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THE SIMONDS' UNIVERSAL METAL ROLLING MACHINE.

BY GEORGE F. SIMONDS, Fitchburg, Mass.

[*Read at the Stated Meeting of the FRANKLIN INSTITUTE, Wednesday,
June 20th, 1888.*]

JOS. M. WILSON, President, in the chair.

MR. PRESIDENT, MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The invention which I have the honor to explain to you, is the result of incident, of mistake, of reasoning, of experimenting. From a small germ, it has shown a steady and substantial growth. Difficulties have been encountered, but almost invariably the removal of a difficulty has developed some new and unexpected advantage. It has spread out and covered fields, broader than we dreamed of two years ago, until there seems to be no limit to its capabilities. It is the natural way to make an endless variety of articles, in the saving of manual toil, in the improving

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of the quality of the articles produced, and in opening new opportunities for the employment and convenience of mankind. That it has reached perfection in all its details is not claimed. Far from it! for the possibilities of an invention covering so much ground could hardly be exhausted in the short space of four years, but the underlying principles are established, and it can safely be declared a success.

In January, 1884, while journeying from home, my attention was incidentally called to the possibility of forging round metal articles, like articles ordinarily made in a turning lathe, between oppositely moving surfaces. As has always been my custom when a new idea presented itself, I made a sketch of a device for practically carrying it into effect, and wrote a description of the same. On my return an experiment was made with putty as a material between two tapering shingles, grooved to form a ball, and with sufficient success to convince me that it could be developed to substantial results.

I wrote to my solicitor in Washington, explaining and describing what had been done, and asked him to make an examination in the Patent Office and report to me what had previously been attempted in that line. In due time he reported that he had made a careful preliminary examination of the records of the Patent Office, that there was nothing there of the character referred to, and that I had the field to myself. I was much surprised at this report, as it seemed very strange that so simple a principle had not been tried before, but, acting under the information received, I built a machine.

I had in my employ a young and intelligent mechanical engineer who made my drawings, superintended the construction of the machine, and tested it. After some weeks of persistent experimenting he reported to me, that, in his opinion, the thing was a failure and we must give it up. I told him to cover up the machine, and we would let it rest. Up to this time my dies had been constructed on inclined planes, approaching each other as the dies were moved forward, like the illustrations shown in *Figs. 1 and 2*. After a few days, I told him to make the drawings and construct dies to make a miniature car axle, in which the forming or shaping surfaces of the two dies should run parallel to each other, and the reducing and spreading surfaces diagonal to the

forming surfaces, and also at an angle to said forming surfaces and to each other, and said reducing and spreading surfaces to be provided with corrugations to force and control the rotation of

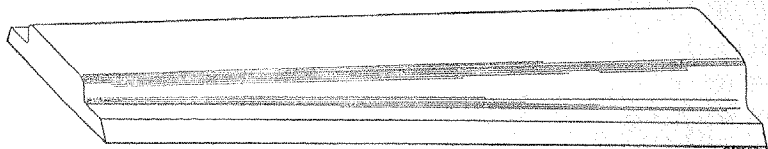


FIG. 1.



FIG. 2.

the blank being worked upon. These dies are illustrated, as shown in *Figs. 3, 4, 5, 6, 7*, and this was the germ from which the success of the invention developed. In addition to the small

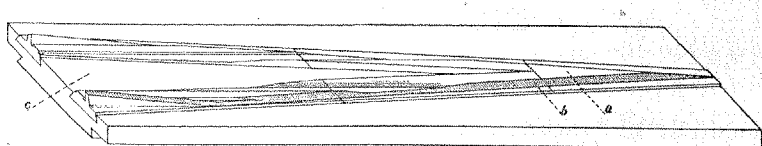


FIG. 3.

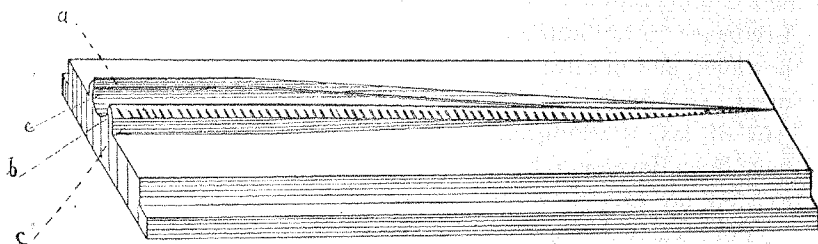


FIG. 4.

miniature car axles, which were then produced, I made dies for rolling balls and small projectiles, and applied for patents.

