April 19, 1938. I. HARTER 2,114,302

METHOD OF MAKING ROUND BILLETS

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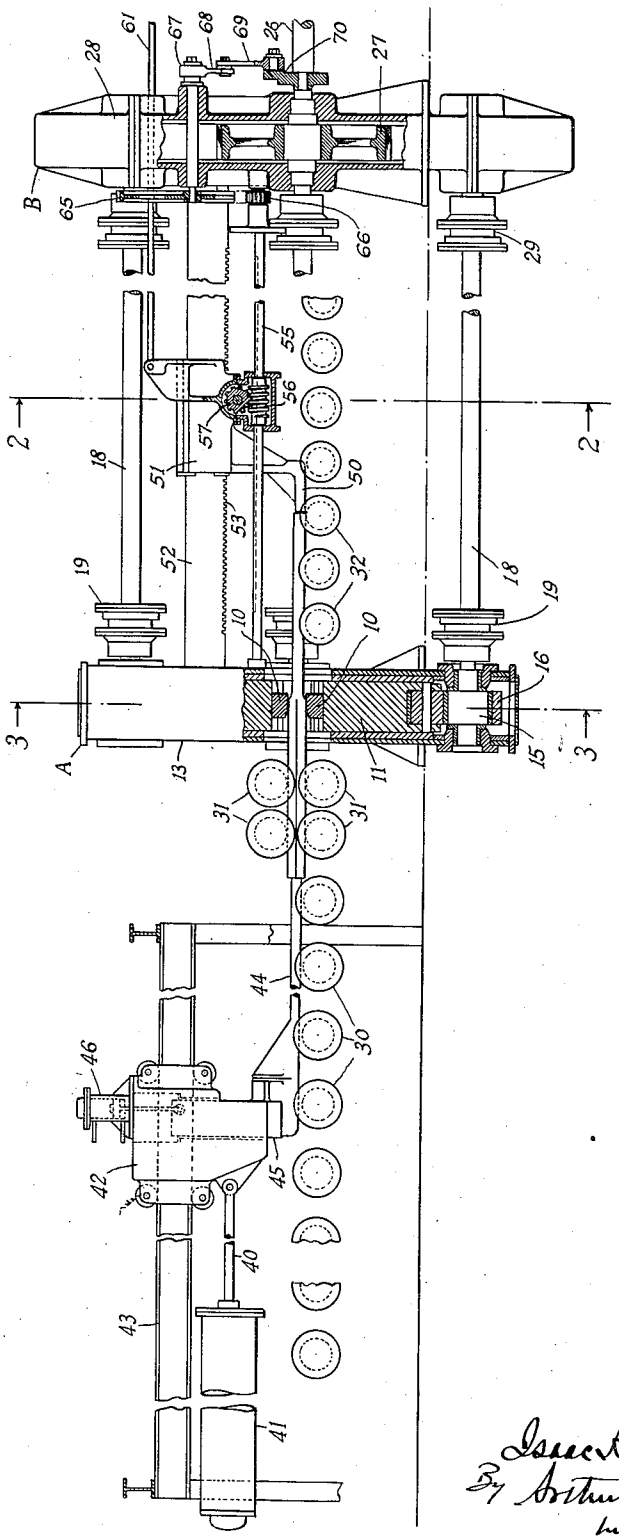


