Oct. 14, 1930. F. KOCKS 1,778,111

PROCESS OF AND APPARATUS FOR EXPANDING BLANKS BY ROLLING

Filed March 1, 1929 3 Sheets-Sheet 1

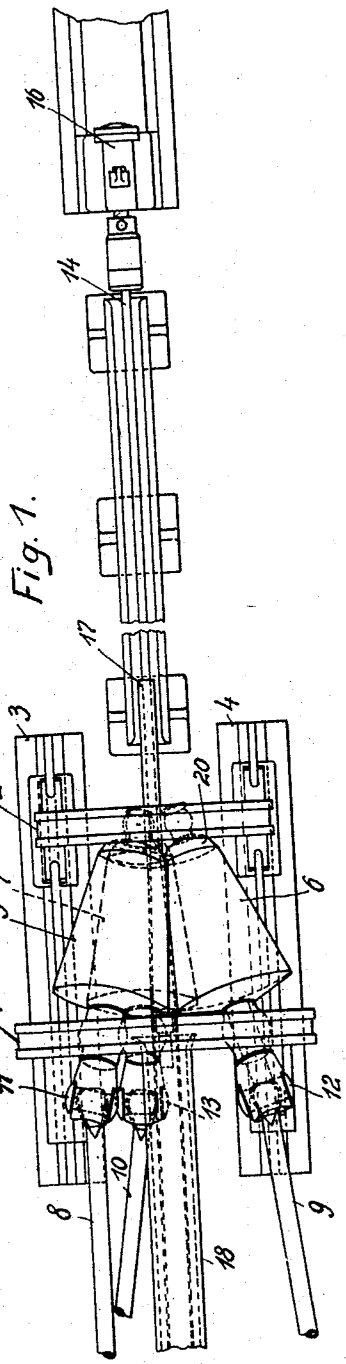

Fig. 1.

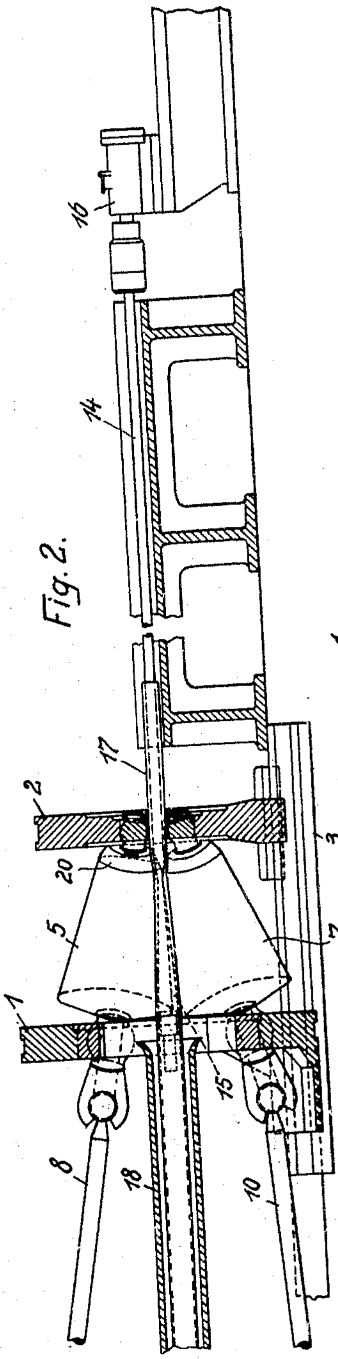

Fig. 2.

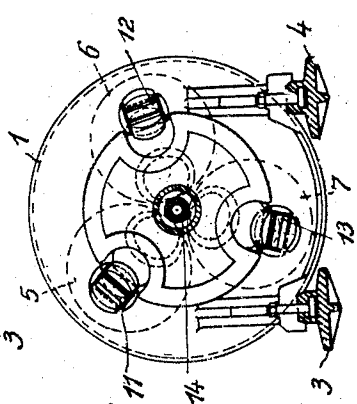

Fig. 3.