In June, 1884, I learned that the Patent Office work was much in arrears and that my application would get no hearing for six

months in the regular course. Through the courtesy of the Secretary of War, on account of the adaptability of the machine for war purposes, my cases were made "Special" and got immediate hearing. Much to my surprise I was confronted with a

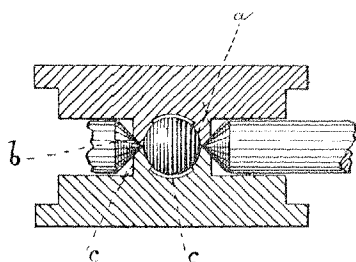


FIG. 5.

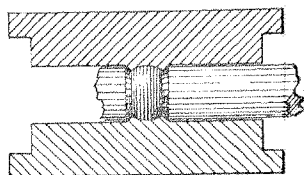


FIG. 6.

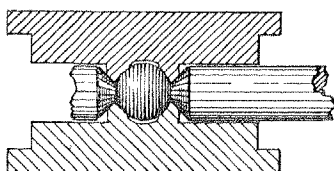


FIG. 7.

multitude of patents, and learned that many before me had attempted to accomplish results in the same direction, but so far as I could judge no machine was then in successful operation. I returned to my home from Washington, somewhat demoralized however, and uncertain as to the fate of my experimental investment. I would say here, that, except for this mistake on the part of my Washington solicitor, this invention would never have been developed by me, for, had he reported the facts as they existed, my original machine would not have been built.

For nearly a year the machine remained covered up, during which time it became apparent that no other person had ever accomplished what I had done, and after a personal investigation in many places in this and other countries, with the best of counsel, and with all the reference patents that could be found before us, we set to work to ascertain what I had done that they had not, that I should have gotten a result which they did not

attain. As a result of that investigation, my patents of June 9th, 1885, were issued to me.

Up to the time of the issuing of my original patents, I had made but one experimental machine. I immediately constructed what is termed a horizontal 6-inch and a 12-inch machine, and in November of the same year took two 6-inch machines and one 12-inch machine to London, England, set them in operation, secured an order from the English Government for a half million of Nordenfelt steel projectiles, and in February returned to America, having formed a company which owns the patents and is operating the machines in that and other European countries. The facilities and force of workmen in Fitchburg were at once increased, and developments continued in various directions until November, 1886, at which time a company was formed in the City of Boston, and substantial developing works were erected in the City of Fitchburg. In the summer of 1886 machines were made with dies running vertically with a marked success over the horizontal form of construction, and all machines for practical working are at present built on that principle.

(Illustrations of the first original machine, and of the machine of latest design were here shown on the screen.)

It is a somewhat remarkable fact, that among all those who had applied for patents on devices of this character, the man who came nearest success previous to the construction of this machine, made his experiments more than eighty years before mine commenced. So far as the records show, he made no attempt to roll anything but lead, and this only into balls, which is the simplest form on which the machine operates. But, with the softest of metals and on the simplest of forms, his dies were a failure.

The hardest metal, when heated, will yield and shape itself to your will with perfect ease, if you handle it right, but attempt to force it too rapidly, or against itself, and the result is a total failure. Dies that were made previous to mine, were so constructed as to attempt to force the metal into shape by direct pressure toward the axis of the bar. Again, no attempt was made to control the rotation of the blank to the required velocity, or to prevent the twisting of the blank or article between the dies, conditions absolutely essential to a successful prosecution of the work: to express it differently, the method of manufacture

under this principle was not discovered till my dies were originated.

If two platens with plane surfaces placed at a given distance apart, with their surfaces parallel, are moved in opposite directions, a round bar, with a diameter equal to the distance between the surfaces placed between them with its axis at right angles with the line of movement of the plates, will be rotated, without moving in the direction of either of the platens. If the diameters of the bar be somewhat greater than the distance between the platens, and if it be of plastic material, it is obvious that if it is introduced between the platens and rotated, its diameter must be reduced and its length increased. This is the fundamental conception which underlies what I have done and what others have attempted. If on the face of each of the platens, a narrow tapering rib be formed running in the direction of the line of motion, the rib of one platen being directly opposite that of the other, it can be easily seen that the movement of the platens will form a groove around the bar corresponding in cross-section with a cross-section of the ribs. It can also be seen that the metal at the bottom of the grooves formed by the ribs will be nearer the axis of the bar than the metal in contact with the plane surfaces of the platens. If the rate of rotation of the bar is determined by its contact with the surfaces of the platens, the rate of motion of the metal at the bottom of the grooves will be less than that of the surface of the ribs, and the ribs must slide over the surface of the bottom of the grooves. On the contrary, if the rate of rotation of the bar is determined by the contact of the metal at the bottom of the groove with the faces of the ribs, the metal in contact with the general surface of the platens will move faster than the dies. These facts present the first difficulties which arise in the attempt to make the fundamental idea available for practical purposes.

