate frame members due to a rolling reaction force generated in the rolling operation on the workpiece is effectively reduced or minimized, leading to a significant improvement in the dimensional accuracy of rolled products to be obtained by the present rolling machine. The fastening device provided according to the present invention eliminates a need of increasing the rigidity of the frame members, which unfavorably results in an increase in the size and weight of the rolling machine. Further, the tightening device adapted to apply the tightening force sufficient to resist the rolling reaction force for minimizing the deflection of the frame members makes it possible to effectively minimize undesirable vibrations and noises which would take place due to pulsation of the rolling reaction force in the rolling process.

[0010] In one preferred form of the rolling machine of the invention, each of the above-indicated at least one tightening rod member is a bolt member extending through the pair of elongate frame members and one of the at least one spacer member. This bolt member has a head at one of opposite ends thereof, for contact with one of the pair of elongate frame members, and a threaded end portion remote from the head, the fastening device further including a nut which engages the threaded end portion of the bolt member so as to be brought into contact with one of the pair of elongate frame members when the bolt member has been elongated by heating thereof by the heater.

[0011] In another preferred form of the rolling machine, the above-indicated at least one spacer member consists of two spacer members which are spaced apart from each other in a third direction perpendicular to the first and second directions, and the above-indicated at least one tightening rod member includes two rod members which extend through the two spacer members, respectively.

[0012] In one advantageous arrangement of the above preferred form of the rolling machine, the above-indicated at least one tightening rod member consists of four rod members consisting of two rod members extending through one of the two spacer members and spaced apart from each other in the first direction, and two rod members extending through the other of the two spacer members and spaced apart from each other in the first direction.

[0013] In a further preferred form of the rolling machine of this invention, each of the at least one tightening rod member is formed of a material that permits each tightening rod member to be elongated by heating thereof by an amount equal to 0.05-0.15% of a distance between outer surfaces of the pair of elongate frame members with which the at least one tightening rod member is associated for applying the tightening force. For instance, each tightening rod member may be formed of a chrome-molybdenum steel. The amount indicated above is preferably within a rnage of 0.06-0.12% of the above-indicated distance, more preferably within a range of 0.08-0.10% of the distance.

[0014] The second object indicated above may be achieved according to a second aspect of this invention, which provides a method of fastening together the pair of elongate frame members and the at least one spacer member in the flat-die type rolling machine according to the first aspect of his invention, the method being characterized by comprising the steps of: placing at least one tightening rod member on the flat-die type rolling machine, in association with the pair of elongate frame members and the at least one spacer member interposed therebetween; placing a heater in the longitudinally extending hole of each of the at least one tightening rod member, and turning on the heater to heat each tightening rod member, for causing each tightening rod member to be elongated; fixing each tightening rod member, after each tightening rod member has been elongated, so that a tightening force is applied to the pair of elongate frame members such that the elongate frame members are forced against the at least one spacer member in the opposite directions toward each other in the second direction after each tightening rod member has been contracted by cooling thereof; and turning off the heater to allow each tightening rod member to be cooled and contracted for applying the tightening force to the pair of elongate frame members.

[0015] In one preferred form of the method of the invention, the step of placing the at least one tightening rod member comprises positioning at least one bolt member such that each of the at least one bolt member extends through the pair of elongate frame members and the at least one spacer member and such that a head of each bolt member provided at one of opposite ends thereof is in contact with one of the pair of elongate frame members, and the step of fixing each tightening rod member comprises screwing a nut on a threaded end portion of each bolt member remove from the head, in contact with the other of the pair of elongate frame members when each bolt member has been elongated by heating thereof by the heater.

[0016] In another preferred form of the method of the invention, the step of placing a heater in the longitudinally extending hole and turning on the heater comprises holding the heater in an on state until each tightening rod member has been elongated by an amount equal to 0.05-0.15% of a distance between outer surfaces of the pair of elongate frame members with which the at least one tightening rod member is associated for applying the tightening force. The amount indicated above is preferably within a rnage of 0.06-0.12% of the above-indicated distance, more preferably within a range of 0.08-0.10% of the distance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The above and other objects, features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of a presently preferred embodiment of the invention, when considered in connection with the accompanying drawings, in which:

Fig. 1 is a front elevational view of a flat-die type rolling machine constructed according to one embodiment of this invention;
Fig. 2 is a cross sectional view taken along line 2-2 of Fig. 1;
Fig. 3 is a cross sectional view taken along line 3-3 of Fig. 1;
Fig. 4 is a right-hand side elevational view of the rolling machine of Fig. 1;
Fig. 5 is a fragmentary view of a fastening device incorporated in the rolling machine of Fig. 1 in two different states; and
Fig. 6 is a graph showing relationships between a load and amounts of elongation and contraction of elements of the fastening device of Fig. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Referring first to Fig. 1, there is shown a flat-die type rolling machine 10, which includes a base 12 and a pair of generally planar elongate frame members 14 which are fixed on and extend upwards from the upper surface of the base 12, in parallel with each other. The two frame members 14 are spaced apart from and opposed to each other in a first horizontal direction. The two frame members 14, which are connected at their lower ends to each other by the base 12, are connected at their upper ends to each other by a connecting frame 16. Thus, the rolling machine 10 has a generally portal configuration, as shown in Fig. 1.