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PROCESS OF AND APPARATUS FOR EXPANDING BLANKS BY ROLLING

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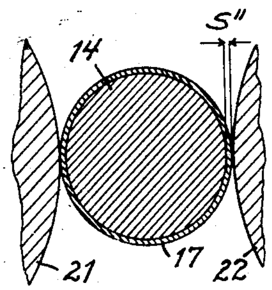

Fig. 7

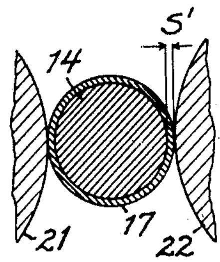

Fig. 6

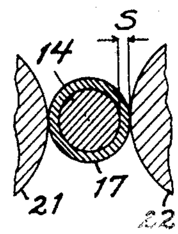

Fig. 5

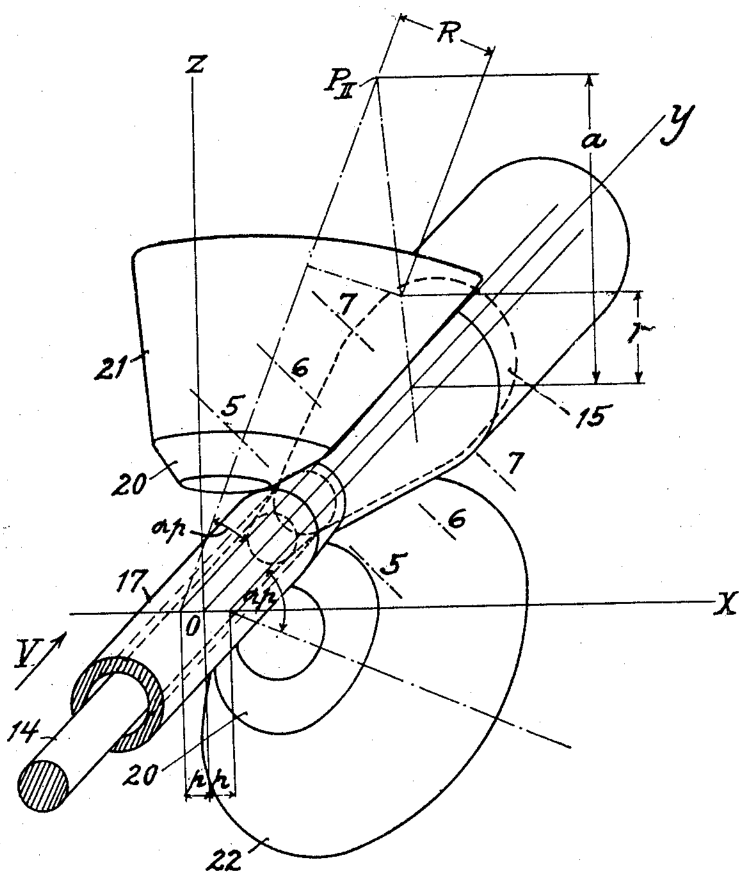

Fig. 4

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Fig. 8.