Fig. 1

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Fig. 2

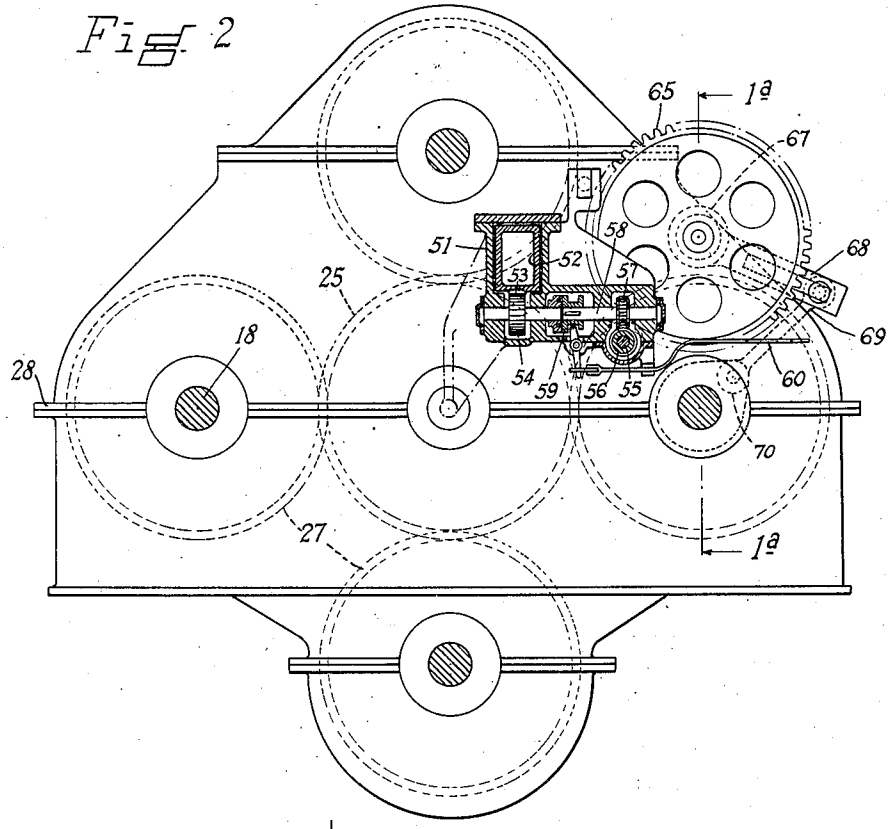


Fig. 3

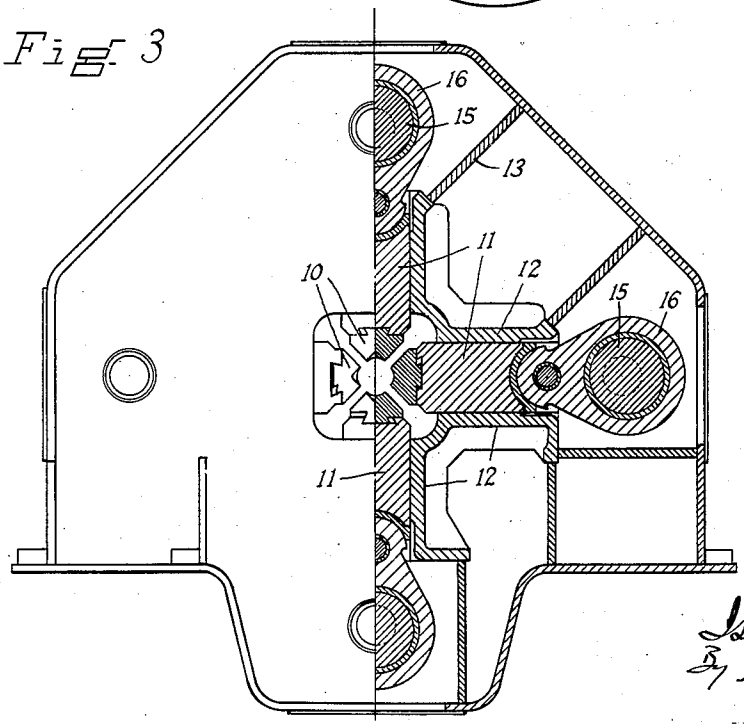
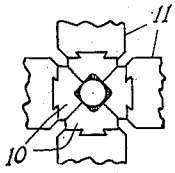