[0019] A spacing between the two frame members 14 is determined by two spacer blocks 18, 20 interposed between mutually corresponding and opposed longitudinally intermediate portions of the two frame members 14. As shown in Figs. 2 and 3, the spacer block 18 is located at one of widthwise opposite end portions of each frame member 14, which are opposed to each other, as viewed in a second horizontal direction perpendicular to the first horizontal direction in which the two frame members 14 are spaced apart from each other. The other spacer block 20 is located at the other widthwise end portion of each frame member 14. As described below in detail, the two frame members 14 and the two spacer members 18, 20 are fastened together by four tightening rod members in the form of long tie bolts 48, and corresponding nuts 50.

[0020] Each of the two frame members 14 has a T-shaped guide rail 22 formed on its inner surface such that the guide rails 22 of the two frame members 14 extend in the vertical direction and are opposed to each other in the first horizontal direction. The two frame members 14 carry respective slides 24 which have respective T-shaped slots or recesses 26 engaging the respective T-shaped guide rails 22. In other words, the slides 24 are vertically slidably mounted on the guide rails 22. The slides 24 carry respective die holders 30 fixed thereto by suitable means such as bolts. The die holders 30 support respective flat dies 28 fixed thereto, such that a pair of flat dies 28 are opposed to each other in the first horizontal direction and are movable in the vertical direction relative to each other with the respective slides 24.

[0021] To the upper end of each slide 24, there is fixed a piston rod 34 of a reciprocating hydraulic cylinder 32 attached to the connecting frame 16, as shown in Fig. 1. These two reciprocating hydraulic cylinders 32 are controlled to move the corresponding two slides 24 in the opposite vertical directions so that one of the two flat dies 28 is moved down with the corresponding slide 24 while the other flat die 28 is moved up with the corresponding slide 24, and vice versa. As shown in Figs. 2 and 3, each of the slides 24 has a rack 36 fixed thereto such that the rack 36 extends in the vertical direction. A synchronizer pinion 38 is held in meshing engagement with the two racks 36. As shown in Fig. 2, this synchronizer pinion 38 is mounted on a rotary shaft 40 which is rotatably supported by the spacer block 20 through bearings 42. When the two slides 34 are reciprocated in the opposite directions, the reciprocating movements of the two flat dies 28 with the slides 34 in the opposite directions are accurately synchronized with each other by the racks 36 and pinion 38.

[0022] The distance between the two flat dies 28 is determined so be slightly smaller than the diameter of a cylindrical workpiece W whose outer circumferential surface is shaped at one of its opposite end portions, by and between the flat dies 28. Described more specifically, the workpiece W is supported at its opposite axial ends by respective centers supported by respective center holders 44, 46 such that the workpiece W is rotatable about its axis which is aligned with the axis of rotation of the pinion 38. The end portion of the workpiece W to be shaped is squeezed and rolled on the outer circumferential surface between the two flat dies 28 while the flat dies 28 are reciprocated in synchronization with each other.

[0023] The center holder 44 is disposed axially movably by a pushing hydraulic cylinder (not shown), to push the workpiece W for forcing the end portion in between the two flat dies 28. The other center holder 46 extends axially slidably through the rotary shaft 40, and is connected to a retracting hydraulic cylinder (not shown) which is activated in synchronization with the pushing hydraulic cylinder, so that the center holder 46 is retracted or pulled as the center holder 46 is advanced or pushed by the pushing hydraulic cylinder. Namely, the center holders 44, 46 are moved while the flat dies 28 are reciprocated to axially move the workpiece W while it is squeezed and rolled between the flat dies 28. The axial movement of the workpiece W by the pushing and retracting cylinders permits the workpiece W to be rolled over a relatively large axial length, even though the dimension of the flat dies 28 in the axial direction of the workpiece W is relatively small. For instance, the flat dies 28 are designed to form a spline at one axial end portion of the workpiece W.

[0024] In a rolling operation on the workpiece W by the flat dies 28, the flat dies 28 receive respective components of a rolling reaction force in opposite directions away from each other toward the two frame members 14. These components of the rolling reaction force are transferred from the flat dies 28 to the respective frame members 14 through the respective die holders 30 and the respective slides 24. More specifically described, the two frame members 14 are disposed such that the pair of flat dies 28 are interposed between the two frame members 14, so that the frame members 14 receive from the respective flat dies 28 the respective components of the rolling reaction force which are transferred from the workpiece W. The rolling reaction force is received by a relatively large area of the bearing surface of each of the guide rails 22 on which the respective slides 24 are slidably mounted. The rolling reaction force thus received by the two frame members 14 acts on the mutually corresponding longitudinally intermediate portions of the frame members 14 in the opposite directions away from each other in the direction in which the frame members 14 are spaced apart from each other.

[0025] The two spacer blocks 18, 20, which are interposed between the longitudinally intermediate portions (vertically intermediate portions as seen in Fig. 1) of the frame members 14, as indicated above and 3, are located at the widthwise opposite end portions of each frame member 14, respectively, as shown in Figs. 2 and 3, such that the two slides 24 are located between the two spacer blocks 18, 20 in the second horizontal direction which is the direction of width of the frame members 14.