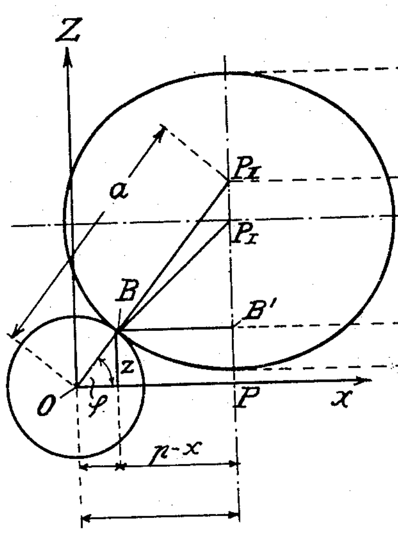


Fig. 9

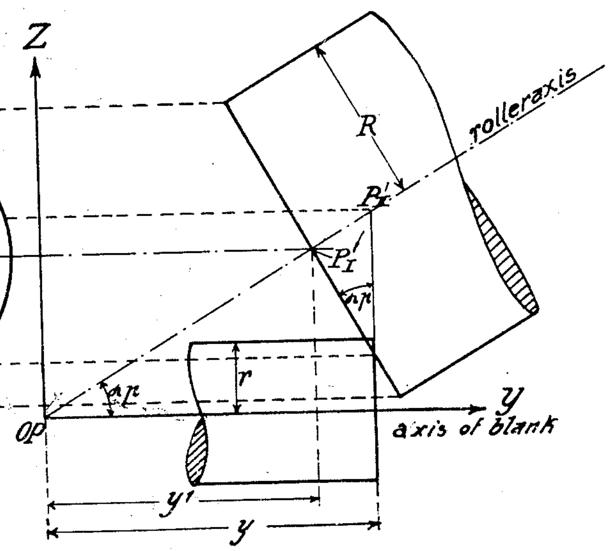


Fig. 10.

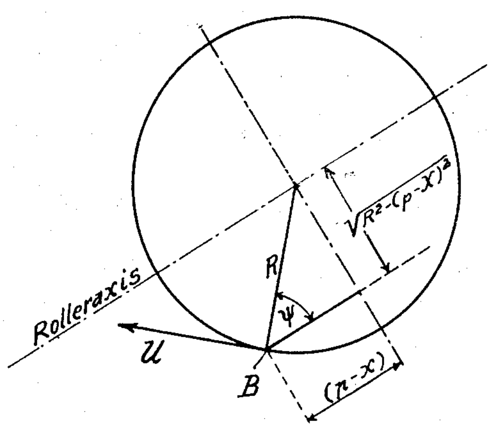
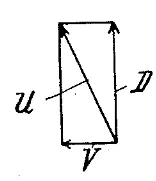


Fig. 11.



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UNITED STATES PATENT OFFICE

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PROCESS OF AND APPARATUS FOR EXPANDING BLANKS BY ROLLING

Application filed March 1, 1929, Serial No. 343,781, and in Germany March 31, 1928.

My invention relates to an apparatus for expanding blanks by rolling, more particularly by means of inclined rollers. It is an object of my invention to reduce the stress exerted on the material in rolling down its sections, which in the process as performed heretofore often became excessive so that the blanks were broken.

To the end of reducing the stress I design my apparatus in such manner as to impart the same velocity of feed to the blank at all points where the blank is in contact with the rollers, and to rotate the blank at the same angular velocity throughout the process. This is accomplished by so determining the ratio of the outer radius (r) of the blank to the distance (a) of the central point of the circle having the radius (r), from the point (P_{II}) where the extension of the radius (r) intersects the axis of the roller, that it is a constant throughout the process.

In other words, the distance line (a) which extends at right angles to the axis of the blank and ends at the axis of the roller, is divided by the point of contact between the blank and the rolls at the same ratio for all positions of the point of contact.

The modern tendency in the art of rolling and more particularly in the manufacture of seamless tubes by rolling is to reduce the weight of the tubes per unit of length by reducing the wall thickness, the object being to render seamless tubes more marketable as compared with welded tubes, but, as mentioned above, the expedient of reducing the wall thickness involves the risk of failure.

Besides in the process as heretofore performed it was not practicable to roll the tubes of large size having about two feet outside diameter and more, in great lengths. By designing the existing rolling mills for the Perrin's process and other processes in sizes corresponding to such large tubes the walls of the tubes would become so thick and their weight per unit of length would become so high as to be uncommercial.

The difficulty encountered in the process of expanding comparatively thick-walled tubular blanks by means of inclined rollers was that the material was stressed beyond its ultimate strength on account of unfavourable conditions of velocity and friction between the rollers and the blank and that the requirements under which the expanding should be performed were not considered. Therefore the expanding of tubes at a high rate (100 per cent or more) and rolling thin-walled tubes were impracticable.

According to my invention the requirements for expanding blanks as outlined above are reduced to practice. Expanding a tubular blank means increasing its outer and inner diameters and reducing its wall thickness while the length remains constant. With constant length, however, the cross-sectional area of the blank will also remain constant as the volume remains constant. As the condition that the product of the sectional area Q and the feed velocity V, i. e. the volume, should be constant, applies also to mills having inclined rollers, and as the cross-sectional area Q is constant if the blank is only expanded without altering its length, it follows that with the product Q . V constant, and one of the factors a constant, the other factor must also be a constant, i. e. V, the velocity which the rollers impart to the blank in the direction of its axis, must be the same at all points where the rollers are in contact with the blank.