Fig. 4



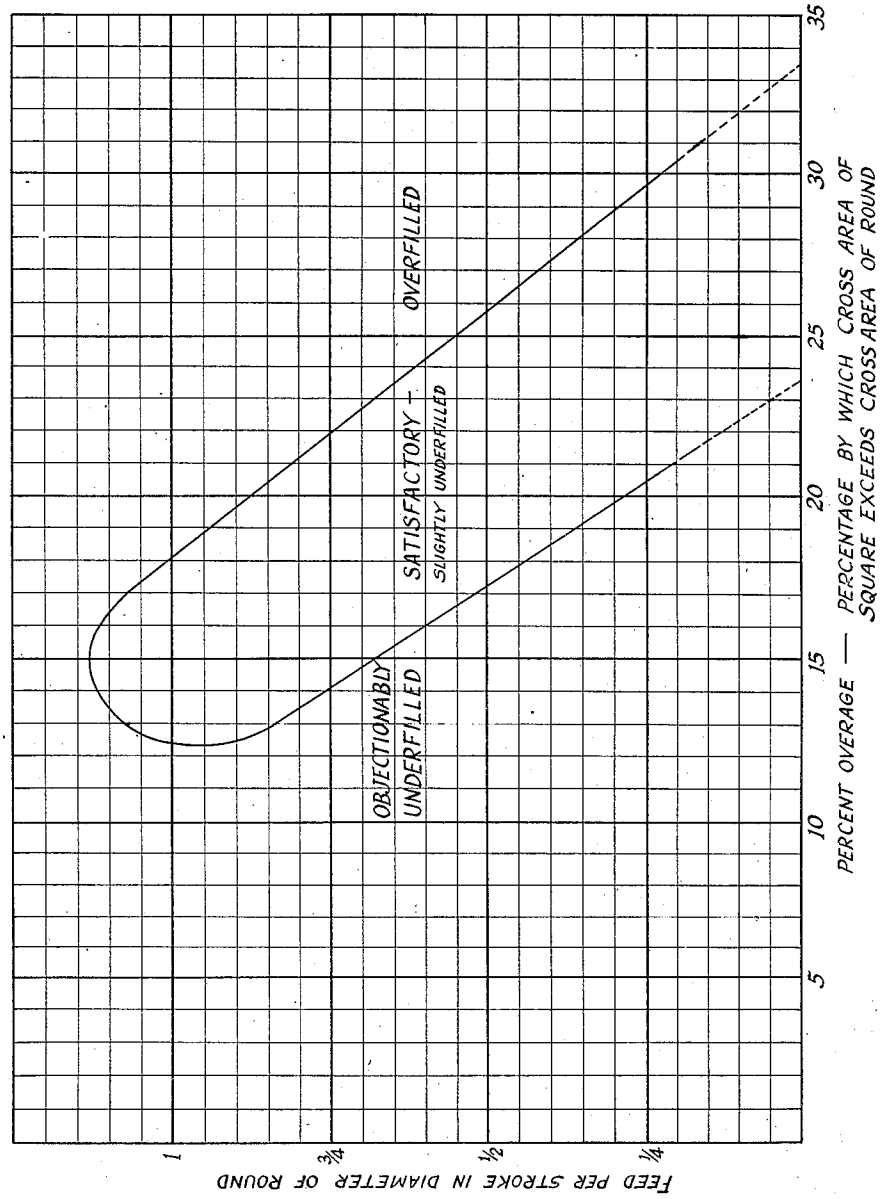
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Fig. 5



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UNITED STATES PATENT OFFICE

2,114,302

METHOD OF MAKING ROUND BILLETS

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Application November 10, 1936, Serial No. 110,095

8 Claims. (Cl. 78—81)

This invention relates to the making of round billets from square billets. The invention has been made especially with the idea of providing an improved method of producing round billets for piercing to form tubes, although the method may obviously be employed for producing rounds for other uses.

Makers of seamless metal tubes have had much difficulty in obtaining satisfactory rounds for piercing, and this difficulty has been the cause of uncertainty in the quality of tubes and in the number of good tubes obtainable from a given number of rounds. The tubes are customarily made from round billets produced in rolling mills, the final operation at the rolling mill being to roll square billets or blooms between the grooved rolls of a bar mill to produce the rounds. While standard bar mill practice produces very accurately sized billets and more accurately sized than is required for piercing, this method of producing the rounds in a bar mill is not only very hard on the metal but it is also liable to produce seams in the finished round resulting from the rolling down of fins produced in a previous pass. Moreover, the capital charges for the apparatus for producing the rounds in this way are very great, so much so that it is impossible as an economical proposition when applied to the relatively small tonnages that even a good size tube mill requires.

