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CA 2234218 C 2006/05/30

(11)(21) 2 234 218

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 1998/04/06
(41) Mise à la disp. pub./Open to Public Insp.: 1999/04/08
(45) Date de délivrance/Issue Date: 2006/05/30
(30) Priorités/Priorities: 1997/10/08 (DE197 45 603.0); 1997/11/06 (DE197 50 787.5)

(51) Cl.Int./Int.Cl. *B21B 21/00* (2006.01)

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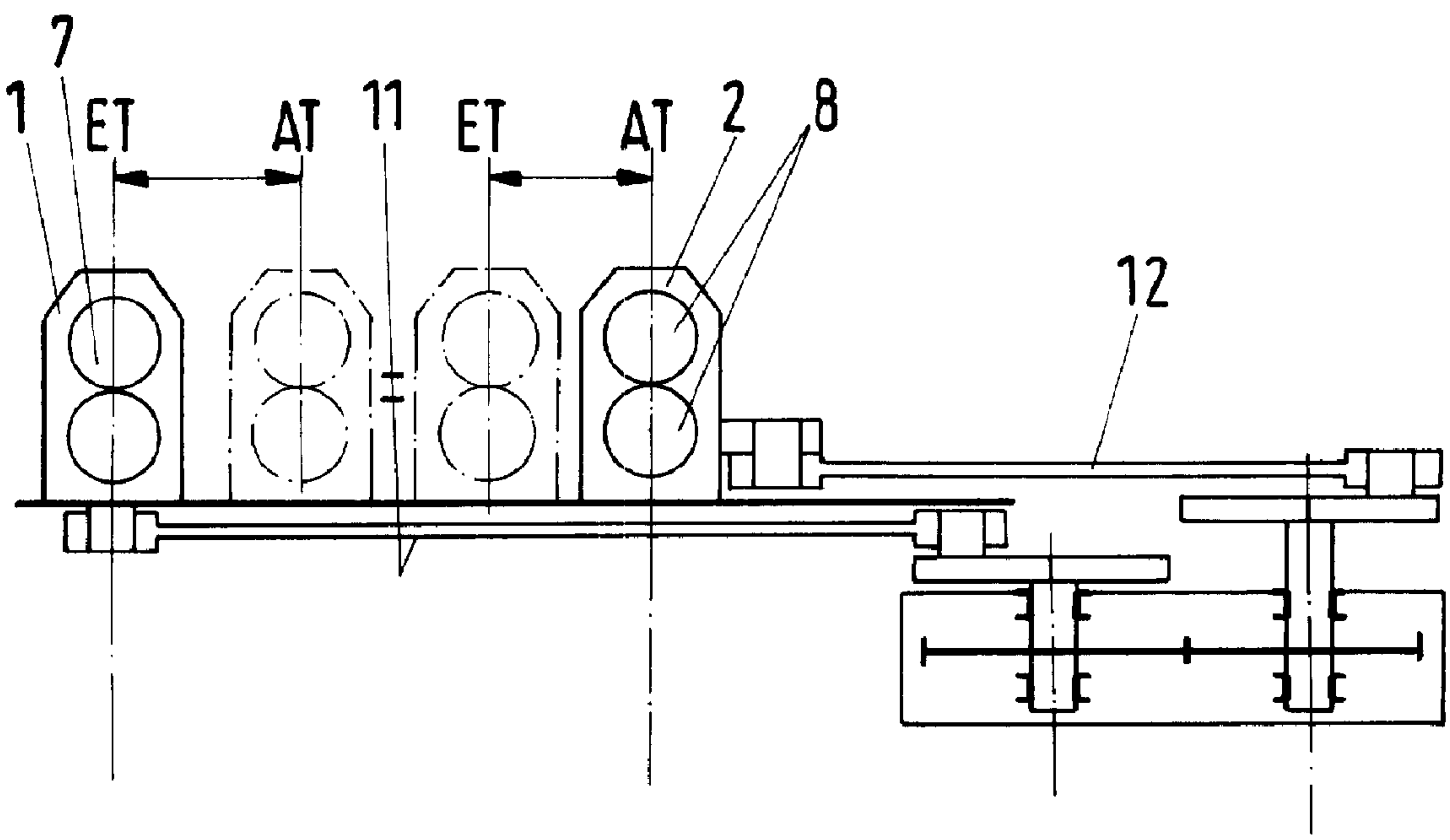
(54) Titre : FABRICATION DE TUBES AU MOYEN DU PROCEDE ETAPE PAR ETAPE DE LAMINAGE A FROID A PAS DE PELERIN
(54) Title: PROCESS FOR MANUFACTURING TUBES USING THE COLD PILGER STEP-BY-STEP PROCESS



(57) Abrégé/Abstract:
The present invention relates to a process and an apparatus for manufacturing tubes, preferably from high-strength steels or special alloys, using the cold pilger step-by-step process, with two roll stands that can be driven, at least intermittently, back and forth in opposite directions by crank drives, said roll stands having tapering grooved rolls that are driven by rack-and-pinion systems and roll over the rolled stock with alternating directions of rotation. The present invention is characterised in that the greater part of the shaping work is performed on the first roll stand and a lesser part is performed on the second roll, where additional smoothing is carried out; and in that in both roll stands reducing rolling is carried out over a mandrel that is matched to the roll calibre; and in that the angular offset of the crank drive systems is so selected that the shaping zone on the first stand does not coincide in time with the shaping zone of the second stand. The present invention also relates to a machine for carrying out the process.