I will now proceed to explain my invention by the aid of suitable diagrams but I will first describe and illustrate a rolling mill embodying my invention. In the drawings affixed to this specification and forming part thereof such rolling mill is illustrated diagrammatically by way of example.

My invention will be described as applied to a mill in which a tubular blank is placed on a mandrel but it may also be applied to mills in which a solid blank is made into a tube, and the tube is then expanded by my process.

In the drawings

Fig. 1 is a plan view of a rolling mill having three inclined rollers, the gearing being not shown,

Fig. 2 is an elevation of the mill, in section along the axis of the blank,

Fig. 3 is an end elevation of the mill viewed from the left in Fig. 2,

Fig. 4 is a perspective illustration on a larger scale showing a mill having two rollers instead of three as illustrated in Figs. 1—3,

Figs. 5, 6 and 7 are sections on the corresponding lines in Fig. 4 showing various stages of the rolling process,

Figs. 8, 9 and 10 are the diagrams referred to,

Fig. 11 is a diagram of velocities.

Referring now to the drawings and first to Figs. 1, 2 and 3, 1 and 2 are circular housings which are supported on suitable foundation bars 3 and 4, 5, 6 and 7 are three tapered and inclined rollers supported in the housings 1, 2 and adapted to be rotated through the medium of shafts 8, 9 and 10 from any suitable gearing, not shown. The shafts are connected to the roller shafts by knuckles 11, 12 and 13.

14 is a mandrel, 15 is a boss or collar at its inner end, 16 is a bracket by which the mandrel is held against axial displacement, 17 is the blank on the mandrel 14, and 18 is a pipe for the reception of the finished blank.

Each roller is provided with a short taper 20 at its front end, the apex angle of which is larger than that of the body of the roller so that the blank is drawn in between the rollers automatically and feeding appliances are not required.

Referring now to Fig. 4, this illustrates a mill having two rollers 21 and 22 instead of the three rollers 5, 6 and 7 in Figs. 1-3, and it is understood that I am not limited to a definite number of rollers. The figure also shows the mandrel 14 and the blank 17, as in Figs. 1-3, the blank being drawn in between the rollers at the feed velocity V in the direction of the axis of the mill as indicated by the arrow. The two rollers 21, 22 are equipped with tapers 20 with the object set out above.

With rollers designed in this manner the clearance (S) between the rollers is gradually decreased while the blank is engaged by the tapers 20 and this exerts the desired axial thrust on the blank by which it is drawn automatically in between the rollers.

In accordance with the object of my invention it is necessary that the clearance (S), Figs. 5, 6 and 7, between the rollers 21, 22, Fig. 4, or the rollers 5, 6 and 7 in Figs. 1-3, and the mandrel 14 should be such at any given section that the inner area of the blank is equal to or slightly larger than the corresponding area of the mandrel. In Figs. 5, 6 and 7, S, S′ and S″ are the clearances corresponding to the several sections. The sectional area Q of the blank 17 is a constant and if the sections of the blank are to be circular or approximately so throughout the process, the gaps S, S′, S″ must be calculated in conformity with this condition, as follows:

$$S=r-\sqrt{r^2-\frac{Q}{\pi}}.$$

In this equation r is the corresponding outer radius of the blank at the point of contact.

Referring now to Figs. 8, 9 and 10, a coordinate system is illustrated having the axes X, Y, and Z with the origin O. The blank 17 is supposed to be rotating about the Y—axis. The axis of one of the rollers is supposed to extend at an angle αp to the horizontal plane X—Y. R is the radius of the roller at a given point of contact B, the coordinates of which are x, y, and z. The horizontal distance of the roller axis from the origin O is p, Fig. 8. This distance and the angle αp are fundamental data for any given roller position.

The point B is rotating about the centre P_I, Fig. 8, at the end of the radius R. The circle which the point B described about the center P_I is defined by the equation of a sphere with the point P_I as its centre and the section of the sphere with a plane $P_I B'$ at right angles to the roller axis.