The object of the present invention is to provide a method whereby round billets of metal of uniformly high quality free from seams may be produced with apparatus of comparatively low installation cost and reasonable operation cost.

The invention comprises a method wherein round billets are formed from square billets by die forging by means of four symmetrically arranged dies each shaped in cross section in its main working part to a quarter segment of a circle and reciprocated simultaneously diagonally of the square billet and perpendicular to its longitudinal axis, the desired result being obtainable, however, only by observing certain principles which I have discovered.

This four-die forging produces two results, first, a lateral or transverse flow of the metal from the corners of the square billets to the sides, and, second, a longitudinal flow. If there were no longitudinal flow, then a perfect round could be produced by using dies which when in their closed position form a cylindrical pass of a cross-sectional area just equal to that of the square billet, and the change in the billet would be merely one of peripheral form without change in length. There is always, however, some longitudinal flow, so that the cross-sectional area of the round is always less than that of the square billet, and if the cross-area of the pass between the closed dies is equal to that of the square billet there will be four longitudinal flats on the rounds. If, on the other hand, the pass between the closed dies is too small, this will result in overfilling and the formation of longitudinal fins on the round.

The longitudinal flow of the metal as the dies close is retarded by the friction between the metal and the dies, and if long dies are used the longitudinal flow is comparatively large at both ends of the pass where the total frictional resistance to longitudinal flow is small and becomes progressively less toward the center where the resistance due to friction is greater. The cross-sectional area of the round at any point varies inversely with the longitudinal flow. Therefore, if such long dies are designed and operated so as to produce a completely filled round at the center where the longitudinal flow is least, there will be serious underfilling at the ends. If, on the other hand, the dies are designed to produce a completely filled round at the ends, there will be overfilling at the center, resulting in the formation of fins.

I have found that finning on the one hand and objectionable underfilling on the other hand may be avoided by causing the dies to act on successive portions of the square billet of a limited length so that the billet is converted into a round in a step-by-step, or continuing intermittent, operation, and by having the cross-sectional area of the pass between the dies when in their closed position bear a certain relation within quite definite limits to the cross-sectional area of the square billet, such limits varying according to the length of the successive portions of the billet on which the dies act, that is, according to the feed distance between die closings.

For rounding billets of low carbon steel having substantially the following composition:

C	0.14
Mn	.48
S	0.027
P	0.017
Si	0.18
Fe	Balance

heated to around 2100° F., I have found that the feed distance should not be substantially greater than the diameter of the pass and that the cross-sectional area of the square billet should be from 12 to 30% greater than the cross-sectional area

of the round pass, that is, the cross-sectional area of the round to be produced; and that the percentage overage, that is, the percentage by which the cross-sectional area of the square billet exceeds the cross-sectional area of the pass, should be decreased within this range as the feed distance with respect to the diameter of the pass is increased from around ¼ toward the maximum of about 1, since the elongation of the billet is less as the feed distance is greater, and, conversely, as the percentage overage is increased within the stated range the feed distance should be decreased within its stated range. The feed distance may be less than the diameter of the pass without producing either finning or excessive under filling provided the percentage overage of the square billet is within the proper limits, and the shorter the feed the more uniform the surface of the round billet, but in order to obtain a desirable speed of operation the feed distance should not be less than about one-quarter of the diameter of the pass and most desirably not less than about one-half of such diameter, and in order to reduce the elongation it is desirable to have the feed distance nearer one diameter. Having all these considerations in mind, I consider it most desirable to operate with a feed distance of about ¾ of the diameter of the round pass with a corresponding excess of the cross-sectional area of the square billet over the cross-sectional area of the pass. For other steels and other metals the above relationships will vary to some small degree.