[0026] As also indicated above, the two frame members 14 and the two spacer blocks 18, 20 are fastened together by the four long tie bolts 48 extending these frame members 14 and spacer blocks 18, 20, as shown in Figs. 1, 3 and 4. The two tie bolts 48 extend through the spacer block 18 while the other two tie bolts 48 extend through the other spacer block 20, as shown in Fig. 4, such that the two tie bolts 48 extending through each of the spacer blocks 18, 20 are located one above the other, as indicated in Fig. 4. Each of the tie bolts 48 has a hexagon head 48a at one of its opposite ends, and a threaded end portion 48b at the other end, as shown in Fig. 3. A nut 50 is screwed on the threaded end portion 48b, for thereby forcing the two frame members 14 against the opposite end faces of the corresponding spacer block 18, 20. It will be understood that the tie bolts 48 serving as the tightening rod members cooperate with the nuts 50 and the spacer members 18, 20 to constitute a fastening device for fastening the frame members 14 for protecting the longitudinally intermediate portions of the frame members 14 against the rolling reaction force.

[0027] Described in detail, the four tie bolts 48 extend through holes which are formed through the frame members 14 and the spacer blocks 18, 20 in the first horizontal direction in which the frame members 14 are spaced apart from each other. The tie bolts 48 and the nuts 50 apply a tightening force to the frame members 14 such that the frame members 14 are forded against the spacer members 18, 20 in the opposite directions toward each other in the above-indicated first horizontal direction, so that the tightening force resists the rolling reaction force which acts on the frame members 14 in the direction opposite to the tightening force. Thus, the tightening force applied by the tie bolts 48 and the nuts 50 serves to prevent or minimize the outward deflection of the two frame members 14 in the directions away from each other and from the flat dies 28 and the workpiece W. The tightening force given by the tie bolts 48 and the nuts 50 is larger than the expected rolling reaction force received from the flat dies 28, so that the frame members 14 are kept forced against the opposite end faces of the spacer blocks 18, 20 even while the rolling reaction force is generated in the rolling process.

[0028] In order for the tie bolts 48 and the nuts 50 to generate the tightening force, each tie bolt 48 has a longitudinally extending hole 52 for accommodating a suitable heater which is activated or turned on to generate heat for heating the tie bolt 48. The heater may be an electrically resistive heating wire coated with an electrically insulating material. When the frame members 14 and the spacer blocks 18, 20 are fastened together, each tie bolt 48 is first inserted through the holes in the frame members 14 and spacer blocks 18, 20 such that the head 48a is in contact with the outer surface of one of the two frame members 14, as shown in Fig. 3. Then, the heater is inserted into the hole 52 formed through the tie bolt 48, and is turned on to generate heat for heating the tie bolt 48 so that the tie bolt 48 is elongated in its longitudinal direction by thermal expansion by the heat. When each of the tie bolts 48 has been elongated, the nut 50 is tightened on the threaded end portion 48b of the tie bolt 48 with the nut 50 being forced against the outer surface of the other frame member 14, as also shown in Fig. 3. Subsequently, the heaters accommodated in the holes 52 of the tie bolts 48 are turned off or de-energized, to allow the tie bolts 48 to be air-cooled to the ambient temperature, so that the tie bolts 48 are contracted in the longitudinal direction. As a result, the tightening force larger than the rolling reaction force is generated by the tie bolts 48. The amount of this tightening force generated by thermal contraction of the tie bolts 48 is extremely larger than that generated by the conventional tie bar device. For instance, the tightening force generated by each tie bolt 48 may amount to at least several tens of tons, and the total tightening force generated by the four tie bolts may amount to at least a few hundreds of tons, as described below in detail.

[0029] The accuracy of rolling on the workpiece W, namely, the dimensional accuracy of the rolled product obtained by rolling the workpiece W is considerably influenced by the outward deflection of the frame members 14 at their longitudinally intermediate portions. Although it is desirable to form the two frame members 14 as respective parts of an integral frame structure, for improving the accuracy of the rolled product, it is difficult or impossible to do so. However, the fastening device constructed according to the present embodiment of this invention assures a significantly reduced amount of deflection of the separate frame members 14, owing to the sufficiently large tightening force by which the frame members 14 can be held forced against the spacer blocks 18, 20 in the opposite directions toward each other, even while the rolling reaction force acts on the frame members 14 in the opposite directions away from each other. Accordingly, the rigidity of the rolling machine is significantly increased by the present fastening device, and the outward deflection of the frame members 14 is reduced to such an extent as in an arrangement wherein the frame members are parts of an integral frame structure.

[0030] The increased rigidity of the rolling machine provided by the present fastening device appears to be based on a fact which will be described.

[0031] When each tie bolt 48 is tightened with the nut 50 in the manner as described above, the tie bolt 48 is subject to a force of elastic elongation or tension in its longitudinal direction, while at the same time the appropriate spacer block 18, 20 is subject to a force of elastic contraction or compression. In other words, the spacer block 18 can be considered to be equivalent to a compression spring whose rigidity is extremely high. Fig. 5 schematically illustrates this state at (a), while no rolling reaction force is generated. That is, a tensile force Pi acting on the tie bolt 48 is equal to a compressive force Pi acting on the spacer block 18, with the tensile force Pi acting in the opposite directions away from each other while the compressible force Pi acting in the opposite directions toward each other, as indicated at (a) in Fig. 5. The tensile or compressive force Pi (internal force Pi) is considered to be the tightening force when the rolling reaction force is not applied to the frame members 14.