Again, it is easily seen that if two or more ribs are formed on each platen, their engagement with the metal of the bar will interfere with and restrain the axial elongation of the bar, which is indispensable to its reduction in diameter. This fact presents the second difficulty which is met and must be provided for, in forming round articles of varying diameters.

Again, if the rotation of the bar is secured only by the friction

of its working surface it is liable to fail, especially where the portions of the bar in contact with the dies are of different diameters. I think that all persons who, before myself, have endeavored to solve the problem of rolling round articles of varying diameters have failed to provide for these difficulties and conditions.

In my dies the portions which perform the work of shaping the article are raised above the general surface of the platens. These raised portions commence at a point and extend in two directions diagonally across the platen, or at an angle with its line of motion. The shaping of the bar commences at a point where the dies first come in contact with the bar, and proceeds spirally in both directions to the ends of the article.

The raised surface of the diverging ribs which form the die proper and which press directly toward the axis of the bar, or to the corresponding part of the opposite die, gives the required form to the article. I call this the forming or shaping surface (see letter *a*.) The outer surfaces of these ribs are formed at an angle of from ten to forty degrees with the axis of the bar, and by virtue of this inclined surface and of its diagonal position across the platen, an axial strain is brought upon the metal in contact with it, and the surplus metal is forced toward the ends of the article. I call this inclined surface the reducing and spreading surface (see letter *b*). This spreading surface is provided with teeth which engage with the metal and insure its rotation, and as the engagement is close to the portion of the rib or die which is acting on the metal, it gives the same rate of motion to the metal at that point that the die itself has. I thus ensure the efficient engagement of the metal with the die; the removal of the surplus metal axially; and the same rate of motion of the metal at the parts being acted upon, that the dies have.

It will be observed that these dies commence their operation by reducing the blank at any given desired point to the finished size of the article at that point, and spread the surplus metal axially, making and finishing the shape as the work progresses. The reducing and spreading surfaces remove the surplus metal outwardly, while the final finishing to accurate size and shape, and the obliterating of the marks caused by the rotating teeth is done on the forming or shaping surfaces near the junction of

those surfaces with the reducing and spreading surfaces. Or, in other words, the principal part of the work is done *outside* of the shape of the article and finished *inside* of the shape of the article. It will also be noticed that the rotation is forced and controlled outside of the shape of the article, or on the blank, instead of on the surface of the article. You will also see that by removing the surface of the die in places, or cutting it away where no work is being performed (see letter *c*), I take away all unnecessary friction between the blank or article and the dies, which leaves the rotating teeth free to force and control the rotation of the blank. By the construction of these teeth the velocity of the rotation of the blank at any given point may be increased or retarded when desirable. The fact that the rotation can be controlled on a given diameter makes the rolling of irregular shapes possible.

One of the earliest and most serious difficulties that presented itself in the practical working of the machine, was occasioned by the dies slipping on the blank that was being rolled. The first experimental dies were constructed of cast-iron, and the corrugations, or teeth, to control the rotation of the work, and prevent the slipping, were formed by cutting transverse grooves on the reducing and spreading surfaces with a round-nose chisel. On the first dies made of steel, the teeth were formed with a chisel, as a file cutter cuts a file. Later on, knurls were introduced for forming the teeth, which method is now employed, and which is entirely satisfactory. The dies, as you will observe by illustration in *Fig. 3*, are made on a cast-iron bed, planed to fit into the platens on the machine, and their faces are provided with dovetail diverging recesses, which receive and retain the steel working surfaces of the dies. These steel surfaces are made in sections, so that they may be hardened and tempered with facility, and nicely fitted to the bed. To give the proper form to the dies, a templet is made conforming to one-half a section of an article to be produced, and the forming and shaping surfaces on the dies, are then planed with that templet to conform to a section of one-half of the article. The dies are then placed diagonal to the bed of the planer, and, with a square-faced tool, the reducing and spreading surfaces are planed diagonal to the forming surfaces, commencing at the starting point on the die, and extending to the finishing end of the die. The question of angles is important in

the construction of these dies, the horizontal angles varying from 8 degrees to 20 degrees, and the vertical angles from 10 degrees to 45 degrees.