As it is not necessary that rounds for piercing be entirely filled out, while finning in producing the rounds should be entirely avoided, the relationship between the size of the square billet, the diameter of the pass, and the feed distance should be such as to give a small degree of underfilling in the round billet.

A full understanding of the invention can best be given by a further description in connection with the accompanying drawings; in which

Fig. 1 is a longitudinal view partly in section showing the essential parts of a four-die forging machine adapted for use in practicing the invention;

Figs. 2 and 3 are sectional views taken respectively on lines 2—2 and 3—3 of Fig. 1;

Fig. 4 is a detail end view showing the four dies in closed position looking from the intake side of the die stand; and

Fig. 5 is a diagram based on actual test operations on steel of the analysis given above showing the range of percentage overage of the square billet for feed distances of ¼, ½, ¾ and 1 diameter of the closed pass.

Referring first to Figs. 1 to 3, the machine illustrated comprises a die stand A, a gear stand B, and means for supporting and feeding the billet. In the die stand there are four dies 10 mounted to have a radial approaching movement in a common plane in paths equally spaced angularly. Each die is carried by a slide or plunger 11 mounted to move in slideways 12 in the housing and supporting frame 13. The die-carrying plungers 11 are reciprocated by means of eccentrics 15, one for each plunger, the eccentrics acting through eccentric rings 16 which are pivotally connected to the respective plungers 11. The eccentrics are carried by shafts 17 journalled in the supporting frame and each is driven by a shaft 18 extending from the gear stand B and connected to the eccentric shaft by a universal coupling 19.

The gear stand comprises a central driving gear 25 on a driving shaft 26 and four driven gears 27 arranged symmetrically about and meshing with the gear 25, all of said gears being mounted within a housing and supporting frame 28. Each of the gears 27 is connected through a universal coupling 29 to one of the shafts 18.

Extending from the intake side of the die stand is a series of grooved rolls 30 forming a run-in table for the square billets, and immediately adjacent to the die stand on the intake side there is a means for guiding and holding the square billet against turning as it is advanced to and through the die pass. Such means as shown consists of two pairs of pinch rolls 31 having V-shaped peripheral grooves adapted to engage and hold the square billet against turning. When the die stand is set as shown so that one pair of dies reciprocates vertically and the other pair horizontally, the billet positioning pinch rolls 31 are mounted with their axes horizontal so that the square billet is held in position with its sides extending at 45° to the horizontal and vertical and with its diagonals extending horizontally and vertically. On the delivery side of the die stand a run-out table is provided which as shown is formed by a series of grooved rolls 32.

The billet being rounded is fed through the die pass step by step, remaining stationary during the forging movement of the dies except for such endwise movement of the extending portions as results from the elongation of the portion in the grip of the dies, and then being moved forward when the dies are retracted. Any suitable feed mechanism may be provided for giving the billet the desired step-by-step feed in time with the operation of the dies and for permitting a slight outward movement of the trailing and leading ends of the billet during each inward stroke of the dies. In the particular construction shown, the billet during the whole forging operation from the time its forward end is entered between the dies is under continuous pressure urging it forward, such pressure being exerted through a piston rod 40 from a hydraulic cylinder 41 which is provided in the usual manner with control valves whereby the piston may be moved forward or backward, and the pressure being strong enough to feed the billet forward when released by the dies and as permitted by the stop means to be described but weak enough to permit the outward movement of the trailing end of the billet during each forging operation. The piston rod 40 is connected to and drives a carriage 42 mounted on a track 43, and from this carriage extends a push rod 44 for engaging the trailing end of the billet to move the billet forward to and thereafter through the die pass. The push rod extends forward from a slide head 45 which is mounted to move vertically in the carriage and which may be raised from the position shown in Fig. 1 by means of a small hydraulic cylinder 46 to lift the push rod so that it may be moved outward away from the die stand and then lowered into operative position again beyond a billet which has been placed on the run-in table.