Abstract

The present invention relates to a process and an apparatus for manufacturing tubes, preferably from high-strength steels or special alloys, using the cold pilger step-by-step process, with two roll stands that can be driven, at least intermittently, back and forth in opposite directions by crank drives, said roll stands having tapering grooved rolls that are driven by rack-and-pinion systems and roll over the rolled stock with alternating directions of rotation.

The present invention is characterised in that the greater part of the shaping work is performed on the first roll stand and a lesser part is performed on the second roll, where additional smoothing is carried out; and in that in both roll stands reducing rolling is carried out over a mandrel that is matched to the roll calibre; and in that the angular offset of the crank drive systems is so selected that the shaping zone on the first stand does not coincide in time with the shaping zone of the second stand.

The present invention also relates to a machine for carrying out the process.

Figure 1

Process for Manufacturing Tubes using the Cold Pilger Step-by-Step Process

The present invention relates to a process and an apparatus for manufacturing tubes, preferably from high-strength steels or special alloys, using the cold pilger step-by-step process, with two roll stands that can be driven back and forth in opposite directions at least intermittently, said roll stands having tapering grooved rolls that are driven by rack-and-pinion systems and roll over the rolling stock with alternating directions of rotation.

A significant share of the costs associated with manufacturing and operating cold-pilger rolling mills is brought about by the necessary rotating and forward feed machinery, as well as charging machinery, which are indispensable for the cold pilger rolling process. A significant improvement of the cost-output ratio can be achieved if a significant increase in output can be obtained whilst retaining this machinery and without reducing the number of strokes per minute achieved by said machinery. One way of achieving this is to increase the shaping work done per stroke and per billet, since this brings about a considerable increase in output for only a small increase in investment costs. This applies to cold pilger rolling mills in general and in particular to cold pilger rolling of relatively small pipes from high-strength steels or special alloys.

Compared to modern drawing processes, known cold pilger rolling mills, in which rolling is carried out conventionally with one billet, are burdened by relatively high investment costs and low output. In order to increase output, it has been proposed that cold pilger rolling mills are operated with a plurality of parallel billets, for example, two to four. However, this means higher stand weight and a reduced number of strokes per minute; the costs involved for charging and for rotary feed machinery a considerably greater, whilst the precision of the tubes rolled in this manner leaves much to be desired.

Attempts have also been made to use so-called tandem cold pilger rolling mills in which two pairs of rolls are combined in one stand, one behind the other. Here, too, increased machinery weight and a lower number of strokes per minute are reflected in an unfavourable cost-output ratio; both sets of rolls work simultaneously on the tube volume that has been advanced, with the rolled pipe length of the first roll said being fed to the second set of rolls as the rolled tube length is being advanced. This can cause the tube to bulge in places, and these bulges are associated with lowered production and lower quality.

Finally, Figures 5 and 6 of German Patent Specification 604 909 show a cold pilger rolling mills that has two roll stands that can be moved back and forth in the direction of rolling, at times in opposite directions, by means of crank drive systems; the rolls of these roll stands are driven in alternating directions of rotation by rack and pinion drive systems. This known arrangement provides that in the first roll stand the bloom diameter is reduced exclusively and without a mandrel, with the wall thickness of the tube being reduced over a mandrel in the second roll stand. The arrangement of the crank drive system is so selected that the sequence of movement of the two roll stands, together with the movement of the mandrel bar and the grip applied by the rolls, make it possible to advance the tube in a specific manner.

Even though the explanation of the way in which the known rolling mill system operates does not clarify the exact sequence of the process used to roll tubes, it can be seen that this rolling mill could be operated at a lower output that was adequate for that time but would no longer be equal to the demands now imposed on a modern cold pilger rolling mill. The hollow roll in the first stand results in a deterioration of the interior surface that is unacceptable today and results in only a small increase in output, or none at all, for the essential wall reduction is effected exclusively in the second stand.

It is the task of the present invention to create a cold pilger rolling process and an apparatus for manufacturing tubes, in particular from high-strength steels or special alloys, using the cold pilger step-by-step process, which permits a significant increase of roll output compared to conventional rolling mills, this being done with the lowest possible additional mechanical costs and without any losses of quality.

In order to solve this problem, a process has been proposed that is characterised in that the greater part of the shaping work is performed on the first roll stand and a smaller part is performed on the second roll, where additional smoothing operations are also carried out; and in that in both roll stands, reducing rolling is carried out over a mandrel that is matched to the roll calibre; and in that the angular offset of the crank drive systems is so selected that the shaping zone on the first stand does not coincide in time with the shaping zone of the second stand.

The process according to the present invention permits an extremely high output, in the first place because shaping work is carried out exclusively in the first roll stand, where no smoothing operations are performed. This means that a significant elongation of the reducing pass is made usable and no demands for precision that can reduce output have to be taken into consideration, whereas in the second roll stand, in addition to smoothing operations, a not-inconsiderable amount of additional shaping work is also performed.

