May 26, 1936. K. KORBULY 2,041,937

TUBE ROLLING PROCESS

Filed Oct. 23, 1935

Fig. 1

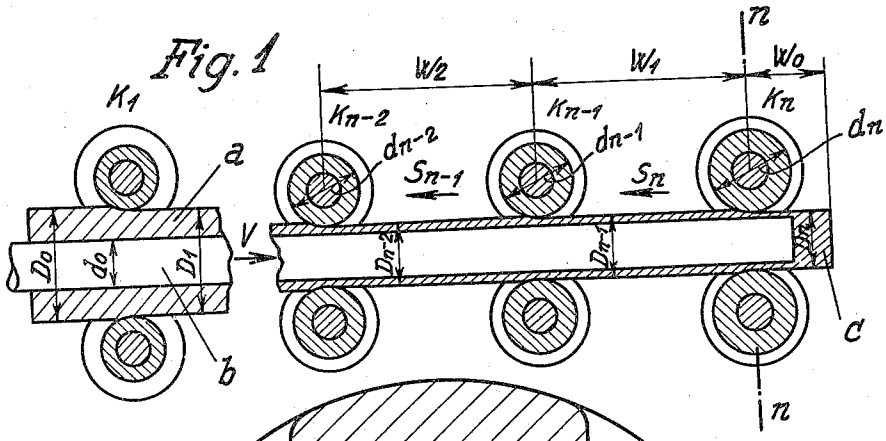


Fig. 2

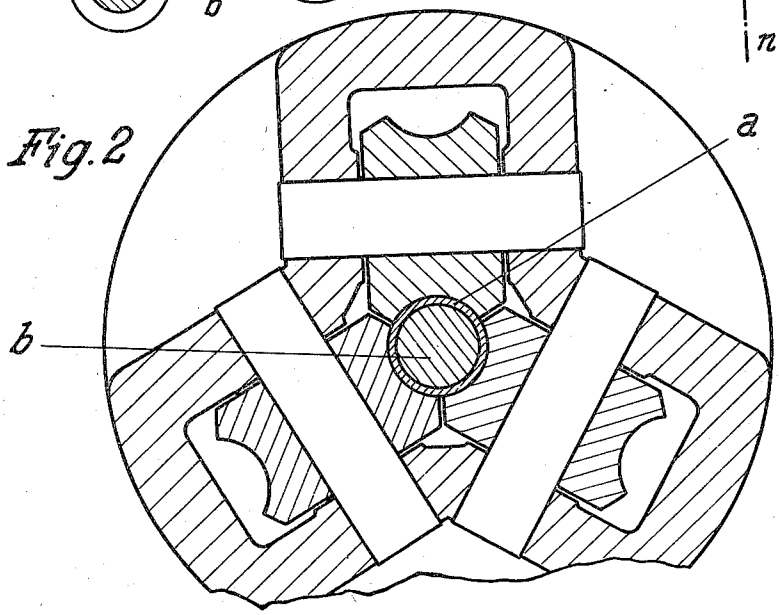
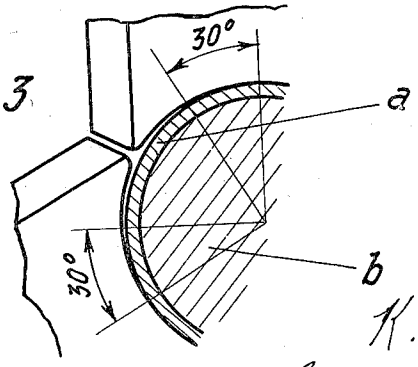