In the practical working of the machine, the bar from which the article is to be produced is heated at one end, the heated portion placed between the dies, and, as the dies move simultaneously in opposite directions, the bar is rotated on its axis between them, and the proper form or shape given to the article during one passage of the dies. The dies are then returned to position, and the operation repeated to make another article.

In the production of any article, other than a plain cylinder, as the dies must of necessity move with equal velocity, there must be a slipping of some part, or parts, of the article on the dies, or a twisting of the article, unless some provision is made to avoid it, and the twisting of the article is very objectionable, as will hereinafter be described. The system of cutting away the dies where the work is not being performed, to a great extent removes this difficulty, and this is an important feature in the successful working of this process. Other features have been introduced to avoid this trouble, which it is not necessary for me to herein enumerate. One of the difficulties encountered, and which at one time seemed serious, was a tendency of the work to come out of round and to show a seam, or a hole through the centre, or, as some would express it, become piped. Any one who has had an extended experience in working iron or steel under a trip-hammer, has encountered this difficulty with inferior qualities of steel and iron. I have discovered that one cause of this condition of things with this machine, is the twisting of the stock between the dies, and if the twisting is avoided the difficulty is largely avoided. Another cause is rolling the bar under pressure after the necessary work is done. If a round bar of iron or steel is rolled between two flat surfaces, with a gradual increased pressure, it will assume a three-cornered shape, or, in other words, more metal will rotate between two plates in a three-cornered than in a round form, and there will be a tendency to shatter the centre of the bar, and a slight seam, or hole, will appear, extending through that part of the bar so acted upon. I have recently made changes in the dies for preventing the articles coming out of round, which is effectual.

In the earlier experiments one uniform grade of high-priced steel was used, for the reason that there could be gotten in the market, any size of this steel and in any quantity, and an attempt to work different varieties of steel would introduce needless complications and delay. When the experiments were transferred to the low-priced, open-hearth, and Bessemer steel, this tendency of the work coming out of round, and with a hollow centre, was more apparent than with the crucible steel, but in the construction of the dies having avoided the difficulty of the work coming out of round, the soundness of the product depends, as in other methods of forging, on the strength and homogeneousness of the steel. We are buying in the open market open-hearth steel, not made expressly for us, from which we are producing a great variety of articles that are without exception satisfactory to purchasers and users, in fact, I think, in every instance, since the correct principle of the construction of the dies was discovered, every article produced has been pronounced superior to those made by the old processes.

From the samples which you see before you, you will notice that we have succeeded in rolling many kinds of irregular shapes like ovals, squares, hexagons, pinions, etc. You will also observe that articles have been threaded with satisfactory results, and during the same operation in which the blank is rolled to shape. In fact, all the underlying principles necessary to a complete success of the process have been fully established, and the problems before us relate principally to the production of accurate and uniform work. By the present methods in the manufacture of many of the articles which this machine produces, after the article is forged to approximate shape and size, the surplus metal is necessarily cut away; to bring it to the finish size, by means of cutting tools. The lack of uniformity by those methods is largely due to the give or spring of the machine, and the wear of the tools in use. By this present method the machine can be constructed with great rigidity, and there is no perceptible wear on the dies to change the form or size of the work. During the past year we have rolled 8,000,000 boot calks, the little pointed tool steel articles, which you see on the case before you. Our dies have not been worked under as good and favorable conditions as we can even now use them, but we can roll, as an aver-

age, 100,000 forgings without removing the dies from the machine, while the surface of the dies is not then materially worn away. After rolling, as an average 100,000 forgings, we find it desirable to renew the rotating teeth, and to do this we anneal the steel portion of the dies, plane their surfaces, taking off a slight chip, temper them, and they are again ready for use. In this way, with one set of steels in a die, we have rolled 600,000 forgings. The dies will invariably produce a reverse *fac simile* of themselves, and under the right conditions the articles will be exact duplicates of each other. Those conditions consist simply in a uniform metal that is being worked, and a uniform heating of that metal. We have reason to believe that we can bring those conditions within such narrow limits as to compete in uniformity in the manufacture of such articles as the machine will produce, with the results as now attained by existing methods. One of the advantages of this system of manufacturing is, we can use steel of high or medium temper, as well as the softest steel or iron. In consequence of this we start with a material that is stronger than is now generally used. Again, it is a well-established fact that a forged steel article which retains the skin surface has a greater tensile strength, will stand a heavier breaking weight, possesses superior wearing qualities, and when used as a projectile will endure a more powerful impact strain to what it does when that surface is removed. These two facts insure a great advantage in the quality of goods produced.