The selection of the phase angle between the two roll stands and the configuration of the rolling tools are subjected to far fewer restrictions if the rolls of the second roll stand release the tube at separately definable times, an annular gap being formed intermittently between the tube and the roll. To this end, one version of the present invention provides that the second roll stand is arranged so as to be offset from the first stand by a crank angle of approximately 180° and on the return stroke, during which no reduction takes place, an appropriate annular gap is opened up between the rolled stock and the roll groove, this gap matching the material from the first stand, the tube that has been reshaped in the first roll stand being introduced into this gap.

This process is advantageously put into practice in that at least the rolls of the second roll stand can be adjusted cyclically to another angle. According to the present invention, the adjustment of the rolls is effected by horizontal displacement of the racks, so that the engagement of the roll groove is changed relative to the rolled stock.

As an alternative, it has been proposed that the spacing between the roll axes be varied cyclically relative to each other during the rolling process so as to create the necessary space in the roll groove that accommodates the material from the rolling process of the first roll stand.

In order to save machinery-construction costs incurred for the cyclical generation of the annular gap between calibre development and rolled stock, an alternative version of the present invention proposes that the second roll stand by arranged so as to be offset by approximately 90 to 150° crank angle from the first roll stand; that its rolls be caused to rotate by fixed racks; and that the spacing between the axes of the rolls remains constant during the rolling process.

A machine for carrying out the process is characterised in that the first roll stand is formed as a break-down stand with rolls that are exclusively of the working calibre; in that the rolls of the second roll stand are of working and smoothing calibre; in that the rolls of both roll stands work in conjunction with appropriately calibrated roll mandrels; and in that the crank drives to drive the rolling stands, which are angularly offset, are designed to drive the roll stands by way of connecting rods that are associated with each roll stand and which have vertical axes of rotation, the two cranks rotating in directions that are opposite to each other.

Using a cold pilger rolling mill that is configured in this way, the roll output can be significantly increased relative to conventional rolling mills. By configuring the first roll stand with rolls that are exclusively of the working calibre, the shaping work performed in this stand can be greatly increased, for then the whole of the pass development can be used for shaping work, because no smoothing operations are carried out in this stand. The smoothing work is first performed in the second roll stand in the smoothing pass that is performed there, which is, however, preceded by a working pass during which an additional and not inconsiderable re-shaping of the tube can be effected. In this respect, machine-construction costs for the rotating and feed drive systems and for charging with new blooms are maintained and do not increase relative to a normal, single cold pilger rolling mill. The arrangement of the crank drive angles relative to each other according to the present invention, makes it possible to rotate and advance the billet at suitable times and, in conjunction with other features of the present invention process, prevents the material from backing-up between the rolling stands while the main forming work is being performed on the first roll stand. The opposite directions of rotation of the two cranks permits a very favourable compensation of the mass forces of the first harmonics and thus permits a large number of strokes per minute that does not have to be reduced vis-à-vis a conventional, single cold pilger rolling mill since, because of the design that has been selected, the inertial forces do not increase.

The machine-construction outlays for a crank-drive system of this kind are only slightly greater than for a drive system used for an individual stand. The arrangement of the crank drives with vertical axes of rotation makes it possible to dispense with deep foundations for the mechanical counterbalances. The space between the two roll stands can be minimised, for example, if according to a further feature of the present invention the connecting rods for each roll stand rotate in planes that are arranged one above the other, or if the two rolling stands are arranged above the crank drives in such a way that the pivot point for the connecting rods are located on the two points of the roll stand that are furthest from each other.

It is preferred that a common crank drive with rotating counterbalance weights be provided for both roll stands on the two counter-rotating crank throws, which compensate the first order of inertial forces, whereas at least a partial compensation of the inertial forces of the second order can be effected by the interaction of the stand masses. A phase angle of 90° is optimal from the aspect of inertial-force compensation, since given this prerequisite the inertial forces of the second order eliminate each other. Nevertheless, difficulties relating to roll technology cannot be ruled out such an arrangement.

In one design variant, the cranks are driven in the same direction and part of the inertial forces of the first order are compensated with counterweight on the cranks. The remainder of these inertial-force components are either uncompensated or are compensated with counterweights on an intermediate shaft that connects the two cranks by way of gear wheels, this intermediate shaft rotating at the same speed of rotation as the crank although in the opposite direction.

It is, however, also possible to provide each roll stand with a dedicated crank drive with inertial compensation, in which case the drive of the second roll stand can preferably be made somewhat lighter than the first roll stand. This means that the drive system for the second roll stand can be smaller, lighter, and less costly than that used for the first roll stand. The phase angle between the two stands can be varied quite simply with separate crank-drives. It is also possible to house the cranks that drive the two roll stands in one housing but drive them by separate motors, so that variation of the phase angle of the two cranks is made possible in a simple manner. The mass balancing of the first order then requires two rotating weights on each crank such that the larger weight is connected rigidly with the crank, whereas the position of the second relative to the crank can be adjusted, for example, by an eccentric that can be rotated about the centre of the crank.

In a further variant of the cold pilger rolling mill according to the present invention, the two roll stands are of different weights and are even operated with different strokes, when once again appropriate counterweights on the counter-rotating shafts or cranks provide for complete equalisation of the first-order inertial forces.