Equation of sphere:

$$(x-p)^2+(y-y_1)^2+(z-y_1.tg\alpha p)^2=R^2 \quad (1)$$

Equation of plane:

$$\frac{y}{y_1}\cdot \cos^2\alpha p+\frac{z}{y_1}\cdot \sin\alpha p.\cos\alpha p=1. \quad (2)$$

The distance of any point on the circular path about P_I from the Y-ordinate is exclusively a function of x and z and by combining Equations (1) and (2) by elimination of "y" the projection of the circle in the X—Z plane is an ellipse having the equation

$$(x-p)^2+\frac{(z-y^1.tg\alpha p)^2}{\cos^2\alpha p}=R^2 \quad (3)$$

The position of the point of contact B is defined by the fact that at this point the normal O P_{II} passes through Y coordinate, that is through the origin O in Fig. 8.

Let x, y and z be the coordinates of B, the equation of the normal is

$$z=\frac{\sqrt{R^2-(p-x)^2}}{\cos \alpha p(p-x)}\cdot x \quad (4)$$

The normal through B intersects the axis of the roller at P_{II}. In order to demonstate this, it must be shown that the line $P_{II}B'$ in Fig. 8 is equal to the line $P'_{II}B'$ in Fig. 9.

From the theory of the ellipse:

$$P_IB'=\sqrt{R^2-(p-x)^2}.$$

In Fig. 9:

$$P'_{II}B'=\frac{\sqrt{R^2-(p-x)^2}}{\cos \alpha p} \quad (5)$$

The inclination of the normal, Fig. 8, is defined by the equation:

$$tg\varphi=\frac{z}{x}=\frac{P_{II}B'}{BB'}=\frac{P_{II}B'}{(p-x)} \quad (6)$$

From Equation (4)

$$\frac{z}{x}=\frac{\sqrt{R^2-(p-x)^2}}{\cos \alpha p(p-x)} \quad (7)$$

From a combination of (6) and (7) it follows that

$$P_{II}B'=\frac{\sqrt{R^2-(p-x)^2}}{\cos \alpha p} \quad (8)$$

and from (5) and (8)

$$P'_{II}B'=P_{II}B'$$

This shows that the point of contact B of the roller and the blank is on the connecting line O—P_{II} which has been termed the distance a, between the axes of the blank and the roller which connecting line or distance is at right angles to the axis of the blank and is the extension of the radius r referred to in the introduction.

After the point of contact B has now been found, the transmission of the feed velocity V to the blank as a component of the peripheral velocity U may be calculated.

Referring to Fig. 10, the feed velocity V is related to the peripheral velocity U as follows:

$$V=U.\cos\psi.\sin\alpha p=\frac{2\pi R.n}{60}.\cos\psi.\sin\alpha p$$

$$\cos\psi=\frac{p-x}{R}$$

$$V=\frac{\pi n}{30}\cdot(p-x).\sin\alpha p$$

The equation for V shows that the feed velocity is a constant when the only variable in the equation, to wit x, is a constant, and x will be a constant if the said ratio $r:a$ of the radius r of the blank to the extension of the radius as far as the intersection P_{II} with the roller axis is a constant.

As mentioned in the introduction, this means that the straight line a which is erected at right angles on the axis OP—Y of the blank and extends as far as the axis of the roller, is divided at a constant ratio for all positions of the point of contact.

The radius R of the rolls results from the condition that x should be a constant, or that the ratio $r:a$ should be a constant, and is calculated from the equation:

$$R=\frac{p-x}{p}\sqrt{p^2+y^2\sin^2\alpha p}$$

This equation yields the radius R of the rolls for all sections, the position of each section being defined in the system by y. All factors except y are constant in the equation.

The possibility of rendering constant the feed velocity has thus been demonstrated.

My process of expanding blanks at constant feed velocity involves another considerable advantage, to wit that torsion is not exerted on the blank during the process and the blank is rotating at uniform angular velocity. Uniform angular velocity of the blank means constant number of revolutions of the blank during the entire process. The number of revolutions N of the blank at the several points of contact with the rollers is a function of two factors, to wit:

(1) The rotary velocity D which the rollers tend to transfer to the blank, this velocity being the component of the peripheral velocity U, Fig. 11, at right angles to the axis Y of the blank.