Experiments have demonstrated that we can roll from the square, hexagon, or octagon bar with equal facility as from the round bar; this enables us to roll from what is known among metal workers as the billet, and produce any shape, round, square, hexagon, oval, tapering, threaded, or otherwise, introducing all the various shapes into the same die and with a uniform result; in this way the whole system under which a great variety of goods are produced can be changed to advantage. Many articles are at present made from a finished bar smaller than some portion of the article, and the larger portion is formed by upsetting; this has a tendency to shatter the fibre of the metal and otherwise weaken it by forming cold shuts. We start from a billet larger than the largest portion of the article to be produced, and shape the whole at one operation; or, in other words, avoid the neces-

sity of using a finished bar from which to make our product, thus saving the expense of one operation in the manufacture of the raw material.

An important advantage by this method of forging is the saving in the power required over the use of hammers, drops, or hydraulic presses. The work is done principally on inclined planes, and there is a continuous and substantially a uniform amount of work from the time the operation is commenced until it is finished, and under the most favorable conditions as regards power, and wear and tear of machines.

Several tests of the quality of the products of the machines have been made, and I will cite two as illustration: The Nordenfelt projectile ordered by the English government are three inches long by one inch in diameter. They were required to vary not over one thirty-second of an inch in length, and less than five one-thousandth in diameter from a given size at three points, and also to be to an exact taper; the machine rolled them within these limitations. Ten shots were fired by the English officers at the testing grounds at Woolrich in the presence of Commander Folger, of the U.S. Navy, and myself. The range was one hundred yards, and they were fired through a one-half inch steel armor plate and against a like plate placed fifteen inches in the rear of, and at an angle of forty-five degrees to the first plate. After this remarkably severe experience they were so little distorted as to stand the gauge tests. The officers in charge pronounced them the best shot that ever went through their guns. The Government was at that time manufacturing these projectiles at Woolwich, they discontinued the manufacture and gave the order referred to.

In April last past, and within a week after the first die was made to roll a fish-bar bolt, ten bolts were submitted to and tested by the Pennsylvania Railroad Company in comparison with five of their standard bolts as now in use. They were pronounced satisfactory in workmanship, and stood a tensile strain of an average of thirty per cent. more than the standard.

Previous to the construction of this machine, hardened steel balls, accurate to size, were unknown. To-day we are furnishing them in any quantity and of any size up to two inches in diameter, that vary less than one-thousandth of an inch in size, and

can manufacture to six inches or even larger if required. The Lick telescope revolves on hardened steel balls one inch in diameter, rolled with this machine. Balls two inches in diameter of great accuracy and precision have been supplied to a famous scientist with which he accomplishes results heretofore impossible.

Four propositions seem to have been fully established pertaining to this invention:

First: Any article that comes within the range of the machine can be made at a less cost than as now produced.

Second: Everything that the machine makes can be turned out superior in quality to the same article as now manufactured.

Third: Experiments have demonstrated that large articles are rolled with the same facility as those that are small in size.

Fourth: There is no conceivable limit to the variety of work that it is capable of producing.

As a comprehensive illustration of the possibilities of this process I may mention, that a coach axle can be rolled from the billet, complete at one pass of the dies, giving all the forms and shapes required, viz.: round, hexagon, square, the collars, the journals, the threads for the nuts, and cut to length, and in less than thirty seconds of time.

[Referring to the illustrations, Plates I., II., and III., Fig. 8 is an illustration of the first machine made with the dies arranged to move horizontally. Fig. 9 is a front sectional view of the same, showing dies for rolling a small car axle; and Fig. 10 an end vertical section. Fig. 11 is a general view of the machine, of a later design, with the dies in a vertical position; while Fig. 12 gives a front elevation of the same. Fig. 13 an end view and vertical section, and Fig. 14 a plan view.]