In order to vary the angular gap between calibre development and rolled stock, a further feature of the present invention makes provision such that at least the pinion racks of the second rolling stand are provided with a shifting device to adjust the pinion racks in their longitudinal direction.

As an alternative, it is possible to provide a cyclically adjustable wedge mechanism to adjust the distance between the axes of at least the rolls of the second roll stand.

From the standpoint of roll technology, it is particularly advantageous to operate the crank drive systems with a phase angle of 180° so that it is possible to rotate and feed the rolled stock at both dead centre positions. The double rotation and feed would increase both the quantity and quality of the product even more here, as in the case of conventional rolling mills. At all events, the second order inertial forces are combined in this case and the cyclical generation of an annular gap between the rolled stock and calibre development during the return stroke of the second stand appears to be necessary.

Cold pilger rolling of thin-walled pipes of small diameter is possible with any rotating and feed movements, e.g., even with continuous movements. If a rolling mill according to the present invention is used, this thin-walled pipe is produced by the second roll stand. Since, in this case, the tube can be fed to the second roll stand in any manner, the rotating and feed movement can be established independently of the phase position of the two roll stands, exclusively on the basis of the demands of the first roll stand, e.g., as rotation and advance at both dead centre positions. In the case of these thin-walled products, the cold pilger process also permits rotation and advance of the tube even though the rolls are still in contact with the tube on the smoothing roll. This means that the pass of the rolls of the second roll stand can also be extended as far as the exit dead centre position of this roll stand.

The present invention combines a series of advantages relative to the prior art. Since the machine-construction outlays for the rotations and feed drive system and for charging with new billets are not increased compared to a normal simple cold pilger rolling mill, the rolling mills can be manufactured at a good cost-performance ratio. The rolling mill can be run at a greater number of strokes per minute, which does not have to be reduced relative to a normal simple rolling mill since the inertial forces do not increase, because of the stand and crank-drive arrangement. The machine-construction outlays for the crank drive are only slightly higher than those for a drive used for only one stand. Particular emphasis should be placed on the fact that the pass length of the first stand can be used completely for shaping, since a smoothing roller is not necessary here and no demands with respect to precision need be taken into account. This results in a noticeable increase in performance, and this is additionally increased in that additional shaping takes place in the second stand. At the same time, relative to former rolling mills, there is the possibility of a significantly longer smoothing pass in the second rolling stand and this reduces manufacturing tolerances still further, despite increased production quantities.

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According to one aspect of the present invention, there is provided a method for manufacturing a tube comprising: feeding a workpiece to be formed into a tube to a cold rolling mill; cold rolling said workpiece in said mill, said mill comprising two rolling stands which are movable in a backward and forward direction and optionally opposite directions and in the rolling direction by crank drives, said rolling stands having rollers which are calibrated in a tapering manner and which are driven by toothed racks via cogs, and roll over the workpiece with an alternating rotation direction, wherein the majority of the forming work is performed on the first rolling stand and a relatively small portion of the forming work is performed on the second rolling stand and additional smoothing work is carried out, wherein reduction rolling takes place in both rolling stands via a mandrel which is matched to the roller caliber, and wherein the crank drives are angularly offset such that the forming zone of the first stand does not occur at the same time as the forming zone of the second stand.

According to another aspect of the present invention, there is provided an apparatus for manufacturing a tube comprising: two rolling stands which are movable in a backward and forward direction in a guide, and optionally in opposite directions; crank drives for moving said rollers in the rolling direction; push rods which are allocated to each rolling stand and have vertical axes of rotation whereby the crank drives drive the rolling stands; and rollers which are calibrated in a tapering manner, said rollers being driven via toothed racks via cogs, to roll over the material to be rolled, with an alternating rotation direction, wherein the first rolling stand is a break-down stand with rollers which have only the working caliber, and the rollers of the second rolling stand have working and smoothing calibers, and a correspondingly calibrated rolling mandrel which interacts with the rollers of both rolling stands.

The present invention will be described below on the basis of examples shown in the drawings appended hereto. These drawings show the following:

Figure 1: a diagrammatic side view of a rolling mill according to the present invention;

Figure 2: a plan view of the rolling mill shown in Figure 1;

Figure 3: a tabular comparison of two embodiments.

The two roll stands 1 and 2 are driven by a common crank drive 3 in such a way that the inertial forces of the first order of both roll stands are completely balanced out. In this embodiment, the counter- rotating balance weights 4 and 5 (Figure 2) compensate only the rotational imbalances of the cranks and connecting rods.

Each roll stand 1 and 2 is driven by only one of the connecting rods 11 and 12, these connecting rods moving in planes that are located one above the other. This is made possible in that the connection point for the first roll stand 1 is located beneath said roll stand 1 and the connection point for the second roll stand 2 is located ahead of this roll stand 2. At the entry dead centre point ET, both sets of rolls 7 and 8 release the rolled stock for rotation and advance, and at the exit dead centre point AT the rolled stock is released for additional rotation, albeit briefly.