[0032] When the rolling reaction force P acts on the frame members 14 as indicated at (b) in Fig. 5, causing an additional amount of elongation δ of the tie bolt 48, the tensile force acting on the tie bolt 48 is increased by Pb, while the compressive force acting on the spacer block 18 is reduced by Pc. The amount Pb of increase of the tensile force and the amount Pc of reduction of the compressive force are expressed as the following equations (1) and (2), respectively:

$$Pb = Kb\delta \tag{1}$$

$$Pc = Kc\delta \tag{2}$$

wherein

Kb = spring constant of the tie bolt 48
Kc = spring constant of the spacer block 18

[0033] The rolling reaction force P applied to the frame members 14 is therefore expressed by the following equation (3), which indicates the equilibrium of the forces:

$$P = (Pi + Pb) - (Pi - Pc)$$
$$= Pb + Pc$$
$$= (Kb + Kc)\delta$$
$$\delta = P/(Kb + Kc) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

[0034] From the above equations (1) and (3), the following equation (4) will be obtained:

$$Pb = [Kb/(Kb + Kc)] \cdot P \qquad (4)$$

[0035] It will be understood from the above equation (4) that the amount Pb of increase of the tensile force acting on the tie bolt 48 upon application of the rolling reaction force P to the tie bolt 48 is not be equal to the entire amount of the rolling reaction force P, but is equal to a fraction of the force P as calculated according to the above equation (4).

[0036] The above equation (4) is expressed by a graph in Fig. 6, wherein the amount of elongation of the tie bolt 48 and the amount of contraction of the spacer block 18 are taken along the abscissa while the force or load is taken along the ordinate, and the point at which the rolling reaction force P is zero (P = 0) indicates the state indicated at (a) in Fig. 5. When the rolling reaction force P is applied to the tie bolt 48, only a portion $P\delta$ of this force P acts on the tie bolt 48, and the amount of elongation of the tie bolt 48 due to the additional tensile force force Pb applied thereto is reduced to be δ, as indicated in the graph.

[0037] If the spacer block 18 were not provided, that is, if the frame members 14, 14 were connected to each other by a suitable tie bar device, the entirety of the rolling reaction force P would act on the tie bar as P2, and the amount of elongation of the tie bar would be equal to $\delta 2$, which is considerably larger than the elongation amount δ. The elongation amount $\delta 2$ is the total amount of outward deflection of the two frame members 14, 14, that is, an amount of increase of the distance between the two flat dies 28 in the direction in which the frame members 14 are spaced apart from each other. However, the fastening device 18, 20, 48, 50 according to the present embodiment permits a significant reduction in the amount of increase of the distance between the flat dies 28, thereby assuring an accordingly increased degree of accuracy of rolling operation in the flat-die type rolling machine 10.

[0038] The fastening device 18, 20, 48, 50 is effective particularly where a rolling operation on the workpiece W is performed while the workpiece W is axially fed by the pushing and retracting hydraulic cylinders connected to the center holders 44, 46 as described above. In this case, the rolling operation is effected over a relatively large axial length of the workpiece W, and the rolling reaction force tends to be large. The present fastening device permits a reduced variation in the dimensional accuracy of the rolled product, namely, an improved dimensional accuracy on the order of several microns, even where the rolling reaction force is considerably large.

[0039] An experiment conducted by the present inventor showed that a rolling reaction force of about 20 tons was generated during a rolling operation on the workpiece W having a diameter of 20mm. This rolling reaction force caused about 0.05mm deflection of the frame members 14, 14 which are not connected to each other by any means at their longitudinally intermediate portions. Deflection of the frame members by such a large amount did not assure a high degree of accuracy of the rolled product. On the other hand, an experiment showed that the frame members 14 whose intermediate portions are forced against the spacer blocks 18, 20 with the tightening force applied by the fastening device 18, 20, 48, 50 suffered from outward deflection of as small as several microns, permitting the workpiece W to be rolled with considerably improved accuracy.

[0040] Further, the reduced amount of outward deflection of the frame members 14 by the large tightening force generated by contraction of the tie bolts 48 after their elongation by heating assures accordingly reduced amounts of vibration of the frame members 14 and resulting noise, which would take place due to pulsation of the rolling reaction force. An experiment conducted by the present inventor showed the rolling noise of 75 db. or lower on the present rolling machine 10, which is considerably lower than the rolling noise of 80 db. on the conventional rolling machine.

[0041] Since the fastening device 18, 20, 48, 50 gives the frame members 14 a sufficiently high degree of rigidity for assuring the rolling accuracy on the order of several microns, the required mass of the frame members 14 can be considerably reduced, with a relatively small transverse cross sectional area, thereby permitting a reduction in the size of the rolling machine 10 as a whole.

[0042] As is apparent from the graph of Fig. 6, the amount of elongation 6 of the tie bolts 48 can be reduced as long as the spacer blocks 18, 20 are held elastically compressed by the tightening force generated by the tie bolts 48. Although this does not require the tie bolts 48 to generate the original tightening force Pi larger than the rolling reaction force P, the original tightening force Pi is required to be determined so that the spacer blocks 18, 20 are held compressed even when the rolling reaction force P is applied to the tie bolts 48.

[0043] A longitudinal modulus of elasticity E of each tie bolt 48 is expressed by the following equation (5):

$$E = Pi \cdot \ell / A \cdot \lambda \qquad (5)$$

wherein

Pi = Tightening force (Kg) generated by each tie bolt 48,

E = longitudinal modulus of elasticity (Kg/cm^2) of the tie bolt 48,

ℓ = distance (cm) between the outer surfaces of the frame members 14 with which the head 48a and the nut 50 are held in contact, as indicated in Fig. 3,

A = transverse cross sectional surface area (cm^2) of the tie bolt 48, and

λ = amount of elongation (cm) of the tie bolt 48 by heating.