(2) The perimeter of the blank.

The rotary velocity D is found from Figs. 8–11 to be

$$D=\frac{2\pi n(p-x)r}{60x\cos\alpha p}$$

in which n is the velocity of the roller.

Under normal conditions the radius of the outer diameter of the blank is equal to the distance of the point of contact B between the roller and the blank from the axis of the blank, i. e. r, Fig. 8.

Consequently

$$2\pi rN=D=\frac{2\pi n(p-x)r}{60x\cos\alpha p},$$

and

$$N=\frac{n(p-x)}{60x\cos\alpha p}$$

where n is the number of revolutions of the roller.

Obviously N will be a constant when the only variable x is a constant and this was already established as the principal requirement in connection with my invention.

Referring now to Fig. 4, the axes of the rollers 21 and 22 are inclined to the axis Y of the blank at the angle αp, Fig. 9, and the distance of their axes from the axis Y of the blank is p, as in Fig. 8. The rollers are so sized throughout and in such a position that at all points in the effective part of the rollers, i. e. the principal part having the slighter taper as compared with the smaller part having the strong taper 20, the ratio of the outer radius r of the blank to the said extensions a of the radius r is a constant. If r', r'' and r''' are radii of the blank at three distinct points and a', a'' and a''' are the corresponding vertical distances, this condition is expresed by the equation:

$$\frac{r'}{a'}=\frac{r''}{a''}=\frac{r'''}{a'''}$$

In order to perform the expanding process successfully, it is necessary that normal conditions should prevail, that is, as assumed above, the outer radius r of the blank should be equal to the distance of the point B from the origin O. The perimeter of the blank is a function of its wall thickness at any given point as the sectional area Q is constant in accordance with my invention, as expressed in the paragraph of the introductory statement relating to the requirements for expanding blanks, and consequently the perimeter is a function of the clearance S, Figs. 5, 6 and 7, between a roller and a mandrel 14. If the clearance is too small the wall will become too thin, the perimeter of the blank will become too large for the given point of contact, and the section of the blank will become oval, i. e. the blank is detached from the mandrel. Moreover, the velocity that is actually absorbed by the blank is distorted with respect to the velocity which the rollers tend to transfer to the blank and therefore the conditions of friction between the rollers, the blank and the mandrel undergo very unfavourable variations with the result that the stress on the blank is excessive.

Conversely, if the clearance S becomes too large the whole blank will be rolled too thick, with too small a perimeter on the inside of the section, and the feeding of the blank is interfered with at the larger diameters of the mandrel.

All these drawbacks are overcome according to my invention by determining the clearance S between the roller and the mandrel at all points so that a wall thickness as calculated above from the equation

$$S=r-\sqrt{r^2-\frac{q}{\pi}}$$

is obtained which renders the inside area of the blank either equal to or slightly larger than the corresponding mandrel area so that the feeding of the blank is performed without trouble and favourable conditions of cooperation between the roller, the blank and the mandrel will permanently prevail. It is obviously that by S the radius of the mandrel 14 is also given by subtracting S from the outside diameter of the blank.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

In the claims affixed to this specification no selection of any particular modification of the invention is intended to the exclusion of other modifications thereof and the right to subsequently make claim to any modification not covered by these claims is expressly reserved.

I claim:—

1. A rolling mill for the expanding of hollow blanks, having inclined rolls and a mandrel, said mill being characterized thereby that a vertical erected on the axis of the hollow blank and ending in the axis of a roller is divided by the point of contact between said blank and said roller at the same ratio for all positions of said point of contact.

2. A rolling mill as claimed in claim 1, characterized in that the diameter of the mandrel is determined for all sections of the pass by the conditions that the cross-sectional area of the hollow blank should remain constant throughout the pass and that the inner perimeter of the hollow blank should be substantially equal for all cross-sections to the corresponding perimeter of the mandrel.

In testimony whereof I affix my signature.

FRITZ KOCKS.