Whereas on the fore stroke of the roll stand 1 as it moves from ET to AT, the advance or feed volume is rolled out and lengthens accordingly, the rolls 7 of the roll stand 2 that are on the return stroke are so rotated by an adjuster system 9 for the pinion racks 10 that the rolls 8 of the roll stand 2 do not cause any reduction, or do so only by an insignificant amount, when they are moving from AT to ET. In the entry area, the adjustment mechanism 9 cancels this adjustment again. On the path from ET to AT, when the roll stand 1 is on the return stroke, for all practical purposes without any plastic shaping work being done, the feed volume previously stretched on the fore stroke of the roll stand 1 is rolled out in roll stand 2 by the length advance times the stretch of the first roll stand 1.

The rolling mill according to the present invention, which is shown in the drawings, and which provides approximately twice the output of a conventional rolling mill, is characterised in that the complete rotation, feed, and charging machinery remains unchanged; in that the oscillating compensating masses of a conventional rolling mill are replaced by a second roll stand; and in that only the additional roll axes with their rack and pinion drive systems are additionally required.

Two exemplary embodiments are described below to provide additional explanation of the present invention and these are also set out in tabular form in Figure 3. Example 1 describes a classic stainless steel rolling process for heat-exchanges tubes and Example 2 clarifies the exploitation of the greater ductility of austenitic steels in order to achieve a greater reduction of cross section.

<u>Example 1</u>

In the table, Example 1 refers to classical rolling of stainless steel for heat exchanger tubes measuring 16 x 1 that, based on experience, can be rolled with approximately 18 mm rolled-out tube length per stroke; at 320 strokes per minute, this results in a theoretical roll output of 346 metres/hour. Of the total pass length of 370 mm, 100 mm smoothing pass is provided for, i.e., approximately 27% that for all practical purposes contribute nothing to the shaping process.

In the case of the rolling mill according to the present invention, no smoothing pass is required in the first roll stand, so that the shaping zone can be lengthened accordingly to 370 mm. This, together with the fact that only a reduction of 33 x 3.5 to 20 x 1.5 is provided in the first roll stand permits at least a 15% increase of the output in mm per roll stand stroke. Since not only the finished tube length per stroke, but also the tube cross section is increased from 16 x 1 to 20 x 1.5, this results in an increase of the throughput weight from 128 to 272 kilograms/hour, i.e., a performance increase of 113%.

The forward feed of 5.6 mm in the first roll stand takes place when the first roll stand is at the entry dead-centre position and the second roll stand is at its exit dead centre position, i.e., the shaping that is done in the first roll stand is effected essentially on its fore stroke, when the second roll stand is on its return stroke. Thus, the forward feed volume of 20 x 1.5, 5.6 mm long, is passed to the latter when it is in its exit dead centre area and this lengthens to 20.7 mm during its return stroke. This means that prior to the start of its fore stroke, a forward feed volume of 20.7 mm is fed to the second roll stand and at a stretch of 1.85 this is rolled out to 38 millimetres in the second roll stand.

One problem that is to be solved is that the rolled stock can be fed forward without hindrance during the return stroke of the second roll stand. To this end, in the present example, the rolls are so rotated by means of cyclical adjustment of the rack and pinion adjustment systems that rotates the rolls that they release the tube on the return stroke. This adjustment is cancelled out in the changeover area of the entry dead centre point. Thus, prior to the start of the roll on the fore stroke, a forward feed of 20.6 mm takes place during the fore stroke and the rolls are once again in the correct position for rolling. Next, on the fore stroke, the 20.6 mm forward feed is rolled, with a 1.85 stretch, to 38 mm tube length per stroke. The output of the rolling mill according to the present invention is thus increased to 2.13 times that of a conventional rolling mill.

Example 2

Whereas the first example shows the output increase given an unchanged tube cross section, in the second example, the great ductility of austenitic steels is exploited to increase the stretch achieved by the rolling mill according to the present invention.

Based on a conventional rolling mill, Example 2 shows the rolling of 33 x 3.5 to 16 x 1 in Example 1, but for the rolling mill according to the present invention, however, 33 x 3.5 to 12 x 1. In this case, the output in metres/hour is approximatley doubled, and the throughput in kilograms/hour is increased by almost 50%, despite the lower weight per meter.

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CLAIMS:

1. A method for manufacturing a tube comprising:

feeding a workpiece to be formed into a tube to a cold rolling mill;

cold rolling said workpiece in said mill, said mill comprising two rolling stands which are movable in a backward and forward direction and optionally opposite directions and in the rolling direction by crank drives, said rolling stands having rollers which are calibrated in a tapering manner and which are driven by toothed racks via cogs, and roll over the workpiece with an alternating rotation direction, wherein the majority of the forming work is performed on the first rolling stand and a relatively small portion of the forming work is performed on the second rolling stand and additional smoothing work is carried out, wherein reduction rolling takes place in both rolling stands via a mandrel which is matched to the roller caliber, and wherein the crank drives are angularly offset such that the forming zone of the first stand does not occur at the same time as the forming zone of the second stand.

2. The method of claim 1 wherein the second rolling stand is arranged with the crank drive angle offset through about 180 degrees with respect to the first stand and, during the reverse stroke when no reduction takes place, opens up an annular gap which corresponds to the workpiece received from the first stand, between the material to be rolled and the roller caliber, into which annular gap the tube which has been formed in the first rolling stand is inserted.