[0044] The tightening force Pi generated by elongation of each tie bolt 48 and subsequent cooling of the same is expressed by the following equation (6), which is obtained by conversion from the above equation (5):

$$Pi = E \cdot A \cdot \lambda / \ell \qquad (6)$$

Where the tie bolt 48 has an outside diameter D1 (Fig. 3) of 8cm and an inside diameter D2 (Fig. 3) of 2cm, the cross sectional surface area A is about $47.1cm^2$. Where this tie bolt 48 is formed of a chrome-molybdenum steel (SCM 435) having a longitudinal modulus of elasticity of $2,100,000Kg/cm^2$, and the distance ℓ is 70cm, the tightening force Pi generated when the amount of elongation λ is 0.06cm is calculated as indicated below, according to the above equation:

$$Pi = 2,100,000 \times 47.1 \times 0.06/70 = 84,780Kg = 84.78tons$$

[0045] Therefore, the total tightening force Pi generated by the four tie bolts 48 is 339.12tons. In the conventional tie bar device, the tightening force generated by one tie bar is about 25tons, so that the total tightening force if the tie bar device has four tie bars is about 100tons. Thus, the tightening force generated by the fastening device 18, 20, 48, 50 in the above specific example is more than three times the tightening force generated by the conventional tie bar device.

[0046] In the above example, the amount of elongation of each tie bolt 48 is about 0.06cm, which is about 0.0857% of the distance ℓ of 70cm. However, the amount of elongation of the tie bolt 48 is desirably selected within a range of about 0.05-0.15% of the distance ℓ, preferably, within a range of about 0.06-0.12% of the distance ℓ, and more preferably within a range of about 0.08-0.10% of the distance ℓ.

[0047] In the illustrated embodiment, the sliders 24 on which the flat dies 28 are mounted are adapted to be reciprocated in the vertical direction, the flat dies 28 may be reciprocated in the horizontal direction. While the two slides 24 are reciprocated by the respective reciprocating hydraulic cylinders 32, only one of the slides 24 may be reciprocated relative to the other stationary slide 24. The illustrated embodiment is adapted such that the workpiece W is fed in the axial direction as the flat dies 28 are reciprocated repeatedly, the principle of the present invention is applicable to a flat-die type rolling machine adapted to roll a workpiece by one movement of at least one of two flat dies in one direction.

[0048] It is to be understood that the present invention may be embodied with various changes, modifications and improvements, which may occur to those skilled in the art, in the light of the foregoing teachings.

Flat-die type rolling machine having a pair of parallel flat dies (28) movable relative to each other for rolling a workpiece (W) therebetween, and a pair of parallel elongate frame member (14) spaced apart from each other, connected at their opposite longitudinal end portions and disposed so as to receive rolling reaction forces transferred from the workpiece to the flat dies in opposite directions away from each other, the machine including a fastening device having at least one spacer member (18, 20) interposed between intermediate portions of the frame members, and at least one tightening rod member (48) each having a longitudinal hole for accommodating a heater and adapted to apply a tightening force to the frame members such that the frame members are forced against the at least one spacer member in opposite directions toward each other, wherein the tightening force is generated as a result of elongation of the at least one tightening rod member by heating thereof by the heater and subsequent contraction of the same by cooling thereof.

Claims

1. A flat-die type rolling machine comprising a pair of flat dies (28) movable relative and parallel to each other for squeezing and rolling a workpiece (W) therebetween to shape an outer circumferential surface of the workpiece, and a pair of elongate frame members (14) extending parallel to each other in a first direction and spaced apart from each other in a second direction perpendicular to said first direction such that said pair of flat dies are interposed between said pair of elongate frame members in said second direction, said pair of elongate frame members being connected to each other at opposite longitudinal ends portions thereof and disposed so as to receive from said pair of flat dies, respectively, respective rolling reaction forces which are transferred from said workpiece to said pair of flat dies in opposite directions away from each other in said second direction, **characterized by further comprising:**

   a fastening device (18, 20, 48, 50) including at least one spacer member (18, 20) interposed between mutually corresponding longitudinally intermediate portions of said pair of elongate frame members (14), and at least one tightening rod member (48) each of which has a longitudinally extending hole (52) for accommodating a heater and applies a tightening force to said pair of elongate frame members such that said elongate frame members are forced against said at least one spacer member in opposite directions toward each other in said second direction, said tightening force being generated as a result of elongation of said at least one tightening rod member by heating thereof by said heater and subsequent contraction of said at least one tightening member by cooling thereof.

2. A flat-die type rolling machine according to claim 1, wherein each of said at least one tightening rod member is a bolt member (48) extending through said pair of elongate frame members (14) and one of said at least one spacer member (18, 20), said bolt member having a head (48a) at one of opposite ends thereof, for contact with one of said pair of elongate frame members, and a threaded end portion (48b) remote from said head, said fastening device further including a nut (50) which engages said threaded end portion of said bolt member so as to be brought into contact with one of said pair of elongate frame members when said bolt member has been elongated by heating thereof by said heater.

3. A flat-die type rolling machine according to claim 1 or 2, wherein said at least one spacer member consists of two spacer members which are spaced apart from each other in a third direction perpendicular to said first and second directions, and said at least one tightening rod member includes two rod members (48) which extend through said two spacer members, respectively.