The forward movement of the billet when it is free from the grip of the dies is limited by a stop 50 which engages the leading end of the billet and which is moved away from the die stand a predetermined distance for each closure of the dies, each such retreating movement of the stop starting as the billet is gripped by the dies, so that the

stop does not resist the outward movement of the end of the billet which occurs at each forging operation; and the distance that the stop is moved during each closure of the dies is such as to position the stop to limit to the desired feed distance the forward movement of the billet when it is released by the dies. The stop 50 is carried by a carriage 51 which is mounted to slide on a beam 52 extending between the die stand housing and the gear stand housing. A rack 53 on the beam 52 is engaged by a pinion 54 fast on a shaft journalled in the carriage, and the pinion shaft is driven to cause the desired retreating movements of the carriage and stop.

For giving this stop-positioning movement to the carriage 51, the pinion 54 is driven from a shaft 55 extending between the die stand housing and the gear stand housing by means of a worm 56 splined on the shaft and held by parts extending from the carriage to move with the carriage. The worm engages a gear 57 on a short shaft 58 which is in alignment with the shaft of the pinion 54 and is connected therewith by means of a clutch 59. The movable member of the clutch 59 may be withdrawn from operative position by means of a hand lever 60 for disconnecting the shaft 58 from the pinion shaft to permit the carriage and stop to be moved by a rod 61 back toward the die stand to bring the stop into position to engage the end of the next billet to be fed through the dies. The shaft 55 is driven for giving the carriage and stop their step-by-step retreating movement by a gear 65 which engages a pinion 66 on the shaft and which is given a partial rotation at each inward movement of the dies by means of a one-way clutch 67 which is operated by a lever 68, connecting rod 69, and crank 70 mounted on the end of the shaft of one of the gears 27. The end of the connecting rod 69 is adjustably connected in a slot extending lengthwise of the clutch lever so that the amount of rotation of the gear 65, and, therefore, the amount of movement of the carriage 51 and stop 50, may be adjusted as desired for varying the distance the billet is permitted to be pushed forward for each closure of the dies.

The working face of each of the dies 10 is shaped so that when in closed position the dies form a pass having a straight cylindrical portion of a length somewhat greater than the maximum feed distance, a flaring entrance portion which tapers to the circular cross-section of the cylinder portion, and a slightly tapered or rounded exit part. The longitudinally straight main working portion of each die is shaped transversely of the pass to a quarter segment of a circle. The entrance portion may be variously shaped. There is some advantage in having the entrance shaped as shown by Figs. 3 and 4, that is, so that the closed pass starts from a square, or from a round cornered square for commercial round cornered square billets, and then tapers and merges into the cylindrical portion of the pass, the advantage being that with an entrance of this shape the pressure of the bulging metal against the flat entrance walls of the dies as the dies close may serve to resist a tendency of the billet to turn slightly under the pressure of the dies. The slightly greater limiting action on the side, or transverse, flow of the metal when the entrance is of this shape, as compared to the action of a truly conical entrance, apparently results, however, in a slightly greater elongation of the billet and, therefore, requires a slightly larger square billet to produce the same size round.

It has been found most desirable to make the dies of a length of about two diameters of the closed pass, with the longitudinally straight segmental working portion about 1½ diameters long and the entrance about ½ diameter long.

As stated, I have found in converting square billets into round billets by step-by-step, or continuing intermittent, forging in a four-die mill that it is necessary, in order to avoid either finning or objectionable underfilling, to have the length of the successive portions of the square billet, that is, the feed distance, not in excess of a certain length relative to the diameter of the closed pass, this maximum feed distance for steel of the composition hereinbefore given being not substantially greater than 1 diameter of the pass, and to have the square billet of a cross-area greater than that of the closed pass by a small percentage which may be varied only within a quite definite narrow range, which range varies according to the feed distance; that the feed distance should not be less than about ¼ of the diameter of the pass, and better, not less than about ½ of such diameter, in order to obtain a desirable speed of operation and to avoid undesirable elongation of the billet; and that as the feed distance is increased toward the maximum of about 1 diameter of the pass, the percentage by which the cross-area of the square billet exceeds that of the pass, which I have called the percentage overage, should be decreased, and, conversely, as the percentage overage is increased within the stated range the feed distance should be decreased within its stated range. The range of percentage overage of the cross-area of the square billet to that of the pass for feed distances of ¼, ½, ¾ and 1 diameter of the pass as found by test operations on steel of the composition hereinbefore given is shown diagrammatically by Fig. 5. The square billets used in the test operations were the usual commercial round cornered square billets, that is, billets having a rounded corner and the corner radius being $\frac{3}{16}$'' for each 1'' of thickness of the billet.