3. The method of claim 1 wherein the toothed racks are cyclically displaced horizontally for the rotational drive.

4. The method of claim 1 wherein the distance between the roller axes is varied cyclically during the rolling process.

5. The method of claim 1 wherein the second rolling stand is arranged at a crank angle offset of about 90 to 150 degrees with respect to the first rolling stand.

6. The method of claim 5 wherein the rollers of the second rolling stand are driven to rotate by fixed-position toothed racks.

7. The method of claim 6 wherein the distance between the roller axes remains constant during rolling.

8. The method of claim 1 wherein the tube is comprised of a high-tensile steel as a special alloy.

9. An apparatus for manufacturing a tube comprising:

two rolling stands which are movable in a backward and forward direction in a guide, and optionally in opposite directions;

crank drives for moving said rollers in the rolling direction;

push rods which are allocated to each rolling stand and have vertical axes of rotation whereby the crank drives drive the rolling stands; and

rollers which are calibrated in a tapering manner, said rollers being driven via toothed racks via cogs, to roll over the material to be rolled, with an alternating rotation direction, wherein the first rolling stand is a break-down stand with rollers which have only the working caliber, and the rollers of the second rolling stand have working and smoothing calibers, and a correspondingly calibrated rolling mandrel which interacts with the rollers of both rolling stands.

10. The apparatus of claim 9, wherein each of the push rods of each rolling stand moves in a plane, said planes being vertically displaced one above the other.

11. The apparatus of claim 9 wherein a common crank drive is provided for both rolling stands and has contrarotating cranks and rotating balance weights on the two crank bends.

12. The apparatus of claim 11 wherein the rotating counterbalances completely compensate for first-order mass forces, and partially compensate for higher-order mass forces being provided by the interaction of the stand masses.

13. The apparatus of claim 9 wherein the cranks are driven in the same rotation direction, and a portion of the first-order mass forces of the cranks is in each case compensated for by counterweights, and the remaining portion of this mass force component.

14. The apparatus of claim 9 wherein the cranks are driven in the same rotation direction, and a portion of the first-order mass forces of the cranks is in each case compensated for by counterweights, and the remaining portion of this mass force component for by counterweights on an intermediate shaft which connects the two cranks via gear wheels and rotates at the same speed as the cranks, but in the opposite rotation direction.

15. The apparatus of claim 9 wherein each rolling stand has a corresponding crank drive with mass balancing.

16. The apparatus of claim 15 wherein the drive for the second rolling stand is weaker than that for the first rolling stand.

17. The apparatus of claim 9 wherein at least the toothed racks of the second rolling stand have a displacement device for displacing the toothed racks in their longitudinal extending directions.

18. The apparatus of claim 9 wherein a cyclically adjustable wedge mechanism is provided for adjusting the distance between the axes of at least the rollers in the second rolling stand.