4. A flat-die type rolling machine according to claim 3, wherein said at least one tightening rod member consists of four rod members (48) consisting of two rod members extending through one of said two spacer members and spaced apart from each other in said first direction, and two rod members extending through the other of said two spacer members and spaced apart from each other in said first direction.

5. A flat-die type rolling machine according to any one of claims 1-4, wherein each of said at least one tightening rod member (48) is formed of a material that permits said each tightening rod member to be elongated by heating thereof by an amount equal to 0.05-0.15% of a distance between outer surfaces of said pair of elongate frame members with which said at least one tightening rod member is associated for applying said tightening force.

6. A flat-die type rolling machine according to claim 5, wherein said amount is 0.06-0.12% of said distance.

7. A flat-die type rolling machine according to claim 6, wherein said amount is 0.08-0.10% of said distance.

8. A flat-die type rolling machine according to any one of claims 5-7, wherein said material is a chrome-molybdenum steel.

9. A method of fastening together said pair of elongate frame members (14) and said at least one spacer member (18, 20) in the flat-die type rolling machine defined in claim 1, **characterized by comprising the steps of:**

   placing at least one tightening rod member (48) on the flat-die type rolling machine, in association with said

pair of elongate frame members (14) and said at least one spacer member (18, 20) interposed therebetween; placing a heater in said longitudinally extending hole (52) of each of said at least one tightening rod member, and turning on said heater to heat said each tightening rod member, for causing said each tightening rod member to be elongated;
fixing said each tightening rod member, after said each tightening rod member has been elongated, so that a tightening force is applied to said pair of elongate frame members such that said elongate frame members are forced against said at least one spacer member in the opposite directions toward each other in said second direction after said each tightening rod member has been contracted by cooling thereof; and
turning off said heater to allow said each tightening rod member to be cooled and contracted for applying said tightening force to said pair of elongate frame members.

10. A method according to claim 9, wherein said step of placing said at least one tightening rod member comprises positioning at least one bolt member (48) such that each of said at least one bolt member extends through said pair of elongate frame members and said at least one spacer member and such that a head of said each bolt member provided at one of opposite ends thereof is in contact with one of said

11. A method according to claim 9 or 10, wherein said step of placing a heater in said longitudinally extending hole (52) and turning on said heater comprises holding said heater in an on state until said each tightening rod member has been elongated by an amount equal to 0.05-0.15% of a distance between outer surfaces of said pair of elongate frame members (48) with which said at least one tightening rod member is associated for applying said tightening force. pair of elongate frame members, and said step of fixing said each tightening rod member comprises screwing a nut on a threaded end portion of said each bolt member remove from said head, in contact with the other of said pair of elongate frame members when said each bolt member has been elongated by heating thereof by said heater.