From these test operations it was found, as Fig. 5 shows, that the cross-sectional area of the square billets should be greater than that of the closed pass by a percentage between 23 minus 12F and 33 minus 15F, where F is the feed distance in terms of the diameter of the pass, that is, the ratio of the distance the billet is fed forward for each reciprocation of the dies with respect to the diameter of the pass; that this percentage should be approximately 28 minus 13F; that the cross-sectional area of the square billet should be from 12 to 30% greater than the cross-sectional area of the pass, the excess within this range being less as the length of the successive portions of the billet pressed to round form is greater; and that when the feed distance is about ¾ the diameter of the pass the cross-sectional area of the square billet should be from about 14 to about 22 per cent greater than the cross-sectional area of the pass, that is, of the round to be produced.

Also, as appears from Fig. 5, for feed distances of from ½ to 1 diameter of the pass the thickness of the square billet should be slightly less than the diameter of the pass, or of the round to be produced, since the cross-area of a square is 27 percent greater than that of a circle the diameter of which is equal to the length of the sides of the square, and Fig. 5 shows that for feed distances of from ½ to 1

diameter of the pass the excess of cross-area of the square billet as compared to the pass should be less than 27 percent. Although the square billets used in the test operations on which Fig. 5 is based were commercial round cornered square billets, the cross-areas of which were slightly less than if the billets had been full square in cross-section, the rounds produced were slightly underfilled, so that their cross-areas were also somewhat less than if they had been truly round.

It will be seen that the range within which the cross-sectional area of the square billet for a given feed distance should exceed the cross-sectional area of the round to be produced is such that a considerable departure in size of the square billet from a specified size having a cross-sectional area about midway in this range may take place without leading to overfilling or objectionable underfilling. This leeway is sufficient to more than take care of the commercial tolerance under which square billets, a semi-finished steel product, are supplied. And if the square billet is of a size somewhat greater than the maximum size within this range, or somewhat less than the minimum size within the range, this slight excessive departure from the specified size may be compensated for by correspondingly decreasing the feed distance for a larger size or increasing it for a smaller size.

What is claimed is:

1. The method of making substantially round metal billets in a forging machine having symmetrically arranged dies each shaped in cross section substantially to a quarter section of a circle and forming when closed a cylindrical pass, which comprises heating to a forging temperature a substantially square billet the thickness of which is approximately equal to the diameter of the round to be produced, feeding the billet through the pass of the forging machine a predetermined distance for each closure of the dies, and after each feeding of the billet said predetermined distance converting a portion thereof of the length of the feed distance to round by pressure applied simultaneously in the four radial directions which are diagonal of the square billet and perpendicular to its longitudinal axis by a single closure of the dies.

2. The method of making substantially round metal billets in a forging machine having symmetrically arranged dies each shaped in cross-section substantially to a quarter section of a circle and forming when closed a cylindrical pass, which comprises heating a substantially square billet to a forging temperature, feeding the billet through the pass of the forging machine a predetermined distance for each closure of the dies, and after each feeding of the billet said predetermined distance converting a portion thereof of the length of the feed distance to round by pressure applied simultaneously in the four radial directions which are diagonal of the square billet and perpendicular to its longitudinal axis by a single closure of the dies, the cross-sectional area of the square billet being greater than that of the pass between the dies when in their closed position by a percentage between about 23 minus 12F and about 33 minus 15F, where F is the ratio of the distance the billet is fed forward for each reciprocation of the dies with respect to the diameter of the pass, such ratio not being substantially greater than 1 nor substantially less than ¼, whereby both finning and excessive underfilling are avoided.