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PATENT AGENTS

Fig.1

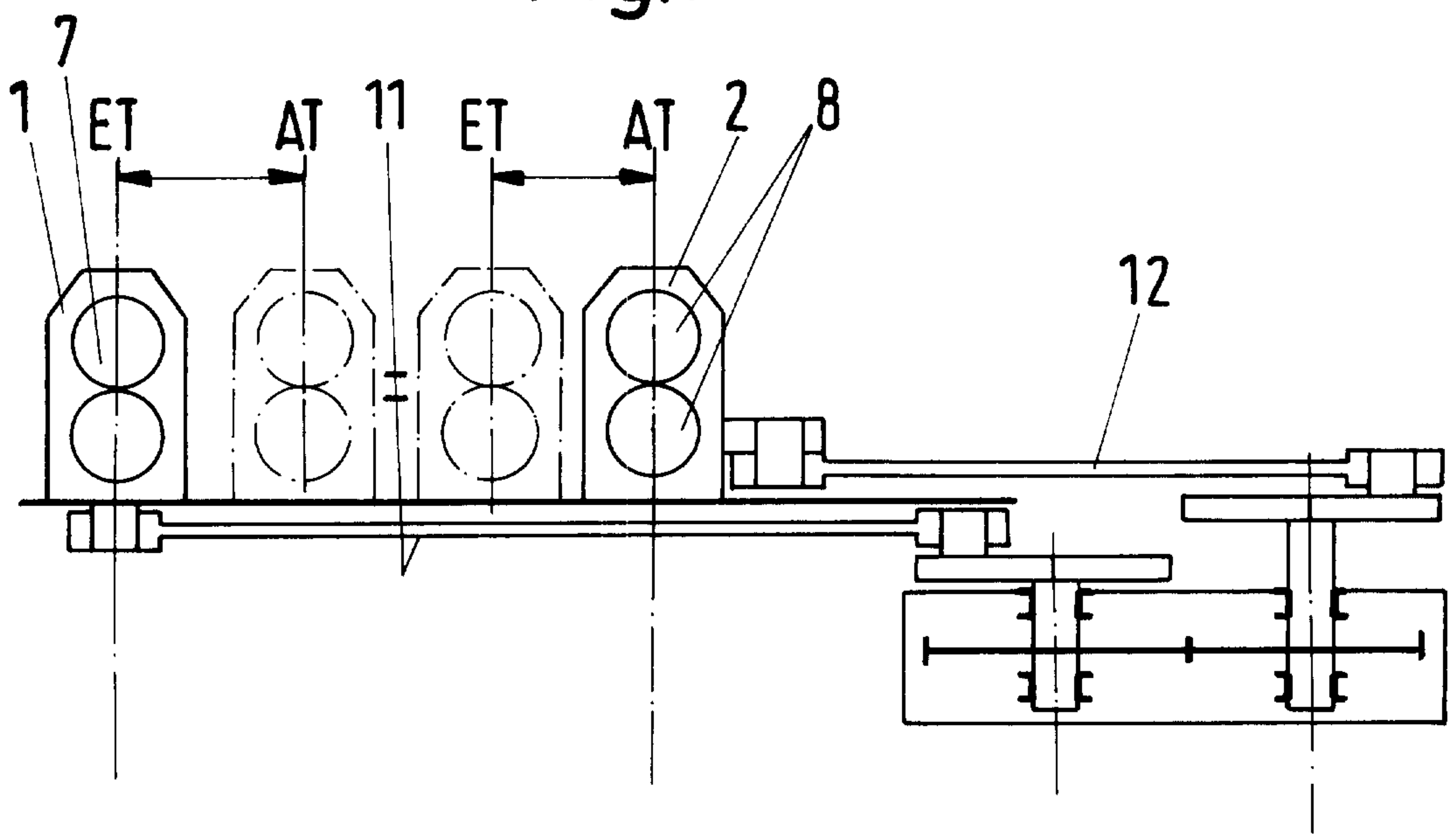
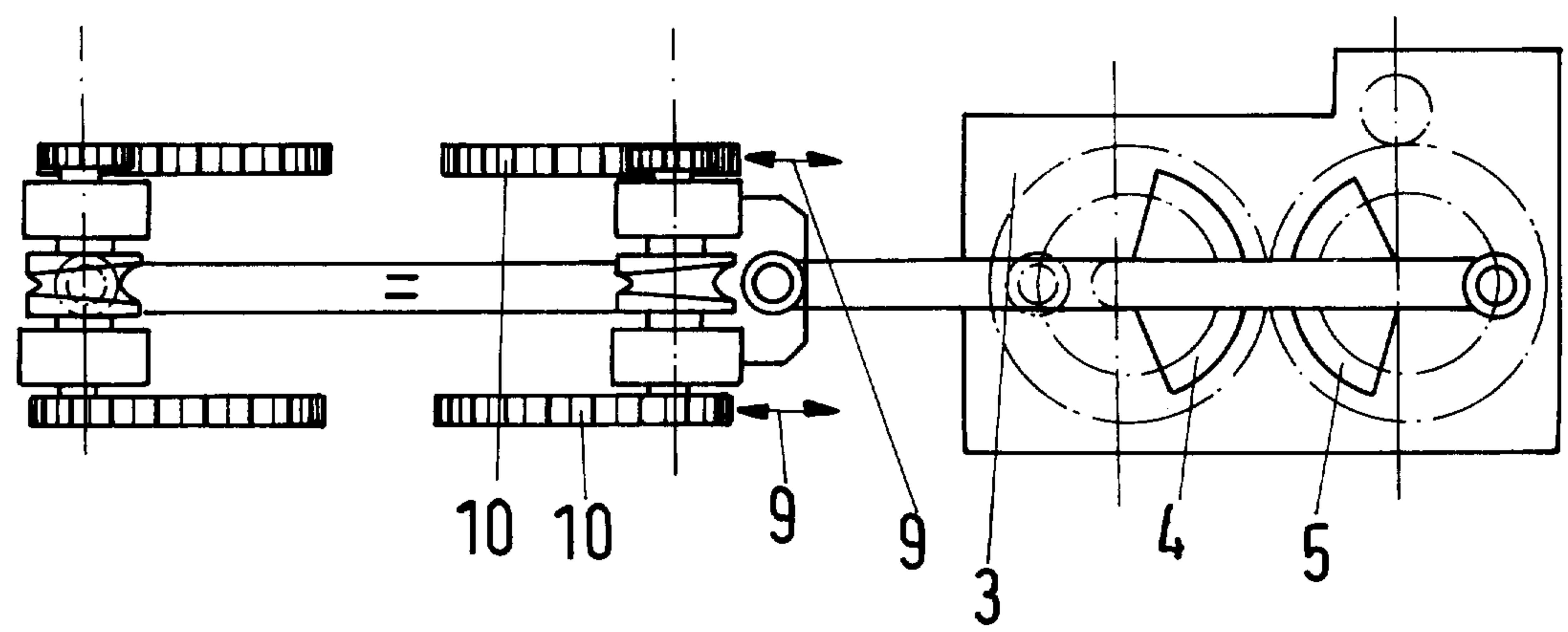