12. A method according to claim 11, wherein said amount is 0.06-0.12% of said distance.

13. A method according to claim 12, wherein said amount is 0.08-0.10% of said distance.

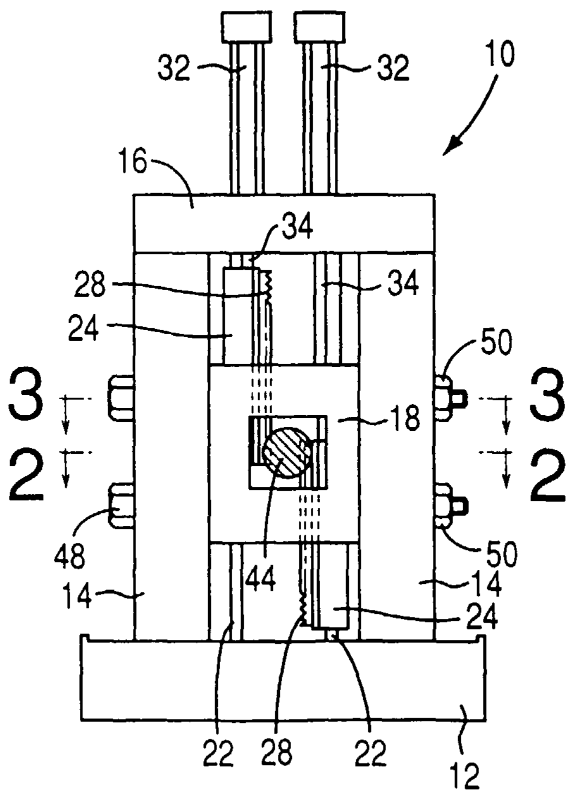


FIG. 1

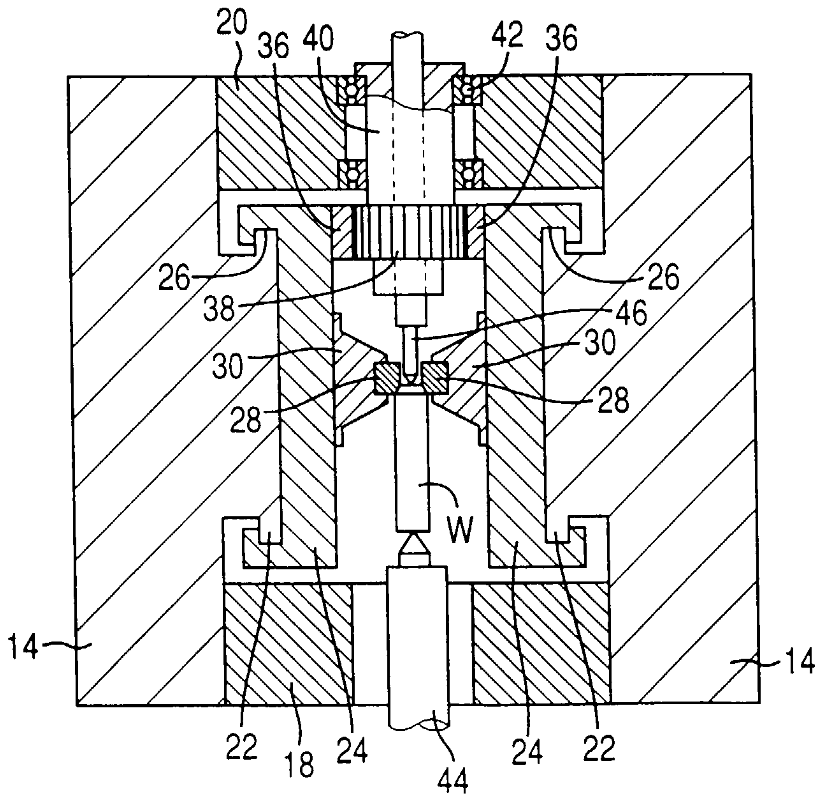


FIG. 2

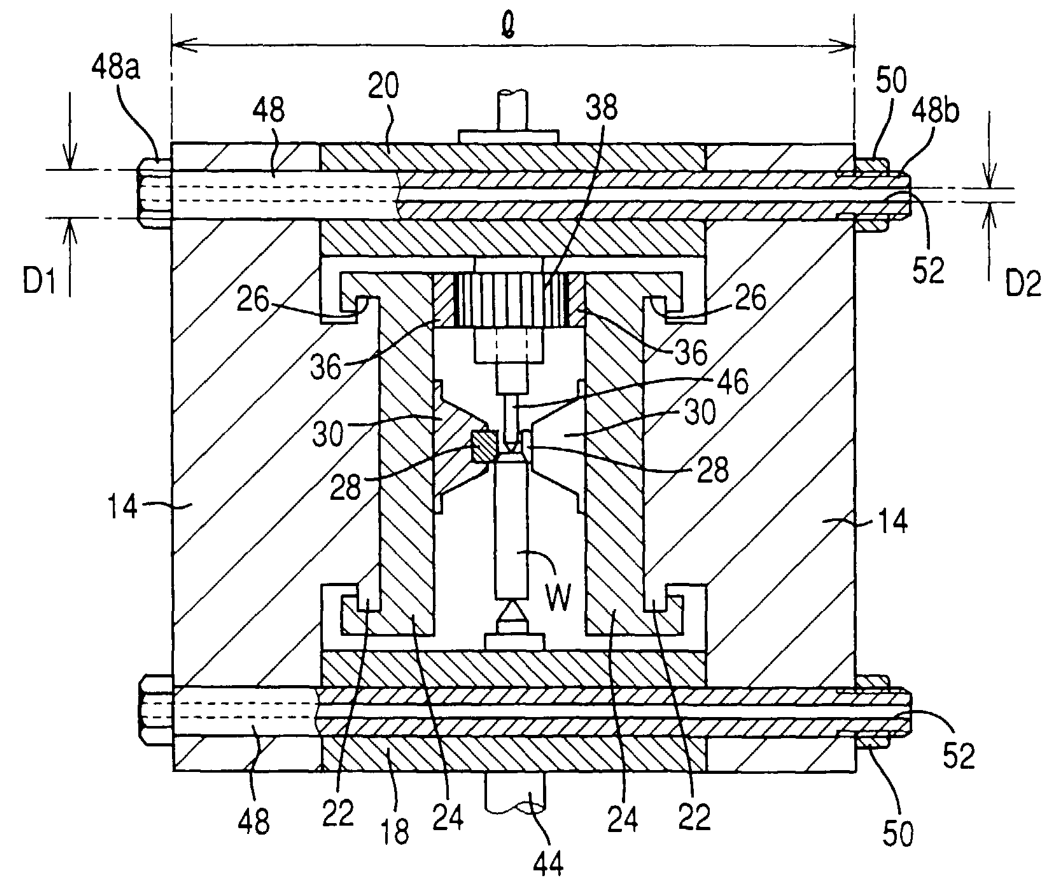

ℓ
48a
48
20
38
50
48b
D1
52
D2
26
26
36
36
46
30
30
28
28
14
14
W
48
22
18
24
44
24
22
52
50

FIG. 3

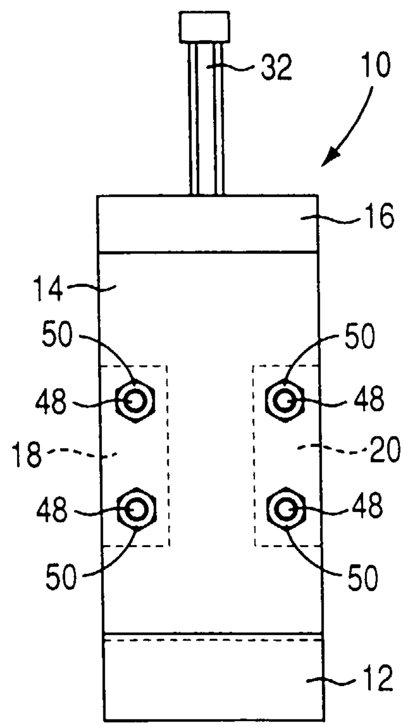


FIG. 4

FIG. 5(a) FIG. 5(b)