Fig. 3



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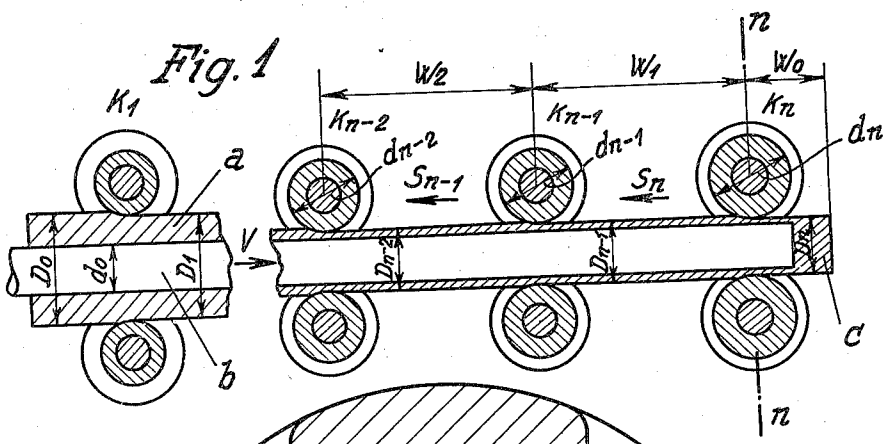


Fig. 2

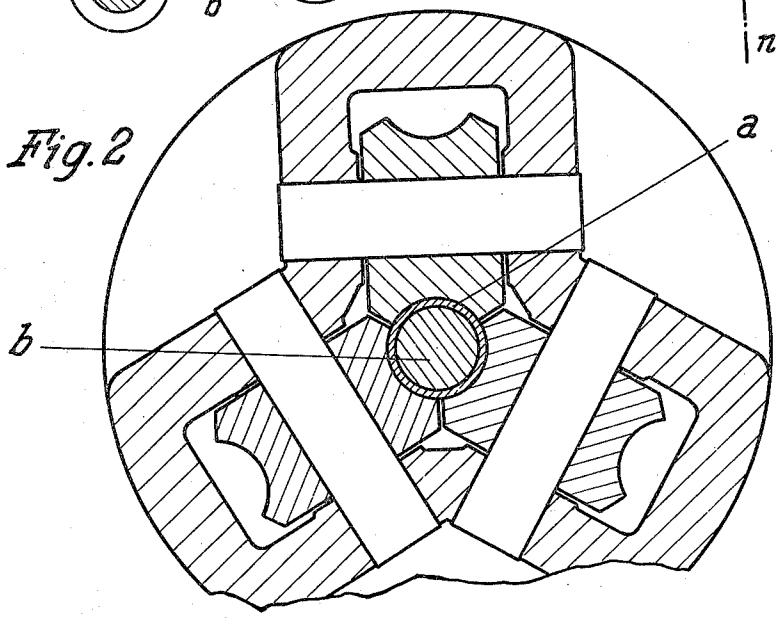
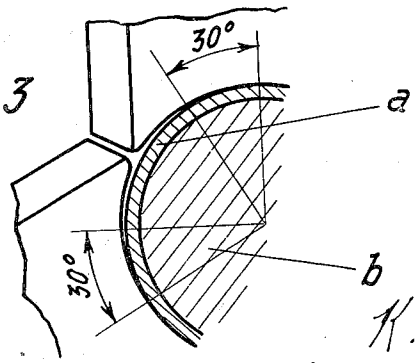


Fig. 3



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2,041,937

TUBE ROLLING PROCESS

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Application October 23, 1935, Serial No. 46,402
In Austria October 27, 1934

2 Claims. (Cl. 80—62)

Attempts have often been made to make seamless metal tubes by drawing or rolling on a mandrel from a blank in one heat with a small wall thickness, and with a reduction in the cross-sectional area of the material of the blank down to 1/15 and at least 1/5, but heretofore it has not been possible to obtain useful results in the case of hard metals, such as iron.

Since such a considerable reduction in the cross-section requires a comparatively large number of drawing tools arranged in series, the said number exceeding the denominator of the fraction representing the reduction in cross-section, the stresses produced in the material are very considerable. The high frictional resistance which occurs in the usual rigid passes and which has to be overcome by the pressure of the drawing or forcing mandrel acting upon the bottom of the tube blank should not attain the tensile strength of the material in the smallest cross-section of the blank, that is to say, in the vicinity of the bottom of the blank, and thereby a narrow limit is set to the maximum reduction in cross-section attainable in one working operation.