3. The method of making substantially round metal billets in a forging machine having symmetrically arranged dies each shaped in cross section substantially to a quarter section of a circle and forming when closed a cylindrical pass, which comprises heating a substantially square billet to a forging temperature, feeding the billet through the pass of the forging machine a predetermined distance for each closure of the dies, and after each feeding of the billet said predetermined distance converting a portion thereof of the length of the feed distance to round by pressure applied simultaneously in the four radial directions which are diagonal of the square billet and perpendicular to its longitudinal axis by a single closure of the dies, the cross-sectional area of the square billet being greater than that of the pass between the dies when in their closed position by a percentage of approximately 28 minus 13F, where F is the ratio of the distance the billet is fed forward for each reciprocation of the dies with respect to the diameter of the pass, such ratio not being substantially greater than 1 nor substantially less than ¼, whereby both finning and excessive underfilling are avoided.

4. The method of making substantially round metal billets, which consists in heating to a forging temperature a substantially square billet the cross-sectional area of which is from 12 to 30 percent greater than the cross-sectional area of the round to be produced, feeding the billet endwise, and converting from square to round successive portions of the billet each of a length equal to from about ¼ to about 1 diameter of the round by pressure applied simultaneously in the four radial directions which are diagonal of the square billet and perpendicular to its longitudinal axis by four symmetrically arranged reciprocating die members each shaped in cross-section substantially to a quarter segment of a circle and forming when closed a cylindrical pass, the excess within the range stated of cross-sectional area of the square billet over the cross-sectional area of the round being less as the length of the successive portions of the billet pressed to round form is greater within the range stated.

5. The method of making substantially round metal billets, which consists in heating to a forging temperature a substantially square billet the cross-sectional area of which is from 12 to 30 percent greater than the cross-sectional area of the round to be produced, feeding the billet endwise, and converting from square to round successive portions of the billet each of a length equal to from about ¼ to about 1 diameter of the round by pressure applied simultaneously in the four radial directions which are diagonal of the square billet and perpendicular to its longitudinal axis by four symmetrically arranged reciprocating die members each shaped in cross-section substantially to a quarter segment of a circle and forming when closed a cylindrical pass, the length within the range stated of the successive portions of the billet pressed to round form being less as the excess of cross-sectional area of the square billet over the cross-sectional area of the round is greater within the range stated.

6. The method of making substantially round metal billets, which consists in heating to a forging temperature a substantially square billet the cross-sectional area of which is from about 14 to about 22 percent greater than the cross-sectional

area of the round to be produced, and converting from square to round successive portions of the billet by pressure applied simultaneously in the four radial directions which are diagonal of the square billet and perpendicular to its longitudinal axis by four symmetrically arranged reciprocating die members each shaped in cross-section substantially to a quarter segment of a circle and forming when closed a cylindrical pass, the billet being fed forward for each closure of the dies a distance equal to approximately ¾ of the diameter of the pass.

7. The method of making substantially round metal billets, which consists in heating to a forging temperature a substantially square billet the thickness of which is slightly less than the diameter of the round to be produced and the cross-sectional area of which is somewhat greater than that of the round, and applying to successive portions of the square billet pressure by four symmetrically arranged die members moving simultaneously diagonally of the square billet and perpendicular to its longitudinal axis and each shaped in cross-section substantially to a quarter segment of a circle and forming a cylindrical pass when closed, the billet being fed forward for each closure of the dies a distance equal to from about ½ to about 1 diameter of the pass.

8. The method of making substantially round metal billets, which consists in heating to a forging temperature a substantially square billet the thickness of which is no more than slightly greater than the diameter of the round to be produced and the cross-sectional area of which is somewhat greater than that of the round, feeding the billet endwise, and converting from square to round successive portions of the square billet each of a length of from about ¼ to about 1 diameter of the round by pressure applied simultaneously diagonally of the square billet and perpendicular to its longitudinal axis by four symmetrically arranged die members each shaped in cross-section substantially to a quarter segment of a circle and forming a cylindrical pass when closed.

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