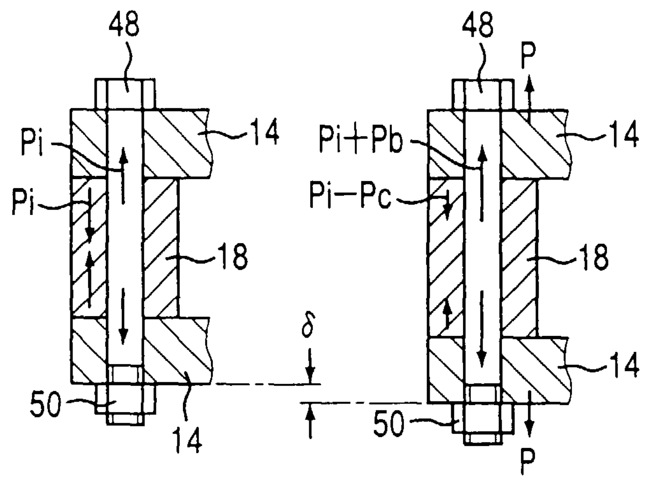
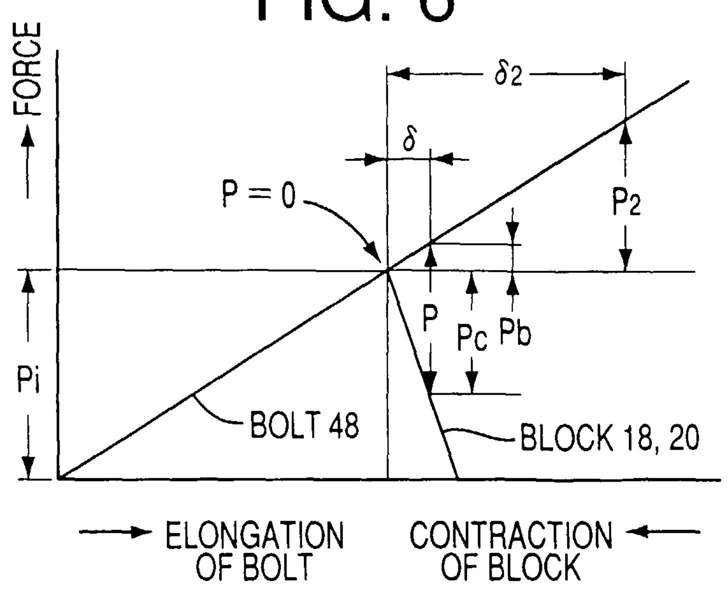


FIG. 6



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 4437

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,A	JP 50 099243 U (...) 18 August 1975 (1975-08-18) * figures *	1-4,9,10	B21H5/02 B21H3/06 B21B31/04 B21H1/18
A	EP 0 123 851 A (OSG MFG ;OSG CORP (JP); NHK BUILDER CO LTD (JP)) 7 November 1984 (1984-11-07) * page 11, line 6 - page 12, line 14; figures 1,2 *	1-4,9,10	
A	US 4 991 563 A (ASHLEY ROYCE C) 12 February 1991 (1991-02-12) * column 1, line 1 - column 2, line 45; figures *	1,9	
A	US 4 622 730 A (STEINBOCK ROLF) 18 November 1986 (1986-11-18) * abstract; figures * * column 1, line 12 - column 2, line 9 *	1,9	
A	DATABASE WPI Section Ch, Week 199046 Derwent Publications Ltd., London, GB; Class M21, AN 1990-347010 XP002126141 -& SU 1 555 005 A (KRAMA IND INST), 7 April 1990 (1990-04-07) * abstract; figures *	1-4,9,10	TECHNICAL FIELDS SEARCHED (Int.Cl.7) B21H B21B B23P B25B
A	US 3 130 628 A (BLINN) 28 April 1964 (1964-04-28) * column 3, line 63 - line 72; claim 1; figures *	1-4,9,10	
	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 December 1999	Plastiras, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 4437

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	PATENT ABSTRACTS OF JAPAN vol. 1995, no. 03, 28 April 1995 (1995-04-28) -& JP 06 335743 A (SHII N K:KK), 6 December 1994 (1994-12-06) * abstract; figures *	1,9	
A	US 2 176 601 A (BATES) 17 October 1939 (1939-10-17)		

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 December 1999	Plastiras, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 11 4437

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-12-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 50099243 U		NONE	
EP 0123851 A	07-11-1984	JP 59174240 A	02-10-1984
		DE 3468341 A	11-02-1988
		KR 8800405 B	22-03-1988
		US 4646549 A	03-03-1987
US 4991563 A	12-02-1991	NONE	
US 4622730 A	18-11-1986	CA 1242089 A	20-09-1988
		DE 3510926 A	10-10-1985
		FR 2562182 A	04-10-1985
		GB 2156935 A,B	16-10-1985
		JP 1877000 C	07-10-1994
		JP 6001084 B	05-01-1994
		JP 61010107 A	17-01-1986
		US RE33490 E	18-12-1990
		AU 584077 B	18-05-1989
		AU 4052285 A	03-10-1985
		BR 8501493 A	26-11-1985
		ES 541699 A	16-03-1986
		IN 161860 A	13-02-1988
		IT 1200434 B	18-01-1989
		ZA 8501815 A	30-10-1985
SU 1555005 A	07-04-1990	NONE	
US 3130628 A	28-04-1964	NONE	
JP 06335743 A	06-12-1994	JP 2860040 B	24-02-1999
US 2176601 A	17-10-1939	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82