In order to minimize the friction, it is known to construct the drawing passes of loose rolls, but in this case also the blank on the mandrel had to pass through only one drawing stage in one working operation, so that a thin-walled tube can only be made by repeated treatment on the drawing bench.

It is also known to pass the blank in one working operation on the same drawing bench successively through two drawing passes formed by loose rollers, but in this case the second pass is of a shape to flatten only the ribs produced in the first pass, and to loosen the tube on the mandrel without any further reduction of its wall thickness.

According to another known proposal, in order to reduce the resistance of the drawing passes formed by the rolls, the rolls of the passes are set in rotation by the fact that the drawing passes driven by the blank roll on tracks on the drawing bench. Since however, the peripheral speed of the rolls is dependent upon the feed of the blank, the differences in the internal diameters of the various passes may only be small. It is also not possible in this way to attain any considerable reduction in cross-section in one working operation.

It is further known to drive the rolls of the drawing passes through which the blank is drawn by the mandrel, positively by means of a gear wheel mechanism, so that the feeding of the blank is effected both by the driven mandrel and by the driven rolls of the drawing passes, on the assumption that it is thereby possible to obtain a much greater reduction in one operation than previously. In this case, however, the pressure produced in the pass is so high that the metal is forced deeply into the gaps between the rolls, and the resulting rib formation gives rise to fresh difficulties. A number of various proposals have been made to remove these difficulties. It was then recognized that it is impossible to effect a considerable reduction in cross-section in one drawing pass, even if the pass is composed of rolls of the smallest possible diameter and both the rolls and the mandrel are driven positively, but that it is necessary to arrange a relatively large number of drawing passes in series the positive drive of such passes being, however, retained. In this case, however, there is the difficulty of having to drive the rolls of different drawing passes at different speeds, which latter have to be adapted to the size of each particular pass and the degree of reduction occurring in the various passes, so that special change speed gears would have to be incorporated for each of the large number of drawing passes to be employed, which would result in very considerable constructional difficulties rendering the practical application of this proposal impossible.

Attempts have therefore been made to dispense with the positive drive of the rolls of the drawing passes. According to a known proposal in this direction, the rolls of every alternate drawing pass are provided with a positive drive whilst the rolls of the intermediate passes are driven by the blank.

Finally, there are also entirely non-driven rolls in a plurality of drawing passes arranged in series. The arrangement according to this proposal, however, is such that during the main drawing operation the blank is forced from a closed cylinder by a special plunger, after the manner of an extrusion press through the pass and around the mandrel which is stationary relatively to the forwardly-driven blank. In addition, the outer surfaces of the rolls are supported on stationary drawing rings, so that they are unable to move freely during pressing, that is to say, the friction in the drawing pass will not be a rolling one. In addition the ratios of the roll diameters to the pass apertures are not selected so that the desired effect can be attained, even if braking of the rolls by the stationary drawing rings did not take place.

It is thus intended to solve the problem of

drawing seamless tubes of hard metal, particularly iron, starting from the tube blank, down to the usual wall-thickness of gas piping in one working operation by forcing the glowing blank carried by the mandrel through a large number of drawing passes disposed in series and formed by non-driven rolls. Since in this case the force required for drawing is transmitted to the blank solely through the mandrel applied against the bottom of the tube blank, then—if the total reduction in cross-section to be effected in one working operation is so great that the force necessary for this purpose, together with that required for overcoming the frictional resistance of the drawing passes, would produce in the smallest cross-section of the blank a stress exceeding the tensile strength—rupture of the blank in the dangerous cross-section would necessarily occur. The stress in the dangerous cross-section cannot be diminished in practice to any desired extent by increasing the distances at which the drawing passes follow one another so far that only one or only a few of the large number of drawing passes required for effecting the desired total reduction in cross-section, act simultaneously on the blank at any given instant. In this case, the drawing bench would have to be so long as to give rise to difficulties in regard to its construction. In addition, since the speed of the blank cannot be increased to any desired extent, the blank would cool during the time required for passing through the entire series of drawing passes, below the temperature necessary for the treatment before the completion of the working. The means for reducing the resistance opposed to the passage of the blank through the passes by constructing the drawing passes of rolls of the smallest possible size is not in itself sufficient to produce such a considerable reduction of the stress in the dangerous cross-section of the blank that it would be possible to discard the external drive of the rolls or of some of them.