Fig.2



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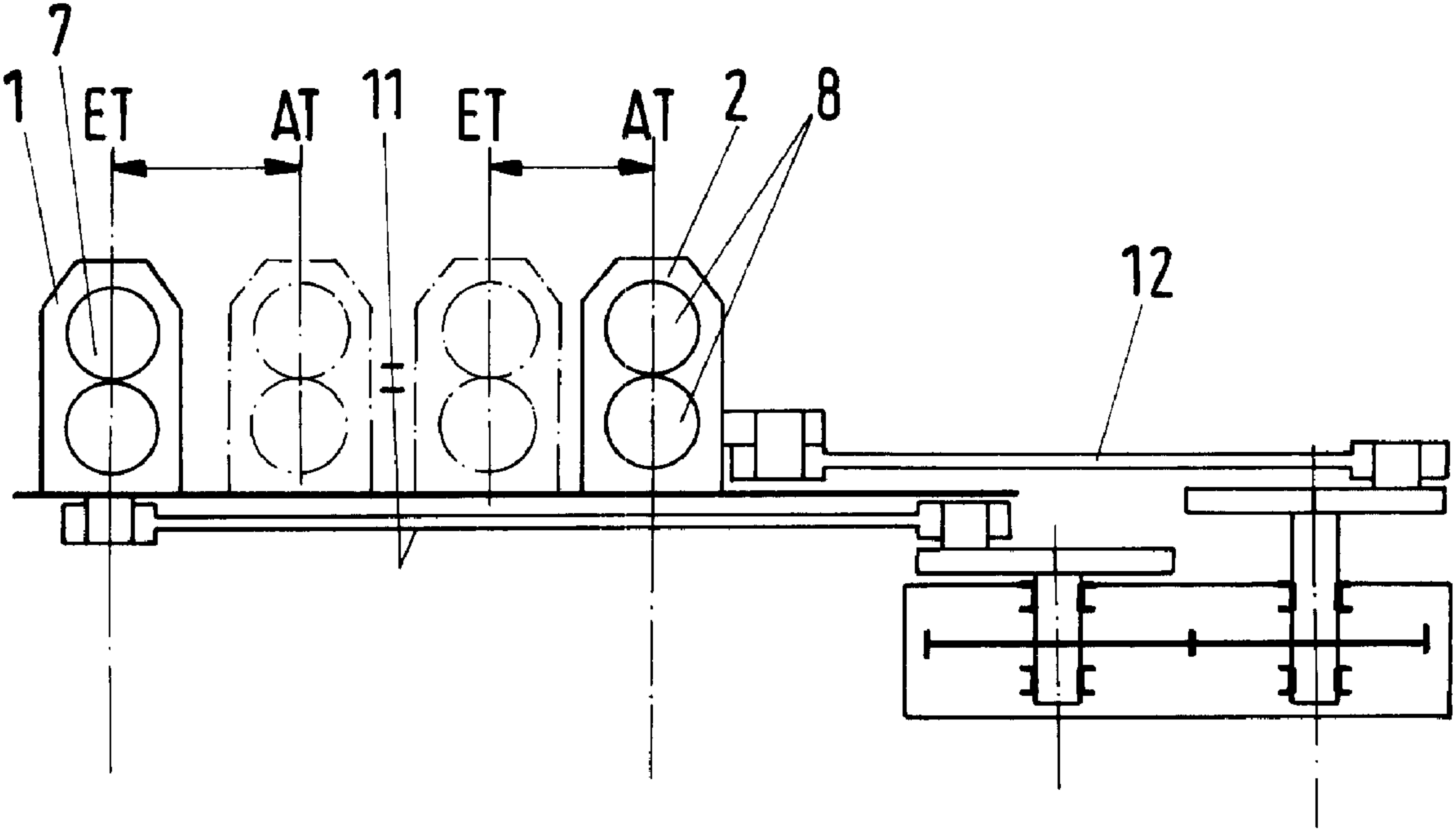
Example 1

		Conventional Rolling Mill	Rolling Mill according to the invention	
same stretch			1st Stand	2nd Stand
billet - outside diameter	mm	33	33	20
billet wall	mm	3.5	3.5	1.5
tube - outside diameter	mm	16	20	16
tube - wall	mm	1	1.5	1
stretch	--	6.88	3.72	1.85
stroke number	min^-1	320	320	320
total pass length	mm	370	370	370
reducing pass length	mm	270	370	270
smoothing pass length	mm	100	0	100
tube per stroke	mm	18	20.7	38
partial stretch	--	6.88	3.72	1.85
forward feed	mm	2.6	5.6	20.7
theoretical performance	m/h	346	397	735
	kg/h	128	272	272
	%	100	115	213

Example 2

		Conventional Rolling Mill	Rolling Mill according to the invention	
increased stretch			1st Stand	2nd Stand
billet - outside diameter	mm	33	33	16
billet wall	mm	3.5	3.5	1.3
tube - outside diameter	mm	16	16	12
tube - wall	mm	1	1.3	1
stretch	--	6.88	5.40	1.74
stroke number	min^-1	320	320	320
total pass length	mm	370	370	370
reducing pass length	mm	270	370	270
smoothing pass length	mm	100	0	100
tube per stroke	mm	18	21	36
partial stretch	--	6.88	5.40	1.74
forward feed	mm	2.6	3.9	21.0
theoretical performance	m/h	346	403	700
	kg/h	128	190	190
	%	100	117	203

Figure 3



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ET
AT
11
ET
AT
2
8
12