In order to obviate entirely the use of driven rolls it has now been proposed to provide behind or between the drawing passes, wherein rolls in the narrowest cross-section have at the most twice the diameter of the corresponding pass, also passes which produce an increased friction by the fact that the diameter of the rolls forming these passes is greater than that of the other rolls and in the narrowest cross-section amounts to from 1.5 to 4 times the diameter of the pass.

It has now been found that this object is not achieved with all arrangements of passes wherein the roll diameters are below the above-mentioned limit value of at the most twice the diameter of the pass at the largest pass, and wherein for some passes, the friction passes, the roll diameters are between 1.5 and 4 times the diameter of the pass, and that the sequence in which the rolls of different diameters follow one another is not a matter of indifference.

The difficulties produced by the tensile-stresses exerted on the blank and the necessity for taking special steps to diminish these stresses come of course into consideration only when it is necessary to attain in one operation the greatest possible reduction in cross-section of the material, for instance down to at least $\frac{1}{5}$ to $\frac{1}{15}$ and below, the reciprocal value of the reduction in cross-section being termed the "reduction factor". The optimum conditions both with regard to the length of the drawing or forcing bench and with regard to the power required are provided if an endeavour is made to effect the reduction to be performed with the smallest possible number of passes, that is to say, each pass effects a reduction of about 20% to 25% relatively to the entrance cross-section of the material in the respective pass.

For a total reduction to $\frac{1}{5}$ of the cross-section of the material it will be necessary to have at least 6 roll passes arranged in series, for a reduction to $\frac{1}{10}$ at least 12 and for a reduction to $\frac{1}{15}$ at least 15, i. e. a number of roll passes at least equal to the reduction factor will be necessary.

According to the invention, it is important that the roll diameter measured at the bottom of the groove, that is to say, the trough diameter of the rolls in the largest pass should be at least 0.3, and in the smallest pass should be at the most 2.5 times the corresponding internal diameter of the pass, and that the ratio between the roll diameter and pass diameter increases gradually from the largest pass to the smallest pass.

In making tubes of a diameter below about 100 millimetres and having the usual wall-thickness of gas piping, about 2–3 millimetres, the roll diameter, which within the above mentioned limits is smaller at the largest pass than the internal diameter of the pass, increases according to the invention gradually towards the smallest pass to exceed the internal diameter of this pass. Preferably the actual size of the rolls of the smallest pass, within the value

$$d > D,$$

D being the internal diameter of the pass and d the trough diameter of the rolls of this pass, will be made as small as possible but large enough for the ratio

$$\frac{d}{D}$$

to be diminished in stages which must satisfy the requirements set forth hereinafter, towards the largest, that is to say the first, drawing pass, without reaching the limit value d being only 0.3 of D, beyond which d cannot be practically decreased.

In drawing a tube blank of 102 millimetres in diameter with a mandrel of 49 millimetres diameter down to 55 millimetres external diameter, good results have been obtained for example with fifteen passes disposed in series, in which, in the smallest, i. e. the fifteenth pass

$$\frac{d_{15}}{D_{15}} = 1.36$$

and in the first, i. e. the largest pass

$$\frac{d_1}{D_1} = 0.72$$

The choice of the size of the diameter of the rolls of the several passes or the graduation of the diminution of the roll diameters are based on the following considerations explained with reference to the accompanying drawing.

Figure 1 is a diagrammatical longitudinal section through the passes of a drawing bench.

Figure 2 is a cross-section through one of the passes on a larger scale.

Figure 3 is a part front elevation of a pass on a still larger scale.

The mandrel b of diameter d_o carrying the blank a which is closed at one end c and has the initial diameter D_o is forced with the speed V in the direction of the arrow through the passes K_1 to K_n arranged in series one after the other. The original cross-section

$$Q_o = \frac{D_o^2 \pi}{4} - \frac{d_o^2 \pi}{4}$$

of the blank is to be reduced to the cross-section

$$Q_n = \frac{D_n^2\pi}{4} - \frac{d_o^2\pi}{4}$$

In Figure 1 only the first and the last three passes are shown, but the number of passes will be from 6 to 16 according to the reduction.

The passes K_1 to K_n are composed of loose, that is to say non-driven, rolls which enclose the blank as completely as possible in their grooves. The grooves of the rolls follow, however, preferably, as shown in Figure 3, only up to an angle of 30° at either side of the middle plane of the rolls the circular periphery of the cross-section of the work-piece and deviate slightly from this latter towards the ends of the rolls. The roll diameter d is the diameter measured at the bottom of the groove, that is to say, the smallest or trough diameter of the roll. The length w_o of the blank extending from the cross section $n—n$ through the axes of the rolls of the last pass K_n to the closed end c of the blank moves with the speed V of the mandrel in the direction of feed, so that in the cross-section $n—n$, there is no difference in speed between the mandrel and the material. Since by an increase in the roll diameter, for the same reduction ratio of the cross-section Q_{n-1} with which the blank enters the pass K_n to the cross-section Q_n of the material, with which the blank leaves the said pass, the vertical pressure on the blank and hence the pressure with which the material is applied against the mandrel can be increased, the friction between the blank and the mandrel can thereby be increased to such an extent that the bottom of the work-piece is partly relieved of the pressure of the forcing mandrel, and hence only a part of the tensile stress of the material is transmitted from its bottom to the cross-section $n—n$. Due to the reduction produced by the pass K_n, the material flows backwardly at the speed s_n opposite to the direction of feed of the mandrel, so that the material between the last pass K_n and the penultimate pass K_{n-1} will move with the speed $V—s_n$ in the direction of feed. Whereas the pressure with which the material is applied against the mandrel by the rolls of the last pass K_n may if desired be even so great that the material is completely bound to the mandrel, this is inadmissible in the penultimate pass K_{n-1}, so that in this pass the rolls must have a smaller diameter relatively to the diameter D_{n-1} than in the last pass, that is to say

$$\frac{d_{n-1}}{D_{n-1}}$$

must be less than

$$\frac{d_n}{D_n}$$

Hence an upper limit is thereby set to the diameter of the rolls in the penultimate pass. The lower limit is determined by the preceding passes K_{n-2} to K_1 firstly by the fact that the rolls of all the preceding passes have to satisfy the requirement that the ratio

$$\frac{d_1}{D_1}$$

up to the first pass K_1 should not fall below 0.5 or in the extreme case below 0.3. Secondly, the roll diameter is limited downwardly by the fact that though the frictional force between the material and the mandrel must not be so great as to prevent a backward flow at the speed s_n, it should nevertheless be as great as possible below this limit in order to relieve the blank partially of the tensile stress produced by the forcing mandrel.

In the length w_2 between the passes K_{n-1} and K_{n-2}, the material will owing to the reduction produced by the pass K_{n-1} be forced backward at the speed s_{n-1}, so that the material moves under the rolls of the pass K_{n-2} in the direction of feed at a speed equal to the difference of the speed of feed V of the mandrel and of the sum of speeds $s_n \div s_{n-1}$. The diameter d_{n-2} of the rolls of the pass K_{n-2} must consequently be made small enough that the friction produced by the pressure with which the blank is applied against the mandrel may not hinder the backward flow of the material and that the rolls of the pass may be able to rotate with the peripheral speed of $V—(s_n \div s_{n-1})$. In view however of the following larger pass in the backward direction i. e. opposite to the direction of feed, the rolls must be made as large as possible in order to relieve partially, owing to the friction caused by the application of the material against the mandrel, the material from the tensile stress, and in order to render possible a further diminution of the ratio

$$\frac{d}{D}$$

towards the rearwardly following larger passes up to the first pass K_1 without going below the lower limit of this ratio.

Despite the diminution in stages of the ratio

$$\frac{d}{D} \text{ from } \frac{d_n}{D_n} > 1$$

but 2.5 at the most, to

$$\frac{d_1}{D_1}$$

but not below 0.3, the absolute magnitude of the roll diameter does not undergo any excessive diminution, because of course the value D increases in stages from the smallest pass K_n to the largest pass K_1. Another circumstance which renders it possible not to have to diminish excessively the roll diameter relatively to the rolls of the next smaller pass is that the admissible radial pressure in the pass may be greater for a greater thickness of the layer of material than for a thinner layer of material without checking the backward flow of the material under the rolls to such an extent as to produce a jumping up of the layer of material fed to the next smaller pass. The increase in the pressure of application towards the mandrel with increasing thickness of the layer of material is, however, also necessary in order to produce through a greater wall-thickness the desired friction between the material and mandrel.

Due to the fact that, for the smallest pass K_n, the roll diameter is not made so great that the pressure of the roll forces the material into the gaps between the rolls, and the ratio between the roll diameter and pass diameter is diminished in stages towards the larger passes, there will not be produced in any of the passes such a high pressure that the material pressed into the gaps between the rolls would form ribs so pronounced that they would not be evened out in the next pass without over-rolling. On the other hand, however, the pressure of application between the material and the forcing mandrel is sufficient that the tensile stress produced in the material

by the force necessary for the reduction from the original cross-section

$$\frac{\pi}{4}\left(D_o^2-d_o^2\right)$$

to the final cross-section

$$\frac{\pi}{4}\left(D_n^2-d_n^2\right)$$

and imparted to the blank by the mandrel, may be distributed among all the passes, so that a stress exceeding the ultimate strength of the material cannot occur in any cross-section of the blank. For the absolute magnitude of the diameter of the rolls of a pass, however, there is a tolerance corresponding to the force necessary for accumulating the material in the length lying between the pass under consideration and the next smaller pass. Within this tolerance, if there are a sufficiently large number of passes, it is possible in the individual passes to depart from the optimum value of the ratio

$$\frac{d}{D},$$

in order that for constructional reasons rollers having diameters of equal magnitude may be employed in two or more adjacent passes.

Finally, it should be noted that by the above-mentioned first and last passes are to be understood always reducing passes, that is to say, passes which effect an actual stretching or reduction and do not serve other purposes, such as for instance for smoothing the tube or loosening it from the mandrel.

What I claim is:—

1. A process for the manufacture of seamless metal tubes in which the blank, mounted on a mandrel is reduced by means of reducing passes, consisting of loose rollers, in one operation to at least ⅕ of the cross-section of the blank, characterized in that reduction takes place in passes disposed in series and in a number at least equal to the reduction factor, in which passes the ratio between the roll diameter and pass diameter increases successively from the largest reducing pass to the smallest reducing pass and characterized in that the trough diameter of the rolls in the largest reducing pass is at least 0.3 times and in the smallest reducing pass is at the most 2.5 times the internal diameter of the respective pass.

2. A process as claimed in claim 1, characterized in that reduction takes place between loose rollers, the trough diameter of which, within the limits specified in claim 1, is smaller in the largest pass than the internal diameter of the latter, and increase successively towards the smallest reducing pass to a magnitude lying above the internal diameter of this last-mentioned pass.

KÁROLY KORBULY.